Al-Azhar University
Faculty of Engineering
Architectural Engineering
Department

جامعة الأزهر
كلية الهندسة
قسم هندسة العمارة

Using Decentralized Private Utilities for Sustainable Architecture as an Alternative to Formal Public Utilities

استخدام المرافق الذاتية للعمارة المستدامة كبديل للمرافق الرسمية

By

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Chronicle of the Research			
No.	Date	Day	Process
1	29/3/2012	Thursday	Registration at the office of the postgraduate studies.
2	2/4/2012	Monday	First seminar during the Architectural Department's Staff meeting.
3	2/4/2012	Monday	Research approval by the Architectural Department Committee.
4	27/11/2012	Tuesday	Endorsement of the Faculty Committee.
5	8/6/2014	Sunday	Endorsement of the University Committee.
6	7/3/2016	Monday	Second seminar during the Architectural Department's Staff meeting.
7	9/5/2016	Monday	Third seminar during the Architectural Department's Staff meeting
8	9/5/2016	Monday	Final approval by the Architectural Department Committee, and certification of the "Research Validity for Arbitration".
9	31/5/2016	Tuesday	Endorsement of the Faculty Committee.
10	28/6/2016	Tuesday	Endorsement of the University Committee.
11	28/12/2016	Wednesday	Jurisdiction and Discussion.

ملخص الرسالة

مقدمة:

تعتبر المرافق الملائمة والمتطورة والمعروفة باسم شبكات البنية التحتية (شبكة التغذية بالمياه – شبكة الصرف الصحي – شبكة صرف الأمطار – شبكة نظم الري – شبكة إطفاء الحريق – شبكة الاتصالات والهاتف – شبكة التغذية بالكهرباء والطاقة – شبكة الغاز الطبيعي – شبكة نظم التخلص من المخلفات الصلبة - ونظام توزيع البوتاجاز) كلها تعتبر خدمات أساسية تلتزم كل الدول المتحضرة بتقديمها لمواطنيها ، كما تُعدّ مقياسا رئيسيا للتقدم والرخاء وجودة الحياة. لكن توفير هذه المرافق في مصر يعتبر عبئا كبيرا على الدولة حيث تنفق سنويا البلايين من الجنيهات لتركيب وتشغيل وتجديد وصيانة هذه المرافق والشبكات. هذه الاستثمارات الهائلة تشكل عبئا على الاقتصاد المصري الذي يعاني عجزا مزمناً.

من ناحية أخرى فإن المرافق المركزية القائمة لها العديد من الآثار البيئية الغير مستحبة حيث تستنفد الموارد الغير متجددة من الوقود الأحفوري وتؤثر على النظام الحيوي – كما أن غياب هذه المرافق في بعض المناطق المحرومة يتسبب في أضرار مضاعفة بيئيا.

تتزايد صعوبة توفير المرافق المركزية في مصر مع الوقت – حيث أن نصيب مصر من المياه مهدد بالنقص واحتياطياتها من الطاقة محل قلق – لذا فالمرافق تزداد نقصا وتزداد أسعارها غلاء مع رفع الدعم المتزايد عن المواطن بالتدريج.

وقد ظهرت مؤخرا العديد من تقنيات المرافق اللامركزية في عدة مناطق من دول العالم وتم تطبيق العديد منها بنجاح لكن الظروف التي نجحت فيها هذه التقنيات ربما تختلف عن الظروف المحلية في مصر ، لذا فإن القضية الرئيسية لهذا البحث هو دراسة مدى ملاءمة هذه التقنيات للتطبيق في مصر كما حدث في الخارج.

- المشكلة البحثية : يناقش البحث مدى ملاءمة المرافق اللامركزية للتطبيق في مصر كمحاولة لحل مشكلة الامتداد العمراني خارج الوادي القديم بشكل اقتصادي ومستدام
- الفرضية البحثية : الفرضية الرئيسية للبحث هي : (المرافق اللامركزية يمكن تطبيقها في مصر لحل مشكلة نقص المرافق ولتشجيع الامتداد العمراني في الصحراء المصرية بشكل اقتصادي وكفء ومستدام)
- الأهداف البحثية: الهدف الرئيسي للبحث هو : (تشجيع الامتداد العمراني في الصحراء المصرية باستخدام المرافق اللامركزية)

الأهداف الثانوية هي:

- حل مشاكل المرافق المتهالكة وغير المستدامة في بعض المناطق بمصر.
- العثور على مرافق رخيصة وكفء ومستدامة لتناسب المناطق المختلفة بمصر (ريف – حضر-مدن جديدة).

- تشجيع السكان على تركيب وتشغيل مرافقهم الخاصة وصيانتها بأنفسهم وتشجيع المشاركة المجتمعية.
- تقليل الأثر البيئي للمرافق القائمة بواسطة تبني معالجات وتقنيات قد تساهم في تخفيف هذا الأثر.
- تقليل تكلفة تركيب وتشغيل وصيانة المرافق عموما خاصة في المناطق ذات المحددات الجغرافية والطبوغرافية الصعبة.
- تخفيف أثر أزمتي نقص مياه النيل المتوقع ونقص الطاقة الحالي.

- المنهجية البحثية :

1- المنهج التحليلي الإحصائي لتقييم المرافق الحالية المركزية.
2- المنهج التجريبي لاختبار المرافق اللامركزية المقترحة وملاءمتها للتطبيق في مصر
3- المنهج التطبيقي للمرافق المقترحة في المجتمعات العمرانية المختلفة .

- الأهمية البحثية:

1- يناقش البحث مشكلة تمس الحالة الاقتصادية والعمرانية والمعمارية في مصر.
2- يعطي دفعة للامتداد العمراني المطلوب في الصحراء المصرية .
3- يقترح حلولا بديلة لحل أزمة الطاقة ونقص المياه في مصر.

- هيكل البحث: يتكون هيكل البحث من جزئين أساسيين :

الجزء النظري والتحليلي في الجزء الأول ببابيه الأول والثاني:

1. **الباب الاول** يختبر أداء المرافق المركزية في مصر مستخدما خمس معايير للتقييم وهي : الاقتصاد – الكفاءة – الاستدامة – عدالة التوزيع – استعمالها للأراضي وأثرها على التخطيط العمراني ، وذلك على مدار فصوله الثلاث التي تناقش مرافق:
   - **الفصل الأول :** مرفق مياه الشرب والصرف الصحي.
   - **الفصل الثاني :** مرفق الكهرباء المنزلية.
   - **الفصل الثالث :** مرفق غاز الطهي (الغاز الطبيعي – اسطوانات الغاز).
2. **الباب الثاني** يستعرض المرافق اللامركزية الأشهر والأكثر استعمالا في دول العالم – ويشرح آلية عملها ثم يختبر أداءها مستخدما خمسة معايير : التكلفة (للتركيب والتشغيل) – الكفاءة – الاستدامة والأثر البيئي – استعمالها للأراضي وأثرها على التخطيط العمراني – وأخيرا ملاءمتها للتطبيق في مصر ، وذلك على مدار فصوله الأربعة التي تناقش التقنيات اللامركزية لكل من:
   - **الفصل الأول :** تقنيات توفير المياه المنزلية.

- **الفصل الثاني :** تقنيات معالجة مياه الصرف الصحي المنزلي.
- **الفصل الثالث :** تقنيات توفير الكهرباء المنزلية.
- **الفصل الرابع :** تقنيات توفير غاز الطهي المنزلي.

الجزء التطبيقي في البابين الثالث والرابع :

3- **الباب الثالث:** يطرح هذا الباب أربعة نماذج تطبيقية للتقنيات المقترحة في أربع مناطق عمرانية متباينة في مصر ممثلة لمجتمعات عمرانية مختلفة (ثلاث منها في وداي النيل والرابع في الصحراء المصرية):

- **الفصل الأول :** نموذج تطبيقي في الريف (ممثلا في قرية بلتاج).
- **الفصل الثاني:** نموذج تطبيقي في الحضر (ممثلا في مدينة وادي النطرون).
- **الفصل الثالث:** نموذج تطبيقي في المناطق العشوائية (ممثلة في حي الجنابية بطنطا).
- **الفصل الرابع :** نموذج تطبيقي في المجتمعات العمرانية النائية والمعزولة (ممثلة في مشروع المليون ونصف فدان) .

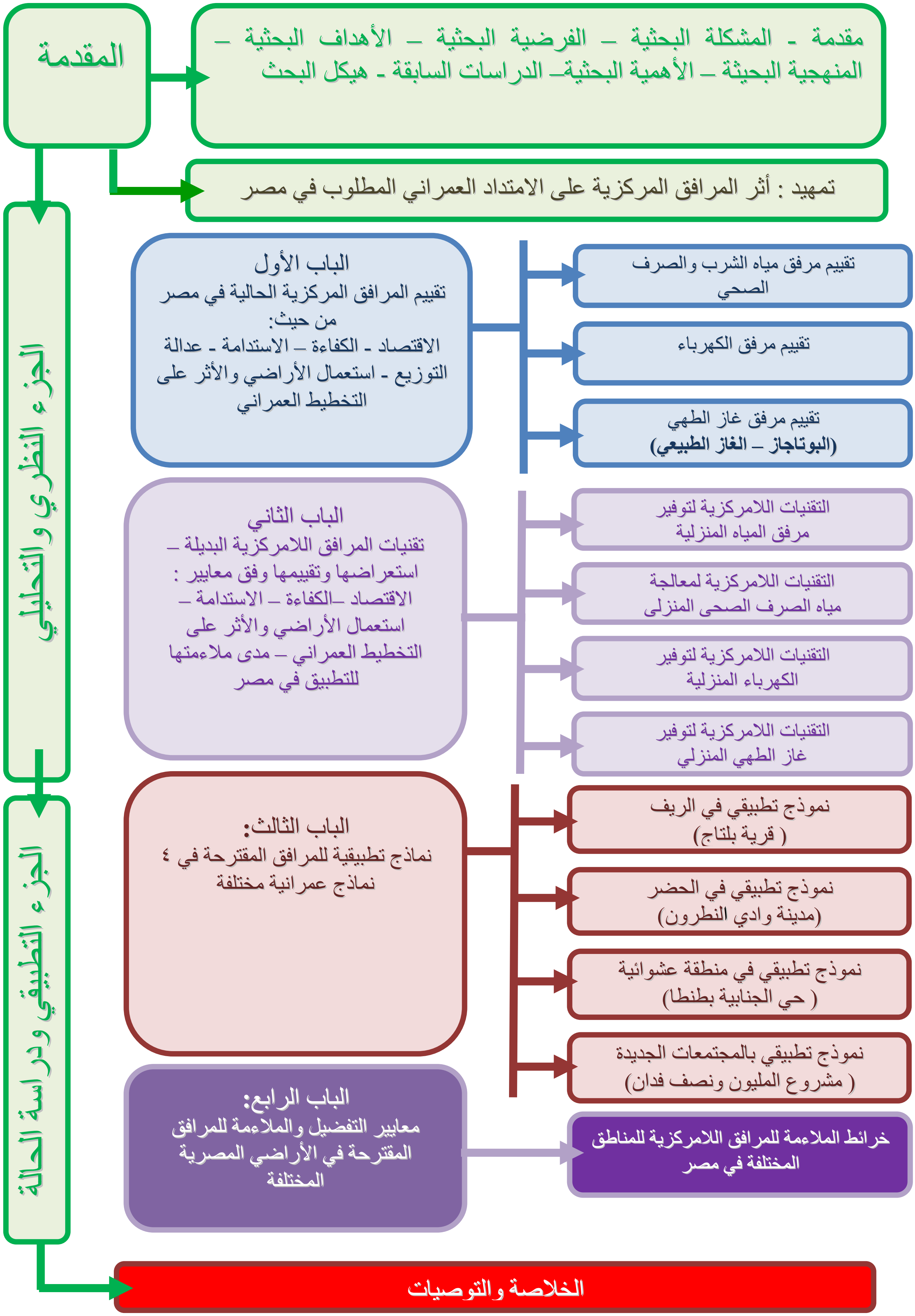
في كل نموذج منهم يتم تحليل أوضاع المناطق محل الدراسة من حيث الجغرافيا المناخ والسكان والتربة والاقتصاد وأهم المشاكل البيئية والاقتصادية والاجتماعية والخدمية القائمة – وأوجه العجز في الخدمات البلدية من مياه وصرف وكهرباء وغاز ونظم التخلص من المخلفات الصلبة - وذلك تمهيدا لمعرفة أنسب المرافق اللامركزية لهم والتي يمكنها أن تحل هذه المشكلات أو على الأقل تخفف وطأتها – بما يتناسب مع ظروف السكان الاقتصادية والاجتماعية والتعليمية والثقافية والبيئية.

3- **الباب الرابع:** يتناول هذا الباب أهم المعايير التي يجب مراعاتها عند اتخاذ قرار تطبيق المرافق اللامركزية من عدمه ، وأهمها : (الكثافة السكانية – الطبوغرافية – درجة الحرارة طوال العام – الرطوبة النسبية – خصائص نفاذية ومسامية التربة – منسوب المياه الجوفية ودرجة ملوحتها ونقاوتها وحاجتها للمعالجة – معدلات سقوط الأمطار وسرعة الرياح – معدلات النشاط الزلزالي ومدى التعرض للسيول – وأخيرا مدى توافر المناخ الآمن وعدم التعرض للكوارث الجماعية سواء طبيعية أو على شكل أعمال تخريب).

يلي ذلك تقديم خرائط ملاءمة لكل مرفق من المرافق المذكورة بحيث تساعد صناع القرار على تحديد أفضلية وملاءمة هذه المرافق في الأقاليم المصرية المختلفة.

الدراسات ذات الصلة بموضوع البحث : ناقشت العديد من الدراسات السابقة تقنيات المرافق اللامركزية وكيفية تركيبها واستخدامها- تضيف هذه الدراسة إلى مدى ملاءمة هذه المرافق للتطبيق في مصر بمختلف أقاليمها ومجتمعاتها العمرانية المتباينة – وتضع نماذج للمعماريين والمخططين والمصممين البيئيين لكيفية دراسة

المناطق المراد تركيب هذه المرافق بها وكيفية اختيار أفضل التقنيات بعد هذه الدراسة – كما تضيف تقييما متكاملا للمرافق الراهنة وكيف أنها تعيق الامتداد العمراني خارج الوادي القديم ومشاكلها البيئية والوظيفية والتخطيطية القائمة وكيفية حل هذه المشاكل على مستوى القطر المصري ككل.


المقدمة
مقدمة - المشكلة البحثية – الفرضية البحثية – الأهداف البحثية – المنهجية البحثية – الأهمية البحثية– الدراسات السابقة - هيكل البحث
تمهيد : أثر المرافق المركزية على الامتداد العمراني المطلوب في مصر
الجزء النظري والتحليلي
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تقييم مرفق مياه الشرب والصرف الصحي
تقييم مرفق الكهرباء
تقييم مرفق غاز الطهي (البوتاجاز – الغاز الطبيعي)
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تقنيات المرافق اللامركزية البديلة – استعراضها وتقييمها وفق معايير : الاقتصاد –الكفاءة – الاستدامة – استعمال الأراضي والأثر على التخطيط العمراني – مدى ملاءمتها للتطبيق في مصر
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التقنيات اللامركزية لمعالجة مياه الصرف الصحى المنزلى
التقنيات اللامركزية لتوفير الكهرباء المنزلية
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نموذج تطبيقي في الحضر (مدينة وادي النطرون)
نموذج تطبيقي في منطقة عشوائية (حي الجنابية بطنطا)
نموذج تطبيقي بالمجتمعات الجديدة (مشروع المليون ونصف فدان)
الباب الرابع:
معايير التفضيل والملاءمة للمرافق المقترحة في الأراضي المصرية المختلفة
خرائط الملاءمة للمرافق اللامركزية للمناطق المختلفة في مصر
الخلاصة والتوصيات

ملخص البحث :

تم تقسيم البحث إلى ثلاث أجزاء رئيسية :

أولا : في القسم الأول : تم دراسة المرافق المركزية القائمة في مصر لبحث مزاياها وعيوبها ومشاكلها القائمة ومدى ملاءمتها للتنفيذ في الريف والحضر والعشوائيات والتجمعات العمرانية الصحراوية الجديدة ، وقد تم استخدام خمس معايير لتقييم هذه المرافق وهي :

1- معيار اقتصاديات المرافق : حيث تم مناقشة تكلفة إنشاء وتركيب وتشغيل هذه المرافق التقليدية الشبكية سواء التكلفة الأولية أو الجارية **Initial and running cost** ، وبيان التكلفة على كل من الدولة والشركة القابضة والمواطن .

2- معيار كفاءة المرافق : حيث تم فحص مدى كفاءة المرافق القائمة من حيث التغطية والقدرة ونسبة التوصيل والأمان والمعالجة والمطابقة للمواصفات المحلية القياسية.

3- معيار استدامة المرافق : حيث تم فحص الآثار المترتبة على تشغيل هذه المرافق ومدى مطابقتها للمعايير البيئية والآثار التي تتركها على المياه والتربة والهواء والموارد.

4- معيار سهولة التوصيل وعدالة التوزيع : حيث تم بحث مدى وصول هذه المرافق لكل السكان على مستوى المدن والقرى والمجتمعات العمرانية الجديدة ونسبة تغطية هذه المرافق للسكان في كل منها.

5- معيار استعمال الأراضي والأثر على التخطيط العمراني : حيث تم دراسة استعمال هذه المرافق للأراضي وحجم ما تحتاجه من مساحات للتركيب والتشغيل خاصة في المناطق التي يشكل فيها سعر الأرض الفضاء عاملا مهما – كما يناقش أثر التصميم الحضرى وشبكات الشوارع القائمة على سهولة توصيل شبكات المرافق وعلاقة تكلفة التركيب والصيانة بالطراز الحضري الشبكي للمنطقة المخدومة.

وفي نهاية القسم الأول من البحث تم تلخيص نتائج هذا التقييم في جدول تم به إعطاء تقييم لكل مرفق من هذه المرافق من حيث أدائه في كل معيار من المعايير الخمسة السابقة.

ثانياً : الجزء الثاني من البحث: تم استعراض أهم تقنيات المرافق اللامركزية محل هذا البحث وعرض تقنياتها وتقييم كل منها بنفس المعايير الخمسة السابقة (الاقتصاد – الكفاءة – الاستدامة – سهولة التوصيل وعدالة التوزيع - استعمال الأراضي والأثر على التخطيط العمراني) ومدى ملاءمة هذه التقنية للتطبيق في مصر:

1- ففي الفصل الاول تم استعراض تقنيات الإمداد بالمياه المنزلية لامركزيا بواسطة المياه الجوفية ، وتم مناقشة مدى ملاءمة المياه الجوفية للاستغلال في مصر وأهم المعايير التي تحدد الملاءمة من عدمها، وأهمها معايير العمق والملوحة ونفاذية التربة وجودة المياه ومدى حاجتها للتنقية ومعدلات الشحن الجوفي الطبيعي بقياس معدلات سقوط الأمطار (والتي لا يمكن الاعتماد عليها منفردة في

إعادة الشحن) وكيفية عمل إعادة شحن صناعي للمخزون الجوفي وذلك على مقياس المنزل الواحد والمجاورة السكنية.

ثم تم عرض تقنيات استخراج المياه الجوفية لامركزيا باستعمال الطلبمات الشمسية **Solar pumps** وتقنيات تنقية الملوحة إن وجدت باستخدام وحدات التنقية التي تعمل بالطاقة الشمسية **Solar Desalinators** وكذلك تقنيات الفلترة والتنقية من الشوائب لامركزيا على مستوى المسكن الواحد أو المجمع السكني بخامات مستدامة باستعمال الكربون المنشط والرمال والركام وألياف النخيل **Date palm fibers** .

2- وفي الفصل الثاني تم استعراض تقنيات معالجة مياه الصرف الصحي المنزلي لامركزيا وذلك حسب مراحل المعالجة كالتالي:

أ- تقنيات المعالجة الأولية Primary Treatment Technologies وتشمل تقنيات : خزان التحليل **Septic Tank** ، والهاضم متعدد الحواجز **Anaerobic Baffled (ABR) Reactor** حيث تم شرح مكوناتهما وتقييم تكلفة التركيب والتشغيل والأثر البيئي واستعمالهما للأراضي وإمكانية الزراعة على الأرض التي يشغلانها وإمكانية تركيبهما لخدمة عشرات البيوت كمعالجة أولية.

ب- تقنيات المعالجة الثانوية Secondary Treatment Technologies وتشمل تقنيات : المرشح الركامي **Leaching System** وخندق التصريف **Infiltration trench** والمرشح الركامي **Infiltration Pit** وهذه الأنظمة هي الأكثر شيوعا في الولايات المتحدة وبريطانيا ، وتم تقييمها بالمعايير الخمسة السابق ذكرها ومدى ملاءمتها للتطبيق في مصر.

ت- تقنيات المعالجة الثالثة Tertiary Treatment Technologies وتشمل تقنيات الزراعة المائية **Wetland System** والمعالجة بألياف النخيل **Date Palm Tree Treatment** ومدى كفاءتهما في إزالة الملوثات والمعادن الثقيلة من مياه الصرف المنزلي وتقييمها بالمعايير السابقة.

ث- تقنيات المعالجة المتكاملة Septic System والتي تشمل الأولية والثانوية ومدى ملاءمتها لمعالجة الصرف الرمادي والصرف المختلط.

ج- تقنية الهاضم الحيوي Biodigester والتي تعتمد على التخمير اللاهوائي في خزان محكم تحت الأرض حيث يتحول الصرف الأسود إلى سماد وغاز الميثان وماء ، وكيف أن هذه التقنية مطبقة في الهند وأمريكا اللاتينية ، وتم تقييمها أيضا بالمعايير السابقة ومدى ملاءمتها للتطبيق في مصر خاصة في المجتمعات الزراعية ذات النفايات العضوية الوفيرة.

3- وفي الفصل الثالث تم استعراض تقنيات توليد الكهرباء المنزلية لامركزيا كالتالي:

أ- تقنية الأنظمة الشمسية Solar Energy: تم استعراض تفاصيلها وطرق التركيب والمقاييس اللازمة لمستوى المنزل الواحد وتكلفة التركيب والتشغيل ومدى الاستدامة والأثر البيئي لها وشروط الكفاءة وأنسب الاماكن لتطبيقها في مصر.

ب- تقنية الغاز الحيوي Biogas : حيث تم استعراض كيفية توليد الكهرباء المنزلية من غاز الميثان الناتج من الهاضم الحيوي السابق ذكره في الفصل الأول – وكيفية الاستفادة القصوى من الغاز وكيفية الحصول على أكبر محصول من الغاز باختيار النفايات العضوية الأغزر إنتاجا للميثان حال تخمرها مثل قش الأرز وروث الماشية وبقايا الخبز بالإضافة للنباتات المتوافرة بكثرة على ضفاف الترع والقنوات كالغاب والبوص ، وكذلك نباتات مثل ورد النيل والنفايات الناتجة من الأنشطة الزراعية كبقايا أعواد قصب السكر وحطب القطن وأعواد الذرة إلخ . وتم تقييم هذه التقنيات بنفس المعايير السابقة .

ت- تقنية السخانات الشمسية Solar Collectors : والهدف من تطبيقها هو خفض استهلاك الكهرباء المنزلية إلى الثلث تقريبا بالاستغناء عن تسخين المياه بالغلايات الكهربائية الأكثر استهلاكا للطاقة ، وتم توصيف وتقييم هذه التقنية بنفس المعايير السابقة.

4- وفي الفصل الرابع : تم استعراض تقنيات توفير وقود الطهي المنزلي لامركزيا وذلك باستخدام تقنية الغاز الحيوي Biogas وكيفية فلترة الغاز الناتج للتخلص من رائحته الغير مستحبة وكذلك تجفيفه للتخلص من الرطوبة وكيفية الاستغلال الأمثل له وخواصه في الاشتعال والتسخين مقارنة بالغاز الطبيعي المتوافر مركزيا في المنازل.

وفي نهاية الجزء الثاني من البحث تم تلخيص نتائج هذا التقييم في جدول تم به إعطاء تقييم لكل تقنية من تقنيات المرافق اللامركزية المقترحة وذلك من حيث أدائها في كل معيار من المعايير الخمسة السابقة.

5- **<u>الجزء الثالث من البحث:</u>**

في بداية هذا الجزء تم تقديم دليل عمل ملخص للمعماري والمصمم البيئي لما يجب عليه فعله قبل اختيار المرفق الملائمة للمنطقة المخدومة ، حيث يجب عليه دراسة عدة معايير للمنطقة أهمها :

1- الخصائص المناخية Climatic Elements : ومن أهم هذه الخصائص:

أ- درجات الحرارة على مدار العام : حيث تؤثر الحرارة على أداء الهاضم الحيوي فتزداد كفاءته بازدياد حرارة الجو المحيط كما تتحسن كفاءته بازدياد تعرضه المباشر لأشعة الشمس مما يسرع عملية التخمر اللاهوائي داخل الهاضم ويزيد انتاجيته من الغاز الحيوي ويحسن معالجته لمياه الصرف.

ب- الرطوبة النسبية ومعدلات سقوط المطر Relative Humidity & Precipitation: حيث يؤثر إيجابا على معدلات إعادة شحن المياه الجوفية طبيعيا مما يعوض المياه الجوفية المسحوبة منه عبر الطلمبات المنزلية- و يؤثر سلبا على أنظمة التصريف Leaching Systems حيث أنها تزيد من الحمل الهيدروليكي على التربة وتقلل سرعة التصريف خلال حبيباتها- كما يؤثر سلبا على أنظمة الزراعة المائية wetland systems حيث تتداخل المياه النظيفة مع المياه المعالجة مما يزيد الحمل البيولوجي على النباتات المائية المعالِجة.

ت- الإسقاط الشمسي وصفاء السماء Sun exposure & sky clearance : حيث تؤثر الشمس إيجابا على كل مستخدمي المرافق اللامركزية عموما –فالشمس تزيد إنتاج الطاقة في الخلايا الشمسية ، وتسرع تسخين المياه في السخانات الشمسية ، وتسرّع التخمر والمعالجة في أنظمة المعالجة اللاهوائية لمياه الصرف كما في خزان التحليل والهاضم الحيوي متعدد الحواجز ABR والهاضم الحيوي bio-digester - وتساعد على سرعة تبخير وتجفيف التربة في أنظمة التصريف Leaching Systems كما تزيد سرعة وكفاءة قتل الكائنات الدقيقة والملوثات pathogens في مياه الصرف خلال المعالجة – كما أنها تحسن أداء أنظمة الزراعة المائية wetland systems وذلك بازدياد التمثيل الضوئي للنباتات photosynthesis مع زيادة تعرضها للشمس، كما يجب أيضا دراسة صفاء السماء بالموقع sky clearance لضمان أن أشعة الشمس لن تجد ما يعوق نفاذيتها ووصولها للأنظمة المستهدفة.

ث- معدلات سرعة الرياح Average Wind Speed: حيث تؤثر سرعة الرياح إيجابا على أداء العديد من أنظمة المرافق اللامركزية – فهي تحسن أداء أنظمة التصريف وتسرع معدلات تبخير وجفاف التربة فنحتاج لانظمة تصريف أصغرحجما – لكن سرعة الرياح عن المعدل المطلوب فقد تتسبب بتعرية أنظمة التصريف ونحر التربة من فوقها مما يؤدي لفشلها – الأنظمة الشمسية أيضا تتأثر بسرعة الرياح حيث يتحسن أداؤها بازدياد سرعة الرياح بشرط ألا تصل السرعة إلى حد العاصفة لأنها ممكن أن تقتلع النظام بالكامل.

2- خصائص الموقع Site Features : ومن أهم هذه الخصائص:

أ- الطبوغرافية : يجب دراسة طبوغرافية الموقع لأنها تؤثر على العديد من الانظمة اللامركزية خاصة أنظمة التصريف – حيث تؤثر الميول على تصميم النظام المستخدم لضمان عدم تراكم المياه في جانب واحد من الموقع - يجب توظيف الميول الطبيعية بالموقع لخدمة أداء أنظمة التصريف دون الإضرار بالمباني المجاورة – كما يجب تجنب أنظمة التصريف السطحي في المناطق ذات مخرات السيول او الانهيارات الصخرية وذلك لتفادي انهيار المنظومة – عند استعمال الهاضم الحيوي متعدد الحواجز

ABR لخدمة اكثر من منزل - يجب مراعاة تركيبه في أقل منسوب في الموقع لضمان التدفق الطبيعي لمياه الصرف نحو الهاضم دون حاجة للضخ الميكانيكي – بينما في حال استخراج المياه الجوفية من الأرض فيجب مراعاة تركيب الطلمبات في أعلى منسوب بالموقع لضمان عدم هدر الطاقة في ضخ المياه نحو المباني عكس اتجاه الجاذبية.

ب- خصائص التربة Soil Properties :

من المهم دراسة خصائص التربة في الموقع قبل اختيار المرافق اللامركزية الملائمة له – فعلى سبيل المثال فإن معدل تصريف التربة في الموقع يؤثر على جودة وأداء نظام التسريب أو الترشيح السطحي Leaching System ويحدد المساحة المطلوبة للنظام ليقوم بعمله بكفاءة – كما أن المحتوى البكتيري والعضوي للتربة يؤثران في كفاءة المعالجة بواسطة التصريف السطحي من عدمه – كما أن خصائص التربة العميقة تؤثر في قابلية استخراج المياه الجوفية بالموقع من حيث نفاذية التربة وخصائصها الهيدروليكية (م^{٣}/ م^{٢}/ اليوم) .

جـ - خصائص المياه الجوفية بالموقع Groundwater Properties :

تؤثر خصائص المياه الجوفية في الموقع على مدى ملاءمة الاستخراج والمعالجة لهذه المياه قبل الاستخدام – أهم الخصائص التي يجب دراستها هي :

- الخصائص الكيميائية والبيولوجية للمياه المستخرجة – لتحديد نظم المعالجة الملائمة لها قبل الاستخدام.
- معدلات الملوحة ، لتحديد الحاجة لنظم تحلية من عدمه .
- مصادر التلوث المحتملة للمياه الجوفية (مثال: مصانع قريبة من الموقع وما تنتجه من صرف صناعي ونفايات كيميائية – أنشطة زراعية تستخدم مخصبات كيميائية أو مبيدات زراعية غير عضوية – مدافن صحية قريبة للنفايات المنزلية أو النفايات الخطرة وما يمكن أن يرشح منها من سوائل قد تصل للمياه الجوفية – إلخ) وكيفية معالجة هذه المصادر لتقليل أثرها وضمان أمان المياه المستخرجة وقابليتها للاستخدام.
- من الهام جدا اختيار نقطة الاستخراج بعناية – حيث يجب أن تكون أبعد ما يكون (أفقيا ورأسيا) عن أي مصادر تلوث محتملة كأنظمة التصريف السطحي أو المصانع أو الملوثات الأخرى.

3- الخصائص العمرانية Urban Characteristics :

وهي خصائص الأراضي والمباني بالموقع وأهمها :

أ- استعمال أراضي الإسكان والخدمات وملكياتها Land Use & Ownership: :

تؤثر استعمالات الأراضي على المرافق المقترحة للموقع – فمثلا إذا كانت المنطقة تجارية فيجب اختيار أنظمة التصريف السطحي السريعة التسريب وذلك لموائمة تدفقات الصرف الجماعية في ساعات الذروة- ويجب أن تكون أصغر حجما لأن المناطق التجارية عادة سعر المتر فيها مرتفع – أما المناطق الصناعية فتحتاج للأنظمة التي لا تتأثر باهتزازات الأرض الناجمة عن تشغيل الآليات الثقيلة وكذلك الأنظمة التي يمكنها معالجة الصرف الصحي السناعي بكفاؤة وإزالة الملوثات الثقيلة منه – وفي حال الاستعمالات الدينية كالمساجد مثلا فيجب توفير خزانات مياه لتلائم الاستهلاك المفاجيء في ساعات الوضوء الجماعي للمصلين – وكذلك أنظمة الصرف الصحي التي تلائم التدفق المفاجيء لهذه المياه في أنظمة الصرف.

من المهم أيضا دراسة ملكيات الأراضي حيث انها تؤثر في آلية اتخاذ القرار العمراني – فمثلا بعض المرافق اللامركزية يتطلب تصريحا مسبقا من مالك الأرض او المبنى قبل تركيبه – وفي حال أن الساكن لا يملك العقار فربما لا يستطيع تغيير المرافق به لمرافق أفضل حتى إذا رغب بذلك.

ب- الحالة الإنشائية للمبنى Construction State :

يجب دراسة الحالة الإنشائية للمباني بالموقع المخدوم قبل اختيار أنسب المرافق له – فعلى سبيل المثال فإن أنظمة التصريف leaching systems يجب تجنبها في حال ارتفاع منسوب المياه الجوفية ووجود رطوبة في جدران المبنى - ومثال آخر المباني رديئة الحالة الإنشائية لن يتم توفير مرفق الغاز الطبيعي لها فيجب التفكير في توفير الهاضم الحيوي لإمدادها بغاز الطهي – ومثال آخر إذا كانت المباني السائدة بالمنطقة من الحوائط الحاملة فيجب تجنب أنظمة السحب الغزير من مخزون المياه الجوفية أسفل هذه المباني حيث يمكن أن يتسبب ذلك في انضغاط التربة وهبوطها ولو بمقدار بسيط مما قد يسبب شروخا وأضرارا للحوائط الحاملة.

ج- ارتفاعات المباني ومعامل التظليل Buildings' Heights & Shading Coefficient :

ارتفاعات المباني ومعامل التظليل لها يجب دراستهما جيدا قبل اختيار المرافق الملائمة – فعلا سبيل المثال عند تركيب الأنظمة الشمسية يجب اختيار الأماكن ذات الإسقاط الشمسي العالي والمستمر على مدار ساعات النهار – وفي حال تركيب الهاضم الحيوي على سطح المبنى فيجب دراسة التشميس الجيد في هذا المكان لضمان أعلى معدلات تخمر وأسرع معالجة داخل الهاضم . في مصر فإن الواجهات الغربية والجنوبية هي عادة الأنسب لتركيب الأنظمة التي تتطلب إسقاطا شمسيا عاليا - يجب أيضا مراعاة الارتفاعات المتوقعة للمباني المجاورة مستقبلا وذلك بمعرفة قواعد البناء في هذه المنطقة والارتفاعات المسموح بها وعادات السكان من خرق أو التزام بهذه القواعد – وذلك منعا لتعطيل عمل الأنظمة الشمسية بعد تركيبها بسبب تظليل مفاجيء من الجار مستقبلا.

د- الكثافة العمرانية والبنائية Urban Density :

الكثافة البنائية هي عدد الوحدات البنائية في وحدة المساحة – يجب دراسة هذه الكثافة عند اختيار المرافق الملائمة فكما ذكرنا سابقا فإن الأنظمة اللامركزية تكون في أفضل أداء في الأماكن ذات الكثافة البنائية والعمرانية المنخفضة لتوافر أعلى معدلات تشميس وتهوية وتبخير إلخ – فمثلا عند تركيب أنظمة التصريف Leahing systems في منطقة كثيفة بنائيا فيجب استخدام الأنظمة الأصغر مساحة والتي تتسم بسرعة تصريف عالية - وتكون الأنظمة الأنسب للتصريف هي خنادق التصريف أو حفر التصريـــــــــــف Soak pits or infiltration trenches - تؤثر الكثافة البنائية أيضا في قرار المصمم عند المفاضلة بين الأنظمة الفردية والأنظمة شبه المجمعة في المرافق اللامركزية – فكلما زادت الكثافة البنائية كانت الأنظمة المجمعة أفضل (كخزان التحليل المجمع والهاضم الحيوي ABR الجماعي) – لأن في هذه الحال تنقسم تكلفة المرفق على عدد أكبر من الوحدات وبالتالي تقل تكلفته – ربما كان النظام الفردي أنسب في المجتمعات ذات العلاقات الغير قوية والتي تكثر فيها خلافات الجيرة عامة حتى وإن كانت كثافتها البنائية مرتفعة.

هـ- عروض الشوارع والنمط العمراني Street width and Urban Tissue (Fabrique):

يجب دراسة عروض الشوارع وانحناءاتها والنمط العمراني السائد – فمثلا إذا كانت العروض كبيرة والنسيج شبكي منتظم كانت المرافق المركزية وشبه المركزية أنسب – وإذا كان النسيج عضويا حرا والشوارع ملتوية وكثيرة الانحناءات كانت المرافق اللامركزية أنسب . يجب أيضا دراسة الأماكن العامة من شوارع ومتنزهات وحدائق وممرات مشاة لاختيار أنسب الأماكن لتركيب المرافق اللامركزية فمثلا يمكن تركيب كل من (خزانات التحليل – حفر التصريف وخنادق التصريف) بأمان تحت منسوب سطح الأرض في مناطق ممرات المشاة والمناطق التي لا تمر فوقها المعدات الثقيلة لأنها قد تتسبب بتحطيم هذه الأنظمة - بينما يمكن تركيب الهاضم الحيوي متعدد الحواجز ABR تحت الحدائق العامة والساحات والأحواش الداخلية للمباني والمناطق المفتوحة لأنها تتطلب تهوية جيدة وعدم مرور المركبات فوقها.

و- السعة الموسمية ومعدلات الإشغال Seasonal Capacity & Occupation :

المناطق ذات التشغيل الموسمي (المصايف والمنتجعات الساحلية) هي الأنسب لتطبيق المرافق اللامركزية حيث أن معدلات التشغيل منخفضة ومن غير المجدي اقتصاديا تركيب المرافق المركزية باهظة التكاليف لمثل هذه الاستعمالات . عند اختيار المرافق اللامركزية للمنازل الصيفية يجب مراعاة أن تكون الأنظمة مرنة بحيث لا تتعطل عند التوقف عن العمل فترة طويلة ولا تحدث بها صدمة تشغيلية عند الاستعمال

الكثيف المفاجيء – من الموصى به استعمال المنظفات القابلة للتحلل العضوي في هذه المساكن بدلا من المنظفات الكيميائية التقليدية وذلك حفاظا على العمر التشغيلي لها[i] .

4- الخصائص الاقتصادية والاجتماعية للسكان: Socioeconomic Properties of the Inhabitants:

أ- السن – التعليم – ومعدلات الفقر Age, Education and Poverty :

إن المستوى العمري والثقافي والتعليمي والاقتصادي للسكان يؤثر بشكل كبير على المرافق اللامركزية المقترحة لهم – حيث أن الشباب والطبقات المتعلمة تعليما عاليا هم بصفة عامة أكثر قابلية لاستعمال التقنيات الجديدة وتجربة التكنولوجيا الحديثة دون خوف- كما أن المستوى الاقتصادي يؤثر في مدى قابلية المجتمع للتعامل مع التقنيات الجديدة ، حيث أن الطبقات الفقيرة جدا والغنية جدا هم عادة أقل قبولا للتغيير فالفقراء لا يملكون ترف التغيير والأغنياء جدا لا يرغبون فيه – بينما الطبقات المتوسطة هي عادة الأكثر قبولا للتقنيات الجديدة مادامت في حدود إمكانياتهم.

ب- معدلات البطالة والمهن السائدة Dominant Profession and Unemployment Rates :

لا بد من دراسة المهن السائدة في المجتمع المستهدف وذلك لاختيار المرافق الأنسب له – مثلا إذا كان السكان يعملون في صيد الأسماك أو تربية الماشية فإن تقنية الهاضم الحيوي تكون ملائمة جدا لهم لوفرة النفايات العضوية لديهم – وإذا كان السكان يعملون في صباغة الملابس مثلا فإن أنظمة معالجة مياه الصرف الصحي لهم لا بد أن تكون مزودة بألياف النخيل الجاف لإزالة الكروميوم الناتج من مواد الصباغة – وإذا كانوا يمتهنون التعدين مثلا فيجب استعمال أنظمة الزراعة المائية لتمتص جذور النباتات بقايا المعادن الثقيلة من مياه الصرف وهكذا.

5- الخدمات والمرافق المحلية المتوفرة Available Local Public Services and Utilities: :

يجب دراسة المرافق والخدمات المتوفرة بالمجتمع المخدوم قبل اقتراح مرافق بديلة – فإذا كانت المرافق الموجودة كافية ومناسبة وتعمل بكفاءة فلا مبرر لاستبدالها بمرافق بديلة – إما إذا كانت تعاني بعض المشاكل في الوفرة او الأداء أو الأثر البيئي فيجب اقتراح تعديلات تعالج هذه المشاكل وتحسن أداء المرافق القائمة بدلا من استبدالها بالكامل. أما إذا كانت المرافق المركزية غير متوفرة بالمرة وليس من المتوقع توفرها قريبا فيمكن التفكير في المرافق اللامركزية كحل بديل – أما إذا كانت غير موجودة ولكن متوقع توفرها قريبا فيجب اختيار المرافق التي يمكنها التواؤم مع هذه الشبكات حال تركيبها (مثال خزان التحليل والهاضم الحيوي يمكنهما التواؤم مع الشبكات المركزية فيما بعد ويساهمان في تحسين جودتها).

يجب أيضا دراسة خدمة جمع القمامة في المجتمع المخدوم وذلك لمعرفة مدى وفرة النفايات العضوية الصلبة ونوعها وإنتاجيتها في حال استخدام الهواضم الحيوية لتوليد غاز الطهي أو لتوليد الكهرباء.

6- أهم القوانين والأعراف المحلية بالمجتمع المخدوم :

Laws, Regulations, and Prevailing Traditions in the Served Society :

يجب دراسة أهم القوانين والنظم والأعراف المحلية والعادات المنظمة للحياة والبناء في المجتمع المخدوم لاختيار المرافق اللامركزية الملائمة له وذلك لمنع رفض المجتمع لهذه التقنيات فمثلا لا يجب استعمال المرافق التي تعتمد على الصرف الصحي الجاف والمنتشرة في بعض الدول الغربية dry urinals & dry toilets لتعارضها مع الثقافة الإسلامية التي تتوجب استعمال الماء ، وعدم استعمال المراحيض ثنائية المسار diverting Toilets التي تفصل المخلفات السائلة عن الصلبة وتستعمل المخلفات السائلة في تخصيب المحاصيل ، وذلك لتعارضها مع الذوق العام في الدول العربية عامة - وبالنسبة للقوانين المحلية في مصر فإن القانون الأكثر ارتباطا بالمرافق اللامركزية هو القانون رقم ٤٨ لسنة ١٩٨٢ والخاص بتنظيم تصريف ومعالجة مياه الصرف الصحي قبل طرحها في المياه السطحية أو المياه الجوفية – وكذلك المرسوم الوزاري رقم ٣٣٤ لسنة ٢٠٠٢ المختص بالكود المصري لأعمال الصرف الصحي وتغذية المياه بالمساكن والمنشآت – يوفر الكود المواصفات والشروط لأعمال وتركيبات شبكات المياه والصرف والمعالجة للمناطق المعزولة عن الشبكات المركزية - هناك مواصفات لخزانات التحليل والترنشات ومصايد الزيوت والمواد البترولية من مخلفات صرف المباني والمصانع – كما يوفر الكود دليلا لأفضل اماكن تركيب خزانات التحليل والترنشات وحفر التصريف في المناطق المعزولة والمباني الصحراوية..

7- أهم المشاكل الاجتماعية والاقتصادية والبيئية في المجتمع المخدوم

Major Social, Economic or Environmental Problems:

وذلك لاختيار أنسب المرافق التي يمكنها حل هذه المشاكل أو تخفيف أثرها- أو على الاقل عدم تزايد حدتها - فمثلا :إذا كان المجتمع المخدوم يعاني سوء علاقات الجوار وعدم التجانس الاجتماعي فإن المرافق الجماعية لاتناسبه لأنها تتطلب الحوار والاحتكاك بين أفراد المجتمع مما قد يزيد النزاعات بينهم – وإذا كان يعاني من البطالة فيفضل استخدام المرافق التي تعتمد على الأيدي العاملة (وليس الماكينات) في الأداء ، لتوفير فرص عمل بالمجتمع ، وإذا كان المجتمع فقيرا يجب اختيار المرافق غير الباهظة والتي يغلب عليها طابع استرداد التكلفة (كالهاضم الحيوي) ، وإذا كان مرض ما متفشيا في المجتمع (كالأمراض المتولدة بالمياه waterborne diseases) فإن أنظمة التصريف يجب تجنبها لمنع تلوث المياه الجوفية بالمزيد من هذه الأمراض وهكذا.

تم في الجزء الثالث من البحث تقديم أربع نماذج تطبيقية للمرافق اللامركزية المقترحة وذلك في أربع مجتمعات عمرانية مختلفة بمصر :

- نموذج ريفي في قرية بلتاج بمحافظة الغربية
- نموذج حضري بمدينة وادي النطرون بمحافظة البحيرة
- نموذج لمنطقة عشوائية وهي حي الجنابية بمدينة طنطا
- نموذج للمجتمعات العمرانية النائية والمعزولة وهي مشروع المليون ونصف فدان المقترح من قبل الدولة مؤخرا.

في كل حالة من الحالات الأربع تم تقديم دراسة تحليلية لأهم معطيات هذه المنطقة من جغرافيا ومناخ وعادات ومعطيات اقتصادية وجيولوجية وخواص التربة إلخ – وكذلك تحليل أهم المشكلات التي تعاني منها من نقص خدمات أو مشاكل بيئية أو صحية إلخ– وتم استخدام هذه المعطيات وتحليلها واختيار أنسب التقنيات الملائمة لكل حالة تبعا لها بحيث تحل هذه المشكلات او على الأقل تخفف من حدتها حسب رؤية الباحثة.

فمثلا في نموذج قرية بلتاج كانت المشكلة الأساسية عدم وجود صرف صحي ووجود أزمات موسمية في غاز الطهي خاصة في فصل الشتاء – فتم اقتراح نموذج لتوفير هذين المرفقين فقط مع الاكتفاء بوجود مرفقي مياه الشرب والكهرباء بشكل كافي بالقرية وبالتالي لا داعي لاستبدالهما (مع تقديم توصيات بشأن التطوير والارتقاء وإعادة التأهيل لهذين المرفقين).

وفي نموذج مدينة وادي النطرون كانت المشكلة الأساسية قيام الأهالي بالصرف على البحيرات عالية الملوحة مما جعلها غير صالحة لاستخراج الملح أو الاستشفاء كما في السابق ، وكذلك مشكلة عدم وجود شبكة غاز منزلي ، فتم اقتراح نموذج لاستقبال مياه الصرف في هواضم متعددة الحواجز Anaerobic Baffled Reactor يليها أحواض للمعالجة بالزراعة المائية Wetland System وتركيب هذين المرفقين على ضفاف البحيرات ليقوما معا باستقبال ومعالجة مياه الصرف المنحدرة من المنازل قبل وصولها للبحيرات المتضررة.

وفي نموذج منطقة تل الحدادين العشوائية في طنطا كانت المشكلة الأساسية انقطاع المياه المستمر ووجود نسبة عالية من المعادن الثقيلة بها وكذلك الضعف في مرفق الصرف الصحي حيث يتم التخلص من الصرف الصناعي الناتج من ورش الحدادة بالمنطقة في شبكةا لصرف الأهلي مما يسبب أعطال مستمرة في الشبكة ، فتم اقتراح مرفق الهاضم متعدد الحواجز Anaerobic Baffled Reactor (ABR) لتخفيف الحمل الهيدروليكي على الشبكة القائمة وتأخير ساعات الذروة القصوى ، وكذلك اقتراح خزان الفصل للمعادن الثقيلة والرمال من مياه الصرف الصناعي قبل وصوله للشبكة العمومية ، كما تم اقتراح نظام فلترة مجمع للمياه لتنقية المعادن الثقيلة قبل وصولها لمنازل المنطقة.

وفي نموذج المليون ونصف فدان لا توجد أي مرافق قائمة مركزيا فتم اقتراح نموذج متكامل يصلح للتطبيق في المناطق النائية والمنعزلة تماما حيث يجمع بين تقنيات استخراج المياه الجوفية وتسخين المياه بالشمس وتوليد الطاقة بالأنظمة الشمسية وبالغاز الحيوي معا لضمان وفرة الطاقة ، وكذلك معالجة مياه الصرف المنزلي وإعادة تدويره واستعمال الماء الرمادي في الري والحمأة المعالجة بالهاضم الحيوي في تسميد أراضي الزراعة الموجودة بالمشروع .

تلا تقديم كل نموذج طرح تقييم له ومناقشة مميزاته وسلبياته المحتملة وكيف يمكن تجنب هذه السلبيات.

رابعا : الباب الرابع : معايير الأفضلية وخرائط الملاءمة :

في هذا الجزاء تم تقديم مجموعة من الخرائط التي توضح مدى ملاءمة كل تقنية من التقنيات المقترحة على حدة وذلك وفقا للمعايير الأكثر تأثيرا على كل منها :

- فتقنيات استخراج المياه الجوفية للإمداد المنزلي تم تقديم خرائط ملاءمة له بناء على معايير وفرة المياه الجوفية ومستوى العمق ودرجة الملوحة ، ومعدلات سقوط الامطار باعتبارها الوسيلة الأضمن لإعادة شحن الخزان الجوفي طبيعيا – وتم إضافة معيار البعد عن الأراضي التي يتم فيها استعمال الري المفتوح المستخدم فيه مبيدات كيماوية ضارة وذلك لاحتمال تسربها للمياه الجوفية مما يقلل صلاحيتها للاستخدام.
- وتقنيات الهاضم الحيوي لمعالجة الصرف المنزلي تم تقديم خرائط ملاءمة له بناء على معايير السطوع الشمسي ومعدلات الحرارة خلال العام وذلك لأثرهما على سرعة التخمر اللاهوائي وتسريع المعالجة.
- وتقنيات أنظمة الزراعة المائية تم تقديم خرائط ملاءمة له بناء على معيار القرب من الأنهار والبحيرات والسواحل وذلك لاعتماد هذه المنظومة على الصرف بعد المعالجة في جسم مائي طبيعي ، وكذلك بناء على معيار وجود المنخفضات والمنحدرات الطبيعية Depressions وذلك لاستخدام الميول الطبيعية في توجيه المياه المعالجة نحو المنظومة ، وكذلك معيار ارتفاع درجات الحرارة والسطوع الشمسي لدورهما في تسريع المعالجة وقتل الميكروبات الموجودة بالمياه المعالجة.
- وتقنيات أنظمة التسريب والترشيح عبر التربة Leaching Systems تم تقديم خرائط ملاءمة له بناء على معيار مسامية التربة Soil Permeability ومعيار ارتفاع الحرارة والسطوع الشمسي لتسريعهما معدلات البخر وجفاف التربة ، ومعيار سرعة الرياح حيث تزيد سرعة التبخير أيضا وكلما زادت قيمة هذه العوامل الأربعة قلت المساحة المطلوبة لتركيب المنظومة.
- وتقنيات توليد الكهرباء بالأنظمة الشمسية Solar Systems تم تقديم خرائط ملاءمة له بناء على معدلات درجات الحرارة – السطوع الشمسي – وسرعة الرياح باعتبارهم العوامل الأكثر تأثيرا في المنظومة.

ثم تم تقديم خرائط ملاءمة للتقنيات اللامركزية بصفة عامة بناء على عوامل شاملة مثال :

- خرائط الكثافة السكانية حيث كلما قلت الكثافة كلما زادت ملاءمة التقنيات اللامركزية والعكس بالعكس.
- خرائط البعد عن الكتلة العمرانية القائمة حاليا (والمتمركزة في الوادي والدلتا) حيث كلما ابتعدت المنطقة المستهدفة عن هذا المحور العمراني المزدحم كلما زادت قابلية تطبيق المرافق اللامركزية لبعد المنطقة عن الشبكات المركزية القائمة..
- خرائط المناطق الأكثر أمانا : حيث كلما زادت قابلية المناطق لوجود أعمال تخريبية كلما زادت ملاءمة المرافق اللامركزية لتحاشي الاستهداف الجماعي عبر شبكات الخدمة المركزية.
- خرائط الطبوغرافية والوعورة : حيث كلما زادت وعورة المناطق كلما صعب تركيب المرافق الشبكية المركزية وكلما زادت أفضلية المرافق النقطية اللامركزية .
- خرائط النشاط الزلزالي والفيضانات ومخرات السيول : حيث أن هذه المناطق لا تناسب الشبكات المركزية لاحتمال تضررها وتلفها بالزلازل والسيول فتكون المرافق اللامركزية أكثر ملاءمة.
- وأخيرا خرائط الحالة الاقتصادية للسكان : حيث كلما زادت معدلات الفقر الشديد أو الثراء الشديد فإن السكان يكونون أقل استعدادا لتقبل تقنيات جديدة ، في حين تتقبل الطبقة المتوسطة دخلا والأكثر تعليما هذه المرافق بشكل أكبر .

الجزء الخامس : الخلاصة والتوصيات :

في نهاية البحث تم تقديم الخلاصة والتوصيات وذلك باستعراض أهم مميزات وعيوب المرافق اللامركزية وكيف أنها لا تلائم المناطق عالية الكثافة السكانية والبنائية وأنها تزداد ملاءمة كلما ابتعدنا عن العمران القائم وكلما كانت كانت شبكة المرافق المركزية أبعد ما يكون –

وفي نهاية البحث تم تقديم ملخص لمزايا وعيوب المرافق اللامركزية عموما وكيفية تلاشي هذه العيوب في التطبيق ، وتم تقديم توصيات عامة للمخططين والمصممين وصانعي القرار ، حيث تم التأكيد على ضرورة وجود تشريعات قوية تنظم تركيب وتشغيل هذه المرافق لضمان الكفاءة والجودة ، وعدم الاستخفاف بالمستخدمين أو المبالغة في تقدير إمكانياتهم ، وضرورة إشراكهم في صناعة القرار واختيار المرفق الأنسب لهم أولا ، والأثر المتوقع في حال نجاح هذه المنظومة في تحويل المسؤولية نحو المستخدم وتخفيف العبء عن الدولة وتحفيز التطوير التقني والتصنيع وتقليل تكلفة التركيب والتشغيل وتقليل استنزاف الموارد الطبيعية وتسهيل الامتداد العمراني في المناطق المعزولة والخروج خارج الوادي القديم .

Thesis Summary

Proper and clean utilities (potable water supply, sewerage, electricity and cooking gas) are a problematic issue in Egypt. Although Governments spend billions of pounds every year on utilities' provision, the provided services are not always sufficient or convenient. Expanding these utilities to new urban settlements is another challenge as it requires huge investments that may exceed the government's capabilities.

On the other hand, conventional utilities have many environmental drawbacks. They deplete our non-renewable resources and affect our ecological systems. Utilities' provision is getting more difficult by the time as our water share is threatened and our energy is in shortage. This research suggests that nonconventional decentralized utilities can mitigate the problem. If people can build up their own utilities they will feel responsible, stop complaining, gain experience, reserve the resources, and make their best to improve and maintain their utilities. Water will be wisely consumed and energy will be green and sustainable. Decentralized utilities can suit slums and rural areas where central utilities are absent or deteriorated. They can also suit new settlements and remote areas with low population capacity, where investing in central utilities is economically unfeasible.

In the first chapter the researcher came across the evaluation of central utilities and how they affect our health, economy, urban planning and environment.

The second chapter reviewed the main off-grid utilities' technologies used in some areas in different countries. It has discussed their feasibility, efficiency, sustainability and suitability for application in Egypt.

The third chapter has reviewed four different societies in Egypt by analyzing their potentials, needs and problems, Afterwards it introduces suggested utilities for these societies and evaluates the possible pros and cons of these applications.

The Research Problem has investigated the suitability of applying decentralized utilities' technologies in Egypt as an attempt to solve the problems of central utilities and help expanding to new settlements in the Egyptian desert in an economical and sustainable manner.

The research aims to encourage the desired expansion in the Egyptian desert by using decentralized utilities. It also seeks to find cheap, efficient and sustainable utilities that suit the Egyptian built environment in rural areas, slums, touristic resorts, coastal regions and new settlements in the Egyptian desert.

The research concluded that off-grid utilities can be a sustainable and feasible choice for new settlements in Egypt.

The applied study concluded that these utilities can be applied in new housing projects especially in Egyptian desert.

Finally the search recommends the application of these utilities in our future housing projects in new remote and isolated housing areas.

Abbreviations

Abbreviation	Page	Line	Explanation
A			
AGA	89	15	American Gas Association, founded in 1918, representing more than 200 local energy companies that deliver clean natural gas throughout the United States. المنظمة الأمريكية لتوصيل الغاز المنزلي.
B			
Bn	22	7	One billion = one thousand million= 1,000,000,000 = 10^9. بليون = وحدة تساوي ألف مليون.
BOD	29	15	Biological Oxygen Demand. طلب الأكسجين البيوكيميائي: هو كمية الأكسجين الذائبة التي تحتاجها الكائنات البيولوجية الهوائية في الماء لتكسير المواد العضوية الموجودة تحت درجة حرارة معينة وضمن فترة زمنية محددة، يستخدم هذا المعيار على نطاق واسع للدلالة على جودة المياه المعالجة وكمؤشر لقياس فعالية محطات معالجة مياه الصرف الصحي.
BOT	22	5	Build–operate–transfer (BOT) or build–own–operate–transfer. (BOOT) is a form of project financing, wherein a private entity receives a concession from the private or public sector to finance, design, construct, and operate a facility stated in the concession contract, which enables the project proponent to recover its investment, operating and maintenance expenses in the project. نظام "البناء والتشغيل والتحويل" أو "البناء والتشغيل ونقل الملكية" أو "التشييد والتشغيل ونقل الملكية": وهو عبارة عن قيام مستثمر من القطاع الخاص بإذن الدولة بتشييد وبناء مشروع على نفقته الخاصة (كإنشاء مطار أو محطة توليد كهرباء) ويتولى تشغيله وإدارته لمدة امتياز تتراوح بين ٣٠ أو ٤٠ سنة بحيث يحصل خلالها على التكاليف التي تحملها بالإضافة لتحقيق أرباح ، وبعد انتهاء مدة الامتياز تؤول ملكية المشروع بعناصره للدولة. فنظام B.O.T يعني وجود آلية تمويلية إنشاء البنى الأساسية في مجتمع ما بعيداً عن موارد الدولة.
Btu/hr	78	15	British thermal unit per hour, a traditional unit of work equal to about 1.055 kilojoules. It is the amount of work needed to raise the temperature of one pound of water by one degree Fahrenheit. One four-inch wooden kitchen match consumed completely generates approximately 1 BTU. وحدة حرارية بريطانية: هي كمية الطاقة اللازمة لتسخين ١ باوند (١ رطل) من الماء لدرجة واحدة فهرنهايت ، وهي تساوي تقريبا نحو ١٠٥٥ جول.
Btu/scf	89	10	British thermal units per standard cubic foot. وحدة حرارية بريطانية / قدم مكعب قياسي من الغاز

Abbreviation	Page	Line	Explanation
C			
CAPMAS	30	26	Central Agency for Public Mobilization and Statistics, established in 1964, is the official statistical agency of Egypt that collects, processes, analyzes, and disseminates all statistical data and the Census الجهاز المركزي للتعبئة العامة والإحصاء.
CGC	86	16	Cairo Gas Company شركة غاز القاهرة الكبرى
CH_4	67	7	Methane gas, a colorless, odorless gas, the simplest alkane and the main component of natural gas. Methane is a potent greenhouse gas with a global warming potential of 34 compared to CO2 over a 100-year period, and 72 over a 20-year period. غاز الميثان: غاز عديم اللون والرائحة وهو المكون الأساسي للغاز الطبيعي المنزلي ، ويسبب تسرب الميثان للغلاف الجوى احتباسا حراريا أكثر من ٣٤ ضعف ما يسببه غاز ثاني أكسيد الكربون خلال ١٠٠ عام، و٧٢ ضعفا خلال ٢٠ عاما.
COD	29	15	Chemical Oxygen Demand. الاحتياج الكيميائي من الأكسجين: هو كتلة الأكسجين المستهلك لكل لتر من الماء ، ويعتبر مؤشرا قياسيا للدلالة على جودة ونوعية المياه حيث يقيس بشكل غير مباشر كمية المركبات العضوية السابحة فيه وبالتالي يمكن تقدير كمية الملوثات العضوية الموجودة في المياه (بحيرات، أنهار، أو مياه صرف صحي إلخ) ، ووحدة قياسه هي ملليغرام لكل لتر (ملغم / لتر).
D			
DO	41	13	Dissolved Oxygen, the amount of oxygen available in the water. It is a main indicator to measure water quality as low DO levels indicates pollution of the measured water body. نسبة الأكسجين المذاب في الماء : ، وهي مؤشر لجودة المياه حيث كلما قل الأكسجين المذاب في الماء قلت جودته ما يعني أن الماء ملوث ويزخر بالكائنات العضوية التي تستهلك الأكسجين لعملياتها الحيوية.
E			
EEAA	41	1	Egypt Environmental Affairs Agency, established 1997 to represent the executive arm of the Ministry of Environment. جهاز شؤون البيئة التابع لوزارة البيئة المصرية.
EEER	40	12	Egyptian Environmental Executive Regulation. اللائحة التنفيذية للقانون المصري المنظم لحماية البيئة.
EEHC	61	11	Egyptian Electric Holding Company. الشركة القابضة للكهرباء في مصر.

Abbreviation	Page	Line	Explanation
EGAS	86	7	Egyptian Natural Gas Holding Company الشركة المصرية القابضة للغاز الطبيعي.
EIA	44	21	Environmental International Agency الوكالة الدولية لحماية البيئة.
EIPR	96	17	Egyptian Initiative for Personal Rights. المبادرة المصرية للحقوق الشخصية: هي مبادرة تأسست عام ٢٠٠٢ بهدف تعزيز وحماية الحقوق والحريات الاساسية في مصر، وذلك من خلال انشطة البحث والدعوة ودعم التقاضي في مجالات الحريات المدنية، والحقوق الاقتصادية والاجتماعية، والعدالة الجنائية - موقعها الرسمي www.eipr.org
EP	22	12	Egyptian Pound, also expressed in (LE). عملة الجنيه المصري.
EPA	13	6	Environment Protection Agency in the United States, established in December 1970 and Headquartered in Washington, D.C. EPA's mission is to protect human and environmental health. It is responsible for conducting environmental assessment, research and education to create and enforce standards and laws that will promote the health of individuals and the environment. وكالة حماية البيئة بالولايات المتحدة.
ETG	86	16	Egyptian Town Gas. شركة تاون جاس : شركة مصرية ضمن الشركات التابعة للشركة المصرية القابضة للغازات الطبيعية وهي مختصة فى تنفيذ كافة الأعمال المتعلقة بادخال الغاز الطبيعى بمناطق امتياز الشركة وهي محافظات : (القاهرة - الجيزة - الاسكندرية - بورسعيد - الاسماعيلية).
EUR	22	8	The currency code used to represent the euro, the official currency for more than half of the 27 members of the European Union (EU). عملة اليورو :العملة المعتمدة في أكثر من نصف دول الاتحاد الأوروبي وعددها ٢٧ دولة.
EWRA	30	18	The Egyptian Water Regulatory Agency, a national entity established in 2006, to be in charge of the economic and technical regulation of utilities in Egypt. جهاز تنظيم مياه الشرب والصرف الصحي وحماية المستهلك.
			F
FOB	113	3	FOB means: Free on Board. It indicates that price includes shipping and delivering to the buyer's location. البيع بشرط التسليم على ظهر السفينة : منظومة يتم فيها حساب السعر بحيث يشمل تكاليف الشحن والنقل لبلد المشتري ، وتكون مخاطر هلاك أو تلف البضاعة على عاتق البائع طوال الشحن ثم تنتقل لعاتق المشتري من اللحظة التي تعبر فيها البضاعة حاجز السفينة الناقلة.

Abbreviation	Page	Line	Explanation
			G
GASCO	86	16	Egyptian Natural Gas Company. is a subsidiary of the Egyptian Holding Company for Natural Gas (EGAS) operating in the field of natural gas transmission, distribution and processing. The company was established in March 1997. The national gas grid has extended to neighboring countries through the Arab Gas Pipeline. شركة جاسكو مصر : هي إحدي الشركات التابعة للشركة المصرية القابضة للغاز الطبيعي (إيجاس) ، تأسست عام ١٩٩٧ وتعمل في نقل وتوزيع الغاز الطبيعي بمصر ومؤخرا لبعض الدول العربية المجاورة عبر (خط الغاز العربي).
GCR	7	10	Greater Cairo Region, consisting of Cairo Governorate, Giza, Shubra El-Kheima, 6th of October City and Obour City, with a total population estimated at 20,500,000 (as of 2012); area: 1,709 km2; density: 10,400/km2. إقليم القاهرة الكبرى
GDP	88	12	Gross Domestic Product. إجمالي الناتج المحلي للدولة : هو مقدار القيمة السوقية لكل السلع والخدمات التي يتم إنتاجها في الدولة خلال فترة زمنية محددة ، ويعتبر إجمالي الناتج المحلي للفرد مؤشرًا لمستوى المعيشة في الدولة.
			H
HCWW	7	10	Holding company for water and wastewater. الشركة القابضة لمياه الشرب والصرف الصحي في مصر
H.F.O	69	14	Heavy Fuel Oil. الوقود الثقيل الناتج من فضلات تكرير النفط
H_2S	41	15	Hydrogen Sulfide, a colorless gas with the characteristic foul odor of rotten eggs; it is heavier than air, very poisonous, corrosive, flammable, and explosive. It is known to warm the oceans, lower their capacity to absorb oxygen and increase the PH level of the water. غاز كبريتيد الهيدروجين (أو الهيدروجين سلفايد) : غاز عديم اللون قابل للاشتعال وهو كريه الرائحة تشبه رائحته عفن البيض. وهو غاز أثقل من الهواء ولذلك تجده في الأماكن العميقة في حالة تسربه. يستخرج من الغاز المصاحب للبترول ويتم فصله بالحرارة وتتم معالجته وتكثيفه لتسهيل عملية نقله حيث يتم تصديره إلى الخارج. يدخل في صناعة بعض الأدوية، ويُستخدم على نطاق واسع في التحاليل الكيميائية.
			K
KWh	65	2	Kilowatt hour (symbol kWh, kW · h, or kW h) is a derived unit of energy equal to 3.6 megajoules. One kilowatt-hour is defined as the energy consumed by power consumption of 1kW during 1 hour. كيلواوات.ساعة: هو وحدة للتعبير عن الطاقة تساوي ٣,٦ ميجاجول ، وهي تعبر عن كمية الطاقة المستهلكة من الكهرباء عبر وحدة زمن تساوي ساعة.

Abbreviation	Page	Line	Explanation
L			
lbs/MWh	71	4	Means the pounds of emissions emitted per the megawatts of electricity produced per hour. رطل/ميجاوات.ساعة : وهي كمية الانبعاثات (الغازية عادة) الناتجة من كل ميجاوات من الكهرباء التي يتم توليدها خلال وحدة زمن تساوي ساعة.
LDC's	86	15	Local distribution companies. شركات التوزيع المحلية.
LEL	78	24	Lower explosive limit, The lowest concentration (percentage) of a gas or a vapor in air capable of producing a flash of fire in presence of an ignition source (arc, flame, heat). The term is considered by many safety professionals to be the same as the lower flammable limit (LFL). الحد الأدنى للاشتعال: هو معيار الأمان لشبكات الغاز بحيث لا تصل إليه خاصة في الغاز المنزلي.
LPG	77	2	Liquefied Petroleum Gas, also known as butane or botagas, a key household fuel in Egypt which is mainly used for cooking. الغاز البترولي المسال (المعروف في مصر بغاز البوتجاز) والمستخدم محليا بكثرة في الطهي المنزلي.
M			
MENA	26	12	Middle East and North Africa region. دول منطقة الشرق الأوسط وشمال أفريقيا
MPN/100ml	40	19	Most Probable Number per 100 milliliter. العدد الأكثر احتمالا لكل ١٠٠ ملليلتر من السائل : هي وحدة قياس تستعمل في عد الكائنات العضوية والحيوية الدقيقة الموجودة في حجم معين من السائل (عادة مياه الأنهار والبحيرات) حيث يصعب معرفة عدد هذه الكائنات برقم مؤكد.
N			
NATGAS	86	16	National Gas Company. الشركة الوطنية للغاز (ناتجاس) : وهي شركة لتوزيع وتركيب الشبكات تتبع الشركة المصرية الكويتية القابضة.
Nawqam	30	29	National Water Quality Monitoring, established in 2001 with a joint fund by the Egyptian Government and the Canadian International Development Agency (CIDA). It's goal is to develop an effective and coordinated national system for sustainable water resources management in Egypt. الجهاز القومي لمراقبة جودة مياه الشرب ، تأسس عام ٢٠٠١ بالشراكة بين الحكومة المصرية والوكالة الكندية الدولية للتنمية CIDA ، يهدف الجهاز لتأسيس نظام مستدام لموارد المياه والحفاظ على إدارة وجودة المياه المنزلية في مصر.

Abbreviation	Page	Line	Explanation
NGO	39	12	Non-governmental organization, it describes any non-profit, voluntary citizens' group which is organized on a local, national or international level. منظمة (غير حكومية) غير هادفة للربح : وتطلق على أي منظمة غير ربحية تطوعية يقيمها مجموعات أو أفراد على مستوى محلي أو وطني أو عالمي.
NH_4	29	15	Ammonia nitrogen, a waste product of the metabolism of animals, fish and humans. Its average concentration is 30 mg-N/l in moderate municipal wastewater. أمونيا النيتروجين : هو مركب ينتج عادة كفضلات ناتجة عن الأيض والعمليات الحيوية في الحيوانات والأسماك والإنسان، يبلغ تركيزه المتوسط ٣٠ مليجرام/ لتر في مياه الصرف الصحي المنزلي متوسطة التلوث.
Non-OPEC Countries	92	6	Non-OPEC is an abbreviation indicating countries which don't belong to Oil Production Countries' community. الدول الغير منتمية لمنظمة الأوبك (منظمة الدول المنتجة للبترول).
N_2O	67	7	Nitrous oxide, a colorless, non-flammable gas, and a major greenhouse gas and air pollutant. Considered over a 100-year period, it is calculated to have between 265 and 310 times more impact per unit mass (global-warming potential) than carbon dioxide. غاز أكسيد النيتروز: هو غاز عديم اللون، محبب الرائحة وغير قابل للاشتعال، يعتبر من الغازات المسببة للاحتباس الحراري حيث يسبب ٢٦٥ إلى ٣١٠ ضعف ما يسببه ثاني أكسيد الكربون في هذا الشأن. يستخدم الغاز عادة في الجراحة والطب كمسكّن ومخدّر عند استنشاقه وهو مشهور باسم (غاز الضحك).
NOX	93	7	Nitrogen Oxide emissions
NRW	26	3	"Non-revenue water", produced water that becomes "lost" before reaching the customer. Losses can be real (through leaks, also called physical losses) or apparent (through theft or metering inaccuracies). NRW is typically measured as the volume of water "lost" as a share of net water produced (%). However, it is sometimes also expressed as the volume of water "lost" per km of water distribution network per day (L/day/km) نسبة الماء المهدر في الشبكة قبل الوصول للمستخدم ويحسب كنسبة مئوية % أو بوحدة (لتر/يوم/ لكل كلم طولي من الشبكة).
NUCA	3	7	New Urban Communities Authority هيئة المجتمعات العمرانية الجديدة.
			P
PH level	41	17	PH is a numeric scale used to specify the acidity or basicity of an aqueous solution الأس الهيدروجيني : هو القياس الذي يحدد درجة حموضة أو قلوية سائل ما ، ويتراوح رقمه بين صفر إلى ١٤ ، فتعتبر السوائل ذات رقم أقل من ٧ أحماضا والسوائل ذات رقم أعلى من ٧ قلوية أو قاعدية. أما السوائل ذات الرقم ٧ فهي متعادلة وتعادل حموضة الماء النقي عند درجة حرارة 25 مئوية.

Abbreviation	Page	Line	Explanation
PV solar panels	112	15	Photovoltaic solar panels, a system that adapts the conversion of light into electricity using semiconducting materials. أنظمة توليد الطاقة من الشمس (خلايا شمسية).
			R
RBAS	28	13	The United Nations Development Program for Arab States: (Regional Bureau for Arab States), a United Nations global development network advocating sustainable development and inclusive economic growth across the Arab region. It has country offices in 17 Arab countries while headquarter is based in New York. It aims to help these countries to build and share their own solutions in: Sustainable development, Democratic governance and peace building, Climate and disaster resilience. برنامج الأمم المتحدة الإنمائي (المكتب الإقليمي للدول العربية) .
			S
SF_6	67	10	sulfur hexafluoride, an inorganic, colorless, odorless, non-flammable, extremely potent greenhouse gas, which is used as an excellent electrical insulator. سداسي فلوريد الكبريت المصنع منه عوازل كابلات الكهرباء.
SO_2	7	4	Sulphur di oxide, a toxic gas with a pungent, irritating smell, and a major air pollutant which has significant impacts upon human health. ثاني أكسيد الكبريت : هوأحد أكاسيد الكبريت وينتج طبيعياً من البراكين وصناعياً من بعض العمليات الصناعية ومن حرق المشتقات النفطية، يعد من أبرز الملوثات حيث يعد أحد أهم مسببات الأمطار الحامضية وفي حال التعرض له فإنه يشكل ضررا هاما على صحة الإنسان.
			T
TDS	43	16	Total Dissolved Solids, a measure of the combined content of all inorganic and organic substances contained in a liquid, usually measured in mg/L. TDS is not associated with health effects, but commonly used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of a broad array of chemical contaminants. إجمالي المواد الذائبة في الماء (سواء عضوية أو غير عضوية) وتقاس بوحدة (مليجرام/ لتر)، يشيع استخدامها لقياس جودة مياه الشرب حيث كلما قلت قيمة الرقم كلما ارتفعت جودة الماء المقاس.
TP	29	15	Total Phosphorus, a common compound in municipal wastewater, where average concentration ranges between 5 to 20 mg/l of total phosphorous, of which 1-5 mg/l is organic and the rest in inorganic. Phosphorus can cause health problems to humans, such as kidney damage, liver damage, heart failure and osteoporosis.

(followed) TP			الفوسفور الكلي في المياه: حيث هو مركب شائع في مياه الصرف الصحي المنزلي حيثث يتواجد فيها بصورتيه العضوية والغير عضوية ، يتراوح تركيز الفسفور الكلي في مياه الصرف المنزلي بين ٥ – ٢٠ مليجرام /لتر ، يتسبب حال عدم معالجته في الكثير من المشاكل الصحية للإنسان كالفشل الكلوي والكبدي والأزمات القلبية وهشاشة العظام.
Abbreviation	Page	Line	Explanation
U			
UHI	3	7	Urban Heat Island, a city or metropolitan area that is significantly warmer than its surrounding rural areas due to pollution, industrialization and human activities. جزيرة الحرارة الحضرية : هي ظاهرة تنتشر في المدن الكبرى حيث لاحظ العلماء ارتفاع درجة الحرارة بها بشكل ملحوظ عن حرارة الحزام الريفي المحيط بهذه المدن ، وذلك نتيجة للتلوث الناتج عن الأنشطة الإنسانية والصناعية بهذه المدن.
UNICEF	37	1	The United Nations Children's Emergency Fund, established 1946, is a United Nations program headquartered in New York City that provides long-term humanitarian and developmental assistance to children and mothers in developing countries. منظمة الأمم المتحدة للطفولة والأمومة.
USAID	20	7	The United States Agency for International Development, an independent federal agency of the United States that provides aid to citizens of foreign countries, including disaster relief, technical assistance, poverty alleviation and economic development.
USD	22	11	United States Dollar. عملة الدولار الأمريكي.
W			
WSSIP	40	2	Water, Sanitation and Sewerage Infrastructure Projects. مشاريع البنية التحتية لتوصيل مياه الشرب والصرف الصحي.
WWC	19	1	Water and Wastewater Company for Cairo. شركة مياه الشرب والصرف الصحي بالقاهرة.
WWT	23	12	Water and Wastewater Treatment. معالجة مياه الشرب والصرف الصحي.

Glossary

Word	Page	Line	Explanation
Utilities	i	1	Commodities, services or useful features useful to houses. In this research utilities are water, electricity, wastewater treatment and cooking gas services. الخدمات والبنية التحتية المنزلية كالكهرباء والمياه والصرف الصحي والغاز الطبيعي.
Subsidies	i	5	A sum of money granted by the state or a public body to help an industry or business keep the price of a commodity or service low الدعم الحكومي .
Ecological System	i	11	Also known as "Ecosystem", a community of living organisms in conjunction with the nonliving components of their environment (things like air, water and mineral soil), interacting as a system. النظام البيئي
Centralized Utilities	i	13	Utilities that depend on grid systems for transportation of services to/from central station or plant where generation or treatment is performed. المرافق المركزية (الشبكية)
Decentralized Utilities	i	17	Also known as "onsite utilities", "off-grid utilities" or "network-free utilities", are utilities that work without transportation of the service, depending on off-grid technologies that serve single house or group of houses. المرافق اللامركزية (اللاشبكية)
Municipalities	i	24	The governing body of a city, town, district or community. المحليّات والمجالس البلدية
Mitigate	i	31	Make (something bad) less severe, serious, or painful. يخفّف أو يقلل الأثر
Dilapidated	i	35	Decayed, deteriorated, or fallen into partial ruin especially through neglect, age or misuse. متهالكة لسوء الاستعمال أو القِدَم
Sustainable	ii	4	Able to be used without being completely used up or destroyed, involving methods that do not completely use up or destroy natural resources, able to last or continue for a long time. (مستدامة) أي قابلة للاستخدام دون استنفاد الموارد الطبيعية أونضوبها أو تدمير مقوماتها وتدوم لزمن طويل دون ضرراقتصادي أو صحي أو بيئي.
Rural Areas	ii	16	In Egypt they are defined as "villages" located outside cities and towns, with relatively low population density and where farming and relevant agricultural activities are dominant. القرى والمناطق الريفية.

Word	Page	Line	Explanation
Slums	ii	16	A heavily populated urban informal settlement characterized by substandard housing, commonly lacking reliable sanitation services, supply of clean water, reliable electricity, law enforcements and other basic services. المناطق العشوائية وغير المخططة.
Scarcity	ii	23	Insufficiency or shortness of supply. نقص أو شُحّ في الموارد أو نُدرة.
Methodology	ii	24	A set or system of methods, principles, and rules for regulating a particular discipline. منهجية
Population Density	1	4	The number of people per unit of area, usually quoted per square kilometer or square mile. الكثافة السكانية
Occupancy Rate	3	5	The ratio of occupied or inhabited units versus the total number in the building, city, state, etc. معدلات الإشغال
Monthly Revenue	4	13	Monthly recurring revenue (MRR) is income that a business can count on receiving every single month as predictable revenue. It's a consistent number we can use to track recurring revenue over time, in monthly increments. Often this is a by-product of a subscription business - a service that is billed (and paid for) on a monthly basis. الريع الشهري
High Rise Buildings	4	20	Multi-story structures in which most occupants depend on elevators [lifts] to reach their destinations. المباني المتعددة الطوابق المعتمدة بشكل أساسي على المصاعد الكهربية
Urban Density	5	3	Number of people inhabiting a given urbanized area. الكثافة العمرانية
Suburban Areas	7	10	Residential areas or a mixed use areas, either existing as part of a city or urban area or as a separate residential community within commuting distance of a city. الضواحي.
Flora and Fauna	7	2	Meaning plants and animals; the word "flora" is used to discuss plant life, while the word "fauna" refers to animal life. الحياة البرية من نبات وحيوان
Respiratory Ailments	7	6	The state of the lowest layer of the atmosphere making weather conditions, measured in multiple parameters; including air temperature, atmospheric (barometric) pressure, humidity, precipitation, solar radiation and wind velocity. Each of these factors can be measured to define typical weather patterns and to determine the quality of local atmospheric conditions. الأمراض التنفسية

Word	Page	Line	Explanation
Budget deficit	8	2	A status of financial health in which expenditures exceed revenue. The term is commonly used to refer to governmental spending. عجز الموازنة
Water-borne diseases	9	1	Diseases caused by pathogenic microorganisms that are mostly transmitted in contaminated water. Infection commonly results during bathing, washing, drinking, in the preparation of food, or the consumption of food thus infected. الأمراض المتولدة والمنقولة عبر كائنات دقيقة تنتقل وتتوالد في الموارد المائية وتحدث العدوى عبر الشرب او الاستحمام او تحضير الطعام من هذه المياه
Environmental degradation	9	1	The deterioration of the environment through depletion of resources such as air, water and soil; the destruction of ecosystems and the extinction of wildlife. It is defined as any change or disturbance to the environment perceived to be deleterious or undesirable. التدهور البيئي
The Building Unified Law 119/2008	17	8	قانون البناء الموحد المنظم للبناء والعمران في مصر والمعروف بالقانون ١١٩ لسنة ٢٠٠٨
Old urban cluster (1985 boundaries)	17	9	الحيز العمراني القديم لمدن وقرى مصر والمعتمد عام ١٩٨٥
Sewers	17	10	Underground conduit for carrying off drainage water and waste matter. . البنية التحتية لشبكة الصرف
Initial cost	17	14	The cost incurred during the design and construction process, including planning, building, installation and establishment. تكلفة التأسيس والتركيب
Running Cost	18	6	For a utility, it is the amount regularly spent to operate the utility, such as salaries, maintenance, and operational expenses to keep the utility working تكلفة التشغيل
Privatization policy	18	6	The transfer of ownership, property or business from the government to the private sector- سياسة الخصخصة
Depreciation of the Egyptian pound	19	3	Depreciation of a country's currency refers to a decrease in the value of that country's currency due to market forces, thus the currency has less ability to buy certain commodities. تضخم الجنيه وانخفاض قوته الشرائية .

Word	Page	Line	Explanation
Annual Deficit	19	6	Budget deficit found at the end of the working year. العجز المالي للسنة المالية
Feasibility	19	7	The ability of a project to cover all its expenses (initial and running) after a certain time, after which the revenues become a net profit. الربحية – القابلية للربح
Official tariff	19	13	The official price of a commodity set by the Government التسعيرة الرسمية
The Egyptian Cabinet	19	13	مجلس الوزراء المصري
Pricing policy	19	14	سياسة التسعير للخدمة
Cost recovery	20	1	استرداد التكلفة عبر التشغيل
United Nation Transparency Index	21	12	An international corporation founded 1993, aiming to disclose corruption by ranking its levels in different sectors all over the world. It has offices in more than 100 countries and an international secretariat in Berlin. مؤشر الأمم المتحدة للشفافية
Soft loans	22	8	A loan with a below-market rate of interest, and made on terms very favorable to the borrower قروض ميسرة
Interest rate	22	8	The proportion of a loan that is charged as interest to the borrower, typically expressed as an annual percentage of the loan. فوائد القروض
Stabilization Ponds	23	13	Abbreviated as (SPs) are large, man-made water bodies, used for wastewater treatment. It has three types; anaerobic, facultative and aerobic (maturation), each with different treatment and design characteristics برك الاستقرار
Aeration tanks	24	6	Are tanks for wastewater treatment, where air (or oxygen) is injected in the mixed liquor to achieve aerobic digestion of the waste. أحواض التهوية
Aerobic digestion	24	7	A collection of processes by which microorganisms break down biodegradable material in the presence of oxygen التخمر الهوائي
Chlorination tanks	24	11	Tanks where chlorine ($Cl2$) or hypochlorite is added to water to kill certain bacteria and other microbes, and to prevent the spread of waterborne diseases such as cholera, dysentery, typhoid etc أحواض الكلورة.
Ultraviolet sterilization	24	15	Is a disinfection method that uses short-wavelength ultraviolet (UV-C) light to kill or inactivate microorganisms by destroying nucleic acids and disrupting their DNA, leaving them unable to perform vital cellular functions. It is mainly used for food, air, and water purification تعقيم المياه بالأشعة فوق البنفسجية.

Word	Page	Line	Explanation
Germs and Microorganisms	24	16	Germ is a microorganism causing disease. The four major types of germs are: bacteria, viruses, fungi, and protozoa الجراثيم والكائنات الدقيقة
Parasites, Viruses and other Parasitic Microorganisms	24	24	الطفيليات ، الفيروسات والكائنات الطفيلية الدقيقة
Typhus and Diarrhea	25	4	Typhus is a serious disease that is carried by small insects that live on the bodies of people and animals and that causes high fever, headache, and a dark red rash التيفوئيد While Diarrhea is an increased frequency or decreased consistency of bowel movements الإسهال .
Benchmark	26	15	A standard or point of reference against which things may be compared المؤشّر
Leaks and Infiltrations	27	9	Leaks are water seep from sewers to surrounding groundwater التسريب من مواسير الشبكة إلى المياه الجوفية, while infiltrations are groundwater getting into the sewers التسرب من المياه الجوفية لداخل مواسير الشبكة عبر اللحامات غير المحكمة
Ozonation	27	17	"Also referred to as Ozonisation", is a chemical water treatment technique based on the infusion of ozone into water تعقيم المياه بالأوزون
Removal efficiency	28	11	A percentage representing the number of molecules of a contaminant removed or destroyed in wastewater relative to the number of molecules that entered the system. كفاءة إزالة الملوثات من مياه الصرف الصحي (%).
Brackish	33	11	Is water that has more salinity than fresh water, but not as much as seawater, see page 108 in this research for more details مياه قليلة الملوحة لكن غير عذبة.
Vaults	33	25	Underground non-leaching cavities installed to receive raw wastewater from the house to be evacuated periodically. خزانات الأرضية لاستقبال مياه الصرف المنزلي الخام دون السماح للجدران بالرشح للتربة المحيطة ويتم تفريغها دوريا
Cesspits	33	26	Underground leaching cavities installed to receive raw wastewater from the house and allow it to leach to surrounded soil. خزانات الأرضية لاستقبال مياه الصرف المنزلي الخام وتسريبها بالترشيح للتربة المحيطة المياه الجوفية
Renal Impairments	37	6	Also known as "Kidney failure", "Renal failure" or "Renal insufficiency", a medical condition in which the kidneys fail to adequately filter metabolic wastes from the blood. فشل كلوي أو قصور في وظائف الكلى

Word	Page	Line	Explanation
Bilharziasis and Chestomaises	38	1	A disease caused by contact with fresh water contaminated with a parasite called schistosomesthe. Signs and symptoms may include abdominal pain, diarrhea, bloody stool, or blood in the urine. Long time infection may cause liver damage, kidney failure, infertility, or bladder cancer. In children, it may cause poor growth and learning difficulty. البلهارسيا.
Cholera	38	2	An infection spreads mostly by water and food that has been contaminated with human feces. Symptoms are diarrhea, vomiting and muscle cramps. It may develop within hours to severe dehydration and electrolyte imbalance which if not treated may lead to death. الكوليرا
TB	38	6	Tuberculosis, a serious infectious disease that mainly affects lungs and can spread from one person to another through tiny droplets released into the air via coughs and sneezes السل الرئوي.
Rheumatic heart disease	38	6	A chronic heart condition caused by rheumatic fever caused by a preceding group A streptococcal infection. حمى القلب الروماتيزمية
Rheumatic joints	38	6	An autoimmune disease that causes chronic inflammation of the joints and other areas of the body. التهاب المفاصل الروماتيزمي
Polio	38	7	An infectious disease caused by the poliovirus. Signs are muscle weakness resulting in an inability to move شلل الأطفال
Epidemic	38	7	A rapid spread of infectious disease to a large number of people in a given population within a short period of time وباء متفشي فجأة في عدد كبير من المرضى بمكان أو بلد معين.
Urban Encroachment	38	19	The invasion of buildings over surrounding land الزحف العمراني والتعدي على الأراضي المحيطة

Word	Page	Line	Explanation
Wetlands	40	5	Land areas that are saturated with water, either permanently or seasonally, such that it takes on the characteristics of a distinct ecosystem الأرض المغطاة بالمياه موسميا أو دائما مثل المستنقعات والمروج والسباخ والتي تكون نظاما بيئيا مميزا
Forests	40	5	Large areas of land covered with trees or other woody vegetation غابات شجرية
Grasslands	40	5	Areas where the vegetation is dominated by grasses غابات عشبية
Litigator measures	40	7	Legal action taken because of an individual's or corporation's actions, inactions, products, services or other events... الدعاوى القضائية
Faecal Coliform	40	17	An anaerobic, rod-shaped, gram-negative bacterium, generally originating in the intestines of warm-blooded animals and humans. Its presence in water may not be directly harmful, but indicate the presence of feces بكتريا القولون البرازية.
Escherichia coli	40	18	A gram-negative, facultatively anaerobic, rod-shaped bacterium, commonly found in the lower intestine of warm-blooded organisms (Animals and humans). They may cause serious food poisoning in their hosts, and are occasionally responsible for product recalls due to food contamination بكتيريا الاشرشيا القولونية
Pesticides and herbicides	44	14	مبيدات الآفات الزراعية ومبيدات الحشائش
Cyanobacteria	44	15	Also called "blue-green algae", a kind of bacteria that obtains its energy through photosynthesis and produces Cyanotoxins in receiving water body البكتيريا الزرقاء تستطيع القيام بالتمثيل الضوئي وتتكاثرمع وفرةالغذاء في المياه ووفرةالسطوع الشمسي وتنتج السموم الطحلبية.
Eutrophication	44	15	Excessive richness of nutrients in a lake or other body of water. وفرة المغذيات العضوية في المياه
Cyanotoxins	44	16	Toxins produced by cyanobacteria, they poison and even kill animals and humans. Cyanotoxins can also accumulate in fish and cause poisonings for fish consumers' السموم الطحلبية.

Word	Page	Line	Explanation
Malignant Mesothelioma of the Peritoneum	44	16	A cancer of mesothelial tissue, associated especially with exposure to asbestos. ورم خبيث بالغشاء البريتوني "المصلي البطني"
Gastrointestinal Tract	44	16	Digestive tract, which consists of the stomach and intestines, and is divided into the upper and lower gastrointestinal tracts الجهاز الهضمي شاملا المَعِدي والمعوي.
Larynx	44	16	The hollow muscular organ forming an air passage to the lungs and holding the vocal cords in humans and other mammals; the voice box الحنجرة.
Retention time	46	5	Also called "Residence Time" is a calculated quantity expressing the mean time that water spends in treatment lake or baisn. It is especially important where pollutants are concerned زمن المكوث.
Feddan	46	22	A unit of area used in Egypt and equals 4200 square meters فدان.
Cul-de-sacs	48	8	Street or passages closed at one end طرق مغلقة النهايات
Coded revenue meters	64	14	العدادات الكودية – المخصصة للمباني المخالفة
Restricted heights imposed by civil aviation	66	20	قيود الارتفاعات البنائية المفروضة من قبل وزارة الطيران المدني
judicial dispute	66	21	نزاع قضائي
Greenhouse Effect	67	4	greenhouse effect is the process by which radiation from a planet's atmosphere warms the planet's surface to a temperature above what it would be without its atmosphere. الاحتباس الحراري أو ظاهرة الصوبة الزجاجية
Greenhouse Gas	67	5	(sometimes abbreviated GHG), a gas in an atmosphere that absorbs and emits radiation within the thermal infrared range, which leads to greenhouse effect. غازات الاحتباس الحراري
Hydropower	69	1	Electricity generated from Dam,s like Aswan High Dam in Egypt. الكهرباء المولدة مائيا من سدود الأنهار
Thermal power	69	7	Electricity generated from burning fossil fuel like Natural gas or Petrolium. الكهرباء المولدة حراريا بحرق الوقود

Word	Page	Line	Explanation
Fossil fuel	69	13	Non-renewable fuels containing high percentages of carbon, such as petroleum, coal, and natural gas الوقود الأحفوري
Anthropogenic climate change	69	23	Climate change Caused or influenced by humans harmful activities التغير المناخي الناتج من تدخل الإنسان وتلويثه للبيئة
Particulate Matter	69	25	Abbreviated as "PM", is the sum of all solid and liquid particles suspended in air many of which are hazardous. This complex mixture includes both organic and inorganic particles, such as dust, pollen, soot, smoke, and liquid droplets and may cause serious respiratory diseases to exposed humans الجسيمات العالقة في الهواء نتيجة التلوث أو الطقس.
Crude oil	71	18	Is a naturally occurring, unrefined petroleum product النفط الخام
Metric Ton	77	4	A unit of weight equal to 1,000 kilograms (2,205 lb). الطن المتري ويساوي ١٠٠٠ كيلوجرام
Fainting & Suffocation	78	25	الإغماء والإختناق
Asphyxiant	78	26	substance that can cause unconsciousness or death by suffocation مادة تسبب الإغماء أوالموت خنقا بمجرد استنشاقها
Frontier Governorates	79	20	المحافظات الحدودية (كمطروح وشمال سيناء)
Toxins	94	14	Poisonous substances capable of causing disease or death on contact with or absorption by body tissues. سموم
Formaldehyde			A naturally-occurring organic compound with the formula CH2O. It poses a significant danger to human health, it is highly toxic regardless of method of intake. Ingestion of 30 mL (1 oz.) of a solution containing 37% formaldehyde has been reported to cause death in an adult human. الفورمالدهايد
Soil Transmissivity	108	4	the rate at which groundwater flows horizontally through an aquifer نفاذية التربة
Salinity	108	9	Salinity is the saltiness or dissolved salt content of a body of water, commonly measured in one part per million (ppm). نسبة الملوحة للمياه (جزء في المليون)

Word	Page	Line	Explanation
Thermal distillation	114	18	A process that uses thermal energy (e.g. fuel) to evaporate water and subsequently condense it again. تحلية المياه بالطاقة الحرارية
Electro dialysis			Electrodialysis (ED) is a water purification method based on transporting salt ions from saline water to fresh water tank through ion-exchange membranes under the influence of an applied electric potential difference. تحلية المياه وتنقيتها عبر غشاء باستخدام فرق الجهد الكهربي على جانبي الغشاء
Reverse osmosis			a process by which a solvent passes through a porous membrane in the direction opposite to that for natural osmosis when subjected to a hydrostatic pressure greater than the osmotic pressure التناضح العكسي.
Solar desalination			Solar desalination is a technique to desalinate water using solar energy. Water is evaporated by sun heat and the vapor is condensed into fresh water collection tank. تحلية المياه بأشعة الشمس

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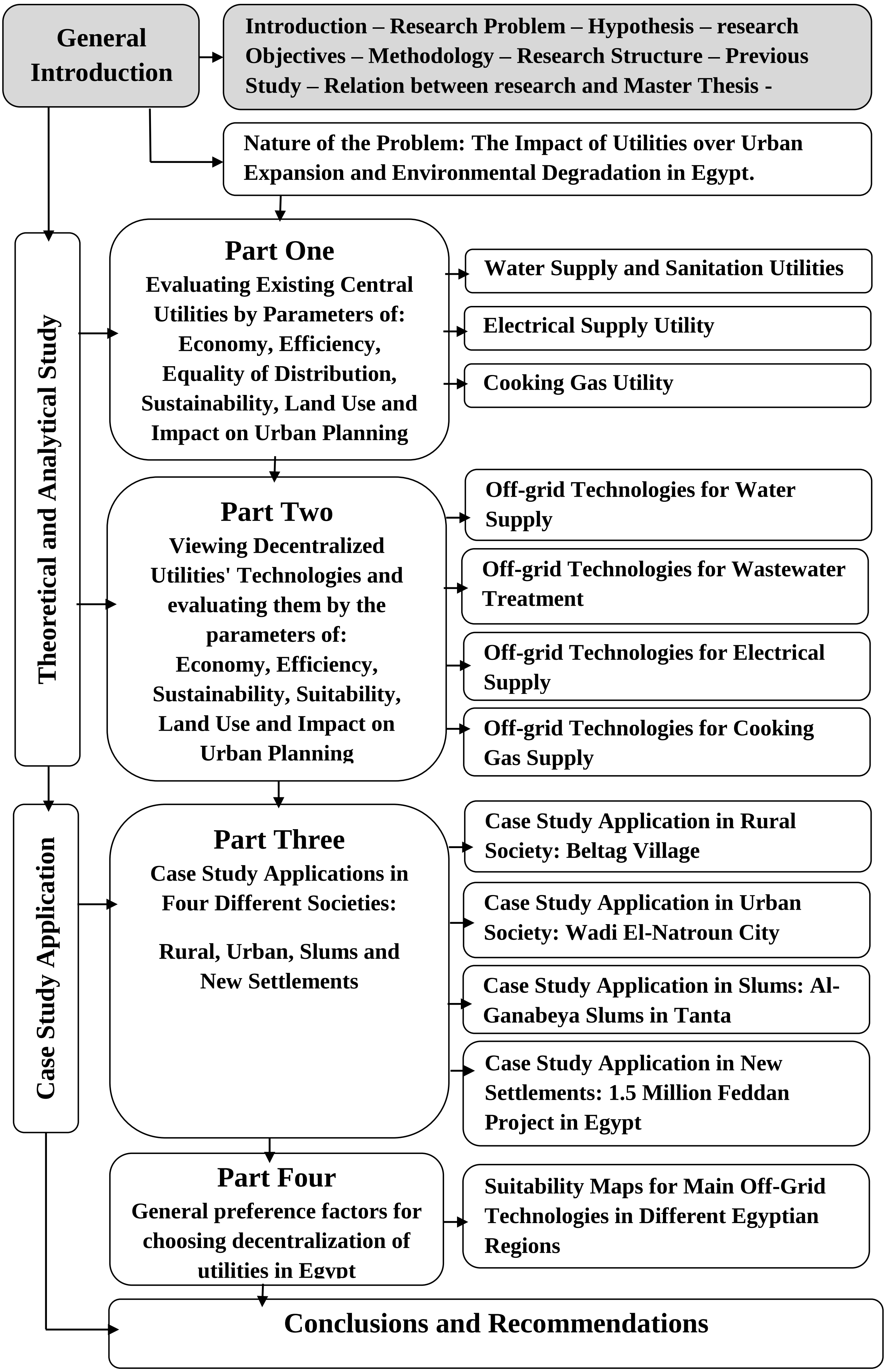
General preference factors for choosing decentralization of utilities in Egypt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Introduction:

Proper and clean utilities and services (e.g. potable water supply, wastewater disposal, electricity and cooking gas etc.) are basic indications for civilization and prosperity as identified by the United Nations Developmental Program. In Egypt, providing these utilities in an affordable price is a growing challenge to the government. Although it spends billions of pounds every year on major utilities' projects and subsidies, the provided services are not always sufficient or convenient. Expanding these utilities to new urban settlements is another challenge as it requires huge investments that may exceed the government's capabilities.

On the other hand, conventional utilities in Egypt (which are usually centralized or "on-grid" utilities) have many environmental drawbacks. They deplete our non-renewable resources and affect our ecological systems. The absence of these utilities also results in using unsustainable alternatives which may have serious polluting features.

Providing central utilities in Egypt is getting more difficult by the time. Egypt's water share from the river Nile is threatened and its energy is in shortage, so centralized utilities are getting less available and more expensive, which may hinder the developmental plans and cause social, economic and political unrest.

Decentralized utilities (as defined by Robaa, 2003) are off-grid utilities that work individually without a collection point or transportation system [(1).] While "Formal Utilities" are the utilities provided by municipalities or governmental entities. In Egypt, public utilities are generally centralized, based on transporting the utilities from/to a production or collection point. These systems are usually more expensive and complicated than decentralized utilities applied individually by each family or group of families.

Decentralized utilities in this search are limited to the non-governmental utilities, installed individually by the dwellers themselves, under supervision and licensure of municipalities or governmental entities.

The limitations of this research are:

- Geographical limits : The research is limited within the Egyptian boundaries.
- Functional Limits : Which are residential buildings only, all other uses are not discussed in this study.
- Time limits : Which are the present time and the future.

This research suggests that nonconventional decentralized utilities can mitigate the utilities problem in new cities and remote areas where installing grid-utilities is so expensive and hard to apply. The main target of this research is to find a proper utility system for new settlements and remote areas with low population capacity, where investing in central utilities is comparatively less feasible.

Research Problem:

The research investigates the suitability of applying decentralized utilities' technologies in Egypt as an attempt to mitigate the problems of central utilities and help expanding to new settlements in the Egyptian desert in an economical and sustainable manner.

Hypothesis:

The main hypothesis of the research is:

Decentralized utilities' can be applied in Egyptian new settlements to mitigate the utilities' shortage problems and encourage the urban expansion in the Egyptian desert in an economic, efficient and sustainable manner.

Research Objectives:

The main objective of this research is:

Expanding urban communities and agglomerations in the Egyptian desert using decentralized utilities.

The secondary objectives are:

1. Mitigating the problems of deteriorated and unsustainable utilities in some Egyptian areas.
2. Finding cheap, efficient and sustainable utilities that suit the Egyptian built environment in rural areas, spontaneous areas and new settlements in the Egyptian desert.
3. Encouraging the inhabitants to share in building, installing and maintaining their own utilities which enhance social contribution.
4. Limiting the environmental impact of the existing utilities by adopting better technologies with a smaller environmental footprint.
5. Decreasing the cost of installing, running and maintaining of utilities especially in areas with topographic limitations and hindrances.
6. Mitigate the effect of both energy shortage and water scarcity in Egypt.

Methodology:

The research adopts two main methodologies:

1- Analytical and Statistical methodology in evaluating existing central utilities as well as viewing off-grid technologies' and examining its' suitability for Egypt.

2- Experimental methodology in applying suggested utilities in different societies.

Importance of the Research:

The importance of this research is that it:

1- Discusses problems that affect urban, social, economic and environmental status in Egypt.

2- Gives a push to the desired urban expansion in the Egyptian desert.

3- Suggests solutions for energy shortage and water crisis in Egypt.

Structure of the Research:

The main structure of the research is:

Theoretical and analytical part in Part (I) and Part (II): This part examines the present centralized utilities in Egypt and their performance, using many examining tools: Economy feasibility, efficiency, equality of distribution, ease of access, sustainability, environmental footprint, land use and impact on urban planning.

Chapter 2 views the decentralized off-grid utilities and examines them using five tools: cost, efficiency, sustainability, environmental footprint, land use, impact on urban planning and the suitability for application in Egypt.

Applications and case-study part in Part (III): This part analyzes the status and conditions of four different Egyptian societies and examines their present utility shortage. Then it suggests several decentralized solutions that may be compatible with their climatic, economic, urban, social and educational conditions.

Previous Studies: Many previous studies have discussed off-grid utilities' technologies and how to install them. This research adds to the evaluation of the suitability of these utilities for application in different Egyptian societies. It also adds to the suggestions of the proper application of these utilities to solve present and future urban problems in Egypt.

Relation between the Research and the Master Thesis:

The master thesis discussed the social contribution in the decision making at the level of architectural design, urban planning and local governance. The Islamic principles gave the authority to the inhabitants to create and manage their built environment with minimal governmental interference. It also encouraged social contribution in building grand facilities using money of Zakat and Awaqf. This self-motivated Muslim society have innovated many new building technologies that survived successfully for hundreds of years. This research links this social partnership with new technologies and helps to adopt new solutions for old accumulating problems.

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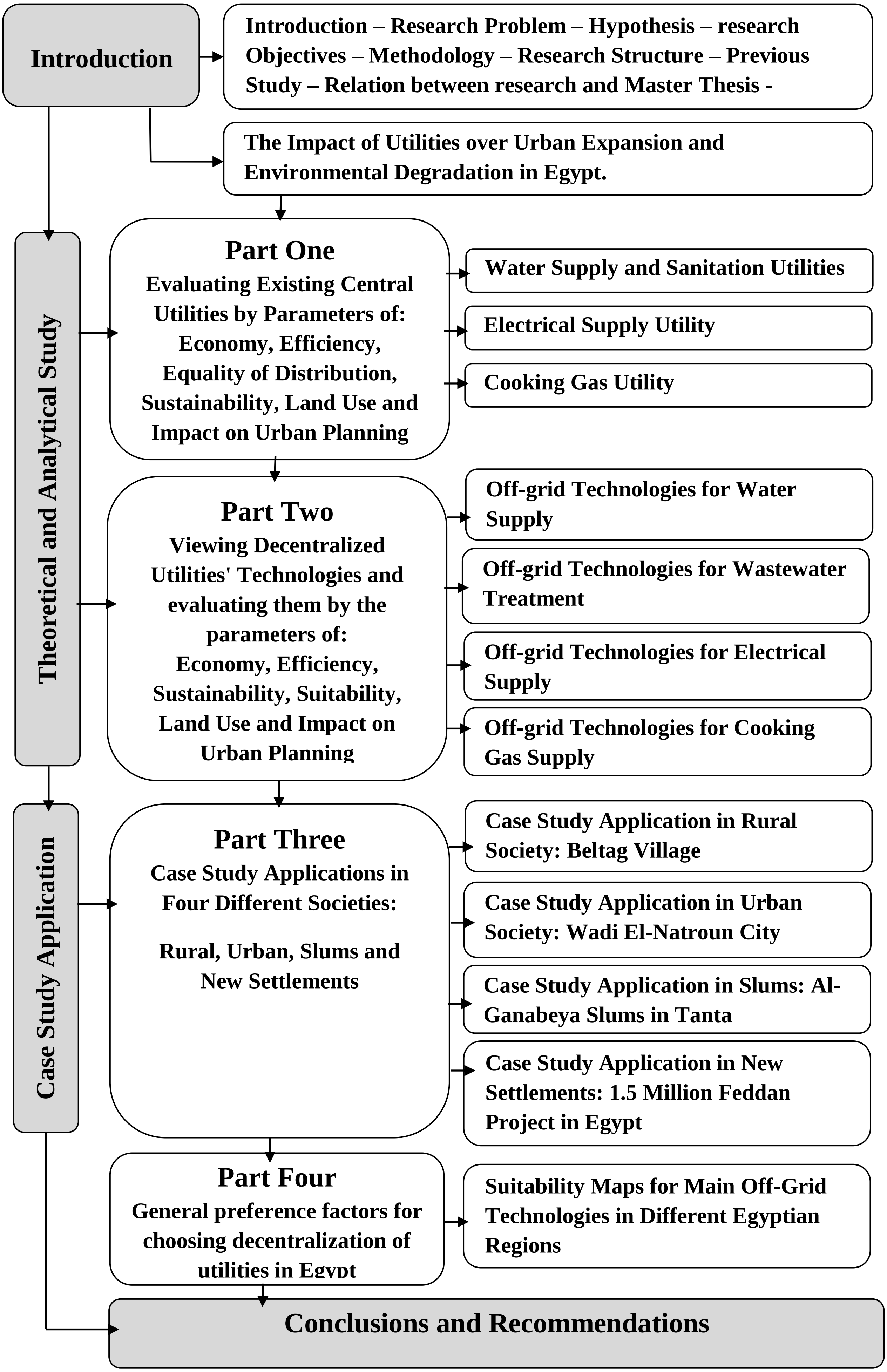
(1) **David Black: Living Off the Grid, Concept and Applications, skyhorse publishing inc, 1st Ed., 2013 pp. (31-32).**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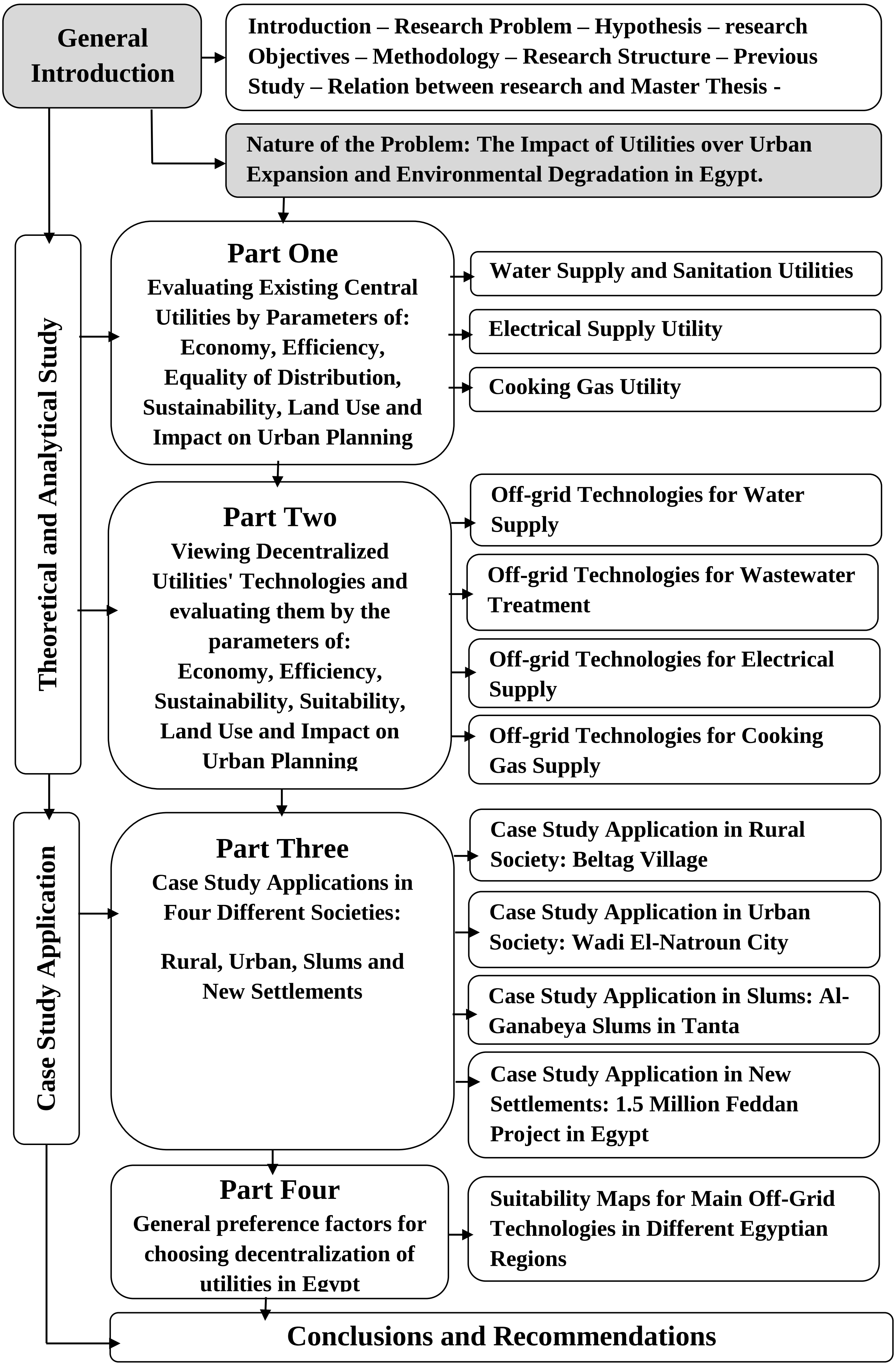
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Part Two
Viewing Decentralized Utilities' Technologies and evaluating them by the parameters of: Economy, Efficiency, Sustainability, Suitability, Land Use and Impact on Urban Planning
Off-grid Technologies for Water Supply
Off-grid Technologies for Wastewater Treatment
Off-grid Technologies for Electrical Supply
Off-grid Technologies for Cooking Gas Supply
Case Study Application
Part Three
Case Study Applications in Four Different Societies:
Rural, Urban, Slums and New Settlements
Case Study Application in Rural Society: Beltag Village
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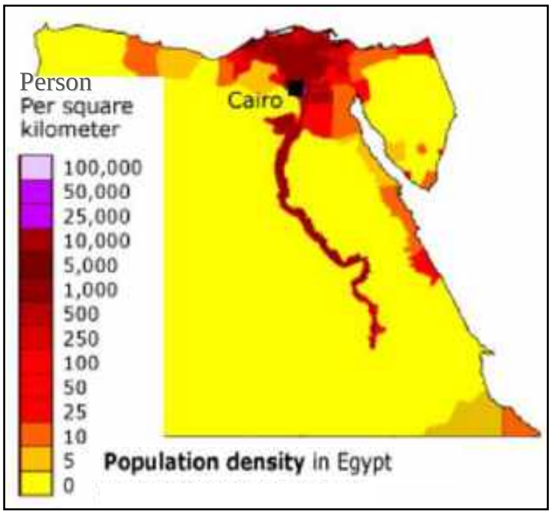
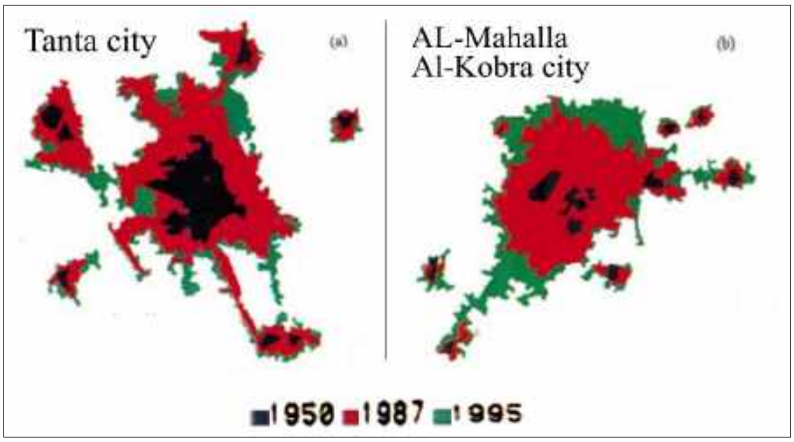
Part Four
General preference factors for choosing decentralization of utilities in Egypt
Suitability Maps for Main Off-Grid Technologies in Different Egyptian Regions
Conclusions and Recommendations

Impact of utilities on urban expansion and environmental degradation in Egypt:
One of the main challenges facing the decision makers in Egypt is the accumulation of population in the old valley. As shown in Fig (1), most of the populations inhabit only 5% of the Egyptian land, causing many developmental and environmental problems. High population density in mega cities is usually accompanied by air pollution and environmental degradation[1] Rapid and uncontrollable urbanization had affected our limited fertile land which has markedly diminished during the last decades, fig(1),(2).




Fig(1): (Left): Population Density map of Egypt (Top right) Accumulation of people in Cairo causing traffic jams (down right) Building over agricultural land in Benha
Source : (left) www.cia.com (Top Right) www.egyptianstreets.com/ (Down Right) www.cairoobserver.com/



Fig(2): Encroachment of urban areas over agricultural land in Tanta and Al Mahalla AL Kobra cities in 4 decades (1950 – 1995)-
Source: Fahim, et. al, 1999

The invasion of urban areas onto fertile agricultural lands as well as the rapid population growth and massive migration from rural to urban areas, all have resulted in the loss of thousands of feddans of highly fertile agricultural land. In light of these conditions, the desired expansion into Egyptian desert is being a must, but this urban shifting requires huge investments which must be offered in conjunction with the building process.

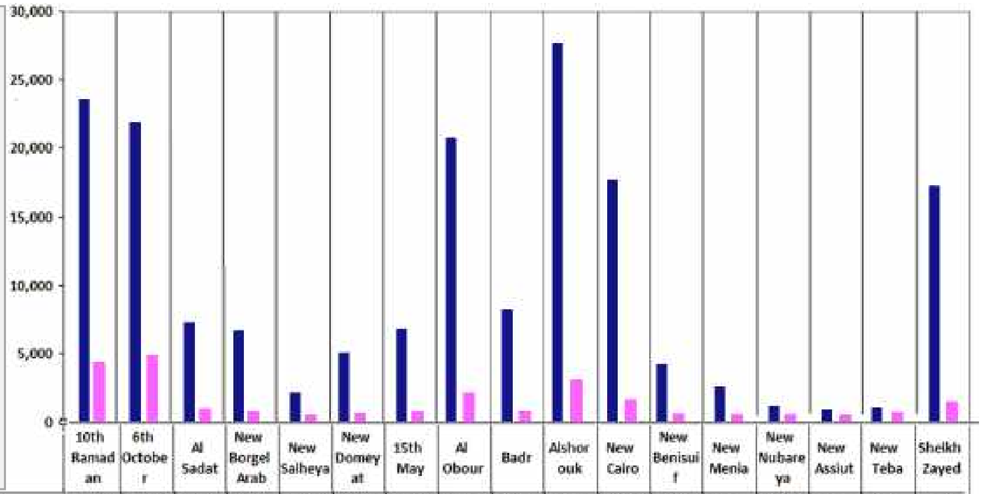
A considerable portion of these investments is required for installing main water, sanitation and power networks in these cities. Since 1977, the consecutive Egyptian governments had established several new cities to attract population outside the old valley. Billions of pounds had been spent over these cities to build houses, install utilities, provide services and plant trees as shown in table (1). Utilities sector had the lion share of the investments spent over these cities. Among 80 billion pounds spent on

City	Governmental Investments in New Cities in Different Sectors (LE Million) As published by New Urban Communities Authority (NUCA), 2015					Utility Sector Among Total Cost %
	Housing Sector	Utilities Sector	Services Sector	Agriculture Sector	Total Investments	
10th of Ramadan	2800	7800	316.6	102.7	11019.3	70.7
Sadat	681.8	1736.3	221.9	59.7	2699.7	64.3
15th May	526.3	1013.6	257.8	22.3	1820	55.69
6th of October	14900	10000	579.4	72.2	25551.6	39.13
Badr	1100	1900	151.9	43.5	3195.4	59.46
Obour	1415	3566.5	500.6	106.5	5588.6	63.81
New Cairo	1500	10700	330.5	43.5	12600	84.9
Shorouk	933.2	1406.8	117.7	40.6	2498.3	56.3
Sheikh Zayed	741.3	1836.2	94.9	64.7	2737.1	67.08
New Beni-Suief	714.3	1197.8	137.6	42.2	2091.9	57.25
New Menia	923.4	1356.8	201.7	44.3	2526.2	53.7
New Assiut	459.9	1321.1	248.1	20.2	2049.3	64.4
New Sohag	518	861.5	94.3	15.7	1489.5	57.8
New Borg El-Arab	396.8	2409.7	176.5	23.4	3006.4	80.15
New Salheya	8.1	430.9	88.3	19.2	546.5	78.8
New Nubareya	55.8	542.1	105.8	9.6	713.3	75.99

Table(1): Official figures of the governmental investments in new cities in different sectors (LE Million)
Source: New Urban Communities Authority (NUCA) , 2015 http://www.newcities.gov.eg/english/New_Communities/

different sectors, 48 billion were spent over utilities sector alone, forming 60% of the total investments in these cities, which, in some cases, may exceed the construction cost of the city itself. But without these utilities, new cities may not attract dwellers due to low quality of life. All these investments in utility sector where not enough to cover all housing areas with adequate utilities. Most of housing areas in these cities have poor or inadequate utilities causing the inhabitants to refrain from moving in. (Shalaby, 2003) has made a statistical study to measure the percentage of utility provision in most new Egyptian cities. The utilities provision percentage was less than 20%, even among first generation cities which were established 2decades before the date of the study.[2] Fig(4).

Fig (4): Areas provided with utilities in new Egyptian cities, measured in Feddan, year 2000.
Based on data from: (Shalaby, 2003).



	10th Ramadan	6th October	Al Sadat	New Borgel Arab	New Salheya	New Domeyat	15th May	Al Obour	Badr	Alshorouk	New Cairo	New Benisuif	New Menia	New Nubareya	New Assiut	New Teba	Sheikh Zayed
Housing Aea (Feddan)	23,423	21,965	7,029	6,284	1,768	4,712	6,455	20,579	7,898	27,528	17,779	3,920	2,263	849	340	685	17,125
Utility Provided Area (Feddan)	4038	4516	548	347.5	30.4	153.6	238.8	1732	326	2598.6	1109.4	123.872	2.059	16.3	1.088	3.356	887.15
Utility Coverage %	17.24	20.56	7.8	5.53	1.72	3.26	3.7	8.42	4.13	9.44	6.24	3.16	0.91	1.92	0.32	0.49	5.18

As a result of poor utility coverage, as well as other social and economic factors, many of these new cities have failed to achieve the expected occupancy rate, and some of them are considered "ghost cities"as shown in fig(5).

Fig(5): Low occupation rates in some new cities in Egypt http://www.iskanmisr.com, (Attia, 2014) has measured the occupancy rate in Egyptian new cities in year 2012, based on the statistics of the New Urban Communities Authority (NUCA) [3]. She found out that most of these cities have failed to achieve more than 10% of their expected population growth after 20 to 40 years of establishment[4]. Fig (6).

Fig(6): Occupancy rate in Egyptian new cities in year 2012

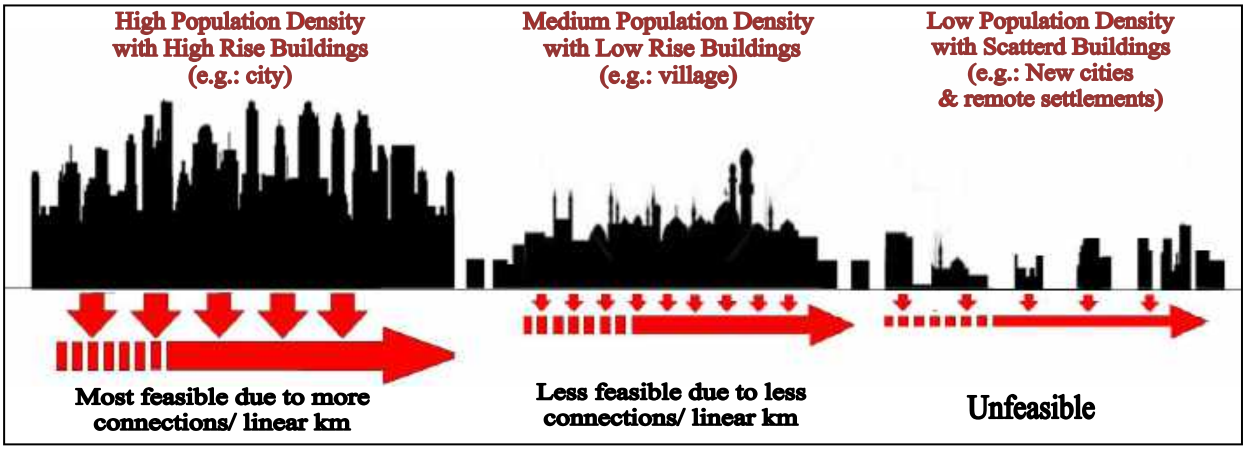
Sahar Attia: Rethinking New Cities in Egypt, 2014. Ref. No. 4

This low occupation rate causes further losses to local economy. As many house s were established without providing utilities, no one inhabited them. When utilities where provided after many years, the constructed houses where old and needed repair or renewal, meaning that the lack of synchronization between construction and utility provision has caused massive financial losses. Two examples are housing projects in "Haram City" and "Ebni Beitak" located in 6th October city. Houses were built without adequate utilities, urging the dwellers to demonstrate many times. Some of these houses got dilapidated before inhabitance, forming great losses to the owners. The same to say about summer houses expanding all over the North West Cost of Egypt. Billions of pounds where spent over expanding utilities for these houses with no real revenue. Short occupation periods of these houses has lessen water and power consumption rates, making monthly payments insignificant and not covering the installation expenses. Huge investments where "frozen" in establishing utilities for empty resorts with no or little "monthly revenue", causing losses to the government and the utility suppliers. See Fig (7).

Fig(7) (left)Demonstrations against lack of utilities in Ebni-Beitak (middle) Dilapidated houses in Haram City (right) Vacant summer houses in the north cost.

Source: (up) Alwafd newspaper, issue 11/11/2012 – (Down) Al-Fagr Newspaper 17/1/2015 -www.elfagr.org

"Monthly revenue" is a main factor that affects the feasibility of any central utility project. The cost effectiveness of central utilities depends on two main factors: high population density, and short transportation. As the cost of moving utility (e.g. water or wastewater) through distribution networks can account for up to 80% of utility's cost, shortening the path is vital for feasibility[5]. The same to say about density; with more users inhabiting the same served area, central utilities become more feasible, having more bills collected without further extension. Central utilities are most feasible in dense cities with high rise buildings, while they become less feasible in rural areas with low density and low rise buildings. They may become unfeasible at all in Bedwin communities with scattered houses as shown in fig(8).

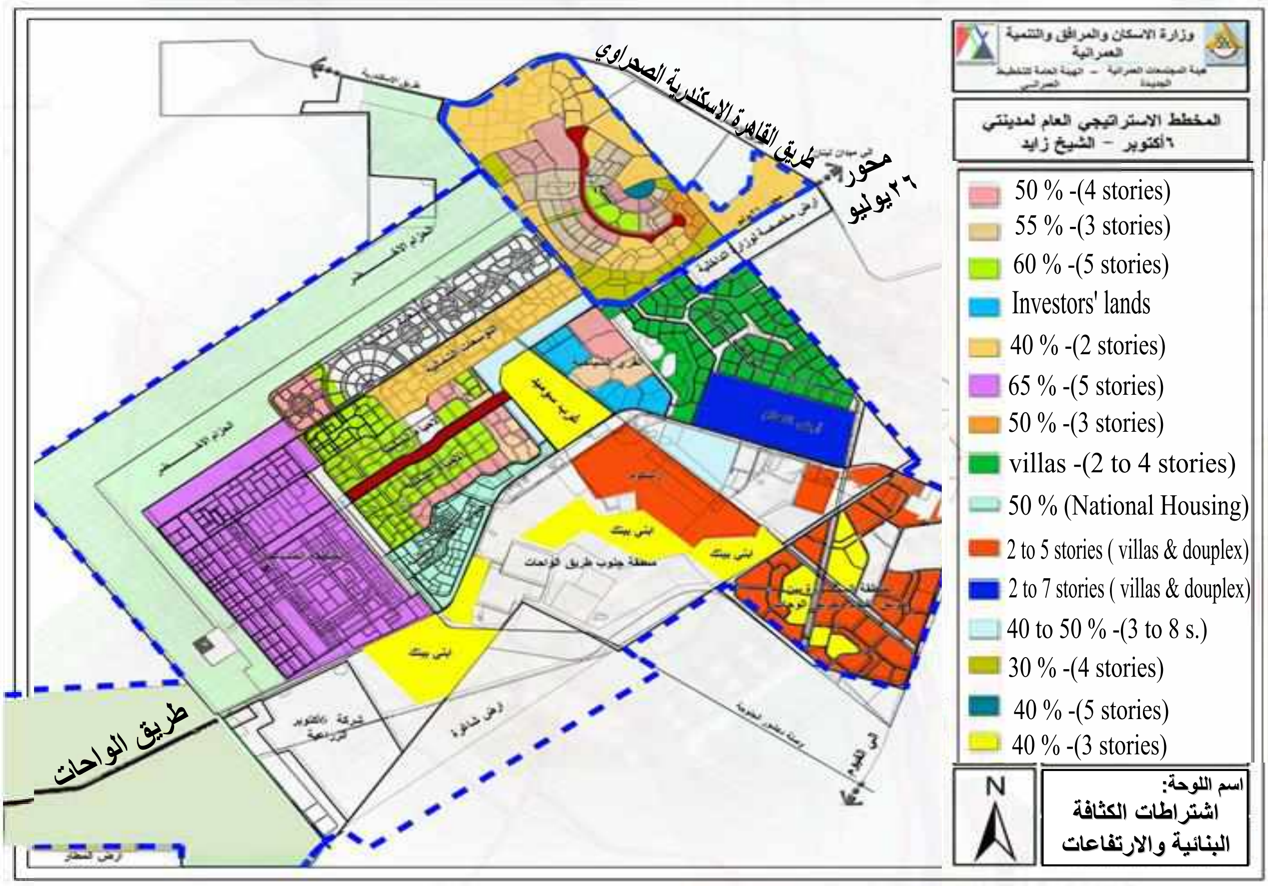


Fig(8): Feasibility of central utilities in different urban forms - designed by the researcher.

Using this economic parameter, we can assume that central utilities are less feasible in new Egyptian cities in general. As all these cities have strict building regulations that limit the maximum building capacity by 40 to 60% of land area, the resulting urban density is comparatively low as shown in fig(9). The same regulations limit the number

Fig(9): Low urban density in (a) October city, (b) Fifth Aveneu, and (c) al-Hammam town.
Source: www.googleearth.com

of stories in each district, causing low rise building to overrule the city as all, fig(10).



Fig(10): Regulations of building density and number of stories as set by local authorities in October and Zayed cities- **Source: General Organization for Physical Planning GOPP maps.**

The same to say about old remote cities like Marsa Matrouh (North-West Coast) , Al-Hammam and Al-Arish. These cities have low urban density and central utilities are usually unfeasible for them. The cost of treating water and wastewater in low dense governorates is high in comparison with dense ones. For example the cost of running wastewater utility in Matouh and Sinai was nine times the cost in Cairo, Geiza and Kafr El-Sheikh in year 2010/2011 as shown in fig(11) .

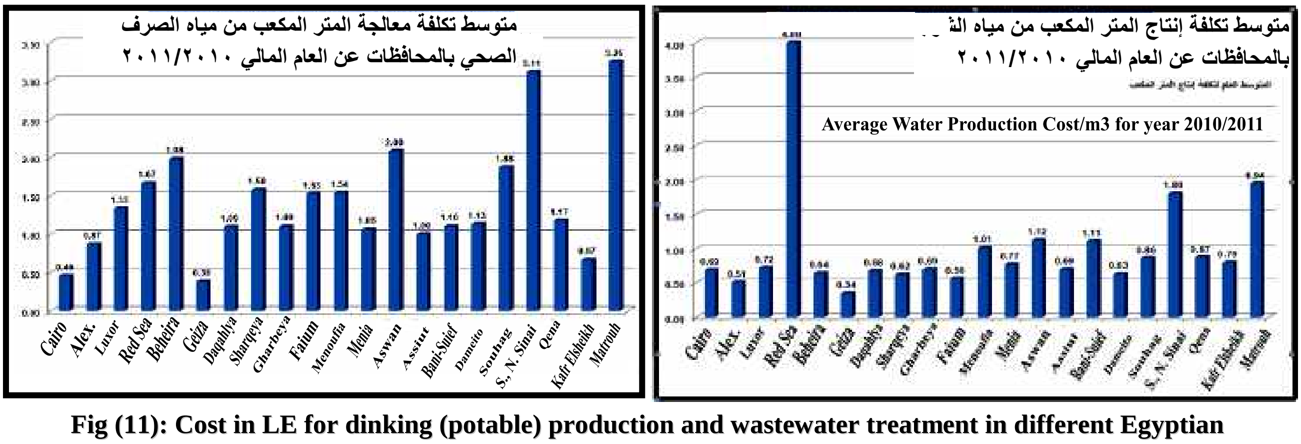
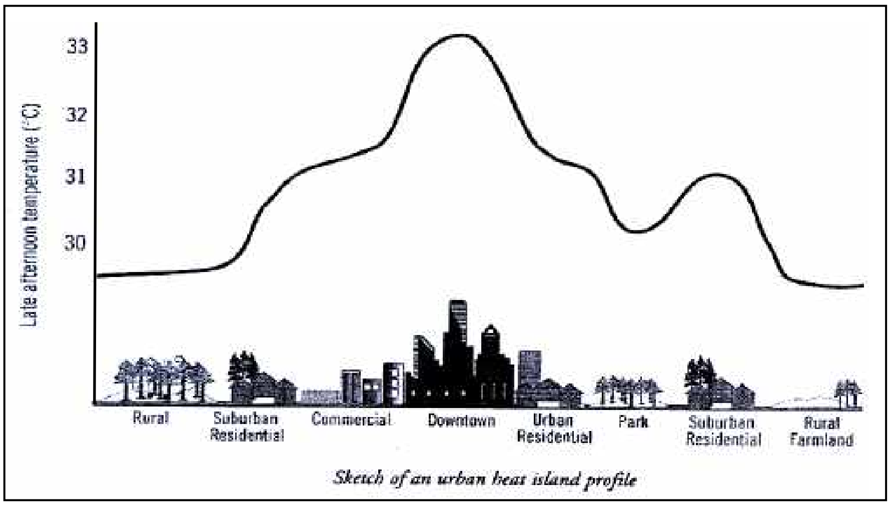


Fig (11): Cost in LE for dinking (potable) production and wastewater treatment in different Egyptian governorates in fiscal year 2010/2011

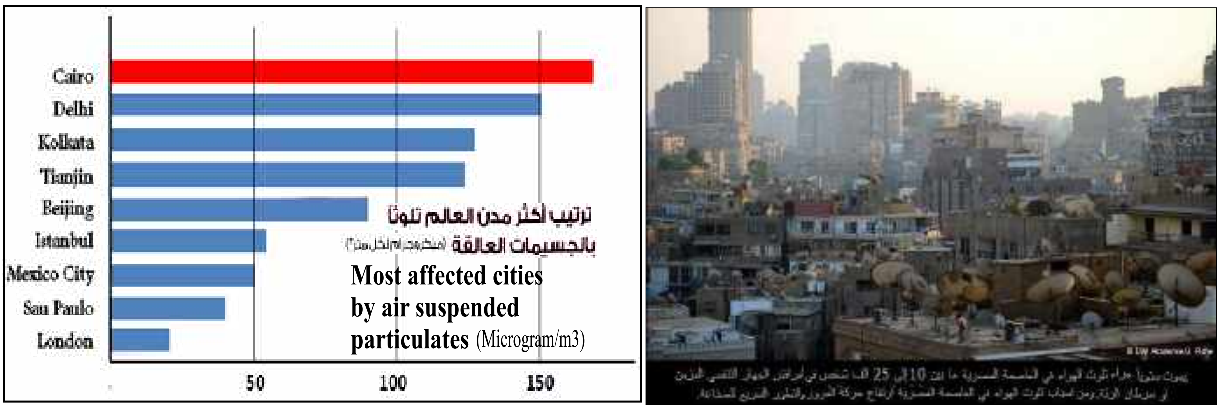
Source: Annual report of the Egyptian Water and Wastewater Regulatory Agency 2010/2011

Aside from its economic disadvantages, low density has many environmental benefits. It provides space for green areas, improves air movement in the city, increases sun exposure and evaporation rate of the soil and enhances the health and prosperity of the inhabitants. (Oke, 1995) has examined the impact of high urban density over temperature and air movement, he concluded that temperature gets higher and air movement gets slower in dense urban areas (e.g. cities), forming the "Urban Heat Island (UHI)" phenomenon. This phenomenon is less present in rural and suburban societies as shown in fig (12)[6].



Fig(12): Urban Heat Island profile in different rural and urban societies.
Source: Katzschner et.,al, 2006, Ref. No. 6

UHI negatively affects the health and energy levels of the inhabitants; it destroys many ecological systems of flora and fauna and increases the presence of air suspended particles in the city. According to (Shaltout, 2001), Cairo has recorded a very high ranking of air pollution by suspended solid particles and Sulphur di oxide SO_2 among mega cities of the world as shown in fig (13). Air pollution has inclined the incidence of serious respiratory ailments and different types of cancer[7].

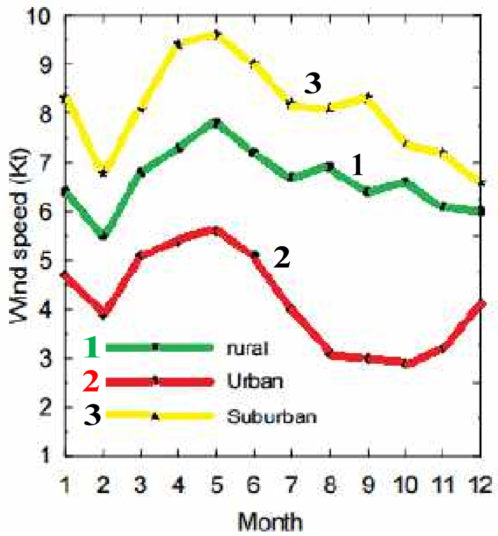


Fig(13): (left) Air quality in Cairo compared to major cities (right) Air pollution in central cairo
Source: (left) Shaltout et. al.-**Reference No.7 (right)** www.cairoobserver.com/

In comparison with central Cairo, suburban cities like6[th] October, Zayed and Al-Shorouk have much better environmental conditions as shown in fig(14). (Robaa, 2002) has measured the atmospheric parameters in Central Cairo, suburban new areas and rural areas, all within the Greater Cairo Region (GCR). He concluded that suburban areas had much better environmental conditions than both urban and rural areas. For example, wind speed was higher in suburbs than rural areas in the same region like Bahteem and Kerdasa[8], fig(15).

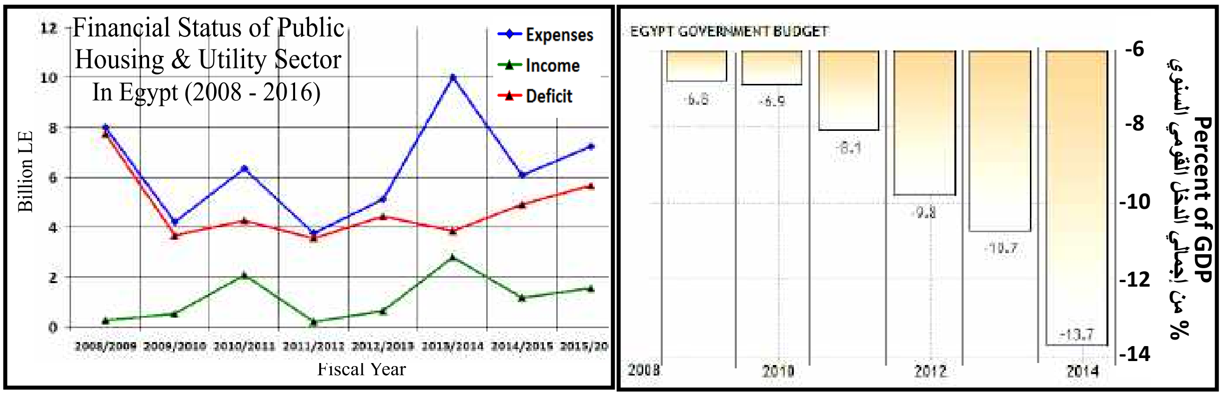
Fig(14): Sky clearance in October city, Egypt

So if we wish to live a healthy life we must keep following low urban density patterns in our new settlements, no matter how their utilities would cost. But can we keep doing this with our existing economic status?



Fig(15): Mean wind speed in five years, measured in urban, suburban and rural areas among Greater Cairo Region.
Source: Robaa, 2003 –Ref. No.8

The answer is probably no. In the presence of massive accumulating debts and inclining budget deficit, the government has limited ability to keep spending over supplying utilities to new cities by its own. Public "housing and utility sector" suffers annual losses and deficit measured in billions as shown in fig(16).



Fig(16) (left) Public spending over housing and utilities in years(2008-2016) (right) Budget deficit in Egypt in years (2008-2014) **Source: (left) Designed by the researcher based on data from the official website of Ministry of Finance www.mof.gov.eg (right) http://www.tradingeconomics.com/egypt/government-budget-value**

The private sector was recently allowed to share in building and running new cities, but the resulting cities were basically targeting the elite. Fancy houses, villas and resorts were provided for them in gated communities away from the crowded capital. Fig(17).

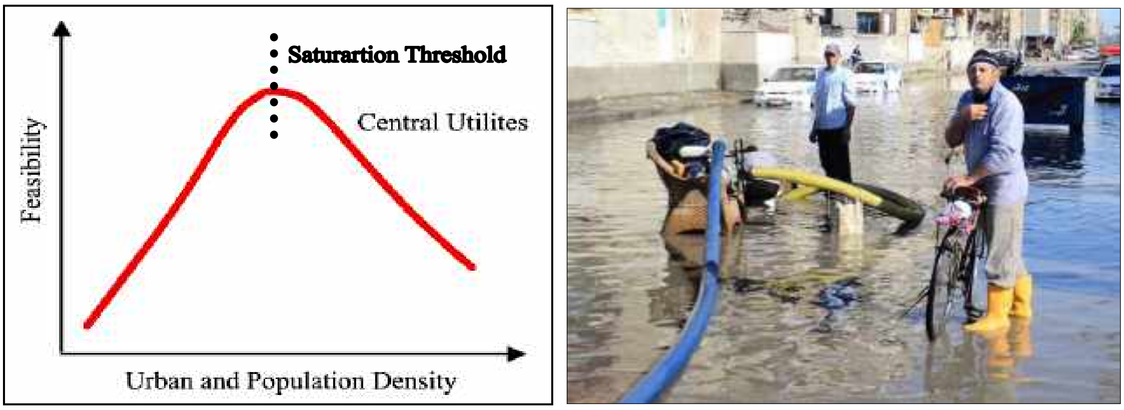
Supplying utilities for these cities is not a problem because the owners can pay. Beside the purchase price, owners are committed to regular payments for basic public services such as gardening, road pavement, security and utility maintenance. These communities are good example for successful utility provision. According to unofficial statistics, the dwellers of these cities are less than 0.04 % of the Egyptian people, so what about the rest?

Fig(17): Gated communities in Egypt: Bright and successful but beyond the reach of many Egyptians
Source: Mountain view project review - www.mountainviewegypt.com/

Moving to these communities is beyond the capabilities of most of the Egyptian people. 26.3 per cent of the Egyptians live under poverty line[9], 18 per cent of the families live in "one room" units[10], and 45 percent are living in slum conditions. Nearly half of the population was not connected to municipal sewage network while 16 % didn't have indoor water access in 2011[11]. Poverty and lack of utilities are mainly present in rural areas especially in Upper Egypt. The quality of provided services is also inadequate which caused the eruption of many water-borne diseases and more environmental degradation and polluting main natural resources, the resources that utilities rely on for running.as shown in fig(18)[12].

Fig(18):Environmental degradation caused by bad utilities, poverty and high density in rural and urban areas in Egypt – The last picture shows water intake belongs to Tala water plant, Menofeya, July 2013.

Middle class and urban dwellers also face the chronic drawbacks of increasing population in their cities. Central utilities, if over loaded with extreme urban and population density, may experience chronic failures and become unfeasible again as shown in fig(19).

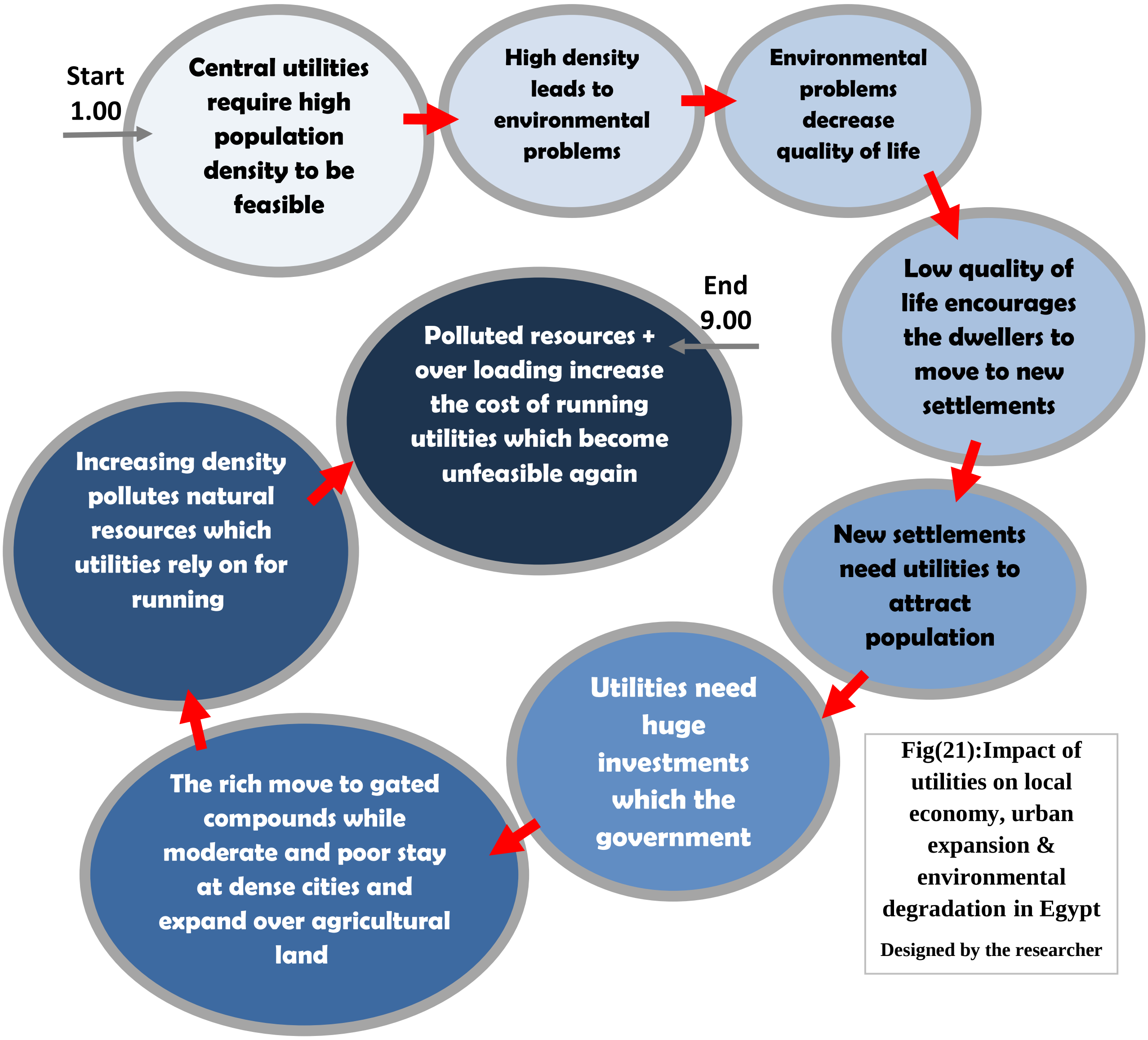


Fig(19): (left) Feasibility of central utilities based on population and urban density (right) Utility failure due to overloading in Tanta, November 2016.
(left) designed by the researcher (right) Al-Ahram Newspaper, November 21st 2016

The extreme pressure over the existing networks requires massive investments for repair and maintenance. As stated by the Housing Minister, the existing water and wastewater networks need an annual budget of 1.9 billion LE for substitution and renewal. Another 109 billion is needed to solve water and wastewater utility problems as seen in fig(20).

Fig(20): Contradicted statements from the Minister of Housing about water and wastewater utilities in Egypt.
Source: (left) http://www.youm7.com/ 29/11/2015 – (right) http://www.iskanmisr.com/ 10/5/2015

So the problem is somehow complicated, utilities need density for feasibility. But density affects sustainability and pollutes the natural resources. Pollution increases the cost of utilities again and over population density cause as shown in fig(21).



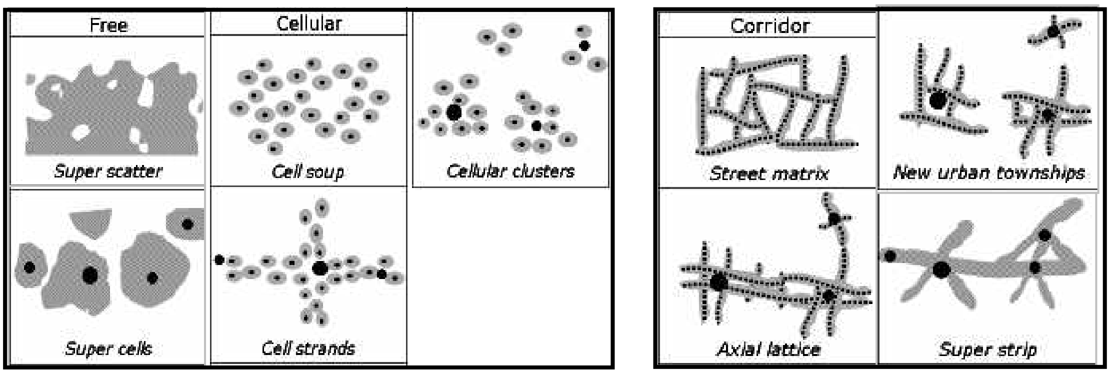
Fig(21):Impact of utilities on local economy, urban expansion & environmental degradation in Egypt

Designed by the researcher

Escaping from such circle, we must reconsider our traditional utility models. Centralization, with all its requirements, may be not the proper model for our desired urban expansion. Decentralization as a concept adapts the idea of independence and self-sufficiency. As in a living organ where each cell performs its own biolog al functions in co-ordinance with the whole organ, each house or group of houses perform its own daily tasks in water provision, wastewater treatment, power generation and food production, with transportation network connecting the cells together, fig(22). If any cell fails to perform its functions, the damage will be localized and the cell can be treated or eradicated, but the whole system is not severely affected. In centralized utilities, the damage usually affects the whole system all at once.

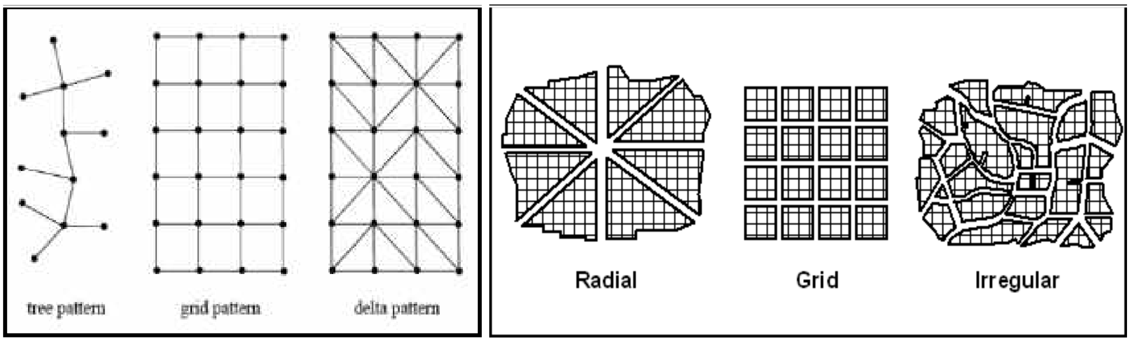
Fig22: Leaf-like organic urban pattern where every cell performs its biological functions in co-ordinance with the whole organ. Source: https://www.flickr.com/photos/martonjancso/6274716546/in/photostream/

Unlike central utilities which usually require grid patterns and rigid lines for best performance, decentralized utilities suit almost all urban and street patterns, allowing urban planners to adopt more free and **creative** designs and forms in their work. Decentralized utilities give more importance for every single house, enhancing the concept of participation and equity, see figures (23), (24).



Fig(23): Urban patterns suitability with central utilities: (left) less suitable (right) most suitable

Source: http://www.suburbansolutions.ac.uk/ Retrieved March, 11th 2013



Fig(24): (left) Best street patterns for central utilities (right) Suitability of different urban patterns with centralized utilities.

Source : (left) https://cybergeo.revues.org Retrieved Augst, 1st 2014 (right) www.urbanscope.com.au Retrieved December, 14th 2016

The expected impacts of decentralized utilities' application over architecture and urban planning:

Decentralized utilities, also called "onsite utilities" or "off-grid utilities" all are "network-free" utilities (but with road network of course). No transportation of water, wastewater or power is required. Power is generated in the site as well as water supply and wastewater treatment. Adapting these utilities, if possible and suitable, may have revolutionary impacts over architecture and urban planning as follows:

1- Architects and engineers will have different designs and working drawings, following the requirements of new utilities.

2- Urban planners will have freedom in applying free-form or organic urban patterns, without concerns about how utility networks are installed.

3- Utility Engineers will have fewer concerns about slopes and topography when applying utilities.

4- As some decentralized utilities can be mobile and easy to move from a house to another, owners will have the flexibility to move from house to another carrying their own utilities with them.

5- Applying decentralized utilities give the city the chance to grow gradually, just like a living organ, which decreases the initial cost required for city establishment.

6- The government will have fewer responsibilities towards housing projects. This advantage can solve the problem of unutilized housing units. For example, "Youth Housing Project" in Giza Governorate is still without utilities though built 7 years ago, fig(25).

Fig(25): Vacant houses in the housing project in Geiza, and the owners complaining to the media.

Source: Screen shots of "Moftah Al-Hayah" talk show broadcasted in 13/9/2015: https://www.youtube.com/watch?v=Yw5GnBpDJS

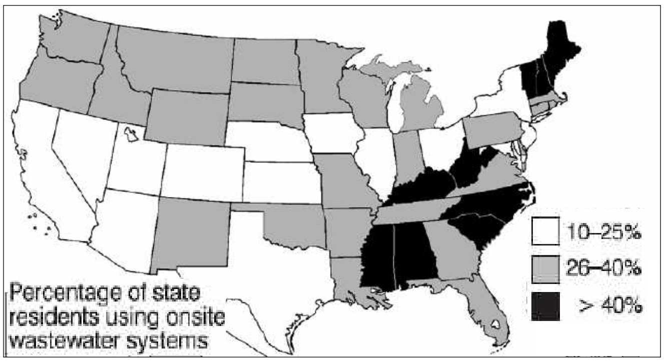
7- Owners will have the freedom to contract with any utility supplier they desire, which will create high competition among private utility suppliers, decreasing its cost and increasing its efficiency.

8- As utilities affect the operational time of the buildings, proper and sustainable utilities will elongate the life time of these buildings, fig (26).

Fig(26): Buildings' affected by bad quality of utilities.

Source: www.nabanews.net

These systems are applied in many areas of developed and under-developed countries where installing central networks is somehow complicated and expensive. For example, the United States has approved applying these systems with strict environmental regulations set by the Environment Protection Agency (EPA) as shown in fig (27). They are applied also in many Asian and African countries, especially in rural and remote districts[13,14].



No. of Families Using Onsite Wastewater Treatment Systems, 2014	
Ireland(Northern)	500,000
United Kingdom	800,000
Scotland	100,000

Fig(27):The commonness of onsite wastewater treatment systems in US (left) & in some districts in the United Kingdom (right)
(left) Onsite Wastewater Treatment Systems Manual , Ref. No. 13 (right) Terry O'Leary, 2010 , Ref. No. 14

Summary of Nature of the Problem

Summary

Egypt suffers the accumulation of population in less than 10% of its area so urban expansion among the vast desert is required. This expansion is partially hindered by shortage of finance, especially the finance needed for utilities' installation in new settlements. Billions of pounds were invested in these utilities thus are not yet enough to cover all needed areas. Centralized utilities are more feasible in high dense areas due to high monthly revenue, so they are less suitable for new settlements with low population density and scattered houses. They are also less feasible for projects with intermittent inhabitance like summer houses and beach resorts. Decentralization suit low population densities and almost all urban forms and street patterns. It also has many economic and functional advantages so it may be useful for application in Egypt especially in new settlements and scattered housing projects in the Egyptian desert. This research examines the suitability of these decentralized utilities for application in Egypt. Suitability concludes their feasibility, efficiency, sustainability and availability in the Egyptian market

End of Summary of Nature of the Problem

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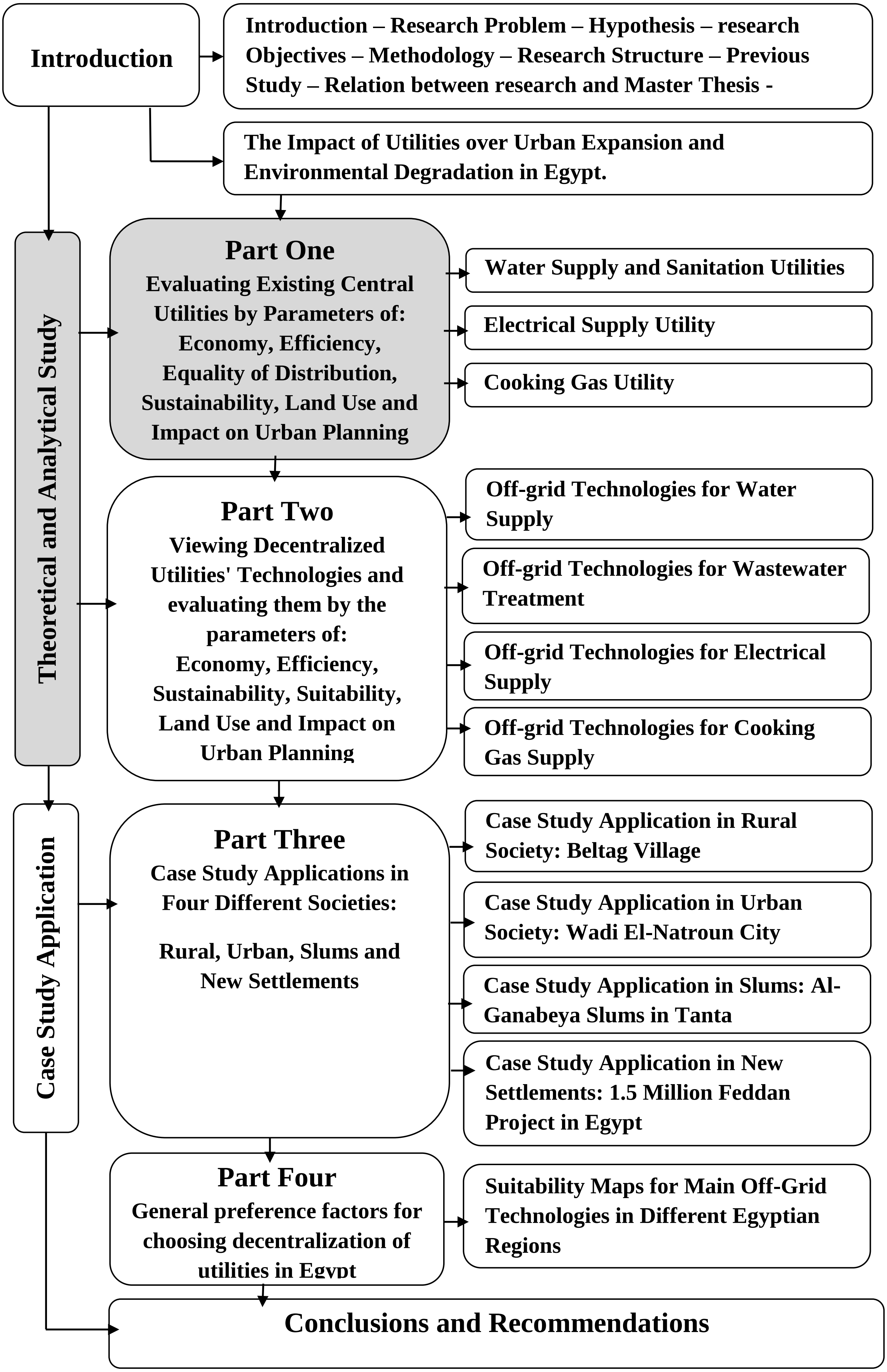
Introduction
Introduction – Research Problem – Hypothesis – research Objectives – Methodology – Research Structure – Previous Study – Relation between research and Master Thesis -
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Conclusions and Recommendations

Part (I)

Theory

Introduction to Part (I)

This part evaluates the existing central utilities in Egypt: (water supply, sanitation, power supply and cooking Gas), using the parameters of: economy, efficiency, equality of distribution, sustainability, land use and impact on urban planning.

In the first chapter the researcher shall discuss central water supply and sanitation, and in the second chapter we discuss the power supply and natural gas utilities in Egypt by the same parameters. The goal of this evaluation is to have the image clear about the existing central utilities in Egypt before discussing decentralization as an idea and an application.

This Part includes the following:

1- Chapter one: Evaluating Water supply and Sanitation utilities

2- Chapter two: Evaluating Electrical Supply Utility.

3- Chapter three: Evaluating Cooking Gas Supply Utilities.

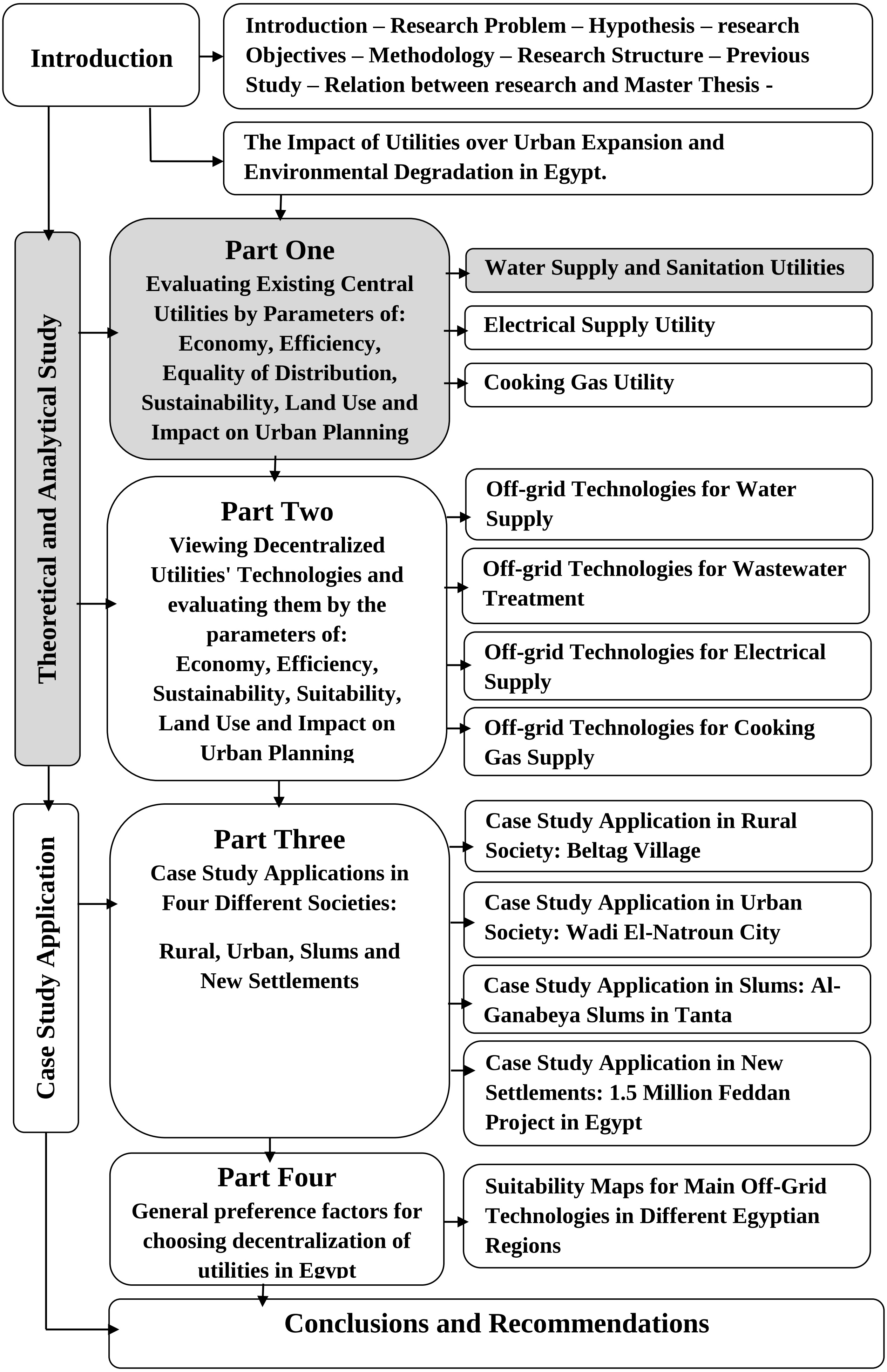
Summary of Part One

End of Introduction to Part (I)

Basic Definitions of Part (I):

- **Utilities:** Basic services provided generally by a publicly regulated agency, e.g. electricity, gas and water supply, sewerage and drainage, telephone.
- **Public Services**: Services such as water, gas, electricity supplied to the population as a whole and controlled by the National or Local Government. May include Public Transport System.
- **Sanitation**: Removal and disposal of sewage and refuse.

End of Basic Definitions of Part (I)


Introduction
Introduction – Research Problem – Hypothesis – research Objectives – Methodology – Research Structure – Previous Study – Relation between research and Master Thesis -
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Theoretical and Analytical Study
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General preference factors for choosing decentralization of utilities in Egypt
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Part (I)- Chapter 1
Theory
Introduction to Chapter (1)

Water and wastewater utilities are the most health-affecting and environmental-related utilities at all. they have obvious impacts over surface water, groundwater, soils and plantation. They may heavily weigh on the environment and destroy flora and fauna, as well as the health of the human beings.

Here we shall discuss the existing water and wastewater utilities in Egypt by evaluating them through five parameters: (1) economy, (2) efficiency, (3) sustainability, (4) equality of distribution, as well as their (5) land use and impact on urban planning. This evaluation is mandatory to compare these utilities with the suggested decentralized utilities later on this research.

End of Introduction to Chapter 1

(1-1) Evaluating water supply and sanitation utilities in Egypt:

Water supply and sanitation utilities in Egypt are provided by one entity called: "The Holding Company of Drinking Water and Wastewater" الشركة القابضة لمياه الشرب والصرف الصحي, established 2004. Here we are discussing the performance of this company in Egypt as it forms the sole and dominant part controlling these two basic and health-related utilities in Egypt:

(1-1-1) Economical aspect:

There are three main parties funding water and wastewater sector in Egypt: (1)The Egyptian Government, (2)the Holding Company and the (3) consumer. Additional funds are sometimes provided by international donors. Here we are discussing the feasibility of central water and wastewater utility for the main three funding parties.

(1-1-1-A) Feasibility to the consumer: (Initial & Running Cost):

a- Initial Cost:

The Building Unified Law 119/2008 differentiates between old and new urban areas concerning the installation of utilities. If the house is located inside the old urban cluster (1985 urban boundaries), the owner only pays the cost of his own connections and sewers, but if the house is located within 2007 added areas, he bears the cost of both public and private connections and sewers as evaluated by the supplier company. The 2007 added areas are confined between old and new boundaries as shown in fig (28).

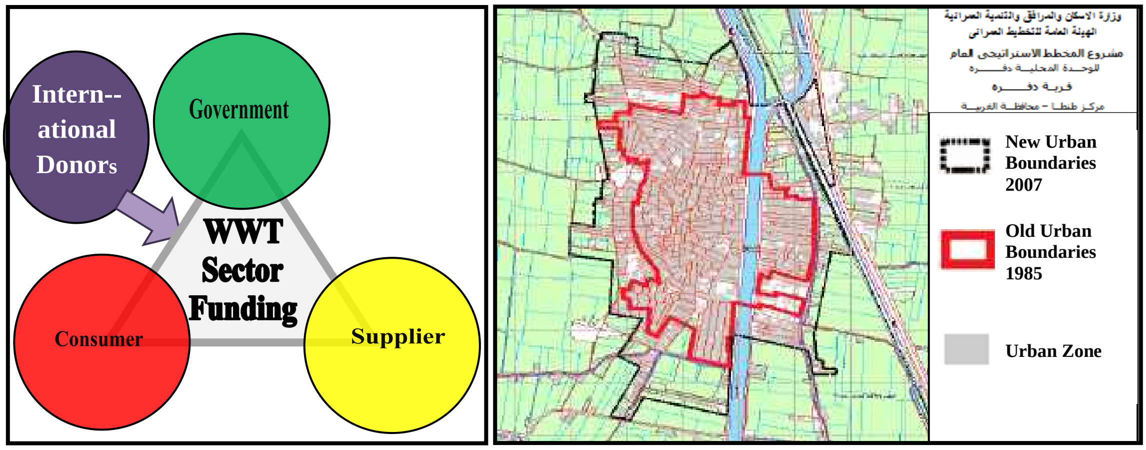


Fig (28): (left) Funding parties for water and wastewater sector in Egypt (right) Map for old and new urban frame for Difra village, Gharbeya, 1985 – 2007.

(left) Designed by researcher based on data from www.ewra.com. (right) General Organization for Physical Planning (GOPP) main bureau.

The initial cost varies greatly according to the distance from nearest available grid and the pricing policy of the supplier company. In average, water pipes expansion costs 150 LE / linear meter, and wastewater pipes costs 350 LE / linear meter for 2007 added areas (for public connections, 2014 prices) *[1]. Private connections' cost also varies, but the average 2013 cost was (3 LE × space of the floor in square meters × number of the floors) + 300 LE for new water meter + 300 LE insurance + 730 LE administrative expenses *[2] like fees and taxes (2013 prices).

b- Running Cost:

Water tariff has gradually inclined after the application of privatization policy in Egypt. Water sector was reformed in 2004 and the holding company for water and wastewater was established since then. The current price of cubic meter of tap water also varies according to building's use and values of consumption. Household water price ranges from 0.35 to 0.50 LE /m^3 for first 10 m^3 of use. The tariff gradually increases with the increase of consumption. The sewer tariff is also added as 75 to 100% of the total water price. Other costs are added like maintenance, stamps and other fees and taxes, see fig (29). Monthly water bill for one family starts with 7 LE as minimum charge, and may reach 1200 LE / month or more * [3].

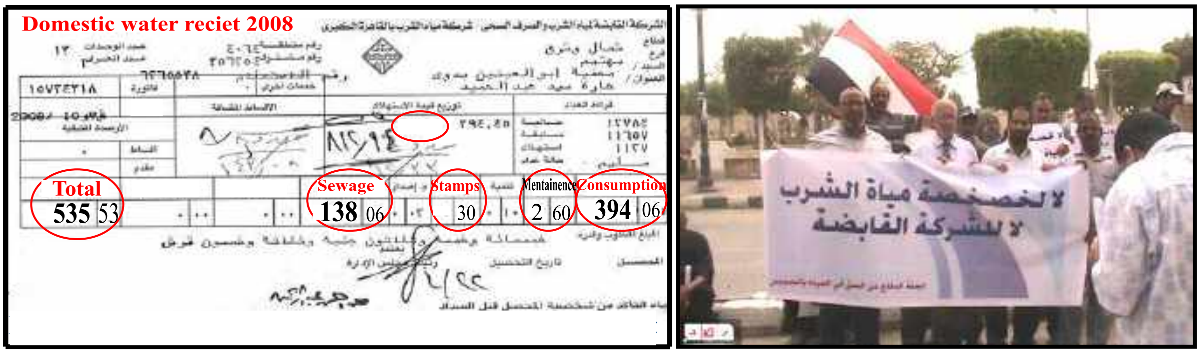


Fig (29): (left) Water recite for a house in Bahteem showing the way of payment (righ): Stand-up against water privatization Policy, Suez, March 2012

(left) http://rassd.com

As a result of privatization of water utility, the suppliers have doubled their collected revenue many times. The bill was collected four times a year and then six times, while in 2013 it became 12 times. The revenue of supplier companies hiked many times since 2004.

For example, the Water and Wastewater Company (WWC) supplying Greater Cairo Region has officially declared that its collected bills have doubled twelfth times (1200 %) in five years duration (2005 – 2010) as shown in fig(7) * [4]. The depreciation of the Egyptian pound was (-0.037) % during the same period as shown in fig (30).

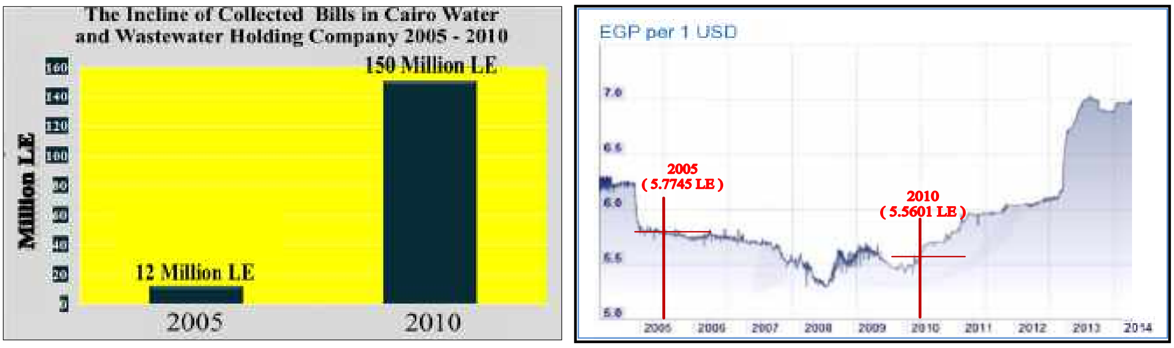


Fig (30): (Left) The incline in collected water bills in Cairo 2005-2010 (Right) The exchange rate of Egyptian pound to U.S. dollar in 10 years

Source : (Left) www.hcww.com.eg/en/HCWW.pp Retrieved Feb.13th 2013 (Right) http://www.xe.com Retrieved Feb.11th 2013

Despite the hiking tariff, most of the Holding companies do not cover their expenses and losses as they have an annual deficit estimated at L.E. 14 billion * [5] as shown in the next paragraph.

(1-1-1-B) Feasibility to the supplier:

a- Operating and pricing costs:

Water and wastewater sector is run by 23 holding companies that are geographically distributed as shown in fig(29). Each company is economically independent *[6]. Although tied by the official tariff set by the Egyptian Cabinet, they have complete authority to set their own pricing policy which explains the difference in consumption fees from one governorate to another.

Different pricing is due to different operating cost for every governorate. As seen in figure (31) in introduction, the cost is comparatively low in Cairo and Giza because overpopulation equals millions of customers in a small heavy loaded area. On the contrary, the governorates with low-dense population like Matrouh and Sinai, have the maximum cost because small number of houses are scattered on a vast land area.

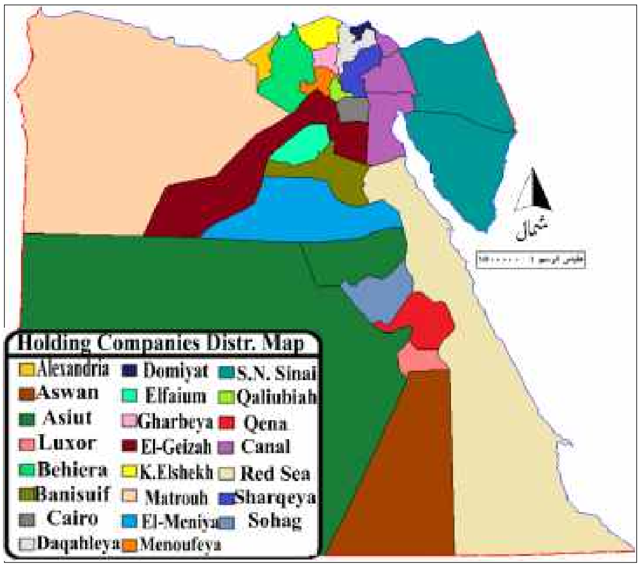


Fig (31): Water & wastewater 23 distribution companies in Egypt

http://ar.wikipedia.org/wiki Retrieved Nov. 1st 2013

The average capital cost for providing wastewater collection and treatment in Egypt per household among different governorates was estimated with 535 USD / household in 2002 * [7] No recent estimation could be found for initial cost, but the cost is expected to be doubled twice in 2015 as a result of the increase of international prices of fuel and other construction materials.

b- Inadequate cost recovery:

Cost recovery is a main indicator for economic performance. The estimates of the degree of cost recovery for water and wastewater sector in Egypt vary depending on the source of information, the years analyzed and the definition of costs. According to one estimate dating in 2004, the sector has 40% cost recovery* [8], while another study conducted in 2007 has estimated the cost recovery with 20%, with tariffs at 0.23 LE per m^3 and costs at 1.10 LE per cubic meter * [9].

A study conducted by The United States Agency for International Development (USAID) in 2012 showed that the recovery of operation and maintenance costs, excluding depreciation, through operating revenues varied between 31% in Sinai to

134% in Beheira. The average bill collection rate was only 57%, ranging from 48% in Cairo to 85% in Beni Suef. (*)[10]

The cost recovery percentage for sanitation sector was 48% to 116% in different governorates in 2011 as shown in fig (32). Variation is due to technical and geographical differences in each governorate.

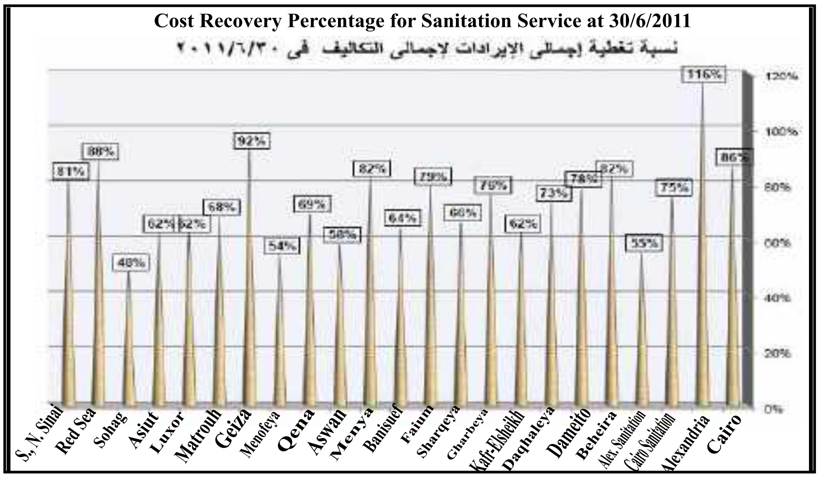


Fig (32): Water Holdings' cost recovery percentage in Egypt, 2011

Annual report of the Egyptian Water and Wastewater Regulatory Agency 2010/2011

Cost recovery is significantly low in rural areas and slums because their basic supply is through public standpipes and pumps that provided water for free as shown in fig(31), or through illegal connections that are hard to control. Urban areas also have low cost recovery due to dilapidated leaking pipes and invalid water meters. Another loss factor is the bad quality of water which makes the inhabitants buy their drinking water from water vendors thus lessens their consumption from the central grid.

In comparison with their regional peer cities, Cairo and Alexandria have low operating cost coverage for utilities in general (water, electricity, etc…)*[11]as seen in fig (33).

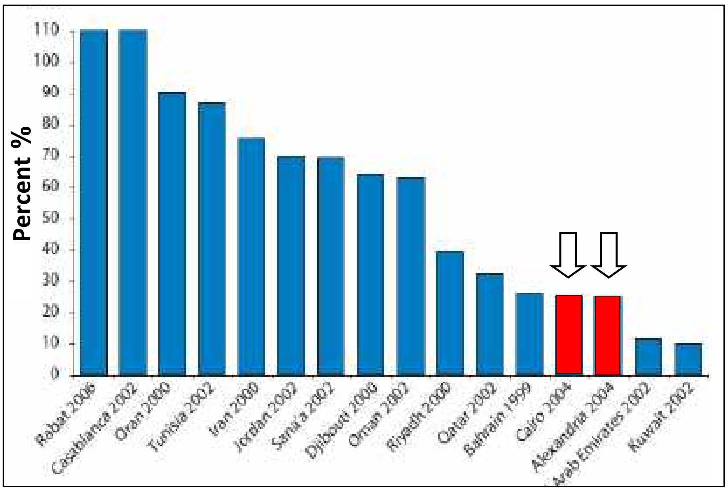


Fig (33): (left) Cost recovery ratio for water utilities in several cities. (Up) Public taps augmenting water holdings' losses.

Source: (left) USAID Report, Ref. No. 12
(up) www.Doniaelwatan.org.eg
Retrieved Oct.31th, 2013

c- Heavy employment:

Egyptian water and sanitation utilities are overstaffed due to outdated technologies, manual accounting, corruption and political-based employments. Overstaffing has increased from 6.5 employees per 1000 connections in the early 2000s * [12] to 11.8 employees per 1000 connections in 2010* [13] . Good practice for water and sanitation utilities is to have less than 5 employees per 1000 connections* .[14] By 2012 the sector had a staff of 173,000 employees for 9.5 million subscribers, with a salary budget of 52 million and 765 thousand LE /month besides insurances and incentives* .[15] The sector also contracts with unemployed consultants for technical assistance with an average budget of 12 million LE / month which raises questions about the transparency of the sector. The situation has also been aggravated by salary increases after many stand-ups and demonstrations before and after the Arab Spring. Fig (32) shows the social stress over the government to approve more salary raisings and rewards for the water sector employees.

Economic Sector	No. of Employees (Thousand employees)	
	2009/2010	2010/2011
Farming and Fishing	6728	6810
Mining	47	50
Industry	2882	2292
Gas and Electricity Production & Distribution	266	260
Water & Wastewater Transportation & Treatment	150	173
Building & Construction	2694	2716
Transportation & Storage	1471	1602
Communication Sector	211	198
Total	23830	23346

Table (2): No. of employees in different economic sectors in Egypt 2010/2011

Ministry of Finance Annual Report 2011/2012 - www.mof.gov.eg

Fig(34): Stand-ups of water holdings' employees in Al-Menya & Qena

www.hoqook.com.eg

d- Corruption:

Water sector in Egypt is infected with corruption as defined by the United Nation Transparency Index* .[16] The Global Corruption Report for Corruption in Water Sector 2008 ranked Egyptian water sector as number 118 in a rank of 180 countries, with a score of 2.9 / 10 of transparency in water sector performance* .[17] The corruption basically involved contracting, employing, discrimination and surveillance (discrimination here means the distribution of rewards according to personal interests rather than work productivity) * .[18]

An estimate by the World Bank report suggests that twenty to forty percent (20 – 40%) of water sector finances in Egypt are being lost due to dishonest practice. As a result for low cost recovery, over staffing, dilapidation and corruption, the Holding's face an operating deficit of LE 7.6 billion and an accumulated debt of LE 7.3 billion* ;[19]which is partly covered by the governmental subsidies for this sector as seen in the next paragraph.

(1-1-1-C) Feasibility to the government:

The Egyptian government supports water and wastewater sector (WWS) by three means: investments, electricity and direct subsidies.

a- Investments:

Water and wastewater major projects are mostly financed by the government with the support of external donors. The private sector makes a limited contribution to finance, mostly through a single BOT that has so far been awarded for a US$ 160 million wastewater treatment plant. Between 2005 and 2010 Egypt has received more than 1bn Euro in external aid for water supply and sanitation, out of which 30% were grants and the remainder soft loans with an average interest rate of 1%. This corresponds to EUR 200 million per year, corresponding to only about 10% of the government's investment budget for the sector in 2009/10. According to the Ministry of Housing, government subsidies to water and wastewater utilities amounted to more than 15 billion Egyptian pounds (USD 2.5bn) in 2009/10, including 13.4bn LE (USD 2.2bn) investment subsidies, 0.66 billion LE (USD 0.1 billion) op erating subsidies and1 billion LE (USD 0.2billion) repair and rehabilitation subsidies Fig(35) shows the total investments in water and wastewater se c tor in 7 years (2010-2017). The total investments over this sector has formed 2.4 % of the Gross Domestic Product إجمالي الناتج المحلي (GDP) of Egypt in year 2004 as shown in fig (36).

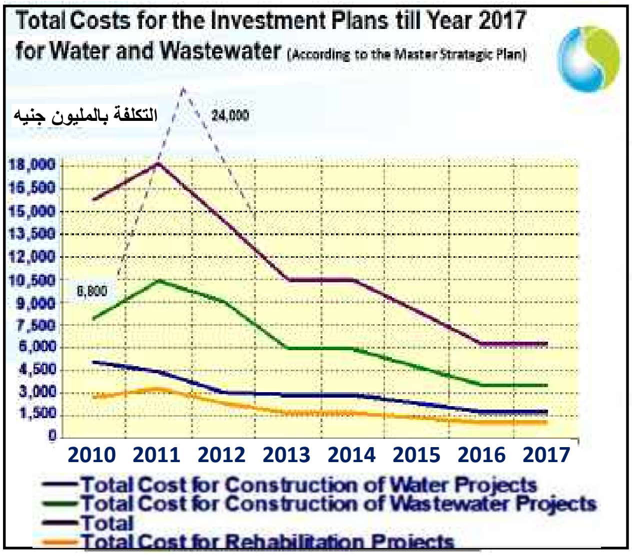


Fig (35): Total costs for the Governmental investments plans over water and wastewater sector in Egypt in years 2010/2017

HCWW annual report 2010- www.hcww.com.eg/en/HCWW.pp

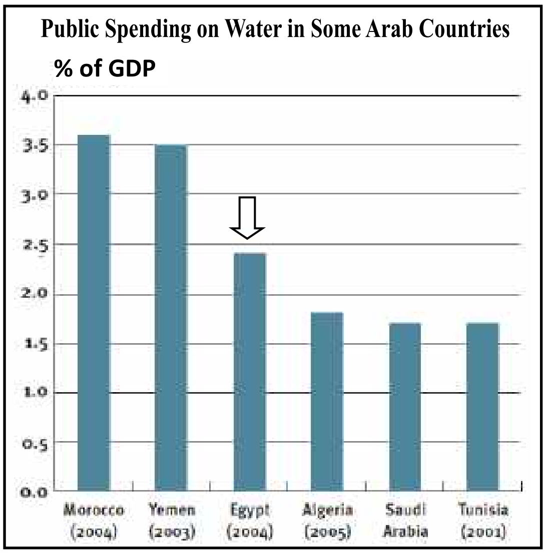


Fig (36): Public Spending on Arab water sectors as a percent of the countries' total GDP (2002/2004)

Source: The Arab League periodical report, 2007

b- Subsidies by Providing Electricity with Lower Tariffs:

Water and wastewater utilities consumes about 10.8% of total National produced electricity in Egypt [5], compared with 30-40 percent of total energy consumed by the municipalities in the United States * .[20] In Egypt, electricity is needed for this sector to perform pumping, purification and treatment process.es. With the knowledge that electricity production in general is subsidized by average 5.00 billion LE annually, we can assume that water sector consumes 540 million LE of electricity subsidies/ year (2013 statistics) [5] as shown in fig (37).

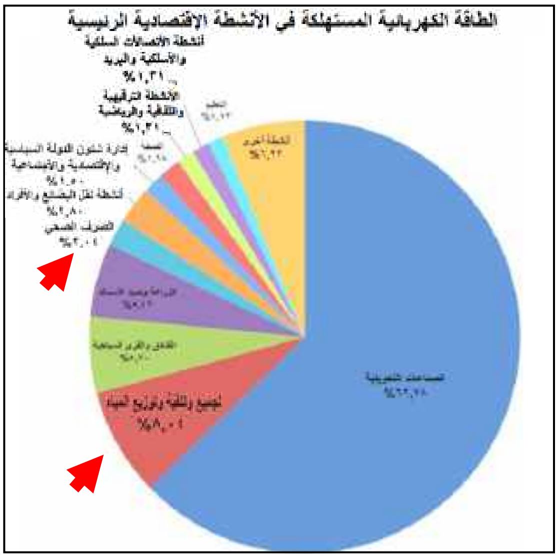


Fig (37): Water & wastewater utility consumption of total generated electricity in Egypt, 2011
Source: Ministry of Electricity Annual Report 2010/2011

c- Direct Subsidies:

As shown before, the annual deficit of the Holdings is covered by the Egyptian governmental subsidies. The government highly subsidizes water and wastewater treatment sector as part of its social responsibilities towards the poor. Between 1982 and 2004 the government spent 65 billion Egyptian pounds (about 10.73 billion USD at the exchange rate of 2004 [49]) for water supply and sanitation. Although the sector was reformed in 2004 towards privatization, the subsidies continued to incline. As shown in table (3), the governmental subsidies to the sector has doubled three times in years (2006- 2010) as shown in Table (3)* .[21]

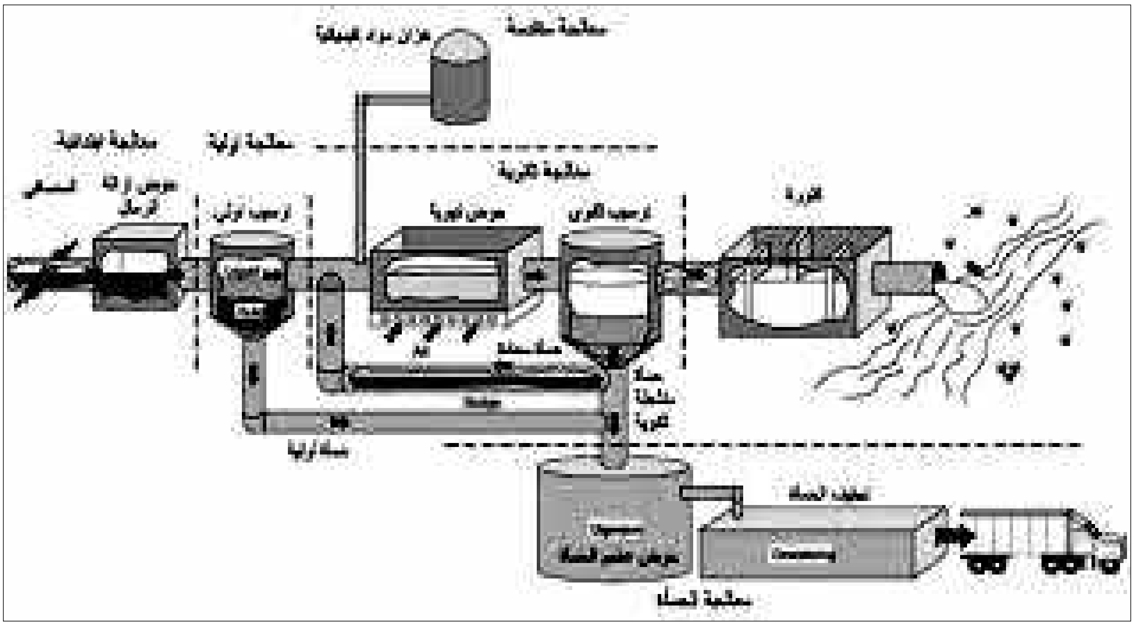
Holding Company for Water and Wastewater

Increasing government subsidies	in million LE
2006/2007 (14 companies)	276
2007/2008 (16 companies)	410
2008/2009 (19 companies)	750
2009/2010 (23 companies)	750

Table (3): Governmental Subsidies in million LE for water and wastewater sector in Egypt 2006/2010
Source: HCWW annual report 2010-2011- www.hcww.com.eg Retrieved in April 23th, 2013

(1-1-2) Efficiency of Central Water & Wastewater Sector:

In centralized system, wastewater is collected from sewers and transported to treatment plant where it passes through 3 stages of treatment: primary, secondary, and tertiary treatment as shown in fig (38).



Fig(38): Wastewater treatment stages applied in centralized systems
www.hcww.com.eg

a- Primary treatment:

This treatment is used in almost all Wastewater Treatment (WWT) plants in Egypt. The main technology used is Stabilization Ponds. After wastewater is screened through iron bars that block big solids and garbage (paper, tissues, gravel, wood, etc), screened water is put in basins and artificial ponds to allow sedimentation of fine solids (sand and small particles) which are collected and sent to a digester then to a drier before they are transported to a burial site.

b- Secondary treatment:

The effluent water from primary treatment is aerated in big aeration tanks to allow aerobic digestion of organic contents. These contents are allowed to sediment in secondary sedimentation tanks and then are digested, dried and buried. The effluent water goes into chlorination tanks and then poured into nearest water body, fig(39).

Fig(39): Stabilization ponds & aeration tanks pouring their effluent in water courses.
http://www.newcities.gov.eg/english/New_Communities/

c- Tertiary treatment:

Some plants apply tertiary treatment by replacing the chlorination by ultraviolet sterilization. Ultraviolet rays usually kill germs and microorganisms. This water is usually reused in irrigation or industrial purpose.

(1-1-2-A) Evaluation of Central Water and Wastewater Sector's Efficiency on Egypt:

There are many parameters to measure the central water supply efficiency, here we discuss three parameters: quality, continuity, and proper connectivity.

a- Water quality:

Tap water quality in Egypt is often below standards because some water treatment plants are not maintained properly and thus are inefficient in removing parasites, viruses and other parasitic microorganisms* .[22] In 2005, 7912 samples were taken from municipal tap water in Menofeya Governorate. Samples were examined for compliance with Egyptian chemical and bacterial standards. Less than 51% of collected samples were compliant with chemical standards while less than 13% of them were compliant to bacteriological standards as shown in table (4). Another study conducted in 2009 by the Ministry of Health showed that drinking water for half a million people in Assiut was unfit for human consumption* .[23]

Samples taken from drinking water facilities during 2005

Type of sample (Among Menofeia Governorate)	No. of Samples	% of non complying samples	
		Bacteriology	Chemistry
Outlet of treatment plants	624	8	24.3
Reservoirs	70	12.8	41.4
Filtered water	1298	12.6	18.9
Groundwater supplies	5920	10.3	50.6

Table(4): Samples taken from drinking water facilities in Menofya Governorate
Framework for the Environmental and Social Impact Assessment Framework (ESIAF), 2010- ISSIP

The chlorination systems of wells, which had been installed years ago because high levels of bacteria had been detected in the groundwater, failed for lack of maintenance and have been shut down so that untreated water is provided to the residents.[24] Water quality is particularly poor in mature informal districts where about 20% of the Egyptian population lives.[25] Partly because of bad water quality and improper sanitation, about 17,000 children die each year because of typhus and diarrhea* [26] .

b- Continuity of supply:

According to the government's National Research Center, some district in Cairo did not get water for more than three hours per day while other districts had no supply of piped water at 2006 *[27]. In Upper Egypt, 46% of households suffer low water pressure, 30% suffer frequent water cuts and 22% had no water available during day time. These problems lead many people to use water from canals which could be hazardous to health*[28].

Water cuts may last for weeks, especially in rural areas and Upper Egypt. In Fauim, the inhabitants of Ezbet Allam had to take their household water directly from the open canal (Bahr Elsafraweya)as shown in fig(40). Many demonstrations concerning this issue took place in many occasions, where people blocked main roads and caused social unrest.

Fig (40):
(left): Villagers taking household water from the open canal (Bahr Elsafraweya) in Ezbet Allam, Fauim.
(up right):
Getting water from tanks in Menyet Elnasr, Dakhalya-Egypt.
(down right):
Newspaper comics about water crisis that took place in Al-Burullus, Sharqeya in 2007.
Source:
(A) www.alshahidonline.coml
(B) www.greenline.com
(C) Al-Ahram newspaper, 24/7/2007

c- Proper Connectivity: (Non-Revenue Water):

The evaluation of any water grid is done by a basic parameter called: the non-revenue water (NRW)*[29]. (NRW) is produced water that becomes “lost” before reaching the customer. Losses can be real (through leaks, also called physical losses shown in fig(41) or apparent (through theft or metering inaccuracies). NRW is typically measured as the volume of water "lost" as a share of net water produced.

Fig(41) :Physical losses that cause (NRW).

However, it is sometimes also expressed as the volume of water “lost” per kilometers long of water distribution network per day.

Egypt is in law rank considering the efficiency by the NRW parameter. The share of non-revenue water in Egypt is markedly high in comparison with its regional peers. A study concerning the Middle East and North Africa region (MENA), Cairo and Alexandria had the third and fourth highest losses in produced water as shown in fig(42).[30]

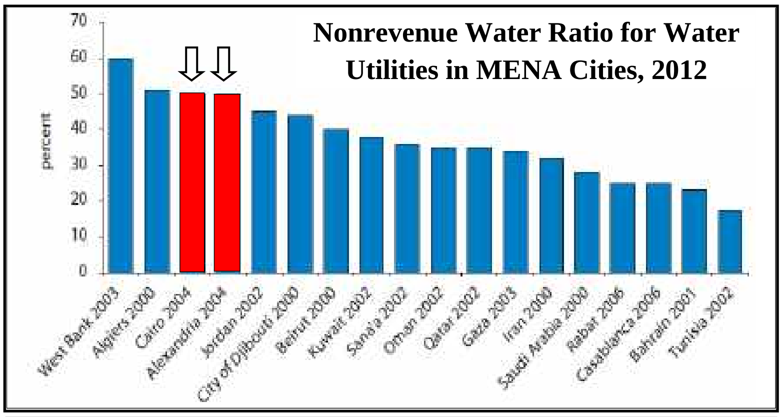


Fig (42): (left)Nonrevenue water ratio for utilities in Middle East & North Africa Region (MENA) major cities in year 2012.
(up right) Leaking pipes in Kafr Hakim, Geiza
(down right) Water leaks under street level causing land collapse.

Source: (left) Reference no. 30
(up rigth) www.almasryalyoum.com Retrieved April 3rd 2013 (down right) https://reported.ly/2015/09/14/ Retrieved April 4th 2013

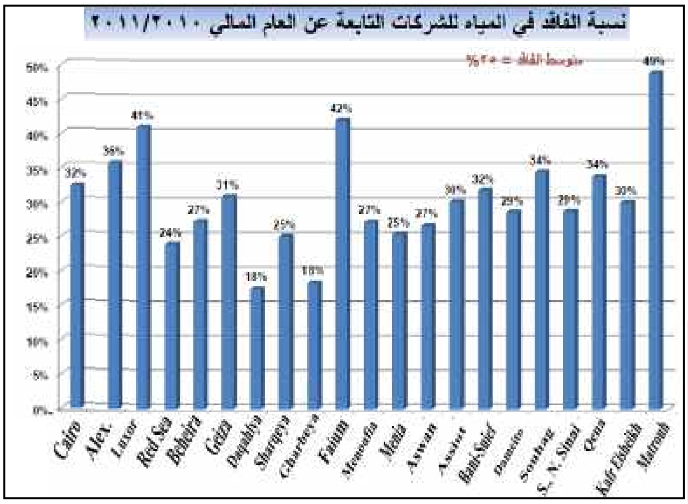
The Egyptian non-revenue water ratio was estimated at 34% in 2005[35] and 40-50% in 2012[3] . The good practice benchmark in the region is in Tunisia where the level of non-revenue water is only 18% * [3] . The total domestic water use in Egypt is about 200 liter per capita per day (l/c/d), or almost twice as much as in Germany. However, actual domestic water use is lower because of network losses* [3] . Water losses are directly[3] proportional with population density. The maximum losses are recorded in dense capital cities like Cairo, Alexandria, Banha and governorates' main cities. It decreases in towns and villages while the lowest losses are recorded in new cities with minimum population density as shown in table(5). As discussed in the introduction in page(9), extreme population densities may cause over-loading to central utilities thus may lead to chronic failures as shown in fig(42).

Category	Daily water consumption Liters/day/capita	Daily losses in water network system Liters/day/capita	Daily Average Water Consumption Liters/day/capita
Governorates' capital cities	180	20-40	200-220
Markaz main towns	150	15-30	165-180
Villages up to 50,000 capita	125	10-25	135-150
New cities	280	0-20	280-300

Table (5): Household water consumption levels in Egypt

Source: Design Review of Water and Wastewater Network Trainig Manual: Water and Wastewater Management Program (GTZ), Dec, 2008

Water losses in Egypt are also caused by invalid meters. According to the official statistics of the Holding company, one and half million water meters are invalid or not working among 12 million meters in Egypt, which means that 12.5 % of total connections in Egypt are randomly billed*.[34] Water losses are directly proportional to network length. Governorates with scattered housing areas like Matrouh and Al-Faium have higher NRW than compacted governorates like Cairo and Alexandria. Scattered buildings require longer distribution networks thus more vulnerability to leaks and breakings[35] as shown in fig(43).



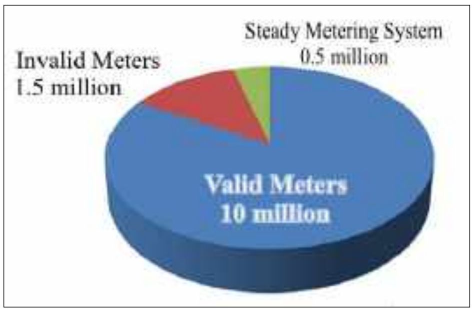


Fig (43): (left) Water network losses in different governorates, 2010/2011 (Up) Status of water meters in Egyptian Water Holdings 2011/2012.

Source: (Up & Left) Reference No. 35.

(1-1-2-B) Efficiency of Central sewage system:

The main parameters used to measure the central sewage system efficiency are: proper collectivity, measured by leaks and infiltrations, and proper treatment measured by removal efficiency.

a- Proper Collectivity:

Central sewer systems usually face two main problems: leaks and infiltrations. Leaks are water seep from sewers to surrounding groundwater, while infiltrations are groundwater getting into the sewers system as shown in fig (44). Both occur due to breaks, corrosions or loose connections.

Fig (44): (left) Leaks from water and wastewater pipes into groundwater (right) Infiltration into water and wastewater pipes from the surrounding groundwater (right)

Leaks cause the contamination of surrounding groundwater and infiltrations cause the dilution of wastewater that goes to treatment plant. The dilution of sewage directly decreases the efficiency of treatment and increases costs of pumping, chlorination, ozonation, and ultraviolet disinfection. High rates of infiltration may make the sanitary sewer incapable of carrying sewage from the design service area. Sewage may back up into the lowest level homes during rainy weather, or street manholes may overflow, see fig(45)* :[36]

Fig(45): (left) Wastewater flooding in the streets of Bahteem, Giza. (Up) Manholes overflow in Talkha.
Source: (left) www.fath-news.com (Up) www.hoqook.com

Sewer pipes are often installed beneath creeks or streams because they are the lowest point in the area and it is more expensive to install the pipe systems beneath a roadway. These sewer pipes are especially susceptible to infiltration when they crack or break and have been known to drain entire streams into sanitary sewer systems.

Average sewer pipes are designed to last about 20-50 years, depending on what type of material is used. In many areas in Egypt, sanitary sewer system pipes along with the lateral pipes attached to households and businesses have gone much longer without inspection or repair and are likely to be cracked or damaged.

b- Proper Treatment and Removal efficiency:

As only 76% of total municipal wastewater in Egypt is collected and transported to treatment plants, 73% of the collected water is actually treated. The United Nations Development Program for Arab States (RBAS) has stated in its 2011 report that Egypt produces 8.5 billion cubic meters of wastewater annually, from which 6.5 billion m^3 is collected and transported to treatment plants, where 4.8 billion m^3 are finally treated, meaning that 56% of total produced wastewater is actually treated in Egypt, table 6 * :[37]

Country	Treated wastewater (municipal) Billion m3 /year		
	Produced municipal wastewater	Collected municipal wastewater	Treated municipal wastewater
Egypt	8.50 (2011)	6.500 (2011)	4.80 (2011)

Table (6): Municipal wastewater' collection & treatment rates in Egypt in year 2011

Source: United Nations Development Programme & Regional Bureau for Arab States (RBAS): **Reference No. 37**

Concerning the treatment technologies applied in Egypt, a research conducted in April, 2013 by group of multinational scientists mentioned that 10 % of WWT plants in Egypt apply only primary treatment, while 65 to 85 % apply both primary and secondary treatment. Only 5% of plants apply primary, secondary and tertiary treatment* :[38] Egypt still depends on natural stabilization ponds برك الترسيب , which treats around 80 % of its wastewater. Limited financial suppor has also contribute to the low treatment efficiency.

The 323 existing treatment plants in Egypt are in need of improvements. Sixteen plants are not even in operation. The plants receive disproportionately large amounts of wastewater due to both heavy household consumption and leakage from the water distribution systems. The leakage in Cairo is estimated to be as high as 70% * :[39]

An example for the removal efficiency in Egyptian plants, are the two main treatment plants serving Alexandria Governorate: The Eastern and the Western Plants). The two plants were studied and measured by a group of researchers in 2008. The study conducted that both two plants were less than 51% efficient and their effluent water was not complying with Egyptian reclamation standards. The average removal efficiencies of BOD, COD, NH4, and TP were 92.8%, 87.9%, 55.8%, and 23% respectively. The two plants had no facility to remove nitrogen and phosphorus, so high concentration of nutrients was disposed into the Mediterranean * ;[40] see table (7).

Mean level of the studied water quality parameters in the inlet and outlet effluents of each of the waste treatment plants in Alexandria and its treatment efficiency.

Plant	Source	BOD *mg O_2/L*	Load *ton BOD/d*	COD *mg O/L*	Load *ton/d*	TSS *mg/d*	Load *ton/d*
ETP	Inlet	338.4	127.6	730.5	275.4	287	108.2
	Outlet	222.2	83.7	634.9	239.3	150	56.5
	Efficiency %	-	34.4	-	13.1	-	47.8
WTP	Inlet	654.1	145.2	1765.5	391.9	592	131.4
	Outlet	323.4	71.8	1268.5	281.6	295	65.5
	Efficiency %	-	50.5	-	28.1	-	50.2

ETP= East Treatment Plant *WTP = West Treatment Plant*

Table (7): Removal efficiency of Eastern and Western wastewater plants in Alexandria, Egypt, 2008 statistics

Source: El-Rayis1, 2008, reference No. 40.

The same problem exists in Delta Region where sewage plants mostly dispose wastewater into water canals without proper treatment, causing serious pollution levels as seen in fig (46).

Fig(46): Raw and semi-treated wastewater being discharged in water bodies: from left to right: The North Coast, El-Manzala Lake, and the Nile in Kafr El-Zayat.

Source: www.hoqook.com

With semi-treated wastewater mixing with Nile water and canals water, which are the main intake for most municipal water plants, and with insufficient purification for produced water, most water distribution pipes suffer the existence of sediments on its inner walls, causing partial or complete blockage for network pipes as seen in fig (47)* .[41]

Fig (47): Water pipes clogged by sediments.

Source: www.heirt.com

d- Satisfaction:

Satisfaction of the consumer is one of the important parameters of the service efficiency. In Egypt the utility of water and sanitation is in general not satisfying. Hundreds of complains, strikes and stand-up express the dissatisfaction. Fig (48) shows that 61 % of the voters in Menofeya Holding see that the service is relatively bad * .[42]

Fig (48): Poll measures the consumers satisfaction in Menofeya

Source: Official site of Menofeya Holding Company, reference no. 42.

d- Fragmentation of responsibility & lack of transparency:

Water sector efficiency is affected by the fragmentation of responsibility. The Ministry of Health and Population is responsible for monitoring drinking water quality. The Egyptian Ministry of Environmental Affairs is responsible for environmental affairs and the assessment and monitoring of water use. The Holding Company for Water and Wastewater is responsible for the financial and technical sustainability to the Governorate-based utilities. The Egyptian Water Regulatory Agency (EWRA), established in 2006, is in charge of the economic and technical regulation of utilities* .[43]

The overlapping responsibilities create a situation where no institution considers itself accountable for the sector problems.

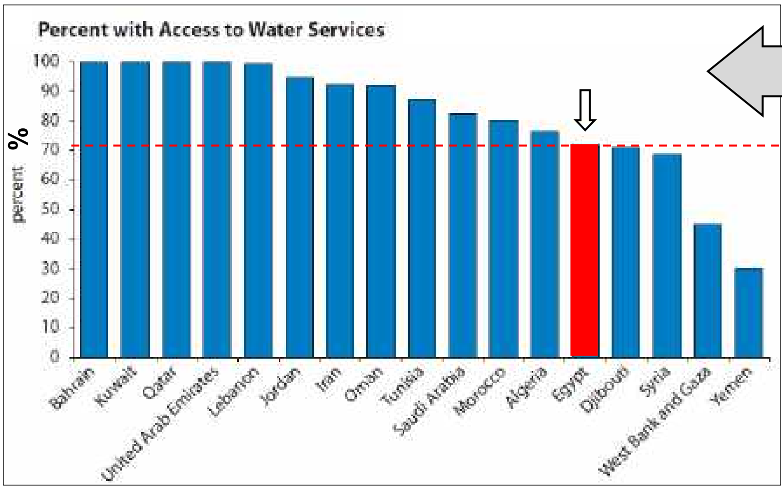
The overall lack of transparency and access to information in the water and sanitation sectors creates an atmosphere of suspicion, which is characterized by a lack of confidence in the quality of drinking water and overall distrust of the Government and the Holding Company* .[44]

(1-1-3) Equality of distribution of water and wastewater utility in Egypt:

There are conflict statistics about the coverage of water and sanitation service in Egypt. Central Agency for Public Mobilization and Statistics (CAPMAS), on its 2012 census, showed that 92.9% of rural buildings had access to potable water networks (93.5% in Delta and 92.5% in Upper Egypt), while 24.3% only were sewered (33.7% in Delta and 11.65% in Upper Egypt)* .[45]On the other side, National Water Quality Monitoring (Nawqam) and Egyptian water Association (EWRA) had different statistics. The EWRA annual report 2010/2011 confirms that only 83.4 % of population have indoor water access and less than half of Egypt's population (49.7%) is connected to central sewage network while the rest either have self-installed systems (11.89 %), or completely deprived from any system (26.93 %) * .[46]

Nawqam's 2012 report states that these ratios do not represent the actual wastewater coverage in Egypt because many of these networks are not connected to wastewater treatment plants, but they were constructed through self-efforts and most probably discharge untreated wastewater to an agricultural drain or even a waterway in some cases; i.e. they are a pollution producer not a pollution prohibitor* .[47]

International agencies also have their own statistics. The USAID states that Egypt's water access services cover only 71.8 % of population. In comparison with its regional peers, Egypt's coverage is lower than Arabian Gulf countries which suffer hot arid weather and have no rivers at all. Fig(49).



Fig(49):Egypt's water service coverage compared to its regional peers.

Source: World Bank special report: Making the Most of Scarcity: Case Studies: Mitigating Risks and Conflicts, reference No. 30

Non-governmental agencies in Egypt have their statistics as well. The Egyptian Organization for Human Rights has mentioned in its 2010 report that 2,315,350 families in Egypt don't have an indoor water tap, while 461,344 families have no sanitation grid at all, neither municipal nor local. Deprived areas are mainly located in upper Egypt as shown in fig (50),(51).

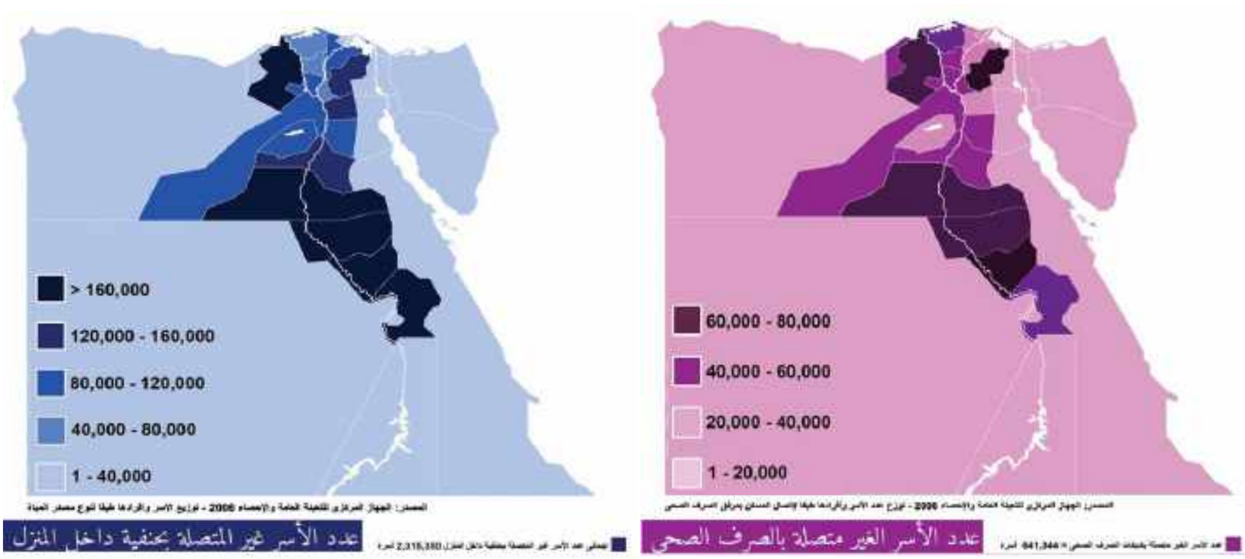
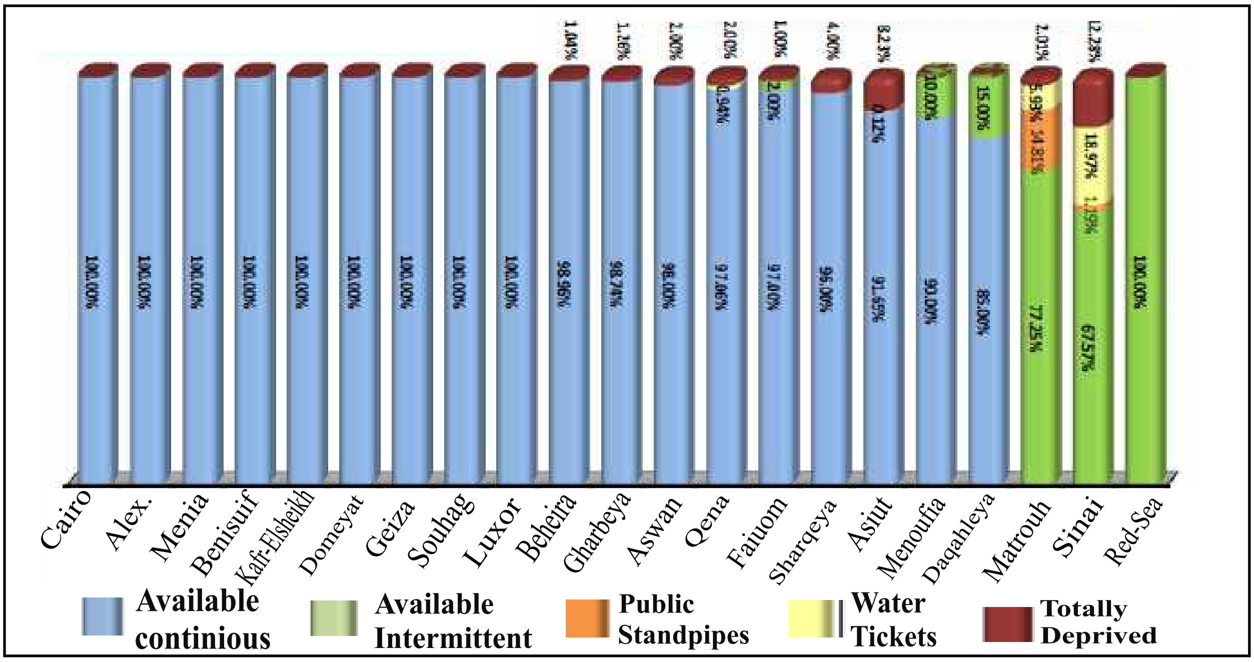


Fig (50) The distribution of water and wastewater utilities' provision in Egyptian Governorates, 2010 statistics – **Source: Egyptian Organization for Human Rights Report 2010**

Another statistic shows the percentage of water utility provision in different Egyptian Governorates. According to this statistic, water supply network is noticeably available in Old Valley Governorates while is almost unavailable in Red Sea, Sinai, and Matrouh Governorates as shown in fig(51).



Fig(51): Water grid availability in Egyptian Governorates According to official statistics

Source: EWRA Annual Report 2010/2011, reference No. 46

The total domestic water use in Egypt forms about 8% of total Egyptian water consumption. The per capita water share is significantly variable among variable Egyptian Governorates. While the per capita water share is 330 liter per day (l/c/d) in Cairo (almost twice as much as in Germany)*[4] , and 300 l/c/d in Alexandria[8], Upper Egypt's share is only 70 l/c/d while zero share is recorded in about 25% of total households in Egypt *[49]. The most deprived areas are rural areas and slums.

Water Supply Alternatives:

When household connections are absent, the main water sources are public standpipes, groundwater wells and water from open canals. Canal water is often used for laundry and washing domestic utensils, and for cleaning vegetables and grain. Rural women prefer canal water to municipal and groundwater as they believe that it is softer and not brackish*[50] as shown in fig(52).

Fig(52): (left) Washing dishes in canal water in Belbais, Sharqeya (up) Hand pumps in rural houses.
Source: www.worldcook.net

Some households depend on buying water from water vendors in Gerry-cans. This act is common where groundwater is highly contaminated to be utilized for drinking or when a sudden water crisis occurs. Gerry-cans are also popular in slums and many urban districts where water grid supply exist but with low water quality. The price of one Gerry-can ranges between 1.5 to 3 LE, with an average budget of 20 to 50 LE per month for a single family. Some times the cost is much higher if water is transported for a long distance or if municipal water-borne disease outbreaks like the case of Al-Barad'a, 2009, fig(53).

Fig(53): Water vendors with gerrycans in Toukh
Source: www.hlrn.org Retrieved Feb. 25th 2014

Sewers Alternatives:

People differently react towards the absence of central sewer system. Some houses discharge their waste directly into nearest canal, while others install vaults and cesspits which need regular evacuation. Others, who are the poorest among the inhabitants, carry on their liquid waste and walk in daily trips to pour it in the nearest drain, fig (54).

Fig(54): (left) Woman disposing her household wastewater in the village's drain, Minya, Upper Egypt (right) Household outlets discharging raw wastewater into water body in Tersa, Fayium, March,2014
Source: (left) http://www.cbm (right) www.mobtada.com/news_details.php

Vaults and cesspits (locally called: Trunch) are prominent in many Egyptian villages and are considered a main contributor in groundwater pollution in Delta Region. Vaults need regular evacuation which commonly doesn't occur properly because of the high cost of evacuation tanks which may lessen the frequency of the process. If not regularly evacuated, vaults overflow and flood the surrounding area, as shown in fig (55).

Fig(55): (left) Evacuation of rural trenches in Met Nama, Qaliubeya (right) Trench flooding in Atfeih, Helwan

Source: -www.maatpeace.org

In the absence of any practical alternative, evacuation tanks dispose its cargo into neighboring waterways, and sometimes by the municipalities own tanks, fig(56)* [51]:

Fig(56): Evacuating raw wastewater into water bodies in Benha (left) and Monshat El-Qanater (middle) and in Tanta(right)

Source: (left) www.egypttoday.com/ (middle) www.almasryalyoum.com/ (right) www.dailynews.com

Some people dig "wastewater wells" which directly discharge raw sewage into ground water. These wells highly pollute groundwater and raise water table which is already 2 to 5 meter high in Delta region. Contaminated groundwater is commonly pumped again for household use when municipal water access is not available.

Impacts of Deprivation:

There are many means of deprivation from municipal water and wastewater utilities, such as: Intermittent supply, low or unsafe water quality, faraway standpipes, poor wastewater treatment and self-installed grids, all are different means of deprivation. This deprivation has social, structural, hygienic, and demographic impacts over the dwellers:

Social Impact:

The absence of indoor water access has negative social impacts on the inhabitants. Water gathering trips and water waiting rows, which women are commonly responsible for, consume their time and effort. 6% of rural women spend time collecting water, for hours in some cases, hence they have less effort for their housekeeping and less time for their children * [52].

Wastewater has also daily discharging trips, mainly performed by women and children; this choice is for good reason. If caught, they are less blamed and won't be punished. These children have less time for study which lessens their opportunities of decent jobs and raises illiteracy in rural society. Fig (57).

Fig(57) : (left) Pouring wastewater in open canal, Tall Basta village, Sharqeya (right) Women's trip for water gathering in al-Rahawe village, outside of Cairo, May 2010

Source: (left) www.globalpost.com (right) http://www.vetogate.com

Another social impact is represented in stand-ups and strikes caused by repetitive water cuts which may extend for weeks in less fortunate areas. These strikes may affect traffic and threat social peace, see fig (58).

Fig (58): Stand-ups against water cuts in Alkhanka,2012 (left), Ibrahemya, 2013 (up right) &Suez, 2011 (downright).

Source: (left) http://test-elramly.blogspot.com (up right) www.egypttoday.com (down right) www.copts-united.com

Impact over Building Structure:

Sewage leaks to groundwater sometimes cause the raise of groundwater level; especially in northern parts of the country were groundwater level is relatively high. The associated risks of threatened structural stability of many rural households are common. Wall dampness is the first sign, which is followed by rotten walls and wet furniture, see fig(59). The over saturated soil becomes less compact which causes a slow drop down of the concrete bases followed by shallow or deep cracks.

Fig(59): (left) Sewage flooding in rural houses in Al-Tall village, Giza- (Middle & Right) High groundwater table affecting the structure of houses in Al-Khadra village, Menoufia.
Source: (left) www.youm7.com/ (middle & right) http://onaeg.com/

Sometimes sewers flood and wastewater overflows and go through houses; causing severe health risks and threatening building stability.

Some villages suffer the existence of open wastewater canals that run through the streets as shown in fig (58). A study conducted in Al-Mufty Alkubra village in Menofeya, 2002 showed that the village is at high risk because of these open canals which carried liquid waste through the village causing structural and health-related problems. The houses were threatened and the walls were wet and rotten. The water have caused some houses to collapse*[5] , fig(60). [3]

Fig(60): Open wastewater canals in the streets of El-Moufty El-Kobra, Kafr El-Sheikh (left), Kafr Ga'far (middle) and Ezbet El-Safeih, Cairo (right) - source:GIZ Report,2002 www.giz.org

Wastewater may also cause catastrophic destruction. In El-Doweqa, 2006. The effluent wastewater coming from Cairo and seeping under Al-Mokattam Mountain caused a massive landslide, smashing the houses of El-Doweqa's inhabitants; which left their homes destroyed, or under threat from an avalanche of rocks from Mokattam's upper plateaus large parts, fig(61).

Fig(61): Al-Doweqa catastrophe, 2006 -
Source: www.parc.org/ Retrieved in December 21st 2013

Health Impact:

According to a UNICEF study, children who live in rural households are 8.7 times more likely to drink from unsafe sources of water than children who live in urban households * :[54] This explains the fact that the incidence of Diarrhea in rural children is three times more than their peers in the city * ;[55] fig(62).

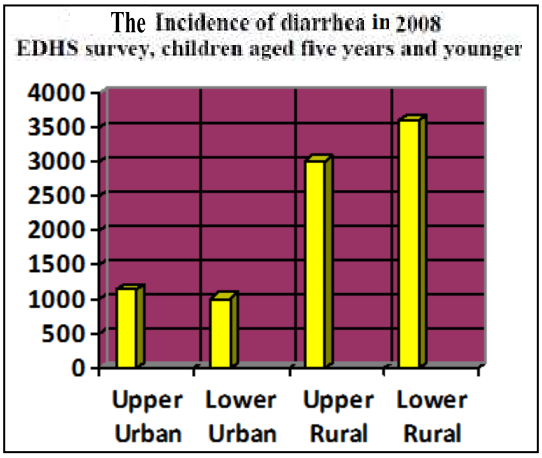
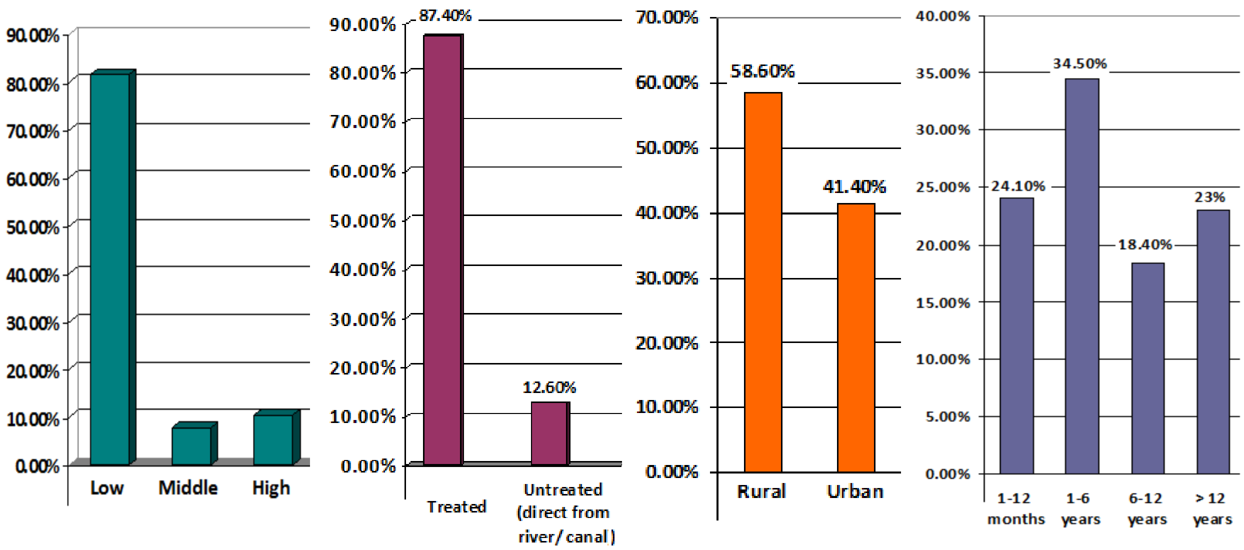


Fig (62): Incidence of diarrhea in Egyptian children according to urban categorization, 2008
Source: Roushdy et.al, 2012. Reference No. 55

The regular consumption of poor treated water may cause serious renal problems. A medical study conducted in rural and urban Egyptian regions showed that 58.6% of renal impairments patients were living in rural areas, and 12.6% of total patient drink directly from the river or untreated well water. 81.6% of them were with low socio-economic status, and 77% were under 12 years old, fig (63) * :[56]



Socio-economic Status **Drinking Water** **Residence**

Fig(63): The incidence of renal diseases in Egypt according to selected socio-demographic characters
Designed by the researcher, based on data from Tawfik, et, al. 2002, reference No. 56

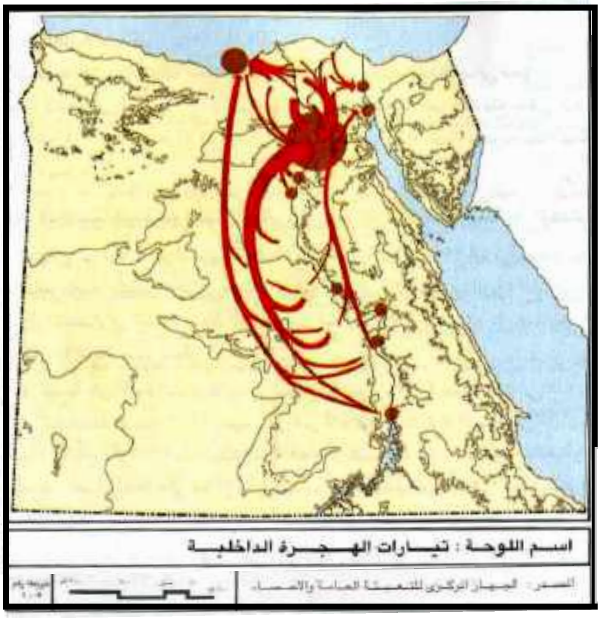
Belharziasis is also caused by physical contact with canal water while washing or bathing, as shown in fig(64). Other water-borne diseases are recorded in Rural Egypt like Cholera and Chestomaises. An outbreak of Typhoid was recorded in Al-Barad'a village in Qalyubeya, in 2009 caused by polluted municipal water intake that fed the whole village.

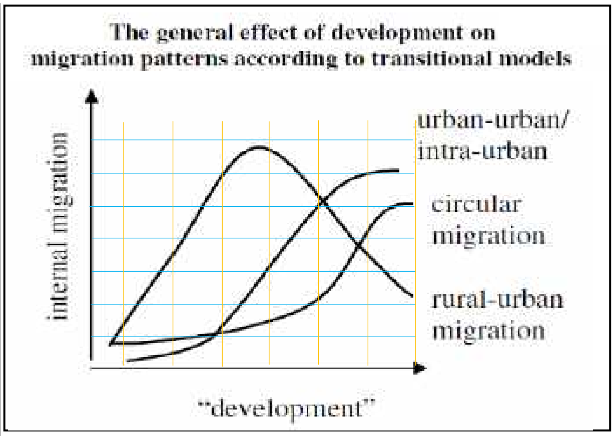
The dampness of walls which threatens the structure of rural houses also affects health by increasing the tendency to get infectious diseases like TB, Rheumatic heart disease, rheumatic joints and Polio. These diseases are epidemic in rural Egypt although they almost vanished from most of the world.

Fig(64): (up) Direct contact with water canal causing Belharzial infection in rural areas (left) Outbreak of Typhoid in Al-Baradaa, Qaliubeya, 2009
Source: www.almasryalyoum.com **(up) 12/12/2014 (left) 22/12/2009**

Demographic Impact:

Uneven distribution of utilities urges rural people to move to cities seeking better life. They abandon their lands and work in other non-farming jobs. As rural-urban migration inclines, cities are overloaded and agricultural land declines as shown in fig(40). Despite the fact that internal migration in Egypt has many other reasons like searching for better jobs and better education, lack of developmental projects and low quality of life and services are main contributors as well, especially in upper Egyptian regions. There is an inverse relationship between internal migration and development as seen in fig(65) * .[57] The streams of internal migration in Egypt are mainly pouring in Cairo accumulated the presence of informal areas around capital cities, causing many social and demographic problems. In a recent study by the Central Agency for Public Mobilization and Statistics (CAPMAS), there are 1221 slums in Egypt from which 76 are present in Cairo alone * [5] . This urban encroachment has diminished the agricultural land and raised food prices. During the last 30 years, thousands of Feddans of fertile lands had turned into concrete blocks, fig(66).





Fig(65): (left) Main directions of internal migration in Egypt in (1965-2000) (up) Impact of development on internal migration

Source: (left) CAPMAS population characteristics report, 2002) - www.capmas.org.eg (up) De Haas, 2008 reference No. 57

Fig(66): Diminishing agricultural land around Cairo - http://cairobserver.com/

Formal and Informal Districts:

Not only rural areas suffer utilities' problems. Formal districts also suffer recurrent water-cuts. A recent study of two Cairo suburbs found that only 69 % of residents in Sixth of October City and 42 % in New Cairo had tap water available at all times* [5] . But the real problem exists in slums and informal district. In these areas, most houses are built without building license, so infrastructure are most likely to be bartered for or self-built. Due to legal conflicts and finance problems, slums are usually not provided by municipal utilities by governmental authorities.

An example for the inequality of utility distribution in Egypt is an informal area called Manshiyat Naser, (also known as "Garbage City" shown in fig(67). In this area, less than 15 percent of clean water needs are met by the municipality; most residents depend upon small private wells which draw from contaminated shallow aquifers" fed by the Nile. An NGO found that 75 percent of water samples "did not meet the minimum acceptable standards for drinking water in Egypt." Yet because districts like Manshiyat Naser are extra-legal, residents can't demand better infrastructure. They collect water in jerry-cans, dig holes for toilets, and illegally connect to electricity* [6] . Not so far from 0
these slums, lay the new luxuries compounds where water supply is abundant and excessively used for filling swimming pools and artificial lakes, aor irrigating Golf playgrounds * [61].

Fig(67): (left) An overview of Manshiyet Nasir, Cairo (right) Excessive water use in Sedra Compound, Katameya, Egypt.

(1-1-4) Environmental pressure of the centralized water and wastewater system:

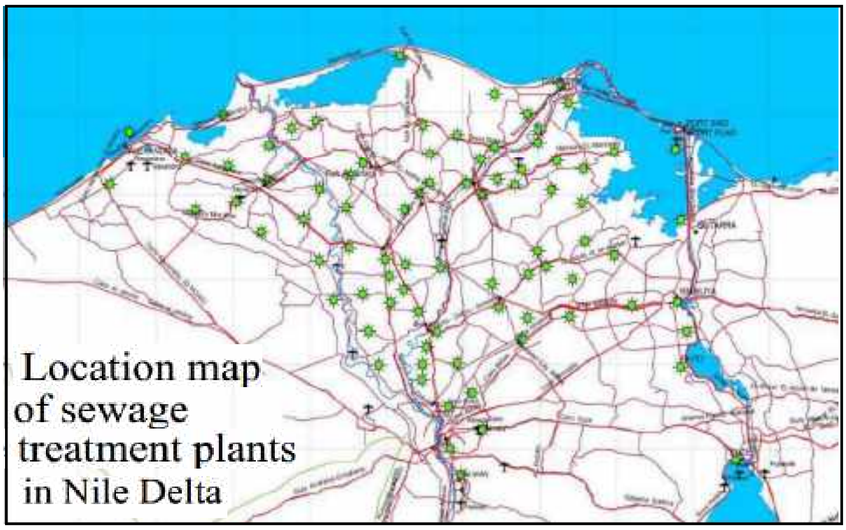
Water, Sanitation and Sewerage Infrastructure Projects (WSSIP) has been classified as Category B project, requiring an environmental assessment. Projects under Category B are defined as projects that "could have potential adverse environmental impacts on human populations or environmentally important areas"- including wetlands, forests, grasslands, and other natural habitats, these impacts are site specific; few if any of them are irreversible; and in most cases litigator measures can be designed * [62]. The environmental impacts that are likely to be caused by the sector are:

a- Contamination of Agricultural Drains:

Egypt has 323 wastewater treatment plants (WWTP's) commonly located nearby agricultural drains as seen in fig (68) * [63].Locating these plants by drains is according to Egyptian Environmental Executive Regulation (EEER), which restricts the discharge of treated effluent wastewater into drains only and not to freshwater canals. Article 66 of the same regulation, states that treated sewage should comply with Egyptian standards prior being discharged to drains* [6] . But these standards are[4] not commonly fulfilled due to technical and economic problems illustrated before. So, with poor removal efficiency and massive daily flow of 12 million m3/day* [6] , drains are heavily [5] polluted with human waste-related bacteria like Faecal Coliform and Escherichia coli. The concentration of Faecal Coliform in some agricultural drains has exceeded 100000 - 500000 (MPN/100ml) while the Egyptian Environmental Standards are not to exceed 5000 (MPN/100ml), fig(69).

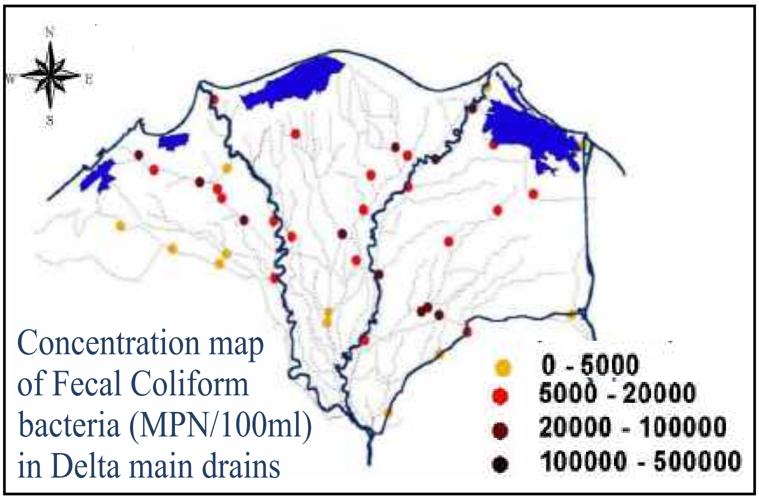
Fig(68): Location map of sewage treatment plants in Delta region

Source: Rifaat Abdel Wahaab & Mohy El-Din Omar: Wastewater Reuse in Egypt: Opportunities and Challenges- www.arabwatercouncil.org/administrator/.../Egypt-Country-Report/



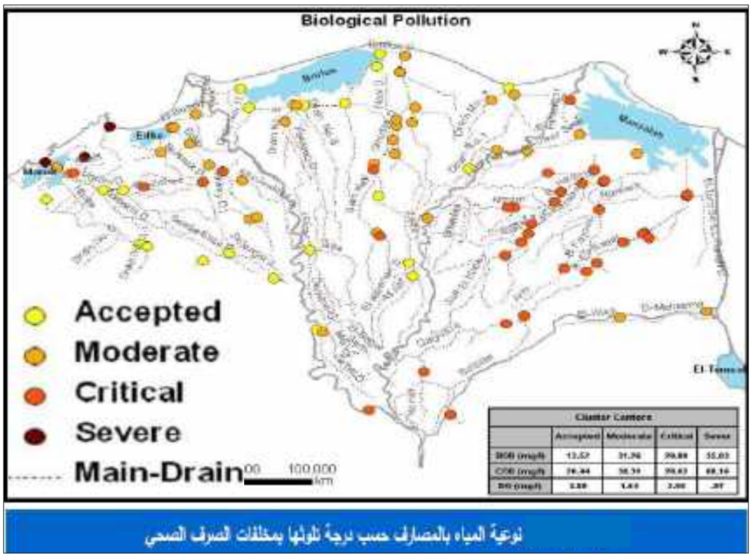
Fig(69): Faecal Coliform Bacteria concentrations in the same Region(2002/2003)

Source: ISSIP 2 -Project Framework for the Environmental and Social act Assessment Framework (ESIAF)- Delta Governorates-Ain Shams University Institute of Environmental Studies and Research-2010



Monitored levels of contamination in the Delta Region are generally by far exceeding Law 48/1982 limits for ambient water quality. Sewage discharges to canals and drains in the Delta Region are believed to be the major contributor to the deteriorating surface water quality. The level of water pollution in agricultural drains in some areas has reached limits preventing the reuse of this water after mixing it with canal water, which is considered a serious waste of an important water resource*[6] . 6

The Egypt Environmental Affairs Agency (EEAA) has measured the biological pollution in Delta region's drains and classified it into accepted, moderate, critical and severe. About 40 percent of measured points were critically polluted and 8 percent were severely polluted, located mainly in western coastal parts as shown in fig(70).



Fig(70): (left) Biological pollution in agriculture drains in Delta region due to wastewater discharge (up)Discharging treated wastewater into water body in Assiut.

Source: (left) Annual report of Egypt Environmental Affairs Agency 2012- www.eeaa.gov/ (up) http://assiutdotcom.blogspot.com/

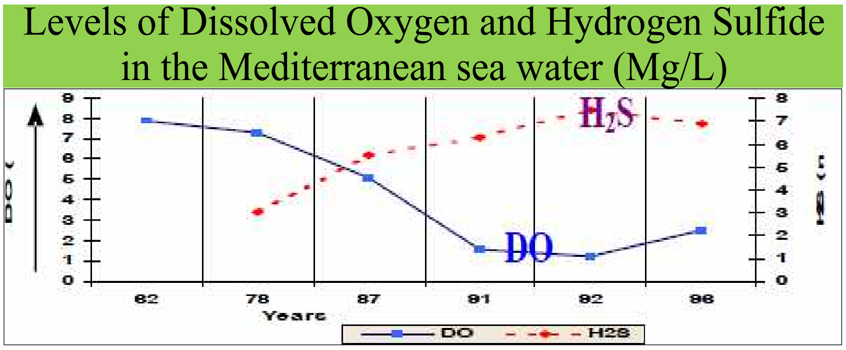
With many plants pouring wastewater without proper treatment, and with increasing scarcity of irrigation water in many villages, heavily polluted drains are used for direct irrigation in many governorates as seen in fig(68). These irrigated crops form a serious threat to the public health and may cause liver failure and sometimes cancer.

Fig(70): (left) Polluted water bodies used in irrigation in Kafr El- Sheikh. (up) Crops irrigated with sewage in Alsaff, Giza.

Source: www.youm7.com/News.asp?NewsID=1096636 Retrieved in January 12th 2014

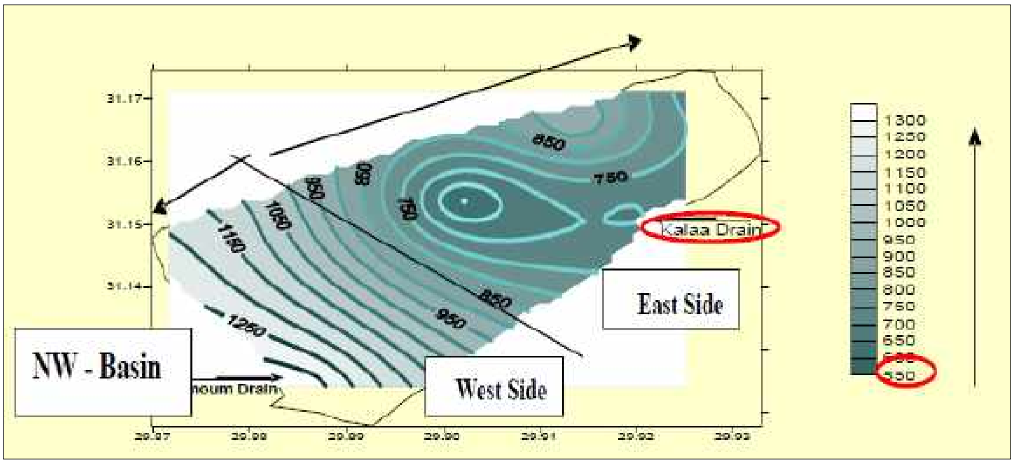
b- Pollution of the Mediterranean:

Treated wastewater effluent reaches the Mediterranean Sea through the terminals of the drainage network. Massive flow of poorly treated wastewater affects the marine environment by several ways. As wastewater is rich with aerobic bacteria that heavily consume Oxygen, the level of dissolved Oxygen (DO) in the sea has decreased apparently during the last three decades *[67] which affected the aquatic life because Oxygen is vital for the existence of marine animals. Wastewater also contains high concentrations of Hydrogen Sulfide (H_2S) which affected the quality of the Mediterranean Sea water. (H_2S) is known to warm the oceans, lower their capacity to absorb oxygen and increase the PH level of the water. The increased levels of hydrogen sulfide could have killed oxygen-generating plants as well as depleted the ozone layer*[68] as shown in fig(71).



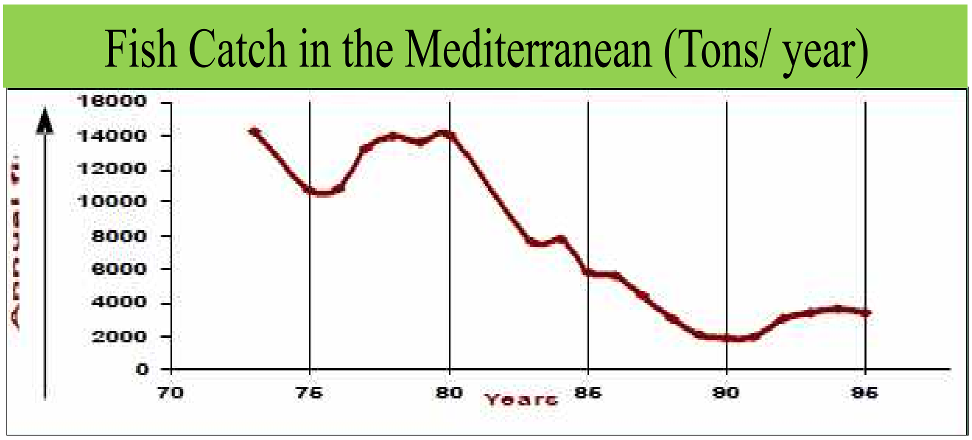
Fig(71): Levels od dissolved Oxygen and Hydrogen Sulfide in the Mediterranean Sea water (Mg/L)
Source: El-Rayis1et. al, , 2008 –Reference no. 67

As most of the Egyptian wastewater plants mainly depend on Chlorination as a cheap method for treatment, the excessive use of Chlorine cause high concentration of this gas in the final effluent discharged into drains and finally to the Mediterranean, High levels of chlorosity have been recorded in the sea as seen in fig(72).



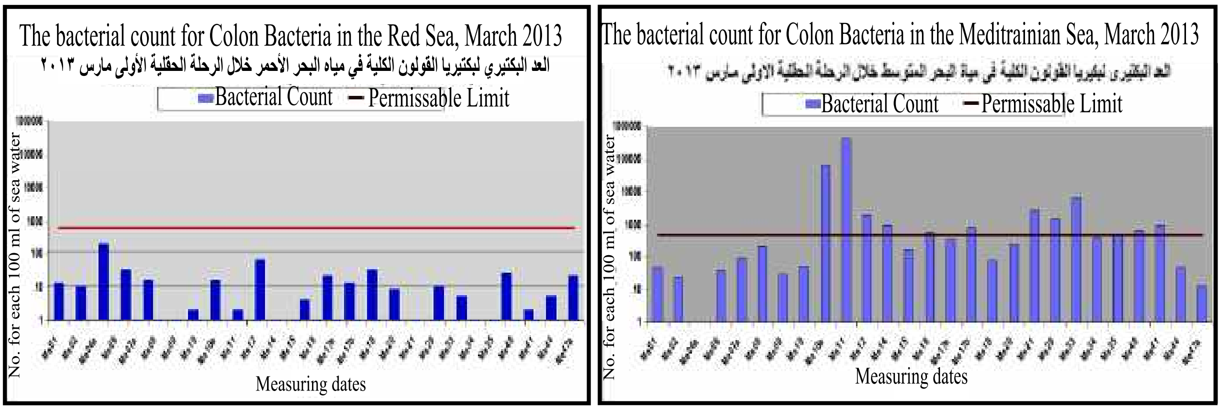
Fig(72): Chlorosity Levels in Mediteranian Sea around Wastewater Plant Outlet in Alexandria
Source: El-Rayis1et. al, , 2008 –Reference no. 67

As a result of high chlorosity, low dissolved oxygen and high concentration of Hydrogen Sulfide, the yearly level of fish catch in Alexandria has declined significantly. The marine life is also affected with wastewater discharge into the sea while some rare species are expected to extent. See fig(73).



Fig(73): The decline in annual fish catch yields in the Mediterranean Sea during 25 years
Rayis1et. al, , 2008 –Reference no. 67

Compared to the Mediterranean, the Red Sea is far less polluted. As no polluted drains pour into it, the main Colon bacterial level in the Red Sea is due to direct discharge of wastewater in the sea without treatment, especially by touristic activities which generally lack proper treatment facilities. Red sea pollution threats the existence of coral reefs which are indispensable and form a main touristic attraction point in the region as shown in fig (74).



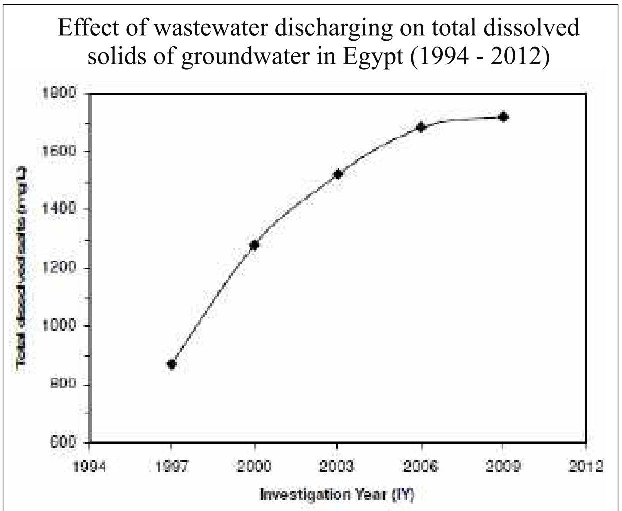
Fig(74): Comparing the bacterial count for Colon Bacteria in the Red Sea (left) & Mediterranean Sea (right), March 2013

c- Groundwater Contamination: Wastewater sector in Egypt has contributed in groundwater contamination by direct and indirect means: the deteriorated and leaking sewage pipe systems that leak raw wastewater into groundwater, and the disposal of insufficiently treated water into drains which seep into groundwater aquifers. The absence of sewage service has led to the commonness of vaults and cesspits which affected the groundwater quality as well.

Many wastewater plants discharge wastewater into drains without proper treatment, especially in rural regions, which leads to pollution of the surface water. The average water table in the Nile Valley and Delta is 3 to 5 meters and is getting higher with time. With high water table and slow movement of water in these drains, the movement of pollutants between groundwater and surface water bodies increases which leads to groundwater contamination* [69].

The total dissolved solids (TDS) of groundwater in Egypt have significantly increased from 800 (mg/L) in 1997 to more than 1700 (mg/L) in 2009, which means more than 200% of augmentation in less than 12 years, see fig (75).

Increasing population densities and rising water tables in the Nile Valley and Delta allow for the increased movement of pollutants between groundwater and surface water bodies * [70].



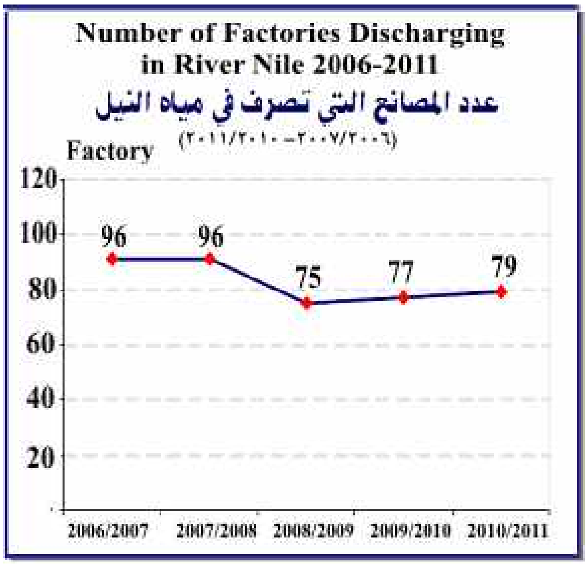
Fig(75): (left) Incline of TDS in groundwater in Egypt as measured in years (1994 - 2012). (up) Discharging treated wastewater into agricultural drain in Mehallet Hassan, Gharbeya.

Source: (left) Easa et. al, 2012, reference no.70 **(up) www.Mahallanews.com/ Retrieved in March 15th 2014**

e- **Pollution of the Nile**:

As raw or poorly treated wastewater finds its way to the Nile; high concentrations of coliform bacteria are found in the river and its branches downstream of Cairo. Values of 1 to 10 million (Most Probable Number) MPN/100 mL have been measured in the Rosetta branch. This is far above the standard of five thousand MPN/100 mL as given in Law 48 of 1982 * [71].

A main contributor in Nile pollution is poorly treated industrial effluents. Central wastewater treatment suffers poor technology required for the removal of highly malicious chemicals from industrial effluent water which requires special machines and materials that do not usually exist. More than 50 major factories discharge more than 250 million m^3 per year of industrial waste-water with little treatment while many others discharge sewage directly into nearest water body without any treatment* [72]fig(76). Despite the strict regulations that forbid that action, the surveillance is weak or corrupted.



Fig(76): (left) Number of factories discharging raw wastewater into river Nile in years (2006/2011).
(up) Discharging industrial wastewater into freshwater body in Kafr El-Zayat.

Source: (left) Ministry of Environment annual report 2010/2011 www.me.org.egwwwkbwindow.com/
(up) www.kbwindow.com/

As a result of industrial pollution, municipal effluents, oil discharge and agricultural pollution the river is contaminated with heavy metals, pesticides, herbicides, and microbes. The blooming of cyanobacteria, elicited by excess nutrients (eutrophication), leads to the production of cyanotoxins, which affect the health of fish and may poison humans * [7] . [3]

f- Using Chlorine:

WWTP's use hazardous materials like chlorine gas, fuels, lubricating oils and laboratory chemicals. Chlorine is considered, in other ministries' hazardous materials lists, among Toxic and Highly Toxic materials that need obtaining a license. Therefore, chlorine (CAS-No. 7782-50-5) that may be used in WWTPs is considered as a hazardous materials in the EIA **(Environmental International Agency)**, and the used chlorine containers are considered as hazardous waste * .[74]

g- Weak Environmental Health Enforcement:

The regulations of the law 48/1982, which forbid the discharge of untreated wastewater to surface waters, are rarely applied and can hardly be applied, given the shortage of staff required for surveillance and the deficit of available wastewater treatment facilities * [75]

h- Augmentation of Green House Effect:

Water and sanitation sector consumes more than 10.8% of total produced electricity in Egypt to perform pumping, purification and treatment processes. With more than 6 million m^3/day of water and 5 million m^3/day of wastewater pumped in Egypt on daily basis, electricity is mandatory for the survival of the sector.

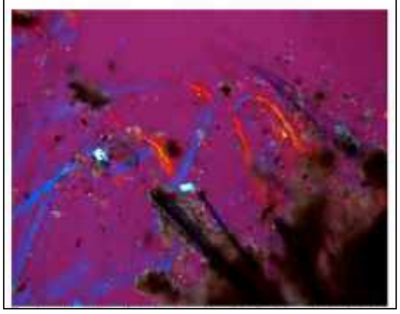
This consumption leads to using of petroleum derivatives like mazot and gasoline. Burning these derivatives causes heavy pollution to air and environment and increases the greenhouse effect.

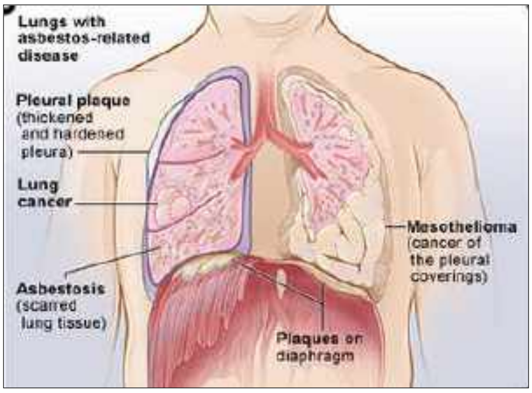
As electricity production is responsible for more than 37.2% of CO_2 emissions in Egypt, central water and wastewater sector is responsible for 4.0176% of total CO_2 emissions in Egypt * [76]. Other environmental impacts of electricity production are further illustrated in chapter 2 of this research.

i- Using Asbestos in water pipes:

Asbestos is a fibrous mineral occurring in natural deposits which is resistant to heat and most chemicals. It is used in more than 3,000 products, including distribution water pipes * [77]. The major sources of asbestos in drinking water are dissolution of asbestos-containing minerals and erosion of asbestos-cement (A/C) pipes in the distribution systems of drinking water as shown in fig(77). The health hazards associated with drinking water from pipes made of asbestos include malignant mesothelioma of the peritoneum and cancers of the gastrointestinal tract and larynx* [78]

Microscopic Image showing Asbestos Bundles in Water Pipe





Fig(77): (left) Asbestos bundles in water pipes (right) Asbestos-related diseases in human body (left) www.asbestosdiseaseawareness.org (right) National Heart Lung and Blood Institute- www.nhlbi.nih.gov/

EPA has announced Asbestos as a hazardous material and recommended the replacement of asbestos pipes with poly vinyl or cast iron pipes * [79].

In Egypt, there is no accurate data about the percentage of asbestos pipes among the distribution system. However, a study conducted in Alexandria in 2006 found that most of the pipes in the city's distribution systems of drinking water were asbestos-cement (A/C) pipes, and most of them suffered erosion especially in old quarters of the city. Although blue asbestos was banned in Egypt in the '70s after its dangers were revealed, the government has not yet undertaken a nationwide campaign to remove it from buildings and existing infrastructure which cause a real threat for the health of the consumers * .[80]

(1-1-5) Land Use and impact on urban planning:

Water and wastewater treatment requires land for building, installing and running the system. There is usually an inverse proportion between land requirements and construction cost, because lower-cost technologies rely on exposure to sunlight for biological treatment, consequently this requires larger areas for treatment basins and longer retention time in these basins. As technology used in Egypt is primitive, it requires vast areas to build and install wastewater plants as shown in fig(78). This may be suitable for coastal governorates and new settlements, but it may cause a problem in the Old valley. Vacant land is scarce in the Delta and its cost is high * .[81]

Fig(78): Excessive land use by treatment plants in New Assiut, Kom-Hamada and Abul-Matameer

As an example for wastewater plant land use is a wastewater plant in Tanta in Al-Ghofran area. This plant is installed over 69,8 Feddan, serving 422,854 inhabitants, at a rate of 0.693 m^2/ capita as seen in fig(79) * [82]:

Fig(79): Land area of 69.8 Feddan for a wastewater plant in Tanta, Egypt.

(1-1-5-A) Street pattern's impact on water and wastewater grid:

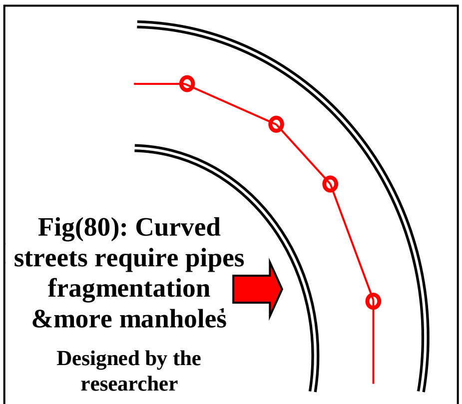
The cost and efficacy of water and wastewater grid is significantly affected by the urban pattern of the serviced city. Water and wastewater grid is in its best shape when the following is available:

A- Straight-line streets with no or minimum curves

As pipes are constructed straight, the best path for them is the straight path. Curves require fragmentation of network to get parallel with street curvature. The joints of these pipes are fitted with (elbows) in water pipes and (manholes) in wastewater pipes as shown in fig(80). The increase of the number of elbows and manholes increase the cost and effort of installation, decrease the safety and efficacy of the system, and raise the threats of leaks and infiltrations.

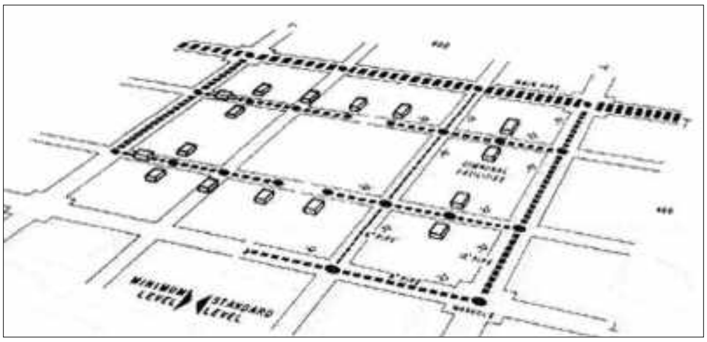
B- Minimum street intersections:

Street intersections demand installing manholes for wastewater network as shown in fig (81). The more intersections in the grid the more expensive it becomes to install as the cost of installing a single manhole is **1500** to **3000** **LE** per unit, according to size and capacity, (2014 price).



Fig(80): Curved streets require pipes fragmentation &more manholes

Designed by the researcher



Fig(81): Sewer disposal grid pattern
http://web.mit.edu/urbanupgrading/waterandsanitation/levels/provide-san-serv.html/

C- Natural topography with mild slopes that serve the service's gravity:

Natural topographic slopes help accelerating the flow of wastewater towards treatment plant. Negative slopes require pumps and energy to pump wastewater against gravity, which increases the cost of both installing and operating the system.

D- Minimum public access points:

Sewers and pipes in public space are the responsibility of the government (or the company) to fix and install. The less fixtures in public spaces the more sparing and efficient the system is. Fig (81) shows borderline of responsibility for the water and wastewater utility.

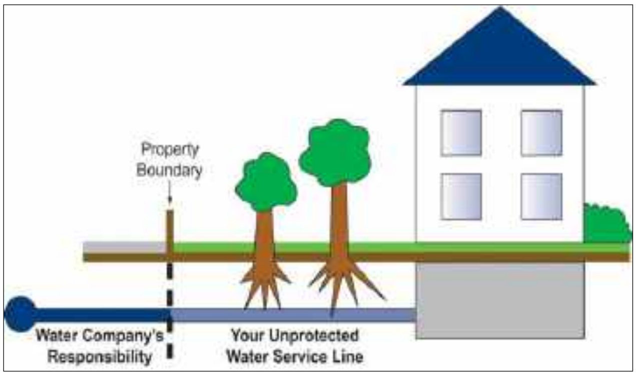


Fig (82): Borderline of responsibility for water & wastewater utility
Source: www.homeserve.tumblr.com/

E- Minimum street linear meters for maximum served blocks:

Population density affects the economy of wastewater installation. The urban pattern with short streets serving more blocks and people means less expenses and better quality in wastewater systems. Short path also requires less maintenance. Each linear meter costs additional 1610 to 2250 LE/m according to size and material. (2010 prices).

Table(8) shows a comparative analysis of different street patterns and their effect on pipes intersections, pipes length, no. of blocks served, percentage of straight pipes, no. of access points and service accesses, and no. of loops and cul-de-sacs. The best pattern for the central grid by these parameters is the (Loops and Lollipops) pattern as shown in the table.

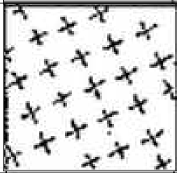
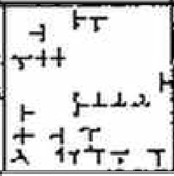
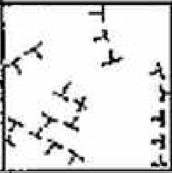
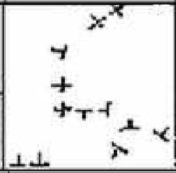
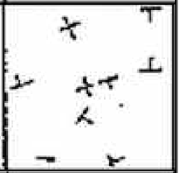
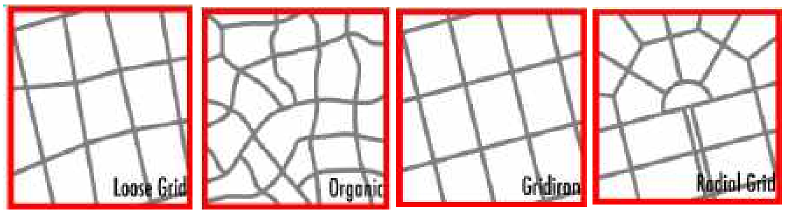
Category	Gridiron	Fragmented Parallel	Warped Parallel	Loops and Lollipops	Lollipops On a Stick
Street Patterns					
Pipes Inter-sections					
No. of Inter-Sections	26	22	14	12	8
Straight line pipes %	100 %	100 %	3 %	73 %	50 %
Linear Meters of public pipes	6339.84	5791.2	5029.2	4663.44	4754.88
No. of Blocks	28	19	14	12	8
No. of Access Points (Service Access)	19	10	7	6	4
No. of Loops and Cul-de-Sacs	0	1	2	8	24

Table (8): Comparative analysis showing the impact of street patterns on water and wastewater pipes network

Source: www.fccdr.usf.edu - with modification by the researcher.

(1-1-5-B) Impact of street patterns on wastewater grid in Egypt: In Egypt, the most common street pattern is (Loose Grid) in modern cities and formal districts. Other patterns are present also, like the (Gridiron pattern) in pre-planned cities like Nasr city, The (Organic pattern) in old districts and informal quarters and the (Radial grid) in new settlements like New Cairo and 10th of Ramadan city, see figures (83) and (84).

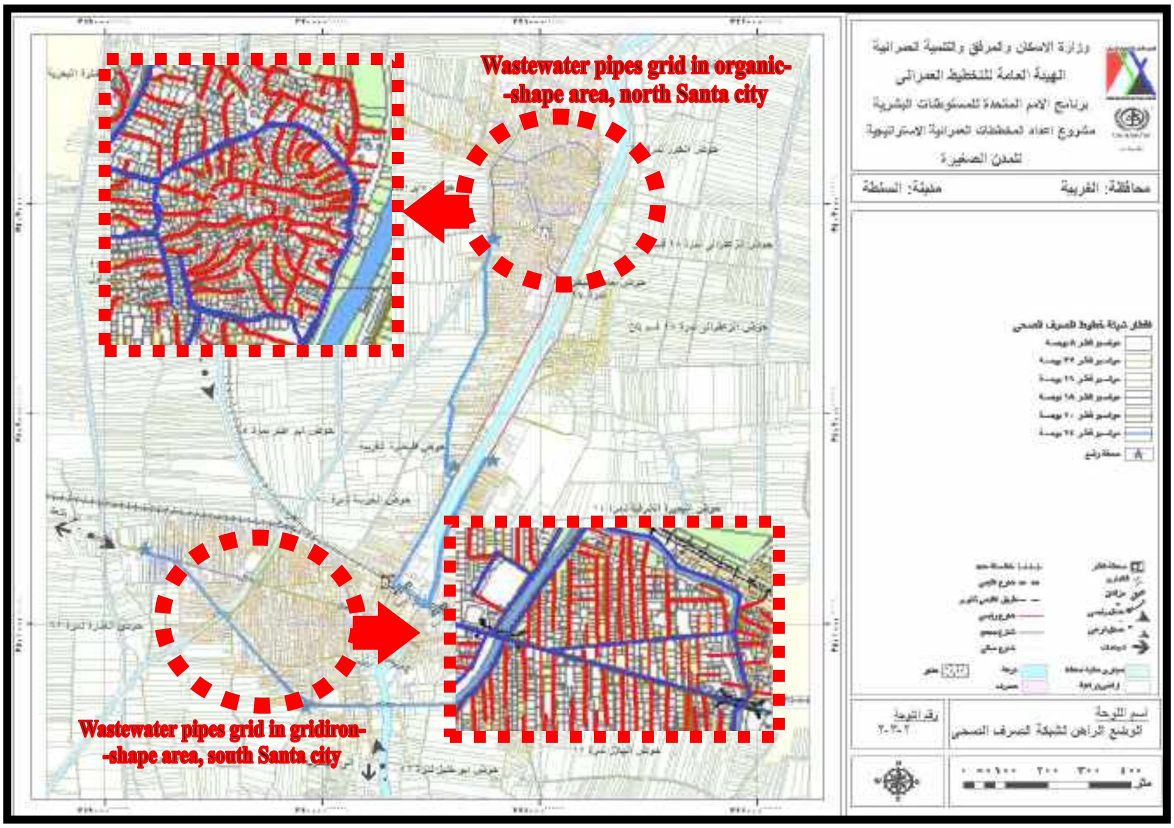


Fig(83): Common urban patterns in Egypt

Source: http://munsonscity.wordpress.com/tag/loose-grid/

Fig(84): Four samples for Egyptian urban patterns, (from left to right): Loose grid in Shubra Al-Khaima, Organic pattern in Al-Santa, Gridiron in Nasr City and Radial Grid in New Cairo.

These patterns differently correspond to water and wastewater grid as shown before. Municipalities find more difficulty in installing and maintaining pipes in organic and informal districts. This difficulty explains the absence of this utility in many rural areas and slums where streets are not pre-planned and the urban pattern is not compatible with the grid requirements. Fig(85) shows Al-Santa city as a good example that shows the difference in wastewater pipes path in different urban types. In Al-Santa, we can notice



Fig(85): Comparing grid lines in organic and gridiron-shape areas in Alsanta village, Gharbeya, Egypt.

Source: Designed by the researcher based on present sanitation network map of Al-Santa city from General Organization for Physical Planning (GOPP)

two types of urban patterns, each having a different wastewater pipes path. Pipes are straight and reaching almost all houses in southern modern area, while pipes are curved and bended in the northern old district where pipes couldn't reach all houses due to informal and organic pattern of the area.

(1-1-5-C) Impact of horizontal sprawl on sanitation grid's economy:

Rural areas and new extensions tend to expand horizontally which leads to low land use, see fig (86). When supplying these areas with water and wastewater pipelines, more linear meters are needed for fewer connections.

Low dense loading for wastewater may start with 100 to 500 connections / linear km, while high dense loading may start from 500 to 4800 connections / linear km. Each linear meter of sanitation pipes expansion cost 350 LE (for public connections, 2014 prices), which means that covering rural areas with central sanitation is more expensive and less feasible.

Fig(86): Horizontal sprawl of rural houses, Luxor, Egypt - www.touregypt.net

(1-1-5-D) Side effects of Pipes' long Paths:

As water/sewer pipes go underground in long paths, it faces many threats. The longer the path is, the more occurrences of pipes' slidings and breaks. These breaks and slidings mainly occur because of differential ground movement, heavy vehicle traffic on roadways above the pipes, careless construction practices, roots intrusion from trees, or soil pressure as shown in fig(87).

The long path also may cause the increase of sedimentation inside the pipes. The longer the path is the more accumulation of sediments over the pipes inner walls. These sediments cause the clogging of pipes and decrease the flow capacity of the system.

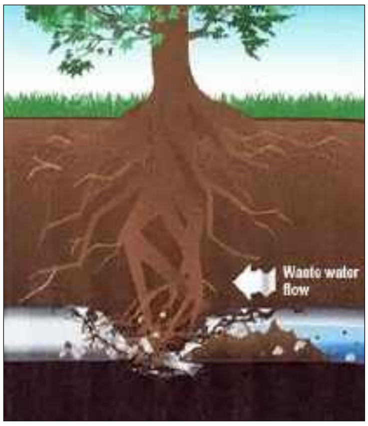


Fig (87): Hazards of long paths of water and wastewater pipes: (left): Heavy traffic hazards, (middle) Accumulation of sediments, (right): Roots intrusion into pipes.

Source: www.greenearth.com/ (middle) www.livingoffgrid.net (right) www.engineeringforum.net/

In Egypt these threats are also present due to low quality of pumped water and poor maintenance of the entire system. These problems decrease the efficiency of the system and cause a quick degradation of the sewer pipe materials.

In 2011, the length of the water distribution networks was 107,000 km and the length of the wastewater collection network was 29,000 km, table (9).[83]

An example for pipe water lengths, Al-Santa city has a 77,69 kilometers of sewage pipes serving a population of 70,300 with an average of 1.105 meter of sewage pipes/capita.

Holding Company for Water and Wastewater

	2007	2010
Water distribution networks	74,000 km	143,000 km
Wastewater collection networks	28,000 km	33,000 km

Table (9): Lengths of water and wastewater distribution pipes in 2007/2010
HCWW annual report 2010- www.hcww.com.eg/en/HCWW.pp

(1-1-5-E) Impact on streets and open canals:

Central Water & Wastewater grid in Egypt usually passes under streets, railways and over canals and water bodies. The deterioration of the grid causes many breakings and leaks which cause serious damage for the roads and heavy pollution for water. Fixing and maintaining pipes may paralyze the traffic for many days.Fig(88).

Fig(88): Pipes passing over waterways and leaking occasionally In Kafr Hakim, Geiza.

A model of wastewater network in Al-Zarqaa city, Damietta, is shown below in fig(89). The main pattern problems are present in: the long path of pipes for small number of blocks, manholes in all intersections and curves, deprived areas in old quarter and rural boundaries of the city, and passing across roads and water bodies.

Fig(89): Wastewater grid in Al-Zarka city, Damietta
Source: General Organization for Urban Planning (GOPP).

(1-1-5-F) Installation and maintenance of pipe network:

Central water and wastewater distribution network needs installing pipes and manholes in the streets of the served area. Excavation works are done in installation, replacement and maintenance. These works usually paralyze the traffic and cause inconvenience for weeks as shown in fig(90).

Fig (90): Excavation works for sewage pipeline installation in streets of Alexandria, June 2013
Sourcs: http://www.correspondents.org/ar/node/2897

Streets are also affected with sudden breakings and overflows that may occur any time. Water and wastewater floods are a common scene especially in coastal cities like Alexandria and Matrouh. These floods affect the traffic, breed mosquitos and cause bad odor and inconvenience, fig(91).

Fig (91): Water and Sewage overflow in streets of: (a) Al-Santa 2012 and (b&c) Alexandria, June

Source: http://www.correspondents.org/ar/node/2897

g- Risks of damaging underground infrastructure:

During excavation for laying pipes, there are risks of damaging underground gas pipes or telecommunication lines. Although having sewers normally laid in the middle of roads, while water pipes and telecommunication lines, if it is underground, normally laid on road sides will reduce damage risks, most of these infrastructure lines were laid long time ago without adherence to their normal locations, especially in rural and informal districts, fig(92).

Fig(92): Laying water and wastewater pipes in October city (left) and Samatay village (right), 2015

GOPP studies for Strategic Planning of October & Samatay

In many cases, the contractors usually can't have access to maps of existing underground lines because of the absence and the inaccuracy of data in regards to infrastructure underground network (drinking water, electricity, and telecommunication).

Part (I) Chapter 1

Summary of Chapter 1

Central water and wastewater utility in Egypt is not feasible neither for the government nor the suppliers. It is not so affordable for some consumers as well. The problem is expected to exacerbate with the aggravation of water crisis which will affect the availability of water and thus increase the tariff. The energy crisis will also affect the water tariff as the sector consumes more than 10 percent of national produced energy. The accumulating debts and National budget deficit shown in fig (93) may hinder the subsidies, and the suppliers may draw their investments if the losses aren't covered by governmental aid.

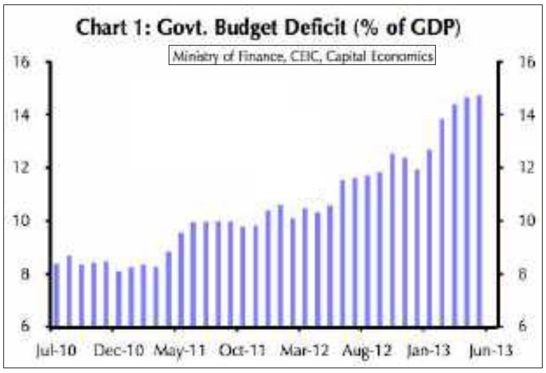


Fig (93): Inclining Governmental Budget Deficit –Source: **Ministry of Finance, CEIC, Capital Economics-www.rebeleconomy.com**

Considering efficiency, the utility suffers many technical and operating problems. Half of the produced water is lost before reaching the client and one eighth of the meters are invalid. Tap water's quality is almost below standard and most households rely on indoor filtration systems. Sewage pipes suffer leaks and dilapidation which leads to groundwater contamination. Low removal efficiency in wastewater plants threatens the receiving water bodies. Utilities are not evenly distributed causing many social and economic problems. Unfair distribution increases internal migration and affects demographic structure of the society while the expansion of cities erodes the surrounding fertile lands and inclines the existence of slums. Some areas are threatened by structural risks duo to wastewater seepage problems. Bad water and sanitation affects the health of the Egyptians and may cause diseases to be endemic. Water cuts are prominent in many areas while other areas enjoy massive water use.

Central wastewater treatment utility has negatively affected Nile water, groundwater, and the Mediterranean. The incline of water-borne diseases and the decline of fish-catch in the sea are direct impacts of bad sanitation.

Using asbestos pipes is still common and the utility helps augmenting the greenhouse effect.

Water and wastewater plants and stations occupy thousands of Feddans and require spacious lands to build treatment basins following old and sun-related technologies. Pipe network prefer straight and rigid street patterns as well as minimum bindings and intersections. Installation and maintenance of pipe networks may block traffic and cause inconvenience. Floods and system failures may cause similar impacts especially in coastal regions.

During the last three years, The Egyptian government has been working to create a favorable, competitive landscape and may be ready to provide guarantees on payments for public-private partnership water projects to help mitigate the currency risk. The Holding Company for Water and Wastewater (HCWW) has finalized the country's master plan for water and sanitation up to 2037, which prioritizes a number of potential water projects according to socio-economic need. HCWW says capital expenditure of over USD 2 billion will be invested into water supply and more than USD 3.5 billion will go into wastewater between 2015 and 2020.

End of Summary of Part (I) Chapter 1

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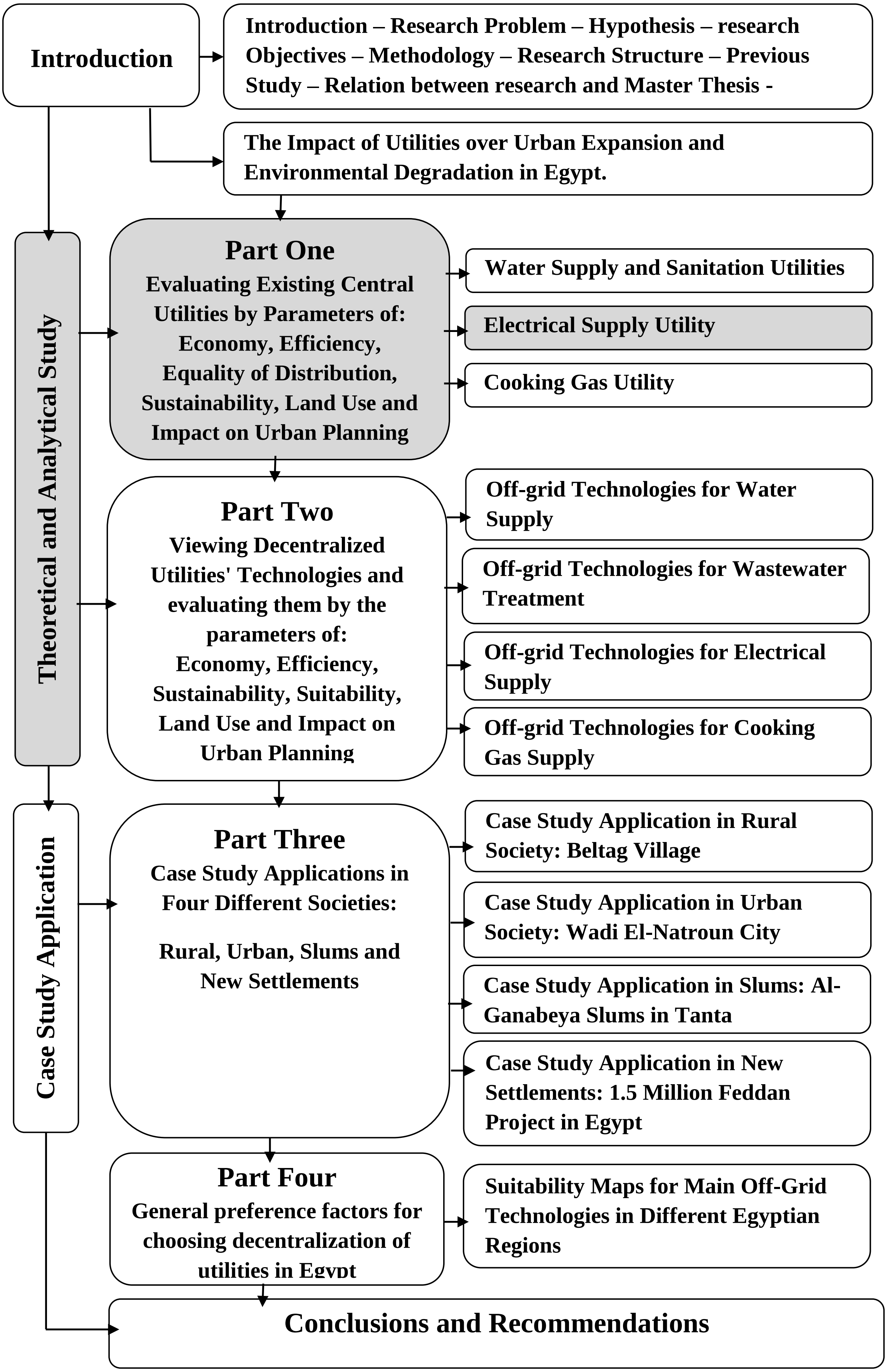
Introduction
Introduction – Research Problem – Hypothesis – research Objectives – Methodology – Research Structure – Previous Study – Relation between research and Master Thesis -
The Impact of Utilities over Urban Expansion and Environmental Degradation in Egypt.
Theoretical and Analytical Study
Part One
Evaluating Existing Central Utilities by Parameters of: Economy, Efficiency, Equality of Distribution, Sustainability, Land Use and Impact on Urban Planning
Water Supply and Sanitation Utilities
Electrical Supply Utility
Cooking Gas Utility
Part Two
Viewing Decentralized Utilities' Technologies and evaluating them by the parameters of: Economy, Efficiency, Sustainability, Suitability, Land Use and Impact on Urban Planning
Off-grid Technologies for Water Supply
Off-grid Technologies for Wastewater Treatment
Off-grid Technologies for Electrical Supply
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Case Study Application
Part Three
Case Study Applications in Four Different Societies:
Rural, Urban, Slums and New Settlements
Case Study Application in Rural Society: Beltag Village
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General preference factors for choosing decentralization of utilities in Egypt
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Conclusions and Recommendations

Part (I)- Chapter 2

(1-2) Evaluating Electrical supply utility in Egypt

Introduction to Chapter (2)

Electricity is the main key for any desired social or economic development and is a main utility in every household. Here we shall evaluate the present supply systems for electricity in residential sector in Egypt by evaluating it through five parameters: (1) economy, (2) efficiency, (3) sustainability, (4) equality of distribution, as well as their (5) land use and impact on urban planning. This evaluation is mandatory to compare these utilities with the suggested decentralized utilities later on this research.

End of Introduction to Chapter 2

(1-2) Evaluating Electrical Supply Utility in Egypt:

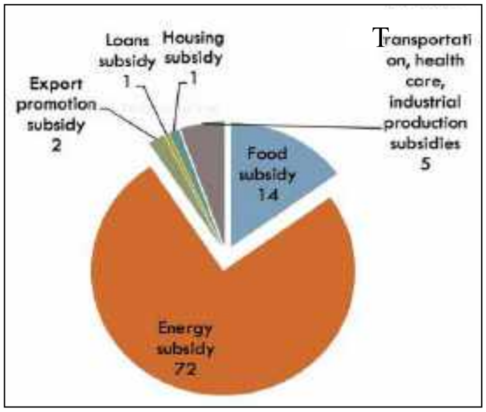
Electricity was first introduced in Egypt in 1893 by private companies, which after 70 years have been nationalized and the government became the only owner and operator of the utility by 1963. The first ministry for electricity power was formed in 1964, and the Egyptian Electricity Authority was established by law no. 12 in 1976. In 1978, seven distribution companies were established on geographical basis, and in 1996, law no.100 was issued allowing both local and foreign investors to construct, operate and maintain electric generation stations (BOOT).

The major conversion took place in year 2000 by issuing the Law no. 164 that converted the Egyptian Electricity Authority to a contribution company called the Egyptian Electric Holding Company (EEHC). After being profit-targeting, the electricity utility in Egypt contained both State-owned companies & private sector companies, where the State-owned companies became under the authority of the (EEHC), while private sector companies are independent working by BOOT system[1]

(1-2-1) Economic aspect: Just like water utility, electricity utility in Egypt is financed by the same three parties: the consumer, the supplier and the Government.

(1-2-1-A) Feasibility to the Government: The provision of basic utilities like water and electricity has always been an evaluation meter for the governmental performance in Egypt. For a long time, the Egyptian government has been responsible for offering great subsidies for electricity sector. Energy and electricity sector consume an average 70 % of the total governmental subsidies as shown in fig (94).

Electricity subsidies are structured in a way that offers biggest support to poorest population. As seen in table (10), subsidies are inversely proportioned with consumption.



Fig(94): Average subsidies structure in Governmental Annual Budget in Egypt

Source: Egyptian Center for Economic Studies Report 2011/2012.2014

Category of Consumption (KWh)	Number of Families Million Families	Amount of Subsidies Million LE	Category of Consumption (KWh)	Number of Families Million Families	Amount of Subsidies Million LE
0-50	4.19	273.02	350-400	0.39	97.58
50-100	3.48	375.42	400-450	0.25	61.59
100-150	3.44	518.48	450-500	0.176	43.04
150-200	2.23	431.37	500-550	0.055	13.27
200-250	1.44	287.51	550-600	0.043	10.21
250-300	0.82	184.5	600-650	0.033	7.7
300-350	0.48	120.11	650-1000	0.169	11.78

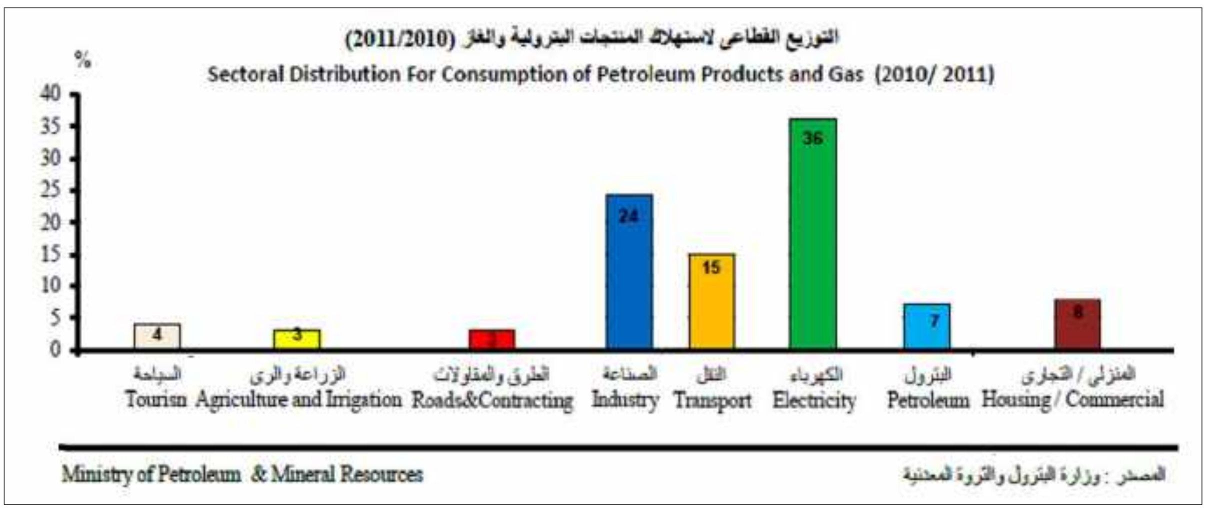
Table (10): Electricity subsidies to Egyptian families in 2010

Source : CAPMAS Annual Report 2010

This structure aims to support the poor, but in fact it benefits the rich, because the higher income part of the population consumes more of the energy products that are subsidized by the government. The analysis of Egypt's household surveys indicate that the top 40% of the population enjoy about 60% of the energy subsidies while the bottom 40% receive about 25% of these subsidies [2].

Although they benefit the rich disproportionately, removal of these subsidies will have significant adverse impact on the poor [3]. The elimination of energy subsidies, without any offsetting policy actions, would reduce the household welfare at all levels of income distribution [4]. But paying L.E 2.5 billion annually to cover subsidies is a heavy burden on the government's shoulders, especially with a high budget deficit and an external debt of $45 billion and internal debt of $ 243 billion [5]. So, the government is under pressure to cut energy subsidies, which weigh heavily on its fiscal position [6].

On the other hand, electricity sector consumes above one third of the subsidized fuel as shown in fig (95). Knowing that fuel subsidies exceed 8 billion pounds annually, we find that electricity sector is weighing heavily over our National budget.



Fig(95): Consumption of petroleum products and natural gas in different sectors in Egypt (2010/2011)
Source: Energy and Electricity Report Egypt September 2013, Reference no. 5

Another economical aspect is the initial cost investment. New plants and expansions require huge investments that the government usually takes responsibility for as a part of developmental strategy. About 16.9 billion pounds were invested in electricity sector in fiscal year 2010/2011 as shown in fig (96). Electrical supply projects and maintenance usually consume 15 to 18% of total investments done by Egyptian governorates annually, fig (96).

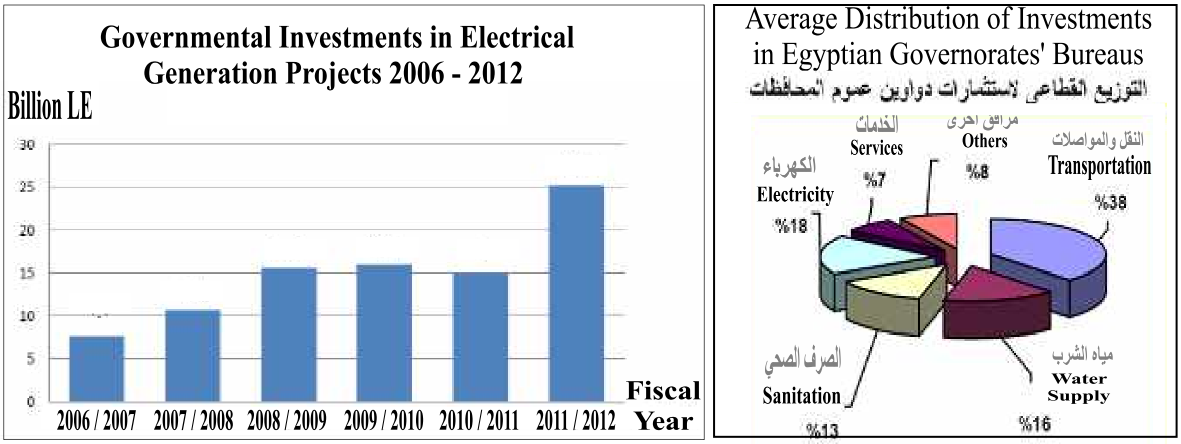


Fig (96): (left) Governmental Annual Investments in Electricity Sector (right) Average distribution of investments in Egyptian Governorates' Bureaus

(left) Parameters of Economic and Social Performance in Egypt- CAPMAS annual report, Feb, 2012 (right) CAPMAS Annual Report 2010.

(1-2-1-B) Feasibility to the consumer:

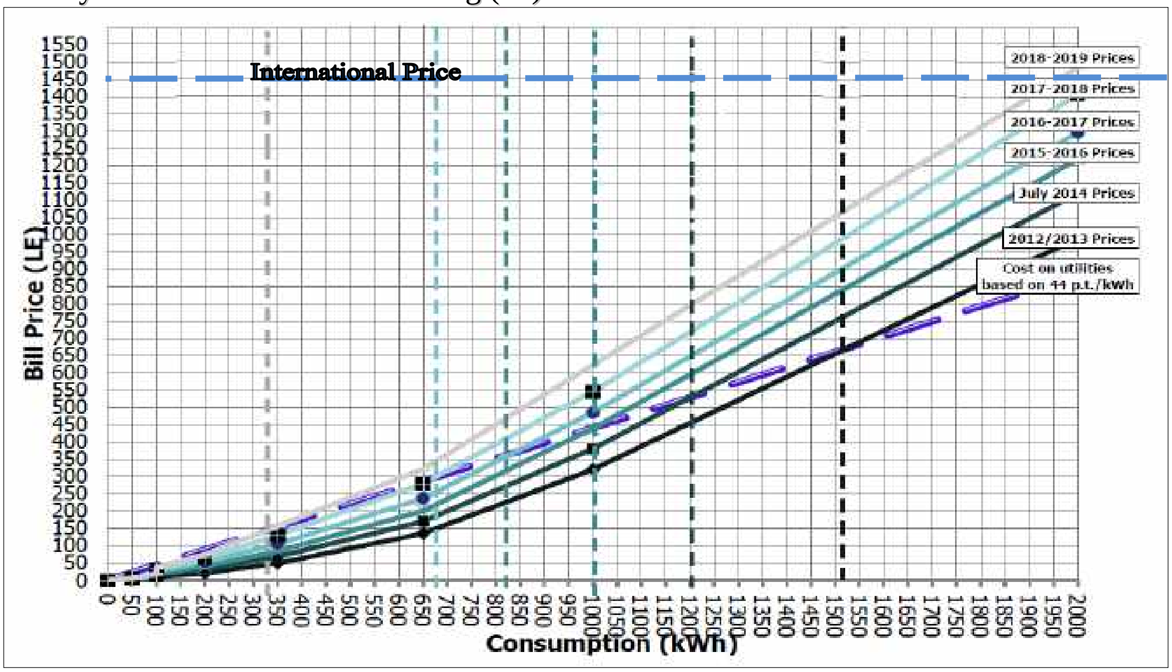
Due to heavy subsidies, electricity in Egypt is considered cheap compared to many other countries. The residential tariff in Egypt starts with 1.09 US cent/kWh for the lowest consumption and reaches 10.77 US cent/kWh for the highest one (2014 prices), which is less than tariff in Jordan, Turkey, Dubai and Israel. Some countries like Kuwait hasn't changed the tariff since 1966 as shown in table (11).

Despite low tariff, the Egyptian citizen considers electricity bill as a burden due to his low monthly income. An ordinary Egyptian family pays from (20 – 950) LE monthly for residential electrical consumption, which forms 0.5 – 0.7 % of the family total income[7] and 2.5 – 3 % of total household expenditure [8]

Country	Residential Electricity Tarrif US cents/kWh	Date of Last Pricing
Turkey	12.57 to 18.63	Feb 4, 2014
United Kingdom	20.0	Nov 30, 2012
United States	8 to 17	Sep 1, 2012
Russia	2.4 to 14	Oct 2, 2013
Pakistan	2.00 to 15.070	May 16, 2012
Kuwait	1	Jun 1, 1966
Jordan	5 to 33	Jan 30, 2012
Israel	16	Jun 1, 2013
Iran	2 to 19	Jul 1, 2011
Dubai	6.26 to 10.35 (plus 1.63 fuel surcharge)	
Egypt Priced into sections at a kWh/Month, subsidized	1.09 0-50 kWh/M 2.11 51-100 kWh/M 2.33 0-200 kWh/M 3.49 201-350 kWh/M 4.95 351-650 kWh/M 8.73 651-1000 kWh/M 10.77 1000+ kWh/M	Jul 17, 2014

Table (11): Residential Electricity Tariff in Egypt compared with different countries.
Source: Ref. No, 8

Moreover, the tariff is expected to incline rapidly due to "subsidy reform" policy that has been in act recently. Since the submission of privatization policy in 1997, the tariff has inclined many times. Tariff incline was also caused by the energy crisis and decline of natural gas production in Egypt, as well as the economic pressure that hindered the gas import. Due to all these factors, the subsidies supplied to the electrical sector in Egypt are planned to be gradually reduced and the tariff is planned to meet the international price by fiscal year 2018/2019[9] as shown in fig (97).



Fig(97): Electricity tariff and bill prices in Egypt 2012/2018- **Source: (Environics SAE)**

(1-2-1-C) Feasibility to the supplier:

Despite the governmental subsidies, the electricity supplying companies suffer great losses annually. The cost recovery percentage for production, transmission and distribution companies for residential consumption was 31% before 2014 price adjustment, and barely reached 42% after it, see fig (98) [10]. The residential consumption forms 41% of total electricity purchased in Egypt.[11]

The holding companies' losses are generally caused by many factors, like illegal connections, fuel shortages, power cuts, inefficient transmittance, improper metering and payment delays.

As a response to their commercial losses, the distribution companies were allowed to install coded revenue meters at unauthorized buildings and customers with illegal connections, to allow the metering of their consumption. But this allowance was shortly cancelled in Feb, 2014 because it exacerbated the illegal buildings' problem, especially with the weak surveillance by the authorities and the political unrest. This cancellation has caused an incline in losses for the supplier companies again.[12]

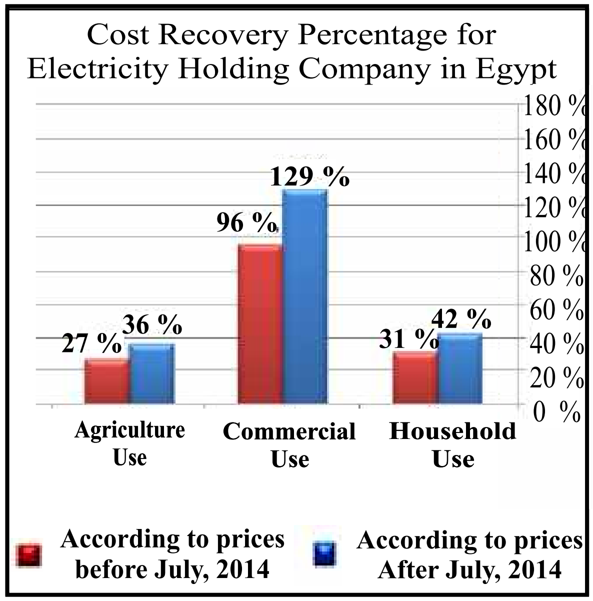


Fig (98): Cost recovery percentage for electricity Holding Companies in Egypt- Source: Ref. No. 10

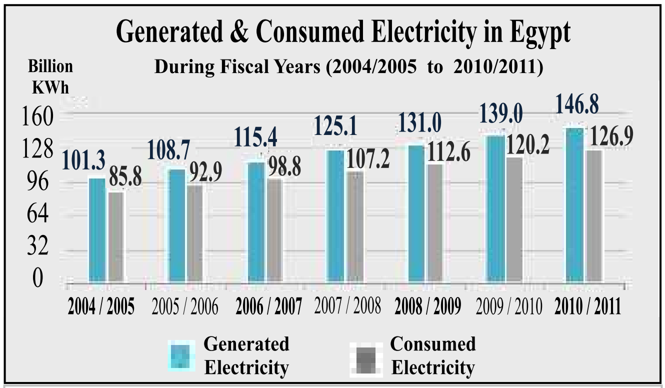
(1-2-2) Efficiency: distribution and transmission Fire threats and electric shocks Power cuts:

- Efficiency in distribution and transmission: Due to their losses, electrical suppliers companies usually can't provide sufficient budget for grid renewal, repair and maintenance. Some outdated grid lines, like the one shown in fig(99), cause a gap in transmission. As a result, a considerable leak of electrical current takes place during transmission.

Fig(99) : (a&b) Deteriorated conductors and un-insulated cables in residential destricts in Kerdasa and Bahteem (c) Electrical Tower falling by storm in Alwadi-Algedid governorate, March.2014

http://al-mashhad.com/News

The deterioration of cables and transformers between supplier and consumers causes losses estimated by 8.2% to 24% of total electricity produced. More than 20 Billion KWh of power was lost in 2010/2011 alone, and an accumulated leak of 122 billion (KWh) had been lost from our power grid in last 7 years[13] as shown in fig. In comparison with Kuwait and United Arab Emirates, Egypt's lost electricity due to bad transmission lines are far greater than these two countries as shown in fig(98).[14]



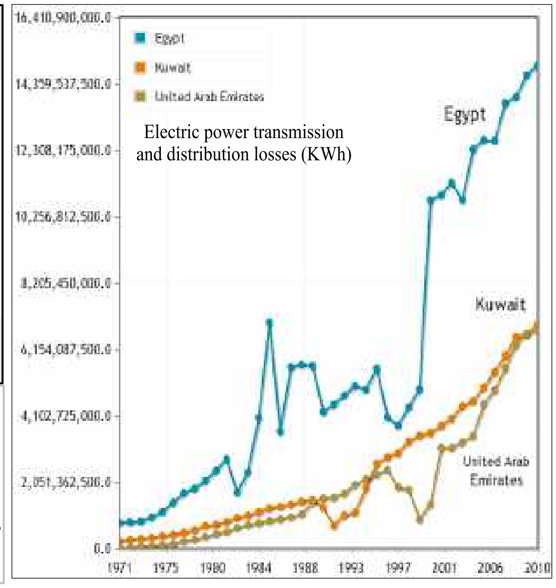


Fig (100): (left) The gap between generation and consumption of electricity in Egypt. (right) Electricity transmission & distribution losses in Egypt compared with Kuwait and Imarates (1971-2010).
Source: (up) Parameters of Social and Economic Performance in Egypt, CAPMAS Annual Report, Feb, 2012
(right) www.indexmundi.com/facts/indicators/EG.E

- Fire threats and electric shocks: As 75 % of the total low-voltage network in Egypt is non-insulated,[15] cables and conductors are serious threat to inhabitants. Many accidents took place due to the falling down of bare cables penetrating residential quarters, causing injury or death.

Fig(101): (left &middle) High voltage cables passing through houses in Al-Salam district, Cairo and a village in Geiza, Egypt and near mosque in Shobar, Gharbeya (right) Falling electric column in Al-Hamoul, Kafr El-Sheikh, April,2015- Source: (left) www.masress.com (middle) www.almasryalyoum.com

- Power cuts: As a result for their economic losses, electricity suppliers became unable to meet fuel needs for power generation plants, which resulted in frequent power-cuts all over the country in the years 2012 to 2014. Power cuts during these years have become one of the biggest problems facing the development in Egypt, causing many economic, social and even political problems. It is noticed that these cuts have recently been rare in 2015 due to strict governmental reforms in the sector.

Fig(102) : (a) Power cuts affecting politics (b) Stand-ups against power cuts in Egypt

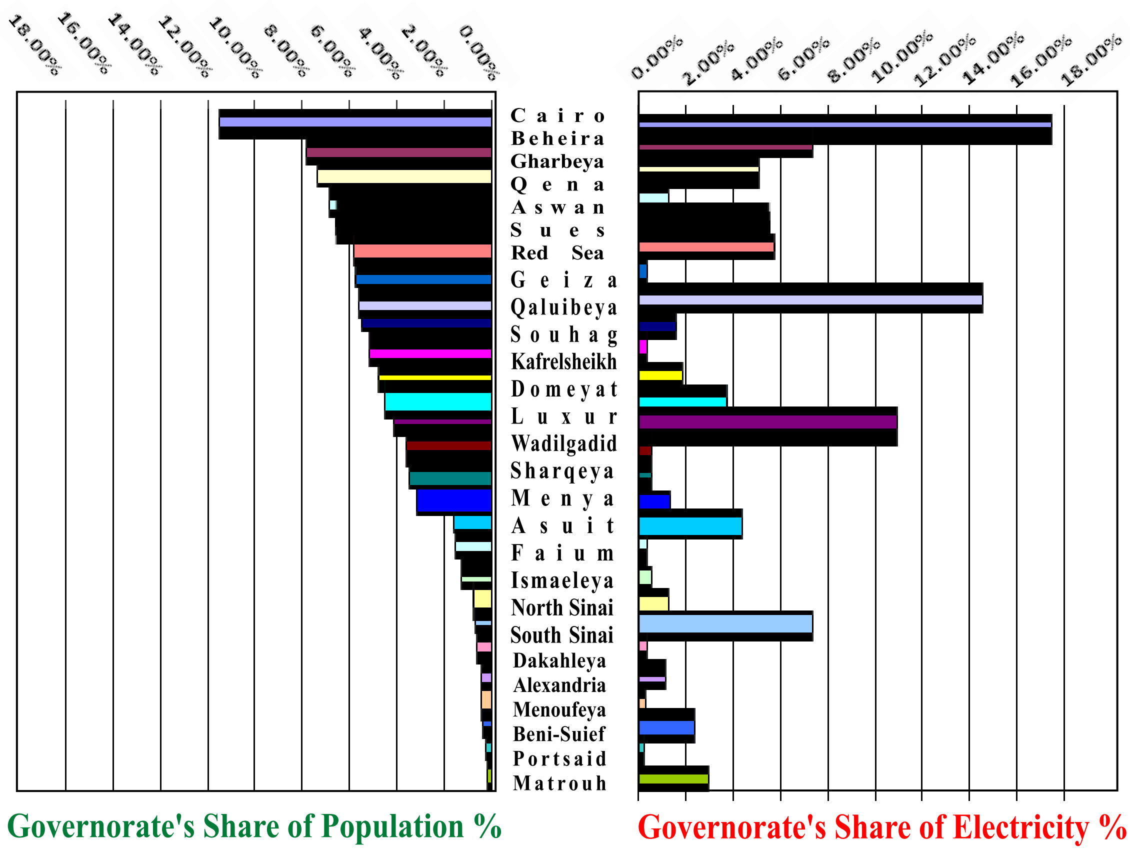
(a)Alyoum Alsabe3 Newspaper 31/5/2013 (b) www.Egyptendipendent.org (c) www.hoqook.com

(1-2-3) Equality of distribution: Adequate provision of electricity is an important factor in improving the living standards of people.[16] In Egypt, there is an obvious difference in electrical supply provision between different governorates as shown in fig(101). By comparing each governorate's share of population with its share of provided electricity, we find that an Egyptian citizen in Cairo enjoys more than **300 %** of electricity than his peer in Almenya, and **1500 %** of electricity more than his peer in Suhag.

This unequal provision is due to many factors. For rural areas and remote settlements, the centralized energy expansion is heavily expensive due to the dispersed nature of both bedwin and rural communities, in addition to their low demand and scattered population.

Due to heavy population density, citizens in major cities enjoy bigger share of electricity and less installment prices which gives their children better chances in education thus better future jobs.

Ease of access: Supplying electricity to any building requires many procedure, documents, inspections and approvals from municipalities and distribution companies. Many buildings may be deprived from electricity due to restrictions imposed by laws like the restricted heights imposed by civil aviation, building on agriculture lands and under high voltage transmission lines.[17] Due to judicial disputes or bureaucratic procedures, some owners who cannot install electricity in a legal way, try to install illegal connections to have a source of power supply till they can compromise their situation with the authorities, this action leads to more commercial losses for supplier companies.[18]



Fig(103): Comparing the share of population to the share of electricity for each Egyptian Governorate in year 2011

Designed by the researcher based on data from www.ecom.com and http://egypt.unfpa.org

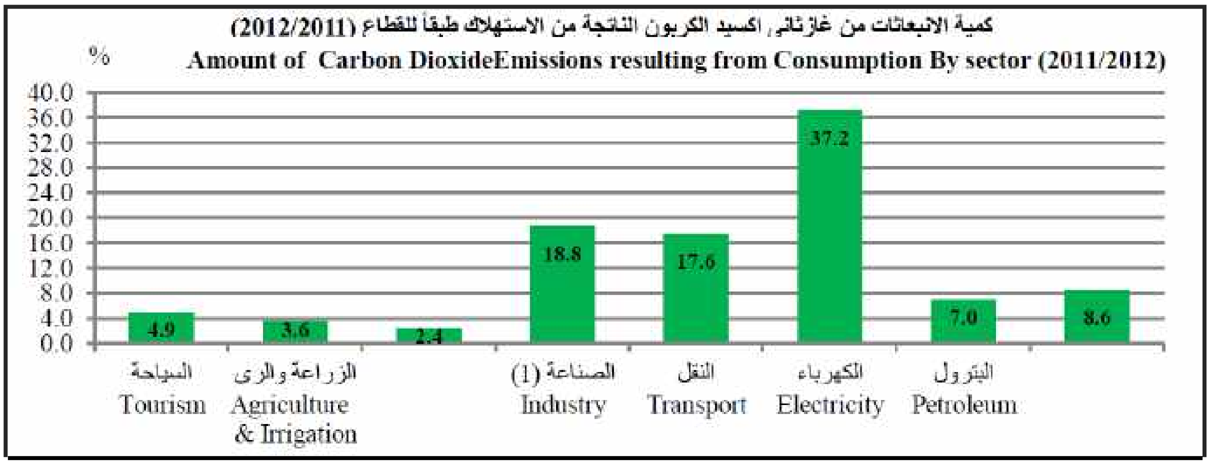
(1-2-4) Sustainability and Environmental Impact: Electrical generation process has a heavy footprint over our climate, as well as our fresh water resources and aquatic life. It also depletes our non-renewable reserves of fuel and recently threatens the purity of our air as shown below:

(1-2-2-A) Greenhouse effect: According to U.S. Environmental Protection Agency (EPA) statistics, electricity production sector is the biggest source of greenhouse gas emissions globally[19].Carbon dioxide (CO_2) makes up the vast majority of greenhouse gas emissions from the sector, but smaller amounts of methane (CH_4) and nitrous oxide (N_2O) are also emitted. These gases are released as a result for two factors:

- The combustion of fossil fuels, such as coal, oil, and natural gas, to produce electricity.

- The usage of sulfur hexafluoride (SF_6), in insulating electricity transmission and distribution equipment.[20]

In Egypt, electricity sector is responsible for even more damage. In year 2011/2012; this sector was responsible for 37.2% of Co2 emissions. Next to it was the industry sector with 18.8% (about half of electricity share), and then the transportation, followed by Petroleum sector as seen in fig (104).



Fig(104): Carbon Dioxide emissions from different sectors in Egypt as measured in 2011/2012

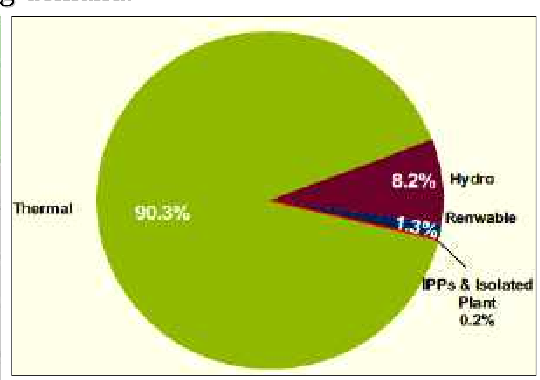
CAPMAS Annual Data Report 20111/2012 - www.capmas.org.eg

CO_2 emission from the sector is progressing in a rate that exceeds the population growth rate in Egypt. In 9 years duration (2004-2012), CO_2 emission from the sector has increased by 33.3% while the population in the same period has experienced only 13.6% growth as shown in table (12). The sector is expected to cause even more CO_2 emissions in the next few years as illustrated before. It is noticed that the incline of electric demand in Egypt is far above the population growth, meaning that there must be additional power sources (conventional and renewable) to cover the growing demand.

Electricity in Egypt			
Year	Population	Electricity	CO_2-emission
	Million	TWh	Mega Ton
2004	72.64	88	141
2007	75.47	111	169
2008	81.51	116	174
2009	83.00	123	175
2012	82.54	138	188
Change 2004/12	13.6 %	56.8 %	33.3 %

Table (12): Comparing the incline of Co_2 emissions from electricity with population growth in Egypt in 2004-2012

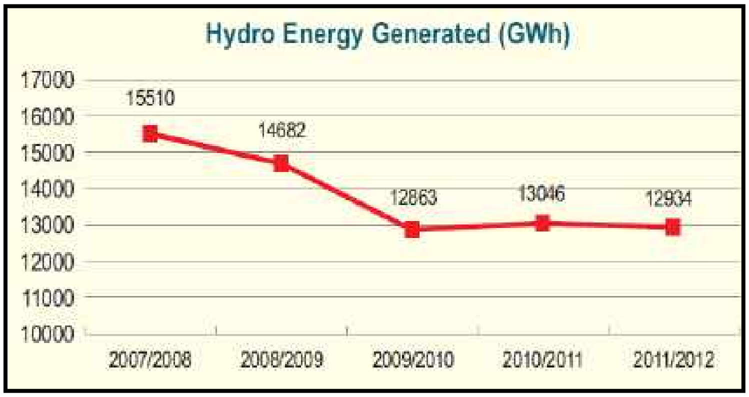
http://en.wikipedia.org/wiki/Energy_in_Egypt- Retrieved 5/6/2015

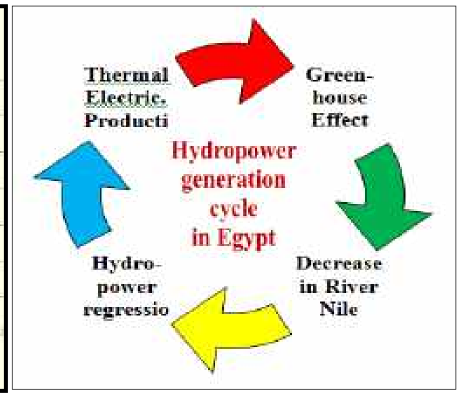


Fig(105) Generated electricity in Egypt by source & technology

Egyptian Electricity Holding Company annual report 2011/2012

(1-2-2-B) Hydropower regression effect: After 50 years of building the High Dam in Aswan, Egyptian electricity sector still depends mainly on thermal technology to generate electricity. The hydropower from Aswan Dam contributed only with **8.2**% in total electricity generation in 2011/2012, while thermal sources contributed with **90.3**% as shown in fig (13). Hydro power in Egypt has been in regression during the last few years as shown in fig(104). It is also expected to decline due to both the climatic changes and the construction of Ethiopian Dam. The less hydropower generated, the more fuel burnt to generate thermal power. So, it is a closed circle: The electricity sector causes the greenhouse effect, which by turn helps decreasing the level of River Nile, thus more regression of hydropower generation happens which means more thermal technology is used for electricity production and the greenhouse effect gets worse, and so on.





Fig(106): (up) Regression of hydropower production in Egypt in years 2007-2012 (right) Hydropower generation cycle in Egypt

(left) Egyptian Electricity Holding co. report 2011/2012 (right) Designed by the researcher

(1-2-2-C) Fuels used for production: As mentioned before, about 90 % of generated electricity in Egypt is thermal, meaning that it depends on burning fossil fuel for generation. The main two fuels used by this sector in Egypt are Natural Gas and Heavy Fuel Oil (H.F.O.).

Heavy fuel oil (HFO), or "residual fuel oil" is a highly viscos, tar-like mass which remains after crude oil is cracked to produce lighter hydrocarbon products such as methane, hydrogen, gasoline, distillate diesel fuels and heating oils or lubricants. As a residual product, HFO is a relatively inexpensive fuel – typically its costs around 30% less than distillate fuels. It thus became the standard fuel for large marine diesel engines. Its use required extensive adaptation of the injection system and other components of low and medium speed engines - which are still the only engines capable of running on HFO.[21]

The use of HFOs has raised concerns over their environmental impacts and, in particular, their contribution to anthropogenic (human-induced) climate change caused by the greenhouse gases emitted by the burning of HFOs to generate power. HFO emissions can adversely affect human health. These emissions are nitrous oxides, sulfur oxides and particulate matter.[22]

Egypt had a strategy which aimed to increase the reliance on natural gas in power plants and gradually stop using HFO because of its environmental footprints. But unfortunately, the reliance on HFO has increased due to shortage of natural gas production in the last 3 years. For example, the reliance on HFO in generating electricity has inclined by 42.9% in year 2012/2013, while natural gas use has declined by 1.3% in the same year as shown in table(13).[23]

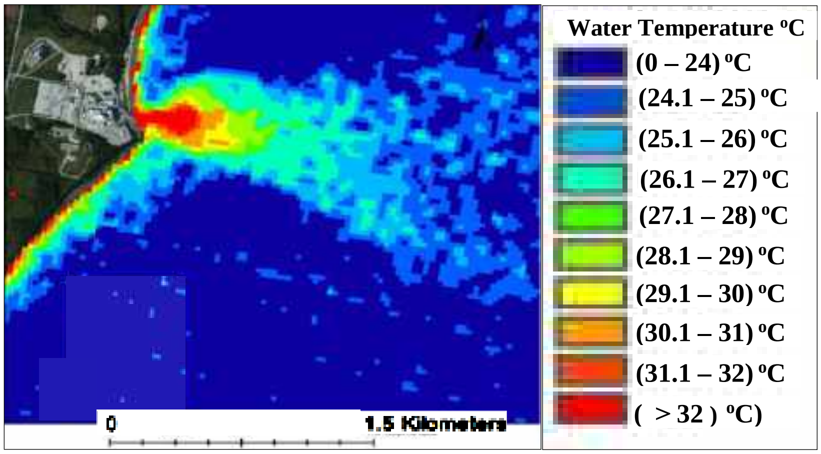
		11/12	12/13	Variance %
H.F.O	Ktons	4605	6582	42.9
N.G	Million m^3	29210	28817	(1.3)
L.F.O	Ktons	3.5	18.6	430
Special L.F.O	Ktons	59.2	81.1	36.9
Total	Ktoe	29728	31750	6.8

Table (13): Increase of reliance on oil for generating electricity in Egypt 2012/2013
Source: Ref. No. 23

Fig(107): Heavy Fuel Oil used in electricity production www.epa.org

(1-2-2-D) Environmental Impacts of H.F.O and L.F.O usage in generating electricity:
Although power plants are regulated by national laws to protect human health and the environment, there is a wide variation of environmental impacts associated with power generation technologies. There is specific air, water, and solid waste releases impacts associated with oil-fired electricity generation:

(1-2-2-D-1) Water Use: Thermal power plants use large quantities of water for steam production and cooling. Thermal release in water bodies may raise temperature up to 19 degrees at field of hundred miles, see fig (106). This action increases the temperature of the water and thus many kinds of fish and aquatic lives may be killed. This damage also affects people who depend on these aquatic resources as a source of living.[24]



Fig(108): (up) Water temperature near a power plant discharging hot water into the ocean during the cooling process in Florida, USA (right) Power plants located near water canals in Egypt for cooling purpose.

Source: (up) http://www.bluewatersatellite.com – (right) Ref. No. 25

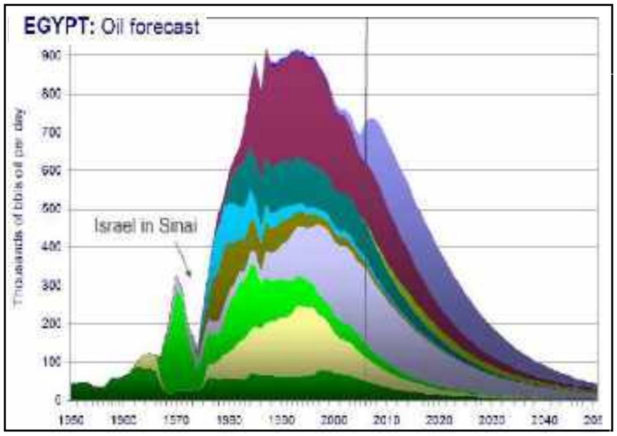
(1-2-2-D-2) **Air Emissions:** Burning oil at power plants produces nitrogen oxides, sulfur dioxide, carbon dioxide, methane, and mercury compounds. The amount of sulfur dioxide and mercury compounds can vary greatly depending on the sulfur and mercury content of the oil that is burned. The average emissions rates from oil-fired generation are: 1672 lbs/MWh of carbon dioxide, 12 lbs/MWh of sulfur dioxide, and 4 lbs/MWh of nitrogen oxides .[25]

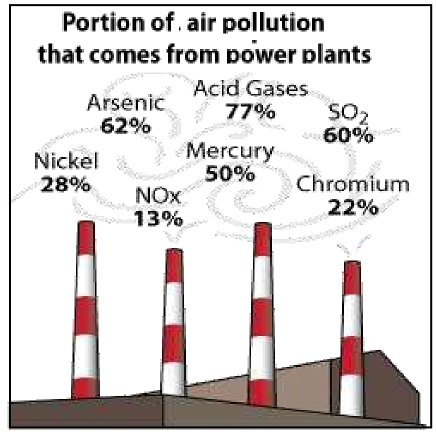
In addition, oil wells and oil collection equipment are a source of emissions of methane which is a potent greenhouse gas. The large engines used in oil drilling, production, and transportation processes burn natural gas or diesel that also produce emissions.

(1-2-2-D-3) Solid Waste Generation: When oil is burned at power plants, residues that are not completely burned can accumulate, forming a source of solid waste that must be disposed.[26]

(1-2-2-D-4) Contamination of Land: The construction of large power plants can destroy habitats for animals and plants. Waste products from power plants (such as wastewater sludge and residues) can cause land contamination if not properly disposed. In addition, when oil spills occur on land, soils are degraded.[27]

(1-2-2-D-5) Reserves: Egypt oil reserves are not well estimated due to shortage of funds needed for exploration and extraction. Oil production in Egypt started to decline 20 years ago, while consumption is inclining regularly. Oil in Egypt is expected to be completely depleted by 2050 as seen in fig(107). The government compensates this oil gap by importing crude oil products from Arab peers.





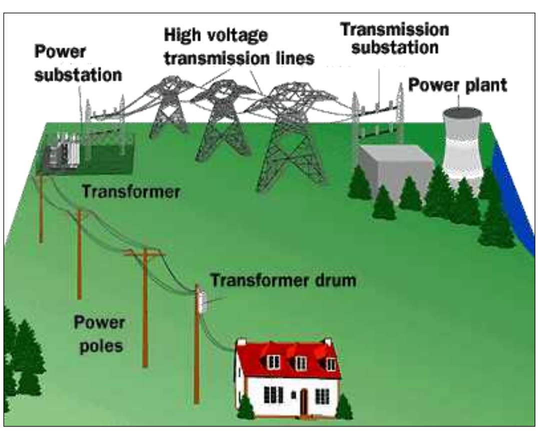
Fig(109): (left) Egypt oil production forecast till 2050 (right) Average toxic gases that emit from a typical power

(a) http://www.crudeoilpeak.com/ (b) www.EPA.gov

Since 2004, the Egyptian electrical sector has been augmenting the reliance on natural gas for generating power as the minimal environmentally damaging fossil fuel available in Egypt. After a decade, natural gas production has been in shortage, so the Egyptian government has approved the use of coal in power plant as an economic substitute. Although being an economic option, coal is a serious environmental polluter. A typical coal power plant emits around 1450 pounds of CO_2 per megawatt hour, compared to 800 pounds of CO_2 in Natural gas plant. Meaning that coal environmental footprint is 1.8 times bigger than N.G's.[28]

(1-2-3) Land use and Impact on Urban Planning:

Central electricity grid requires land for installing production plants, transmission towers,



Fig(111): (left) Land requirements for central electrical grid (right) High voltage transmission towers

(a) http://wikipedia.org (b) www.greenplanet,com

transforming cabinets and distribution columns. Building is prohibited near and under high voltage cables and transmission towers, and certain distance must be left around towers not to affect their magnetic fields. These terms and requisites have an impact over the shape and area of street and thus the urban form of city.

The total transmission lines in Egypt national grid was 43.6 thousand kilometers in 2012/2013, plus 414.4 thousand kilometers of distribution lines, serving 29.7 million connections in the same year as shown in table (14). This means that each connection in Egypt requires an average 13.95 meters of distribution lines and 1.46 meters of transmission lines. This share is comparatively high considering that almost all connections are located in a small dense land area equals about 50,000 km^2 as shown in fig(111).

For best transmission performance, streets of the served city are preferred to be gridiron or radial, as entangled or free form streets may affect the quality of the system.

Description		2011/2012	2012/2013	Variance%
Total Transmission Lines and Cables [6]	Km	43634	43600	(0.1)
Total length of distribution MV&LV Lines & Cables	Km	405199	414401	2.3
Total no. of customers in Distribution Companies	Million	28.1	29.7	5.8

Table(14): Total lengths of electrical transmission and distribution networks in years 2011/2012- 2012/2013
Source: Holding Company Annual Report 2012/2013

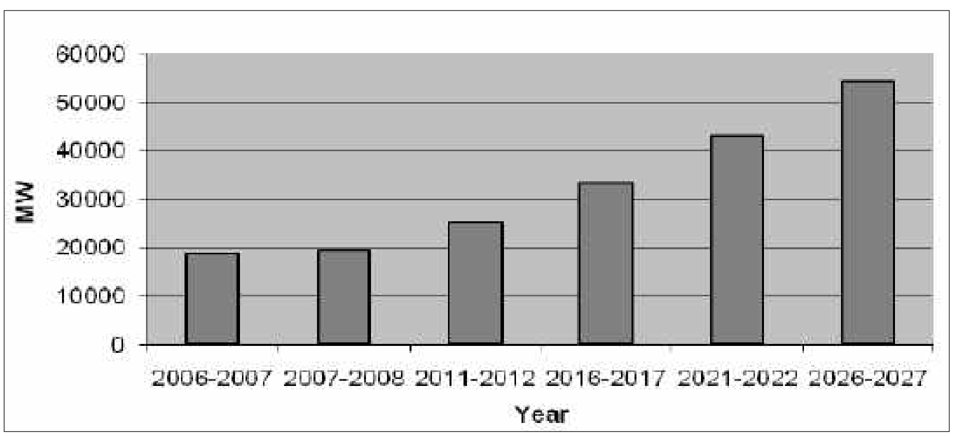


Figure (111): The Expected Evolution of Peak Demand till 2027
Wind Energy in Egypt: Osman, G.: Wind Energy in Egypt: Implications for Scaling Up. World Wind Energy Association.(2008)mgt.guc.edu.eg

Part (I)- Chapter 2

(1-2) Evaluating Electrical supply utility in Egypt

Summary of Chapter (2)

Electrical sector in Egypt is the best in coverage among other utilities and the tariff is low in comparison with other countries. However, the massive subsidies lay heavily on the national economy; so they are targeted for gradual reduction till cancellation in 2019. Low quality of the national grid causes transmission losses while non-insulated cables threat the safety of the inhabitants. Utility is not evenly provided in different governorates and bureaucratic procedures may hinder its provision. The sector emits greenhouse gases and affects our ecological system. Fuel reserves are diminishing while energy demand is increasing and expected to double by 2027. Coal has been approved as a substitute with expected environmental worries. Solar systems have been applied in a very limited scale while nuclear plants are being gradually applied with expected production start at 2022.

End of Summary of Part (I) Chapter 2

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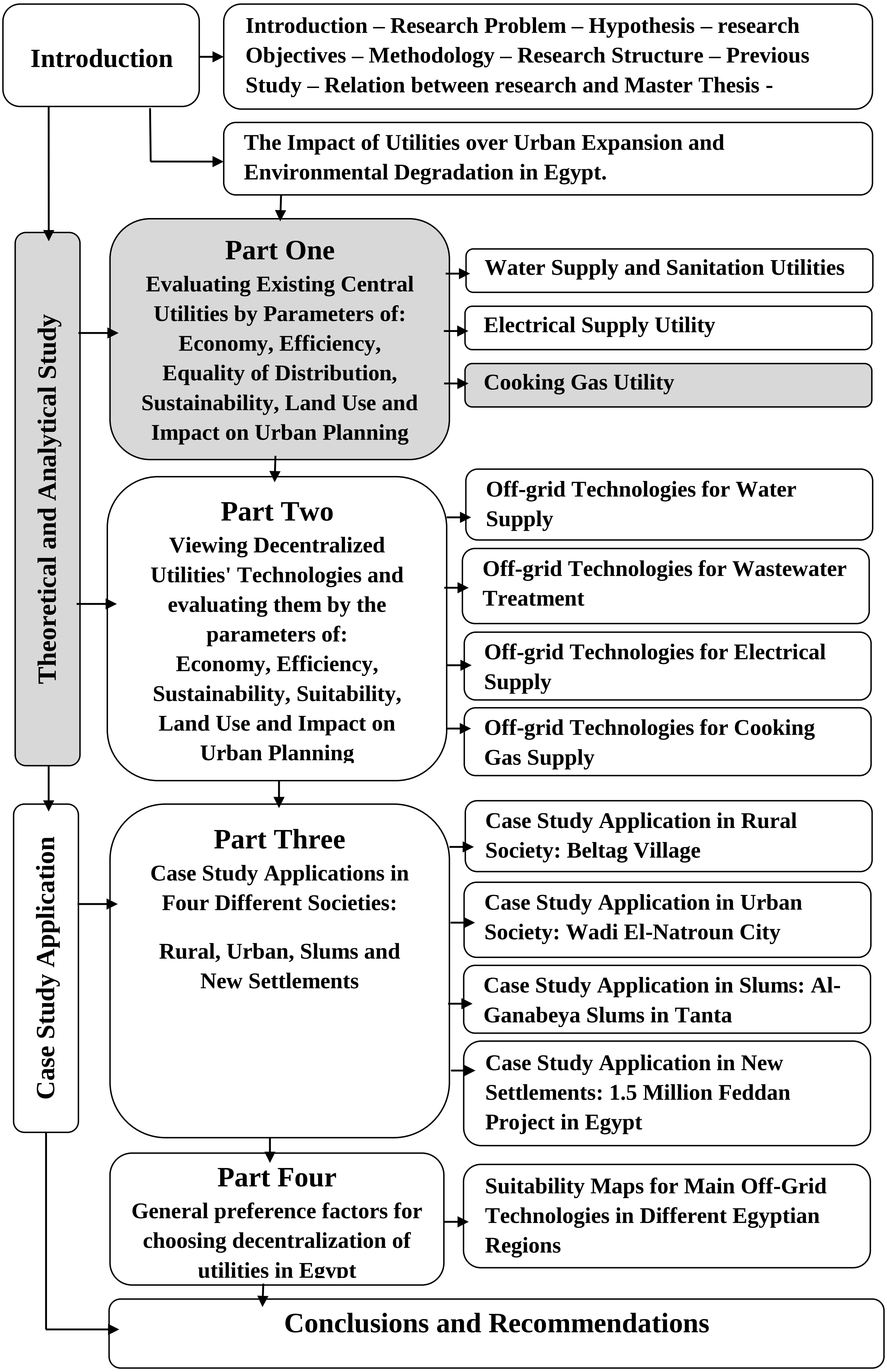
[25] The same source of (22).

[26] The same source of (22).

[27] www.EEA.com/ Retrieved September,24, 2014.

[28] *Lorena Rios*: WHEN NATURAL GAS IS NOT ENOUGH: Diversifying Egypt's Energy Mix, A publication published by Egypt Oil & Gas web portal, Jan.,2015- http://www.egyptoil-gas.com/publications/when-natural-gas-is-not-enough-diversifying-egypts-energy-mix


Introduction
Introduction – Research Problem – Hypothesis – research Objectives – Methodology – Research Structure – Previous Study – Relation between research and Master Thesis -
The Impact of Utilities over Urban Expansion and Environmental Degradation in Egypt.
Theoretical and Analytical Study
Part One
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Water Supply and Sanitation Utilities
Electrical Supply Utility
Cooking Gas Utility
Part Two
Viewing Decentralized Utilities' Technologies and evaluating them by the parameters of: Economy, Efficiency, Sustainability, Suitability, Land Use and Impact on Urban Planning
Off-grid Technologies for Water Supply
Off-grid Technologies for Wastewater Treatment
Off-grid Technologies for Electrical Supply
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Case Study Application in Rural Society: Beltag Village
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Case Study Application in New Settlements: 1.5 Million Feddan Project in Egypt
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Conclusions and Recommendations

Part (I)- Chapter 3

(1-3) Evaluating Cooking Gas Supply utilities in Egypt:

Introduction to Chapter (3)

Cooking gas is a main utility which no modern household can manage without. In Egypt, cooking gas is supplied in two forms: Liquefied Petroleum Gas cylinders (LPG) and Natural gas pipes network (NG). LPG is supplied in gas cylinders that are exchanged and refilled by LPG tankers, while natural gas is supplied to homes by pipelines (reticulation system).

This chapter discusses both systems by evaluating them through the same five parameters. We evaluate the social and economic impacts of this utility, as well as the sustainability of its production, distribution and consumption. We also discuss the availability of reserves and the environmental impacts of extraction and the consequences of possible depletion.

The main goal of this discussion is to have a clear background about the present challenges and problems facing household cooking gas supply in Egypt, to use it in choosing the best off-grid utility that can face these challenges and mitigate these problems.

End of Introduction to Chapter 3

(1-3-1) LPG Supply System in Egypt: Liquefied Petroleum Gas (LPG), also known as butane or botagas, is a key household fuel in Egypt which is mainly imported. Egypt imports annually about 3 million metric tons of LPG to cover the market needs. The average annual LPG consumption in Egypt in 2012 was 5.15 million tons from which 4.4 million tons for residential use, forming 85.5% of total use. The average Egyptian family annual consumption of LPG is about 15.6 cylinder/year, while the average per capita consumption is 55 kilograms per year (equals 4.58 cylinders, as each LPG cylinder contains 12 kilograms of gas), see table (15). This massive use makes LPG fuel vital for household uses. Here we evaluate this source of energy by the five parameters: economy, efficiency, sustainability, equality of distribution, land use and impact on urban planning.

Country	Year	Production	Imports	Exports	Consumption	
		Thousand Metric Tons	Thousand Metric Tons	Thousand Metric Tons	Total Thousand Metric Tons	Per Capita Kilograms / capita
Egypt	2006 2007 2008 2009	1711 1898 2027 1820	1961 1888 2059 2456	.. ..	3754 3932 4220 4400	50 51 54 55

Table (15): Production, Trade and Consumption of LPG in Egypt in four years (2006 – 2009)

2009 Energy Statistics Yearbook United Nations / 2009 Annuaire des statistiques de l'énergie des Nations Unies - http://unstats.un.org/unsd/energy/yearbook/2009/2009_240.pdf

(1-3-1-1) LPG Economy: The majority of LPG consumed in Egypt is imported and its costs are subsidized by the Government to ensure that it is affordable by the lower income groups; however there is no differentiation and everyone benefits from the subsidy.

- Every LPG consumer family in Egypt cost the Government about 200 US dollars annually to cover the difference between international import price and the end user purchase price.
- LPG subsidies form about 14 to 19 % of total annual petroleum subsidies in Egypt.
- Attempting to cut the subsidies, the Government raised the official user price of LPG for domestic use from 5 LE to 8 LE in July, 2012. This rise has decreased the LPG subsidies by 4% as shown in fig(112).
- Despite the price incline, LPG subsidies rose again due to shortage of local production. The import has increased and the subsidies rose to 19% in fiscal year 2014/2015, exceeding 19 billion LE, as shown in table (16).

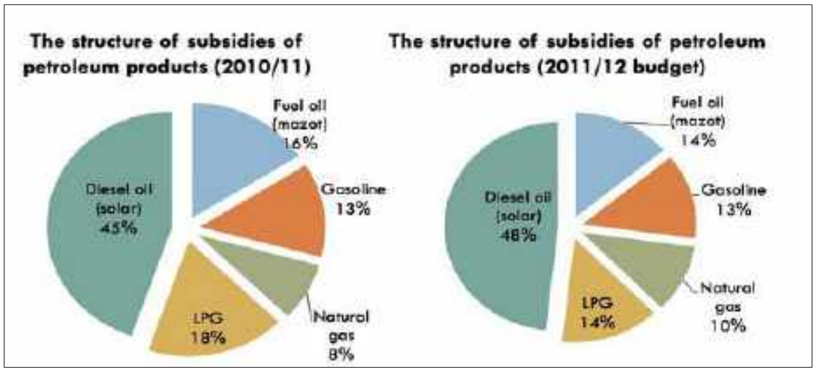


Fig (112): Decline of LPG subsidies in Egypt after price increase (2010/ 2012)

Egyptian Center for Economic Studies - http://rebeleconomy.com/economy/egypt-lifts-cooking-gas-prices-why-its-trivial/

Fuel Type	Quantity Thousand Tons	Cost Million LE	Selling Income Million LE	Subsidy Million LE	% of Total Fuel Subsidies
LPG cylinders	4000	20236	1120	19116	19.1 %

Table (16): LPG Subsidy Structure in Egypt in Fiscal Year 2014/2015

Egypt Information and Decision Support Center (IDSC): http://www.idsc.gov.eg/IDSC/publication/DetailsList.aspx- Retrieved 12/6/2015

- Egypt is gradually replacing LPG use with grid-connected natural gas to reduce the burden of subsidies, because Natural Gas is locally produced and not imported. Switching households from LPG, to Natural Gas will help lowering the government's bill with US$200 a year for each household.[1]
- Despite the heavy subsidies, and due to frequent shortages, LPG prices for consumers could vary widely, reaching 50 LE / canister in some areas during shortage times.[2]
- Unlike water and electricity, LPG has the advantage of having almost zero losses during filling and transportation. This makes the maximum benefit of both produced and imported LPG gas in Egypt.

(1-3-1-2) LPG Efficiency:

Thermal content and Oxygen consumption: LPG contains 2.44 times more thermal energy per cubic foot than Natural Gas. A domestic stove of 100,000 British thermal unit per hour (btu/hr) needs to consume 97 cubic feet of natural gas compared with 40 cubic feet of LPG in one hour of combustion, so less LPG is required to generate the same heat than NG.[3]

On the other hand, LPG requires more Oxygen for combustion than NG. LPG requires an oxygen-to-gas ratio of approximately 25 to 1, while Natural gas requires a ratio of 10 to

1. To achieve this difference, LPG is typically provided in a smaller quantity but at a higher pressure, drawing more oxygen with it into the combustion process.[4]

Safety for domestic use: LPG is colorless and odorless gas which makes it difficult to detect. To make it safe for household use, it is commonly odorized using an agent with a detection threshold lower than the lower explosion limit (LEL).

Although LPG is non-toxic, high concentrations with long exposure time can cause fainting and suffocation. LPG can cause cold burns to the skin and can act as an asphyxiant at high concentrations.[5] LPG is 1.9 times heavier than air, so when it leaks, it makes displacement of oxygen from the area where the leak occurs, causing suffocation and death for the inhabitants if they were asleep. Countless deaths have occurred in Egypt due to LPG leaks during the last 4 decades.

Transportation and carriage: LPG canisters need refilling on regular basis. The average weight of single canister is 35 kilograms, from which 12 kilograms are gas. The carriage and transportation of canisters is usually done by local individuals (distributors). These distributors usually add 2 to 10 LE (according to season and served area) to the official price as a profit. Some families depend on one of its members to perform this job to reduce expenses. Both distributors and family members usually don't use proper methods of transportation and carriage. In many cases, canisters are rolled over the ground, inverted upside down and kicked with metal tool for so many times during transportation. These actions may affect the quality and safety of the canister and disturbs its gas content.

Fig (113): (left) Local distributers of LPG, (middle & right) Improper transportation and handling for LPG cylinders

http://www.shorouknews.com/uploadedimages/Sections/Egypt/Eg-Politics/original/anbibaa.jpg http://www.almasryalyoum.com/news/details/672643
http://elyomnew.com/news/governorates/2015/01/11/4518 http://www.alnaharegypt.com/upload/press/n/20000/20930.jpg

(1-3-1-3) LPG Equality of Distribution: Concerning the distribution of LPG in Egypt, there are official and non-official data. The official statistics define the number of LPG authorized distribution points in different governorates, as well as the number of families served by each point. The unofficial survey shows the recurrent shortage of LPG supply which occurs usually in winter season as illustrated below:

LPG distribution points: Allocation and Capacity: Egypt had 2105 authorized LPG distribution points in 2010 statistics **No official statics could be obtained about LPG distribution points after this date**, from which 29.1% were located in Upper Egypt Governorates, 47.6% in Lower Egypt Governorates, 22.3% in urban Governorates, and 1% in frontier Governorates. This distribution didn't match with the distribution of population in these Governorates in the same year. As shown in fig(113), Upper Egypt Governorates population form 37% of the total population in Egypt, while Lower Egypt has 43%, Urban Governorates have 18% and Frontier Governorates have 2% of the total population. Both Urban and Lower Egypt Governorates enjoy more LPG distribution points than others, considering that these governorates are also more fortunate in natural gas network availability as shown later in this research.

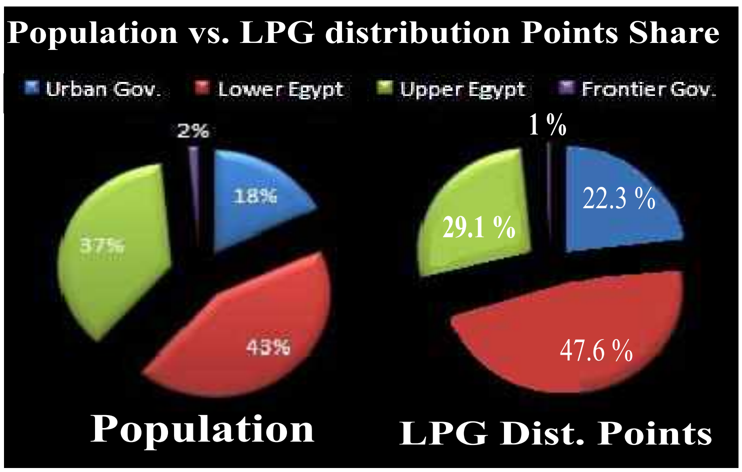


Fig (114): Comparing Population Share with LPG Distribution Points Share in Egyptian Governorates

http://egypt.unfpa.org/english/Staticpage/54790f72-6e8b-4f77-99e2-4c5b78c20d5c/indicators.aspx

The average serving capacity for every distribution point was not the same as well. With an average serving capacity of 6130 families/point in total Egypt, some distribution points had less serving capacity of 1400 families/point (in Red Sea Governorate), while other points served up to 17700 families/point (in Cairo Governorate). This unequal capacity is due to variable requirements for distribution points' authorization in different districts.

LPG seasonal shortage: survey and impact: LPG supply suffers a chronic shortage during winter season due to both inclining consumption and the chaotic distribution mechanism. A survey conducted in 2014 in 11 Governorates during winter season showed

that 62.5% of the families surveyed reported that LPG cylinders are not easy to be obtained. (37.7%) of the families complained that LPG distributors have raised the price of LPG informally up to 400% of the official price, while almost fifth of the families surveyed complained about the long queues they have to stand in to get an LPG cylinder.[6]
The same study showed that the first and main source of LPG cylinders in their districts was informal distributors (55.3%), followed by the LPG stores (31.8%). Due to bad LPG distribution mechanism as well as black marketing activities, many groups of the society try to participate in the distribution activities seeking for profit, causing a noticeable incline in the cylinder end-user price.[7]

Fig (115): (1) &(2) LPG seasonal shortage at official stores (3) A woman fainted in LPG waiting row

(1) www.watani.com (2) http://www.hoqooq.com (3) www.almasryalyoum.com

Social Impact:

The absence of LPG access during shortage time has negative social impacts on the inhabitants. The waiting queues consume the family members' time and effort; hence they have less time and effort for their occupational and social duties. Sometimes children also contribute in LPG refilling queues to help their parents, which may affect their ability of attending school or practicing their hobbies.

Chronic shortage of LPG have caused many strikes and demonstrations demanding a permanent solution for this crisis. LPG shortage have sometimes forced Egypt's police and army to provide armed guards for gas deliveries as shown in fig (117).

Fig(117): Different demonstrations against LPG shortages: (a) Tahrir Square in Cairo, March 2012 (b) Beila, Kafr El-Sheikh, March 2015 (c) Dakahleya, March 2012 (d) Kafr Hakim. Geiza, April 2014

(a) www.albadil.com (b) http://www.elwatannews.com (c) www.almasryalyoum.com (d)

Fig(118): Army forces surveillance over LPG queues in Qena (left& middle)vDaqahleya (right), Egypt, 3, 2015

(1) http://www.almasryalyoum.com/news/details/671162 (2) http://www.almasryalyoum.com/news/details/675227

(1-3-1- 4) LPG Environmental Impact:

LPG is derived from fossil fuels. Burning LPG releases carbon dioxide which is a greenhouse gas. The reaction also produces some carbon monoxide CO. LPG does, however, release less CO_2 per unit of energy than does coal or oil. Being a mix of propane and butane, LPG emits less carbon per joule than butane but more carbon per joule than propane.

LPG can be considered to burn more cleanly than heavier molecule [hydrocarbon], in that it releases very few particulates.[8]

The main components of liquefied petroleum gas (LPG) are C3 propane, C4 butane and non-saturated hydrocarbons. Propane and butane belong to a group of light saturated hydrocarbons. Small quantities of gas are obtained from oil drilling. The largest LPG gas volumes are obtained during the treatment of crude oil. The main suppliers of liquefied petroleum gas are refineries.

- LPG (either Butane or Propane), is classified as highly flammable and if it contains more than 0.1%Butadiene, it is also classified as a carcinogen and mutagen.[9]
- LPG is non-corrosive but can dissolve lubricants, certain plastics or synthetic rubbers.
- LPG combustion products in the air can contain: carbon dioxide, nitrogen oxides, and non-combusted hydrocarbons.
- LPG is unsustainable and non-renewable source of energy and it may be depleted in near future.
- Both extraction and purification methods of the crude elements of LPG affect the natural habitat of the work field and cause serious environmental problems.

(1-3-1- 5) LPG Land use and Impact on urban planning:

LPG system has no direct impact on the urban pattern of the served area, but land use is represented in local warehouses where the cylinders are stored.

There are certain conditions for proper LPG cylinders' storing:

- Cylinder must be stored upright (vertical) at all times and must be firmly tighten and not allowed to tip over, either by cages or chains as shown in fig(118).

Fig (119): LPG cylinders vertical storage and caging practiced in South Africa, Us, and India

http://roemarga.strefa.pl/forklift-accident-pics.html - http://thumbs.dreamstime.com/z/propane-tanks-cylinders-warehouse-await-transport-truck-35033764.jpg http://www.element14.com/community/community/design-challenges/blog

- Cylinders must be stored in a way that allows regular inspection for their condition to make sure they are free from rust and sealed properly. The standard layout for LPG warehouse is shown in fig(119), where LPG are stored vertically, with corridors for maintenance and with maximum 4 adjacent rows.

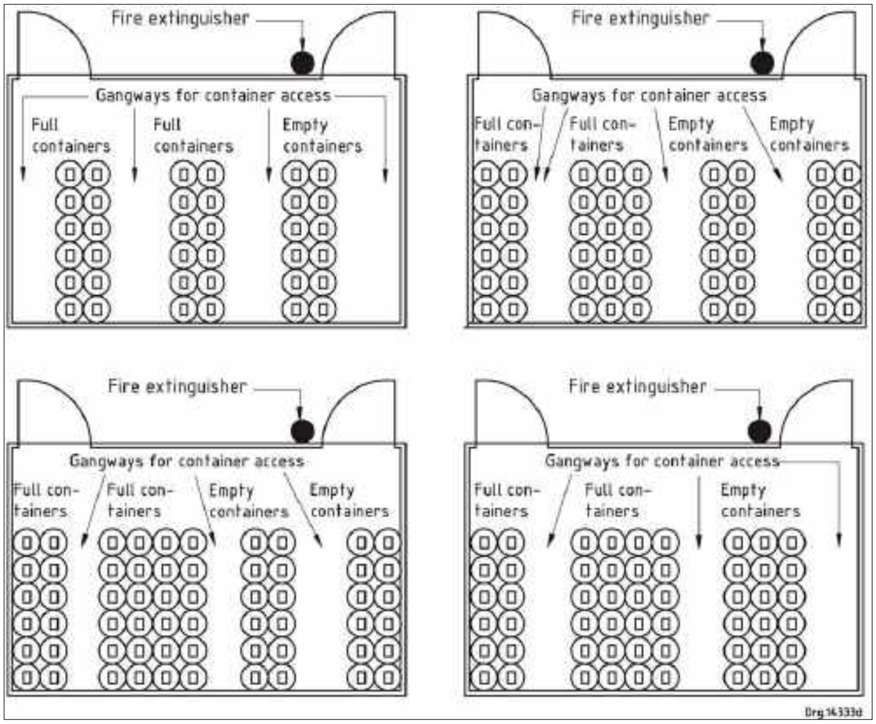


Fig (120): LPG warehouse standard layout

https://law.resource.org/pub/za/ibr/za.sans.10087.7.2011/za.sans.10087.7.2011_031_01.jpg

- Cylinders must be stored in an area with good ventilation and controlled temperature where the ambient air temperature is never allowed to exceed 28^{o} Celsius.
- Stores must be chosen in a secure location to protect against falling, damage, fire games and probable vandalism.
- Storehouses must be away from any oxidizing source (e.g. oxygen gas cylinders in craft shops) by at least 3 meters.
- Storehouses must be away from any possible ignition source (e.g. flame, cigarettes, blacksmith shop, etc.) by at least 15 meters.[10]
- Storehouses must be shaded and cylinders must not be exposed to direct sunlight, especially in hot climate. Direct sun exposure can cause an uncontrolled rise in the temperature of the contents leading to over-pressurization and possible catastrophic explosion of cylinders.
- Stores must be located above ground level, as LPG is heavier than air and will accumulate in basements and low areas if leaked.[11]
- Excessive cold is not a concern in LPG storage places.

- LPG storehouse must be out of residential cluster, but if no other place available, it must be surrounded by fire-retardant walls. If such walls are not available, a separation distance of minimum 3 meters must be provided around the storehouse from all sides. The same distance must be left from the street side to protect passing cars,[12] as shown in fig(120).

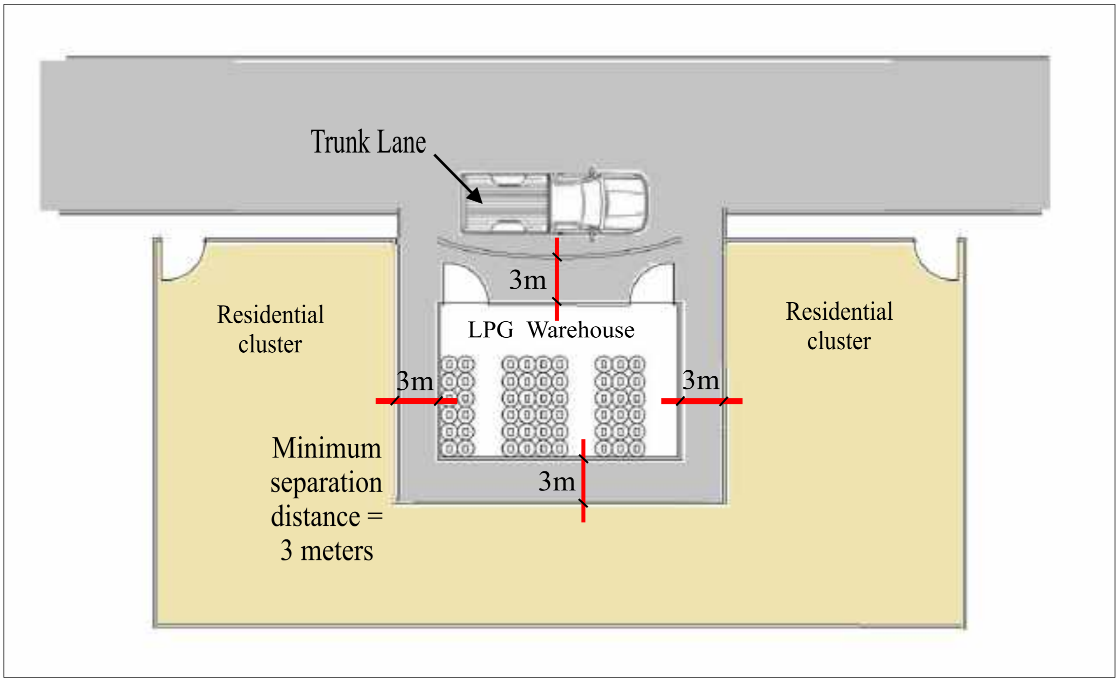


Fig (121): Standard layout for LPG warehouse in residential area, designed by the researcher based on data from the British code (UKLPG Codes of Practice).

The handling, storage, distribution and maintenance of liquefied petroleum gas in domestic, commercial and industrial installations, Part 7- Reference No.12

Unfortunately, most of these conditions are not fulfilled in LPG storehouses in Egypt. Cylinders are stored both vertically and horizontally to save space, they are stored in a manner that doesn't allow proper inspection and maintenance, the surrounding neighborhood is not observed to prevent oxidization and ignition, temperature is not

Fig (122): Improper LPG cylinders storage: (a&b) Horizontal storage & accumulation (3) Direct sun

(a) http://www.almasryalyoum.com (b) www.elshaab.org (c) www.elwatan.com

controlled and firefighting systems are usually not adequate.
Due to improper storage and handling, several LPG storehouses had destructive explosions. One of these explosions took place in Al-Warraq, Cairo in Jan., 2010. The LPG storehouse was destroyed and the neighborhood was affected as shown in fig(122).

Fig(123): Firemen fighting an explosion in LPG storage site in AlWarraq, Cairo, Jan 2010
Source: www.youm7.com/

Brief of LPG Supply Evaluation in Egypt:

LPG is a common source of cooking gas in Egypt. It is mostly imported and heavily subsidized by the government. The user's price is cheap due to subsidies but it becomes relatively expensive in shortage seasons. The transportation, storage and handling of LPG cylinders in Egypt usually do not meet the proper standards which may cause serious threats to users' life and safety. LPG combustion emits greenhouse gases, but much less than coal or oil combustion does.

(1-3-2) Natural Gas Household Supply in Egypt:

Natural Gas was first introduced to Egyptian local market in 1975 when the first natural gas field "Abu-Mady" was put on stream. Major discoveries afterwards have given natural gas increasing importance as an energy source in Egypt. Significant deposits of natural gas have been found in Western Desert, Nile Delta and offshore from the Nile Delta.

The main official entity in NG sector in Egypt is the Egyptian Natural Gas Holding Company (EGAS). EGAS is a state-owned holding company, which owns and manages state stakes in different gas projects. EGAS was established in August 2001 and it is responsible for natural gas exploration and distribution licensure in Egypt.[13]

Natural gas has been used in domestic sector for the first time in 1981, since then, thousands of household connections have been installed. The total number of residential consumers connected with natural gas reached 5.53 million consumers since commencing the activity in 1981 till June 2013.
EGAS has authorized many companies to work in local distribution of NG in Egypt for domestic use. Currently there are 13 local distribution companies (LDC's) extending NG to different governorates. Examples for LDC's are: Egyptian Natural Gas Company (GASCO), Egyptian Town Gas (ETG), National Gas Company (NATGAS), Cairo Gas Company (CGC), Nubaria Gas Company, Sinai Gas and TAQA Group.[14]

The government has a working plan to extend gas distribution network by connecting 800,000 households/year in corporation with EGAS, Town Gas and with the Assistance of the World Bank. The governmental plan aims to install 1.1 million household connections by year 2017, to reach 6.63 million connections in total Egypt, see fig(123).

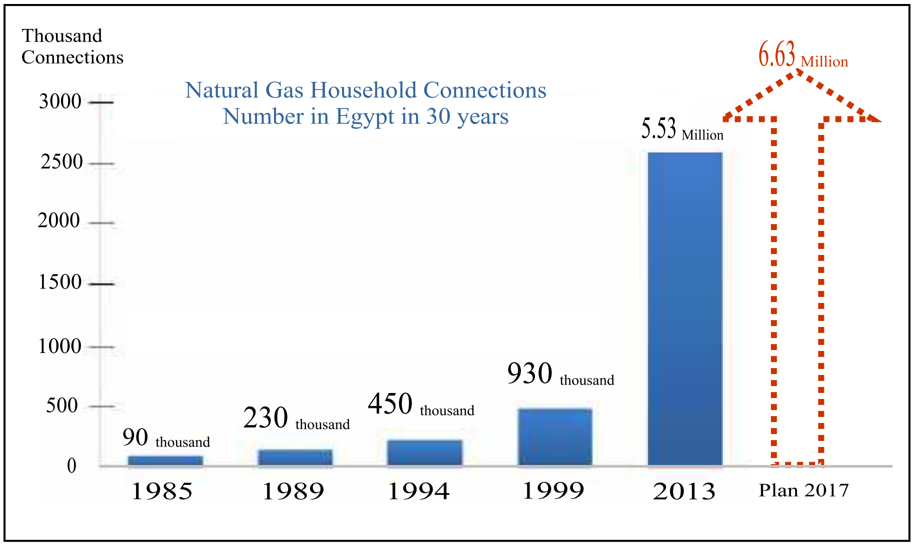


Fig (124): Natural Gas Household Connections Progress in Egypt (1981-2013) and the planned addition in 2017

Source with translation and additional illustration: http://www.petroleum.gov.eg/en/aboutministry/keyindicators/gaskeyindicators/pages/default.aspx

(1-3-2-1) N.G. Household Supply Economy:

Initial Cost: The initial cost of NG network installation in Egypt is massive in a way that forces the government to depend on loans to accomplish such project. An example for the initial cost is the ongoing project established in dec.2014 for extending natural gas network to connect 1.1 million households in 11 governorates between 2014 and 2017. The project is funded with the assistance of a World Bank loan of US$500 million and the French Agency for Development financing of €70 million. The total cost of connecting the prospective 1.1 million customers is US$850 million. By dividing the cost on customers, we simply find that the initial cost is about 772 US$ for each new connection in this project.[15]

Fig(125) : Initial cost for Natural Gas installation to house in Samanud, Egypt, 2010

NG network installation cost is partly shared by the customer by a variable percentage, commonly averaged between 30 to 35 percent. The average customer's share in the initial cost in the ongoing project is estimated with 1500 EGP, and it may increase if the served area has installation difficulties or special features. Fortunately this payment can be made either upfront or in installments over a period of time, because the government provides facilitation payments strategies through offering the following types of installments:

Installment	Total Payment
138 LE/Month for 12 months	1656
74 LE /Month for 24 months	1776
52 LE /Month for 36 months	1872
42 LE /Month for 48 months	2016
35 LE /Month for 60 months	2100
31 LE /Month for 72 months	2232
28 LE /Month for 84 months	2352

Table (17): NG household cost/connection for consumer, using the installment payment system, April 2014

Executive Summary ESIAF NG Connection 1.1M HHs- 11 governorates- March 2014

In spite of these facilitations, some poor families couldn't extend natural gas pipes to their houses. Paying regular installments may be an added financial burden on the poor families who do not have secured source of income. Because it is optional to have NG connection, it is common to see adjacent residential blocks with different gas supply systems: the able dwellers with NG connections and the poor dwellers with LPG cylinders.[16]

The NG supply project has positive economic impact on the Egyptian government. By converting the targeted 1.1 million houses to natural gas, the government will be able to cut LPG subsidies by 221.1 million dollars annually, meaning that the saved subsidies will cover the initial cost of the project in 4 to 10 years (considering the loan added interest and expenses).[17]

Running Cost: NG is heavily subsidized by the Egyptian Government to assure an affordable price for local consumers. As shown in fig(..) in page(..), NG subsidies have inclined from 8% in fiscal year 2010/2011 to 10% in 2011/2012 and rose again to 11.8 % of total energy subsidies in 2012/2013 as shown in table(18).

	Total energy subsidies ($ bn)	Share of gas (%)	Total subsidies as % of GDP	Fiscal balance as % of GDP
Algeria	10.6	--	6.6	-1.1
Libya	4.2	6.2	5.7	8.7
Egypt	20.3	11.8	9.3	-8.1
Saudi Arabia	43.5	--	9.8	6.7
Qatar	4.2	34	3.2	2.9
UAE	18.2	54.9	6	-1.1
Iraq	11.3	2.5	13.8	-9.1
Kuwait	7.6	11.8	5.8	22.6

Table (18): Natural gas subsidies in Egypt compared with other regional peers, 2013

http://worldenergyoutlook.org/methodology_sub.asp - retrieved 28/6/2015

The total NG subsidies in Egypt have reached 239 million dollars in 2012/2013 from which 3% was used in residential sector. This considerable amount of money is forming a heavy burden on the government, especially with a budget deficit of 8.1 % of total Gross Domestic Product (GDP) of the same year.

Attempting to cut the subsidies, the Egyptian prime minister have issued the "363 Decree" in May 2014, by which the price of domestic NG rose about 400 to 500% as shown in table (19). Prices are expected to rise again gradually to cut more subsidies in near future.

Consumption's Category	Before May, 2014	After May, 2014
0 - 25 cubic meters	10 piasters / cubic meter	40 piasters / cubic meter
25-50 cubic meters	20 piasters / cubic meter	100 piasters / cubic meter
> 50 cubic meters	30 piasters / cubic meter	150 piasters / cubic meter
Additional Fixed Fees	2 LE/ connection/month	6 LE/connection/month

Table (19): Natural gas domestic consumption prices in Egypt, before and after May,2014

Based on data from the Ministry of petroleum www.petroleum.gov.eg/

(1-3-2-2) N.G. Household Supply Efficiency:

Natural gas consists primarily of Methane (generally above 85 percent). When it is extracted from the ground it may also contain Ethane, Propane, Butane, and Pentane, although most of these are usually stripped out for other specific applications before it is passed along through the pipelines. Impurities are also removed, including water and Sulphur. The chemical formula for Methane is CH_4.

a- **Thermal content and Oxygen consumption:** As mentioned in LPG section, NG contains less thermal value than LPG and consumes less oxygen during combustion. The average gross heating value of natural gas is approximately 1,020 British thermal units per standard cubic foot (Btu/scf), which equals 0.298 kWh/scf.[18]

b- **Leaks and losses:** NG usually travels for thousands of kilometers in pipeline network before reaching the end consumer. This long journey may cause some losses in the pumped quantity. Production and transmission losses vary from one country to another. According to EPA, producing and delivering natural gas directly losses are about 10 percent of its usable energy, while the American Gas Association (AGA) estimates the average transmission losses in domestic natural gas network in US with 8.1 % of total pumped value as shown in fig (126).

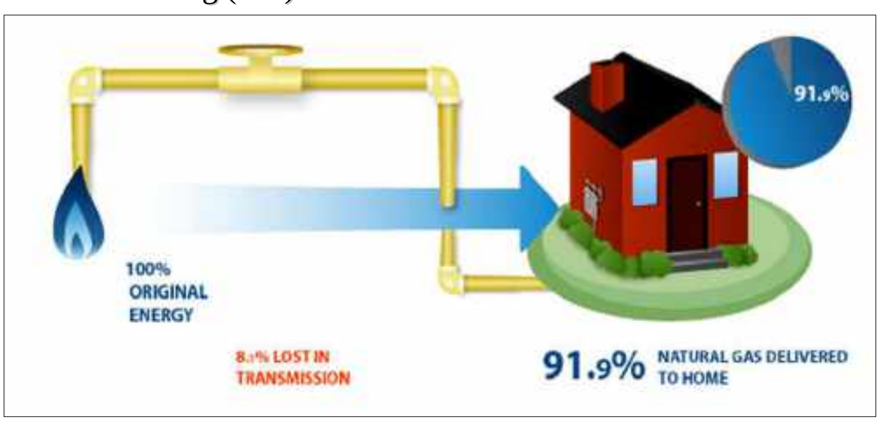


Fig (126): Household NG transmission efficiency as set by the American Gas Association (AGA)

Source Energy and Emission Factors for Building Energy Consunption, Copyrright 2009, American Gas Association - http://www.originalgreenenergy.com/whynaturalgas/energyefficiency/

In Egypt, no available data could be obtained about NG transmission losses, but there are some difficulties that may augment the losses to exceed the American standards. One of these difficulties is the recurrent attacks targeting the major NG transmission lines. Although most attacks occur in Sinai Peninsula, targeting the pipelines delivering gas to Jordan and Israel, some lines were attacked in Mariutyea, Beheira, Dahshur and the Western Desert. Recurrent attacks have forced the Egyptian government to provide protection for some main delivering pipelines.

Fig (127): Recurrent Natural gas lines attacks in different locations in Egypt

(a) www.alarabiya.net (b) www.elshaab.org (c) http://www.algareda.com/2015/02

Fig(128): NG leak causing explosion in Cairo, Dec, 2015 **-www.youm7.com –Retrieved 27/12/ 2015**

c- **Safety:** Though NG network is usually safer than traditional kerosene stoves and butane canisters, some accidental bursts may occur. Untighten fixtures may cause gas leaks which can be destructive as shown in fig(..).

(1-3-2-3) N.G. Household Supply Equality of distribution: According to 2014 statistics, only 25 percent of Egypt's households enjoyed the natural gas supply, while the remaining 75 percent still rely on LPG cylinders as the only source for cooking gas.[19]

Among Governorates: N.G. household supply varies to great degree from one governorate to the next. Remote governorates like Matrouh and ElWadi El Gideed were deemed too distant from the existing network to fulfill the minimum levels of economic and technical feasibility. Fig(127) shows the number of served population with NG network in each governorate, compared with the total population no. in Nov,2014.

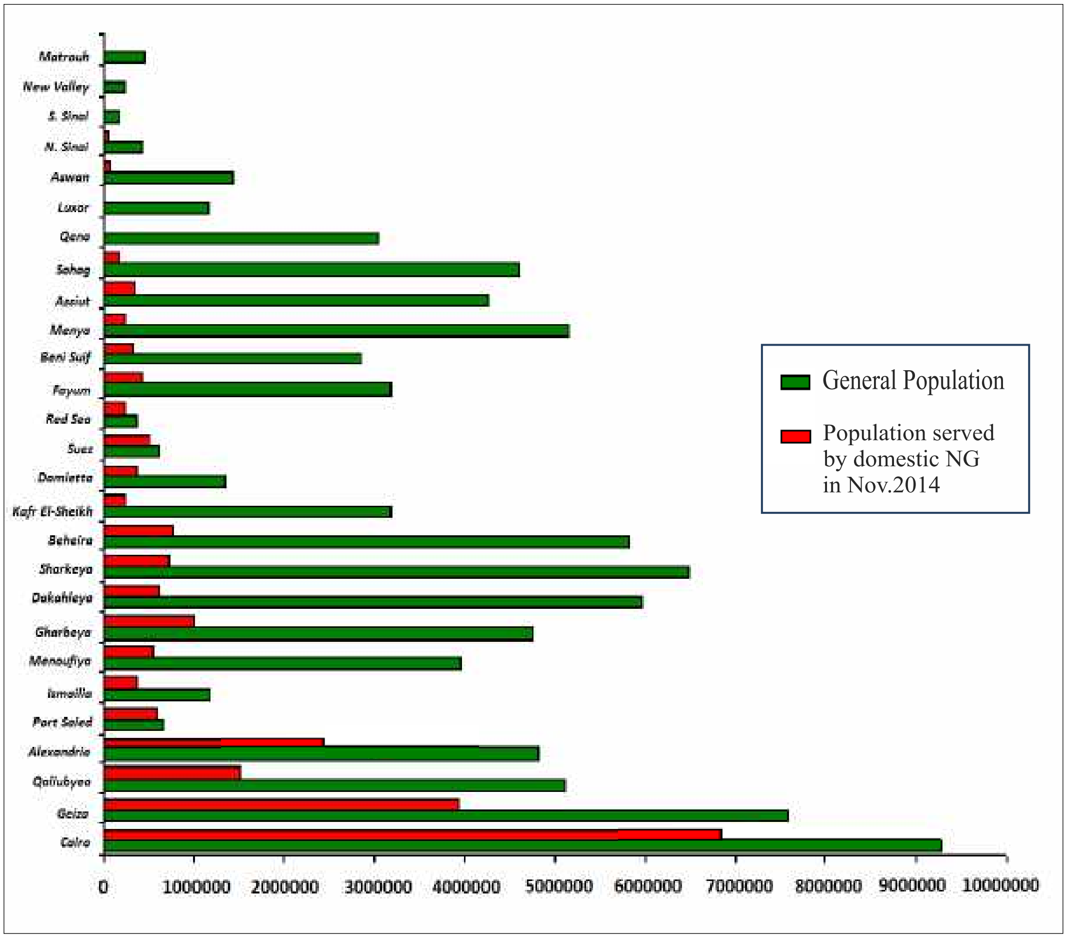
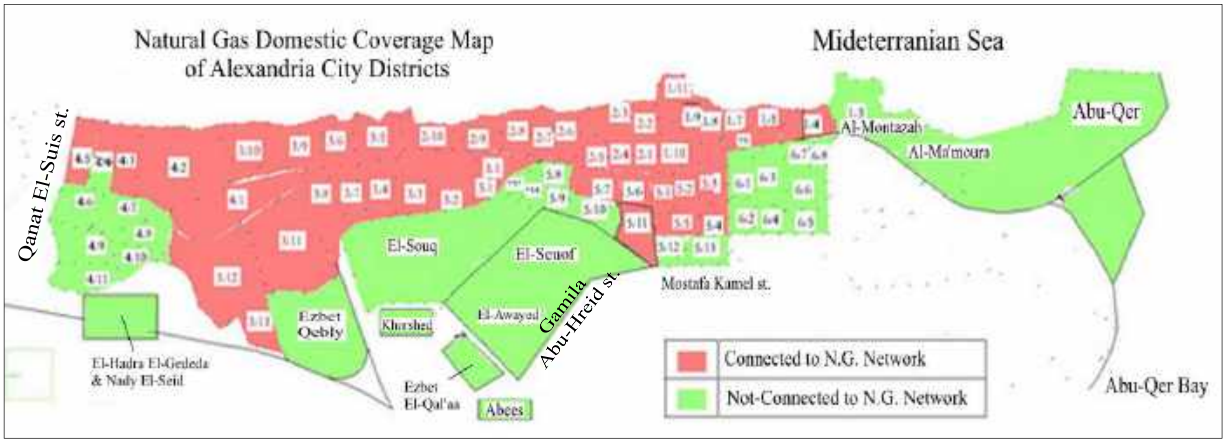


Fig (129): No. of population served with domestic NG network, compared with total population in different Egyptian Governorates , Nov 2014 - **Designed by the researcher, based on population statistics (Central Agency for Public Mobilization And Statistics (CAPMAS) 2015) and NG connections number in each governorate (http://www.egas.com.eg) multiplied by 4.2 as the average family size in total Egypt.**

As shown above, some governorates are totally deprived from NG network like Matruh, Qena, Luxor and New Valley, while some others have very low coverage that doesn't match with their population like Assiut, Meneya, Sharkeya and Sohag. Some cities like "Wadi El-Natrun" have no single gas connection, though it hosts the main gas pipelines of SUMED in its land.

Among the same Governorate: NG installation is not equally available among the same Governorate. The rules of NG installation necessitate an access to sewage systems as one of the requirements to install the NG network, which makes many villages in Egypt too far from installing gas network in near future.[20] NG network is commonly not available in remote areas, slum areas, organic pattern areas and suburbs, due to numerous selection criteria based on economic aspects and technical consideration.

Among the same City: NG network coverage is not equal in the same city due to financial, technical, and sometimes political factors. An example for this inequality is Alexandria city. The most fortunate districts of the city were early introduced to NG supply project, while other districts are still in waiting row. Till Nov.2014, almost 50% of the city hasn't been covered yet with NG network as shown in fig (128).



Fig(130): Natural Gas Household Network Coverage in Alexandria City, Nov. 2014

http://www.towngas.com.eg/en/Coverage-Map.html - Retrieved

Among the same Street: It is common to find dissimilarities of NG provision in the same street. This may be caused by different financial capabilities of the inhabitants as discussed before. Another reason is that NG installation requires the provision of an electricity bill, so, houses constructed without the necessary permits do not have access to "state electricity" and will not be able to provide the required bills. The construction status of the building is also an important factor. Gas supplier companies usually require good construction status for the served building before NG installation. Old, dilapidated and mud houses are usually not connected to the service.

Fig (131): Installing natural gas pipes require good construction status in served buildings

http://www.natgas.com.eg

(1-3-2-4) Natural Gas Environmental Impact:

Natural Gas has much environmental consideration during extraction, transmission and combustion process. There are also considerations about the reserves of this valuable gas in Egypt.

a- Sustainability and Reserves:

Egypt ranks 7th among non-OPEC countries and 16th worldwide in Natural Gas reserves. The NG reserves in Egypt were estimated with 76 trillion cubic feet in 2014. The Egyptian Government has continued to expand its natural gas production to meet demand for exports, which could increase slightly from the current 630 billion cubic feet to 800 billion cubic feet by 2030, and also meet rising domestic demand.

However, the current policy to expand natural gas usage in all sectors as a substitute for petroleum products have caused a rapid growth in consumption, which together with exports, have caused the remaining reserves to diminish rapidly, even if discoveries increase the reserve base. Within approximately 20 years, Egypt's natural gas production will face the same fate that domestic oil production has encountered since the mid-1990s: stagnation and decline in production. Sluggish economic growth would postpone this exhaustion. With desired rapid economic growth, however, Egypt's extensive gas strategy is bound to reach its limits during the 2020s.

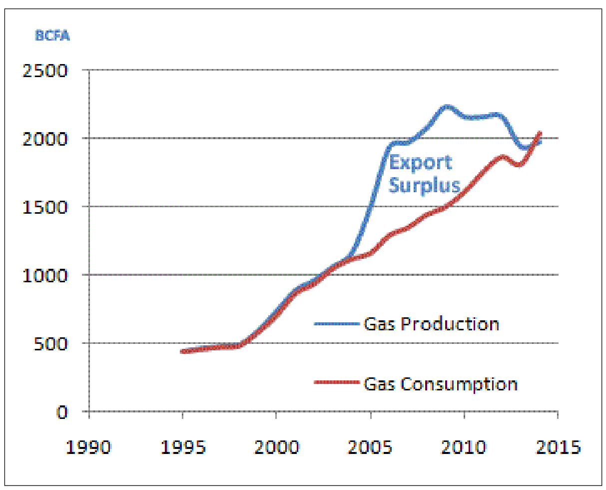


Fig (132): Egypt Natural Gas Production and Consumption 1965/2015 (Billion Cubic Feet Annually)
Source: http://www.gulfoilandgas.com/webpro1/images/news/gas_consumption_egypt.gif

In Dec.2012, Egypt has announced that it has changed from a gas-exporting to a gas importing country. According to the gas deficit, EGAS has started to import gas from international markets and via contracting companies. The gas is transferred via national networks with an import price of US$14 per 1 million thermal units, whereas the government exports gas to Jordan at $5.50 per one million units. Importing gas at international prices would affect the subsidy system in Egypt and the domestic consumption may be affected with the price incline.[21]

While gas production in Egypt is expected to have a deficit of 3.7 billion cubic feet by 2018, the daily consumption has doubled in fiscal year 2014/2015 reaching 25 million cubic feet, compared to 12 million cubic feet in 2011/2012. Importing more gas would require infrastructure and facilities that would cost around $600 million to develop.[22]

b- Emission and Combustion Natural gas is less polluting fuel than other fossil fuels, like coal and oil. Carbon emissions from natural gas combustion are around 60% lower per unit energy than for coal. Also Nitrogen Oxide emissions (NOX) are often lower. Natural gas combustion also produces none of the Sulphur Dioxide that causes acid rain, making NG better than other fossil fuels.[23]

On the other hand, the increased use of natural gas might produce more global warming than coal because of leakages, since its primary component methane (CH4) is a particularly potent greenhouse gas; a ton of CH4 leaked has a global warming impact that is initially 44 times that of a ton of CH4 burned, although CH4's short atmospheric half-life of 8 years ameliorates this effect.[24]

The carbon footprint of NG used for cooking was measured in the European continent in comparison with other cooking fuels like electricity and LPG. The study conducted in 2009 has showed that natural gas cooking has a marginally lower footprint than LPG's throughout Europe, while electricity's footprint had significantly higher footprint than LPG in Eastern Europe and significantly lower footprint in Western Europe as shown in table (20).[25]

Fuel	Burner type	Efficiency	Cooking footprint g CO_2e
Natural gas,	Standard	39.9%	56.6
LPG	Standard	39.9%	62.2
Electric	Smooth	74.2%	63.5
Electric	Coil	73.7%	63.9
Electric	Induction	84.0%	56.1

Table (20): Carbon footprint of different cooking fuels as measured in the European Continent, 2009

Atlantic Consulting, 2009 – **Reference No. 25**

c- Electric Use of NG Sector: The N.G. sector in Egypt usually consumes electricity to perform production, transmission and distribution activities properly. The NG sector consumption of electricity was 355.4 million kWh in 2009/2010 and 710 million kWh in 2010/2011, forming 0.14% of total national electricity uses in Egypt.[26] Electricity is mainly used in operating pressure reduction stations as well as gas distribution pumps. Pressure Reduction Stations reduce the NG pressure from 70 Bar to 7 Bar to be suitable for residential users, while distribution pumps assure a steady flow in the network. As mentioned before in this research, electric use is responsible for many environmental problems and share in greenhouse effect.

d- Gas Drilling and Hydraulic Fracturing: Gas drilling is commonly performed by conventional extraction. Although it may be expensive, it is much safer than what is called "Hydraulic Fracturing", also known as "Fracking". Fracking is simply pumping millions of gallons of fluid underground in high pressure, to break apart the rocks and release the gas for extraction. The injected pressurized liquid is commonly a mixture of water, sand and chemical agents, injected into a wellbore to create cracks in the deep-rock formations through which natural gas, petroleum, and brine will flow more freely. When the hydraulic pressure is removed from the well, small grains of sand and chemicals hold the fractures open for easier extraction as shown in fig(131).

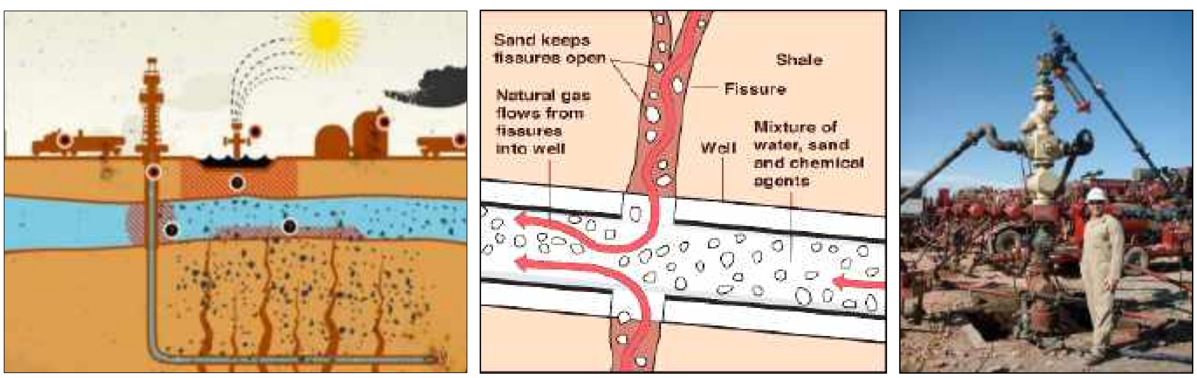


Fig (133) (a) Hydraulic Fracturing method, (b) Fractured rocks releasing gas for extraction, (c) Well Head where fluids are injected into the ground

(a) http://www.watershedcouncil.org/ (b & c) https://en.wikipedia.org/wiki/Hydraulic_fracturing

During this process, methane gas and toxic chemicals leach out from the system and contaminate nearby groundwater. Methane concentrations are 17 times higher in drinking-water wells near fracking sites than in normal wells.[27] Fracking is a massive water consumer as well; single fracking process uses about 10,000 cubic meters of water, mixed with approximately 40,000 gallons of chemicals.[28] Chemicals used in fracking are up to 600 elements including carcinogens and toxins such as: Uranium, Mercury, Radium, Methanol, Hydrochloric Acid and Formaldehyde.[29] Only 30-50% of the fracking fluid is recovered while the rest is mixed with groundwater and the chemicals in it are not biodegradable.[30] Contaminated groundwater travels among the aquifer and is commonly used for drinking water for nearby cities and towns. There have been over 10,000 documented cases of water contamination next to areas of gas drilling in US as well as cases of sensory, respiratory, and neurological damage due to ingested contaminated water [31]. The recovered fluid is left in open air pits to evaporate, releasing harmful volatile organic compounds into the atmosphere, and creating contaminated air, acid rain, and ground level ozone.[32]

High concentration of Methane in groundwater has resulted in "flammable water" phenomena in several states in the US where fracking is applied as shown in fig(134).

Fracking is also believed to cause inclining seismic activities due to fracturing the deep rock table 10,000 feet under earth surface. High frequency of earthquakes was recorded in American States were fracking is applied. An example for this impact is Oklahoma State, were fracking activity started in year 2009. In 5 years of application, the frequency of earthquakes has doubled more than ten times, mainly located 0 to 50 kilometers near fracking wells, see fig(132).

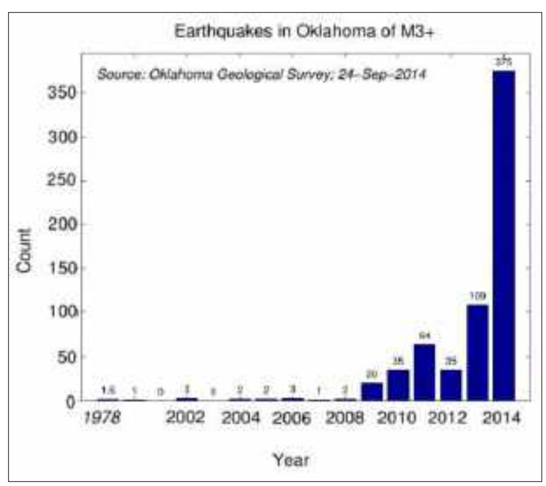


Fig (134): (a) Flammable tap water in Washington DC, USA. (b) Groundwater contamination due to fracturing in New York, USA. (c) Earth cracking in Oklahoma believed to be caused by fracking (d) Earthquake frequency before and after fracturing application started in Oklahoma in 2009.

(a) www.thinkprogress.org **(b)** www.demotix.com
(c) www.theenergycollective.com
(d) https://cornell.app.box.com/okquakes

Due to these environmental and health related problems, hundreds of demonstrations and campaigns were held against fracking worldwide as shown in fig(..). The anti-fracking societies have succeeded in banning all hydraulic fracturing activities in France, June 2011;[33] and Bulgaria, Jan. 2012.[34] Several American States like Maryland and New York have also banned fracking in March and Dec. 2014.[35]

Fracking technology has been applied in Egypt since 2009 by many international companies for gas extraction. For example, Apache Company (USA) applies it in East Bahariya field and in Western Desert, Shell Petroleum (British) applies it in well "18/3" in Shawish-Alam, Western Desert, Agiba Petroleum (joint Italian & Russian company) also applies it in “Falak” and “Dorra” fields in Western Desert,[36] while Dana Gas (UAE) applies it in West "Al Baraka-2" well in Kom-Ombo, Aswan.[37]

Fracking in Western Desert may contaminate aquifer systems in the area on which both tourism and all agriculture by the inhabitants of the western oases depend, while fracking in Kom-Ombo may affect groundwater which is very near to Nile water and can affect its quality. The inclining fracking activities by Dana Gas in Aswan are believed to be the main contributor in the incidence of floods and mild seismic activities in the area. Since the fracking started in Kom-Ombo in 2009, two 4.6 and 4.2 earthquake were detected in Aswan at Nov 7th 2010 and Dec 27th 2011, forming no threat on the body of Aswan High Dam.[38] The inhabitants in Kom-Ombo also noticed the rise of contaminated groundwater in their villages, especially "Fares" village, as shown in fig(136).

Fig (135): Demonstrations against fracturing activities in Philadelphia, London and Oklahoma

(1) www.cnn.com (2) www.theguardian.com (3) http://www.dailymail.co.uk/ (4)

Fig (136): The possible environmental impact of fracking activities in Fares village: Floods, Wreckages and contaminated groundwater uprisings.

http://www.egyptindependent.com/news/fracking-responsible-flooding-upper-egyptian-village

Many Egyptian entities have opposed the invasion of fracking activities in Egypt. For example, the Egyptian Initiative for Personal Rights (EIPR) has called on the Egyptian government to place an immediate moratorium on unconventional extraction activities using hydraulic fracturing and condemned the use of this technology in view of the of the lack of any regulations to govern the process in Egypt.[39]

(1-3-2-5) N.G. Household Supply Land Use and Impact on Urban Planning:

The production and transmission of natural gas requires land for drilling, purifying, pumping and pressure adjustment. The distribution network is installed aboveground for long transmission lines with big diameters, while small diameter lines are installed underground in the streets of the served area.

Fig (137): Installing main pipelines for NG above & under ground level in Egypt

Photo from NATGAS official website: http://www.natgas.com.eg

a- Proper Positioning and Installation: The proper location for NG pipelines is to be installed under the pavement to be away from the loads of cars and vehicles. The proper positioning for water, wastewater, gas and electricity cables is shown in fig(138) as set by the American code for utilities.

Fig (138): (Up): Preferred positioning for utility lines
(Left): Installing Gas pipes beside the walkway in Colorado, USA

(Up): http://strongerchristchurch.govt.nz
(Left): http://dailyreporter.com/files/2009/10/trench-101509.jpg

In Egypt, NG lines are installed directly under the streets due to lack of proper pavements and walkways in most of the served areas. But even in new cities were sidewalks are available and properly designed, the NG companies prefer to install the pipes under the street as well, due to technical and economic reasons, see fig(139). This positioning may expose the lines to breakings or damages due to street loads or careless future excavations. NG lines damage may cause severe environmental problems and threat the safety of the inhabitants.

Fig (139): Installing NG lines under the street even with sidewalks available, October city, August 2012
Photo from NATGAS official website: http://www.natgas.com.eg

b- Potential Negative Impacts during NG pipelines Construction:

- Traffic congestion and loss of access due to excavation and installation works.
- Possible disruption or displacement of ecological systems (especially in excavation and installation of the 70-bar steel pipelines).
- Potential risk to weak structures may arise in areas where building standards are not followed or in areas where high groundwater levels affect integrity of foundations.
- Structural and aesthetic effects on culturally-valuable sites and antiquities.

c- Risk on Infrastructure and underground utilities:

As mentioned before, NG lines should be the last facility to be installed, mainly due to safety requirements. In many locations across Egypt, underground utilities and infrastructure pipelines (drinking water, wastewater, electricity cables and telephone lines) have been installed years ago without accurate documentation and maps for its routes and depths. Therefore, the risk of damage to such utilities during excavations for Natural gas pipeline installation is considerable.

d- Restoration to Original State:

After installing N.G. network, the restoration to original state, locally known as " رد الشيء لأصله" must be considered. Restoration includes backfilling of the excavated trenches and re-pavement of the streets. The implementing entity (Gas Company) is legally responsible for restoration, but unfortunately, it makes arrangements with the local municipalities to perform these fixings on its behalf and pays them fees. The municipalities use the fees to include the restoration and re-pavement of the streets in its “pavements plan”. In many cases, the pavement plan is several months away and the streets remain unpaved, causing nuisances and potential damage to vehicles. Another source of delay is that the local units sometimes do not possess the equipment and materials required for re-pavement. In that case, the local unit commissions the regional “Roads and Bridges directorate” to perform the restoration. This may lead to further delays in re-pavement and prolongs impacts on the public and vehicles, see fig(140).

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Fig(140): Damaged streets due to delay of restoration after N.G. network installation in Qena (right) and Sheikh Zayed (left). (1)&(2)

(1) http://www.rassd.com/15-62024.htm (2) http://www.masress.com/rosadaily/70033

Part (I)- Chapter 3

(1-3) Evaluating Cooking Gas supply utility in Egypt

Summary of Chapter (3)

Domestic natural gas in Egypt has a high initial cost but a low running cost compared to LPG monthly expenses. The Egyptian government pays millions of dollars annually to keep the prices affordable, but with an increasing economic pressure, it's planning to gradually raise the tariff to meet the prices of NG .

NG contains less thermal value than LPG and consumes less oxygen during combustion. The sector has production and transmission losses which may exceed (8-10) % due to recurrent attacks against networks. 75 percent of Egyptian households have no NG connection due to economic and technical difficulties.

Natural Gas has much environmental consideration during extraction, transmission and combustion process. There are also considerations about the reserves of this valuable gas in Egypt. NG has fewer emissions during combustion than oil and coal, but the gas itself, if leaked, can magnify the greenhouse impact 44 times more than CO_2 does.

N.G. production, transmission and distribution activities consume 0.14% of total national electricity produced in Egypt.

The use of Hydraulic Fracturing in NG extraction is starting to get common in Egypt since 2009 Fracking helps contaminating groundwater and Nile water as well as augmenting the incidence of floods and mild seismic activities, especially with the absence of any regulations to govern this process in Egypt.

NG production and transmission require land for drilling, purifying, pumping and pressure adjustment. NG distribution network are installed above and under ground level according to pipe diameters and distance of transportation. Due to technical and economic reasons, NG lines in Egypt are installed under streets rather than pavements, which may expose lines to breakings or damages. Streets' restoration is commonly delayed for years due to bureaucratic pavement plans.

End of Summary of Part (I) Chapter 3

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[6] Executive Summary ESIAF NG Connection 1.1M HHs- 11 governorates- March 2014.

[7] The same reference of (6)

[8] https://en.wikipedia.org/wiki/Liquefied_petroleum_gas/

[9] Carcinogen element is every element causes, or makes it more possible to cause cancer in human beings, while mutagen element is every agent, such as radiation or a chemical substance that causes genetic mutation, causing deaths among unborn babies or life-long congenital anomalies.

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[17] http://www.worldbank.org/projects/P146007?lang=en/

[18] http://www.elgas.com.au/blog/486-comparison-lpg-natural-gas-propane-butane-methane-lng-cng/

[19] The World Bank Official Website: http://www.worldbank.org/en/news/press-release/2014/07/24/loan-connect-households-egypt-natural-gas- retrieved 11/6/2015/

[20] Executive Summary ESIAF NG Connection 1.1M HHs- 11 governorates- March 2014

[21] http://crudeoilpeak.info/23-of-egypt%E2%80%99s-oil-is-gone-20-years-after-its-peak/

[22] http://www.egyptindependent.com/news/egypt-officially-becomes-gas-importing-country-meet-demand/

[23] http://www.originalgreenenergy.com/whynaturalgas/energyefficiency/

[24] Zeke Hausfather: Climate Impacts of Coal and Natural Gas-http://static.berkeleyearth.org/memos/climate-impacts-of-coal-and-natural-gas.pdf , 2014

[25] Atlantic Consulting(an independent, privately-owned firm based in Zürich and London, specializes in the assessment of environmental impacts): LPG's Carbon Footprint Relative to Other Fuels, A Scientific Review, 2009- http://www.aegpl.eu/media/21020/atlantic%20consulting%20scientific%20review%20carbon%20footprint,%20ed.%202009.pdf

[26] Ministry of Electricity and Renewable Energy in Egypt, Official Annual Report, 2012

[27] http://www.dangersoffracking.com/

[28] The same reference (26)

[29] The same reference (26)

[30] The same reference (26)

[31] The same reference (26)

[32] The same reference (26)

[33] http://www.bbc.com/news/world-europe-16626580

[34] http://blogs.scientificamerican.com/observations/france-becomes-first-country-to-ban-extraction-of-natural-gas-by-fracking/

[35] http://www.ogj.com/articles/uogr/print/volume-3/issue-1/new-york-state-decides-to-ban-hydraulic-fracturing.html.

[36] http://thedailynewsegypt.com/2012/07/26/shell-to-invest-600m-in-western-1./desert-operations

[37] http://eipr.org/en/pressrelease/2012/09/19/1492

[38] https://www.youtube.com/watch?v=1KqWUF0X0Rw + https://www.youtube.com/watch?v=NwfSltELXr4

[39] http://eipr.org/sites/default/files/pressreleases/pdf/eipr_fracking_brief_ar.pdf

Results of Part One: The general criteria of central utilities in Egypt is being high to moderately efficient but complicated, land consuming and heavily subsidized by the government. Some utilities are more efficient than others while some are more available or more sustainable. The following table views the main evaluation results as estimated by the researcher based on previous data and analysis:

Utility/ Evaluation Parameter	Water	Wastewater	Electricity	LPG	Natural Gas
Feasibility	C	C	C	C	A
Efficiency	D	E	C	C	B
Equality of Distribution	B	E	B	B	E
Sustainability	B	E	F	F	F
Land Use	D	F	D	B	D
Impact on Urban Planning	D	F	C	B	D

Positive / Negative

Table(21): Evaluation of present utilities in Egypt as estimated by the researcher, based on data and statistics in Chapter One.

The following chapter will view the suggested off-grid utilities to compare their performance with the existing utilities for better architecture in Egypt.

Part (II)

Viewing Decentralized Utilities' Technologies and evaluating them by the parameters of:
Economy, Efficiency, Sustainability, Suitability, Land Use and Impact on Urban Planning

Introduction to Part (II)

Scientists and manufacturers have developed many technologies for off-grid building utilities. Some of these technologies have been in service for more than 60 years. Hundreds of researchers have examined these technologies to evaluate its efficacy and performance. They have developed many modifications and improvements for these utilities to maximize its quality and minimize its environmental footprint. These technologies have been in market for years, with many trade names.

This part is divided into 4 chapters as follows:

1- **Chapter One :** Off-grid water supply technologies.

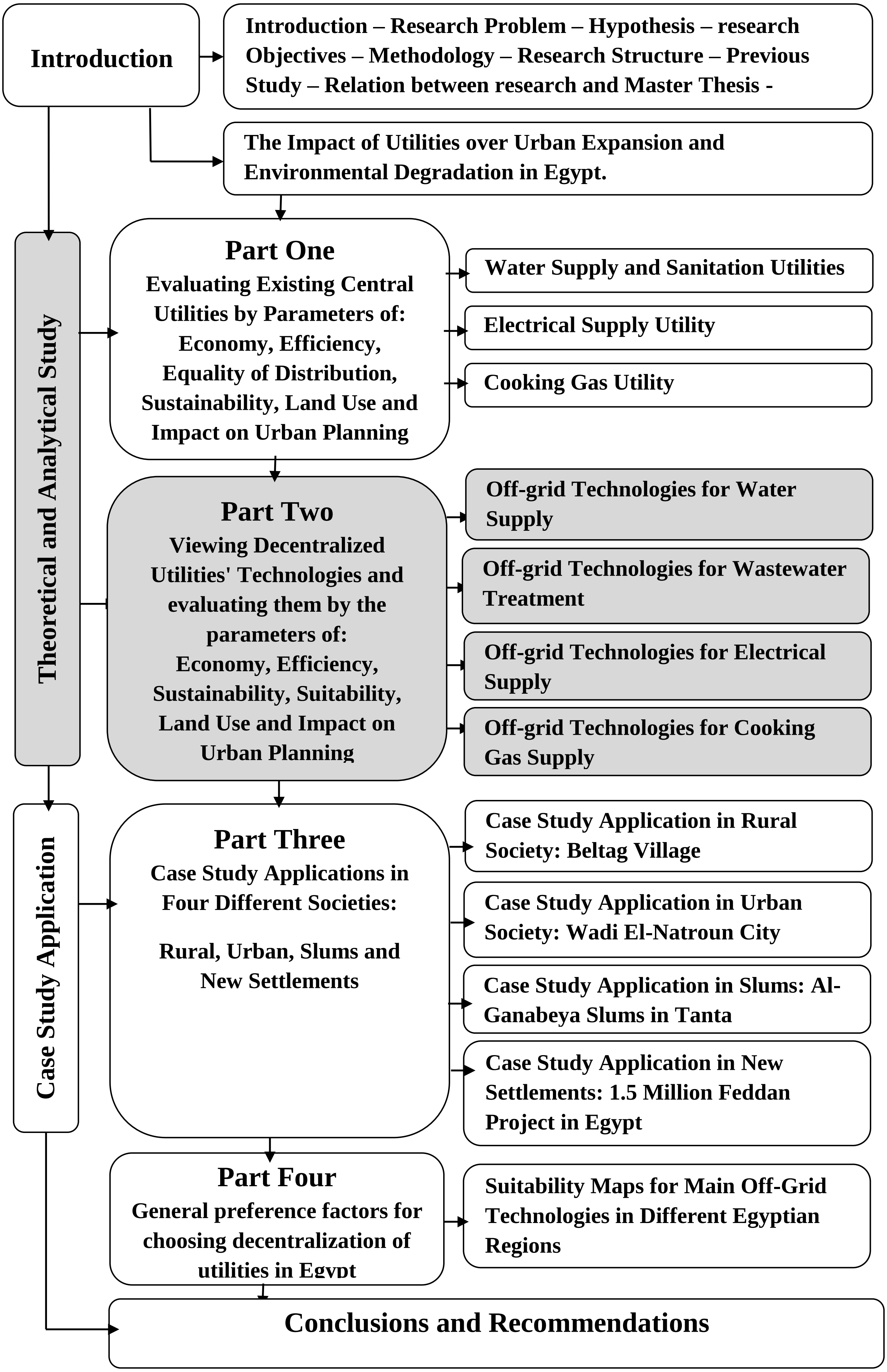
2- **Chapter Two:** Off-grid wastewater treatment technologies.

3- **Chapter Three:** Off-grid electrical supply technologies.

4- **Chapter Four:** Off-grid cooking gas supply technologies.

In each chapter, we shall present some of the most common off-grid utilities used worldwide, with evaluation of its suitability and performance. Using the parameters of: Economy, Efficiency, Sustainability, land use and Impact on Urban Planning, as well as their Suitability for Egyptian use.

End of Introduction to Part II


Introduction
Introduction – Research Problem – Hypothesis – research Objectives – Methodology – Research Structure – Previous Study – Relation between research and Master Thesis -
The Impact of Utilities over Urban Expansion and Environmental Degradation in Egypt.
Theoretical and Analytical Study
Part One
Evaluating Existing Central Utilities by Parameters of: Economy, Efficiency, Equality of Distribution, Sustainability, Land Use and Impact on Urban Planning
Water Supply and Sanitation Utilities
Electrical Supply Utility
Cooking Gas Utility
Part Two
Viewing Decentralized Utilities' Technologies and evaluating them by the parameters of: Economy, Efficiency, Sustainability, Suitability, Land Use and Impact on Urban Planning
Off-grid Technologies for Water Supply
Off-grid Technologies for Wastewater Treatment
Off-grid Technologies for Electrical Supply
Off-grid Technologies for Cooking Gas Supply
Case Study Application
Part Three
Case Study Applications in Four Different Societies:
Rural, Urban, Slums and New Settlements
Case Study Application in Rural Society: Beltag Village
Case Study Application in Urban Society: Wadi El-Natroun City
Case Study Application in Slums: Al-Ganabeya Slums in Tanta
Case Study Application in New Settlements: 1.5 Million Feddan Project in Egypt
Part Four
General preference factors for choosing decentralization of utilities in Egypt
Suitability Maps for Main Off-Grid Technologies in Different Egyptian Regions
Conclusions and Recommendations

Part (II)- Chapter (1)

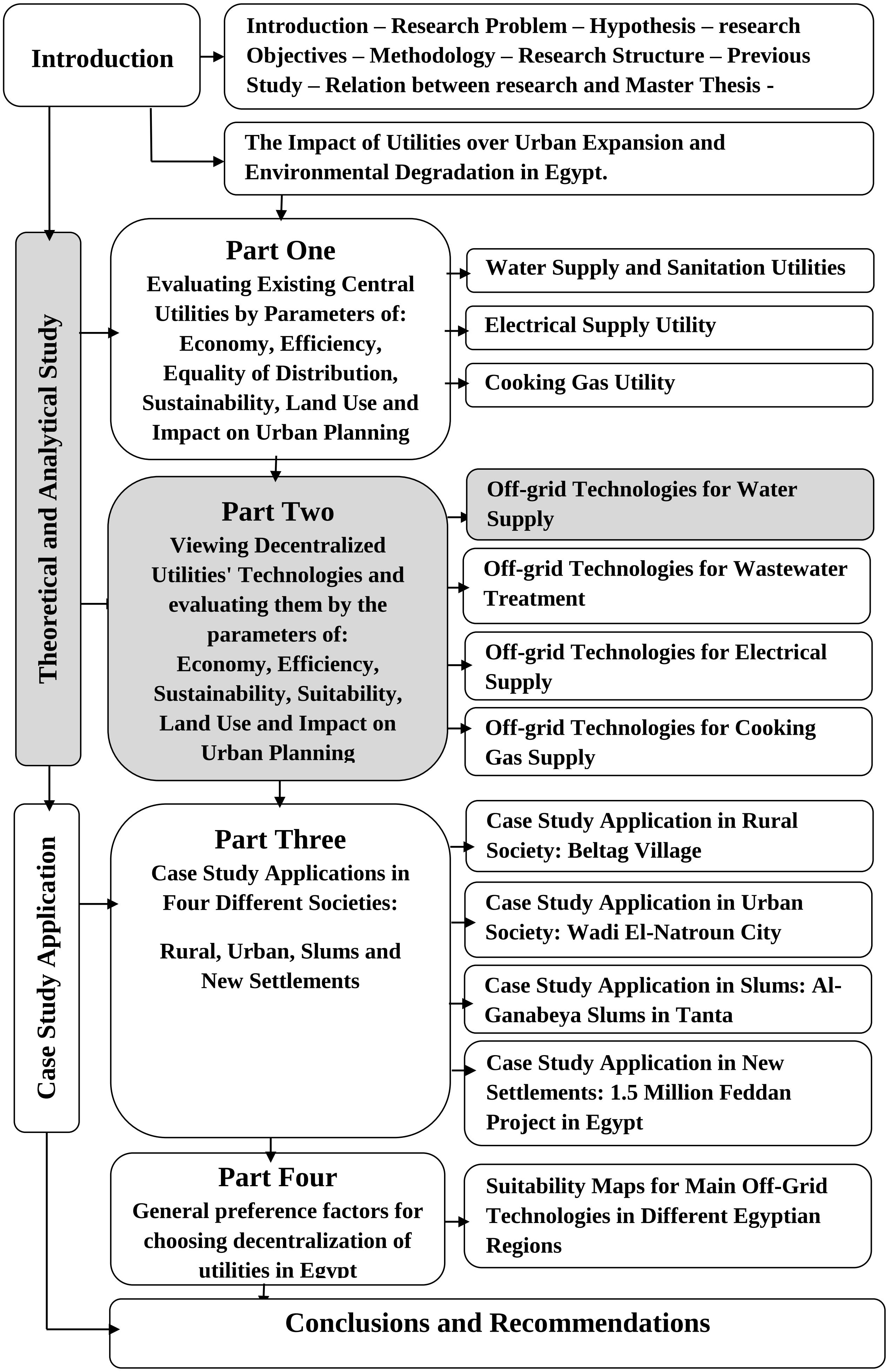
(2-1) Off-Grid Water Supply Technologies for Household Uses:

Introduction to Chapter 1

Whenever municipal water is not available in Egypt, people tend to use groundwater as an alternative. But is groundwater suitable for domestic use in Egypt, the gift of the Nile? That's what we are discussing in the first pages of this chapter.

Later on, we shall view the technologies used worldwide for groundwater extraction, desalination, filtration and recharge. These technologies are evaluated using the parameters of:
economy, efficiency, sustainability, land use and Impact on urban planning, as well as their suitability for application in Egypt.

End of Introduction to Part II- Chapter (1)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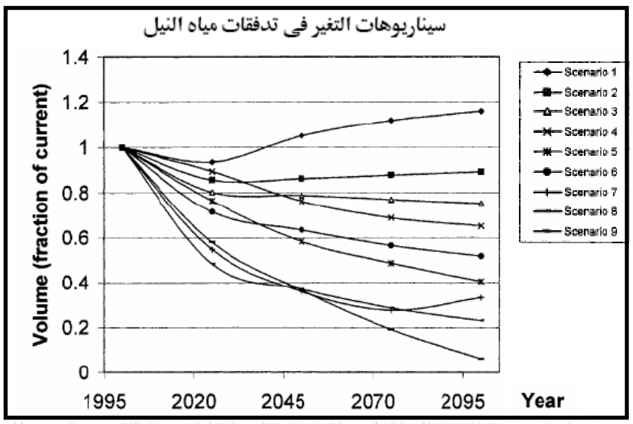
(2-1) Off-grid water supply in Egypt:

(2-1-1) Suitability of groundwater use in Egypt: Groundwater is the sole and essential source of water in the "Egyptian desert" that constitutes 95% of Egypt's total area[1]. Its suitability for consumption depends on many factors that are discussed in this chapter:

a- Vitality and Importance:

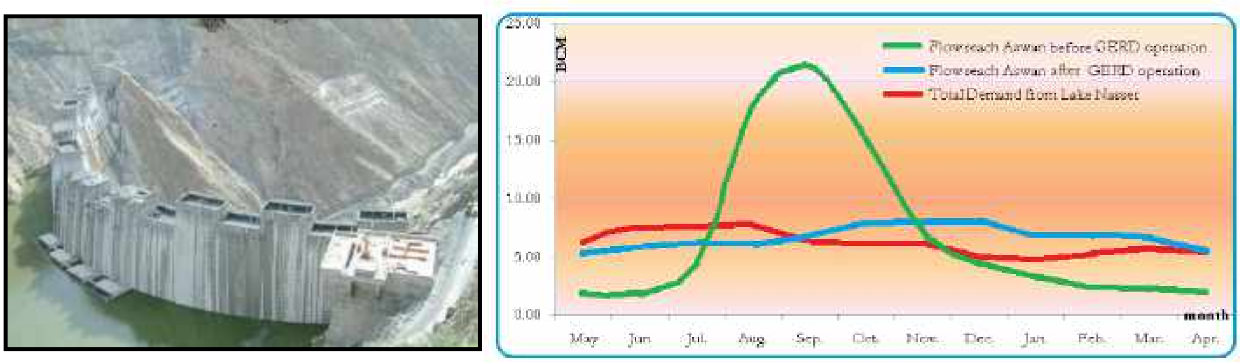
The reliance on groundwater as a main water source is becoming vital in Egypt for two reasons: the climatic change and the Renaissance Dam. A study conducted in 2001 about the impact of climatic change on river Nile's flow, concluded that the flow is going to shrink gradually till 2095 due to inclining global temperature. The expected decline of Nile flow was shown in eight of nine scenarios as shown in figure (139)[2].



Fig(141): Nile flow expected scenarios till year 2095 with the expected climatic changes

Strzepek, K., Yates, D.N., Yohe, G., Tol, R.J.S. and Mader, N. (2001): Constructing Not Implausible' Climate and Economic Scenarios for Egypt. Integrated Assessment 2, 139-157

On the other hand, the Ethiopian Great Renaissance Dam (GRD), if accomplished, may cause serious reduction in Nile flow, estimated by 3 meters of level reduction. It is also expected to affect Egypt's electricity supply by 25 to 40 percent[3] The expected decline of



Fig(142): The Renaissance Dam (left) and its expected impact on Egypt by showing the Nile flow reaching Aswan before & after the dam construction, compared with total Egypt's demand of water from Lake Nasser (right).

Sayed M. Ramadan, Abdelazim M. Negm, Mustafa Smanny & Ahmed Helmy: nvironmental Impacts of Great Ethiopian Renaissance Dam on the Egyptian Water Resources Management and Security. The 23rd. International Conference On: Environmental Protection is a Must 11 – 13 May

Nile water reaching Aswan Dam after the operation of Renaissances Dam is shown in fig(140). So the augmentation of reliance on groundwater consumption in Egypt is being a must.

b- **Availability and Reserves:** Egypt is blessed in fresh groundwater water reserves. A study conducted in 2014 showed that Egypt and Sudan combined groundwater potential is 118 million km^3, forming about 18% of Africa's total groundwater reserves[4]. Another hydrological study lead by British geologists indicated that ground water reserves in Egypt, if compared with its 55 bm^3 per annum Nile water quota, equals the sum of flow of Egyptian Nile water share of 1,000 years or more, see figure(141)[5]. It means that if Nile water flow dries up by some inexplicable natural and/or man-made factors, and the whole quantity of estimate groundwater in Egypt and Sudan is fresh and extractable, then the two nations can lead life for millennia without change to present water usage[6]. This bless belongs to Egypt and Sudan almost alone. Except these two countries, other Nile riparian states have insignificant groundwater reserves[7].

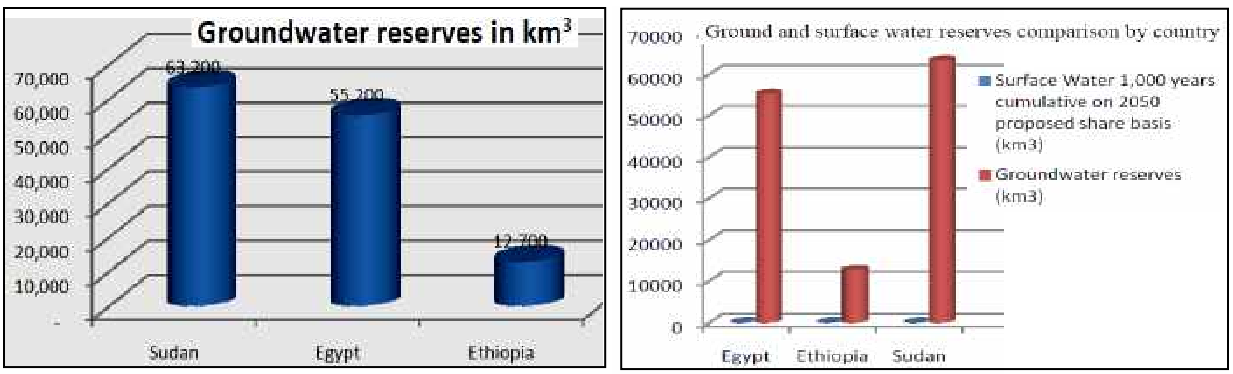
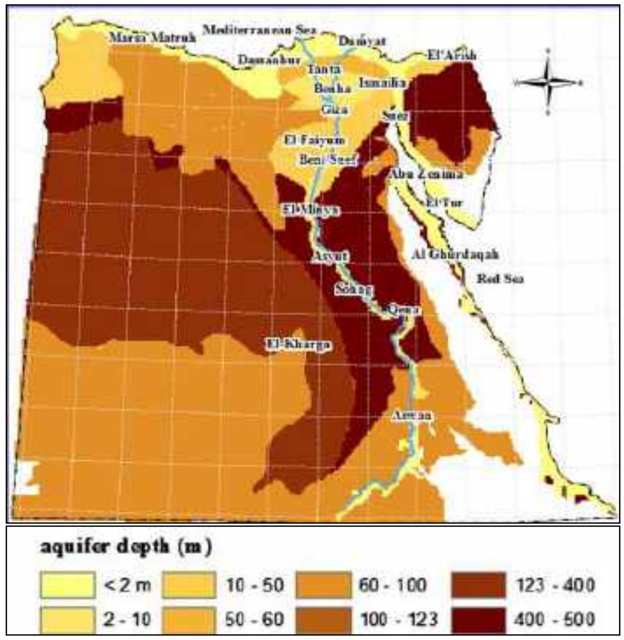


Fig (143): (a) Groundwater reserves in km3 in Egypt compared with Sudan and Ethiopia (b)Comparing groundwater reserves with surface water flow in 1000 years in Egypt, Sudan & Ethiopia

MacDonal A M and et.al,: Quantitative maps of groundwater resources in Africa, iopscience.iop.org

c- **Accessibility & Depth of Extraction:** Ground water depth is an important factor that identifies the feasibility of extraction. Aquifers in Egypt are considered very shallow (< 2 m) in the Nile valley, Delta and the North coast regions. Depth increases (2 to 50 m) in sub-coastal region and south western quarter (AlGulf AlKabeir). It gets much deeper (100 to 500 m) in the Middle East and the center of Sinai Peninsula, fig (143). Groundwater sometimes rises up to the surface without extraction like shown in the picture captured in Siwa oasis, fig (144).

Fig (144): Groundwater rises up to the surface in Siwa,
www.egypttours.com



Fig(143): Groundwater depth level in Egypt
www.hydrologicalmpas.com

Although being shallow in Delta region, groundwater is better extracted from deep intake (25 to 50 m), as shallow water in this region is mostly contaminated due to excessive use of fertilizers, pesticides and herbicides[8].

d- **Soil Transmissivity:** Another main factor that affects the cost of extraction is soil transmissivity. High transmissive soil requires less power for extraction. Soil transmissivity is moderate to high in main groundwater aquifers in Egypt. It starts with 200 m/day in "Al-Arish" coastal region and reaches 250,000 m/day in North Delta region as shown in table (22)[9]. High transmissivity makes extraction feasible and economic in Egypt.

Hydrogeological characteristics of main aquifers

Aquifer	Location	Depth to ground water level, m	Transmissivity, m/d
Nile Valley and Delta	Nile Valley	0–5	5000–10,000
	South Nile Delta	0–5	5000–10,000
	North Nile Delta	0–3	5000–250,000
Coastal Aquifer	Med. Coast	15	
	Qaa Plain	50–70	300–800
	Arish	0–30	200–1000
Nubian Sandstone Aquifer	Western Desert	0–30	1000–3000
	Kharga	0–20	2500–4000
	Dakhla	0–20	9000–15,000
	Bahariya	Flowing	5000–10,000
	Farafra	20–30	1000–2500
	E. Oweinat		
	Eastern Desert	Flowing	—
	Aish El Malha		
	Sinai	200	—
	Nakhl	Flowing	—
	Ain Mussa		
Moghra Aquifer	W. El Natrun	100	—
	Qattara Depr.		
Fissured carbonates	Helwan/Wadi Araba	Flowing	—
Hard rocks	South Sinai	+50	—
	Eastern Desert		

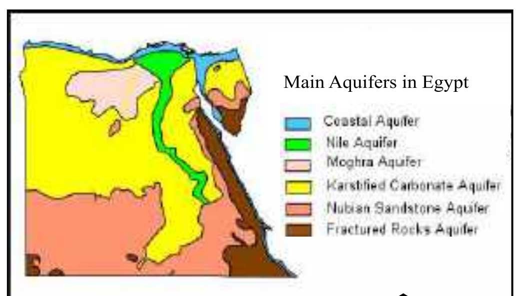


Fig (145): Distribution of main groundwater aquifers in Egypt
Source: Ref. No. 8

Table (22): Soil transmissivity in main aquifers in Egypt (m/day)
Source: Hefny et. al., 2007 – Reference No. 9

e- Salinity:

Salinity is a basic parameter for measuring water quality and suitability for consumption. It is commonly measured by part per million (ppm).[10] The main classifications for salinity levels are:

- Fresh water (typical city water in United States) : < 1000 ppm
- Brackish water, mildly : 1000 - 5,000 ppm
- Brackish water, moderately: 5000 - 15,000 ppm
- Brackish water, heavily : 15,000 - 35,000 ppm
- Sea water : 30,000 - 50,000 ppm (approx. 35,000).[11]

"Brackish water" is slightly saline water that can be used in all household activities (e.g. washing and bathing) but must be filtered before human ingestion (e.g. drinking & cooking). Heavily brackish water may not be suitable for cleaning, unless desalinated, due to its heavy soap consumption. Desalination can be done by solar desalination systems as shown later.

In Egypt, groundwater is mildly brackish (1500 -5000 ppm) in almost 91.6 % of total area. Only 8.4 % of Egypt has moderately brackish groundwater (5000-15000 ppm), basically located in the Middle Delta due to agriculture activities, and behind the western north cost due to sea water intrusion, see fig (146).

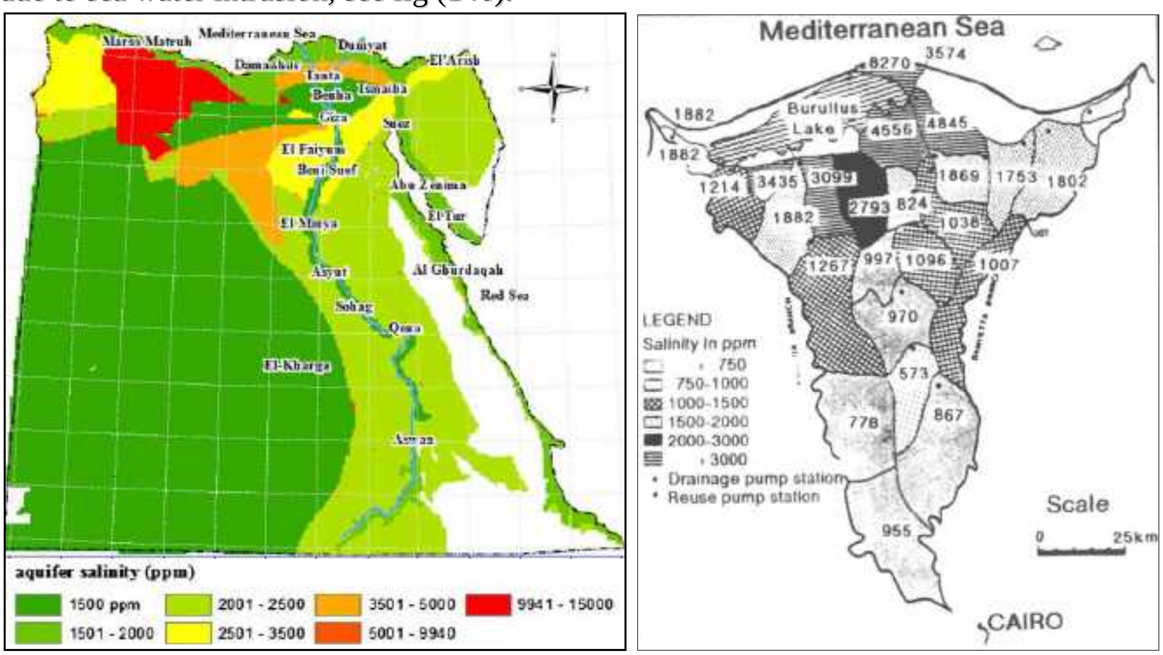


Fig (146): (a) Groundwater salinity map of Egypt (b) Groundwater salinity map of Delta Region

(a)www.hydrologicalmpas.com (b) Abo-Zeid and Biswas 1990

The map indicates that most Egyptian regions contain light brackish groundwater that is ready for household uses without pre-desalination, however, just like municipal water, must be treated before ingestion.

Comparing groundwater to Nile surface water, Nile water's salinity begins with 250 ppm at Aswan and reaches 2,700 ppm at the Delta barrages,[12] where after, salinity reaches 8,250 ppm at the end points (Damietta & Rasheed) due to heavy pollution from residential, agricultural and industrial activities.[13]

f- Need for Treatment:

Water purity is a main parameter of quality and suitability for human consumption. Treatment is needed if water is brackish or polluted. As mentioned before, shallow groundwater in Delta region (< 25 meters) is mostly polluted with fertilizers and pesticides so it must be treated before drinking. Also brackish water is not suitable for drinking and must be desalinated first. But how much of domestic water is really used in drinking and needs pretreatment?.

According to international statistics, household water consumption is 120 liter/capita (90 in rural and 150 in urban houses), mainly divided into 3 categories:

- 3.2 % for cooking and drinking, so it must be fresh (< 1000 ppm) and purified.
- 77.8 % for bathing, washing and cleaning, which needs fresh or mildly brackish water (1000 - 5,000 ppm).
- 39 % for toilet flushing, garden irrigation, carwash, etc., which may be done with greywater recycled from the house.[14]

In Egypt, the average per capita consumption of water is even less, reaching 90 liter/capita/day in urban areas and 45 to 55 liter/capita/day for rural areas. Water uses are also different, less than 1% of municipal water in Egypt is used for human consumption, while the rest is consumed in bathing, cleaning, leaks and washing cars.[15]

Fig(147): Nile water Salinity in ppm.

Designed by the researcher based on data from: Drainage Research Institute yearbook 1995/1996

So, only 1 % of our household water needs desalination and treatment before consumption while other uses can depend directly on raw groundwater as the salinity is within accepted as mentioned before.
Just like municipal water, it is not safe to drink raw extracted groundwater. Drinking water must be treated, filtered or purchased from a trusted source.

Fig (148): Private groundwater pump in Assiut
Water Management Building on Fluid Availability, Sep.2009

Fig(149): International per capita household water uses
Source: www.fryslanleeftmetwater.nl

g- Cultural Acceptance:

A massive number of Egyptian families already use groundwater as a main water source. Even with central water supply available, some people believe that well water is healthier and cleaner. Millions of private artesian wells and pumps are installed allover Egypt as shown in fig(..).Groundwater also contributes already in 11% of total irrigation uses in Egypt as shown in fig(..).[16]

A study conducted by the UNICEF in 2010 stated that 49% % of rural Egyptian families get their household water from wells and pumps, compared with 12% of urban families, both categories form a total percentage of 30% of total Egyptian population as seen in table (23).[17]

Proportion of the population obtaining drinking water from boreholes and dug wells, urban and rural, 1980 and 2010

	Urban %		Rural %		Total %	
	1980	2010	1980	2010	1980	2010
Boreholes	6	8	29	30	19	18
Dug wells	5	4	27	19	18	12
TOTAL	11	12	56	49	37	30

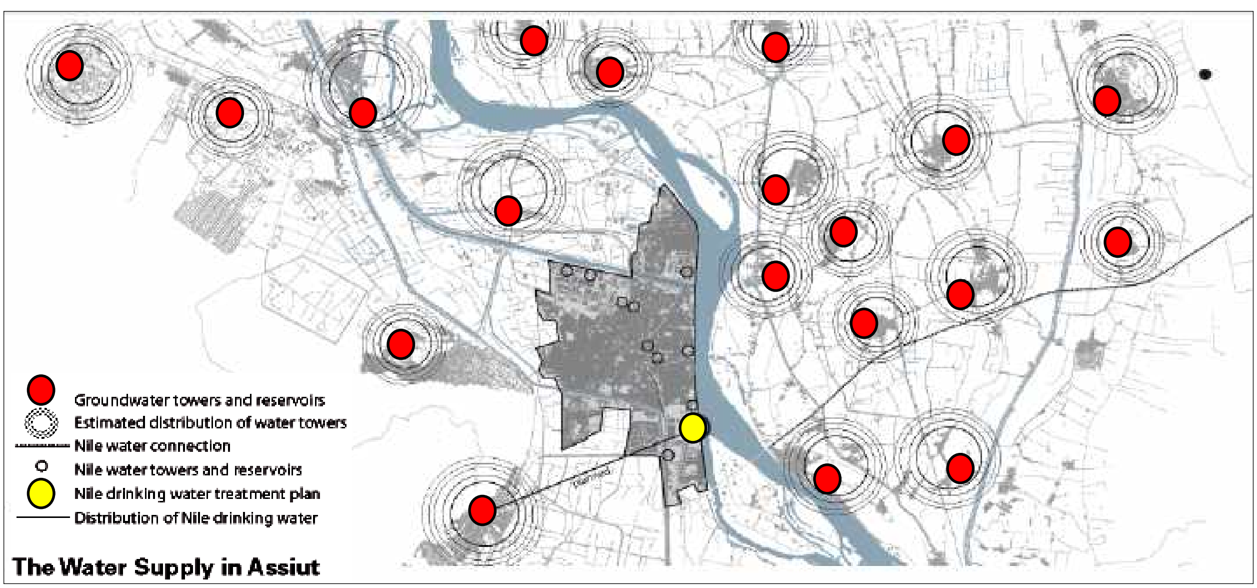
Table (23.): Proportion of population having drinking water from groundwater wells in Egypt, 1980-2010
Source: Progress on Drinking Water and Sanitation, 2012 Update, 2012. UNICEF, World Health Organization, p. 10

Groundwater is also a basic source for municipal water supply in Egypt. More than 14% of water stations in Egypt depend on artesian wells, especially in rural areas.[18] These stations depend on building a water tower besides pumps which simply draw deep groundwater and lift it to the tower where water simply flows by gravity to the village's grid. See fig(..) almost every village in Egypt has a water tower for water reservoir and supply.[19]

Fig(150): Municipal groundwater stations in rural Egypt

Water Management Building on Fluid Availability, Sep.2009

An example for the reliance on groundwater in municipal water supply is the Governorate of Assiut. Although located directly on the Nile bank, Assiut basically depend on groundwater for supplying all its villages. Only one station in the Governorate is supplied from the Nile. The main reason is that digging beneath the village is much cheaper than transporting Nile water to these villages as shown in fig(..).



Fig(151): Water supply stations in Assiut Governorate according to source of intake

Water Management Building on Fluid Availability, Sep.2009

(2-1-2) off-grid Technologies for groundwater use:

After showing the suitability of groundwater use in Egyptian household, we discuss the off-grid technologies that can be used for groundwater extraction, desalination and treatment.

(2-1-2-1) Off-grid extraction system:

Water extraction is commonly done in Egypt with diesel pumps due to low initial cost and subsidized fuel price. But diesel pumps usually cause air pollution and noise, besides that they can have high running cost in the future if fuel subsidies are reduced, and in the present when seasonal fuel shortages occur. That's why we introduce solar pumps as a sustainable alternative that is suitable for off-grid houses, especially for isolated areas where fuel is not easily obtained.

(2-1-2-1-A) Solar Pumps:

a- Description & Mechanism:

Solar pumps are simply water pumps powered by PV solar panels. Solar panels are used in gathering sun rays and transforming them into electricity to feed the pump. Water is extracted towards a storage tank, from which it flows by gravity to be used as shown in fig(..). Solar pumps can be applied to serve farms, buildings, neighborhoods or communities, according to type and scale of the system.

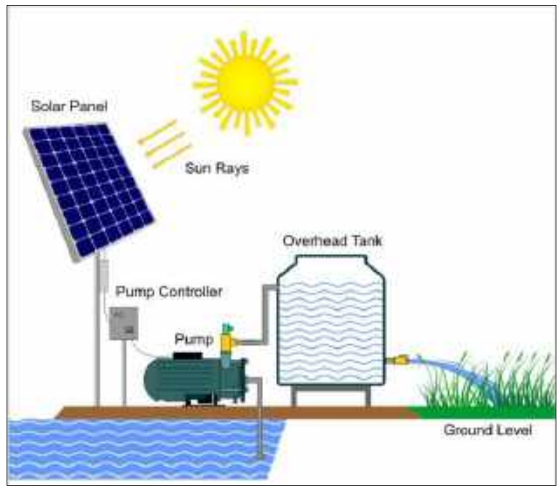


Fig (152): Typical solar pumping system
http://taiyosolar.in/images/surface%20pump.jpg

b- Cost: Solar pumps are known to be more expensive than traditional diesel pumps. A solar pumping system that pumps 25m³/day through 20m head requires a solar array of approximately 800Wp with an average cost of $6,000 FOB[20] including motors and pipes (2014 prices).[21] Although its initial cost is four times more than diesel pumps, solar pumps have almost zero running cost which makes them highly feasible over many years of application. A financial comparison was held between solar and diesel pumps over a 10 years period, showed that solar pumps total cost was 33% less than diesel pumps as shown in table (24).

Comparison in financial requirements between five PV systems and five diesel pump systems of increasing size				
System	**Total Capital Costs (US$)**	**Total Operating Costs (US$/year)**	**Total costs over a 10-year period**	**Total costs over a 20-year period**
PV 1 (2800 Wp)	18 188	600	24 188	30 188
PV 2 (4500 Wp)	27 470	800	35 470	43 470
PV 3 (6300 Wp)	37 398	900	46 398	55 398
PV 4 (10 000 Wp)	56 800	1400	70 800	84 800
PV 5 (15 000 Wp)	82 000	1600	98 000	114 000
Diesel 1 (3.5 KVA)	3840	5642	60 260	116 680
Diesel 2 (4.5 KVA)	4720	5864	63 360	122 000
Diesel 3 (6.3 KVA)	6050	6029	66 340	126 630
Diesel 4 (10.0 KVA)	8350	6307	71 420	134 490
Diesel 5 (15.0 KVA)	10 320	6593	76 250	142 180

Table (24): Comparing the financial requirements of 5 solar pumps & 5 diesel pumps of different sizes (2006 prices)

Odeh, I., Yohanis, Y., G., & Norton, B., (2006). Economic Viability of Photovoltaic Water Pumping Systems. Solar Energy Vol 80 (2006) pp. 850-860.

c- Efficiency: Solar pumps are highly efficient and can manage water extraction up to 200m head and with outputs of up to 250m³/day.[23] They have the privilege of long life and low maintenance, but if needed, maintenance requires skilled technicians with higher wages. On the other hand, solar pumps are susceptible to climatic conditions. For example, cloudy days may affect the extraction, so the storage tank's capacity must coup with such possibilities. Typical solar pump storage capacity is 3-5 days of water demand. In environments where rainy seasons occur, rainwater harvesting can offset the reduced output of the solar pump during this period.[23]

Type	Advantages	Disadvantages
Solar pumps	• unattended operation • low maintenance • easy installation • long life	• high capital costs • water storage is required for cloudy periods • repairs often require skilled technicians
Diesel and gasoline pumps	• quick and easy to install • low capital costs • widely used • can be portable	• fuel supplies erratic and expensive • high maintenance costs • short life expectancy • noise and fume pollution

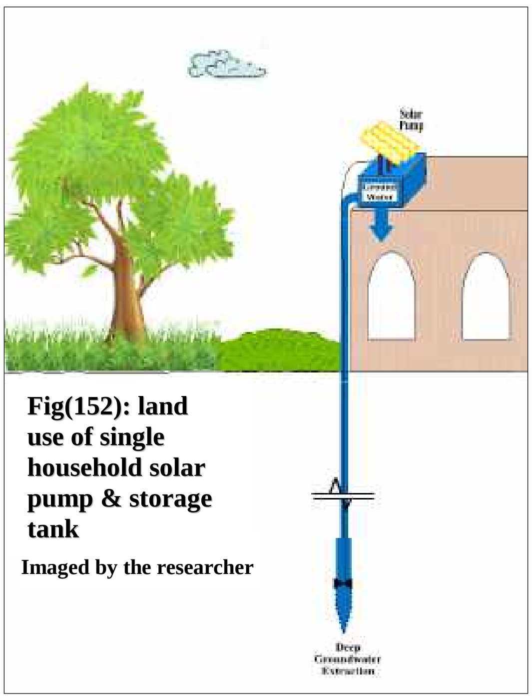
Table (25): Comparing the advantages and disadvantages of solar and diesel pumps

The Schumacher Centre for Technology & Development: Solar Pumps Technical Brief, Bourton Hall, Rugby, Warwickshire CV239QZ, UK, March 2014. www.practicalaction.org

d- Sustainability: Solar pumps are sustainable because they depend on clean and renewable source of energy. They generate zero pollution and cause no noise.

e- Land use & Impact on Urban Pattern: If installed on the roof of the served building, solar pumps can have minimal land use and no impact on urban pattern. Central pumps that serve a neighborhood or a community are usually installed at ground level so land use must be considered in designing and urban planning.

f- Suitability in Egypt: Egypt is blessed with high solar radiation as shown later in this research, which means high power yield per m^2 of solar panels. High soil transmissivity in Egyptian aquifers make extraction more feasible and requires less electric power.
Solar pumping system has started to be familiar in Egyptian market and has recently been adopted by the Egyptian government in irrigation projects in Toshky and Al-Wadi Al-Gadid as shown in fig (153).



Fig(152): land use of single household solar pump & storage tank

Imaged by the researcher

Fig(153): Solar pumps in Toshky, Egypt, 2010

http://i.ytimg.com

(2-1-2-2) Off-grid desalination systems:
Groundwater may need desalination before drinking if its salinity exceeds 1000 ppm.[24] Off-grid desalination can be performed by many technologies; like thermal distillation, electro dialysis, reverse osmosis and solar desalination systems. As we seek a sustainable architecture in Egypt, we introduce the solar desalination systems as the technology with minimal environmental impact.

(2-1-2-2-A) Solar desalination system: There are many solar desalination systems available in the market, but all depending on the same technology that imitates the natural hydrologic cycle, by using sun rays to heat saline water to produce water vapor, which condenses on a cooler surface and gathers in a distillate water tank. The same idea can be applied in simple and advanced models as shown below.

a- Description & Mechanism: The simplest model of solar distillers is the "greenhouse solar still", in which saline water is heated in a basin on the floor of the greenhouse, and the water vapor condensed on the sloping glass roof that covers the basin (Fig 154).[25] This model is very much affordable and best suited for small scale uses by a single family or small village where labor can be organized to maintain the unit.[26]

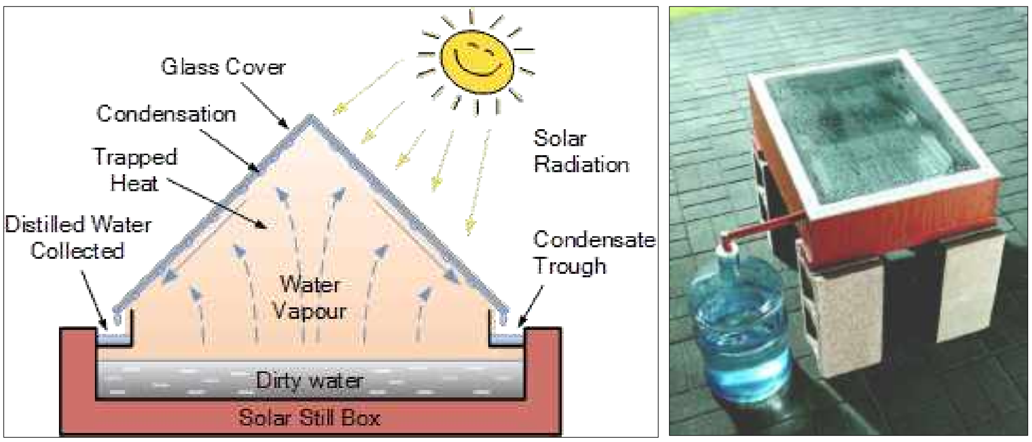


Fig (154): Greenhouse solar still system: (a) Concept and (b) Small scale application

(a) UNDTCD, 1985-reference No. 24 (b) https://www.pinterest.com/explore/solar-energy/

More developed models of solar desalination systems are available in the market. An example of these systems is the "Mediras" model, manufactured by a German company and applied in some Tunisian houses since October 2010. This system has a water production capacity of 120 l/day with a produced salinity of 200 ppm. The system contains a 6.5 m^2 solar collector and a 130 liter distillate tank. Produced water passes through a mineralization and disinfection unit powered by a 100 W PV panel, with a regular monitoring of water temperature, conductivity, PH and alkalinity as shown in fig(155).[27] This system is a small scale one with ability to serve a residential building dwelled by 5 to 7 families according to family size and habits.

Fig(155.):"Mediras" solar desalination model, http://www.mediras.eu/

Medium scale is applied in Masqat, Oman, serving 50 families with a production capacity of 930 L/day and a solar collector area of 40 m^2. Bigger scale is applied in Jeddah, Saudi

Arabia, with a 140m² solar collectors area and a production capacity of 5000 L/day of clear drinking water, serving about 250 Saudi families as shown in fig(156).[28]

Fig(156): Solar desalination systems applied in Mascat, Oman (left) and Jeddah, Saudi Arabia (right) http://www.solarthermalworld.org/sites/gstec/files/MAGE_WaMa_Intersolar_2010.pdf (left)http://www.dwc-

Bigger systems can produce up to 50,000 L/day, with roof area of 600 m^2. Accessory parts can be added on request like re-mineralization unit or disinfection device. See table (26).[29] Mega systems can serve 2500 to 3000 families according to habits and consumption of the dwellers.

Model	MiniSAL™ x2.0	MidiSAL™ x5.0	MegaSAL™ x10.0	MaxiSAL™ x50.0
Production Capacity	2'000 Liters of fresh water	5'000 Liters of fresh water	10'000 Liters of fresh water	50'000 Liters of fresh water
Installation Area	Pre-assembled insulated casing base area 2.40 m x 2.40 m	20' CSC container base area 2.44 m x 6.06 m	40' CSC container base area 2.44 m x 12.1 m	5 x 40' CSC container base area 2.44 m x 12.1 m
Absorption Area	96 m² absorber surface; net area requirement being approx. 150 m²	200 m² absorber surface; net area requirement being approx. 290 m²	400 m² absorber surface; net area requirement being approx. 600 m²	On request
Average power consumption per month	10 kW	20 kW	40 kW	200 kW

Table(26) : Qualifications of mega GMBH solar desalination model

Evaporation based solar desalination systems, Mage Water Management GMBH,Jan. 2012

b- Cost: The cost of solar desalination systems varies greatly according to size, capacity and development of the system. Developed systems for single household range in cost from (300 to 1500) US dollars (Sep.2015 prices).[30] Less developed systems can be locally made and with minimal cost. Running cost for both developed and local systems are very low compared with thermal desalination systems. Solar desalinators can work up to 20 years with little cleaning and maintenance and without parts' replacement. The augmentation of interest in solar systems and the increase of mass production by manufacturing companies, both are making solar desalinators more feasible and economic by time.

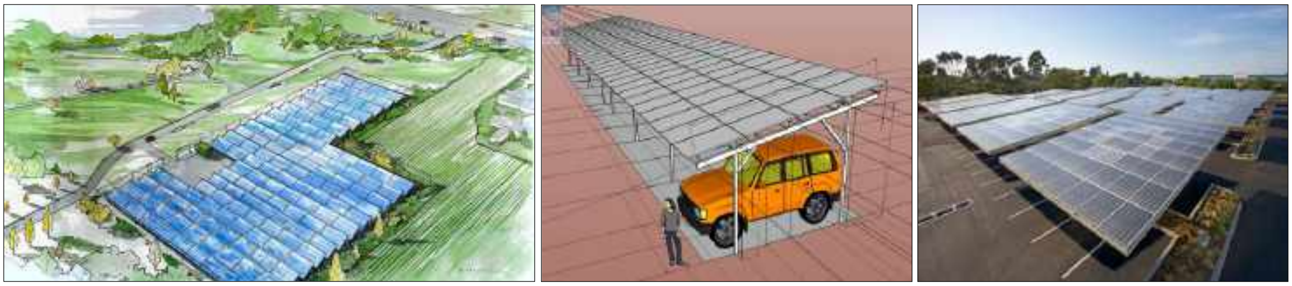
c- Efficiency: Solar desalinators can desalinate seawater and brackish water as well, with minimal maintenance required. Although produced water is fresh and free of dissolved solids, bacteria & organic contaminants, water may be tasteless and doesn't suit human drinking. Developed systems contain filtration and mineralization accessories to assure good taste and quality, but local or hand-made units for small scale system may not have the same technology. To solve the taste problem in local systems, distilled water can be blended by little clean brackish water to add salinity, or re-mineralized with a simple cartridge process using marble stones.[31]

d- Sustainability: Solar desalination of brackish groundwater in Egypt has a great potential with respect to the availability of the resource. Solar power is free and renewable while water is desalinated as much as needed without wasting any of it. All major aquifer systems in Egypt contain vast quantities of brackish groundwater that aren't exploited yet. The remaining solids and salt may be dried and sold for industrial purpose or to fisheries and shrimp farms.[32]

e- Land use & Impact on Urban Pattern: Small and medium scale desalination systems can be located on the roof of the served building so will have zero land use as shown in fig(157). Bigger systems serving a neighborhood or a district may be located in a central garden or upon the roof of a public building with a semi-central distribution system. In this case, urban designer must consider that the system cause minimal land use and use the solar panels as a roof to shade public activities (e.g. parking cars).

Fig(157) : Solar collectors for water desalination located over a residential complex in Odelzhaus, Germany

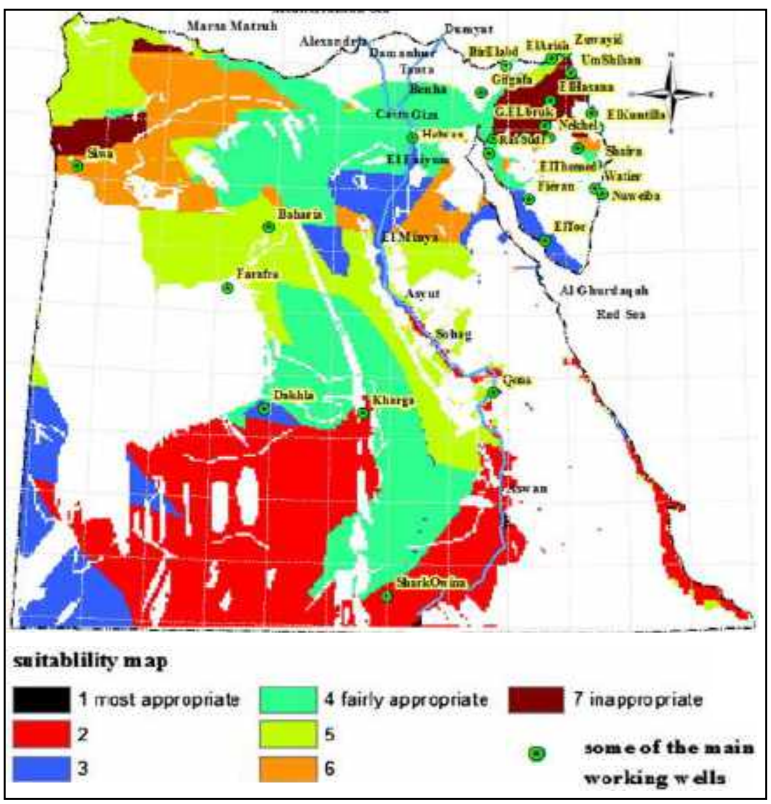
Evaporation based solar desalination systems, Mage Water Management GMBH,Jan. 2012



Fig(158): (a) Grouped solar systems land use: (a) Shading a public garden in Chicago, USA (b) Isometric for proposed use as car parking shading element (c) Public parking zone shaded with solar system in California, US

(a)http://bloximages.chicago2.vip.townnews.com/ **(b)** http://www.alicespringsairport.com.au/ **(c)** Bloomberg Business Week http://buswk.co/U8BACB

f- Suitability in Egypt: Adapting desalination system depends on many factors, e.g.: Sun exposure, water availability, salinity, and soil permeability. A study conducted in 2011 has measured the weight of these factors using GIS software program. It concluded that the most suitable sites for water extraction and desalination by solar systems are North cost and western desert. Suitability was categorized in 7 levels from most to not appropriate as shown in fig (159).[33]



Fig(159): Groundwater desalination suitability in Egypt –Source: Salim, 2011- reference No. 32

(2-1-2-3) Off-grid filtration and treatment system:

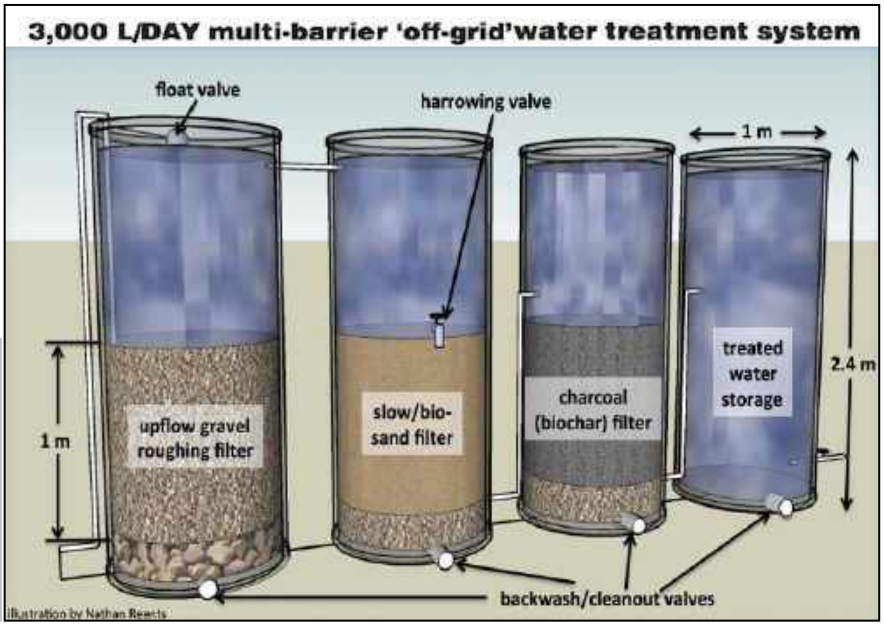
Both surface water and ground water need treatment and purification before human consumption. By 2017, River Nile will become one of the world's most populated river basins;[34] while groundwater in Delta region is contaminated by seepage from trenches and agriculture activities. The main contaminants in groundwater in Egypt are:

- E. coli (>100 MPN/100 mL), found at shallow depths in regions with highly vulnerable groundwater.
- Nitrate (occasionally 70-100 mg/L and expected to increase with time) in regions with highly vulnerable groundwater and intensive fertilizer application.
- Organochlorine pesticides in highly vulnerable groundwater, also at greater depths.
- Organophosphorus and carbamate pesticides, especially in shallow groundwater.
- Iron and manganese (mostly natural) and
- High salinity due to sea water intrusion and (locally) returns flow from irrigation.

Pollution is more severe on the edges and desert fringes of the Nile Valley and in the shallow portions of the aquifers underneath urban areas (domestic sewage). High concentrations of nutrients, E. coli, sulfur, heavy metals, etc. have been observed in the shallow groundwater, largely surpassing WHO standards for drinking water use.[35]

Residential Buildings' Filtration Model:

Filtration of drinking water can be as small as single faucet or as big as community filter as shown in fig.(..). Almost every Egyptian family has an indoor water filter. Most filters perform physical filtration using sand and gravel, followed by chemical filtration using charcoal. Some filters add biological treatment by killing bacteria using ultraviolet rays and chlorine. The simplest big-scale model for residential use is shown in fig(160).This filter can

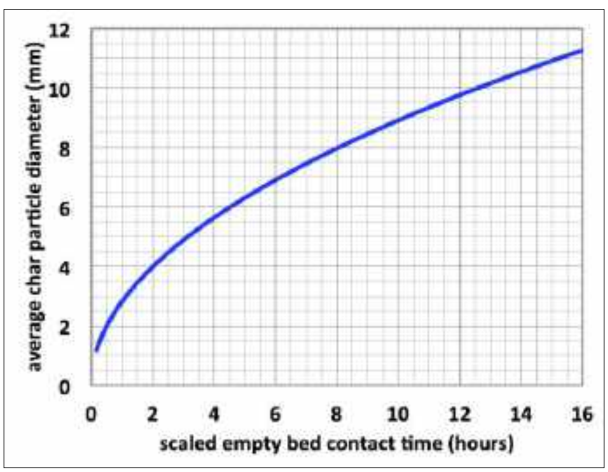


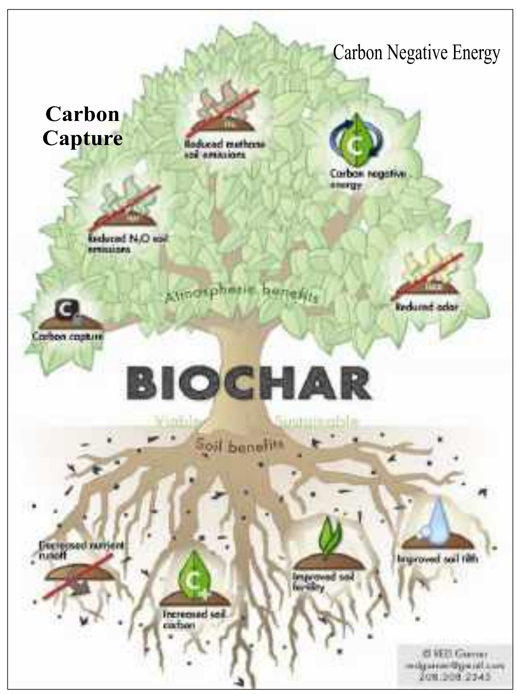
Fig(160): (up) single faucet scale filter (right) Community scale drinking water filter- **Source: (up) www.ecx.images-amazon.com/ (right) Josh Kearns: Sustainable Decentralized Water Treatment for Rural and Developing Communities Using Gasifier Biochar http://resiliencemovement.com/**

treat up to 3,000 liters/day which is a supply for 30 to 100 families. This model can be locally manufactured using low cost, readily available components. It requires a 55 gallon metal drum to make charcoal filter media and four 55 gallon plastic drums for water handling. Charcoal has been a part of water treatment for at least 4000 years, it remove most synthetic pesticides from drinking water[36] According to (Kearns 2015), this system produces a high quality drinking water and greatly reduces contaminate from pesticides and other synthetic organic compounds.[37]

Char particle size: An important factor influencing the uptake of trace organic contaminants by char is particle size. Small char particles exhibit more efficacious uptake of dissolved contaminants than large particles, owing to their greater exposed surface area and shorter distance of travel for contaminants migrating into pores. Thus char for use in water treatment should be crushed and sieved, ideally retaining the approximately 1-5 mm size fraction. Very fine char particles (powder) may lead to clogging, and so ideally should be removed by sieving and put to other uses (e.g. soil amendment, eco-sanitation cover material, etc.).

Reuse of filter's components: Unlike prefabricated filters, this locally-made filter has the advantage of sustainability. All its components can be reused in a sustainable manner. Sand and gravel can be used as land cover while charcoal can be used as a soil amender. Crushed and fine-grained charcoal is added to any kind of organic matter, (e.g.: manure, sludge or agriculture waste), making "Biochar". Biochar is an excellent soil enhancer that can hold





Fig(161): (up) Relation between charcoal particle size and required contact time for water treatment (right) Benifits of charcoal grains as soil fertilizer

Source (up) Kearns, 2015-Reference No.36
(right) http://www.biochar-international.org/

carbon in the soil, boost its fertility, increase biodiversity, while discouraging deforestation. Biochar also creates a fine-grained, highly porous charcoal that helps soils retain nutrients and water.[38]

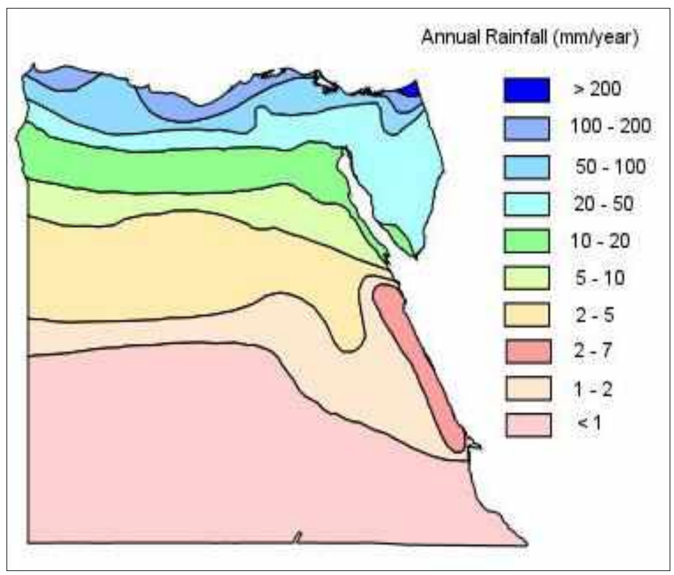
Recharging Groundwater:

There are some issues of concern regarding the groundwater extraction sustainability in Egypt. Calculating groundwater recharge rate is very important to assure that this valuable source will not be depleted soon.

- **Recharge Rate:** Groundwater is usually recharged by rain water and seepage from nearby water bodies. In Egypt, the first source is limited while the second is mostly saline (e.g. sea) or contaminated (e.g. canals and drains). Egypt is a very arid country with scarce rainwater. The mean annual rainfall is 18 mm, ranges from 0 mm/year in the desert to 200 mm/year in the north coastal region as shown in fig(162).[39]

On the other hand, seepage recharge is affected by the quality of seeping source. Groundwater is mostly brackish if seepage comes from a saline water body (e.g. sea or ocean), while it's mostly fresh if seepage comes from fresh water body (e.g. river or spring).

In Egypt, the seepage from nearby water bodies is limited in Nile valley and North coast regions. The seepage from Mediterranean is brackish while seepage from Nile is fresh but full of contaminants. Groundwater recharge in Nile valley and Delta is affected by contaminants from deep percolation of irrigation water and seepage from the irrigation system.[40]



Fig(162):Averageannual rainfall in Egypt (mm/year)

Source: http://environ.chemeng.ntua.gr

Egypt is among the least fortunate countries in groundwater recharge as seen in fig (162). This lack of water recharge in Egypt makes groundwater extraction almost unsustainable, unless recharge is done by human activities[41]. The most familiar technology worldwide for groundwater recharge is treated wastewater injection. Treated wastewater is injected in deep wells for water recharge and water level sustainability as seen in next part of this research.

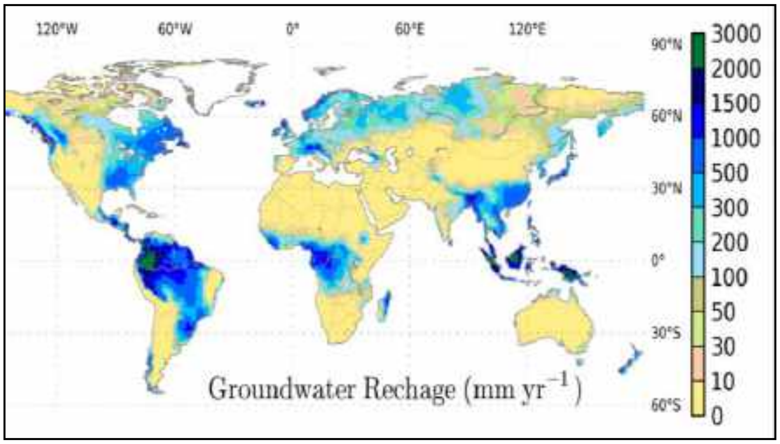


Fig (163): Groundwater annual recharge in Egypt compared to the World

Source: Tokyo University, Hydrological studies: http://hydro.iis.u-tokyo.ac.jp/~sujan/simage/figures/PartI/gwvars.png

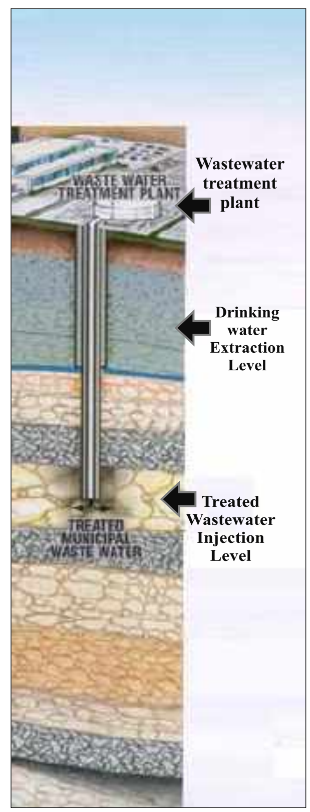
- Artificial Recharge System:

Artificial recharge or aquifer recharge with treated wastewater has been successfully used worldwide to control water depletion in overexploited aquifers. Preliminary estimates show that the implementation of wastewater recycling and reuse projects would lead to water savings of up to 5% of the total global irrigation water[4] . 2

How recharge is achieved?

There are many ways of artificial recharge, but the main two common ways are: **direct injection** and **indirect infiltration**. Direct injection is done by injecting treated wastewater into a deep well which directly leads to a layer that is far below drinking water extraction layer as seen in fig (164). This water is re-pumped for irrigation or industrial use afterwards. The selection of suitable locations for artificial recharge should be based on hydrogeological conditions, economic evaluation and environmental considerations.

Indirect infiltration is the most common groundwater recharge system, particularly for smaller flow applications. In this system, wastewater is primarily treated and then allowed to infiltrate into soil layers as seen in fig (163). Wastewater is physically and biologically treated by soil particles before reaching the groundwater table. This system requires a fair amount of land and soils with at least a

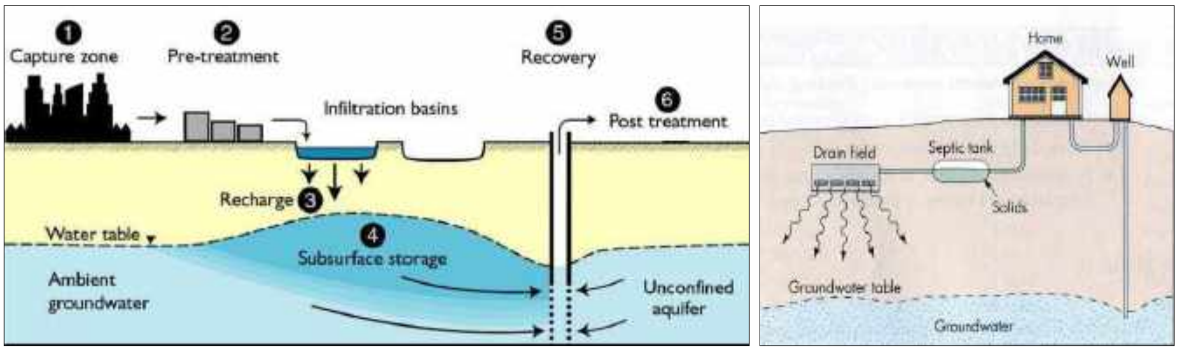


Fig(164): Direct injection system of treated wastewater into groundwater layers

Source: www.watersvstems.com

moderate permeability. They have minimal aesthetic impact on the landscape, but are fairly sensitive to treatment process upsets.

Water is then recovered and used again in irrigation without treatment or in household uses after treatment. It was found that this process improves the quality of wastewater by 85% as soil particles perform a physical and biological filtration for water before it reaches the groundwater beneath. This infiltration process is done either in mass scale by wastewater treatment plants or in small scale by household treatment unit as seen in fig (165).



Fig(165): Wastewater treatment and infiltration into soil in mass scale (left) and household scale (right) - Source: http://www.sswm.info

Part (II)- Chapter 1

(2-1) Off-grid water supply in Egypt

Summary of Chapter (1)

The importance of groundwater in Egypt is escalating due to certain climatic and political conditions.

Egypt is blessed with massive reserves of fresh and brackish ground water allover its land.

The feasibility of groundwater extraction depends on: depth, salinity, soil transmissivity and need for treatment.

Solar pumps can be very suitable for application in Egypt especially in desert areas and new settlements.

Desalination, if needed, can be performed using solar desalination systems.

Treatment is needed only for water used in drinking and cooking, which form about 3% of total household water consumption.

Water treatment can be performed using common commercial filters or grouped filtration systems which rely basically on gravel and charcoal for treatment.

Charcoal can be reused as soil amender after replacement.

Groundwater recharge must be considered to avoid depletion. Natural recharge by rainwater is very limited so artificial recharge must be applied.

The most common ways for artificial recharge is using treated wastewater as resource of replenish. Treated wastewater can be directly injected or gradually seeped into soil layers for more filtration.

Solar systems for extraction or desalination have minimal impact on the environment. Small scale units have minimal land use and zero impact on urban planning.

End of Summary of Part (II) Chapter 1

References of Part2- Chapter1:

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[18] The central water supply in Egypt depends on three main sources: the Nile and its canals (86%), artesian wells (14%), and desalination (negligible so far). http://www.tadamun.info/

[19] http://www.tadamun.info/

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Part (II)- Chapter (2)

(2-2) Off-grid Technologies for Household Wastewater treatment:

Introduction to Chapter 2

Wastewater treatment and management is the most important element in off-grid homes; If not properly managed, it can cause serious environmental problems and threats the health of generations to come.

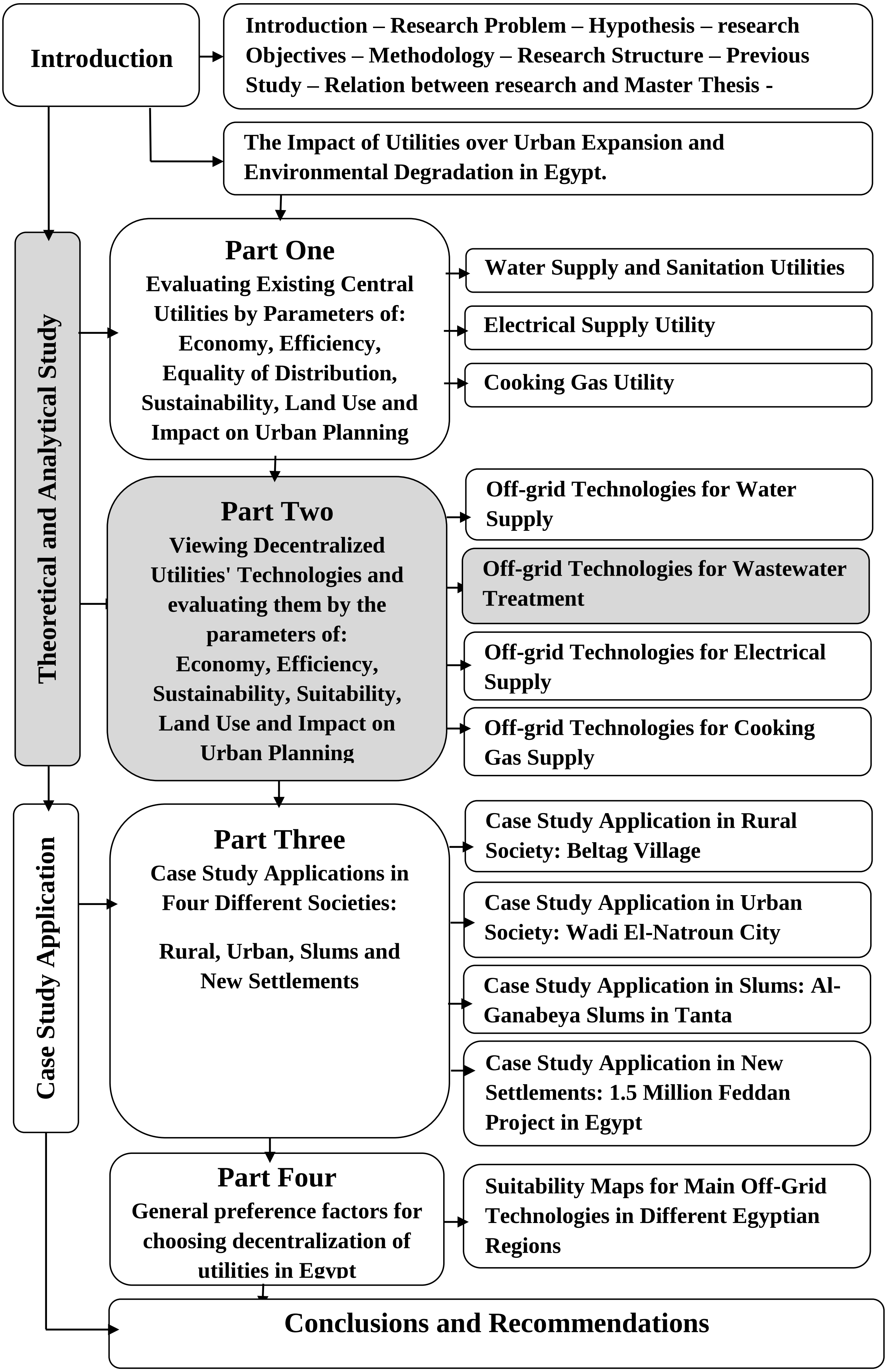
There are two main types of domestic wastewater: Grey and black water. Greywater is the effluent of hand-wash sinks and bathing tubs while blackwater is the effluent of toilets and kitchen sinks. Greywater is less pollutant and easy to treat as it contains basically soap, hair and non-degradable contents, while blackwater is more pollutant, containing human waste, food waste, oils and tissues, which are all organic and degradable. Grey water needs physical filtration and generates no strong odor, while blackwater needs biological treatment and generates strong and explosive gases like methane.

The separation of wastewater into grey and black usually makes it easier to treat each. But all central technologies can't do so because it depends on transporting wastewater to far treatment plants, which means that two pipes will pass in parallel, which duplicates the transportation cost. This problem is fortunately not present in off-grid treatment technologies because it depends on the onsite treatment, not transportation. All technologies mentioned in this chapter are designed for the treatment of mixed sewage (mixed black and grey water), but can be applied for each type separately.

Wastewater is commonly treated primarily, secondarily and in some plants tertiary. All these treatment stages can be performed by off-grid technologies as shown in this chapter.

These technologies are evaluated using the parameters of:
economy, efficiency, sustainability, land use and Impact on urban planning, as well as their suitability for application in Egypt.

End of Introduction to Part II- Chapter (2)

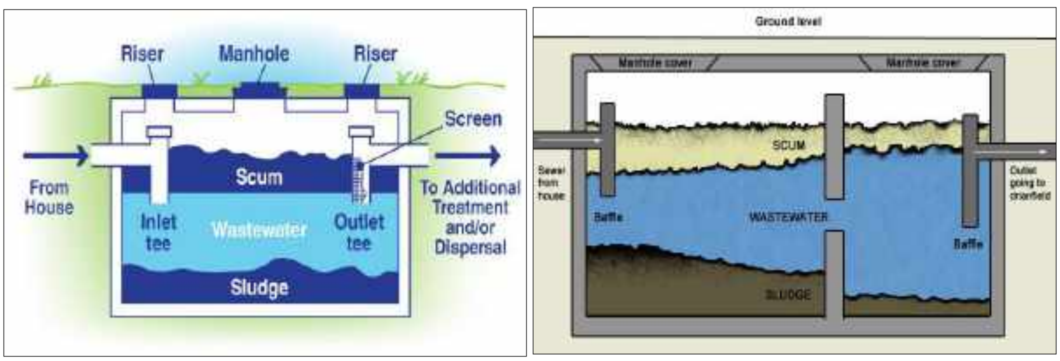

Introduction
Introduction – Research Problem – Hypothesis – research Objectives – Methodology – Research Structure – Previous Study – Relation between research and Master Thesis -
The Impact of Utilities over Urban Expansion and Environmental Degradation in Egypt.
Theoretical and Analytical Study
Part One
Evaluating Existing Central Utilities by Parameters of: Economy, Efficiency, Equality of Distribution, Sustainability, Land Use and Impact on Urban Planning
Water Supply and Sanitation Utilities
Electrical Supply Utility
Cooking Gas Utility
Part Two
Viewing Decentralized Utilities' Technologies and evaluating them by the parameters of: Economy, Efficiency, Sustainability, Suitability, Land Use and Impact on Urban Planning
Off-grid Technologies for Water Supply
Off-grid Technologies for Wastewater Treatment
Off-grid Technologies for Electrical Supply
Off-grid Technologies for Cooking Gas Supply
Case Study Application
Part Three
Case Study Applications in Four Different Societies:
Rural, Urban, Slums and New Settlements
Case Study Application in Rural Society: Beltag Village
Case Study Application in Urban Society: Wadi El-Natroun City
Case Study Application in Slums: Al-Ganabeya Slums in Tanta
Case Study Application in New Settlements: 1.5 Million Feddan Project in Egypt
Part Four
General preference factors for choosing decentralization of utilities in Egypt
Suitability Maps for Main Off-Grid Technologies in Different Egyptian Regions
Conclusions and Recommendations

(2-2) Wastewater Treatment Off-grid Technologies: Wastewater treatment is a main utility that affects human health and must be applied thoroughly. It is usually formed of 3 main stages: primary, secondary and tertiary:

(2-2-1) Primary treatment technologies: The main goal of primary treatment is to clarify wastewater from sediments and scum. Scum is generated from oil and grease waste as well as soap foam, while sediments are generated from solid particles disposed into wastewater either organic or nonorganic. The most common off-grid technologies used for primary treatment are septic tanks and anaerobic baffled reactors as shown below.

(2-2-1-A) Septic Tank:

(2-2-1-A-1) Description & Mechanism: Septic tank is a watertight storage container which is commonly used in off-grid buildings as a primary treatment method. It may have one or two chambers as shown in fig (166).



Fig(166): Single chambered septic tank (left) & double chambered one (right) with separation & polishing rooms

www.walex.com & http://www.usaplumbing.info

Septic tank performs two basic tasks: separation and sedimentation. Liquid flows into the tank where heavy particles sink to the bottom, while scum (oil, fat, surfactants) floats to the top. With time, the solids settling to the bottom are degraded anaerobically. The clarified liquid passes out of the septic tank through a (T-outlet) to prevent the discharge of scum or sludge. The effluent must then be secondarily treated before being discharged into the environment[1].

(2-2-1-A-2) Costs: Septic tank is an appropriate option where users show a moderate willingness to pay. The initial cost varies depending on the material used (brick, concrete, fiberglass) and availability of spare parts. Prefabricated fiberglass unit costs 150 $ / single household (2015 prices)[2], while building septic tank onsite can be much cheaper. Additional cost is added for desludging and potential repair though not expensive but must be considered. Table (27) [3] indicates the standard pumping frequency for septic tanks.

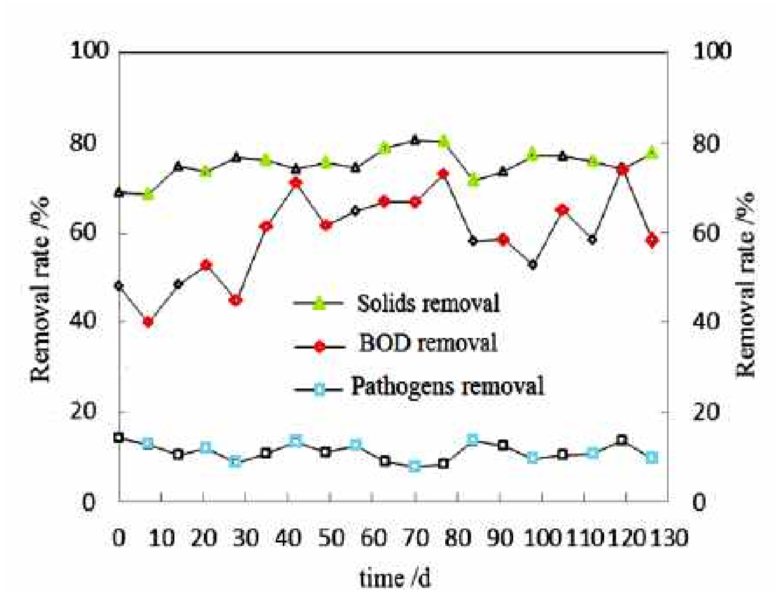
Fig(167):S.Tank pumping in London
http://weatherheadgroup.co.uk/

Tank Size (gallons)	Number of People Using the System				
	8	6	4	2	1
900	11	5	2	1	<1
1,000	12	6	3	2	1
1,250	16	8	3	2	1
1,500	19	9	4	3	2

Table (27): Estimated septic tank inspection and pumping frequency (in years)
Adapted from (Mancl, 1984) –Reference No. 3

(2-2-1-A-3) Efficiency: Septic tank delivers liquid sewage effluent to a secondary treatment system and stores solids and indigestible bits for pumping out every few years. Numerous anaerobic bacteria (water breathing bacteria like those living in the human gut) continue working to reduce some of the strength of the sewage.

- Removal efficiency: Single tanks can remove 60-80 % of solids, 40-78 % of BOD and 10-18% of nutrients, pathogens and metals, etc. Dual tanks even do better removal as they allow more clarification and anaerobic digestion of the sludge, which means better BOD and pathogen removal, see fig(168).[4]



Fig(168): Average removal efficiency of single chambered septic tank
Source:D'Amato, 2015 – Reference No. 5

On account of the delicate ecology of the system, care should be taken not to discharge strong chemicals into the septic tank. Sludge should be removed regularly to ensure proper functioning.

- Possible Failures: Septic tank can fail due to corrosion or crushing. Corrosion may occur in concrete and steel tanks, while plastic and fiberglass tanks are not susceptible to corrosion. Concrete tanks can also deteriorate due to exposure to hydrogen sulfide gas (rotten egg odor) produced by the anaerobic bio-chemical process. If the tank is manufactured using industry standard materials a mechanical failure is not likely to happen.

Crushing may occur due to human error, such as crushing or collapsing the tank with heavy equipment or improper installation. Earth movements and soil sliding may cause the same failure. Prefabricated tanks are usually more resistant, but not totally protected against these hazards. Biological failure may occur due to adding strong chemicals to wastewater. These chemicals may kill or weaken the bacteria working in the system.[5]

- Upgrading: A septic tank is usually connected to a leaching field or soak pit, but it can later be connected to a central sewer system if available. If central sewers are installed afterwards, it's better not to cancel the septic tanks, as they increase the capacity and efficiency of the central system and extend its lifetime.

(2-2-1-A-4) Environmental Impact: septic tank has some environmental concerns that must be considered during use, such as:

- Potential leak or overflow: The main environmental concern about septic tank is potential leak or overflow. Leaks may occur if body is cracked, and overflows may occur if the effluent exceeds design capacity. The best location of septic tank is where it is visible and adjacent to the house. If visible it would be easily monitored and maintained, and if adjacent to the house, pipes would be shorter so less breaking may occur. If located underground, the system is threatened with cracks due to differential ground movement, heavy vehicle traffics, careless construction practices, roots intrusion from trees, or soil pressure, etc. Prefabricated tanks are usually stronger and designed to resist these hazards.

- Odor and fire control: If used for black water treatment, users should be extremely careful when opening the tank, as noxious and explosive gases may be released. Tank's better location is upwind, to ensure odor control.

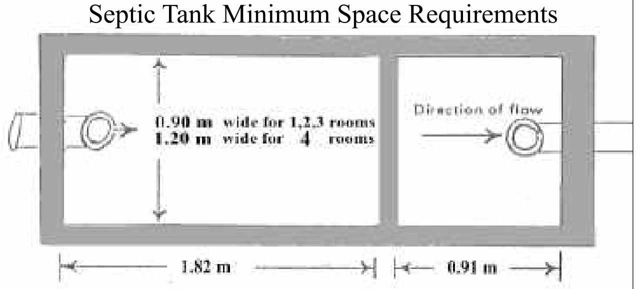
- Disludging: Disludging is commonly mechanical (by a vacuum truck) in two conditions: If the tank serves many families (e.g. a residential complex), and if it receives black water. If serving a single family or receiving only greywater, septic tanks are more likely to get manually vacuumed. EPA has strict safety guidelines for 'Manual Emptying' that should be followed.

(2-2-1-A-5) Land Use and Impact on Urban Planning: Septic tank is usually installed underground in front yard or backyard of the house so it has minimal land use. An ordinary house with 3 rooms would need a tank with dimensions of 0.9 x 2.75 meters as shown in fig(169).[6] Tank's depth ranges between 1 to 1.6 meters according to no. of users.

Septic Tank Capacities	
Number of Bedrooms	Minimum Septic Tank Capacity
1, 2, or 3	1000 gallons
4	1200 gallons
5 or 6	1500 gallons

Table(28): Minimum septic tank capacity based on number of served bedrooms
Murdock et. al – Reference No. 6

Septic Tank Minimum Space Requirements



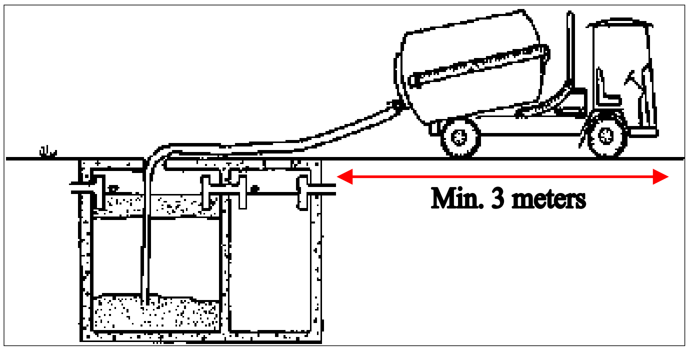
Fig(169): Minimum space requirement for dual septic tank
Murdock et. al – Reference No. 6

Tanks' dimensions are also affected with many design parameters, such as toilet style, flush flow, no. of rooms, no. of residents, culture of the inhabitants and climatic features. Table (28) shows the average recommended dimensions for septic tanks based on residents and toilet style.[7]

Number of residents	Amount of wastewater (m^3/d)		Septic Tank dimension recommended (m)			
	Old style toilet	Western-style toilet	Volume (m^3)	Depth (depth)	Width (m)	length (m)
5	0.1	0.3	1.5	1.00	0.90	1.70
5-10	0.2	0.6	2.0	1.00	1.00	2.00
10-15	0.3	0.9	2.5	1.25	1.00	2.00
15-20	0.4	1.2	3.0	1.25	1.10	2.20
20-25	0.5	1.5	3.5	1.25	1.20	2.40
25-30	0.6	1.8	4.0	1.40	1.20	2.40
30-35	0.7	2.1	4.5	1.50	1.20	2.50
35-40	0.8	2.4	5.0	1.60	1.20	2.60
40-45	0.9	2.7	5.5	1.60	1.30	2.60
45-50	1.0	3.0	6.3	1.60	1.40	2.80

Table (29): Septic tank dimensions based on the number of residents
Source: Wanasen, 2003 – Reference No. 7

Land is also required to perform desludging. If used for grey water treatment only, no space is required, as desludging may occur once every 3 or 5 years and commonly will be done manually. If black water is also treated, desludging will occur annually and probably not manually, so a vacuum truck should be able to access the location, see fig(170). Larger or multi-chamber septic tanks can be installed for groups of houses and/or public buildings, fig (170).



Fig(170): (a) Minimum space requirements for mechanical sludge removal (b) Installing S.T. for a multistory residential building in Indonesia, 2012

(a) Sandec 1995 (b) http://globalintifibertech.co.id

(2-2-1-A-6) Suitability: Septic tank is suitable for sites with limited land, remote sewers, light traffic, low economy and good ventilation. It isn't suitable for sites with heavy traffic, earthquakes or soil sliding. Almost all street types and urban patterns can host this technology, and almost all communities can get familiar with.

(2-2-1-A-7) Advantages:

- If tank is underground, it doesn't require a lot of land.
- Minimum amount of operation and maintenance.
- Semi-skilled or unskilled community labor is required.

(2-2-1-A-8) Disadvantages/Concerns:

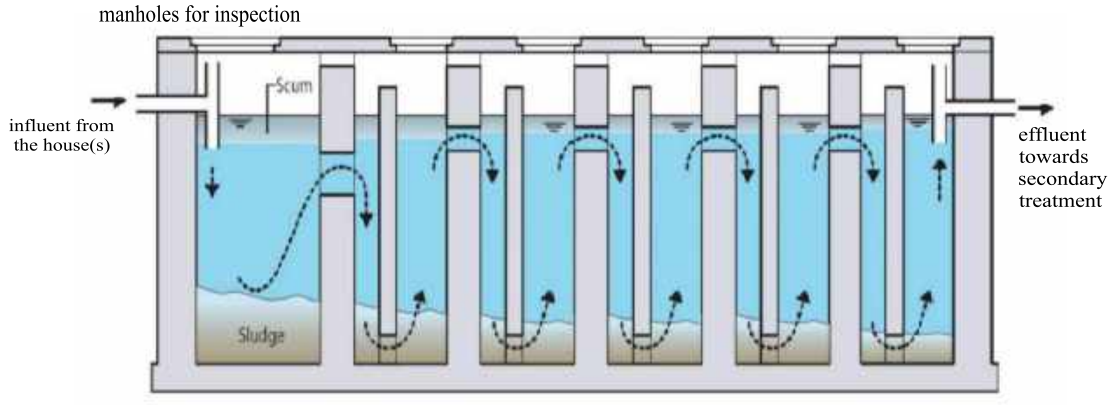
- Professional design and layout are required.
- Not all parts and materials may be available locally.
- Requires water for flushing.
- Minimum removal of organics and pathogens, unless secondary treatment is applied.

- Desludging may be needed annually. If only grey water is treated, desludging may be neglected.

Secondary treatment after Septic tank are usually done by dispersing effluent water in some way, e. g. a leaching field or soak pit.

(2-2-1-B) Anaerobic Baffled Reactor (ABR):

(2-2-1-B-1) Description & Mechanism: ABR is a small septic tank followed by a series of anaerobic tanks (at least three), allowing wastewater to gain more time in treatment process, see fig(171).[8]



Fig(171): Anaerobic Baffled Reactor (ABR) cross section

Suprihatin, 2014 – Reference No. 14

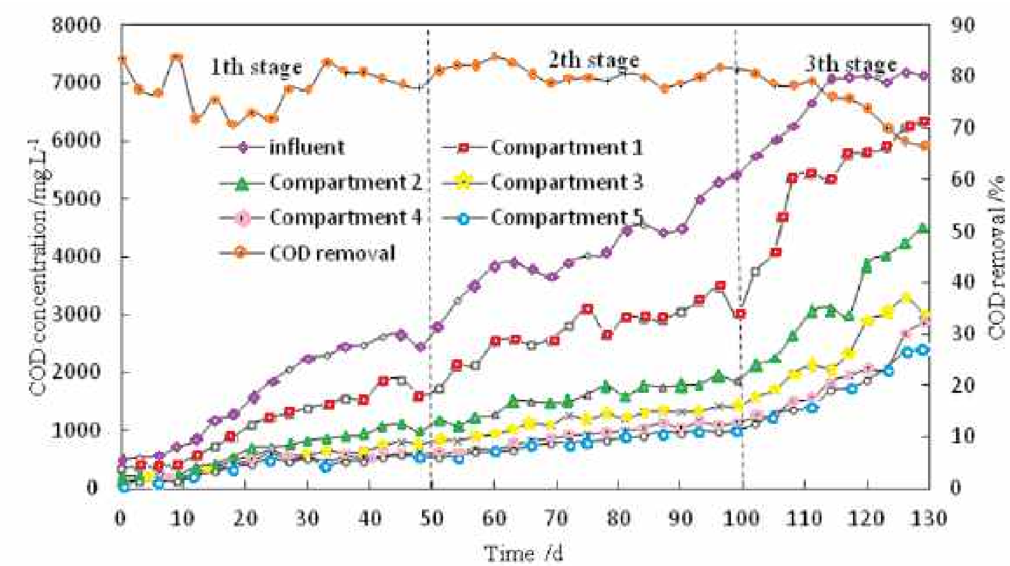
The same process of separation and sedimentation takes place in the first chamber of ABR. This chamber is the first and usually the largest, where most of the solids and scum are removed. Clarified water from the first tank flows through baffles where it is forced to flow up through activated sludge in subsequent tanks.

(2-2-1-B-2) Costs: Costs vary according to availability of materials and economy of scale; however, they are usually not expensive because it is built in site with bricks, and isolated with tar. Fig (172) shows the building process of ABR in rural area in Zambia.

Fig(172): ABR being built in residential quarter in Zambia incorporation with German Toilet
www.germantoilet.org/

(2-2-1-B-3) Efficiency: ABR has much better removal than septic tank. Each chamber provides increased removal and digestion of organics that can reach 90 % of biochemical oxygen demand (BOD).[9] A study conducted in 2014 to measure the removal efficiency of a 5 compartments' ABR system, showed that the system has removed 90% of the BOD, 80% of the COD, and 48% of the pathogens,[10] fig (173).

ABR can be efficiently designed for a daily inflow of up to 1000 m3. A good community organization is required to ensure that the ABR is used and maintained properly. Tanks should be checked for water tightness, and the scum and sludge levels should be monitored to ensure a well functioning tank. Care should be taken not to discharge strong chemicals into the system. The sludge should be removed annually to ensure proper functioning. ABR is considered enough for greywater treatment, but for black or mixed water, ABR is considered a primary treatment technology that must be followed by secondary one before releasing water to the environment.[11]



Fig(173): COD removal efficiency in subsequent compartments of the ABR

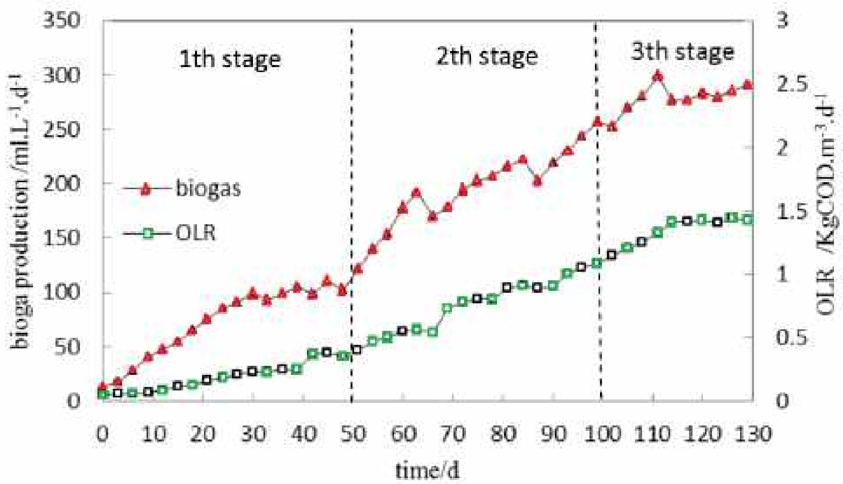
Yu et. al. 2014 Reference No. 9

(2-2-1-B-3) Environmental Impact:

ABR has less potential to crack or overflow so it is safer than septic tank system. Anyway the design capacity must be twice the expected flow because ABR serves number of houses where different behaviors are expected. To avoid cracks, ABR must be far from traffic. The best place for ABR location is yards or gardens where only pedestrians can move through. ABR is commonly built underground so it must be checked and monitored regularly. Pipes should be far from traffic loads to avoid breakings.

- Odor control: ABR is usually used for both grey and black water treatment, so noxious gases may be released. These gases are called "biogas". Biogas is produced from the aerobic and anaerobic digestion of the organic waste in the wastewater. There is a direct relation between organic content of the wastewater and the biogas produced as shown in fig(174). If biogas isn't used, proper ventilation of the system may greatly reduce the gas effect.

- Hand contact: Because of massive use, ABR is usually desludged mechanically by a vacuum truck. Manual emptying rarely happens.

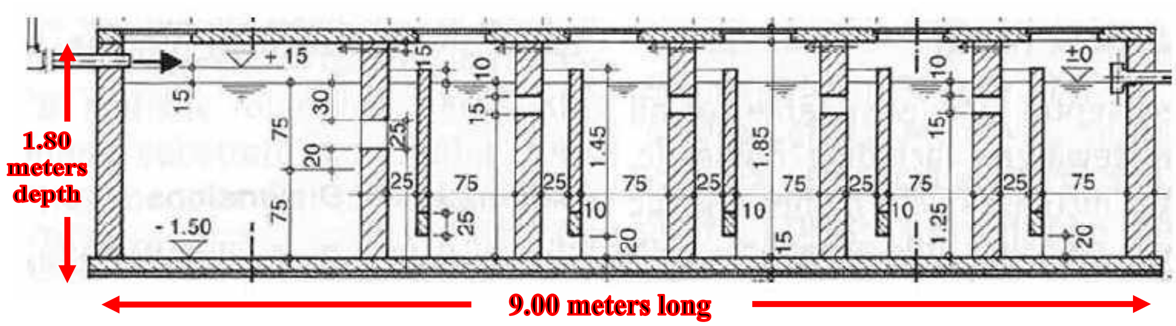


Fig(174): Biogas production from ABR, compared with organic loading rate of disposed wastewater

Yu et. al. 2014 Reference No. 9

(2-2-1-B-4) Land Use and Impact on Urban Planning:

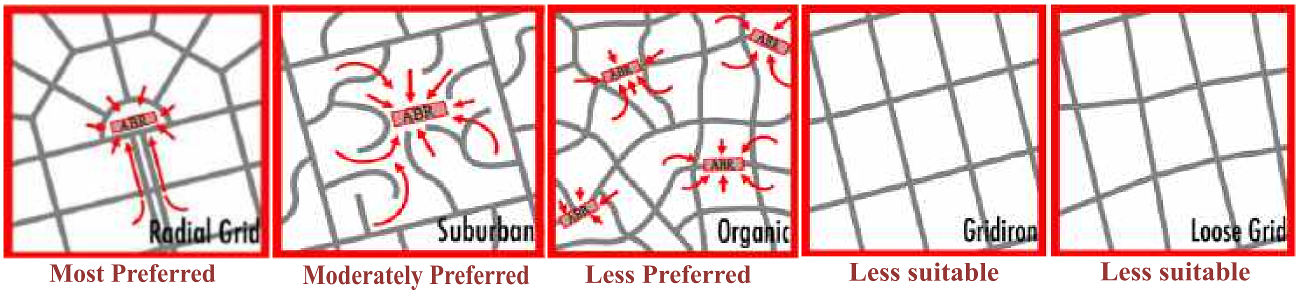
ABR is installed underground and has a fairly small footprint, so it is appropriate for communities with limited land. A residential building with 5 to 8 families need underground space that equals 1.2 m width by 9 m length. The depth is 1.8 m as shown in fig (175).[12] The area may be used as a garden or a side walk but not for heavy loads or heavy traffic.



Fig(175): ABR standard dimensions for serving 5 to 8 families

Sasse 1998,pp.81 – Reference No. 12

If used as semi-centralized system serving small communities, a friendly neighborhood is required for sharing the same utility. One ABR can serve up to 50 families according to its size and capacity. Central semi-public space is required for ABR installation, so the urban pattern suitable for it is the Radial Grid, Suburban and Organic. Other urban patterns may be less suitable. See fig(176).



Fig(176): Compatibility levels of ABR with different urban patterns

Designed by the researcher, adapted from

(2-2-1-B-5) Suitability:

ABR system is suitable for sites with available land, remote sewers, accessible traffic, low economy and good ventilation. Not all street types and urban patterns can host this technology as it requires central vacancy for installation. Not all communities can get familiar with it as it requires strong relations and good sharing of responsibility.

(2-2-1-B-6) Advantages:

- Low cost when divided among members of a housing cluster or small community
- Minimum operation and maintenance
- Resistant to organic and hydraulic shock loads
- Reliable and consistent treatment

(2-2-1-B-7) Disadvantages/Concerns:

- Requires expert design and skilled construction - partial construction work by unskilled laborers.
- Requires secondary treatment and discharge.[13]

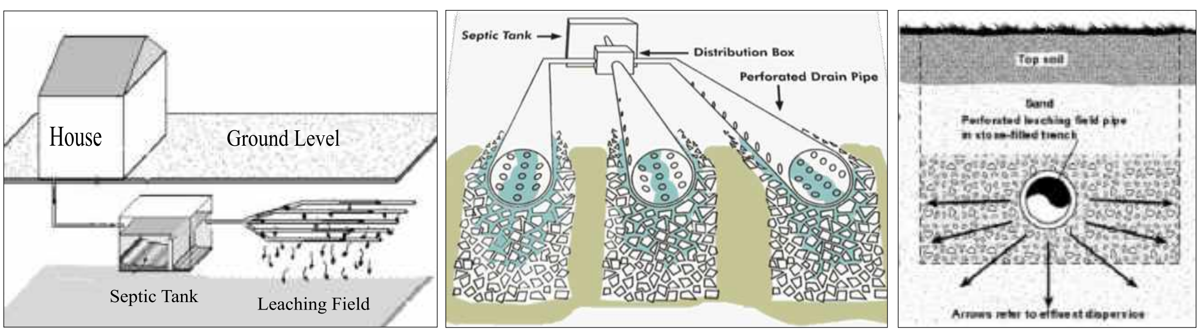
(2-2-2) Secondary treatment technologies:

Secondary treatment is used for the safe disposal of solid-free wastewater, either greywater or effluent water from primary treatment systems. The main technology used in off-grid secondary treatment is infiltration & digestion. Soil particles (sand, gravel, etc.) are used as screens to filtrate wastewater from remaining solids, while the microorganisms, inhabiting the soil, digest most of the organic matter in the treated water. Most off-grid systems use secondary treatment as final treatment, after which water is released to the environment. The main off-grid technologies used for secondary treatment worldwide are leach fields, soak pits and infiltration trenches as illustrated below.

(2-2-2-A) Leach Field System:

(2-2-2-A-1) Description & Mechanism: Leach field is series of perforated pipes surrounded by gravel layer where the clarified wastewater passes through to get purified before reaching groundwater table. See fig(177).

Leaching Field's treatment is done by filtration. Filtration is done by passing the effluent water through a perforated pipe which is totally covered and surrounded with a layer of small diameter gravel, see fig (177). While passing through, water looses most of its sediments and then seeps through surrounded soil to lose th e rest of it. Finally the filtered water reaches the underground water table to be mixed with.[14]



Fig(177): (a) Leaching field System (b&c) Isometric & cross section showing wastewater filtration through

(a)http://timzhifu.en.made-in-china.com (b)http://thetankdr.com/ (c)Onsite Wastewater Treatment Systems Manual , EPA/625/R-00/008,

(2-2-2-A-2) Costs:

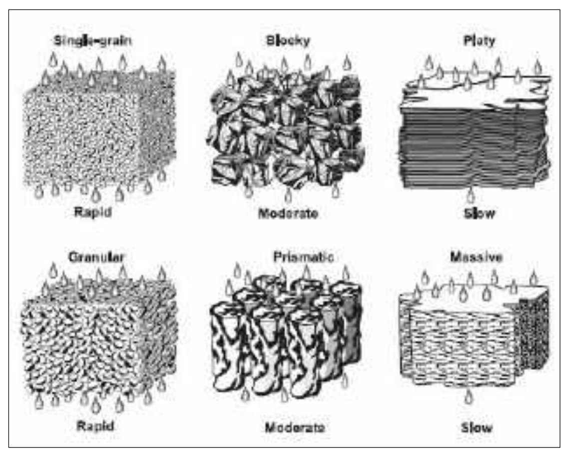
Leach field system has a relatively high initial cost as it requires digging, applying gravel and aggregates, installing perforated pipes over gravel and refilling with soil, see fig(178). Additional geotextile may be applied before refilling to avoid soil and root intrusion into the system. Some systems also install a "distribution box" which regulates the flow of wastewater into the system, as some sites have slopes or uneven distribution of water flow.

This box assures an even distribution of wastewater into parallel pipes, see fig(178). More developed leaching systems have been adopted recently which are "gravel-free". An example for these systems is leaching plastic chambers, polystyrene aggregate pipes, tire chip aggregate pipes, large diameter pipes, or multiple small pipes.[15]

Fig(178): (a) Installing leach field system (b&c) Distribution box installation (d) Polystyrene gravel-free leaching system

(a) http://arkitrek.com (b&c) http://4.bp.blogspot.com (d) http://www.barrplastics.com

In the United States, leaching systems are estimated to cost $1,500 to $20,000 according to size, soils and type of system used (chambers, polystyrene, etc.). Egyptian local market doesn't offer integrated systems but components are available and can be fixed onsite. The prices of components are not expensive but installing them needs qualified workers. In some countries costs of local permits are added too. Areas with naturally porous soil (sandy or gravel natural soil) will need no gravel layer so will be more economic. Leaching cost heavily depends on soil type, as the field does not need to be as large for porous soil conditions as it does for less porous soils. Soil types also affect the required installation area, as rapid infiltration soils need less installation space while platy and massive soils require more area for infiltration, see fig (179).[16] Site landscape also affects the cost as trees and fencings must be removed to prevent intrusion, which will add to the cost. Extra money may be spent over replacing landscape in the area or planting new grass seed after the work is done.[17]



Fig(179): leaching speed based on soil structure

Onsite Wastewater Treatment Manual, 2002 –Ref. No. 16

(2-2-2-A-3) Efficiency: As a secondary treatment technology, leach field should receive only clarified wastewater, all large solids should be retained by a septic tank or an ABR.

The system performs physical and biological treatment. The surrounding material around the pipes (gravel, polystyrene, etc.) performs physical filtration of fine solids that couldn't be removed in primary treatment systems, while the soil beneath the field performs the biological treatment by what is called (The Biomat Layer).

- **The Biomat Layer:** "Biomat" is a bacteria layer which forms in soil, below and around leaching pipes. This black, jelly-like layer formats gradually by the biological interaction between wastewater and the bacteria inhabiting the surrounded soil. Wastewater flourishes the bacterial growth which, in turn, treats wastewater biologically. Biomat is crucial to wastewater treatment as it digests and removes the pathogens and viruses in the effluent. Without biomat, leach field system wouldn't adequately treat the effluent.

As the biomat develop, it tends to restrict the flow of effluent through the soil. The gradual decrease of soil infiltration rate may eventually form a "clogging zone", causing the effluent to rise up in the site, see fig (180).

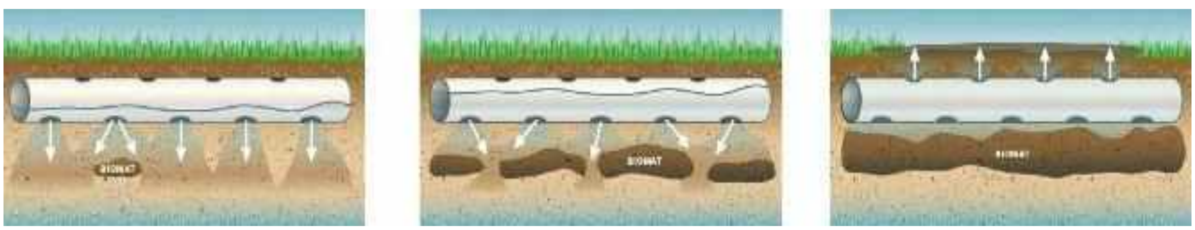


Fig (180): Biomat layer formatting, accumulating, and finally blocking the system

http://www.septicsystemsaver.net

If clog happens, an aggressive volume of clean water must be run into the system, forcing clogged particles to dissolve and allow soil infiltration again. This "system wash" process is rarely needed if wastewater is properly clarified during primary stage before entering the leach system.

- **System Failure:** Leaching system can have mechanical or biological failure, mechanical failure occurs due to pipes corrosion, crushing or collapsing. Corrosion is possible especially with Iron pipes, while crushing and fractures are possible if the soil below isn't properly compacted during installation. Biological failure occurs only if biomat layer stops working as mentioned before.

- **Signs of failure:** System failure is first noticed by odor, then wet areas start to appear, and finally wastewater returns back into the house. If the field is near a water source, contaminants can cause algae growth in lakes and ponds.

Primary treatment's performance greatly affects the efficiency of Leach Field. If not working properly, large solids will enter the leaching system causing pipes clogging, see fig(181). Regular pumping of septic tank is required to extend the life span of Leaching field.

Fig(181): (a,b&c) Signs of failure of leach field system (d) Leaching pipe clogged with sludge due to insufficient primary treatment

(a,b&c) http://www.septicsystemsaver.net **(d)** http://budgeting.thenest.com

- Removal Efficiency: A well-functioning leach field system can remove almost 99% of pathogens and viruses remaining in primarily treated wastewater. Pathogens in the wastewater are absorbed by the soil, causing them to die off, while the bacteria present in the soil helps cleaning the wastewater, along with common soil nutrients such as phosphorous and nitrogen. However, removal efficiency varies greatly from site to another. Soil type, porosity, bacterial content and ground water depth are basic factors that affect removal efficiency. Before installation, a special consultancy must be taken by recording the basic measures of the soil, estimating the system future performance and durability, as well as determining the most suitable leaching system type to be used. Table(30) shows an example for soil removal efficiency for wastewater as measured by USEPA,2002.

Table Examples of soil infiltration system performance

Parameter	Applied concentration in milligrams per liter	Percent removal	References
BOD_5	130–150	90–98	Siegrist et al., 1986 U. Wisconsin,1978
Total nitrogen	45–55	10–40	Reneau 1977 Sikora et al., 1976
Total phosphorus	8–12	85–95	Sikora et al., 1976
Fecal coliforms	NA*	99–99.99	Gerba, 1975

Table (30): Soil infiltration system performance

Onsite Wastewater Treatment Systems Manual , 2002- Reference No. 16

- **Durability and maintenance:** A leaching field should require no maintenance; nevertheless, if the system stops working completely, the pipes should be removed and replaced. Durability is influenced by many factors such as soil type, climate, installation techniques, abuse, and proper maintenance. A well-functioning system with a proper primary treatment may need no replacement for up to 60 years.[18]

(2-2-2-A-4) Special considerations for leach field's best performance:

- Planting trees or shrubs must be avoided on or around the leach field.
- Parking cars or storing heavy things on the field is forbidden.
- Installing water conservation devices in the house (e.g. low-flow toilets) is recommended to lessen the load on the system.
- Long showers and long loading periods of cloth washing a day must be avoided.
- Fibers, gums and undegradable materials mustn't be allowed to enter the system as it may clog the holes in leaching pipes.
- Regular pumping for septic tanks is recommended to avoid leach field clogging.
- For best results, the soil in the leach field should be undisturbed and not compacted.

(2-2-2-A-5) Environmental Impact: the main environmental concern about leach field is groundwater contamination. Wrong installation or bad maintenance of leaching field can lead to system failure, causing soil and groundwater contamination. To avoid such problem, leach field must be kept as far away as possible from any potential water source to prevent contamination. The recommended distance by EPA is 20 m horizontally from any fresh water supply (e.g. river or spring) and 3 meters vertically from groundwater supply (e.g. pump intake) in the case of soil with average speed infiltration rate.

The failure of the leaching system may affect both flora and fauna inhabiting the original soil. Failing leach fields can cause personal inconvenience, as well as groundwater contamination and potential illness.

(2-2-2-A-6) Land Use and Impact on Urban Planning:

Leach Fields require a large area so it is appropriate for spacious areas devoid of fast growing trees. Ordinary leach field requires 3x1.5 meter space for a single household as seen in fig(182). Prefabricated systems require less space as they are flexible and can adopt with sites' variable patterns and contour as seen in fig(183). They also resist plants intrusion to some extent. Planting trees should be avoided near the system and heavy traffic too.

Fig(182): Leach Field dimensions for a single house (Traditional System).

(2-2-2-A-7) Upgrading: A leach field should be laid out in such a way as not to interfere with a future sewer connection. Space and pipe connections should be planned prior to installation of the leach field to facilitate a changeover if a sewer connection is implemented at a later date.

Fig(183): Leach field compatibility with different contours (b) gravel-free leaching system installed in North Carolina, USA (c) Prefabricated leaching system installed in Lancashire, UK.

(a) http://inspectapedia.com (b) Department of Natural Resources, North Carolina. (c) http://loomistank.com

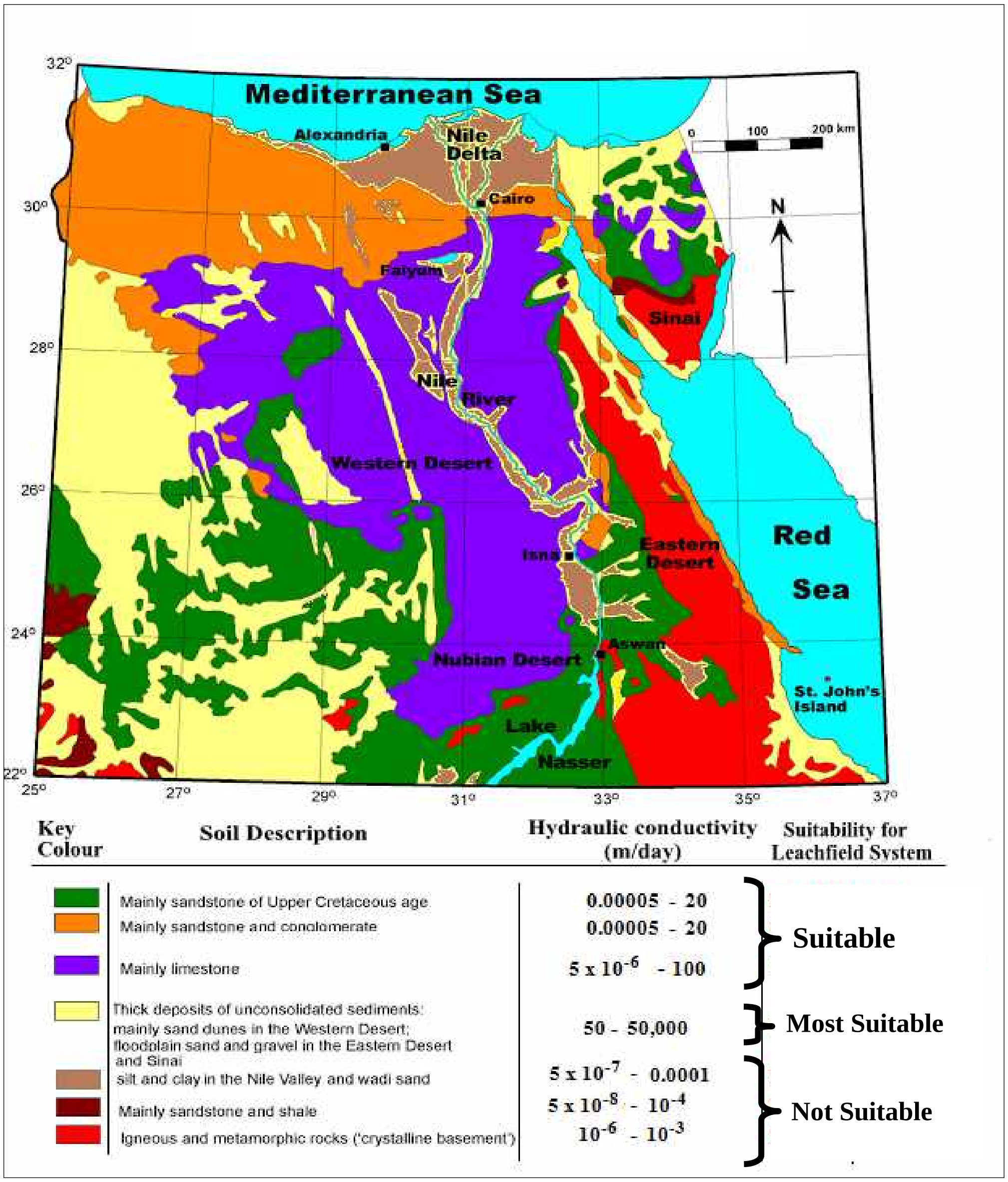
(2-2-2-A-8) Suitability: The main limitations for installation and normal operation are small land areas, inappropriate soils, and shallow water tables. Each soil type has a typical infiltration rate as shown in table (31). These rates heavily affect the land requirements for the leaching system. High permeable soil requires less land space while low permeable soils require more space for leaching.

Soil Type	Physical Description	Infiltration Rate of Wastewater(L/m^2/day)
Gravel, coarse and medium sand	Moist soil will not stick together	50
Fine and loamy sand	Moist soil sticks together but will not form a ball	33
Sandy loam and loam	Moist soil forms a ball but still feels gritty when rubbed between the fingers	24
Loam, porous silt loam	Moist soil forms a ball which easily deforms and feels smooth between the fingers	18
Silty clay loam and clay loam	Moist soil forms a strong ball which smears when rubbed but does not go shiny	8
Clay	Moist soil moulds like plasticine and feels sticky when wetter	Unsuitable

Table(31):Typical infiltration rates according to soil type

Onsite Wastewater Treatment Systems Manual , 2002- Reference No. 16

Suitability of soil in Egypt: As for Egypt, we've classified the soil properties in different regions in the country based on data from the British Geological Survey and Information Products Programme,2006, to sort the country regions according to soil permeability and hydraulic conductivity, measured in m3/day. The data showed that most suitable soils for leaching systems are located in the south western desert and North Sinai, with a hydraulic conductivity reaching 50,000 m/day. Suitability is also fair in the Eastern and Western fringes of the Nile Valley, with a hydraulic conductivity reaching 100 m/day. Soil becomes moderately permeable in the Western North Coast, New Cairo, and Qattara Depression with a hydraulic conductivity reaching 20 m/day, while suitability is nearly absent in Delta and Nile Valley due to the dominance of clay in this fertile soil. The southern east quarter of Egypt is also non suitable due to crystalline based rocks, with permeability less than 10^{-3} m/day as shown in the map.



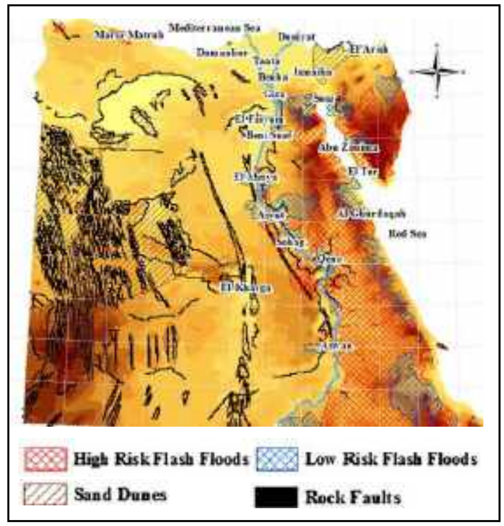
Fig(184): Leaching System Suitability Map for Egypt, based on Soil Permeability

Designed by the researcher referring to data from: BRITISH GEOLOGICAL SURVEY, INFORMATION PRODUCTS PROGRAMME, OPEN REPORT CR/06/160N, Guide to Permeability Indice: Keyworth, Nottingham,2006 as well as base map from http://soilsofegypt.blogspot.com/

(2-2-2-A-9) Areas to avoid: Leaching systems must be avoided in areas with high risk of earth quakes, rocky faults or flash floods. Earth quakes and rocky faults may destroy the system while floods may erode the soil and cause the system to fail. In Egypt, the areas with high risk of faults and floods are shown in map (185).

(2-2-2-A-10) Advantages of leaching system:

- Treats both black and greywater.
- Moderate initial cost and very low running cost.
- High removal efficiency by physical and biological treatment.
- Flexibility with different slopes and contours.
- Treatment is performed underground without contact with the ambient air or with the users.
- No special education needed for use.



Fig(185.): Areas of flash floods and rocky faults' risk in Egypt

www.geaographicfeatures.org

(2-2-2-A-11) Disadvantages/Concerns:

- Requires careful layout, specialized knowledge by the designer.
- Requires a large area that may not be used for other purposes (e.g. agriculture).
- May cause damage to property and landscaping.
- May fail and cause groundwater contamination and illnesses.
- Requires some specialized parts, which may not be locally available

The same filtration technology of the leaching system can be performed by other systems. Here we mention the most two common systems: Soak pits and Infiltration trenches:

(2-2-2-2) Soak pits: Soak pits are a simple leaching system that is widely used for draining unwanted water in a hygienic way. It's used in wastewater secondary treatment as well as rain water, storm water and greywater discharge. It is used after various types of pretreatment, such as septic tank, twin-pits for pour-flush toilets, biogas settler, anaerobic baffled reactor, etc.

aDescription & Mechanism: Soak pit is a covered, porous-walled underground chamber that allows pretreated water to slowly soak into the ground, see fig(186).

Fig(186): (a) Soak pit built in site (b): Open Soak pit (c) Prefabricated concrete pit
(a) http://2.bp.blogspot.com (b) AHRENS (2005) (c) http://www.sswm.info

Just like Leach Field, Soak Pit uses the same technique for treatment, which is filtration and digestions by soil particles and bacteria. In a soak pit, effluent water from a septic tank or an ABR seeps through porous walls of the pit from which it infiltrates into the surrounding soil.

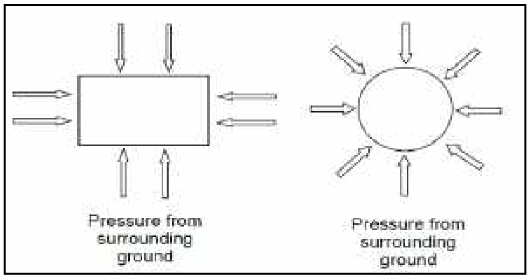
b- Costs: soak pits is one of the most economic treatment systems as its initial cost is very low. Pits can be dug and built in one-day-work with 1-2 laborers. Materials are available and cheap. Pits can be closed or opened as seen in fig(186). Prefabricated pits are also not expensive depending on size and capacity.

c- Efficiency: As wastewater percolates through the soil from the soak pit, small particles are filtered out by the soil matrix and organics are digested by microorganisms. The wastewater effluent is absorbed by soil particles and moves both horizontally and vertically through the soil pores. Sub-soil layers should therefore be water permeable in order to avoid fast saturation. High daily volumes of discharged effluents should be avoided.[19]

Soak pits are used the same way as leach fields, but require less space as well as less operation and maintenance. But they generally can also receive less influent and the groundwater pollution may be higher than with leach fields. The soil above and around soak pit it is not compacted. It can be left empty and lined with a porous material to provide support and prevent collapse, or left unlined and filled with coarse rocks and gravel. A layer of sand and fine gravel should be spread across the bottom to help disperse the flow. To allow for future access, a removable (preferably concrete) lid should be used to seal the pit until it needs to be maintained.[20]

Well-sized soak pit should last between 3 and 5 years without maintenance. To extend the life of a soak pit, care should be taken to ensure that the effluent has been clarified and/or filtered to prevent the excessive build-up of solids.

Rectangular pits tend to collapse more often because pressure is placed on the four walls which leave the corners to absorb the stress, while circular pits are less likely to collapse because the pressure from the surrounding soil is evenly spread, see fig (187).



Fig(187): Comparing ground pressure on rectangular and circular soak pit

(Life water, 2009)

Particles and biomass will eventually clog the pit and it will need to be cleaned or moved. When the performance of the soak pit deteriorates, the material inside the soak pit can be excavated and refilled.[21]

d- Environmental Impact: The main environmental concern in Soak Pits systems is groundwater contamination. Strict rules have been put by EPA considering the installation of soak pits. For example:

- Pits should be located at a safe distance from a drinking water source (ideally more than 30 m).
- Depth should comply with the type of soil. The higher infiltration rate the soil possesses, the less depth required, see table (32).
- Pits base should be at least 2 meters above ground water table.
- Pits should not be allowed to treat raw sewage, pretreatment is mandatory.

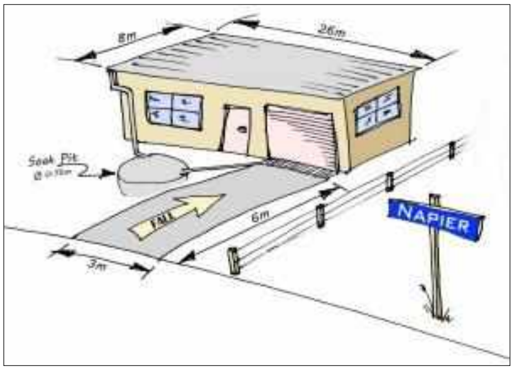
Soak Pit Design for 1 metre Diameter or 1 x 1 metre Square						
Soil Type	Pit Depth (metres)					
	80 litres Daily		120 litres Daily		160 litres Daily	
	Circle	Square	Circle	Square	Circle	Square
Gravel, coarse and medium sand	0.5	0.4	0.8	0.6	1.0	0.8
Fine and loamy sand	0.8	0.6	1.2	0.9	1.5	1.2
Sandy loam and loam	1.1	0.8	1.6	1.3	2.1	1.7
Loam, porous silt loam	1.4	1.1	2.1	1.7	2.8	2.2
Silty clay loam and clay loam	3.2	2.5	4.8	3.8	6.4	5.0

Table (32): Soak pit standard depth for different soil types as set by EPA (for pits with 1 m diameter or 1 x 1 m² it)

Onsite Wastewater Treatment Systems Manual, 2002 – Reference No. 16

Soak pits also have positive impacts to the environment. They help recharging groundwater bodies. This is a privilege in arid weather where rain fall is rare. As long as the soak pit is not used for raw sewage, and as long as the previous collection and storage/treatment technology is functioning well, health concerns are minimal. The technology is located underground and, thus, humans and animals should have no contact with the effluent. Since the soak pit is odorless and not visible, it should be accepted by even the most sensitive communities.

e- Land Use and Impact on Urban Planning: Soak pit has minimum land use in comparison with Leach Field. Pits are installed underground and area required is generally 1 m^3. Depth should be between 1.5 and 4 m. It should be kept away from high-traffic areas so that the soil above and around it is not compacted. The best location for soak pit is to be adjacent to the house, with access to rain water drain as well as septic tank effluent, see fig(188).



Fig(188): Typical soak pit location near served house, leacing both wastewater & rainwater

Soak pits usually don't affect the street pattern of the city because they're installed underground and with minimal space. In slums and rural areas where streets are 3 to 4 meters wide and with many bindings, finding a space for installing pits may be a problem, especially when traffic is forbidden over these pits.

f- Suitability:

Soak pits are appropriate for rural and peri-urban settlements. They depend on soil with a sufficient absorptive capacity, whereas clay soils as well as hard packed or rocky soils are not appropriate. They can be used in almost every temperature, although there may be problems with pooling effluent in areas where the ground freezes. They are not appropriate for areas prone to flooding or that has high groundwater tables and should be constructed in a distance of at least 30 m from drinking water wells in order to prevent cross-contamination.

Soak pits are best suited for soil with good absorptive properties; clay, hard packed or rocky soil is not appropriate. The infiltration rate of wastewater through different types of soil must be considered before determining pit's size and dimensions, see table (32).

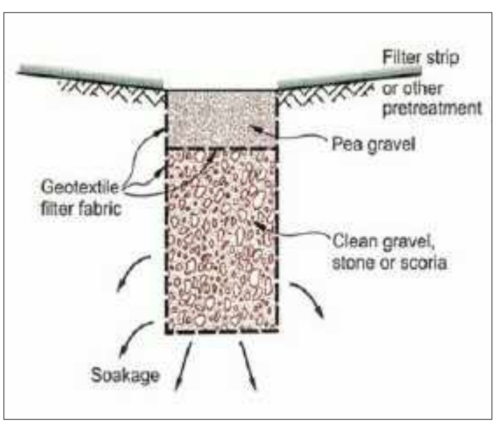
Advantages:

- Can be built and repaired with locally available materials
- Technique simple to apply for all users
- Less land area is required for installation which means less damage to property and landscape.
- Low capital costs; low operating costs
- Recharging groundwater bodies.

Disadvantages

- Primary treatment is required to prevent clogging.
- May negatively affect soil and groundwater properties.
- Applicable only were soil conditions allow infiltration, the groundwater table is at least 1.5 m below the soak pit, there is no risk for flooding and any water well is in a distance of at least 30 m.
- Difficult to realize in cold climate.

(2-2-2-3) Infiltration Trench: Infiltration trenches are long, narrow and shallow built chambers with porous walls and bottom, see fig (189). They are similar to soak pits but with less depth and more required area. Although they require more space and materials, they can infiltrate larger amounts of water than soak pits. They are suitable for mass use especially by multistory buildings. These trenches are widely common for use in draining rain water and storm water, especially in rainy climates. Trenches can be used for both wastewater treatment and rain drainage as seen in fig (190).

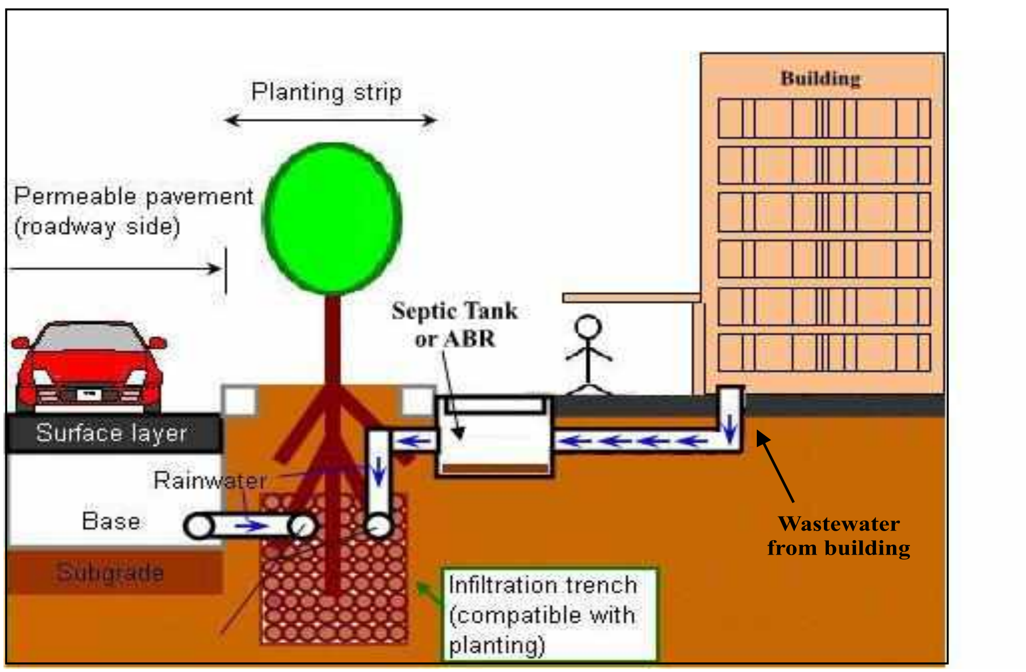


Fig(189): (a) Infiltration Trench cross section (b&c) Trenches' installed around buildings' outline

(a) http://www.riversides.org (b&c) http://www.cob.org

Trenches can be used both in small or big scale, according to flow and number of serviced houses. They suit rural areas and slums as they use 25 to 50 centimeters of street width, and they can bend along the building contour as shown in fig(189). The same environmental rules for soak pits are applied to trenches. Trenches may be less expensive because digging is shallow, with local materials and almost no experienced labor required. Maintenance is done by periodical substitution for aggregates and gravel if necessary. Trenches are easily monitored because they are visible, so any failure will cause an overflow which can be noticed and fixed the same day.

Fig(190) shows a suggested positioning for trench serving a multistory building for both rainwater and wastewater leaching. The septic tank is located under the paved walkway and delivering treated water to trench located under the street public planting zone. The suggested plant must suit with heavy irrigation systems to consume the leached water as much as possible. Soil beneath the walkway must be with adequate permeability as well. Trench soil substitution may be needed every few years.



Fig(190): Suggested positioning of Infiltration trench for dual function (rainwater & wastewater drainage) in a multistory building

Designed by the researcher with guidance from www.pwri.go

(2-2-3) Tertiary Treatment Technologies:

The purpose of tertiary treatment is to provide a final treatment stage to further improve the effluent quality before it is discharged to the receiving environment (sea, river, lake, groundwater, etc.). It is also called "effluent polishing." In centralized systems, more than one tertiary treatment process may be used at the treatment plants, such as chlorination (adding chlorine), ozonation (exposing water to ozone). In decentralized systems, the most common off-grid technology used for tertiary treatment is wetland system as illustrated below.

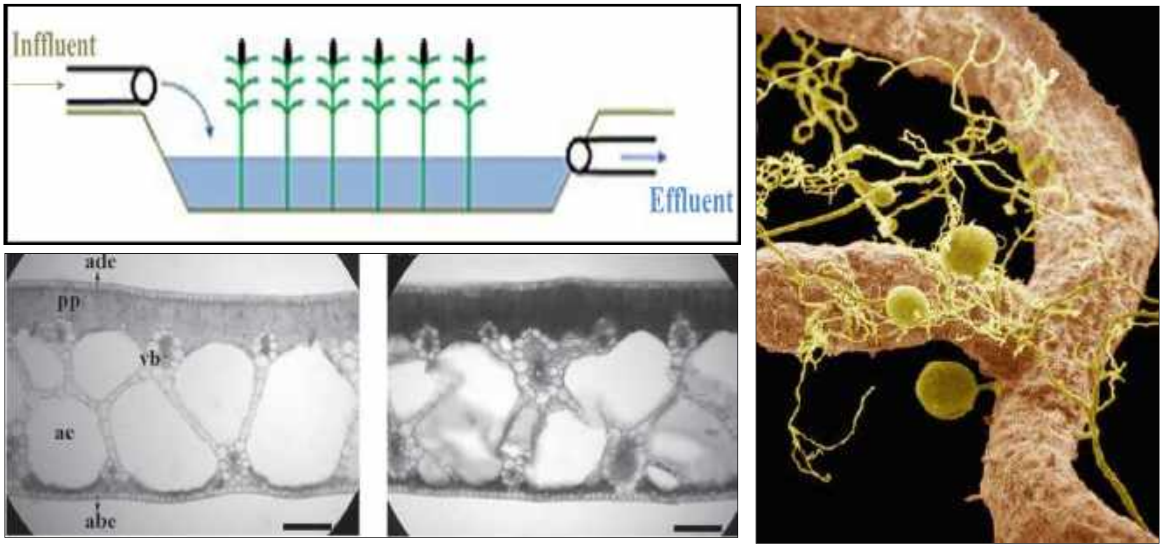
(2-2-3-1) Wetland System:

Wetland system is a biological treatment technology which has proved to be effective for wastewater tertiary treatment. Wetland systems treat domestic sewage effluents to acceptable environmental standards in an economic and efficient manner. They are mainly an off-grid treatment system but recently have been adopted also in some central wastewater treatment systems as shown in this chapter.

a- Description & Mechanism: Wetland system is simply an aquatic system where wastewater runs through. The system is a water basin or pipe wherein some types of aquatic plants are cultured. As water passes through the roots of these plants, it become clean and safe to be released into environment, see fig (191).

In wetland system, the plants' roots act as filters, where the microbes thrive around the roots to do most of the work, breaking down nitrogen and phosphorous compounds, as well as toxic chemicals. Although they don't break down heavy metals, the plants absorb them; they can then be harvested and incinerated or land-filled.[22]

Fig(191) shows the accumulation of zinc oxide particles in wastewater around the aquatic plant root.[23]



Fig(191): (a) Typical wetland system cross section (b) A microscopic image showing Water Hyacinth plant's tissue before and after retaining contaminants from treated wastewater (c) A microscopic image showing zinc oxide particles accumulated around plant's root

(a) www.wikipedia.org **(b)** FABRICIO J. et. al: Lead tolerance of water hyacinth as defined by anatomical and physiological traits, Biological Sciences,vol.86 no.3,Sept. 2014,ISSN 0001-3765 **(c)** Priester, J.H. et al. 2012

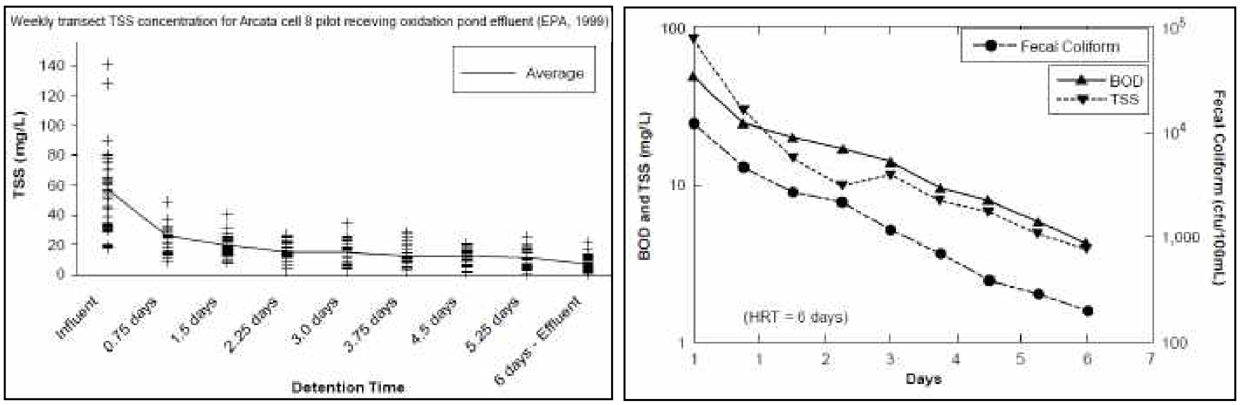
b- Cost: wetland technology is a comparatively cost effective method for wastewater treatment. The materials needed are inexpensive and can be locally provided. Plants of the system are abundant and easily obtained; in fact they are considered waste and given without price.

c- Efficiency (Removal Efficiency): According to EPA, wetland system has very good potentials in removing pollutants from wastewater.[24] The efficiency of wetland systems for wastewater treatment has been very good, especially in terms of biological oxygen demand (BOD), total suspended solids (TSS), and fecal coliform bacteria. Fig(192) shows the decline of fecal coliform, BOD, and TSS in wastewater sample after 6 days of Wetland treatment, measured by EPA, 1999.

Considering heavy metals removal, Average wetland system can remove about 86% of Chromium (Cr) and 67% of Nickel (Ni). It reduces the Zink (Zn) concentration to below 50 μgL^{-1} in most systems. The out-coming water is anoxic in most samplings while 70% and 60% of the incoming nitrate and nitrite are removed. Large denitrification losses occur due to root filtration. Cr, Ni and Zn are retained by the macrophytes in the larger wetland and in sediment in the small-scale one. Metallic ion removal even from strongly acidic waters is considered excellent. But a slight increase in pH is common in the effluent water when influent seep water is moderately acidic.

- **Maintenance**

With time, the gravel will become clogged with accumulated solids and a bacterial film. The material may have to be replaced every 8−15 years. Maintenance activities should focus on ensuring that primary treatment effectively lowers organics and solids concentration before entering the wetland. Maintenance should also ensure that trees do not grow in the area, as the roots may damage the liner.



Fig(192.): left: Decline of total solids in wastewater during wetland treatment-right: Improvement of wastewater quality after 6 days of wetland treatment

Source: EPA Manual of Constructed Wetlands Treatment of Municipal Wastewaters- EPA/625/R-99/010-September 1999

d- Environmental Impact: Wetland system has the minimal environmental footprint as it uses nature to clean up the pollutants coming from human activities. Some risk of mosquito breeding is considered but can be avoided by installing enclosed systems (e.g. wetland cell or pipes system as shown later) which can reduce the incidence of exposed standing water. The system is generally aesthetic and can be integrated into wild areas or parks. Due to the risk of infection, contact with the waste should be avoided.

The main environmental concern in this system is how plants are disposed of after treatment. The plants' tissues become polluted after used in wastewater treatment as shown in fig(..), so reuses are limited. Most users get rid of harvested plants by burial or incineration. Some use them as fodder, though many health concerns arise about animal health in this case. One of the best ways to use these plants is to reuse them as nonedible products, such as furniture. Some aquatic plants like hyacinths and reeds have the potentials to be dried and used in making chairs and tables. In Indonesia, for example, men and women are hired to dry, process and weave stems of these plants as an economic investment, see fig(193)

Fig(193): The reuse of wetland plants: processing dried water hyacinth stems for use as a material to make furniture in Sulawesi, Indonesia

J. S. Salvato: Environmental Engineering and Sanitation, 2003

e- Land Use and Impact on Urban Planning: Wetland system can have both maximal and minimal land requirements, depending on shape, materials used and number of users. The main target of the system is to make wastewater come in contact with aquatic plants' roots as much and as long as possible. So, long paths are required which can be achieved by many means. For example, a European organization has installed a 500 meters of wetland system in a village in Beni-Suief, Egypt as a treatment technology receiving wastewater from the village's station. The system was installed beside the main water canal of the village and the treated water was of high quality and fit to be mixed with canal water after purification as shown in fig(194).

Fig(194): 500 meter of constructed wetland system applied for wastewater treatment, BeniSuief, Egypt

www.overland-underwater.com

This model shows the maximum land use of the system serving a whole village. On the other hand, minimal land use can be achieved in small scale systems serving one family or one building. Single family can use cell type system or perforated water pipes (vertical or horizontal) as shown in fig(195)

Fig(195): (a) Wetland cell serving a house in Thailand (b&c) Vertical & horizontal wetland systems installed through perforated pipes for residential wastewater treatment

http://timzhifu.en.made-in-china.com (b) www.solarcities.blogspot.com (c) www.pinterest.com

In vertical pipes system, septic tank is mounted beside the apartment (in a multistory building) and the effluent water passes through vertical wetland system by gravity in long corrugated path. When it reaches the ground it become treated and safely disposed into drainage system.

Open wetland system can use significant areas of land depending on the depth of the system. For example, a 100 m^2 wetland system can serve 5, 15, 33 persons and more, based on variable depths. Surface flow system with 0.2 m depth has the minimal capacity (5 person/100 m2), subsurface flow system with 0.6 m depth has higher capacity (15 person/100 m2), while vertical flow system with 1.8 m depth has a capacity of 15 person/100 m2 as shown in fig(196).[25]

f- Suitability: Almost all aquatic plants suit the wetland system, but there are some species that perform even better in wastewater treatment, such as water hyacinths ورد النيل , bulrush, duckweed, water lilies اللوتس أو البشنين الأزرق and cattails البوط الدمياطي. These species are abundant in Egypt and are considered as waste. In Burullus Lake, cattails are dominant and the fish-catchers usually burn it regularly to get rid of it as shown in fig(..). Water Hyacinth is also abundant in Egyptian waterways and is considered as a biological problem, as see in fig (197).

Fig(197): (a) Water Hyacinth domination in agricultural waterways in Egypt (b&c): Southern Cattail domination in Al-Burullus Lake, Kafr El-Sheikh, in a way that people burn it frequently

(a) www.alwatannews.com (b&c) www.youm7.com

So, wetland system is suitable for application in Egypt for many reasons. Egypt has the privilege of hot climate which increases the efficiency of the system. The best aquatic plants for wastewater treatment are abundant in Egypt and very easy to obtain. The space needed for system installation is available on roof tops of the houses in small scale units and in open drains in rural areas for big scale systems. The system is cheap, easy to apply and needs no special knowledge. But on the other hand there may be some difficulties in applying this system in Egypt, People may be worried about bad odor, mosquito breeding, humidity and possible dampness. These worries can be removed by proper design and maintenance. Good awareness must be provided to users before applying the system. Generally, people in Egypt are somehow adapted with roof planting, but this kind of planting needs more encouragement by civil organizations and developmental entities in the society.

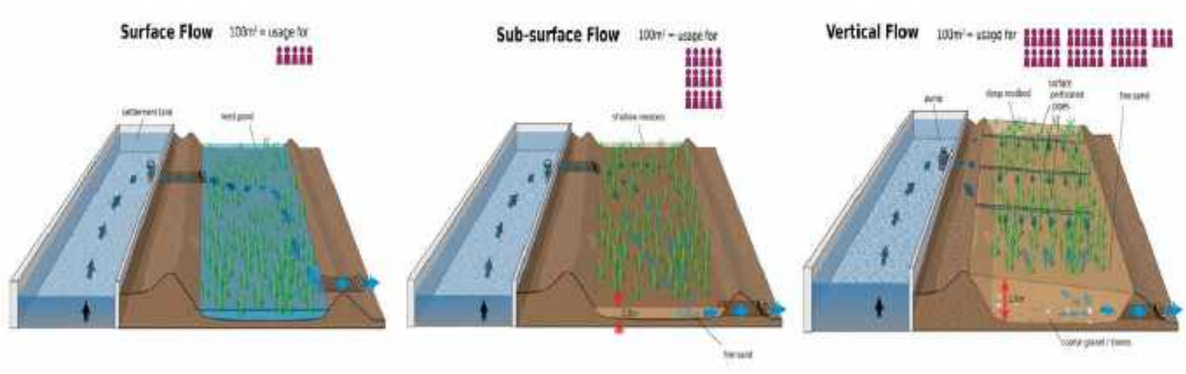


Fig (196): The change of capacity of open wetland system depending on depth of the system

https://en.wikipedia.org/wiki/File:Treatment-pond-raster.png

Wetland systems can also be applied in wastewater treatment plants in Egypt as a mean of tertiary treatment. Some centralized wastewater plants use big scale wetland systems for massive treatment. For example, wetland system is installed for tertiary treatment in the main wastewater treatment plant in Anna Norström, Stockholm, as shown in fig(198).

Fig (198): (a) Roof planting in Cairo (b&c) Hydroponics used in central wastewater treatment plant in

(a)www.greenplanet.com (b&c) Treatment of domestic wastewater using microbiological processes and hydroponics in Sweden-Anna Norström-Stockholm 2005

Advantages:

- High removal efficiency.
- Low construction and operating costs.
- Sustainable and need no special knowledge for application.
- No use for fuel or non-degradable materials.
- No need for chemical additions for disinfection or other procedures used in conventional treatment systems.

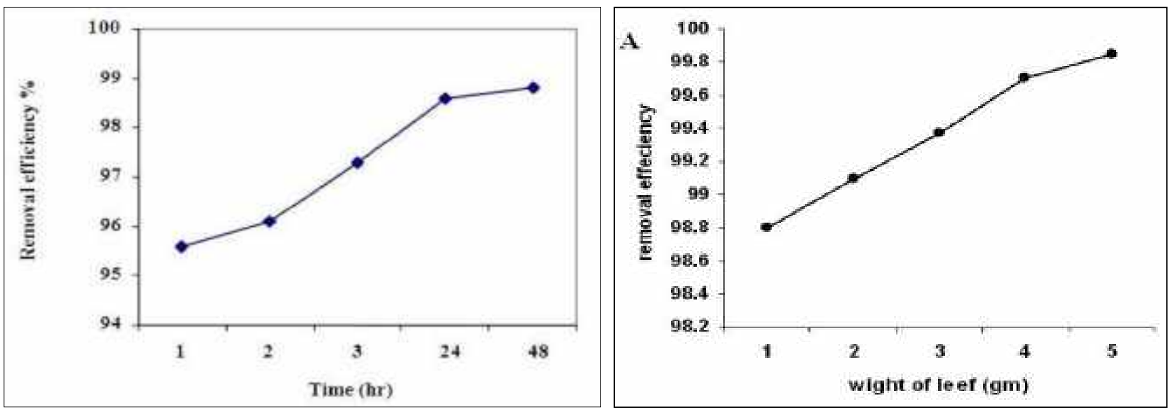
Disadvantages:

- Open wetland systems require more land, which may not suit large cities duo to high land costs.
- Peak removal efficiency is dependent upon vegetation growth and establishment.
- Systems must be covered to avoid bad odor and mosquito breeding.
- Cultivated plants must be disposed in a proper way by burial or industrial use.
- Some research indicates that wetlands may have problems with removing ammonium-nitrogen.

(2-2-3-2) Tertiary Treatment by Date Palm Fibers:

Date-palm fibers filtration is an efficient method to purify secondary treated domestic wastewater. They have the ability to remove turbidity, phosphorus, and organics in term of COD and helminth eggs of domestic wastewater. They can also remove chromium (VI) from industrial wastewater.

A study conducted in 2010 using column experiments to investigate the efficiency of date-palm fibers filters media for the removal of wastewater contaminants, indicated that date-palm fibers filtration removes up to 54.9% of turbidity, 80.6% of COD, 57.7% of phosphorus and 98% of helminth eggs. The removal efficiency of Chromium reaches 98.7% after 48 hrs. of date palm leaves contact as shown in fig(199).[26]



Fig(199): The removal efficiency of date Palm leaf for Chromium in wastewater, related with (a) time of contact and (b) weight of leaf, at 25 ºC and Initial Metal Ion Concentration of 100 mg/ml.

Source: Riahi **et., al. 2012 –Ref. No. 21**

The presence of Chromium in potable drinking water sources has the potential to cause damage to liver, kidney, circulatory and nerve tissues and skin irritation from long-term exposures at levels above the Maximum Contaminant Level (MCL). Currently, the US Environmental Protection Agency's (EPA) MCL in drinking water for chrome has been set at 0.1 parts per million (ppm).[27]

Date-palm fibers also have the ability of removing phosphate from treated water. Phosphate PO_4^3 is a main pollutant in wastewater in Egypt, especially in rural areas. The massive use of phosphate as a chemical fertilizer in rural areas has led to canals, drains, and groundwater contamination with this element.

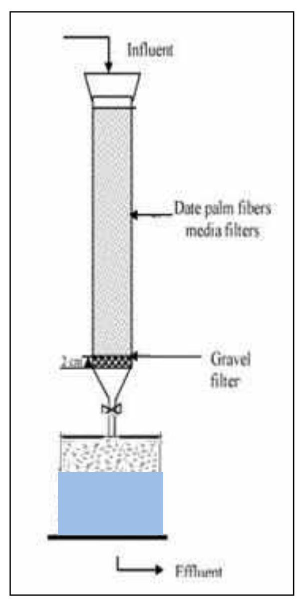
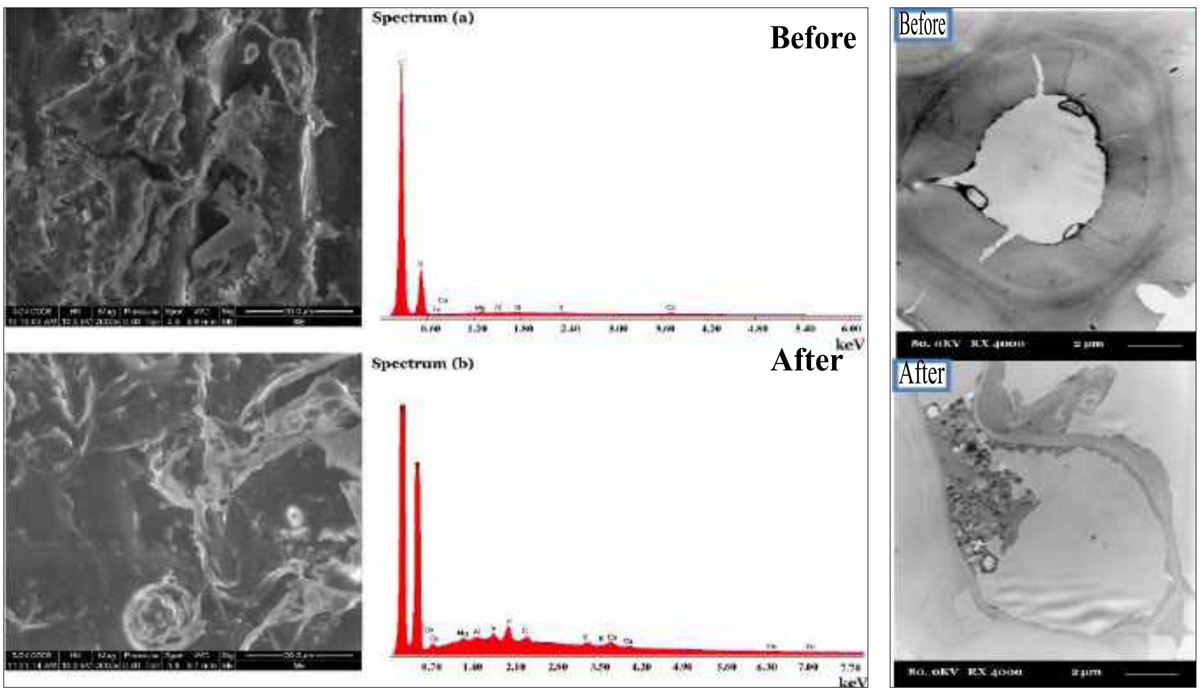


Fig (200): Typical date-palm fiber filter

Source: Haleem et., al. 2010 –Ref. No. 22

The maximum allowable concentration of phosphate in drinking water is 5 milligram/liter/day, while the maximum daily allowed dose per person is 800 milligrams/day.[28] The removal efficiency of Phosphate by date-palm fibers reaches 95.6% . After Phosfate treatment, fibers are commonly contaminated and distorted and radioactive as seen in microscopic image in fig(201). High radio activity is due to Phosphoric acid in date-palm fibers after water treatment.

The proper disposal of fibers after treatment is by burial in agricultural land, where both phosphate and organic matter of the fibers will improve the land fertility.[29]



Fig(201): Date-palm fibers before and after wastewater treatment, imaged using the Scanning electron microscope (SEM) and Energy Dispersive Spectroscopy (EDS), note the fibers distortion (left) and the increasing spectrum (middle) after Phosphate absorption. (right) Microscopic image for fibers before and after phosphate treatment imaged using the Transmission Electron Microscopy TEM

Source with translation and additional illustration: Riahi Riahi **et., al. 2010 –Ref. No. 18.**

Dry fibers of date palm are collected, rinsed with distilled water; sun dried and cut into pieces of approximately 0.5 cm. Dried tissues are kept in a dry place till the time of usage.[30]

(2-2-4) Combined Systems: Anaerobic Digester (AD) System:

Wastewater can be treated primarily and secondarily by combined systems. One of these systems is the Anaerobic Digester System (AD). This system is commonly used for treating black water (toilet & kitchen waste) and not greywater as it may contain chemicals or detergents that can affect the anaerobic digestion process. AD treats black water from the house into water, gas and slurry as illustrated below.

a- Description and Mechanism: Anaerobic Digester (AD) is a small scale unit that treats black water and household organic waste using anaerobic digestion mechanism. It is simply a tank that is mounted or buried near the house, receiving black water and kitchen waste. The tank is dark and sealed so the reaction inside is anaerobic (occurs in the absence of air). The bacteria digests the organic matter and kills the pathogens and viruses, making the effluent less contaminated and safe to be released into the environment.[31]

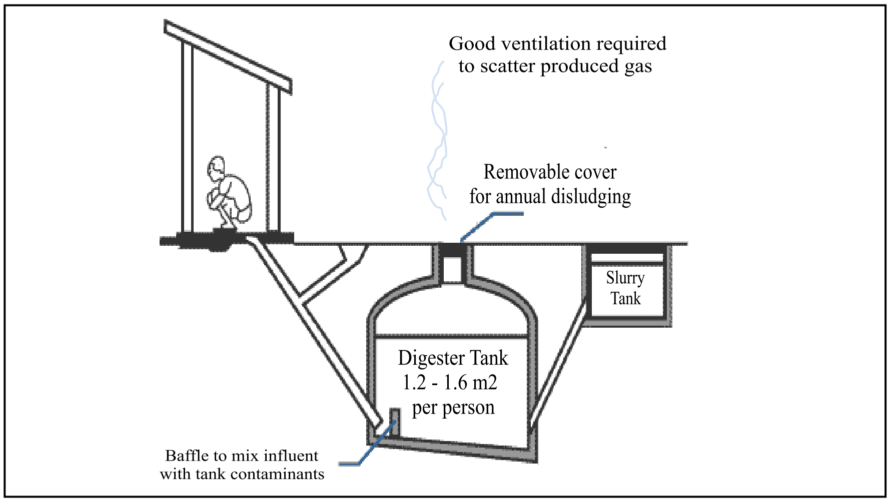


Fig (202): Domestic Anaerobic Digester Cross Section
Source with modifications: WELL (n.y.) – Reference No. 27

b- Cost: This technology is feasible for most economic standards. The initial cost of the digester is considered very cheap as the digester can be made with cheap local materials as shown in fig(203) or built on site using bricks and mortar if located underground.

Fig (203): Anaerobic Digesters made with local materials in Cairo (left) & prefabricated digesters in China (right) for
(1&2) www.solarcities.blogspot.com

Prefabricated digesters are also available in most countries and commonly made of fiberglass, with an average price of 100 to 150 US dollars per unit for single family use.[32] The average life time for the unit is 15–20 years without major problems or re-investments.[33]

c- Efficiency: Most of the pathogens are destroyed in the process of anaerobic digestion.[34] However, the removal efficiency of the Anaerobic Digester depends on many factors, such as time and temperature of the process. There is an inverse relation between time and temperature in digestion process as shown in table (33). Anaerobic digestion is generally classified into 3 types according to temperature, these types are:

- **Psychrophilic digestion**: For digestion that takes place in temperature of (5-20°C), which is common in cold countries like Europe, and in Egypt in winter season. In this reaction, pathogens takes an average 60 days for total removal which means more space required for retaining the accumulating wastewater all this time.
- **Mesophilic digestion:** For digestion that takes place in temperature of (20-40°C), which is common in Egypt most of the year. In this reaction, pathogens are removed faster, in an average 30 days for total removal which means less space required for retaining wastewater.
- **Thermophilic digestion:** For digestion that takes place in temperature of (+ 40°C), which is common in Egypt in desert regions. In this reaction, pathogens are killed in maximum two days and some of them die in just few hours. This digestion requires

Bacteria	Psychrophilic digestion (5-20°C), (typically 15 °C)		Mesophilic digestion (20-40°C), (typically 37 °C)		Thermophilic digestion (+ 40 °C)	
	Days	Removal %	Days	Removal %	Days	Removal %
Salmonella	*44*	100	7	100	1-2	100
Shigella	*30*	100	5	100	1	100
Poliviruses			9	100		
Schistosoma	7-22	100	7	100	Hours	100
Hookworm ova	30	90	10	100	1	100
Ascaris ova	100	53	36	98.8	2	100
Colitire	40-60	10-5,10-4	21	10-4	2	10-1, 10-2

Table (33): Survival time & removal efficiency of domestic Anaerobic Digester in different temperatures conditions

(WERNER et al. 1989)

much small space for wastewater retaining which make it the most suitable for domestic use in the city and rural areas.

It must be considered that the temperature inside the digester is commonly 3 to 5 degrees higher than the ambient air, due to darkness and tightness of the tank and due to reactions inside.

For best results, digesters must be exposed to direct sunlight all day to increase the temperature of the system. Black colored tanks are preferred for the same reason. Some manufacturers in cold countries add a hot water jacket around the digester to provide temperature in winter season. Greywater must not be allowed to access the system because it may contain strong chemicals and detergents which may kill the bacteria performing the digestion job.

d- Environmental Impact: Anaerobic digester is a sustainable system that uses natural ecosystems for wastewater treatment. The main environmental concern in this system is the disposal of the effluent slurry and the ventilation of biogas produced from the system.

Slurry is a watery matter consists of digested organic waste. Anaerobic digestion only removes organics, and the main mineral material, but almost all nutrients remain in the bottom sludge. Almost 100 % of the phosphorus and about 50 to 70 % of the nitrogen as ammonium is still found in the digested slurry [35]. Therefore, the secondary product compost from the digester is a valuable resource for soil amendment. Slurry is commonly mixed with poor soil to improve its fertility with the contained nutrients. European AD systems usually get the slurry dried to minimize its size, and then sell it to farms for agricultural uses,[36] see fig(204).

Fig (204): Dried Slurry as a Fertilizer

(SCHOENNING & STENSTROEM 2004)

Just like ABR system, Anaerobic digesters may generate noxious gases. These gases are "biogas" which is produced from the anaerobic digestion of the organic matter. There is a direct relation between organic content of the disposed water and the biogas produced. Blackwater usually generates 0.02 m^3 gas/user/day.[37] If biogas isn't used, proper ventilation of the system may greatly reduce the gas effect. But it's environmentally better to use this gas in cooking or power generation, because this gas is mainly Methane CH_4, which is a potent greenhouse gas and, if released, may harm the ozone layer.[38]

e- Land Use and Impact on Urban Planning: As mentioned before, Anaerobic Digester can be installed on roof or underground. It can be also installed in the front yard or backyard of the served house. Multistory buildings can be served with one digester installed underground or with several digesters mounted beside each apartment as shown in fig (205). Slurry from mounted digesters is drawn by gravity to an underground septic tank to settle down into water and sludge. Water is leached to irrigate city landscape while sludge is pumped every few months and sold as a fertilizer.

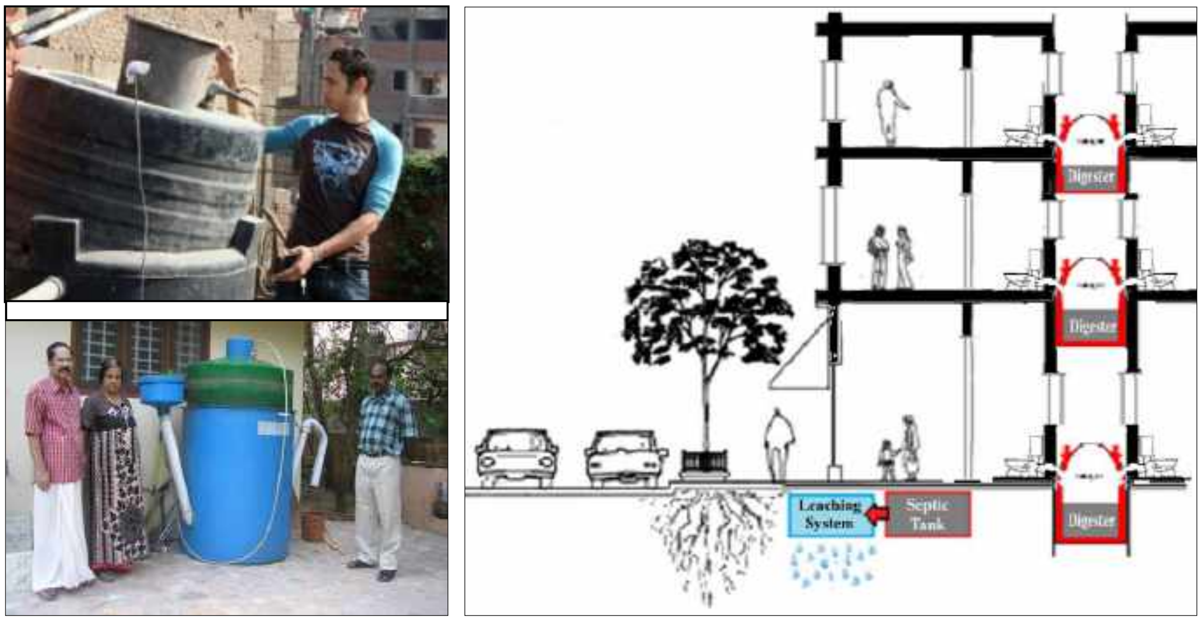


Fig (205): (a) Digester installed on roof in Cairo, Egypt (b) Digester installed in backyard of the house in Bangalore, India (c) A proposed model for mounted digester system in multistory buildings, designed by the researcher.

(a) www.solarcities.com (b) ARTI Biogas Plant: A compact digester for producing biogas from food waste - http://www.arti-india.org/

The former models are more suitable in the city, but there are different models suitable for rural areas. Rural digesters are preferred to be larger to receive the organic waste from cattle and chicken. Rural digesters are commonly built in site with bricks and mortar in dome shape as shown in fig(206).The average size of digestion dome depends on family size, expected quantity of disposed waste, as well as average temperature at the served area around the year.

Fig (206): Building Anaerobic Digester chamber in rural Egypt for both blackwater and animal waste treatment

www.aradina.kenanaonline.com

Rural digester receives wastewater and cattle manure as well as all available organic and agriculture waste. The slurry is pumped towards the land to improve its productivity as shown in fig(207). The produced gas can be used for backing or cooking in rural house. Slurry has better properties if the cattle feeding the digester are 3 and above.

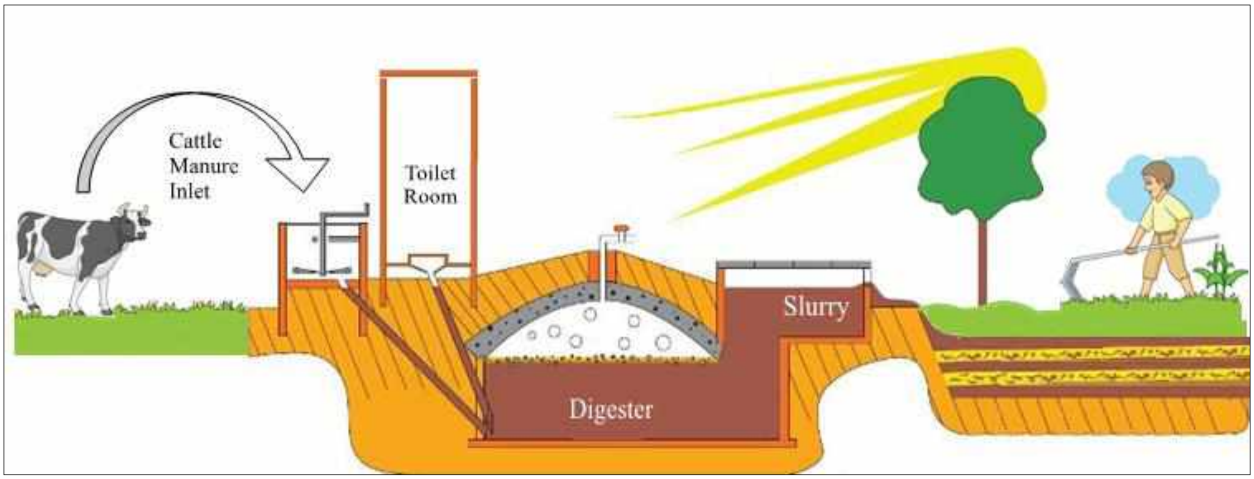


Fig (207): A cross section in a rural Anaerobic Digester installed underground
Modified by the researcher from the original image at: http://en.wikipedia.org/wiki/Biogas

Suitability: This system is more suitable in the following:

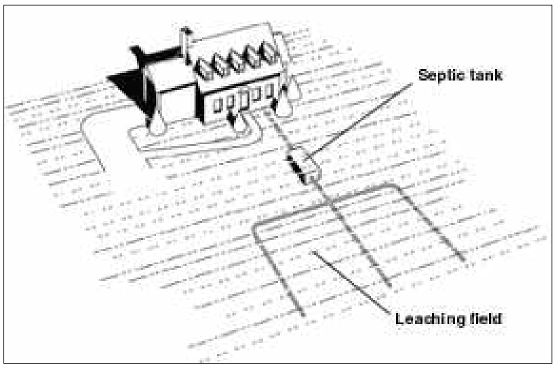
- Areas with hot climate, reaching an optimum of 36 C°, as temperature accelerates the fermentation process.
- Areas with abundant organic waste (e.g. farming, poultry or oil extracting plant. etc.,).

- Areas with good ventilation and sufficient sun exposure.
- Areas near farming lands where slurry can be sold easily.

Most these requirements are available in rural areas and developing countries which makes the technology for small holders in developing countries often suitable.[39]

(2-2-5-1) Integrated Treatment Systems: Septic System:

The most common integrated system in the United States is the Septic System. Septic System is a septic tank followed by a leaching field as shown in fig(208). This system is approved by the Environment Protection Agency EPA but with following the propped design parameters.



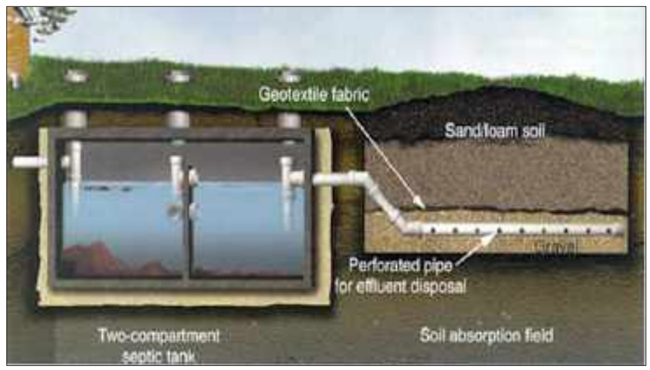
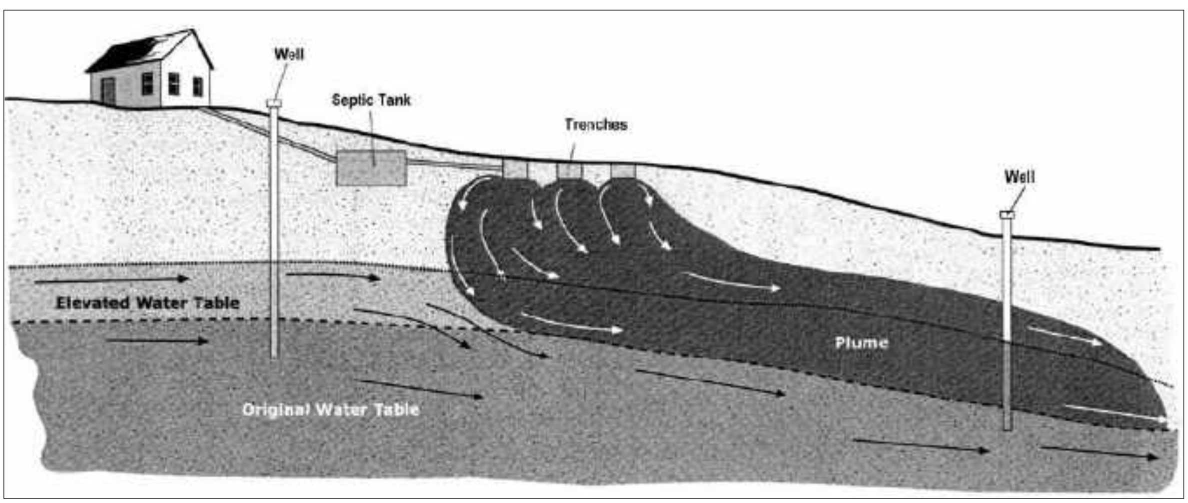


Fig (208): Septic System applied in the United States: (a) Isometric and (b) Cross section

(a) http://interactive2.usgs.gov (b) www.nesc.wvu

Septic systems can affect the quality of surface groundwater. So, if water extraction is needed for consumption, it is preferred to choose deep extraction point to reach the original groundwater level not the elevated water produced from leaching, as shown in fig(209).



Fig(209): Groundwater extraction level acquired in compliance with septic system in isolated

Onsite Wastewater Treatment Systems Manual , EPA/625/R-00/008, February 2002

Septic systems are widely applied in Europe and the United States. One in five homes in the States is served by individual or small, clustered wastewater systems, which collectively treat more than four billion gallons of sewage every day, which forms a vast, decentralized wastewater treatment infrastructure. The strict regulations of EPA have helped in protecting drinking water sources from being contaminated and kept streams, rivers, lakes, and oceans unaffected.[40]

It is noticed that number is inclining with every new house being built in US. In 2007 there 26.1 million houses were applying that system compared with 24.6 million in 1985.[41] About 22 percent of all housing units less than 4 years old used septic systems[4]. It is also noticed 2
that only 3% of septic systems in the US are installed in central cities due to availability of central grid. About 50 % of installed septic systems are installed in rural areas and 47% of them are installed in suburbs as shown in fig(210). The main reason for septic system prevalence in the US is that people pay for central utility, which are usually expensive due to low building capacity and topographic conditions. So, people find that septic systems are more economic and easy to install[4] . 3

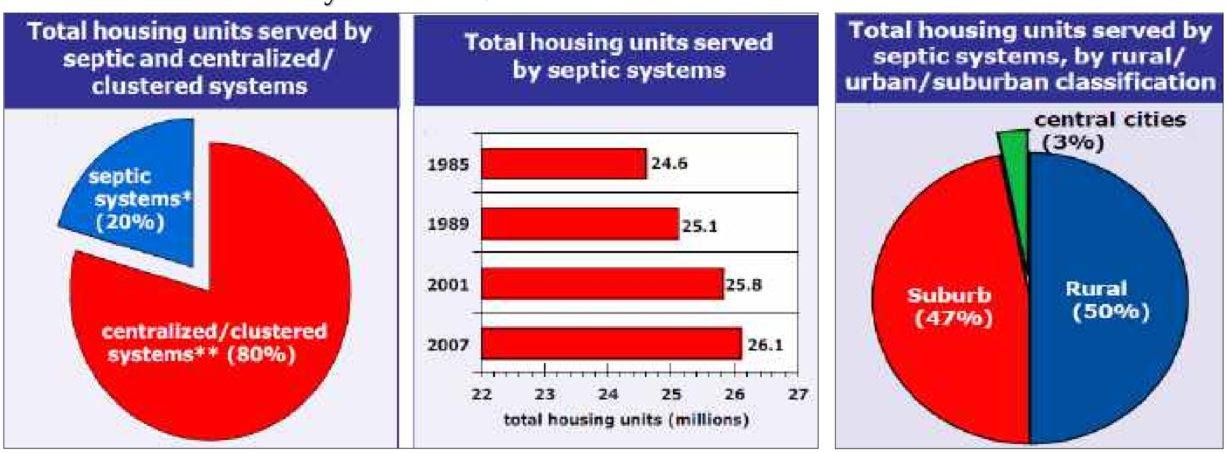
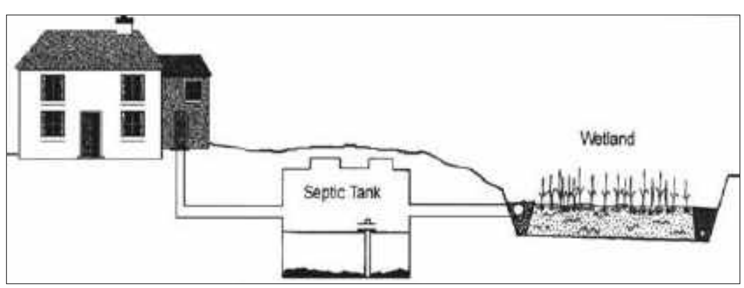


Fig (210): Septic system prevalence in the United States, 2007 census

(a&b) U. S. Census Bureau AHS -www.census.gov/housing/ahs/ (c) Septic Systems Fact Sheet, October 2008

(2-2-5-2) Integrated Treatment Systems: Septic-tank-wetland system:

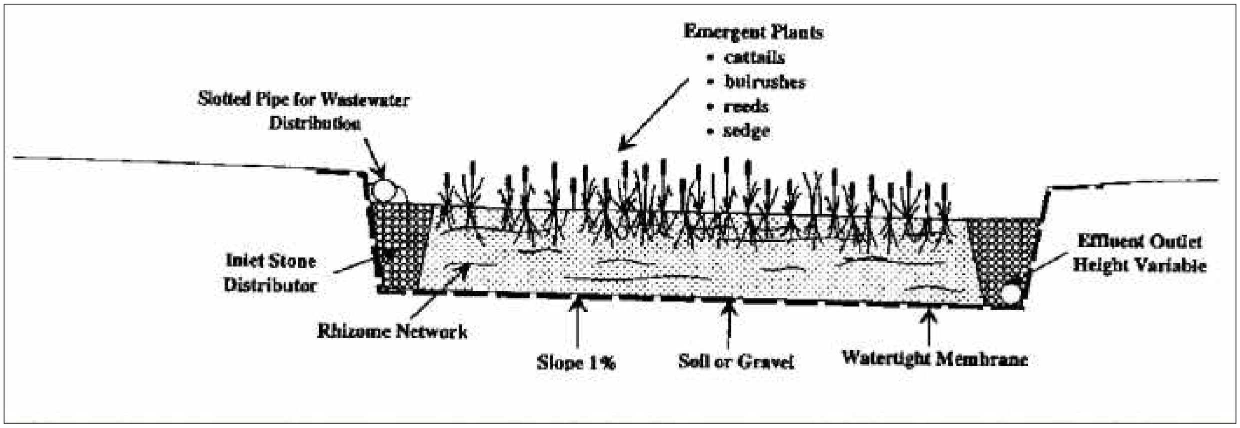
Septic-tank-wetland system is a septic tank followed by wetland system as shown in fig [44](211). .EPA considers that one septic tank



Fig(211): (a) Diagram of Septic-tank-wetland system

Source: Salvato et. al., -Reference No.35

followed by a wetland system is a total integrated system with a standard satisfying performance. In this system, wetland is provided with gravel filters for physical filtration before and after wetland basin. The basin is designed with 1% sloped base to assure moderate flow rate for treated water as shown in fig(212).



Fig(212): Typical wetland cell with gravel filters for wastewater treatment

J. S. Salvato: Environmental Engineering and Sanitation, 2003

This system has an adequate removal efficiency for almost all contaminants in residential wastewater as shown in table (34)[45]. However, It is not as common as septic system due to spacious land needed and because it is installed above ground level. The main users of this system are people living by riverside or lakes, were the effluent water pours directly into nearby water body with minimal environmental footprint.

Typical removal effeciency of septic-tank-wetland system for residential wastewater

Constituent (mg/L)	Septic Tank Effluent[1]	Pond Effluent[3]
BOD	129-147	11-35
Sol. BOD	100-118	7-17
COD	310-344	60-100
TSS	44-54	20-80
VSS	32-39	25-65
TN	41-49	8-22
NH_3	28-34	0.6-16
NO_3	0-0.9	0.1-0.8
TP	12-14	3-4
OrthoP	10-12	2-3
Fecal coli (log/100ml)	5.4-6.0	0.8-5.6

Table (34): Septic-tank-wetland system removal efficiency measured by EPA,1999

Source: EPA Manual of Constructed Wetlands Treatment of Municipal Wastewaters, 1999- Reference No. 45

Part (II)- Chapter 2

(1-3) Off-grid wastewater treatment systems:

Summary of Chapter (3)

Wastewater treatment can be performed on a small scale using off-grid technologies. Primary, secondary and tertiary treatment technologies, if properly applied, can be highly efficient and sustainable in many cases. Many of these technologies are suitable for application in different Egyptian environments. Strict regulations must be set to keep natural resources clean and protected.

End of Summary of Part (II) Chapter 2

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[9] BOD (Biological Oxygen Demand) is the amount of oxygen (in mg/l) that microorganisms like bacteria need to consume (or eat) the organic pollution in wastewater, although not all pollutants can be consumed by bacteria. Chemical Oxygen Demand (COD) measures all organic and inorganic compounds that can be chemically oxidized in wastewater. BOD value in polluted water is normally higher than the fresh water and COD is commonly 1.8 times greater than BOD

10Yaqin Yu , Xiwu Lu and Yifeng Wu : Performance of an Anaerobic Baffled Filter Reactor in the Treatment of Algae-Laden Water and the Contribution of Granular Sludge, *Water* scientific journal, vol. *6*(1), 2014, 122-138; doi:10.3390/w6010122

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Part (II)- Chapter (3)

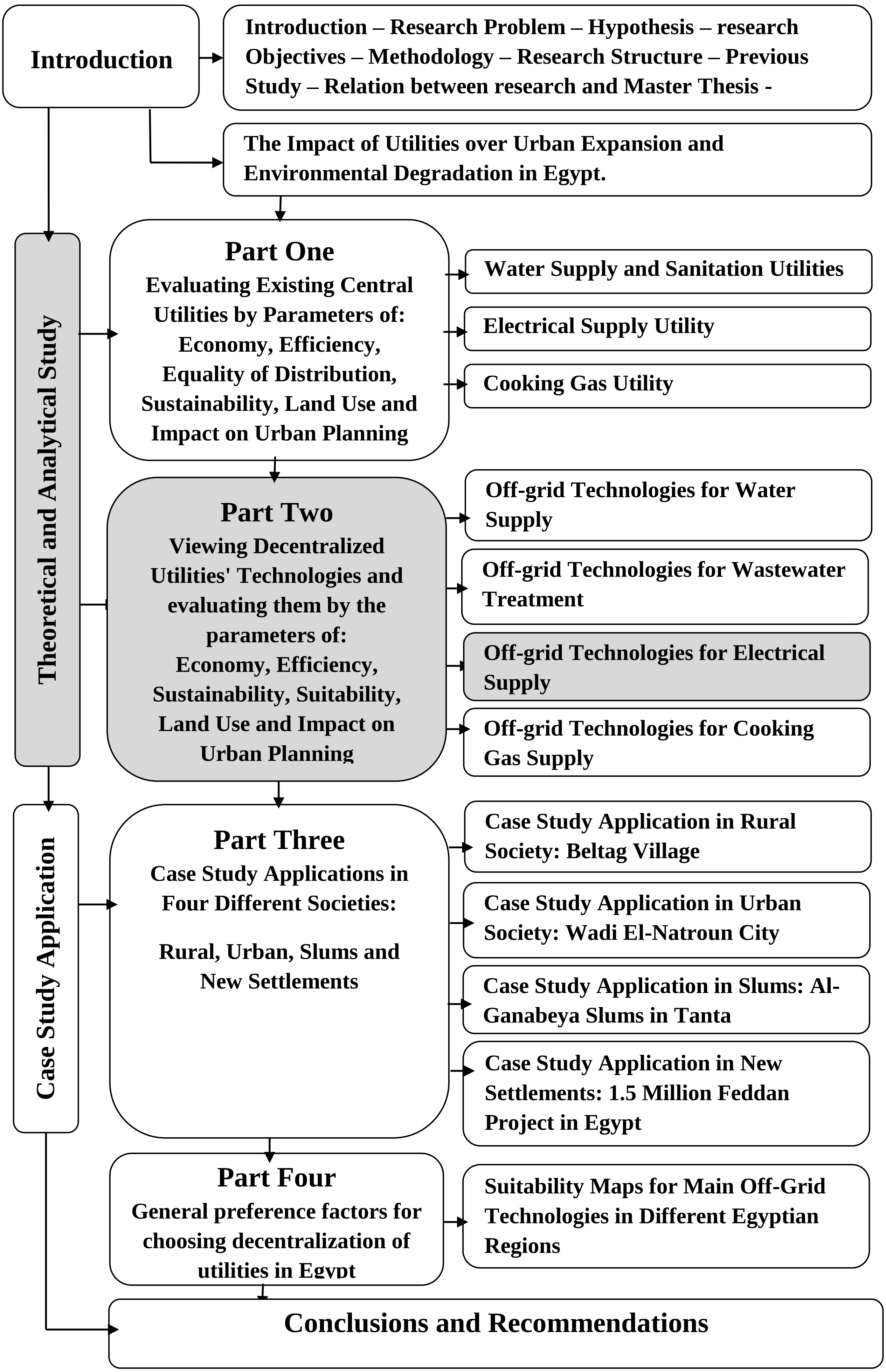
(2-3) Off-grid Technologies for Household Electrical Supply:

Introduction to Chapter 3

Electricity is a main utility needed in every household. Almost all household appliances run by electricity. This chapter discusses solar systems as a sustainable alternative for electrical supply in off-grid houses. It also discusses solar water heaters application as it can save a lot in monthly electrical consumption.

These technologies are evaluated using the parameters of:
economy, efficiency, sustainability, land use and Impact on urban planning, as well as their suitability for application in Egypt.

End of Introduction to Part II- Chapter (3)


Introduction
Introduction – Research Problem – Hypothesis – research Objectives – Methodology – Research Structure – Previous Study – Relation between research and Master Thesis -
The Impact of Utilities over Urban Expansion and Environmental Degradation in Egypt.
Theoretical and Analytical Study
Part One
Evaluating Existing Central Utilities by Parameters of: Economy, Efficiency, Equality of Distribution, Sustainability, Land Use and Impact on Urban Planning
Water Supply and Sanitation Utilities
Electrical Supply Utility
Cooking Gas Utility
Part Two
Viewing Decentralized Utilities' Technologies and evaluating them by the parameters of: Economy, Efficiency, Sustainability, Suitability, Land Use and Impact on Urban Planning
Off-grid Technologies for Water Supply
Off-grid Technologies for Wastewater Treatment
Off-grid Technologies for Electrical Supply
Off-grid Technologies for Cooking Gas Supply
Case Study Application
Part Three
Case Study Applications in Four Different Societies:
Rural, Urban, Slums and New Settlements
Case Study Application in Rural Society: Beltag Village
Case Study Application in Urban Society: Wadi El-Natroun City
Case Study Application in Slums: Al-Ganabeya Slums in Tanta
Case Study Application in New Settlements: 1.5 Million Feddan Project in Egypt
Part Four
General preference factors for choosing decentralization of utilities in Egypt
Suitability Maps for Main Off-Grid Technologies in Different Egyptian Regions
Conclusions and Recommendations

(2-3) Off-grid electrical supply: The main off-grid technology used for power supply is solar technology. Solar technology depends on using solar energy for generating power or heating water. In this part we discuss both types.

(2-3-1) Solar cells (Photo Voltaic System PV):

a- **Description and Mechanism:** PV system is formed of photovoltaic array which receives solar rays and transforms it into power. The main parts of the system are shown in fig(213). Batteries can be added to assure power reserves during night time when sun rays are absent.

Fig(213): Photovoltaic System main components – Source: http://www.alibaba.com - retrieved 13/12/2015

b- **Economy:** The main problem with solar energy applications is their initial cost. Traditional systems are about four times cheaper than solar systems. However, solar systems' cost is reduced by time as running cost is much cheaper. After the initial investment has been recovered, the energy from the sun is practically free.

A study conducted in 2012 shows that the cost of generating electricity by solar cells in Egypt costs 0.35 LE/ 1 kWh of generation compared with 0.05 LE / 1 kWh in the date of the study. However, solar cost is constant and not ascending by different consumption categories like the central grid. The same study is expecting future cost reduction due to many factors like future mass use, development in technology and climatic changes which are expected to increase solar radiation density.[1]

As global fossil fuel reserves had started to diminish, their cost will rise until a point is reached where solar cells become an economically viable source of energy. When this occurs, massive investment will be able to further increase their efficiency and lower their cost.

c- Efficiency: Solar Energy systems are virtually maintenance free and can last for decades. It's not affected by the supply and demand of fuel and is therefore not subjected to the ever-increasing price of fossil fuel. On the other hand, solar batteries need regular replacement after 5-7 years, and solar efficiency is affected by air pollution and bad weather. Another disadvantage is the problem of nocturnal down times which makes solar cells work only during the daytime. In general, the average daily solar energy in a complete year in Egypt was estimated to be about 6 kWh/m^2/day. This corresponds to 6 hours of peak sunshine intensity of 1000 W/m^2 [2].

- Reduction of solar performance by accumulating dust: The performance of a solar energy system (whether using thermal or PV collector) is influenced by the ability of the cover glass to transmit solar radiation to the collection surface besides other factors, such as the intensity of solar radiation, the tilt angle of the absorbing surface, the properties of the materials etc.

For example, Salim et al. had constructed a PV test system at a solar village near Riyadh, Saudi Arabia, to study the effect of long term accumulation of dust on the PV array energy output. With the fixed tilted array at 24.6, the monthly energy reduction for the unclean array was obtained by comparing its performance with an identical array, which was cleaned daily. The reduction in the energy output from the unclean array reached 32% at the end of eight months.

Hassan et al. shows that the degradation progresses rapidly during the first 30 days of exposure. The results imply that the depression of the efficiency is 33.5% after one month and increases to 65.8% after six months without panel cleaning. Similar measurements were made in Kuwait by Sayigh et al., who observed 64%, 48%, 38%, 30% and 17% reduction in the transmittance of the glass plates after 38 days of exposure to the environment with tilt angles of 0_, 15_, 30_, 45_ and 60_, respectively.

- Maximizing efficiency using tilt angle: The tilt angle of the solar system has an obvious impact over its efficiency. (Ahmed and Mohamed, 2000) had measured the solar energy produced by a solar system in different angles: horizontal, titled with36 degree, and rotating with automatic movement. Maximum power was generated from the solar system with automatic angle modifier as it provides the maximum exposure to sun light.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
H_{hori}	3.22	4.29	5.31	6.66	7.03	7.75	7.62	7.14	6.18	4.95	3.63	3.07
H_{tilted}	4.3	5.32	5.92	6.64	6.47	6.7	6.73	6.84	6.67	6.07	4.82	4.17
T_a	14.9	15.9	19.3	23	26	28	29	27	26	25	20	17

Table (35): Average daily solar energy on horizontal and tilted planes in kWh/m2/day, mean ambient temperature& average sun shine hours for a complete year for Cairo city in Egypt (Ahmad & Mohamad 2000)

c- Sustainability and environmental Impact: Environmentally, solar power is the most clean and green energy. It causes no pollution during the process of generating electricity. Solar Energy is clean, renewable and sustainable, helping to protect our environment. Solar energy does not require any fuel. It does not pollute our air by releasing carbon dioxide, nitrogen oxide, sulfur dioxide or mercury into the atmosphere like many traditional forms of electrical generation do. Therefore Solar Energy does not contribute to global warming, acid rain or smog. It actively contributes to the decrease of harmful greenhouse gas emission.

However, there are some potential impacts concerning the manufacturing, transportation and installation of solar systems. These potential environmental impacts can vary greatly depending on the technology used and the scale of the system[3]. The main impacts are:

- Water Use: Solar PV cells do not use water for generating electricity. However, as in all manufacturing processes, some water is used to manufacture solar PV components.

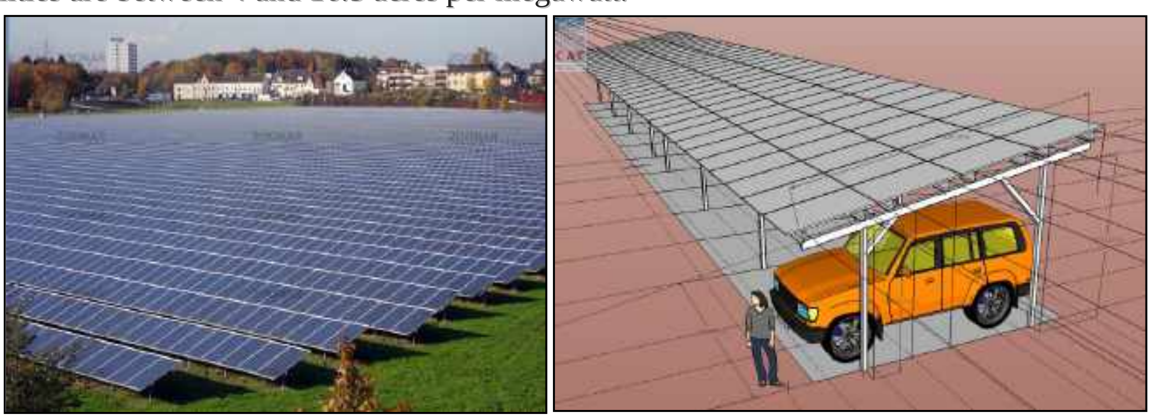
Concentrating solar thermal plants (CSP), like all thermal electric plants, require water for cooling. Water use depends on the plant design, plant location, and the type of cooling system[4]. Many of the regions in the United States that have the highest potential for solar energy also tend to be those with the driest climates, so careful consideration of these water tradeoffs is essential.

- Hazardous Materials : PV cell manufacturing process includes a number of hazardous materials, most of which are used to clean and purify the semiconductor surface. These chemicals, similar to those used in the general semiconductor industry, include hydrochloric acid, sulfuric acid, nitric acid, hydrogen fluoride, 1,1,1-trichloroethane, and acetone. The amount and type of chemicals used depends on the type of cell, the amount of cleaning that is needed, and the size of silicon wafer[5]. Workers also face risks associated with inhaling silicon dust. Thus, PV manufactures must follow EPA laws to ensure that workers are not harmed by exposure to these chemicals and that manufacturing waste products are disposed of properly.

Thin-film PV cells contain a number of more toxic materials than those used in traditional silicon photovoltaic cells, including gallium arsenide, copper-indium-gallium-diselenide, and cadmium-telluride[6]. If not handled and disposed of properly, these materials could pose serious environmental or public health threats. However, manufacturers have a strong financial incentive to ensure that these highly valuable and often rare materials are recycled rather than thrown away.

- Life-Cycle Global Warming Emissions: While there are no global warming emissions associated with generating electricity from solar energy, there are emissions associated with other stages of the solar life-cycle, including manufacturing, materials transportation, installation, maintenance, and decommissioning and dismantlement. Most estimates of life-cycle emissions for photovoltaic systems are between 0.07 and 0.18 pounds of carbon dioxide equivalent per kilowatt-hour. On the other hand, most estimates for concentrating solar power range from 0.08 to 0.2 pounds of CO_2 equivalent/ kWh. In both cases, this is far less than the lifecycle emission rates for natural gas (0.6-2 lbs of CO_2E/kWh) and coal (1.4-3.6 lbs of CO_2E/kWh7

d- **Land use and impact on urban planning :** If applying in mass city-scale plants, depending on their location, large utility-scale solar facilities can raise concerns about land degradation and habitat loss. Total land area requirements vary depending on the technology, the topography of the site, and the intensity of the solar resource. Estimates for utility-scale PV systems range from 3.5 to 10 acres per megawatt, while estimates for CSP facilities are between 4 and 16.5 acres per megawatt.



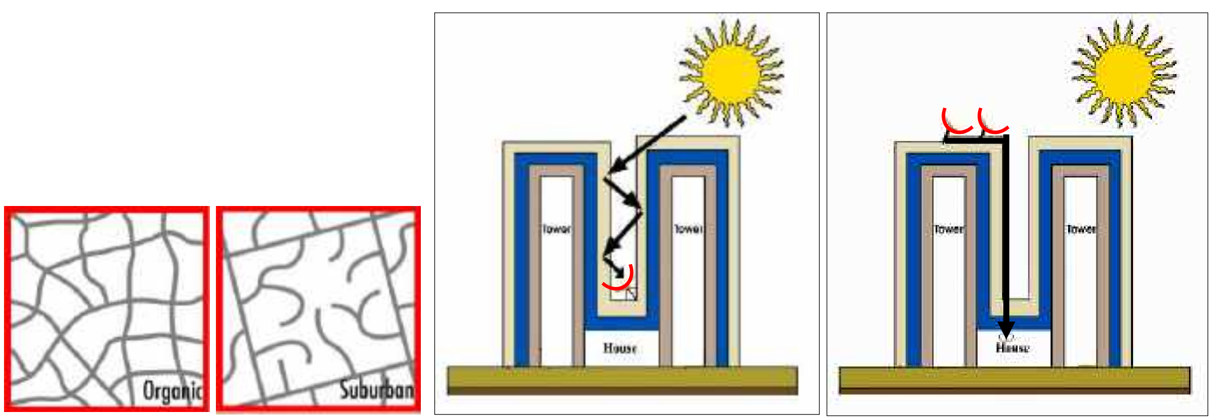
Fig(214): (left) Solar farm land use in Berlin, Germany 2010 (right) Zero land use of solar panels by using them as parking roof

Unlike wind facilities, there is less opportunity for solar projects to share land with agricultural uses. However, land impacts from utility-scale solar systems can be minimized by setting them at lower-quality locations such as brown-fields, abandoned mining land, or existing transportation and transmission corridors. Smaller scale solar PV arrays, which can be built on homes or commercial buildings, also have minimal land use impact.

If applying in residential scale, solar technology can simply be applied over the roof of any building without any special planning requirements. There is no land acquired for generation or transmission. The street form may be straight, organic or even random slums. However, some considered factors may affect this process like shading factor and the building's orientation. For the shading factor, high buildings may deprive neighbors from having adequate solar radiation necessary for generation. This problem can be solved by renting the highest roof in the street and installing solar cells for neighbors on it. For the direction problem, the solar rays may be trapped by installing reflecting mirrors which will reflect opposite directed sun rays and point them into solar cells direction.

On the other hand, the increase of shading factor serves for less power consumption. As the shading factor increases, the need for cooling in summer will decrease, which will positively affect the need for electricity as well.

1 klm^2 is required to produce 300 GWh/y of solar electricity. This means that the average consumption of a single Egyptian family which is 300 kwh/monthly requires 12 m^2 to generate its average electricity consumption.

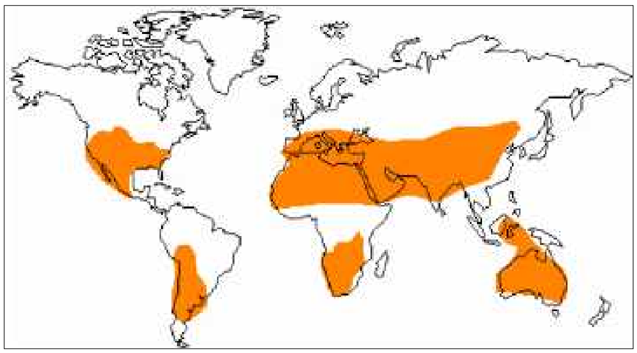


Fig(215): (left) Decentralized solar electricity system suit all street forms including organic and suburban (right) Solutions for shading problem: A: Trapping sunrays by reflecting mirrors- B: Renting neighbors' roofs for solar panels' installation- Designed by the researcher

e- Suitability of Solar systems in Egypt:

Egypt is in advantageous position with solar energy. It belongs to the global sun-belt, Fig. 2. In 1991 solar atlas for Egypt was issued indicating that the country enjoys 2900-3200 hours of sunshine annually with annual direct normal energy density 1970- 3200 kWh/m2 and technical solar-thermal electricity generating potential of 73.6 Petawatt.hour (PWh)[8].

Egypt was among the first countries to utilize solar energy. In 1910, American engineer F. Shuman built a practical industrial scale solar system engine at Maadi south to Cairo using solar thermal parabolic collectors, Fig. 216. The engine was used to produce steam which drove a series of large water pumps for irrigation[9].




Fig(216): (a) Egypt as part of solar belt (b) Frank Shuman parabolic solar collectors, Maadi 1912
Source: Comsan, 2010

Nowadays, PV systems are considered one of the most appropriate applications for remote areas in Egypt. Especially areas that are located away from the national grid. According to NREA photovoltaic technologies are in use for lighting, commercial advertisements, wireless communications and cell phone networks, in water pumping for irrigation in newly reclaimed lands, in rural electrification, refrigeration, etc.[10] It is estimated that present Egypt's PV systems installed capacity is close to 5 MW peak.[11] As an estimate with solar power parameters for Egypt, a 1 km2 of desert equipped with modern trough or Fresnel flat mirror technology can produce 300 GWh/year of solar electricity.[12]

Solar potentials in Egypt vary from one place to another. The direct normal irradiation starts with 5.5 kWh/m2/day in the north coast and increases as we go south, reaching 9 kWh/m2/day in Al-Gulf Al-Kebeir area.

In July 2012, the Egyptian Cabinet has approved the implementation of the Solar Energy Plan[13], while in July 2013, Egyptian Electricity Holding Company (EEHC) has announced an invitation for the investors to submit their qualifications for the construction of 10 photovoltaic power plants. The Board of directors of the Regulatory and Consumer Protection Agency has approved the application of energy exchange which allows the consumers mounting photovoltaic system on their roofs to sell electricity to the grid through a separate meter reading based on the highest level of consumption during the month.

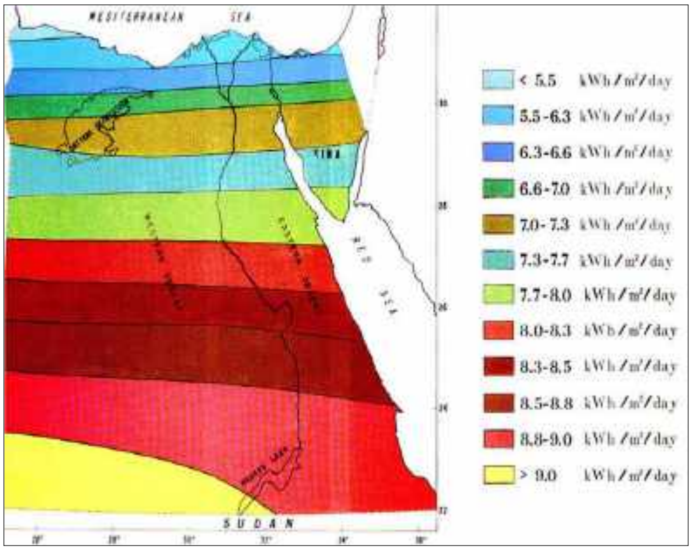
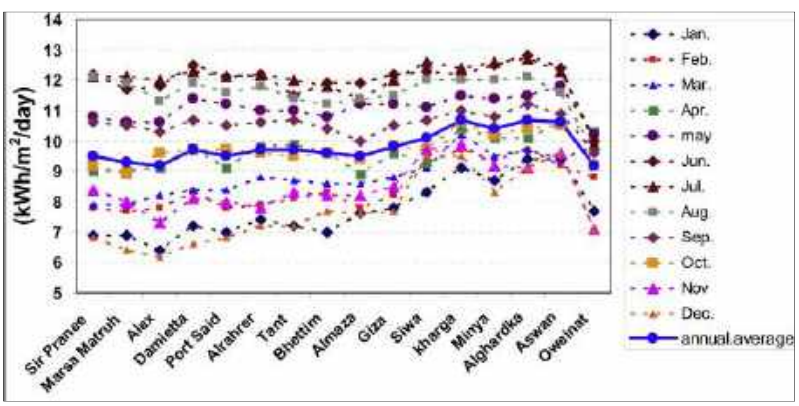


Fig (217) : (left) Annual Direct Normal Irradiation zones in Egypt (right): Solar panels mounted at the Ministry of Electricity and

Source: (left) National Renewable Energy Association (NREA)- (right) Holding Company Annual Report

Solar panels depend basically on sun exposure. Not all Egyptian cities enjoy the same density, but there are similarities in most major cities. Fig(218) shows that 16 cities are enjoying nearly the same average of solar radiation density, which is **9** to **10.8** kWh/m^2/day.



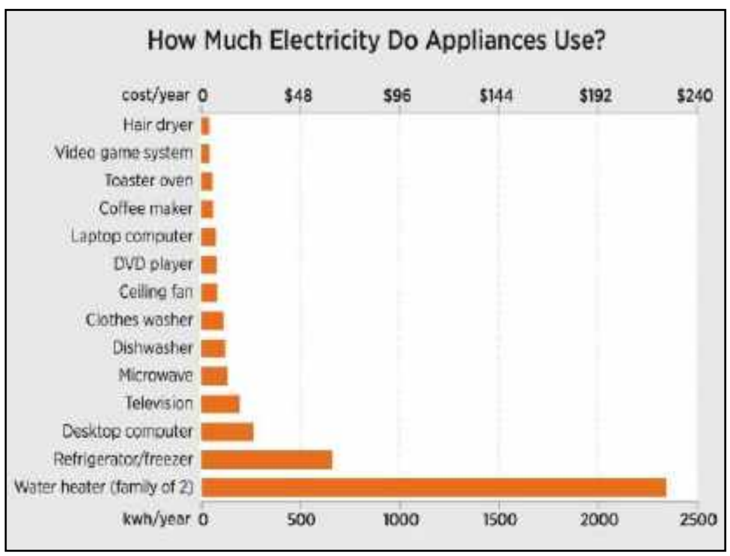
Fig(218): Solar radiation intensity map for Egyptian cities - **source: (Solar atlas for Egypt).**

Solar panels do not require special education. In a country like India, solar panels are installed even in the poor slums and rural areas. With little guidance, people can easily adapt with it and their children will gain new experience, fig (219).

Fig(219) : Applied solar panels in rural Indian house-
www.greenenergy.com

(2-3-2) Reducing electrical consumption by using solar water heaters: Water heating is a basic activity in every household, especially in winter season. Water heating in Egypt is mainly done by electrical heaters and water boilers. However, in rural and upper Egypt, LPG is still the main fuel used for water heating. Some households still use kerosene flame, woods and agricultural waste for heating water. For example, a survey conducted in 2014 showed that (52.3%) of the sample in Sohag governorate and (55.3%) of the sample in Menufia reported that they use LPG for water heating, while remote areas in Matrouh city used dry wood, particularly during the absence of LPG cylinders.[14]

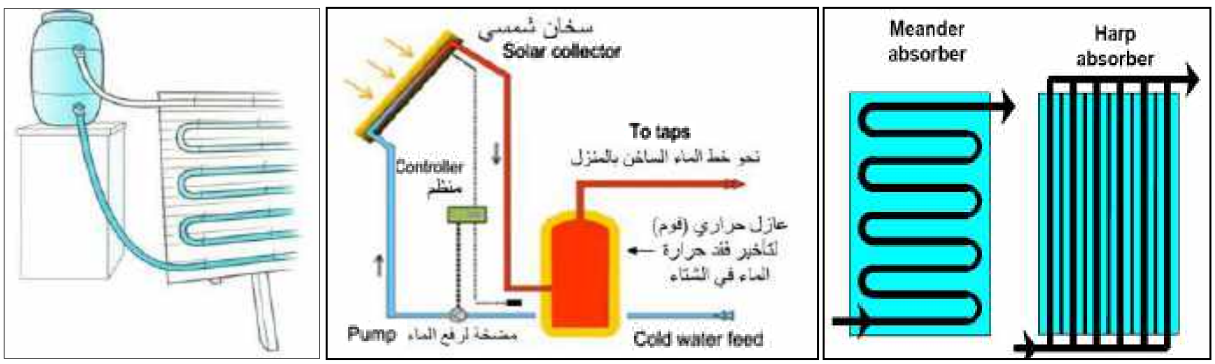
In most urban areas, water heaters are main consumers of residential electricity. Water heating is responsible for more than 1/3 of total household electrical consumption, especially in winter season. As we seek for sustainable off-grid technologies, we must consider renewable water heating systems to save electricity and make the maximum use of solar power with minimum impact over the environment.



Fig(220): The share of water heaters in electrical consumption in American household compared to other electrical appliances - Source: http://energy.gov.usa/

(2-3-2-A) Solar Collectors: The common name for solar water heating systems is "solar collectors", which are very common in many countries around the world.

a- Description and Mechanism: Solar heater is simply a series of tubes wherein water flows to gain heat. These tubes are commonly made of a high conductive material to absorb heat from the sun and deliver it to passing water. Cold water flows by gravity into hot tubes wherein it gains heat by conduction. Hot water becomes lighter than the subsequent cold water, which forces hot water to elevate to the upper part of the collector where it is delivered to hot water tank. Hot water is stored in insulted tank to keep it hot as long as possible. The main shapes of heating tubes are meander shape and Harp shape as shown in fig(221).[15]



Fig(221):Solar water heating systems (left) Illustration of main idea (middle) Cross section (right) Main shapes

Source: (left) http://energy.gov/ (middle) http://www.mojtamai.com/taqa/images/stories/sun-5.jpg/ (right) Werner Weiss: Institute

b- Cost: Solar water heaters can have minimal cost if manufactured in site with local materials as seen in fig(222), but such systems are commonly less durable and less efficient. Prefabricated systems are more efficient and durable and they usually occupy less space area. The cost of prefabricated systems starts from 130 dollars for single family use (Dec, 2015 price).[16] These systems are provided with storage tank, thermostat and insulation layers.

Fig(222): Locally made solar collectors above the roof of Zabaleen informal school (left) and in Historical Cairo (middle)- (right) An example for prefabricated solar collector. Source: (left) Photo courtesy to T.H.Culhane, www.solarcities.blogspot.com/ (middle) http://news.nationalgeographic.com/ (right) http://www.alibaba.com/ retrieved in **13/12/2015**

c- Efficiency: Solar collectors' efficiency is affected by many factors, such as area, material, climate, tilt angle and water purity.

- Material: The most common materials in solar collectors are steel, aluminum and copper. All of them have high thermal conductivity which allows better performance. The best material for solar collectors is copper, which has a thermal conductivity of 380 W/mK, followed by aluminum with a conductivity of 210 W/mK. The least preferred material is steel, with a conductivity of 50 W/mK. These measures are also affected by wall thickness, manufacturing method and purity of used material[1] Table (36).

absorber material	thermal conductivity [W/mK]
steel	50
aluminium	210
copper	380

Table (36): Thermal conductivity of different absorbing materials in solar collectors.
Source: Werner Weiss, Institute for Sustainable Technologies (AEE INTEC)-

- Climate: Just like solar panels, the performance of solar collectors is affected with temperature, wind speed, solar irradiation and sky clearance. Performance is directly proportional with all these factors but if wind speed is very high it may destroy the system[17]

- Tilt angle: As discussed in solar panels, tilt angel affects the performance of the system. Automatically rotating system achieves the most sun exposure thus most efficiency.

water temp. °C		ambient temp.	solar radiation
initial T_{wi}	final T_{wf}	T_a °C	H_t kJ/m^2
24.6	41.9	31.8	3950.0
24.8	36.3	31.1	3504.0
24.0	33.0	24.8	2636.1
24.6	35.1	31.3	1282.5
24.5	32.6	18.3	847.4
23.6	30.5	18.3	383.0
38.6	52.0	30.7	5581.9
36.1	48.5	31.7	3255.9
36.0	46.0	30.6	1329.4
36.0	44.4	18.3	602.6
36.4	39.9	17.3	223.6

Table(37): Direct relation between air temperature, solar radiation and water heaters performance as measured in Cairo city.
(Ahmad & Mohama, 2000).

- Water Purity: Water purity is directly proportional with solar system's efficiency. Turbid water takes more time in heating process and the remaining solids usually attach to inner walls of the tubes and reduce their thermal conductivity.

-Performance reduction by accumulating dust: Just like solar panels, solar collectors are affected by accumulating dust. The reduction may reach 32% in less than one month depending on weather conditions, so regular cleaning must be considered[18]

e- Land Use and Impact on Urban Planning: Just like solar panels, solar collectors have minimal land use and zero impact on urban form if installed over the roof of the served building. Furthermore, solar collectors require less roof space than PV systems. The figures below show the massive use of solar collectors in China, as well as minimal roof space consumption by the system.[19]

Fig(223): (left) Solar water heaters on newly built apartment blocks in Hunchun, China (right) Roof use for solar collectors - Source: (left) UN-Habitat/Alessandro Scotti (right) www.solarcities.com

f- Suitability for application in Egypt: Egypt has good potentials in solar power that make solar collectors very suitable and applicable choice in Egypt. However, these systems are still rarely used due to lack of knowledge and the ongoing governmental subsidies over electrical consumption. Many Arab countries have adapted solar collectors as a green source of energy, especially in coastal cities like Gaza and Beirut.

The diffusion of solar heaters was measured in Egypt in 2012 to compare it with 12 peer Arab countries, using the parameter of square meters installed per 1000 inhabitants. Measures showed that Egypt was no. 7 among the 13 studied countries. Egypt's share of solar heaters was about 10 m^2/1000 inhabitants, compared with 407 in Palestine, 162 in Jordan and 82 in Lebanon as shown in fig(224).[20] Almost 70 % of households in Palestine were equipped with solar water heaters in time of study. Such a high penetration rate is mainly a response to persistently high energy prices.[21]

Solar Energy in Brief: Solar energy utilization includes use of photovoltaic cells, solar water heating and solar thermal power. The main advantage of solar systems are being clean, sustainable and having minimum space requirements for generation. The main disadvantage of these systems is the high initial cost. Air pollution and weather can affect the efficiency of the system. Disadvantages of solar technology can be resolved in the future especially with mass use and technology development.

Fig(224): Prefabricated solar collectors installed in Beirut, 2012
ناجي طنوس: البيئة في لبنان :الواقع والاتجاهات- الفصل التاسع : أزمة الطاقة ٢٠١٠

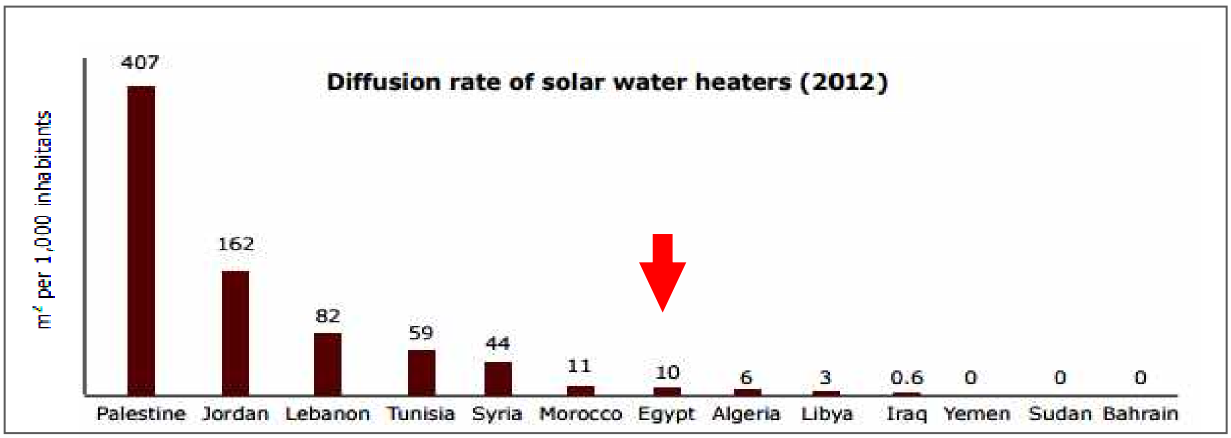


Fig (225): Diffusion rate of solar water heaters in 13 Arab countries in 2012
Regional Center for Renewable Energy and Energy Effeciency (RCREEE): Arab Future Energy Index (AFEX) Energy Effeciency, Index Report, 2013

Egypt has good potentials in solar power generation and these systems are most appropriate in remote rural and Bedouin areas were expanding electricity grid needs huge investments.

The Egyptian government can't offer subsidies to solar projects, but it can offer other kinds of support and incentives. New policies supporting renewable energy projects are required. Such support can play an important role in solar energy cost reduction and competitiveness. If subsidies are not available, other incentives can be offered like flexible debt conditions, low or zero interest rate loans with long maturities for solar energy domestic units. It is also recommended that new legislations are implemented by the government (represented in the **New and Renewable Energy Authority of Egypt**), to promote the adoption of solar energy technologies. Media campaigns and social leaders can also contribute in promoting sustainable solar systems in residential scale.

(2-3-3) Electricity from biogas plant:

Biogas is a byproduct of anaerobic decomposition of organic matter. It consists mainly of methane (60 %) as discussed in the next chapter. Biogas can be an important source of energy as it can be fed to a biogas engine that generates electricity to the house.

Biogas can produce 6kWh of electricity /m^3 Gas. So, for an average family of five with monthly consumption of 500-600 kWh, they need 100 m^3 of Gas per month to generate electricity. So, organic matter sources must be supplied to cover the family's needs of biogas enough to generate the electrical needs of the family.[22] The next chapter discusses biogas production and use in both cooking and electrical generation.

Part (II)- Chapter 3

(2-3) Off-Grid Technologies for Power Supply

Summary of Chapter (3)

Solar energy utilization includes use of photovoltaic cells, solar water heating and solar thermal power. The main advantage of solar systems are being clean, sustainable and having minimum space requirements for generation. The main disadvantage of these systems is the high initial cost. Air pollution and weather can affect the efficiency of the system. Disadvantages of solar technology can be resolved in the future especially with mass use and technology development.

Egypt has good potentials in solar power generation and these systems are most appropriate in remote rural and Bedouin areas were expanding electricity grid needs huge investments.

Biogas can be an important source of energy as it can be fed to a biogas engine that generates electricity to the house. It can produce 6kWh of electricity /m3 Gas. Organic matter sources must be supplied to cover the family's needs of biogas enough to generate their electrical needs. The next chapter discusses biogas production and use in both cooking and electrical generation

End of Summary of Part (II) Chapter 3

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Part (II)- Chapter (4)

(2-4) Off-grid Technologies for Household Cooking Gas Supply:

Introduction to Chapter 4

Cooking gas is a basic utility that no household can manage without. Its consumption varies according to family's size, culture and economic standard. The use also varies according to climate and temperature. The average monthly need of single Egyptian family of cooking gas is about 4-6 m^3 around the year.

As mentioned in chapter I, cooking gas in Egypt is supplied in two forms: LPG and Natural Gas. Natural Gas is mainly Methane CH4 (85%) and it has a smaller carbon footprint than LPG. The most common way to provide cooking gas for off-grid houses is the "Biogas Plant" which is applied in many housing in isolated areas and in developing countries.

This chapter discusses this technology and evaluates it using the same parameters to examine its cost, efficiency, sustainability, land use and suitability for application in Egypt.

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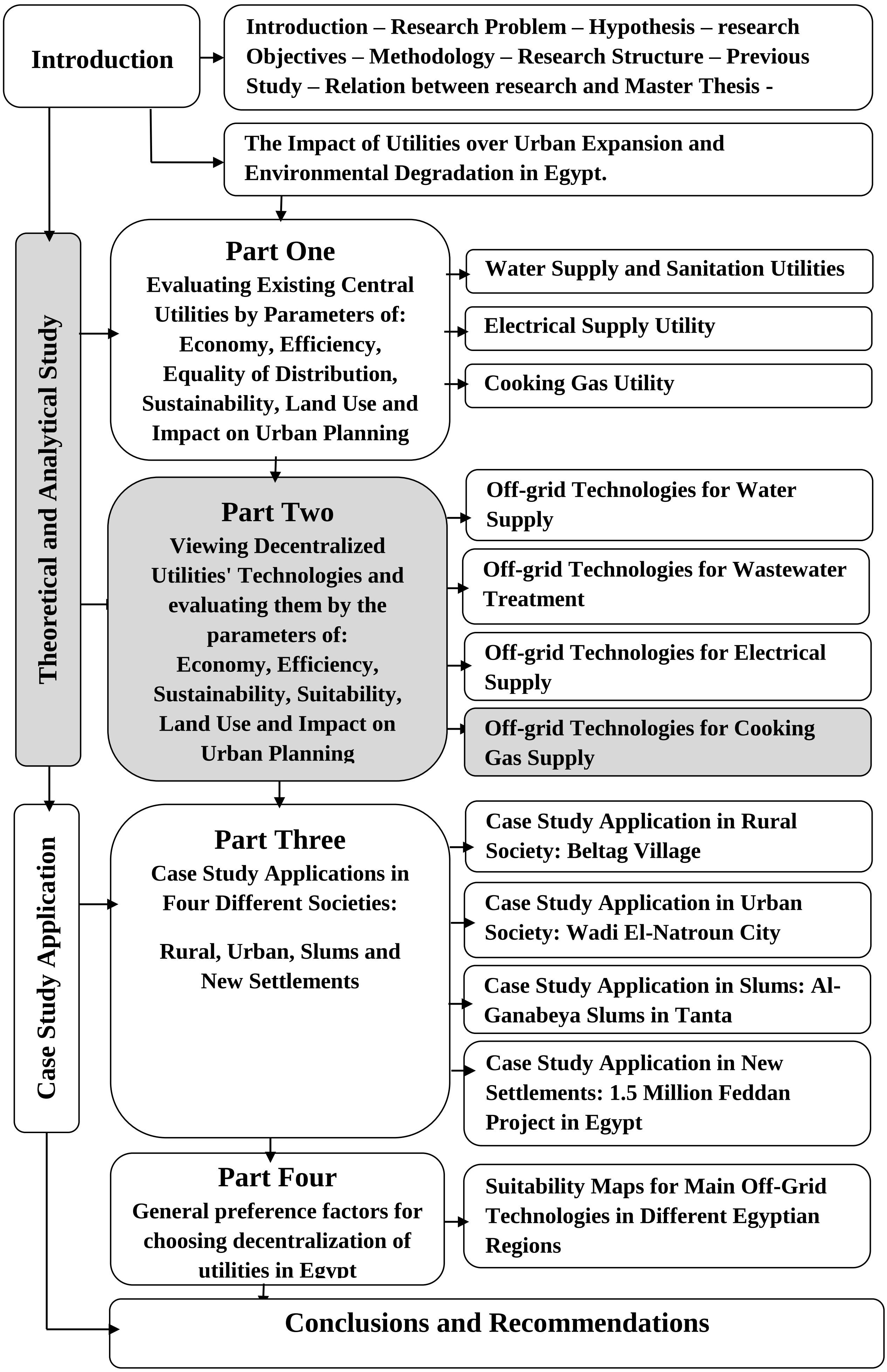
End of Introduction to Part II- Chapter (4)


Introduction
Introduction – Research Problem – Hypothesis – research Objectives – Methodology – Research Structure – Previous Study – Relation between research and Master Thesis -
The Impact of Utilities over Urban Expansion and Environmental Degradation in Egypt.
Theoretical and Analytical Study
Part One
Evaluating Existing Central Utilities by Parameters of: Economy, Efficiency, Equality of Distribution, Sustainability, Land Use and Impact on Urban Planning
Water Supply and Sanitation Utilities
Electrical Supply Utility
Cooking Gas Utility
Part Two
Viewing Decentralized Utilities' Technologies and evaluating them by the parameters of: Economy, Efficiency, Sustainability, Suitability, Land Use and Impact on Urban Planning
Off-grid Technologies for Water Supply
Off-grid Technologies for Wastewater Treatment
Off-grid Technologies for Electrical Supply
Off-grid Technologies for Cooking Gas Supply
Case Study Application
Part Three
Case Study Applications in Four Different Societies:
Rural, Urban, Slums and New Settlements
Case Study Application in Rural Society: Beltag Village
Case Study Application in Urban Society: Wadi El-Natroun City
Case Study Application in Slums: Al-Ganabeya Slums in Tanta
Case Study Application in New Settlements: 1.5 Million Feddan Project in Egypt
Part Four
General preference factors for choosing decentralization of utilities in Egypt
Suitability Maps for Main Off-Grid Technologies in Different Egyptian Regions
Conclusions and Recommendations

(2-4) Domestic biogas plants:

Domestic biogas plant is a small scale unit which converts organic waste into biogas and slurry (slurry is a semiliquid mixture of fine particles of manure, suspended in water).

(2-4-1) Description and Mechanism: Domestic waste from toilets and kitchens is drained into a brick chamber where the anaerobic reaction takes place and converts this organic waste into methane CH_4 which is the main ingredient of the natural gas used for cooking. The effluent digested residue from this reaction is called slurry, which can be buried or sold as fertilizer, fig (226).

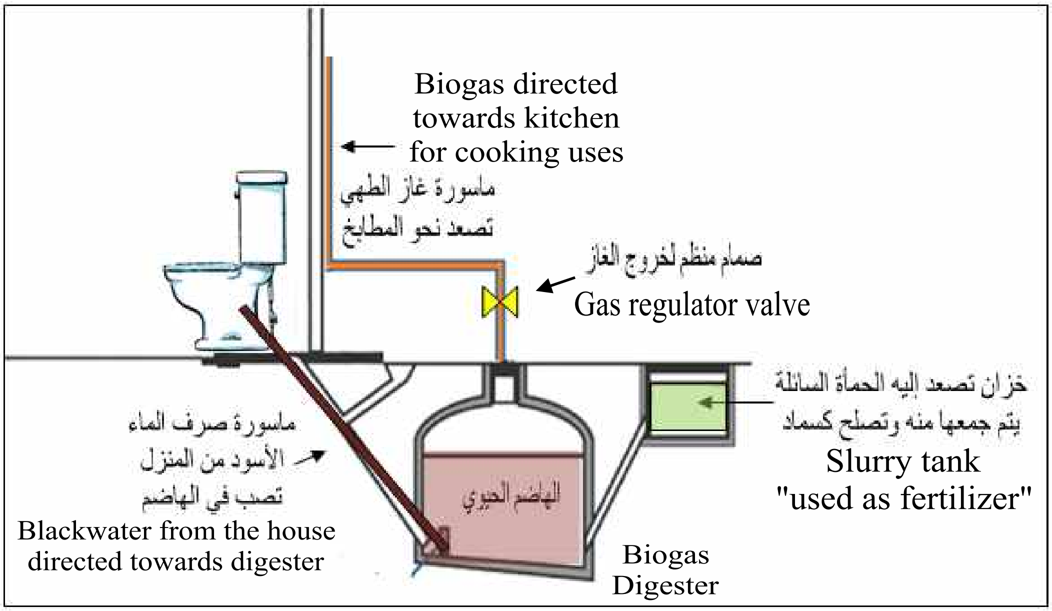
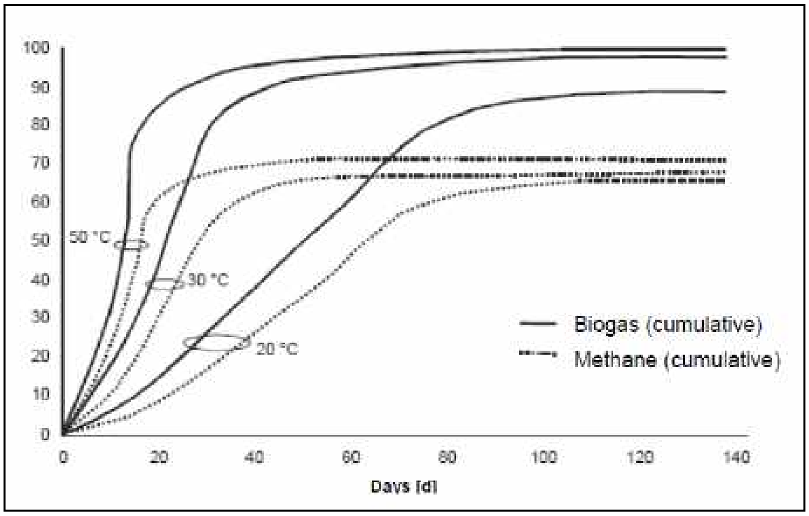


Fig (226): Illustration of biogas digester components and installation
Designed by the Author based on data from: WELL (n.y.) – Reference No. 27

(2-4-2) Cost: This technology is very feasible for small holders in rural areas were raising animals is a basic activity. It's especially feasible with livestock producing 50 kg manure per day, an equivalent of about 3 cows. Depending on size and location, a typical brick made fixed dome biogas plant can be installed at the yard of a rural household with the investment between \$300 to \$500 (2015 prices). A high quality biogas plant needs minimum maintenance costs and can produce gas for at least 15–20 years without major problems or re-investments.[1] Investment costs of biogas plant are moderate and the potential of self-help is relatively high (even though planning requires skilled labor and expert design). Both biogas and fertilizing sludge create value added, thus making biogas digesters interesting from an economic point of view.

(2-4-3) Efficiency: This system is very efficient in hot climate as temperature accelerates the fermentation process and maximizes gas yield[2]. Gas yield augments in high temperature with long retention time as shown in fig(227), so the size of digester must suit longer retention times for better gas production.

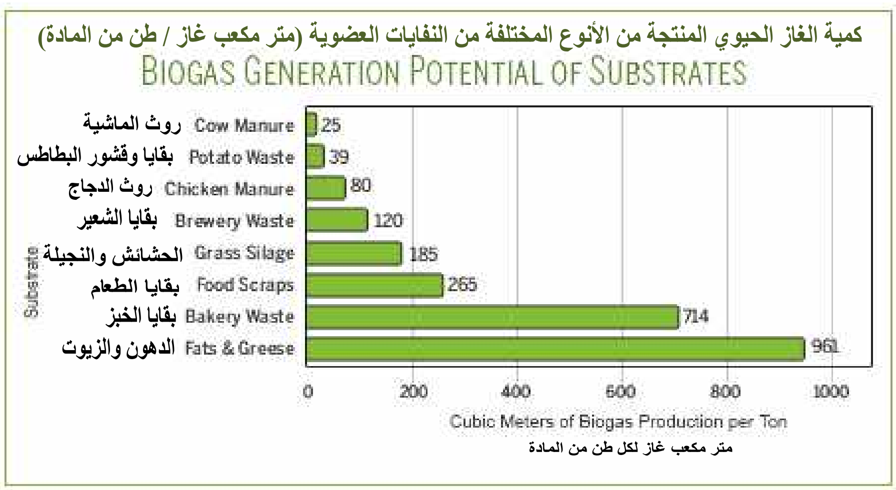


Fig(227): Relative biogas yields, depending on temperature and retention time (LFU,2007)

Gas yield also depends basically on the contents being digested. For example, feeding the digester with chicken manure generates triple gas quantity than the same amount of cow manure. The most gas-yielding materials are fat and grease as shown in fig (228).

Fig(228): Biogas generation potential of substrates

Source: MANG (2005)



Biogas efficiency and composition: Biogas is a byproduct of anaerobic decomposition of organic matter. It consists mainly of methane (60 %), carbon dioxide (35 %) and trace amounts of ammonia, hydrogen sulphide water vapor and other gases[3].

Biogas yield is highly affected by temperature of digestion. As mentioned in previous chapter, anaerobic digestion is classified into 3 types according to temperature of digestion:

- Psychrophilic digestion: in temperature of (5-20°C),
- Mesophilic digestion: in temperature of (20-40°C),
- Thermophilic digestion: in temperature of (+ 40°C),

Higher temperatures produce more gas in short time, so this technology is ideal for hot climate. Biogas is highly efficient in cooking as well as power generating. Each cubic meter of biogas can generate 6 kWh of electricity and cook for 1.3 person/day. One lamp requires 0.1-0.15 m3/hour of biogas. Transforming biogas into electricity is simply done by traditional generators which are fed by gas rather than gasoline. These generators are common and available in the international market, fig(229).

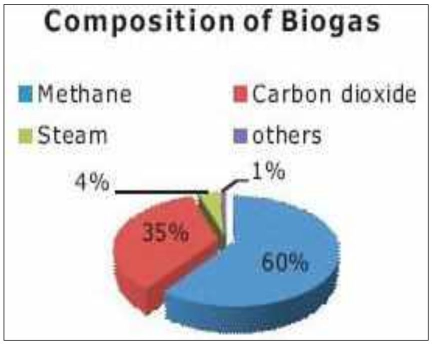



Fig (229): (left) General composition of biogas (middle) Housewife using biogas in cooking in India (right) Typical electrical generator based on biogas feeding –
Source : (left) (Polprasert et al.2001) (middle) (GTZ, 2007) (right) www.swedegas.se/

The following table shows the main features of biogas production and consumption.

Suitable digesting temperature	20 to 35 °C
Retention time	40 to 100 days
Biogas energy	6kWh/m^3 = 0.61 L diesel fuel
Biogas generation	0.3 – 0.5 m^3 gas/m^3 digester volume per day
Human yields	0.02 m3/person per day
Cow yields	0.4 m^3/Kg dung
Gas requirement for cooking	0.3 to 0.9 m^3/person per day
Gas requirement for one lamp	0.1 to 0.15m^3/h

Table(38): Main features of biogas production and consumption
Source: Biogas guideline data. Adapted from WERNER et al. (1989); ISAT/GTZ (1999), Vol. I; MANG (2005)

General comparison of Natural gas and Biogas: The composition of biogas depends on number of factors such as the process design and the nature of the substrate that is digested. Table (39) shows the comparison between typical properties of biogas from digesters and average values for natural gas (SGC, 2007). However, Natural gas is with fossil origin, so it is exploitable while biogas has endless resources.

Property	Unit	Biogas	Natural gas
Calorific value	kWh/Nm^3	6.5	11
Density	kg/Nm^3	1.2	0.83
Methane	vol-%	65	89
Long-chain hydrocarbons	vol-%	0	10
Carbon monoxide	vol-%	0	0
Carbon dioxide	vol-%	35	0.9
Nitrogen	vol-%	0.2	0.3
Oxygen	vol-%	0	0
Hydrogen sulphide	ppm	<500	3

Table(39): General comparison between Natural Gas and Biogas main features
Ola Eriksson: Environmental technology assessment of natural gas compared to biogas-University of Gävle, Sweden, 2010 - www.intechopen.com/

Just like natural gas, biogas is lighter than air and can leak causing fire threats or suffocations. Precautions must be considered to assure safe use of the stored gas. Prefabricated biogas units usually have the ideal safety requirements as set by EPA.[4]

Modifications required for biogas use: For cooking, biogas can be directly used with no modifications required. But if used for running appliances it must be transformed into electricity. There are special engines that produce electricity with biogas as fuel, rather than gasoline or kerosene. These engines are widely used all over the world and their cost ranges between 3,500 to 11,000 L.E.[5]

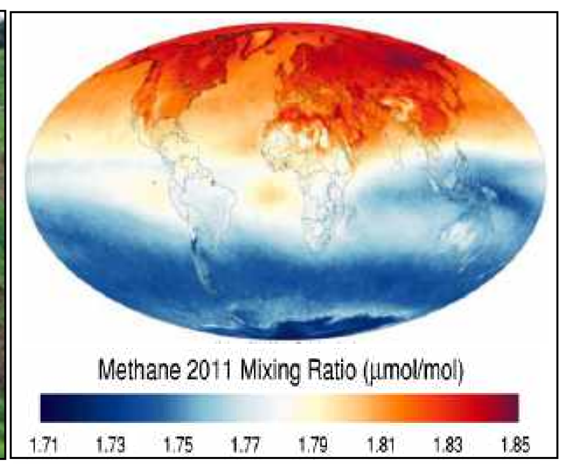
(2-4-4) Sustainability and environmental Impact: Biogas technology is an efficient sustainable technology that uses refused matter to produce renewable energy. The system has many positive impact on the environment:

- **Improving sanitation for rural families**: Biogas plant has the potential to minimize health risks and environmental pollution by using human excreta as a resource for producing energy and fertilizer.[6] Toilets can directly be linked to the biogas plant where human waste is digested together with the other added wastes. This option provides a safe treatment of human excreta and thus improves the hygienic situation of the family.

- **Investing in organic residential waste:** Biogas technology can digest all refused organic waste produced by the family (e.g. food waste, bread cramps, oil and fat, etc.) This will minimize the size of collected municipal waste and reduce the effort of collection, transportation and burial.

Fig(230): (up) Food waste usually disposed into municipal garbage (right) Application of food waste feeding into biogas digester – www.biogas.com/

- **Methane leaks reduction:** Another positive impact is that this technology can help reducing methane leaks from waste burial sites called "landfills". Landfills usually generate massive amounts of methane and leaching water that can pollute both air and groundwater as seen in fig(231).Methane is a potent greenhouse gas that cause global warming 44 times more than Co_2, so stopping methane leaks is vital for the global environment[7]



Fig(231): (left) Gaseous emissions from landfill site in China, 2015 (right) Methane concentration in the upper troposphere measured in 2011- Source: (left) -S.R. Smith; Agricultural Recycling of Sewage Sludge and the Environment, CAB International, UK, 1996 – (right) http://airs.jpl.nasa.gov/composition- Retrieved March 19, 2012

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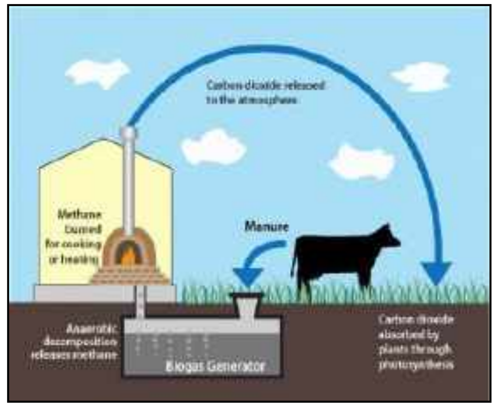
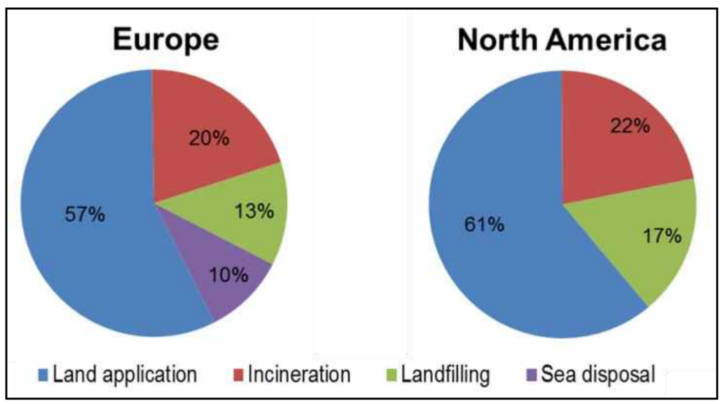
- **CO_2 circulation:** Burning biogas for cooking usually emits CO_2 that is released to the environment. However, in rural areas, the abundance of plants makes Co_2 reabsorbed and used by the plants during photosynthesis process, which makes the circle closed and sustainable. This explains the high suitability of biogas technology in rural areas particularly.



Fig(232) Closed circle of Co2 emission and absorption in rural biogas system
Source: State Energy Conservation Office SECO (n.y) www.renewableenergy.com

- **Providing fertilizer:** Slurry is a perfect fertilizer and soil amender, especially when the feeding substrate is rich in nutrients. Slurry has much better properties as a fertilizer than traditional "sludge" that is produced by all wastewater treatment plants. However, sludge, though less valuable, is heavily used as fertilizer and soil amender all over the world. About 60% of sludge produced in Europe and the US is used in land application as shown in fig(233).



Fig(233): (Up) Slurry as liquid and solid fertilizer (right) Sludge uses in Europe & US. - Source: http://www.intechopen.com/

- **Reduction of odors:** One of the noticeable positive changes which take place through biogas technology is the significant reduction of odoriferous substances (volatile acids, phenol and phenol derivatives) in digested waste. Experience shows that up to 80% of odors in feedstock substrates can be reduced by anaerobic digestion (AD). It is not only a reduction of the intensity and persistence of odors, but also a positive change in the composition of odors, as digestate no longer has the unpleasant slurry smell, but smells more like ammonia. Even if stored for longer periods of time, digestate shows no increase in emission of odors. Fig(234) shows that, 12 hours after the application of digestate, the odor has almost disappeared.

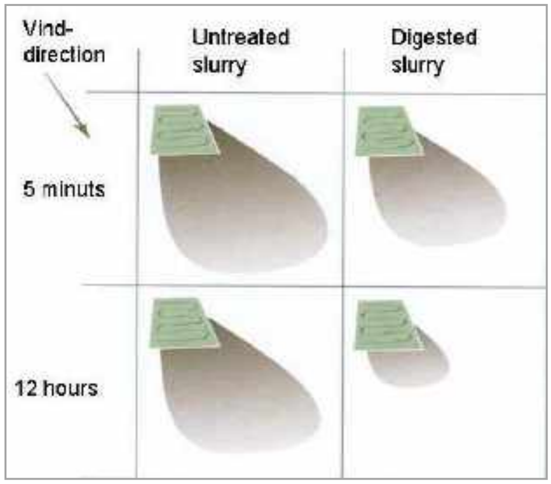


Fig (234): Area affected and persistence of odour nuisance after application of digestate and of untreated slurry on a land field with northwest wind (Brikmose 2002)

(2-4-5) Land Use and Impact on Urban Planning: As mentioned in chapter 2, Anaerobic Digesters can be installed on roof or underground and with minimal land use. Multistory buildings can be served with one digester installed underground or with several digesters mounted beside each apartment. Rural digesters require more land space than urban ones because they receive greater amounts of feedstock and serve bigger family size. Prefabricated digester may be installed above ground level due to aesthetic acceptance as shown in fig(236). An average

Fig(235): Land use of a rural biogas plant installed in the cow shed inside an Indian house- www.solarcities.com/

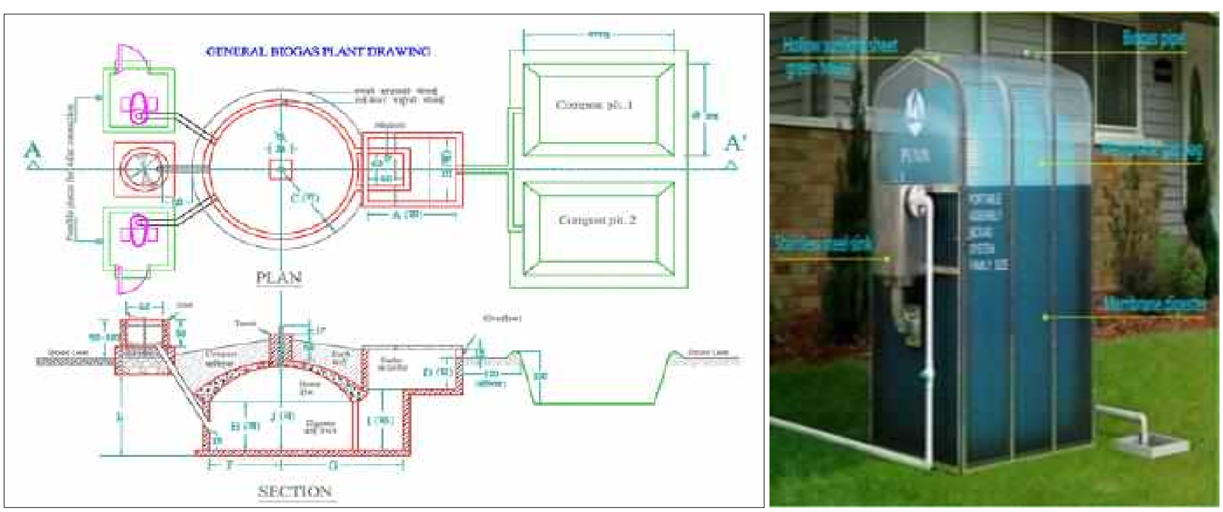


Fig (236): (left) Plan and cross section in rural biogas plant with 2 slurry tanks and 2 attached bathrooms (right) Prefabricated biogas plant receiving black wastewater and installed in house's front yard
Source: (left) Teodorita Al Seadi, Ref. No.9 (right) www.amazone.com/ retrieved in 25/12/2015

prefabricated unit requires 1.2 m^2 of land area for serving a family of 5-8 members.[8]

(2-4-6) Suitability for application in Egypt: Using cow waste and organic matter as a fuel is been practiced in rural Egypt for centuries and recently started to diminish. A study conducted in 1984 in rural Egypt, showed that 76.4% of their power needs were fulfilled by agricultural waste and cow manure as main fuel, while only 23.6% were from central electricity network at the time of the study.[9]

However, biogas technology is more suitable in the following conditions:

- Areas with hot climate, reaching an optimum of 36 C°, as temperature accelerates the fermentation process.
- Areas with abundant organic waste (e.g. farming, poultry or oil extracting plant. etc.,).
- Areas with good ventilation and sufficient sun exposure.
- Areas near farming lands where slurry can be sold easily.

Most these requirements are available in rural areas and developing countries which makes the technology for small holders in developing countries often suitable.[10]

The Egyptian Ministry of Environment has established an independent bureau to activate using biogas digesters in rural households. Technical and financial support is being offered to all families and entities involving in this project. Hundreds of rural houses had applied this technology till 2014 with the support of this bureau.


Fig (237): Rural biogas Project applied in Kafr Saqr, Sharqeya (left) and Asiut (up)- **Source: (left) http://www.sharkiatoday.com/ (up) www.almaydan.com/**

Advantages of biogas plant: Biogas provides clean cooking energy, reduces indoor air pollution, provide clean organic fertilizer that potentially increases agricultural productivity.

- Generation of biogas and fertilizer

- No energy required
- Combined treatment of animal, human and solid organic waste
- Low operation and maintenance
- Underground construction (low space requirement and high acceptance)
- Low risk of odors
- Resistance against shock loads, Long life span if maintained and operated correctly
- Reduces the amount of wood fuel used by the household, ¬ Improving household air quality by reducing reliance on smoky wood burning stoves

Disadvantages of biogas plant:

- Experts are required for the design of the reactor and skilled labour is required for the construction of a gastight tank.
- Substrates need to contain high amounts of organic matter for biogas production
- Slurry may has to be further treated before reuse (e.g. composting)
- Below temperatures of 15°C, biogas production is economically not interesting (heating required)
- Requires seeding (start-up can be long due to the low growth yield of anaerobic bacteria)

Part (II)- Chapter 4

(2-4) Off-Grid Technologies for Cooking Gas Supply

Summary of Chapter (4)

Household cooking gas can be supplied out of the grid using biogas plant unit. Biogas plant is a small scale unit which converts organic waste into biogas and slurry. Domestic waste from toilets and kitchens is drained into the plant where anaerobic reaction takes place and converts organic waste into methane CH_4 .

Biogas plant is feasible in rural areas were raising animals is a basic activity. Typical biogas plant can last with minimum maintenance for 20 years. Its cost is moderate and the potential of self-help is relatively high. Both biogas and fertilizing sludge create value added, making biogas digesters feasible and economic.

Biogas plant is highly efficient in hot climate as temperature accelerates the fermentation process and maximizes gas yield. Gas yield depends on the contents being digested. The most gas-yielding materials are fat and grease. Most these requirements are available in rural areas and developing countries which makes the technology for small holders in developing countries often suitable.

The Egyptian Ministry of Environment has established an independent bureau to activate using biogas digesters in rural households. Technical and financial support is being offered to all families and entities involving in this project. Hundreds of rural houses had applied this technology till 2014 with the support of this bureau.

End of Summary of Part (II) Chapter 4

Refrences of Part2, chapter4:

[1] (WERNER et al. 1989).

[2] (SCHOENNING & STENSTROEM 2004).

[3] (Polprasert et al. 2001, Ch. 1, pp. 5, 6)

[4] Teodorita Al Seadi, Dominik Rutz, Biogas Handbook, Published by University of Southern Denmark Esbjerg, Niels Bohrs Vej 9-10, DK-6700 Esbjerg, Denmark

[5] http://www.ecvv.com/product/1982515.html

6(GTZ 2007)

[7] Zeke Hausfather: Climate Impacts of Coal and Natural Gas-http://static.berkeleyearth.org/memos/climate-impacts-of-coal-and-natural-gas.pdf , 2014

[8] Teodorita Al Seadi, Biogas Handbook, Published by University of Southern Denmark Esbjerg, Niels Bohrs Vej 9-10, DK-6700 Esbjerg, Denmark - October 2008

[٩] سمير الشيمي وصلاح عرفة : ورقة بحثية بعنوان BIOGAS TECHNOLOGY TRANSFER TO RURAL COMMUNITIES IN EGYPT صادرة من وحدة الغاز الحيوي بمركز أبحاث المياه والتربة بالجيزة + كلية العلوم بالجامعة الأمريكية بالقاهرة ١٩٨٥

[1] . (WERNER et al. 1989). ST[0]ENSTROEM 2004).

Results of Part Two: After viewing some off-grid technologies for providing utilities out of traditional networks, we sum these technologies in brief, with the degree of suitability in different Egyptian societies, estimated by the researcher, based on data from Part (II):

Utility/ Evaluation	Feasibility	Efficiency	Sustainability	Land Use	Impact on Urban Planning	Suitability for application in Egypt			
						Near Rural	Near Urban	Remote Rural	Remote Urban
Groundwater Extraction	C	B	G	D	D	F	G	C	A
Solar Pumps	F	B	A	D	B	F	G	A	B
Solar Desalination	D	B	A	D	F	G	E	A	A
Grouped Filtration System	B	D	A	D	D	C	G	B	A
Artificial Recharge	C	B	D	G	F	G	G	A	C
Septic Tank	B	C	G	D	D	C	E	B	A
ABR	B	B	C	G	G	C	C	A	A
Leach Field	F	C	D	G	G	G	G	C	A
Soak Pit	B	D	E	B	D	F	G	C	A
Infiltration Trench	D	D	E	D	E	G	G	C	A
Wetland System	D	B	B	G	G	B	G	A	D
Date-Palm Fibers System	B	B	A	A	A	A	G	A	D
Anaerobic Digester	D	B	B	D	F	A	G	A	D

Table (40): Evaluation of the discussed off-grid utilities as estimated by the researcher, based on data and statistics in Chapter Two. (Classified into 5 categories: From A = Most Positive) to G (Most Negative)

●	Positive
○	Negative

The following Part will view four application studies of the suggested off-grid utilities in four different societies: Rural, Urban, Slum and New settlements in Egypt.

Part (III)

Case Study Applications in Four Different Societies:

Rural, Urban, Slums and New Settlements

Introduction to Part (III)

This part introduces application models of decentralized utilities in different Egyptian societies: Rural, Urban, Slums and New settlements. In each case, analytical study is introduced to cover main data of the studied society. Climate, topography, economy, people, urban services and available utilities, all these features are analyzed to choose the best off-grid utilities suitable for this society.

This part is divided into 4 chapters as follows:

1. **Chapter One**: Case Study Application in Rural Society: Beltag Village

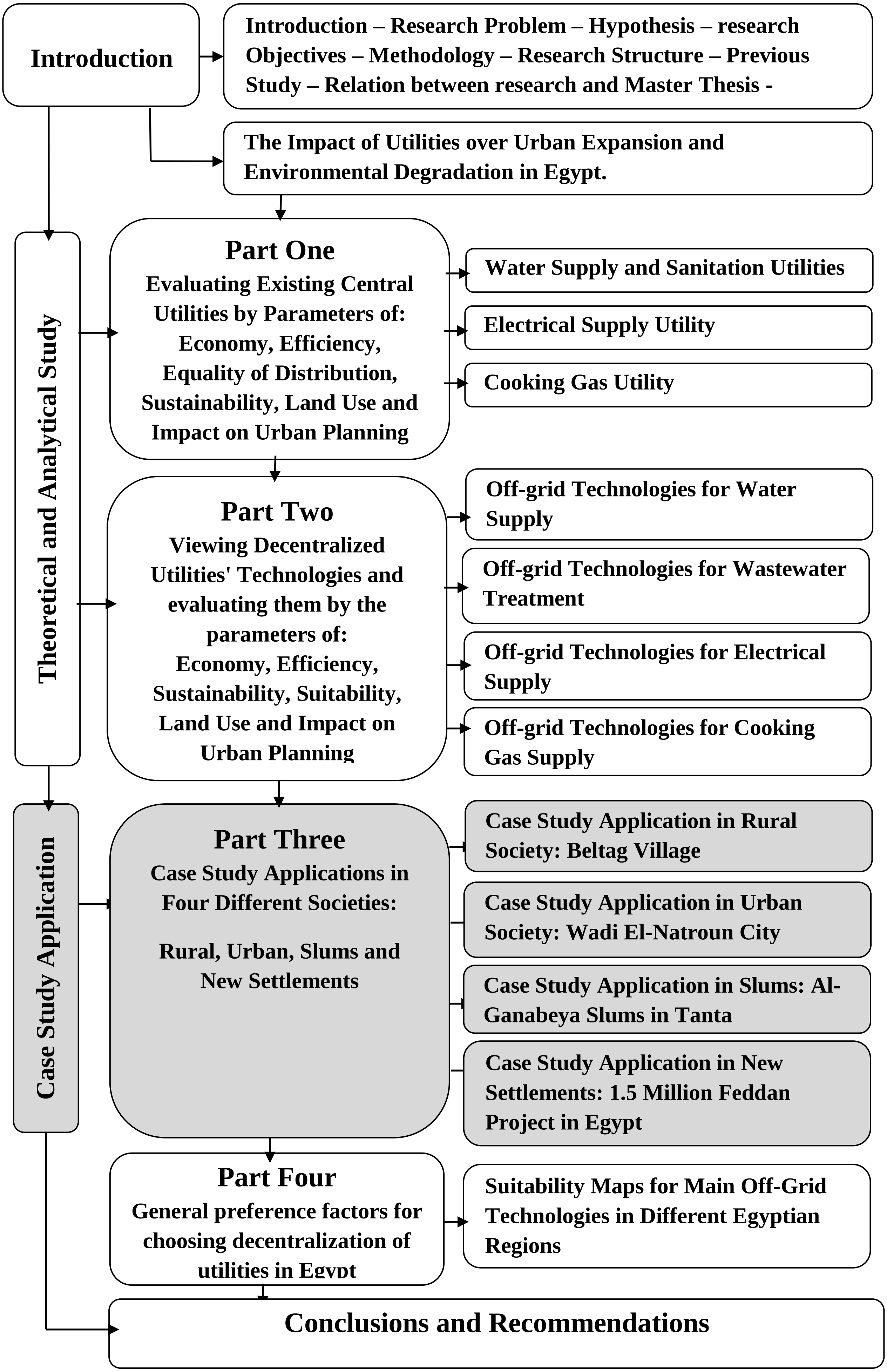
Chapter Two: Case Study Application in Urban Society: **Wadi El-Natroun City**

Chapter Three: Case Study Application in Slums: Al-Ganabeya Slums in Tanta

Chapter Four: Case Study Application in New Settlements: 1.5 Million Feddan Project in Egypt

In each chapter, we shall present some of the most common off-grid utilities used worldwide, with evaluation of its suitability and performance. Using the parameters of: Economy, Efficiency, Sustainability, land use and Impact on Urban Planning, as well as their Suitability for Egyptian use.

End of Introduction to Part III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(3-A) Parameters for Choosing Off-Grid Model:

As seen in chapter two, there are many technologies for off-grid utilities, but each has certain conditions to work properly. Every site has different preferences for utilities that are compatible with it. So it is the job of the environmental engineer (EE) to gather information and measures of the project site before choosing the best utilities for it. For example, he must gather the following information:

(3-A-1) Climatic Features:

a- Temperature around the year:

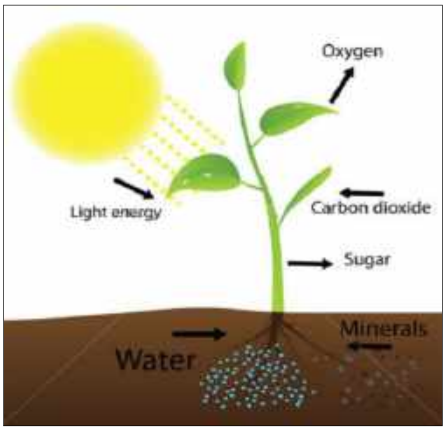
Temperature affects the performance of biogas digester. High temperature and good exposure to sun speed up the fermentation process and increase the biogas yield.

b- Precipitation:

Precipitation is the primary mechanism for transporting water from the atmosphere to the surface of the earth. Several forms of precipitation are available like rain, snow, sleet (البرَد) and dew (الندى). Precipitation has a positive impact on the recharge of groundwater. High levels of precipitation (especially heavy rain fall) speed up the recharge process and help replenishing the pumped water. On the other hand, precipitation negatively affects the leaching system as it increases the hydraulic load over the soil and slows down the infiltration process. It also affects the wetland system as rain can hinder the treatment process of wastewater unless the system was covered and protected from water intrusion.

c- Sun Exposure & Sky Clearance:

Sun is a bless for off-grid utility users. Sunny areas are the most suitable for almost all off-grid utilities. Sun rays are the main source of power in solar systems. Good exposure helps increasing the water heat in solar collectors, and the electricity generated in solar panels. It speeds up the fermentation process in biogas digesters and dries up the soil in leaching systems. It kills pathogens in aerobic digestion systems and improves wetland systems as sunlight is vital for photosynthesis process, see fig (238).



Fig(238) photosynthesis process based in sunlight - www.shutterstock.com/

Sky clearance also must be studied to assure that sun rays won't be screened by clouds which may hinder the functioning of proposed utilities.

d- Wind Speed Average:

Wind speed in the site must be studied carefully as it affects many off-grid utilities' performance. For example, moderate breeze improves the leaching system performance by speeding up the vaporization rate which makes the field dry, but very high speed may cause the top soil of the leach field to erode. Solar systems are also affected by wind speed. High speed improves solar system efficiency, but very high speed (e.g. storm) may damage the solar system completely.

(3-A-2) Site Features:

a- Topography:

The topography of the served site must be considered, especially in leaching system design. Normal slopes must be used in serving proper leaching without affecting neighbors' properties. Leaching systems must be avoided in rocky faults or flash floods areas to avoid system collapse. For ABR with several users, the system must be installed at the lowest contour level to allow wastewater flowing to ABR by gravity. Groundwater extraction for multiusers must be installed in the highest point to avoid power consumption in pumping against gravity.

b- Soil Properties:

Soil properties are very important in off-grid utilities. The infiltration rate of the soil affects the performance of the leaching systems thus the area required for the system installation. Organic and bacterial content of the soil affect the biological treatment and both formation and performance of the bio-mat layer. Deep soil properties affect the quality and accessibility of groundwater in the site.

c- Groundwater Properties:

Groundwater properties affect the applicability of extraction and treatment. The main properties to be measured are:

- Chemical and Biological properties of extracted water, to determine the proper treatment required.
- Salinity levels, to determine whether desalination is required or not.
- Probable sources of contamination (e.g. nearby factory, agricultural activity using chemical pesticides herbicides or fertilizers) and how to avoid or lessen their impact on groundwater safety and quality.

- Choosing the point of extraction is very important. It must be as far as possible (vertically and horizontally) from any nearby leaching system or contamination source.

(3-A-3) Urban Characteristics:

a- Land Use & Ownership:

Land use has an impact on chosen utility. For example, if leaching system is serving a commercial area, it needs to have rapid filtration rate and less land space. Industrial areas need systems that are not affected with heavy machine movements and can adapt with industrial wastewater treatment. Mosques, for example require plentiful water supply at certain rush moments, so reservoir tanks must be considered.

Ownership also affects the decision making process. Some off-grid utilities require prior permission from the building/land owner before installation. So if the inhabitants don't own the property, they can't install certain utilities that may affect its future use.

b- Construction State:

The construction state of the served area must be considered. For example, leaching systems must be avoided for buildings with high wall dampness. Buildings with bad construction state will not be supplied with natural gas network, so biogas plants can be considered for them. Bearing walls buildings may be affected with heavy groundwater exploitation as the soil gets more compact.

c- Buildings' Heights & Shading Coefficient:

Shading coefficient of the building must be studied before choosing the right location for solar systems installation. It also affects the location of the digester (if not installed underground). Western and southern façades are usually the best locations for receiving solar-related applications in Egypt. Future shading by expected neighborhood must also be considered and calculated using local permits of the design area. If sun exposure is not sufficient, sun rays may be trapped by reflecting mirrors as shown in fig (..), or neighbors' roofs can be rented as shown before in fig(215).

d- Urban Density:

Urban density is the number of buildings in a unit of area. It must be considered when choosing the right leaching system. High urban density requires installing less spacious systems (e.g. soak pit or infiltration trench), while low density can adapt with any system that suits its soil type. Urban density is also considered when balancing between cellular and collective systems. It is better for high dense areas to install central and semi-central systems (e.g. Collective septic tanks or Anaerobic Baffled Reactors ABRs) as cost is divided by a group of users inhabiting the same square unit. Sometimes cellular systems are better choices in dense population, depending on social relations and cultural feedback in the served community.

e- Street width and Urban Pattern:

Septic tanks, soak pits, and infiltration trenches can be safely installed underground in walkways and streets for pedestrians only, as heavy traffic can damage them.

ABR's can be installed in medial or central urban space (court, yard or central park) serving 3 to 50 houses in one neighborhood.

Sites with access to heavy traffic are not suitable for installing vehicles

f- Seasonal Capacity & Frequency of Use:

Areas with seasonal occupancy (e.g. summer houses and beach resorts) are the most suitable for applying off-grid utilities, as the frequency of use doesn't require central grids with huge investments. When choosing an off-grid system for holiday homes, consideration should be given to the selection of a system that can adequately deal with periods of inactivity (i.e. when the house is unoccupied for prolonged periods). Systems that are capable of recirculating the effluent would be appropriate. It is recommended that biodegradable cleaning agents be considered for use in these homes[i].

(3-A-4) Socioeconomic Properties of the Inhabitants:

a- Age, Education & Poverty:

The educational, cultural and economic standards of the inhabitants are very important and must be studied before choosing the best off-grid utility for their use. Youth and highly educated people are usually more adapting to new technologies. The economic standard also affects the acceptance of new technologies. Very wealthy people, as well as very poor ones, usually reject off-grid technologies, as the rich prefer not to worry about new technologies, and the poor can't afford to try new systems.

b- Profession & Employment:

The common profession in served area must be considered as it affects the suitability of suggested utilities. For example, if the inhabitants work in fishing, farming or cattle breeding, biogas plant may be very suitable for them as they have plentiful organic waste. If the inhabitants work in tannery, their wastewater treatment system must be supplied with date palm leaf filters to remove chromium properly.

(3-A-5) Public Services:

Water supply, sanitation, electricity and cooking gas systems must be studied. If central utility is available, adequate and sufficient, it may be better to keep it working. If it works but with deficiencies, of grid solutions must be compatible with it and work to improve its performance not to substitute it. If no central utilities are available and are not expected to be provided soon, off grid utilities must be considered as a substitute.

Solid waste disposal system must be studied as well to evaluate the feasibility of biogas digesters and available sources of organic degradable waste.

(3-A-6) Local Laws and Enforcements:

Local laws and permits must be considered before choosing the proper utility. In Egypt, the organizing law for off-grid utilities is the Environmental Law No. 48 of 1982 regarding the discharge of wastewater (of different types) to waterways and groundwater,[ii] as well as the Ministerial Decree No. 334 for the year 2002 concerning the Egyptian Code of Practice for Sanitary Water in Buildings. The Code provides the specifications of sanitary works and wastewater disposal in isolated areas. There are specifications for septic tanks, cesspits and oil/grease traps. The Code also provides guidelines for locating septic tanks and cesspits in isolated areas[iii]

(3-A-7) Major Social, Economic or Environmental Problems:

It is the job of the environmental engineer to discover the major problems of the served society and try to introduce utilities that would solve, mitigate, or at least don't exacerbate the impact of these problems. For example, if the served society has bad social relations, grouped utilities are not favored for them. If the society suffers unemployment, utilities must be designed for manual and not mechanical evacuation and maintenance to provide jobs. If the society is poor, utilities must be economic and of money-back nature. If certain diseases are rampant (e.g. waterborne diseases), leaching systems must be avoided to prevent contaminating groundwater aquifers, and so on.

In the following pages, we propose an application model for this site analysis in four different Egyptian societies: rural, urban, slums, and new settlements.

End of Introduction to Part III

References of Introduction of Part (III):

[i] Environmental Protection Agency: Code of Practice: Wastewater Treatment and Disposal Systems Serving Single Houses (p.e. £ 10)

[i] Egypt National [i]Rural Sanitation Strategy, Final document, published by the holding company for water and wastewater, September 2008

[iii] Ain Shams University, Institute of Environmental Studies and Research, Framework for the Environmental and Social Impact Assessment Framework (ESIAF), Delta Governorates, 2010- ISSIP-2 - ESIAF

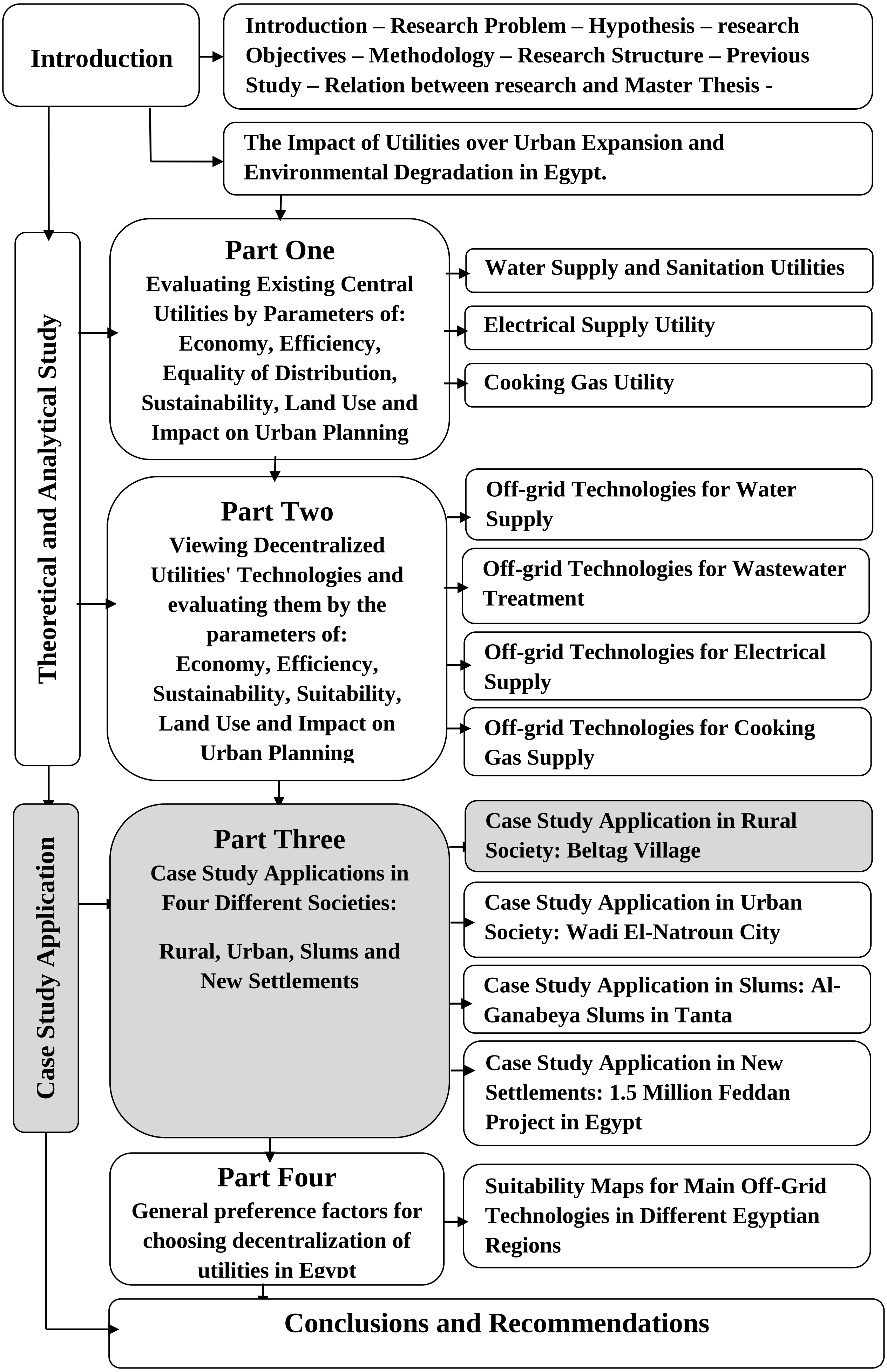
Part (III)- Chapter (1)

(3-1) Application Model in Rural Area in Egypt (Beltag Village):

Introduction to Chapter 1

This chapter introduces a rural area (Beltag Village) which suffers many constructional, environmental and health-related problems due to bad utilities' provision. A complete analysis is introduced to the main data for the village and the main problems, after-which the researcher introduces some suggested off-grid utilities to help solving or mitigating these problems.

End of Introduction to Part III- Chapter (1)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(3-1) Application model in Rural Settlements (Beltag village):

Beltag is a central village located in Markaz Qotour, Gharbeyah Governorate. It has a unique coordinate of 31º N Latitude and 31º E longitude. Beltag is located 20.7 km from Tanta city and 5.3 km from Qotour city as shown in fig(239). It has an area is 1.05 km^2 and has 7 follower villages. The main neighboring water course is Met-Yazeed canal located half kilometer to the East.

(3-1-A) Climate:

Beltag has a Mediterranean climate with hot summers and cool rainy winters. Summer season extends from April through October while winter season extends from November through March. The temperature range in summer is between 22ºC to 30ºC, and in winter between 9º and 18ºC as shown in fig(239).

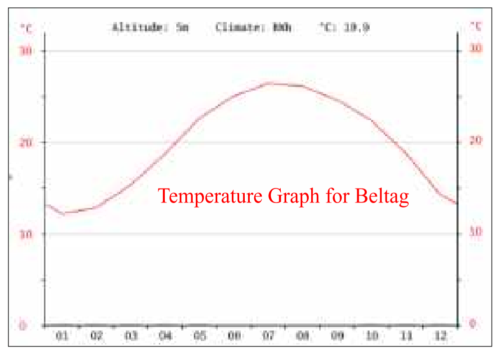


Fig (239): (left) Beltag village location map – (right) Temperature around the year in Beltag
Source : (left) GOPP Strategic Planning Report, 2012 (right) http://en.climate-data.org/location/477912/- Retrieved 28/3/2015

(3-1-A-1) Precipitation & humidity:

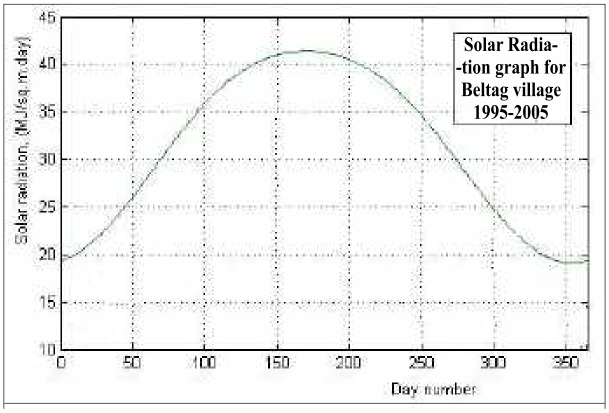
Beltag has an average annual rainfall from 100–200 mm /year, which most of it fall in winter months[1]. The village becomes quite humid during winter months with an average relative humidity of 63% in fall season and 58% in spring season as shown in table (41). This humidity is due to Beltag's location in the heart of an agriculture zone, where regular open irrigation is dominant all-around[2].

Year 1995-2005	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RH%	61.51	62.24	61.84	58.40	60.26	61.79	59.60	61.48	61.72	63.95	63.36	60.46

Table(41): Relative Humidity in Beltag village around the year- stated from 1995-2005 measures
Source: Gad et., al., 2010 – Reference No. 2

(3-1-A-2) Sun Exposure:

Beltag enjoys a relatively high sun exposure especially in summer months. The main reason is that its buildings are low-level and almost with same height as shown in fig(240), so low shading factor exists in the village. The direct solar radiation over Beltag's earth surface is 20 to 42 Mega joule/m^2.day which equals a direct normal irradiation of 5.5 to 6.3 kWh/m^2/day[3].



Fig(240): (left) Solar Radiation on Beltag earth surface (Mega Joul/m2/day) (right) Sun exposure over Beltag's roofs Source: (left) Gad et., al., 2010 – Reference No. 2 - (right) GOPP Strategic Plan Studies –Reference No. 1

(3-1-A-3) Sky Clearness:

Another parameter which affects solar radiation is Sky Clearness factor. If solar radiation is high but the sky is cloudy, less solar power will reach the roofs, meaning less solar power generated by solar systems. In Beltag, this factor is positive. Sky clearness is above 65% all year around. The highest clearness in Beltag occurs in May and June, with 71% , while the lowest clearness occurs in December with 65% as shown in Table (42).

Year 1995-2005	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
k_t	0.68	0.67	0.70	0.71	0.71	0.71	0.69	0.70	0.69	0.67	0.66	0.65

Table(42): Monthly averaged clear sky clearness index in Beltag village
Source: Gad et., al., 2010 – Reference No. 2

(3-1-A-4) Wind Speed:

Wind speed in Beltag is low to moderate around the year as shown in table (43). The highest speed is during February (5.08 m/s) while the lowest is during June (4.19 m/s). This low speed delays the evaporation rate of the soil which means that leaching systems are less preferred for the village.

Year 1995-2005	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind speed (m/s)	4.80	5.08	4.88	4.44	4.30	4.19	4.29	4.36	4.42	4.43	4.28	4.69

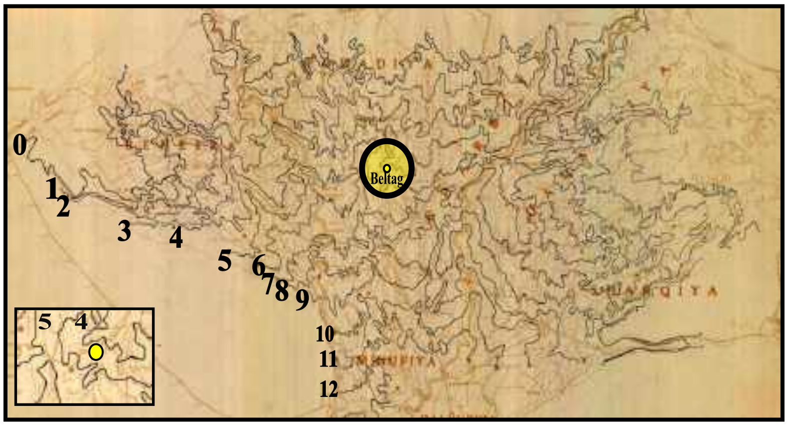
Table(43): Monthly averaged wind speed at 10 m above earth's surface in Beltag village - stated from 1995-2005 measures - Source: Gad et., al., 2010 – Reference No. 2

(3-1-B) Sloping & Topography:

Beltag is standing on a flat base with a unified land level of 4 meters above sea level, fig(241).There's nearly no natural slopes exist in the village, which helps equalizing the impact of trench systems installed all-over the village. If slopes exist, low areas will suffer more wall dampness and sewage overflow than higher areas as illustrated before.

(3-1-C) Soil Properties:

As a part of Middle Delta Region, Beltag has an alluvial soil which consists of heavy clay deck of variable thickness with very low permeability, underlain by a better permeable loamy, sandy or peaty layer. Clay depth varies between 5 and 15 meters depending on location relevant to the main course of Met-Yazeed canal. The hydraulic conductivity of Beltag's soil is $5x10^{-7}$ to 10^{-4} $m^3/m^2/day$, which is less suitable for water leaching (e.g. trenches or leach fields).[4]



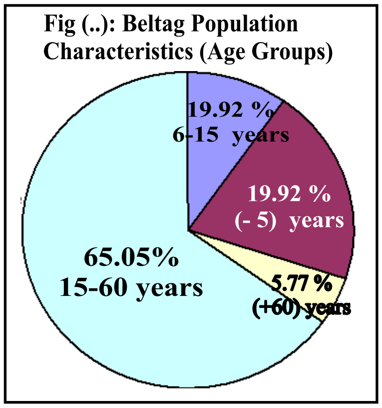
Fig(241): (left) Contour map of Beltag village among total Delta Region (up) Dominant mud soil in Beltag.

Source: (left) http://www.mappery.com/map-of/Draft-Elevation-Map-Nile-Delta/ Retreived 10/4/2015
(right) Photo taken by the researcher

(3-1-D) Population Characteristics: Beltag is a small village with total population of 12,000 in 2006 census. No certified data could be obtained about population after this year.[5]

(3-1-D-1) Age:

Two thirds of Beltag populations are in the age of 15 to 60 years, which is considered the working labor age. Children below five and below 15 are 19.92% and 9.26% respectively, while the elders above 60 are 5. 77% as shown in fig (242).



Fig(242): (left) young woman & her children with fodder bags (middle) Sample of Beltag's dwellers (right) Beltag's age groups.
Source : GOPP Strategic Plan for Beltag village 2009

(3-1-D-2) Education:

Unfortunately, Beltag has high ratio of illiteracy. Those who can barely read and write above age of ten were 10.96% of the total population, while 28.1% were totally illiterate. Middle educational degree holders were 18.94%, while higher educated people were 31.52%. Young women in Beltag are keen to make their children join school, but most of them feel satisfied after their children get a middle education degree.

(3-1-D-3) Poverty & Employment:

Most of Beltag's population work in private sector (e.g. farming, cattle breeding, handicraft or small scale business), while the rest work in public sector. Cattle's breeding is a main activity in Beltag and the whole Markaz of Qotour. The massive manure produced by Qotour's cattle is daily exported to new agriculture settlements like Nubareyah farms in Beheira Governorate. There are many weekly cattle markets held regularly in Qotour city and follower villages. The main cattle market is held every Friday in Qotour city as seen in fig(..). Women in Beltag also work in breeding birds and chicken in their homes as a source of income as seen in fig(243). The ratio of population under poverty line is around 66.1% from the total population, while some others became rich by selling their estate because of the extreme high land value in Gharbeya governorate.



Fig(243): (left & middle) Breeding chicken and raising animals is a basic activity in the study area (right) Friday cattle market in Nawag village- **Source: Ref. No. 5**

(3-1-E) Public Services:

The data of this part is taken from the Strategic Plan for Beltag village analytical report, delivered by the General Organization for Physical Planning (GOPP) in Dec. 2010. As data was relatively old, we've visited the village in March, 2015 to update the data directly from Beltag local governor, Mr. Radwan Farrag, and his vice Eng. Mahmoud Atteia, fig(244).

Fig(244):The Researcher with Beltag's Head Secretary and his Vice.

(3-1-E-1) Water Supply:

Beltag depends totally on its own water plant (Beltag water plant), located half kilometer to the east as shown in fig(245). This plant supplies Beltag and other 5 neighbor villages as well by a 6" pipe network. The plant depends on Met-Yazid canal water for intake. The intake point is 16 meters inside the canal and 4.5 meters in-deep as shown in figures (245), (246). Beltag has no water storage systems so it depends totally on daily water coming from the plant, so, if the plant stops for any reason, water cut occur in the village. The average daily supply of municipal water for Beltag is 800 m^3 / day while the daily water consumption is 52 liters/day/capita, which is much less than the National 125 liter/day/capita household water consumption levels in Egypt shown in table (44).

Fig(245): Beltag's water plant's location nearby the village- www.googleearth.com/

Fig(246): Water plant intake from Met-Yazid canal: upper view &side view. **Source: (left)** www.googleeart.com **(right) imaged by the researcher**

Category	Daily water consumption Liters/day/capita	Daily losses in water network system Liters/day/capita	Daily Average Water Consumption Liters/day/capita
Governorates' capital cities	180	20-40	200-220
Markaz main towns	150	15-30	165-180
Villages up to 50,000 capita	125	10-25	135-150
New cities	280	0-20	280-300

Table(44): Household water consumption levels in Egypt
Design Review of Water and Wastewater Network Trainig Manual: Water and Wastewater Management Program (GTZ), Dec, 2008

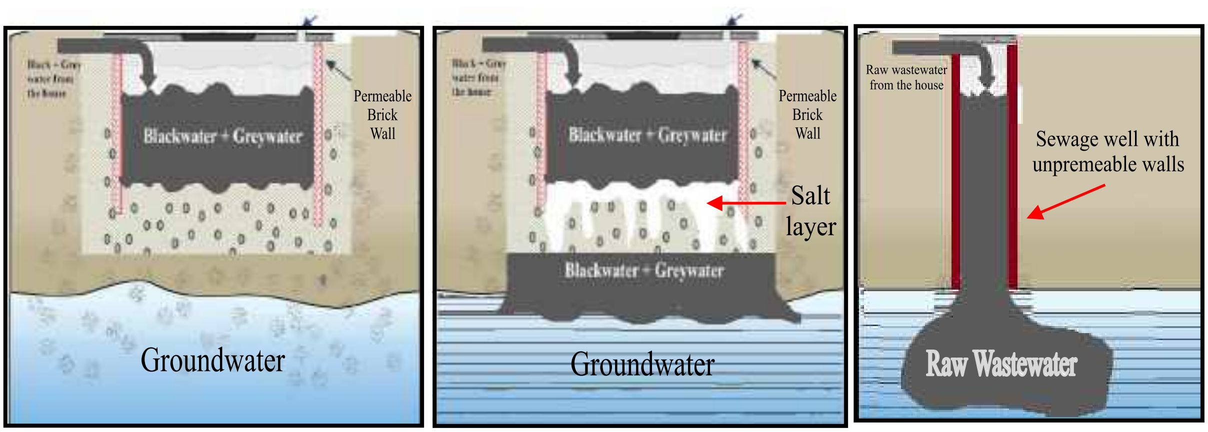
(3-1-E-2) Sanitation: Sanitation is a problematic issue in Beltag . The village has no municipal sanitation system till the date of our last visit (April,2015), although its neighbor village, Samatay, is connected to a sewage plant located beside Samatay drain, 2 kilometers

Fig(247): (left) Single house trench in Beltag (two middles) Grouped trench serving many houses in new area in Beltag (right) Open sewage canal towards group trench – Photos taken by the researcher, April 2015.

far from Beltag. Almost all houses in Beltag have a trench system installed, separately or grouped as shown in fig(247). Few houses with poor owners have dug sewage canals that deliver their wastewater to nearest neighboring group trench. Some houses located by the main canal (Met-Yazeed canal), directly pour their waste into water course.

(3-1-E-2-A) Trench System Types in Beltag:

"Trench" is simply an underground cavity that receives raw wastewater and delivers it to the environment with little or no treatment. In Beltag, people install different trench types according to owner's knowledge and desire. The most common trench type in Beltag is the traditional one, illustrated in fig (248-left). This type is usually bottomless, with red brick walls of permeable nature to allow leaching raw sewage from walls and bottom. Traditional type usually works well during first few years, where after the soil gets blocked (because the dominant soil in rural areas is clay, which is barely permeable). When blockage occurs, sewage overflows in the street or returns to the house. In order to avoid such blockage, some owners add a salt layer in the trench bottm before the first use. Salt maximizes the sewage absorption process, but on the other hand, it causes bottom soil erosion and very quick degradation of soil filtration layers, which allows the sewage to accesses water table before enough physical filtration is done, as shown in fig(248-middle). Another type of trenches is even more disastrous; the owner digs a deep narrow trench with concrete walls to prevent leaching from both sides, but the trench extends to reach water table directly to allow raw sewage to mix directly with groundwater without passing through any kind of soil filtration. This type causes an extreme groundwater contamination, as shown in fig(248-right) .



Fig(248): Trench systems applied in Beltag: (left): Traditional, (middle) Traditional with Salt layer added, (right): Sewage well directly reaching water table- Imaged by the Researcher

The massive use of trenches in Beltag has raised the groundwater level, which is relatively high (less than 2 meters). In addition to the associated risks of contaminated groundwater supplies, trenches have threatened the structural stability of many households. Wall dampness is noticed in almost every street in Beltag as shown in fig(249).

Fig(249): The researcher pointing at wall dampness in Beltag's houses

(3-1-E-3) Electricity:

Beltag and its surroundings are supplied with electricity from Qotour power station which has 66/11 kilo-volt-ampere (kVA) and is connected to the national electrical grid. Belatg also has 6 transformers with total capacity of 1850 (kVA). Most electrical uses are domestic and public lightening except some handicraft workshops use. The average per capita share of electricity is 232 volt-amperes which is less than the Egyptian rural standard of 300 volt-amperes.

All electrical cables in Beltag are still areal, not isolated, and sometimes twisted or entangled as seen in fig(..-right). Cables also pass through narrow streets and corridors which threatens the safety of the inhabitants as seen in fig(250-left). No major complaints were recorded in Beltag from electrical service, except the frequent power-cuts that occur in summer season.

Fig(250): Electric cables so close to buildings in Beltag (left) and entangled electrical cables in Beltag (right)

(3-1-E-4) Gas Supply:

Beltag totally depends on LPG gas canisters for cooking gas supply. There are 4 gas canisters' distribution points in Beltag to fulfil the village's needs, but sometimes they don't.

In general, rural houses consume more cooking gas than urban ones due to three factors:

1- Rural women don't have advanced electrical appliances like electric ovens or microwaves, so they totally depend on gas oven for cooking.

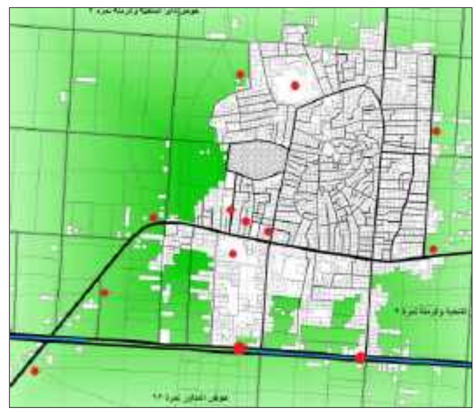
2- Rural family is bigger in number than urban families. In 2006 census, the average number of family members was 4.37 capita/ family in rural areas and 3.94 capita/ family in urban areas, so rural family needs more cooking gas for consumption.
3- Rural women usually bake their own bread and pies, using local baking ovens shown in fig(251), so they need more gas.

Fig(251): Baking ovens supplied from LPG canisters

As well as many villages, Beltag suffer the shortage of gas canisters in winter season and the inhabitants buy the canisters with triple the official price during time of crisis.

(3-1-E-5) Waste Disposal System:

Beltag produces 3.66 ton/day of solid waste which are mostly organic and degradable. Plastic bags are the dominant un-degradable waste material in Beltag. If separated, plastic bags can be recycled in nearby plastic small factories in Qotour city. Beltag has no landfills or open waste fields for waste disposal nor regular process for waste collection as well. The inhabitants usually drop their garbage in vacant lands and by waterways, especially Al-Qayem canal as shown in fig(253). Map(252) shows the locations of waste disposal points in Beltag village.



Fig(252): Main locations of waste disposal points in Beltag village

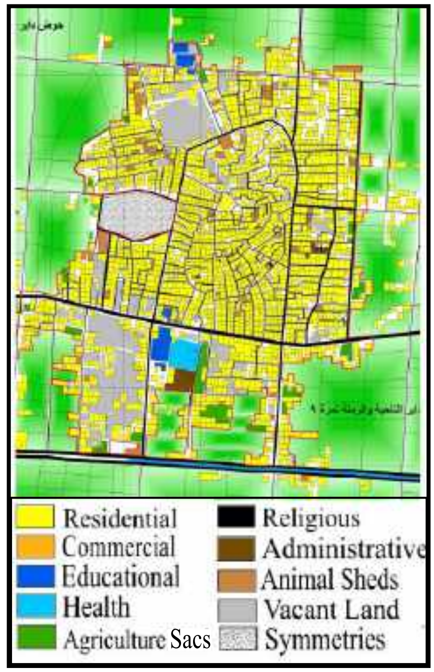
Source: GOPP Strategic Plan

Fig(253): Direct waste disposal in open lands& waterways in Beltag, causing severe environmental degradation.

The regular open disposal of waste increases the threats of air, water and groundwater pollution. People regularly burn waste causing CO_2 emission and fire threats. Polluted waterways are perfect breeders for mosquitos, and farmers use polluted water in irrigation which forms a health risk to people who consume these crops.

(3-1-F) Urban Characteristics:

(3-1-F-1) Land Use: The dominant land use in Beltag village is residential use, estimated by 53.67% of total land. In the second place comes vacant lands (agriculture sacs and barren lands), with a percentage of 12.8%, followed by animal sheds, estimated by 3.6% of total land use. Miscellaneous other uses like commercial, educational, administrative and religious, all occupy 3.3 % of land, while roads and yards occupy 26.6 %. The main symmetry in Beltag is located inside he urban belt and occupies 5.78 % as shown in map(254).



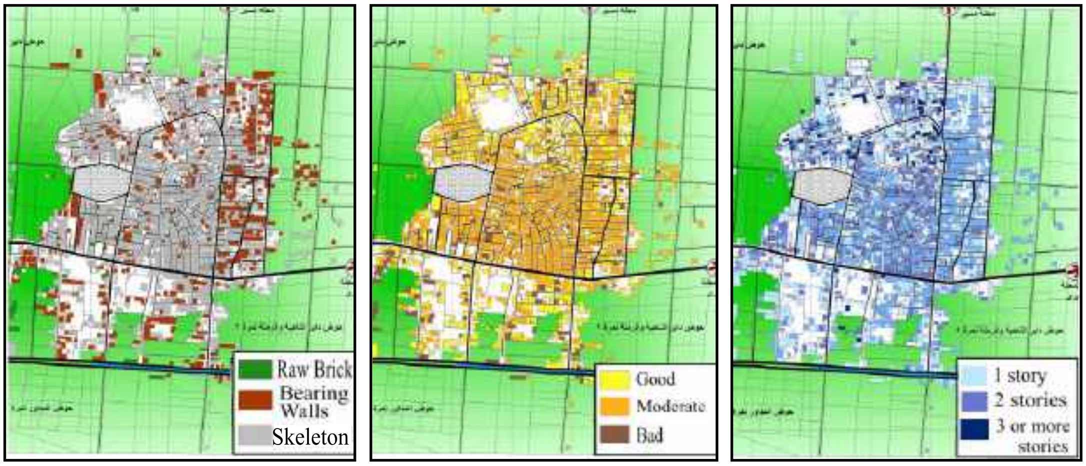
Fig(254): Land Use Map for Beltag village

(3-1-F-2) Urban Pattern: Beltag has two urban fabrics; the organic pattern in the old cluster located in the heart of the village, and the gridiron pattern in new areas located all-around the old core. Scattered buildings in peripheries are usually illegal and follow no pattern, while new legal urban extensions usually follow the pattern of agricultural land determined by land subdivision mechanisms.

(3-1-F-3) Construction State and Capacity: Beltage is not a dense populated zone. Its total urban area is 153.6 Feddan inhabited by 12000 people, with a population density of 135.5 Capita/Feddan, which is far less than the national rural density (certified by the GOPP) of 250 Capita/Feddan. The average buildings height in Beltag is 1.8 story, while the construction state is generally moderate with some sparse deteriorated houses as shown in fig (255). Buildings structure in Beltag is basically skeleton, while 22% of the buildings are still built by bearing walls system. Scant buildings are built with raw brick system and all are in bad condition.

Total Urban Area (Feddan)	Population (2007) (Capita)	Residential Use Area (Feddan)	Vacant Land (Feddan)	Population Density Capita/Feddan	Average Building Height (Story)
153.6	12163	82.8	16.2	135.5	1.8

Table(45): Urban and Construction State in Beltag village, 2010 census



Fig(255): Beltag village's main construction maps (left) construction system (middle) Construction State (right) Buildings' heights.

Source: General Organization for Physial Planning: Strategic Plan Preparation Report for Beltag village, Dec, 2010

(3-1-G) Data Analysis:

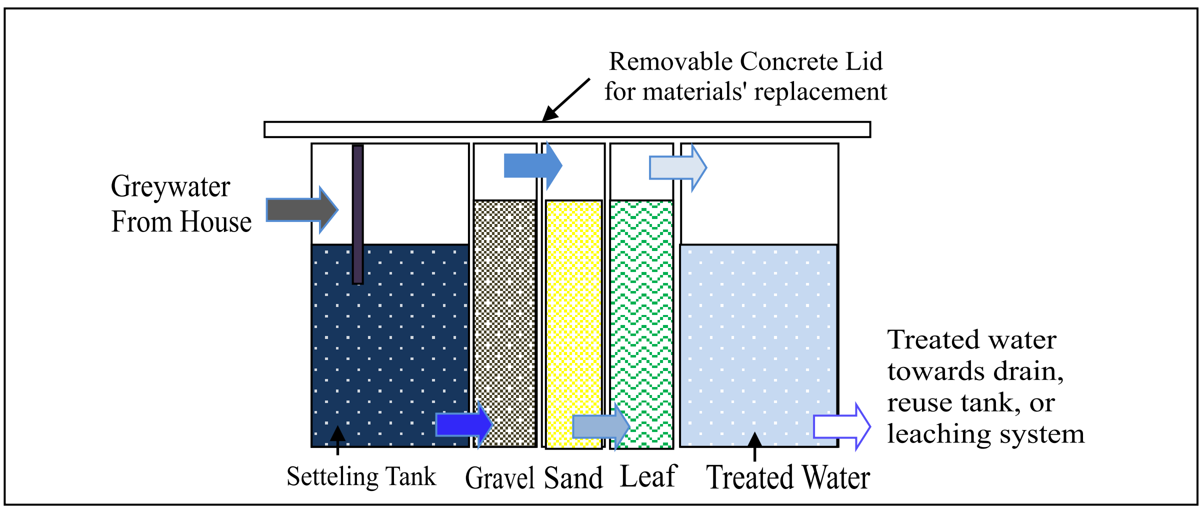
- Beltag is sufficiently supplied with municipal water and electricity, so the main proposed off-grid utilizes must provide clean and sustainable sanitation, gas and solid disposal systems.
- Organic waste in Beltag is abundant: most of the disposed household waste is degradable and cow manure is massively produced and can be used as a feeding material for biogas digesters.
- Soil in Beltag is less suitable for leaching systems because of its low hydraulic conductivity, so leached water must be minimized as much as possible.
- Groundwater is contaminated so leached water must be physically and biologically treated before reaching water table.
- High temperature, sun radiation and sky clearance in Beltag, all make solar systems suitable, but low education level hinders this idea.
- High sun exposure may help speeding the evaporation rate of the soil if the leached water is to be reduced significantly.
- Trenches are installed in every house, so it's not suitable to change the dominant system radically but only modify it as less as possible to help people accept the change.
- Low economical standard may hinder the use of expensive utilities, so minimal cost is preferred.
- Land use is basically residential so no special treatment is needed for sewage.
- Construction status is moderate to bad, so utilities must not get in contact with any part of the buildings' main bearing parts.
- Urban pattern is mainly organic and gridiron, so decentralized utilities are more suitable for the village.

- Vacant land is scarce and very expensive in Delta region, so all proposed utilities must be installed underground or over the roofs to assure suitability.
- Heating is demanded for digester system during winter months to assure quick fermentation.

(3-1-H) Proposed model for Beltag village:
The main problem in Beltag is the lack of sanitation utility and the accumulation of waste. The proposed model aims to offer the village safe sanitation system and sustainable waste management.

(3-1-H-1) Trench System Substitution: As almost every house in the village has an installed trench, it is easier to modify the system without replacing it. Existing trenches are bottomless, with brick walls to allow leaching from both sides. The suggested modification is to install septic tank with impermeable concrete walls. Only greywater will be allowed to access this tank. The tank will be built containing three chambers filled with different materials: Gravel chamber, sand chamber and date-palm leaf chamber. Gravel and sand will physically filtrate greywater while date-palm will perform biological treatment.

The proposed system is expected to remove oil, soap, solids and contaminants from greywater before it's released to the environment. The tank will be covered with a removable concrete lid to allow inspection and layers' replacement as shown in fig(256).



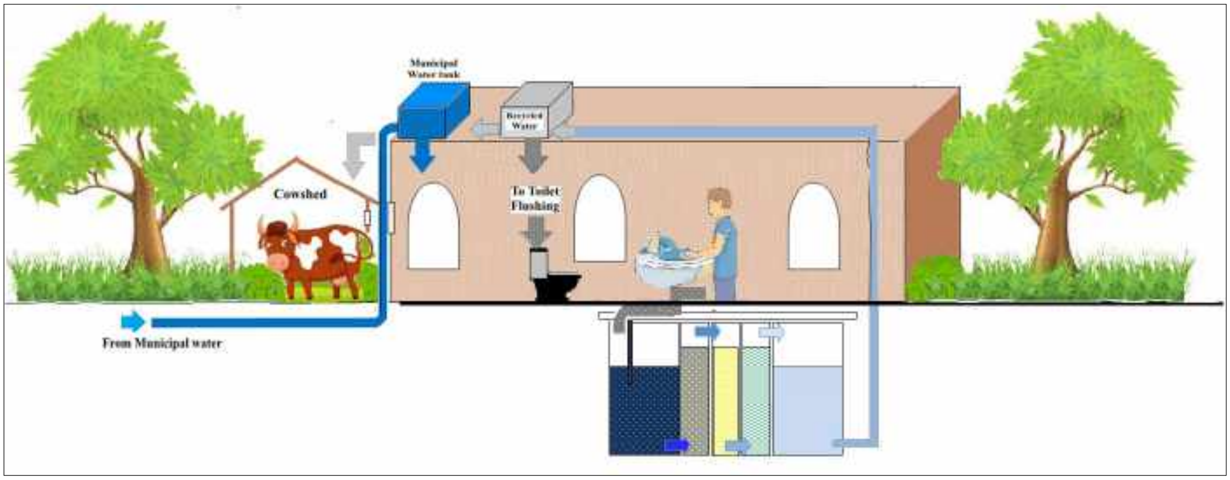
Fig(256):Suggested Septik tank for Beltag's houses - Designed by the researcher

Treated water can be directed in 3 ways, arranged by preference:

a- The most preferred option is reuse: water can be pumped again towards the house's roof, from-which it will flow by gravity towards toilet flushing tanks and cow sheds. It will be used in toilet flushing and in washing the floors of cow sheds and pavements of the house as shown in fig(257).

b- If the house is located near a drain, treated water can be directed towards it.

c- If the dwellers don't prefer to reuse the treated water and they live far away from drains, treated greywater can be allowed to leach to groundwater. As greywater in Beltag is about 50% of total household effluence, the estimated water volume that will leach to the soil is reduced by 50% than before. This reduction, as well as high sun exposure, will mitigate the problem of wall dampness. This option is less preferred but can be considered.

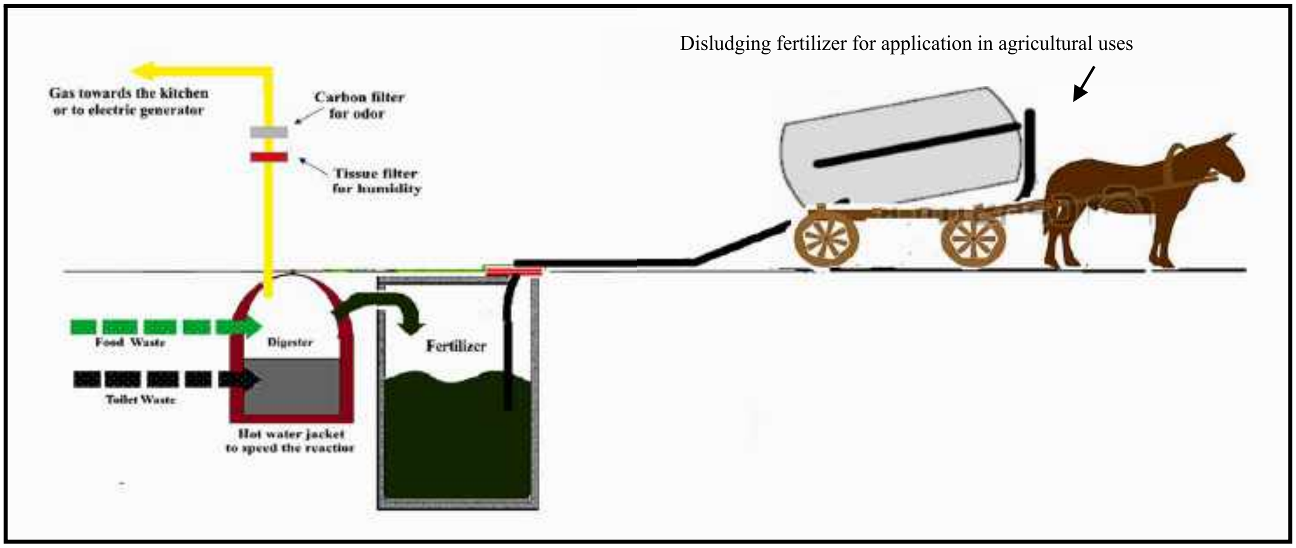


Fig(257): Suggested greywater reuse for toilet flushing and cow-shed uses and pavement washing
Designed by the researcher

(3-1-H-2) Blackwater diversion: The second modification proposed for Beltag's houses is to divert blackwater effluent away from the old trench. Blackwater, as well as kitchen waste, will be directed into a biogas digester, installed under street level in front of the house. It can be installed under the floor of the cow shed if possible. Digester must be tightly closed to assure high temperature and to prevent gas leaks. Blackwater and kitchen waste will be digested during fermentation process and the result will be gas and slurry. Slurry is collected in a nearby tank and pumped out periodically by local collectors and then used as soil amender or fertilizer. The effluent gas is directed to the kitchen and used in baking and cooking.

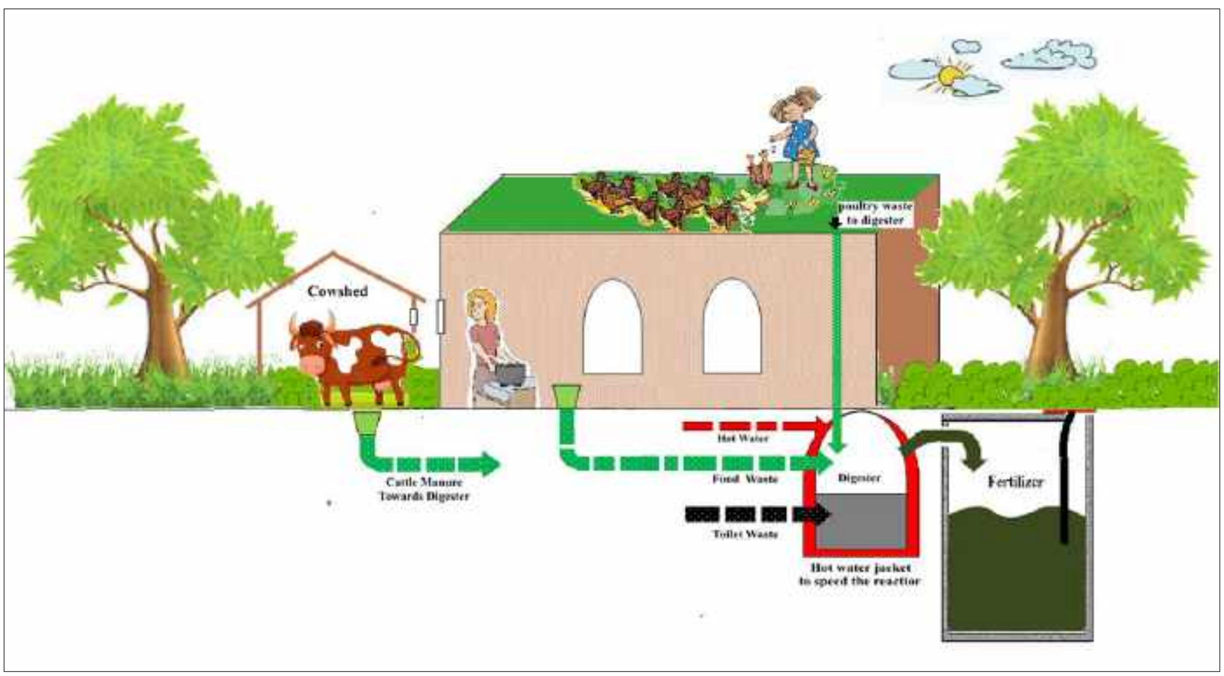
The effluent gas will pass through a "tissue and carbon" filter to clean the gas from humidity and bad odor. If the family don't prefer to cook with biogas, it can be directed to a generator to provide electricity to the house for free (258).

An optional addition is to provide a hot water jacket around the digester to speed-up the fermentation process, especially during winter season. Hot water can be supplied from solar collector on-top the roof, or from electrical water heater in the house



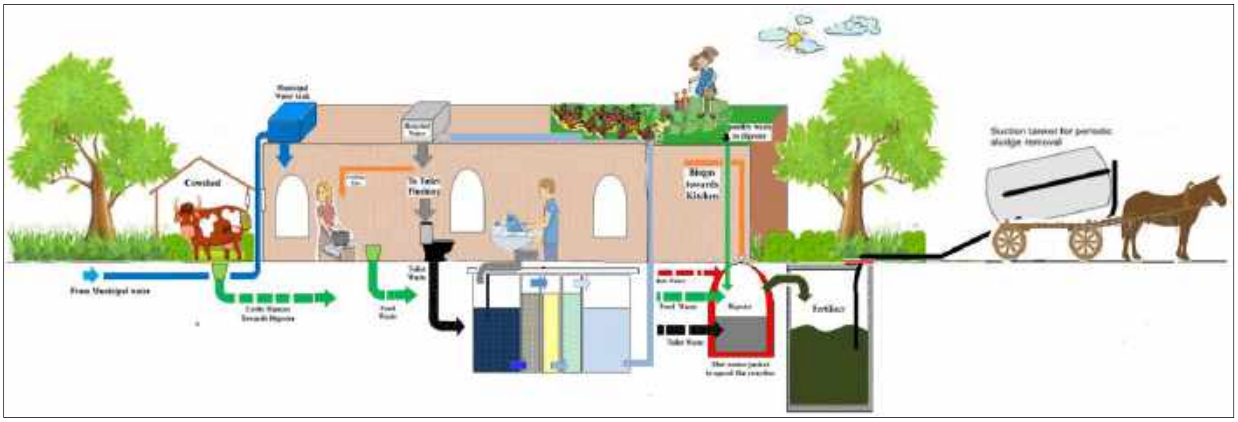
Fig(258): Blackwater and kitchen waste digestion system, suggested for Beltag - Designed by the researcher

(3-1-H-3) Organic waste from animal waste and agricultural waste: Most dwellers in Beltag raise chicken and cattle besides their own career. Chicken waste and cattle manure can be added to the digester to speed-up the fermentation and maximize the gas yield as well. If the dwellers work in farming too, all agricultural waste can be added (e.g. rice straw, corn silage and grass etc.). Straw and silage must be cut into pieces before adding to digester to speed-up their digestion. If applied, this process can reduce the massive seasonal straw burning, practiced every year in fall season. See fig(259).



Fig(259): Kitchen waste, chicken waste and cattle manure directed into digester to maximaize gas yeild - Designed by the researcher

Finally, each family can choose to apply one or more of the four suggested systems. If all the four are applied, they will form an integrated model shown in fig (260).



Fig(260) Integrated off-grid utilities model suggested for Beltag village- Designed by the

(3-1-H-4) The advantages of this system are:

- Leached water is reduced by 50 to 100% which means less wall dampness.
- Date-palm layer, when replaced, can be added to the digester to add to gas yield.
- As most rural household waste is organic, it will be disposed into digesting system and not dumped on canal side. Non organic waste like cans and plastics will be sold to local garbage collectors (Rubabikya buyers).
- Groundwater contamination is reduced by treating blackwater separately away from it, and by proper filtration of greywater, physically and biologically, before leaching it into groundwater.
- Biogas can be used both for cooking and power generation, which will solve the problem of gas shortage and offer electrical supply as well.

(3-1-H-5) Disadvantages and concerns of this system are:

- If gravel or sand are not replaced regularly, the tank may get blocked and raw greywater will overflow.
- If date-palm leaf is not replaced frequently (every 3-6 months) biological treatment of greywater will not be effective and this may contaminate the receiving water body.
- The inhabitants must be aware not to add chemicals or strong detergents into blackwater as this may kill the bacteria performing fermentation process. This will decrease the efficiency of wastewater treatment and the yield of biogas as well.
- Diverting wastewater into black and grey may be unaccepted due to cost and effort.
- Providing hot water for heating the digester in winter season may be difficult for some families who still depend on kerosene flames.

References of Part (III) - Chapter1:

[1] http://en.climate-data.org/location/477912 - Retrieved 28/3/2015 .

[2] H. E. Gad & S. M. El-Gayar: Climate Parameters Used to Evaluate the Evapotranspiration in Delta Central Zone in Egypt, Fourteenth International Water Technology Conference, IWTC14, Cairo, Egypt, 2010,

[3] (1 mega joule=0.2777 kWh). (Radiation is the transmission of waves from Sun to Earth into surrounding Air, while Irradiation is the condition of being exposed to radiation https://in.answers.yahoo.com/question/index?qid=20060930132214AAbyKi8/ - Retrieved 27/4/2015

[4] Ahmed Gehad: Deteriorated Soils in Egypt: Management and Rehabilitation -Executive Authority for Land Improvement Projects الجهاز التنفيذي لمشروعات تحسين الأراضي (EALIP), August 2008- http://ftp.fao.org/agl/agll/ladadocs/detsoilsegypt.doc-retrieved in 27/3/2015

[5] The total statistics for this village are taken from the GOPP strategic Planning studies, dec,2010 as no later studies were available.

Part (III)- Chapter (2)

(3-2) Application Model in Urban Area in Egypt (Wadi El-Natrun City):

Introduction to Chapter 2

This chapter introduces an urban settlement (Wadi El-Natrun City) which suffers some environmental problems and lack of some utilities. The researcher introduces a climatic, socio-economic and environmental analysis of the city as well as its the main problems, after-which she introduces some suggested off-grid utilities to help solving or mitigating these problems.

End of Introduction to Part III- Chapter (2)

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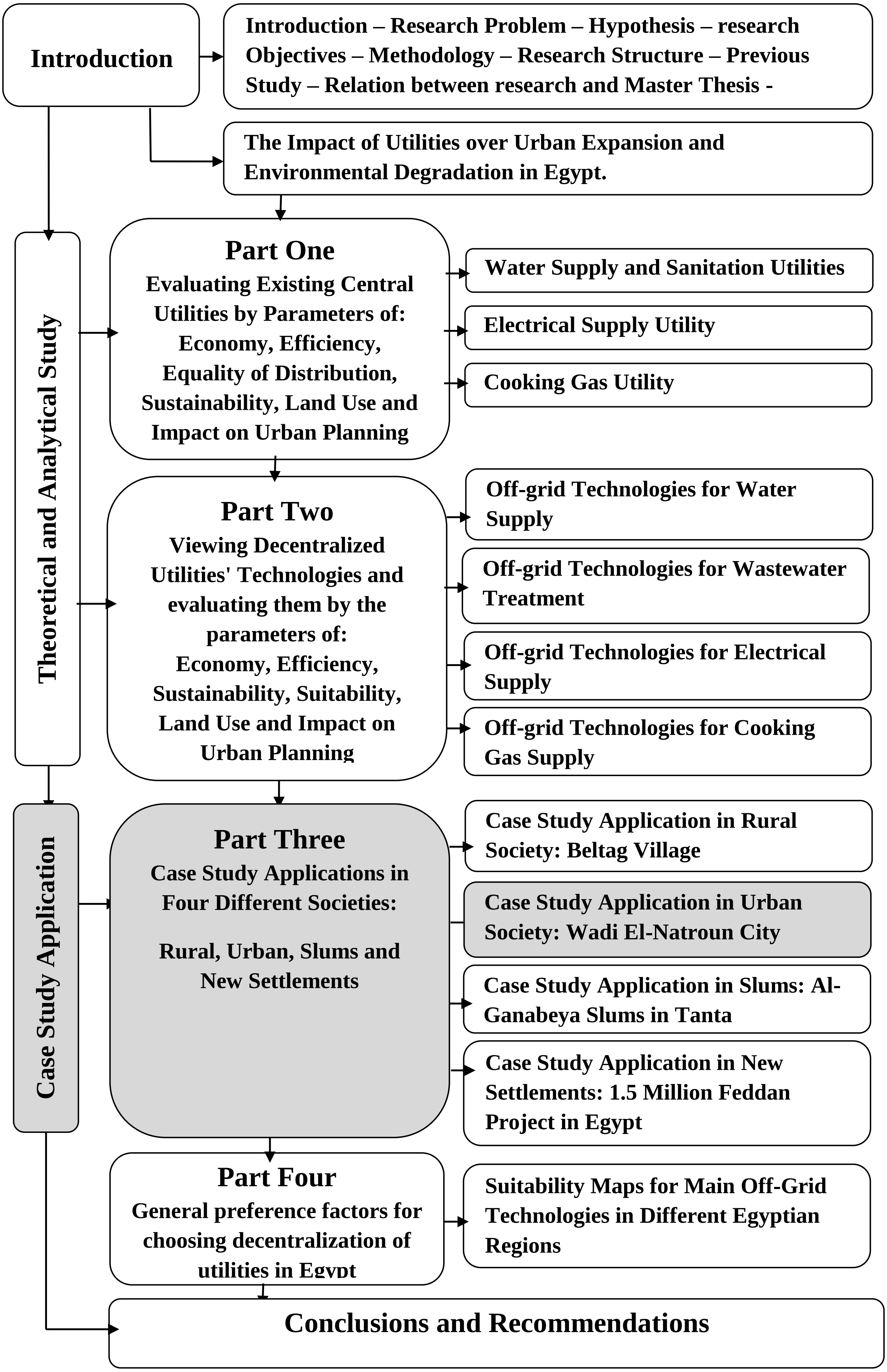
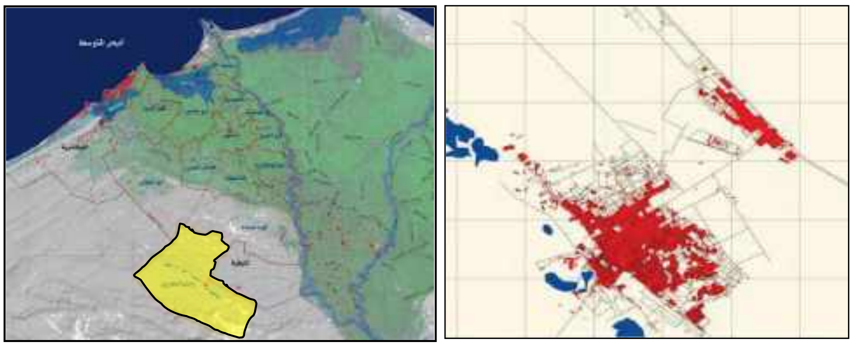

Introduction
Introduction – Research Problem – Hypothesis – research Objectives – Methodology – Research Structure – Previous Study – Relation between research and Master Thesis -
The Impact of Utilities over Urban Expansion and Environmental Degradation in Egypt.
Theoretical and Analytical Study
Part One
Evaluating Existing Central Utilities by Parameters of: Economy, Efficiency, Equality of Distribution, Sustainability, Land Use and Impact on Urban Planning
Water Supply and Sanitation Utilities
Electrical Supply Utility
Cooking Gas Utility
Part Two
Viewing Decentralized Utilities' Technologies and evaluating them by the parameters of: Economy, Efficiency, Sustainability, Suitability, Land Use and Impact on Urban Planning
Off-grid Technologies for Water Supply
Off-grid Technologies for Wastewater Treatment
Off-grid Technologies for Electrical Supply
Off-grid Technologies for Cooking Gas Supply
Case Study Application
Part Three
Case Study Applications in Four Different Societies:
Rural, Urban, Slums and New Settlements
Case Study Application in Rural Society: Beltag Village
Case Study Application in Urban Society: Wadi El-Natroun City
Case Study Application in Slums: Al-Ganabeya Slums in Tanta
Case Study Application in New Settlements: 1.5 Million Feddan Project in Egypt
Part Four
General preference factors for choosing decentralization of utilities in Egypt
Suitability Maps for Main Off-Grid Technologies in Different Egyptian Regions
Conclusions and Recommendations

(3-2) Application model in Urban Settlements (Wadi El-Natrun City):

Wadi El-Natrun, is a narrow depression located in the west of the Nile Delta, approximately 110 km northwest of Cairo. The total area of Wadi El-Natrun depression is about 2960.5 Km^2, extending in a NW-SE direction and 23 m below sea level. Natrun city is located in the middle of the governorate with a population of 21,540 in 2006 census.[1] The city is divided into 2 main urban clusters which are completely apart from each other, excluding the main city road that joins the two parts together as shown in fig (261).

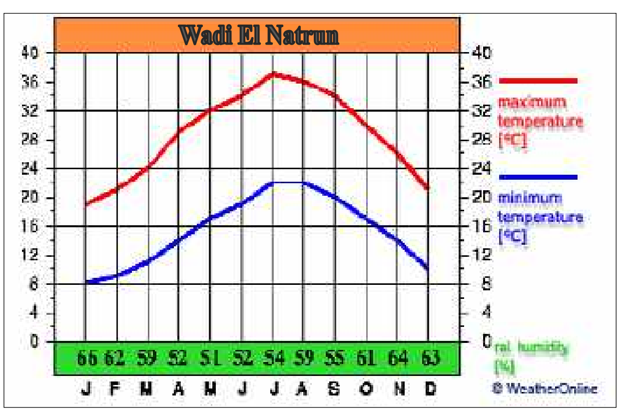


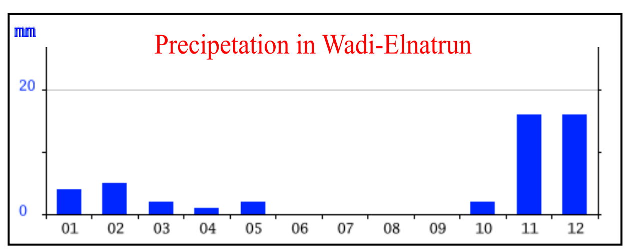
Fig(261): (left) Natrun Governorate map (right) Natrun city's two main clusters

Source: (left) with modification from www.googleearth.com (right) GOPP Strategic Planning Studies for Natrun City, 2011

(3-2-1) Climate:

Natrun has a desert climate, classified as BWh according to Köppen and Geiger.[2] It is considered as an extremely arid region where the mean annual rainfall, evaporation and temperature are 41.4 mm, 114.3 mm and 21ºC respectively.[3] There is virtually no rainfall during the year. The driest month is June, with 0 mm of rainfall. Most of the precipitation falls in November, averaging 16 mm, see fig (262).[4] The relative humidity is above 50 % and may reach 66% in July, which maximizes the feeling of high temperature in summer months. Fig (262) shows the main climatic features of Natrun city.





Fig(262): (left) Natrun's climatic features- (up) Precipitation in millimeters around the year in Natrun city. **Source: (left) www.weatheronline.co.uk**
(up) http://en.climate-data.org/location/768378/
Both Retrieved 10/4/2015

(3-2-1-A) Sun Exposure:

As a desert region, Natrun enjoys a relatively high sun exposure, especially during summer season. High exposure is also increased by the absence of shading factor due to wide streets, buildings' with minimum height and scattered distribution; which augmented the sun exposure upon streets and roofs. Both hot weather and high sun exposure cause seasonal draught for small lakes like Al-Khadra and Al-Razeena lakes. The annual direct normal irradiation in Natrun zone is (6.6 – 7.0) kWh/m^2/day[5]; which allows the city to get benefit from high sun power either in biogas production or solar systems application.

(3-2-1-B) Wind Speed:

Natrun has the privilege of high wind speed which increases both evaporation rate and solar systems efficiency as well. Referring to Egypt Wind Map in chapter 2, wind speed in Natrun is 7 km/hour, compared to 4 km/h in Delta region.

(3-2-2) Topography:

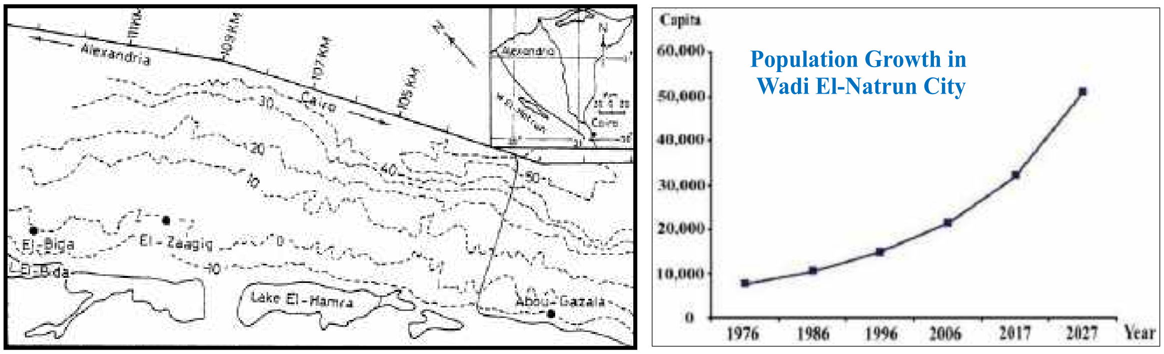
Natrun has a high level difference in land as shown in fig (263). Land level starts with (+55) at the entrance of the city, and ends with (-15) m at the end of the built area beside the lakes. This (65) meters of level difference has encouraged the inhabitants to drain their household wastewater along with gravity to pour into downward lakes. On the other hand, the slope made water supply difficult as pumping is against gravity.

(3-2-3) Soil Properties:

A geological study conducted in 1991 showed that Natrun soil is classified into two categories: the El-Bida and El-Zaagig areas' soil is characterized by interstratified loam, clay and marl layers, while the Abu Gazala section is represented by an interstratification of sand, loam and clay layers[6]. The soil is very suitable for leaching systems as it rapidly drains down liquids. As shown in fig (148), the hydraulic conductivity of the soil in Natrun is (0.00005 to 20) m^3/m^2/day.

(3-2-4) Population Characteristics:

Natrun city's population was 21,540 in 2006 census, and is inclining steadily with an average growth rate of 3.6% for the city and 4.9 for the Markaz. The city population is expected to exceed 50,000 in 2027 as shown in fig (263). The main reason for this rapid growth is the internal immigration due to job opportunities available in the valley. Most immigrants come to work in farming as illustrated later.



Fig(263): (left) Topography & Contour lines for Natrun (right) Population growth in Natrun city
Source: (left) (M. A. Rashed 1991) (right) United Nations Human Settlements Programme (UN-Habitat): Strategic Plan for Natroun City,2011

(3-2-4-A) Age:

As a destination for manpower, Natrun is a youthful city. 61% of its population is 15 – 60 years, while 34 % is younger than 15 years.[7]

(3-2-4-B) Profession & Employment:

The main profession practiced in Natrun is farming, while secondary professions like trading and craftsmanship are less practiced. The unemployment rate in Natrun is generally low compared with National unemployment rate. In 2006, the unemployment rate in Natrun was 0.235person/thousand while in the same year the National unemployment rate was 109 person/thousand [8]. We couldn't find accurate data about unemployment in Natrun after 2006, however, as farming needs no special skills, almost everyone can find a daily job in surrounding farms, see fig(264).

Fig(264): Farming workers in Natroun

Population Age Categories in Natrun City, 2010 census		
Younger than 15 yrs.	(15 - 60) yrs.	Older than 60 yrs.
34.1 %	61 %	4.9 %

Table(46): Population age categories in Natrun City in 2010 census - Source: (UN-Habitat, 2011)

Unemployment in Natrun City Person/thousand, 2006 census		
Males Male/thousand	Females Female/thousand	Total Person/thousand
0.289	0.121	0.235

Table(47): Unemployment in Natrun City in 2011- Source: (UN-Habitat, 2011)

(3-2-4-C)Poverty:

According to the UN Habitat report 2011, about 4.22 % of total population in Natrun city is under poverty line, which is much better than the National 25.2 % of total Egypt in the same year.[9] However, Natrun Markaz is not as wealthy as the main city. 22% of the people living in Natroun's villages were under poverty line at the same year.[10]

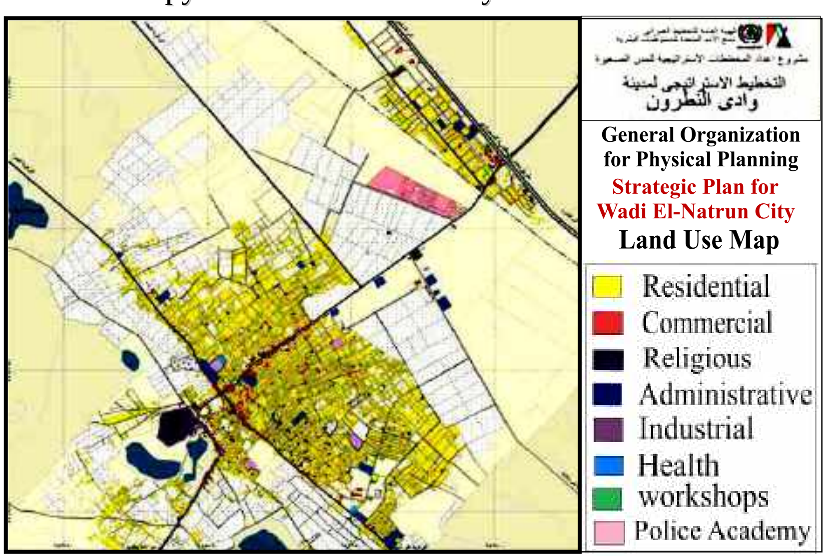
(3-2-4-D) Education:

Although Natroun Markaz has 32 schools occupying 44.3 Feddans, the education level is relatively low. Many children escape education to work in farms. The biggest educational building in the valley is the police academy, built over 30.7 Feddan.

Fig(265): Children working in Natroun and Nobareyah farms

(3-2-5) Urban Characteristics:

(3-2-5-A) Land Use: The dominant land use in Natrun city is residential use, followed by religious (Mosques and Monasteries). Security uses come in the third place represented in the police academy installed over 38 Feddans. Industrial, administrative and workshop uses come in the fourth place as shown in fig(266). Agriculture land occupies Inland saline lakes and salt crusts occupy the area surrounded by contour zero.[11]



Fig(266):Land uses in Natrun city, surveyed in 2011- GOPP Strategic Plan for Wadi El-Natrun city, 2011

(3-2-5-B) Urban state and capacity: Natrun is urbanely divided into four regions:

- **Old city area:** This is the historical core of the city first inhabited in the fourth century. This area is characterized by small units' area (average 95 m^2), high building and population density, narrow streets and trench system dominance.

Fig(267): A view in the old city area in Natrun

- **Main city area:** This is modern area first inhabited in mid-20 century. This area is characterized by medium units' area (average 250 m^2), moderate building and population density, wide streets and low construction level (1 to 2 stories). The main sewage system in this area is locally installed grid that pours into the lakes.
- **New Extensions areas:** This area is recently built (10-15 yrs. old). It is characterized by scattered urban type, with very low building and population density (Average 30 person per Feddan). Houses average room no. is above 5 and no. of house inhabitants is 3.6/unit. Some of these houses have trenches and some of them (which are near to the lakes) have slope pipes pouring into the lakes.
- **Slum areas:** There are 3 main slums in Natrun city: Abu-Eisa, Al-Zuhour and Gharb El-Madeena areas. These areas are characterized with very high population density, low building density and low building percentage as shown in table(48). The area depends completely on trench system and suffers from bad construction state and bad living conditions.



Fig(268): (left) Main City area in Natrun city (middle) New extensions area in Natrun city (right) Top view in Abu-Eisa slum in Natrun city

Construction State & Capacity in Natrun City, 2011 census					
Area/Category	Residential Unit's Average Area (m^2)	Building Percentage (%)	Population Density (Capita/Feddan)	Average No. of Rooms' /House	Average no. of Inhabitants/ Room
Old City	95	80-95	95	3	1.3
Main City	145	48-60	65	3.6	1.1
New Extensions	250	30	30	5.2	0.7
Slums	75	50	100	3	1.3

Table(48): Construction state and capacity in Natrun city- Source: UN Habitat report, 2011

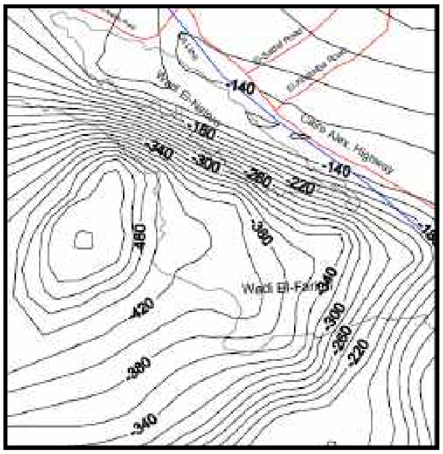
(3-2-6) Public Services:

The main data in this topic was taken from the UN Habitat project for Wadi El-Natrun Strategic plan report, published in May 2011. As this data was relatively old, we've visited the city in April 2015 and gathered new data from the General Secretary of the city and his vice, fig(269).

Fig(269): The General Secretary of Natrun and his vice

(3-2-6-A) Water Supply:

Natrun city depends basically on groundwater for municipal water supply. Underground water in Wadi El-Natroun is originated from Nile stream seepage,[12] so it is considered renewable and naturally recharged. Aquifers surface water is 25 to 88 meters deep while aquifer bottom water starts with 140 to 460 meters deep as shown in fig(..).[13] There are 4 groundwater municipal stations in the city, and several others supplying the neighboring villages. The main treatment used is chlorination. Chlorine is added according to the microbiological analysis of the water in each station. Salinity in produced water varies between 280 to 1050 ppm as shown in table (49). The main problem facing the water utility is weal flow. Because Natrun has a land level differences, water pumping needs more mechanical power. The shortage and dilapidation of pumping stations caused regular water cuts. Most houses have installed water storage tanks on roofs to provide water during water cut times, see fig(270).



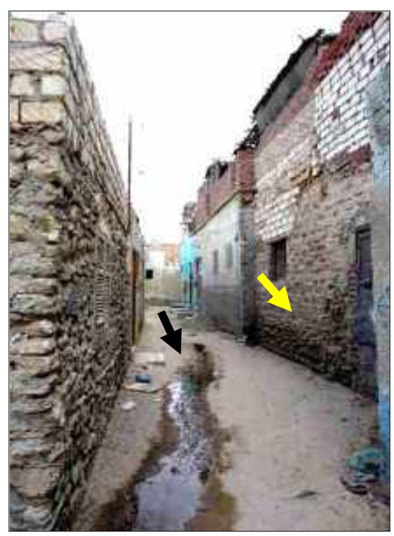
Fig(270): (left) Groundwater depth levels in Natroun (right) Fig(..): Water storage tanks over Natrun roofs
Source: (left) T. Youssef, et, al. 2012 (right) UN Habitat 2011

Well Location	Well Diameter (inch)	Water Depth (meter)	Production capacity (m3/hour)	Salinity (Part per million) (ppm)
Kafr Dawood	10	88	25	1050
Bier El-Hammam	10	25	25	280
Al-Hamra	10	60	60	280
Bani Salama	10	80	Water flows spontaneously	280

Table(49): Main measures of municipal water stations in Natrun
United Nations Human Settlements Programme Report, 2011

(3-2-6-B) Sanitation:

Natrun city was totally deprived from municipal sanitation. People use trenches in outer areas of the city (25% of the population). These trenches occasionally overflow and cause wall dampness and street submergence, especially in winter season, as shown in fig(271). The rest 75% of the population have installed local grid that pours wastewater effluent directly into nearest lake[14]. Because of this problematic condition, the government has installed a major sewage plant, opened at March, 2014, with total cost of 150 million LE, to serve Natrun city and Markaz. The station is located 57 kilometers away from the city, over 10 Feddans of land. It has a treatment capacity of 20 thousand m3/day, to serve the present 77 thousand



Fig(271): Wall dampness and sewage overflow in Trench-serviced areas in Natrun city

population as well as future expected increase, as Natrun city is expected to attract more population especially in farming jobs.

Although installed a year ago, the station hasn't started working because the main slope grid haven't been installed yet. This grid requires additional cost estimated with further 150 million LE, which is as double as usual because Natrun city has a scattered built environment with very low population density. As mentioned before, the main economical factor for sanitation grid is (connections/kilometer). High cost of grid installation may hinder the completion of such project. So, present sewage technologies are expected to remain in service for some time.

(3-2-6-B-1) Environmental impact on the lakes:

Receiving raw wastewater for years, Most of Natrun lakes were affected by the sewage received, which caused a noticeable change in the lakes' ecological system. An example for this change is Al-Hamra Lake, located south west Natrun city, just beside the residential main cluster. This lake was considered a main source of industrial salt for years. But recently, and because of the massive flow of wastewater into it, the lake became bigger and darker, with less salt and more turbidity. Observing the satellite map for this lake in different years, these changes are easily noticed as shown in fig (273).

Fig(272): The researcher standing by Al-Hamra Lake in Natrun

Fig(273): Hamra lake imaged in different years. From left: 2004, 2007 and 2014- Google earth maps

(3-2-6-C) Solid Waste Disposal:

Natrun city has a primitive solid waste disposal system, depending on manual collection by individuals employed the inhabitants. These individuals usually sort the collected garbage and dispose refused materials on the shores of nearest lake. Fortunately, most disposed materials are degraded by heavy sun exposure and high temperature, but unfortunately, they cause bad odor and attracts more flies. While some inhabitants tend to burn these heaps, others use it as fodder for their cattle as shown in fig(274).

Fig(274): Cattle feeding on garbage by the

(3-2-6-D) Electricity:

Natrun city is totally supplied by central electrical grid serving 100% of the population. There are 2 main transformers serving the city with 50 to 500 kv capacity, supplied from the main Nobareyah power plant shown in fig(275). Another supply comes from Sadat Station, located at the south east, with a transformer capacity of 66 kv. Sadat station basically supplies the agricultural projects located nearby, as well as the main Natrun Prison.

The distribution grid in Natrun city is totally aerial, which causes repetitive damages and forms a permanent threat to the inhabitants. Electricity bill is within average and no major complains were stated concerning the service.

Fig(275): (left) Aerial electric cables serving Natrun houses (right) The researcher standing by Nubareya Power Plant supplying Natrun City, April,2015

(3-2-6-E) Natural Gas Supply:

Natrun city hosts the main **Sumed** natural gas pipeline transporting gas from Ain Sukhna terminal on the Gulf of Suez to offshore Sidi Kerir, Alexandria as shown in fig(276).[15]

Sumid pipeline was installed in 2001 with 320 kilometers long and consists of two parallel lines of 42 inches (1,070 mm) diameter. It has many negative impacts on Natrun city. Environmentally, the line has affected the natural habitat of the area and threatens its safety with possible leaks or explosions. Urbanely, the line limits the urban expansion of the eastern part of Natrun city and prevents future union of the two city parts as shown in fig(..). Although being hosted for many years, no natural gas connections have been installed in Natrun for household uses till now. The city still depends completely on LPG canisters for cooking gas supply.

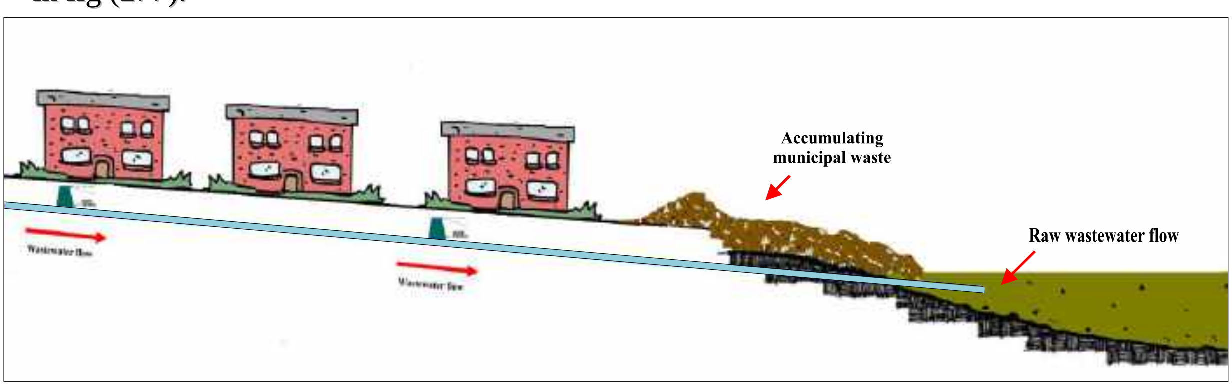
Fig(276): (left) Sumed Natural Gas pipeline path (middle) Sumed path across Natrun city (right) Gas pipes affecting the natural habitat of the area.

(3-2-7) Data Analysis:

- Natrun city is sufficiently supplied with water, electricity and gas canisters. The main shortage is in sewage utility and solid waste disposal.
- High temperature in Natrun makes it suitable for applying biogas digesting system.
- High evaporation rate helps applying the constructed wetland system.
- The society is Natrun is consolidated and suitable for grouped utilities' installation.

(3-2-8) Proposed model for Natrun City:

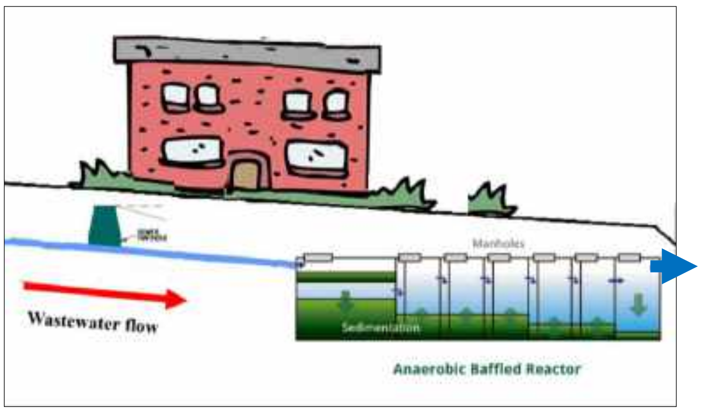
Natrun lakes are polluted either by wastewater effluent or accumulated solid waste as shown in fig (277).



Fig(277): Cross section in polluted lake in Natrun: municipal sewage flow & solid waste disposal Imaged by the researcher

The proposed model aims to offer the city a clean sanitation system and sustainable waste management. The proposed model consists of two systems: ABR, Wetland, and Digester systems as shown below:

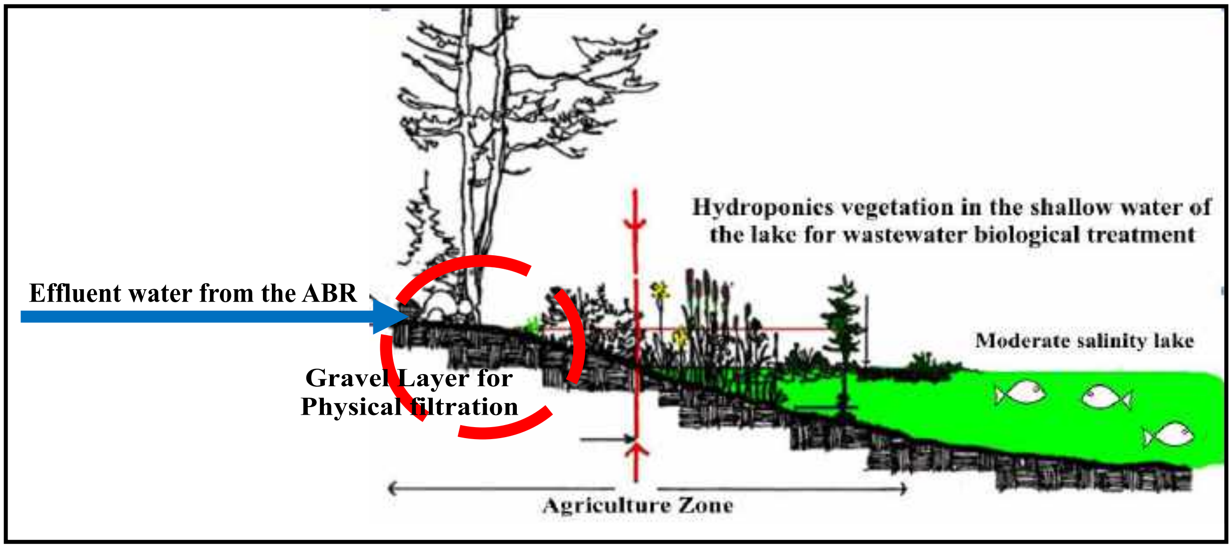
(3-2-8-A) ABR System: 75 % of Natrun houses drain their waste into the lakes. Local sewage pipes are installed along with the natural topographic slope of the city. Anaerobic Baffled Reactor is suggested to be installed at the end point of the grid to receive raw wastewater before reaching the lake. ABR will perform the following tasks:



Fig(278):Proposed Anaerobic Baffled Reactor for primary treatment in Natrun- Designed by the researcher

- Primary treatment of sewage by sedimentation and digestion.
- Physical filtration of wastewater from food, sludge and tissues.
- Delay of hydraulic loads in peak hours so the lakes won't receive massive water flow at the same moment.
- Reduce the final wastewater volume discharged.
- Protect the natural habitat and reduce the environmental damage.

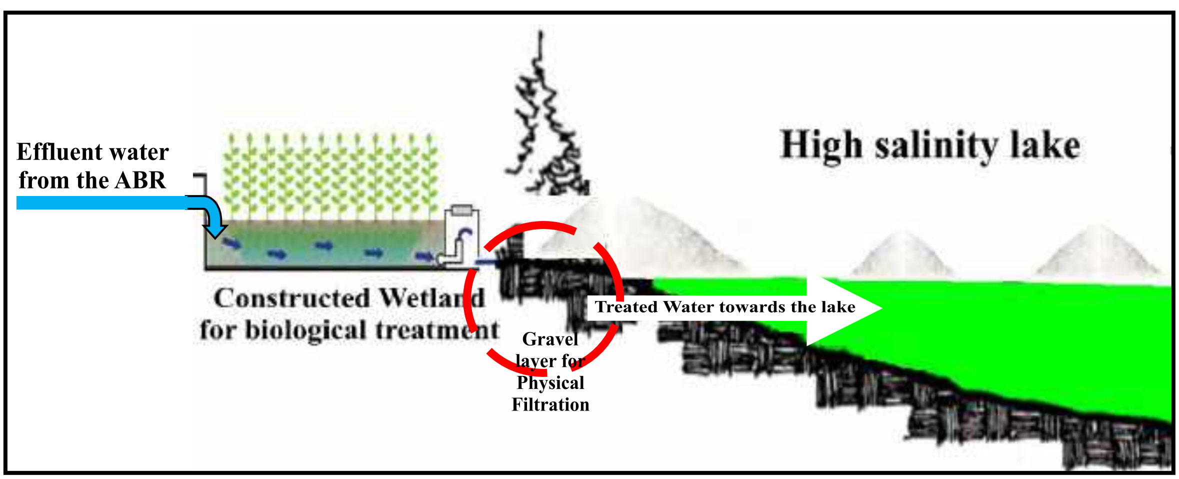
(3-2-8-B) Wetland System: The effluent from ABR needs further treatment before being disposed into the lake. Biological treatment can be performed by wetland system. Wetland can be installed in the lake itself by planting a group of hydroponic plants in the effluent receiving zone of the lake as shown in fig (279). The zone is usually shallow which helps avoiding strong currents and waves. A gravel layer is to be installed before planting zone to perform additional removal of solids from received influent. The roots perform biological treatment as all bacterial contents and heavy metal elements in wastewater will stick to the plants' roots.



Fig(279): Proposed wetland system for wastewater treatment in Natrun lakes- Designed by the researcher

Treated water will safely flow into the middle of the lake, causing minimal damage to its natural habitat and supplying it with clean water with dissolved oxygen that will nourish the lake's flora and fauna.

(3-2-8-B-1) High Salinity Lakes: If the lake is highly saline to a level that no plants can be hosted in it, wetland system can be installed outside the lake as a constructed water basin hosting the plants as shown in fig(280). Wastewater enters the basin and allowed to stay for 24-48 hours before being released to the lake.

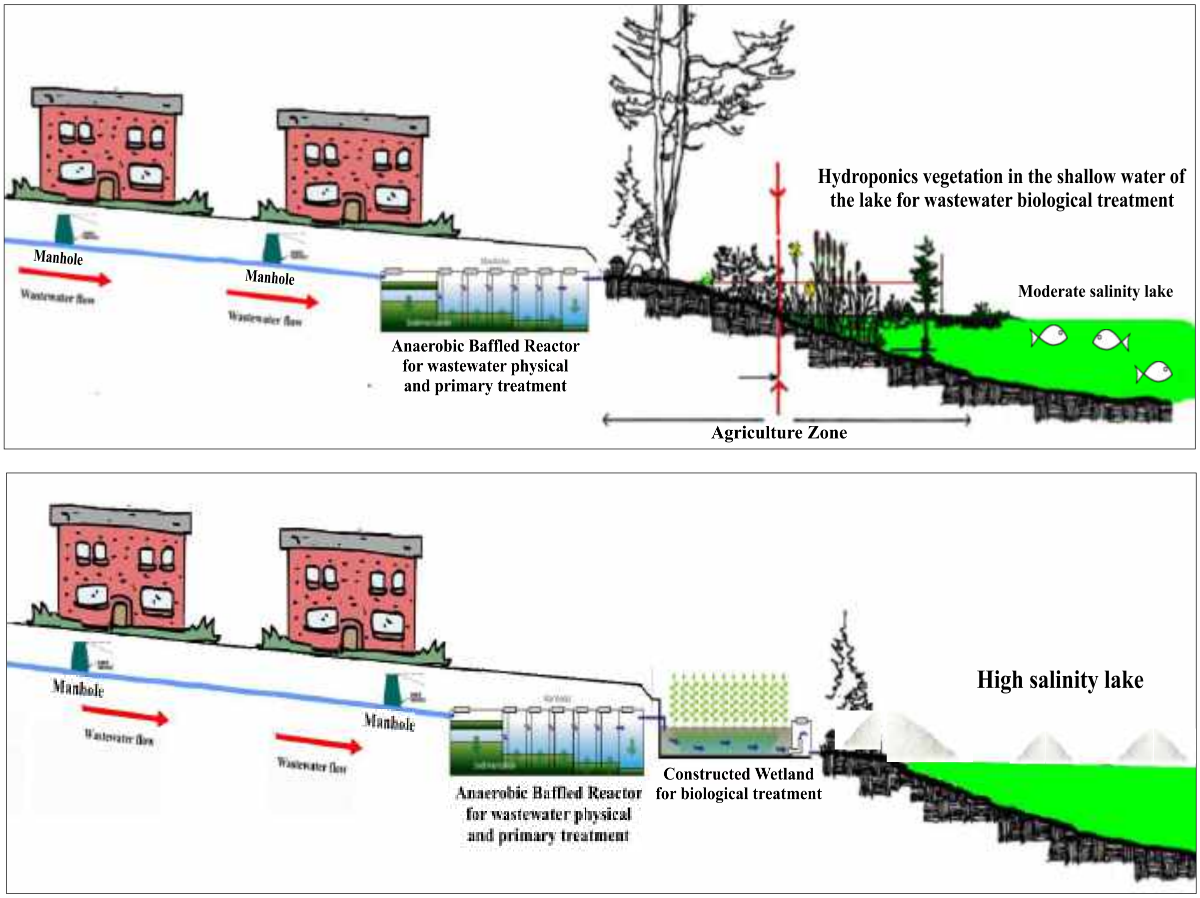


Fig(280): Constructed Wetland installed for wastewater biological treatment in Natrun lakes Designed by the researcher

Wetland system will perform the following tasks:

- Remove contaminants from wastewater (bacteria, fungus and heavy metals).
- Increase oxygen level in treated water.
- Retain very fine solids that escaped both ABR and gravel layer.
- The plants may be harvested and added to an anaerobic digester to generate biogas.

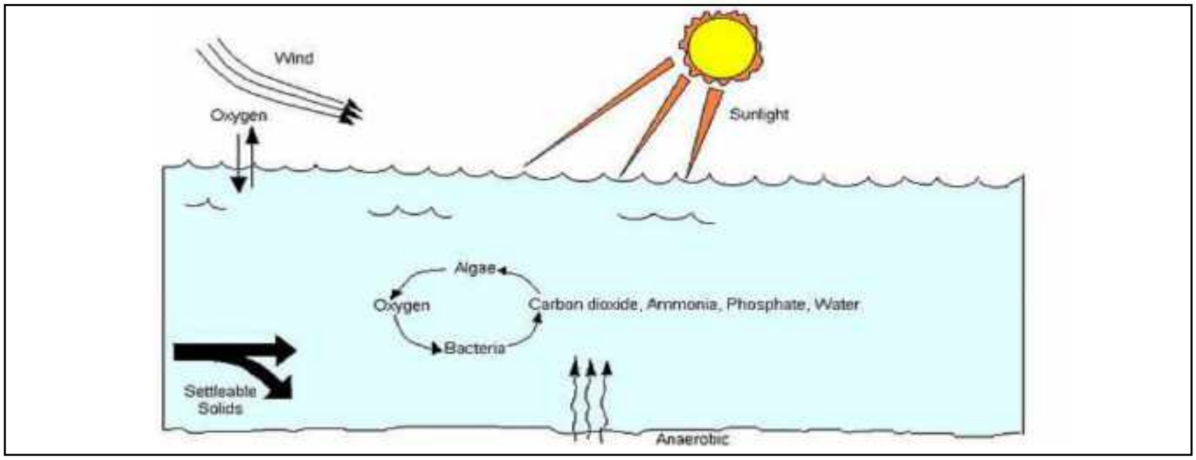
The general view of both systems is shown in fig(281).



Fig(281): Wastewater treatment proposed for Natrun's off-grid areas beside the lakes (up) Lakes with normal salinity (down) lakes with high salinity - Designed by the researcher.

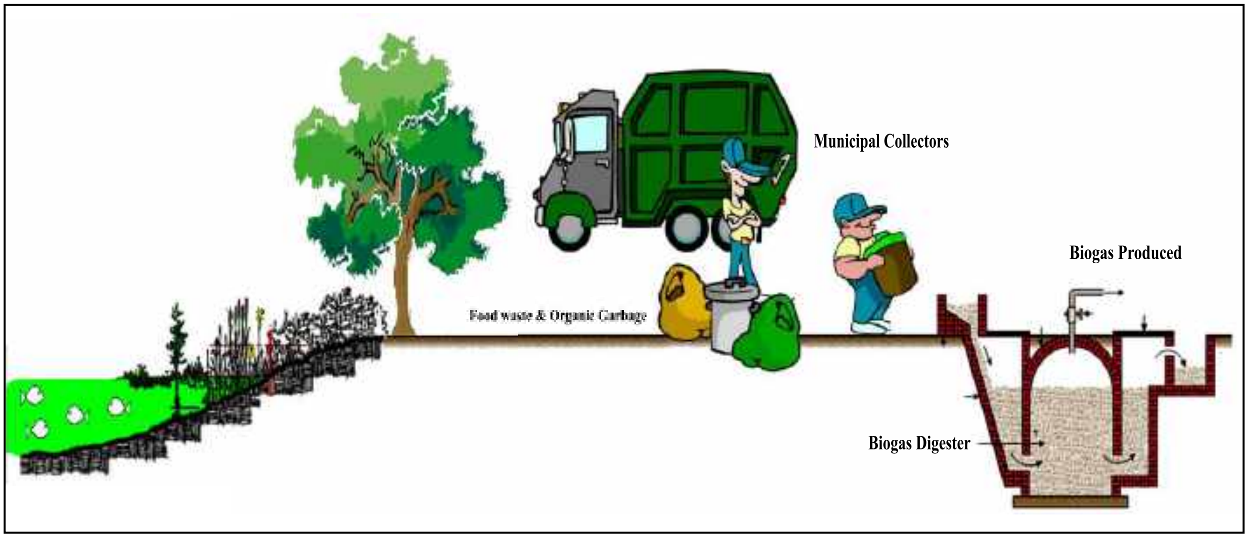
(3-2-8-C) Open Lagoon Treatment System: The effluent treated water is furtherly purified by the natural climatic elements around the lake. Sunrays, wind and Oxygen are the main factors of treating the water by aerobic digestion. This natural ecological system is similar to the artificial facultative ponds that are commonly installed in sewage treatment plants. Treatment ponds involve many physical, chemical and biological processes. The key to operation is the balance between photosynthesis and aerobic decomposition.

Fortunately, Natrun enjoys high sun exposure and high wind speed as illustrated before, which increase the efficiency of treatment process, see fig(282).



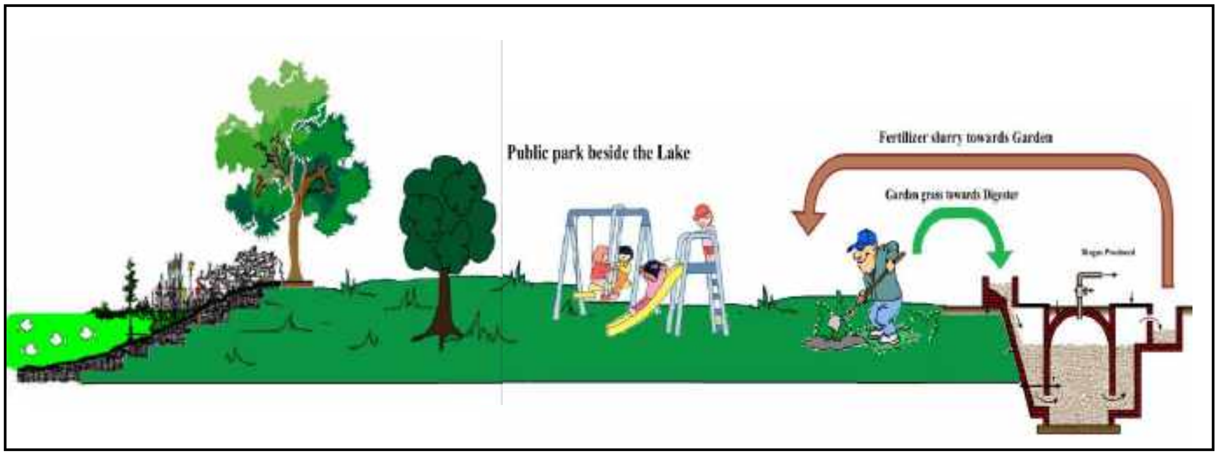
Fig(282): The rule of sunrays, wind and oxygen in aerobic treatment of final effluent
Modified by the researcher from the diagram adapted from:http://web.deu.edu.tr/atiksu/ana52/ani4044.html- retrieved 12/5/2015

(3-2-8-D) Solid Waste Digesting System: The accumulated solid waste disposed on the lakes' shores can be a source of electric power and fertilizer. A digester can be built beside the lake underground. This digester will be fed with all daily refused waste which the collectors throw away after sorting the garbage, as shown in fig(283).



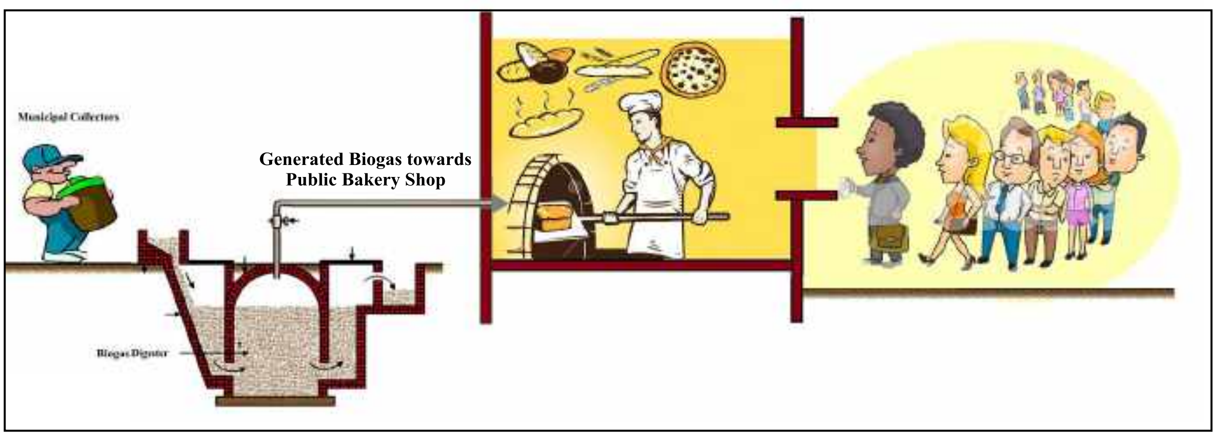
Fig(283): Sorted organic waste disposal system proposed for Natrun City- Designed by the researcher

Another source for organic waste is the manure produced by the cattle around the lake. This system will help providing clean shores and a source of excellent fertilizer as well. Natrun city imports massive amounts of manure from nearby cities and from Gharbeya Governorate (especially Qotur's villages) on regular bases to use as natural fertilizer to improve the quality of new repaired land. The effluent slurry can be pumped regularly by tanks and used as fertilizer. If the quantity isn't plentiful, slurry can be used to establish a small public garden beside the lake as a recreation spot for Natrun people, see fig(284).



Fig(284): A proposed usage for the effluent fertilizer slurry that comes from the proposed Digester in Natrun City- Designed by the researcher

The biogas generated can be fed to a public bakery shop to use for bread making, serving the city as shown in fig (285).



Fig(285): A proposed use for biogas generated from proposed solid waste digester in Natrun City- Designed by the researcher

The biogas produced can be maximized by adding one or all of the following:

- Food waste from the main city market, shown in fig(286).
- Agriculture waste from nearby farms.
- Date palm leaves which heavily grows in Natrun's monasteries.
- Abundant grass that grows by the lake itself, shown in fig (286).

Fig(286): (left) Palms trees by Natroun monasteries (middle) Main vegetable market in Natroun (right) Abundant grass around the lakes in Natrun

(3-2-8-E) Advantages of this system are:

- Wastewater will be treated before being disposed in the lakes, which will improve the quality of lake water and save its marine life and ecological system.
- High salinity lakes will keep saline and clean, so salt extraction career will nourish again.
- ABR will reduce the occurrence of water sudden loads during peak hours. This will help saving the ecological system of the receiving water body.
- Minimal modifications are done to the existing wastewater network so minimum cost is required.
- Further aerobic treatment takes place in the lakes with zero cost and no human interference.
- Organic waste will be digested rather than being burnt on lake shores, so less air pollution will occur.
- Generated gas will provide source of fuel for backing and cooking.
- Digesters will provide natural fertilizer for soil amendment.

(3-2-8-F) Disadvantages and concerns of this system are:

- Some inhabitants may not co-operate in applying grouped systems, which may cause social problems and create bad relations.
- Due to bureaucracy, municipality may not approve ABR installation, even if the dwellers are ready to pay for the cost.

- Garbage collectors may not pay effort in adding organic residues into the digester, they may find it easier to burn it as they used to. It is the rule of social leaders in the area to encourage those collectors, using regular advice and monetary incentives.

References of Part 3- Chapter 2:

[1] No documented population data could be found after this year, even from the local Natrun Governors.

[2] (Köppen climate classification is one of the most widely used climate classification systems including 5 clasifications. BWh is an arid climate, where precipitation is too low to sustain any vegetation at all, or at most a very scanty shrub. The perecipitation is usually less than 250 mm per year and in some years may have no precipitation at all. Areas in BWh regions usually lose more water via evapotranspiration than falls as precipitation. Peel, M. C. and Finlayson, B. L. and McMahon, T. A. (2007). "Updated world map of the Köppen–Geiger climate classification". Hydrol. Earth Syst. Sci. 11: 1633–1644. doi:10.5194/hess-11-1633-2007. ISSN 1027-5606. (direct: Final Revised Paper)

[3] (Egyptian Meteorological Authority, 2006)

[4] http://en.climate-data.org/location/768378/ - Retrieved 10/4/2015

[5] (Source NREA, see page… in chapter2),

[6] M. A. Rashed: Engineering-Geological Properties of Pliocene Argillaceous Sediments of the Wadi El-Natrun Area(Egypt), Bulletin of the International Association of Engineering Geology, No.44, Paris, 1991.

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[8] (http://www.tradingeconomics.com/egypt/unemployment-rate-retrieved 24/4/2015).

[9] (http://data.worldbank.org/indicator/SI.POV.NAHC/countries/EG?display=graph-retrieved 23/4/2015)

[10] United Nations Human Settlements Programme (UN-Habitat): Strategic Plan for Natroun City, 2011- ISBN Number(Series): 978-92-1-131939-2

[11] (Abu Zeid, 1984)

[12] (El- Maghraby, 1990),

[13] T. Youssef , M. I. GAD & M. M. ALI: Assessment of Groundwater Resources Management in Wadi El-Farigh Area Using MODFLOW,IOSR Journal of Engineering (IOSRJEN),Vol.2, Issue10,Oct,2012,ISSN: 2250-3021

[14] United Nations Human Settlements Programme (UN-Habitat): Strategic Plan for Natroun City, 2011- ISBN Number(Series): 978-92-1-131939-2.

[15] [http://www.worldportsource.com/ports/EGY_Sidi_Kerir_Terminal_2598.php]

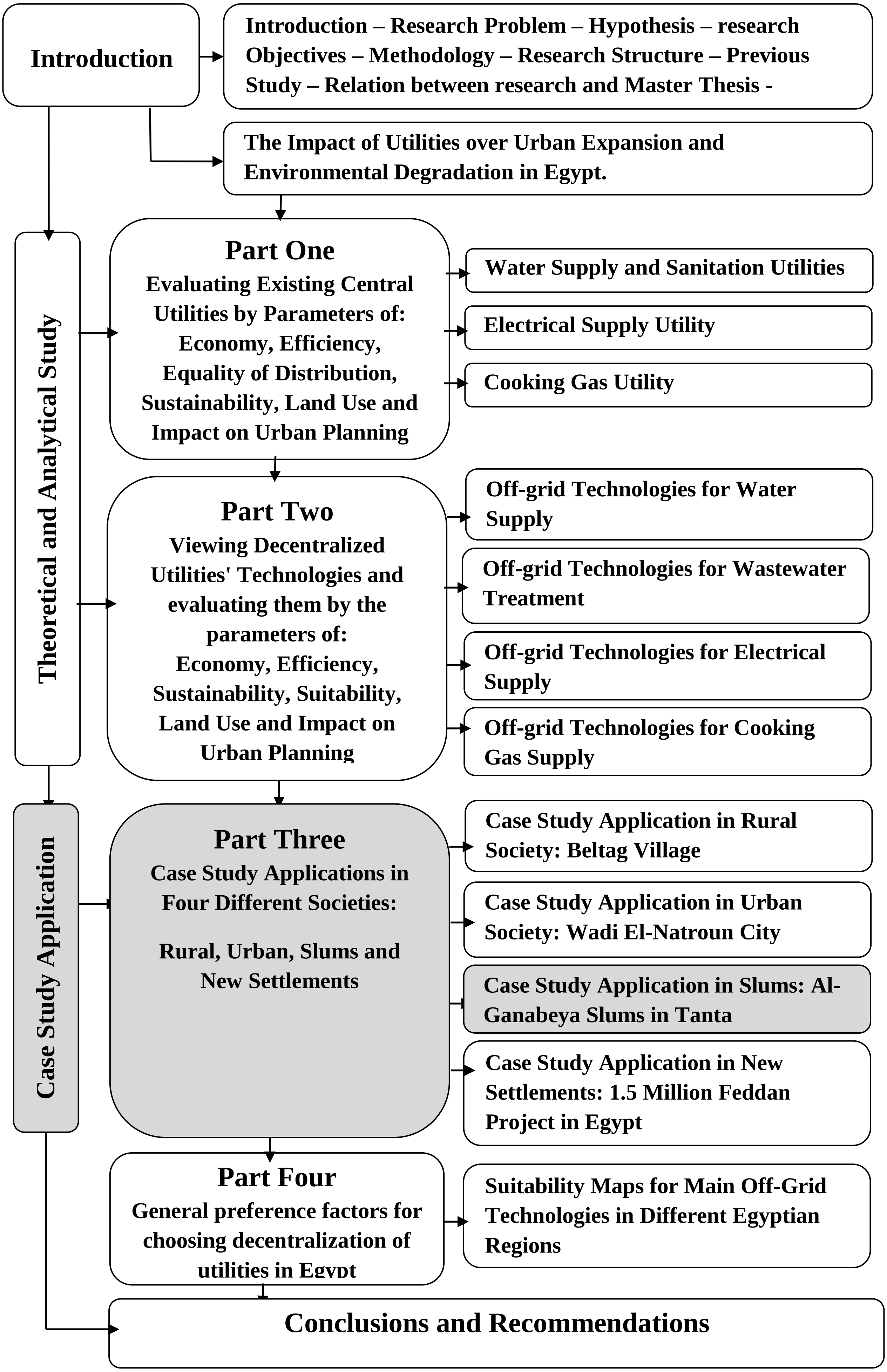
Part (III)- Chapter (3)

(3-3) Application Model in Slum Area in Egypt (Ganabeya Area, Tanta):

Introduction to Chapter 3

This chapter introduces a slum area (Ganabeya Slums) which suffers poor economic, constructional, and environmental status. The research introduces an analysis to the main data for the area and its main problems, after-which it introduces some suggested off-grid utilities to help solving or mitigating these problems.

End of Introduction to Part III- Chapter (3)


Introduction
Introduction – Research Problem – Hypothesis – research Objectives – Methodology – Research Structure – Previous Study – Relation between research and Master Thesis -
The Impact of Utilities over Urban Expansion and Environmental Degradation in Egypt.
Theoretical and Analytical Study
Part One
Evaluating Existing Central Utilities by Parameters of: Economy, Efficiency, Equality of Distribution, Sustainability, Land Use and Impact on Urban Planning
Water Supply and Sanitation Utilities
Electrical Supply Utility
Cooking Gas Utility
Part Two
Viewing Decentralized Utilities' Technologies and evaluating them by the parameters of: Economy, Efficiency, Sustainability, Suitability, Land Use and Impact on Urban Planning
Off-grid Technologies for Water Supply
Off-grid Technologies for Wastewater Treatment
Off-grid Technologies for Electrical Supply
Off-grid Technologies for Cooking Gas Supply
Case Study Application
Part Three
Case Study Applications in Four Different Societies:
Rural, Urban, Slums and New Settlements
Case Study Application in Rural Society: Beltag Village
Case Study Application in Urban Society: Wadi El-Natroun City
Case Study Application in Slums: Al-Ganabeya Slums in Tanta
Case Study Application in New Settlements: 1.5 Million Feddan Project in Egypt
Part Four
General preference factors for choosing decentralization of utilities in Egypt
Suitability Maps for Main Off-Grid Technologies in Different Egyptian Regions
Conclusions and Recommendations

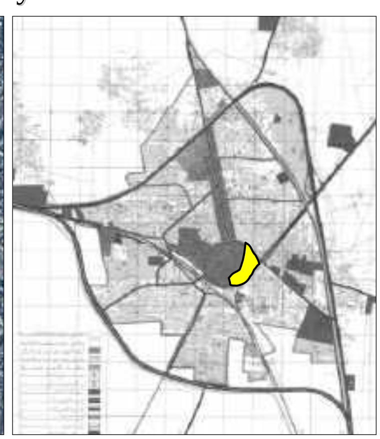
(3-3) Application model in Urban Slums (Ganabeya district in Tanta):

Tanta is the capital city of Gharbeya Governorate located in the heart of Delta region. It lies on both Cairo-Alexandria agricultural road and Cairo-Alexandria railway, 110 km from Cairo and 120 km from Alexandria. Tanta is well known by its famous Al-Badawy mosque and shrine established in the Fatimid era, see fig (287). Tanta had a population of 445,560 in 2012 census[1] and is administratively divided into two districts, each consisting of seven Sheiakhas.

Fig(287): (left) Tanta location map related to Delta Region (right) Fig(..): Al-Saied Al-Badawy Mosque in Tanta

There are 7 slums and informal areas in Tanta with a total area of 525 Feddan[2]. Slums in Tanta are characterized by insufficient solid waste disposal systems, poor quantity and quality of potable water, water canals and drains pollution by industrial waste and sewage, together with violence and a higher crime rate. The oldest slum area in Tanta is El-Ganabeya area, located in the heart of the city as shown in fig (288).

(3-3-1) Location and Area: Ganabeya district is located in the right half of the heart of Tanta city, 200 meters from El-Badawy shrine as seen in fig(288). Ganabeya's area is 78 feddans, which is 2.6 percent of Tanta's total built-up urban area. It accommodates 16,750 people, forming 4.4% of total population of Tanta city.

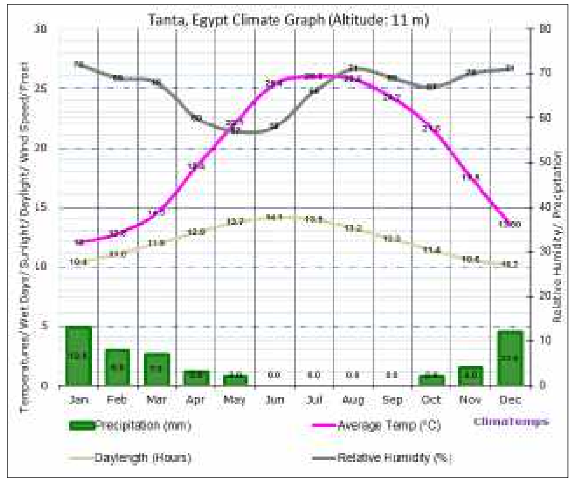


Fig(288): (left) Gannabeya's distance from El-Badawy Mosque (right) Ganbeya location in Tanta City

(3-3-2) Climate:

As a part of Tanta city, Ganabeya has a hot, humid climate. Average temperature is 26^0 in summer and 15^0 in winter. Temperature may reach 44^0 in hottest days or decline to 8^0 in coldest ones. Relative humidity in Ganabeya is obviously high, starting with 22.1 % in May and June, and reaching 72% in January and August.

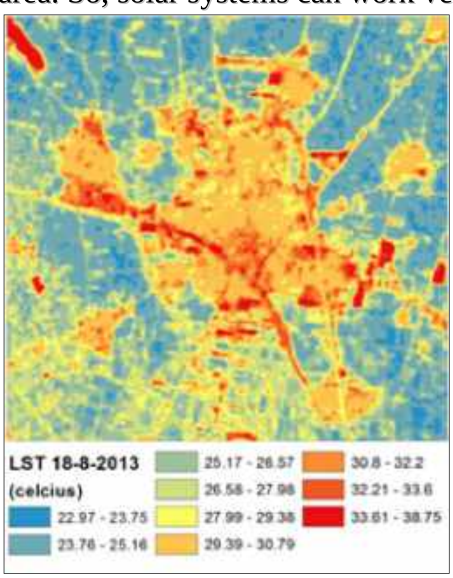
Despite the high humidity levels in Ganabeya, it rarely has rain fall. Precipitation is barely 13 mm in wettest months and zero mm in Summer as seen in fig (289).

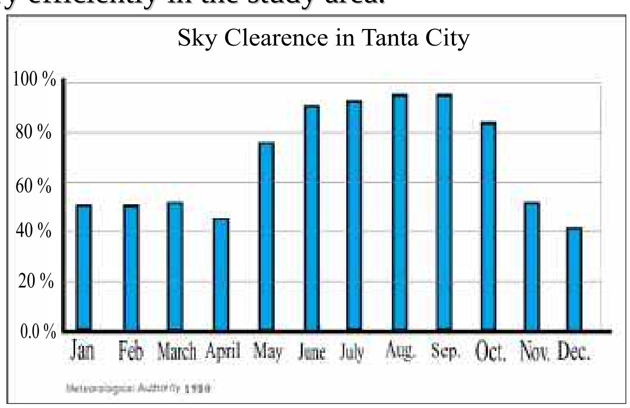


Fig(289): Climatic features in Tanta City
Source: www.wmo.int/

(3-3-2-A) Sun Exposure:

In general, Tanta city enjoys a very good sun exposure around the year. Sky clearance varies between 40% in December and 96% in August as shown in fig(..). Direct normal irradiation on earth surface in Tanta is 5.5to 6.3 kWh/m^2/day as mentioned in chapter 2. Long day duration is also an advantage as it ranges between 10.2 hours in December to 14.1 hours in June. Ganabeya is even more exposed to sun rays due to its high contour level compared to its surroundings. Land surface temperature for Tanta city was measured in August, 2013, showing that Ganabeya district had higher surface temperatures than other neighbouring districts as shown in fig(290).[3] Shading factor is also low due to low construction levels in the area. So, solar systems can work very efficiently in the study area.





Fig(290): (left) Land Surface Temperature in Tanta city, measured in August, 2013 (up) Sky Clearence in Tanta City
Source: (left) Hala Adel Effat, et,al. 2013 (up) Egyptian Metrological Authority Database - www.ema.org.eg/

(3-3-2-B) Wind Speed:

Wind speed in Tanta and its surrounding region is low to moderate around the year. The highest speed is during February (5.08 m/s) while the lowest is during June (4.19 m/s). This low speed delays the evaporation rate of the soil which means that leaching systems is not the most preferred technology for Ganabeya district.

(3-3-3) Topography:

Ganabeya has a high land table compared to the surrounding area. This allows the dwellers to view the touristic sites of Tanta, including the Badawy Mosque from the hill. The level difference is about one meter as shown in fig (291). This level difference caused a difficulty in supplying municipal water and natural gas to the area, as the supplying station is located in a lower level and the dwellers have less willing to pay for it.

Fig(291): (left) Fig(..): Countour lines of Gannabeyah, Tanta (middle) View from the hill in Ganabeya plateau (left) Stairs leading to the streets of Ganabeya.

Source: (left) http://www.mappery.com/map-of/Draft-Elevation-Map-Nile-Delta/ Retreived 10/4/2015 (middle& left) photo taken by

(3-3-4) Soil Properties:

Ganabeya's soil is classified by alluvial soil which consists of clay deck of variable thickness with very low permeability, underlain by an interstratification of sand and loam layers. The soil is not suitable for leaching systems as it slowly drains down liquids. As shown before, the hydraulic conductivity of the soil in Tanta city is $5x10^{-7}$ to 10^{-4} m^3/m^2/day, which is less suitable for water leaching (e.g. trenches or leach-field).[4]

(3-3-5) Population characteristics:

Ganabeya's dwellers belong to two main groups; the native families who exist in the area for many generations, and the immigrants who came from Suez in the aftermath of the 1967 war. Each group is localized in its own quarter and they both are cohesive with very strong relationships. Crime rate is moderate and some disturbances may occur when strangers try to intrude into the area. Women have strong presence and heavily affect most social decisions.

The average family size is 4.2 person/family[5]. Fig(292) shows samples of Gannabeya dwellers.

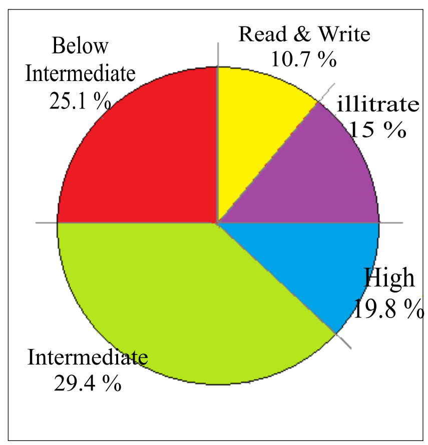
Fig(292): Housewives in Al-Khadem st. (Left), and the researcher with a house owner sitting on her Mastaba (middle), and Workers standing beside public water tap in Al-Hamouly st. (right)

(3-3-5-A) Age:

About 66.7 percent of total Tanta city population is in the age of 15 to 65 years, which is considered mostly the working labor age in Ganabeya, as most dwellers work in private sector that has no defined age for retirement. Children below 14 years are 25.5 %, while the elders aged above 65 are 7.9 % which is higher than total Governorate average. Males form 50.8% of population while females are 49.2% according to 2006 statistics.

(3-3-5-B) Education:

Ganabeya has 2 elementary schools and one Azhar institute, all located over 1663 square meters and serving 3300 students. Educational level in Ganabeya is generally low to intermediate. No official data is available about educational status in Ganabeya area, but fig(293) shows the status in Tanta City as general.



Fig(293): Educational Level in Tanta City, 2010
Strategic Planning Report for Tanta City, 2010

(3-3-5-C) Profession & Employment:

Ganabeya is a commercial / industrial area, containing 132 metal workshops, 10 sweets factories, 34 wood and furniture workshops, and 90 shoe and leather workshops, along with a total of 288 commercial units. The main profession of the dwellers is craftsmanship, especially blacksmithing, metal welding as well as trading and garbage sorting, see fig(294).

Fig(294): The researcher beside a blacksmith shop in Gannbeyah (left), and heaps of metal and paper garbage collected and sold (middle and right) in Gannabeya, Tanta

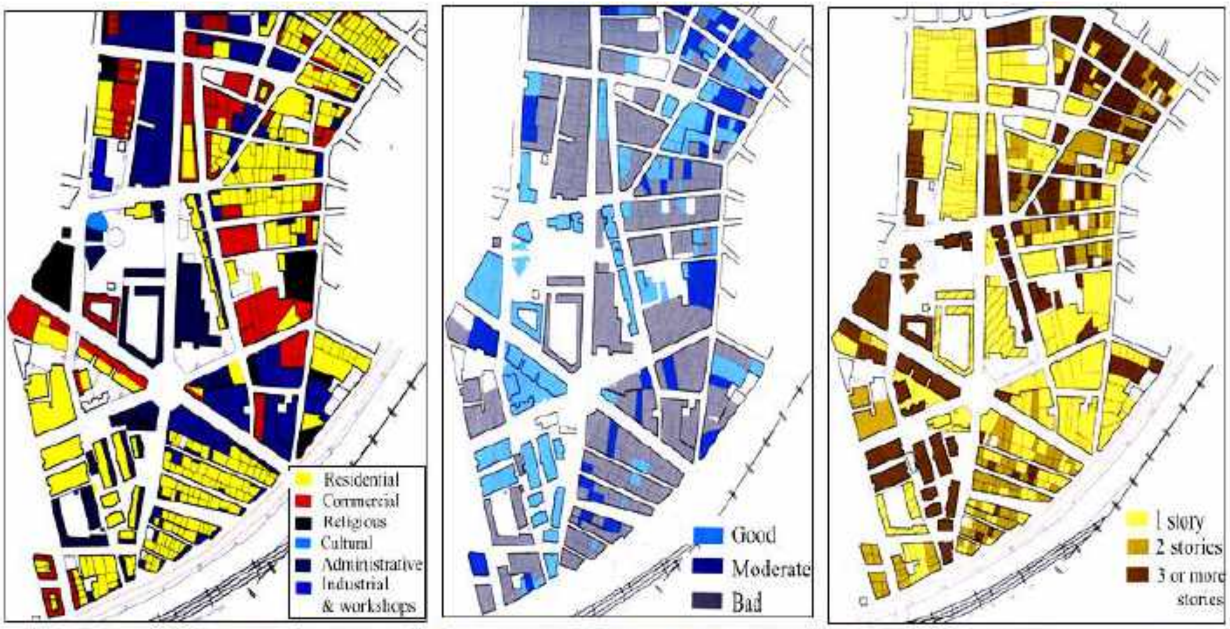
(3-3-6) Urban Characteristics:

(3-3-6-A) Land Use and ownership: Unlike most of Tanta districts, residential land use in Gannabeya is barely 50% of the total area, while industrial and workshop uses are 34%, followed by commercial uses about 15%. Ganabeya contains the main municipality garage, storage facilities, and stables in Tanta city. The local authority and Awkaf own more than 25 % of Ganabia's total land area. The remaining 75 % belongs to private ownership.

Fig(295): The main Municipality Garage of Tanta located in Ganabeya

(3-3-6-B) Urban state and capacity:

- Ganabeya, as well as Sattota and Qorashy districts are considered slum areas having a top priority for upgrading and improvement in governmental strategies.
- About 70 percent of the buildings in Ganabeya are low-rise with one or two floors with bad state and deteriorated infrastructure.
- The most deteriorated quarter is Tall-Elhaddadeen, located south east, where most dwellers work in craftsmanship causing many environmental problems.
- Awkaf houses are deteriorated because the dwellers have neither ability nor authority for renewal.
- Poor migrants and others live in shanties due to social and economic factors that hindered rebuilding or renewal.
- Shanty areas are located side by side with new structural buildings in an obvious contradictive image, see fig(297).



Fig(296): (left) Land Use (middle) Building Status (right) Buildings' heights, in Ganabeya, Tanta- GOPP Maps, 2011

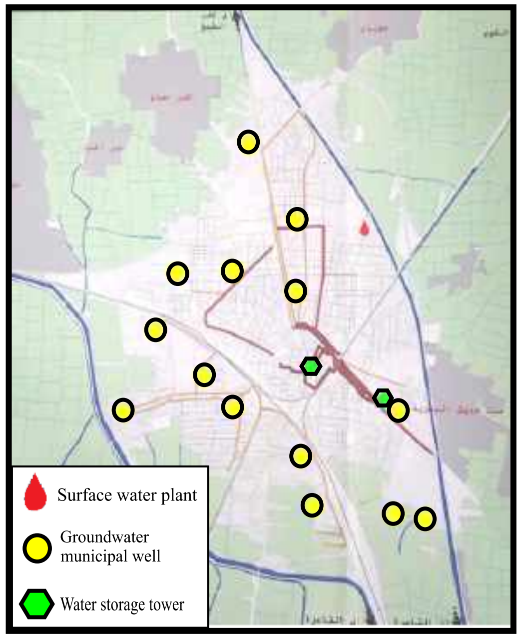
Fig(297): (left) Low rise buildings in Ganabeya (middle) Shanties and workshops all-over the study area (right) Shanties of Ganabeya (uphill) and new towers of Tanta (downhill) in an obvious contradiction.

(3-3-7) Public Services:

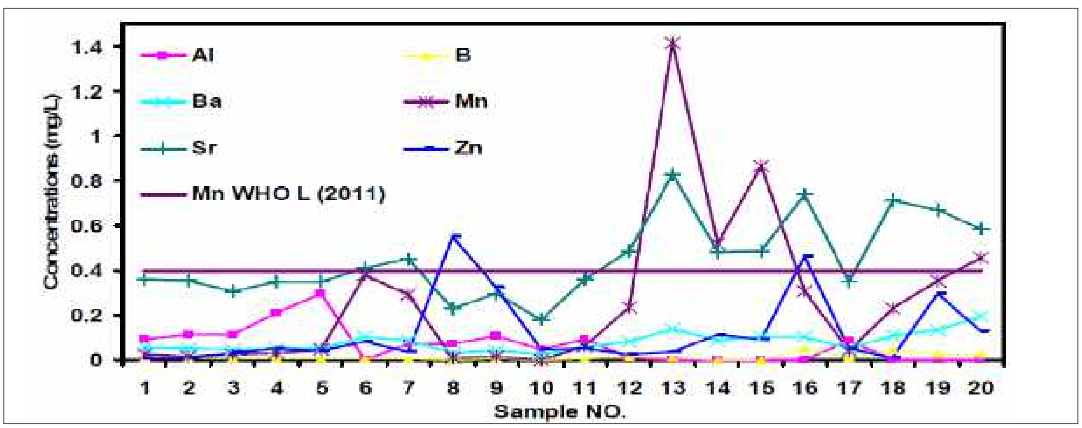
(3-3-7-A) Water Supply: The potable water distribution network serving Tanta City has been in service since 1924. More than half of Tanta city network depend on wells for supply. Water network is basically fed through 14 groundwater wells distributed as shown in fig(298), with a daily production of 92,300 m^3/d. Network is also fed through a surface water plant called Al-Morashaha, producing 67,200 m^3/d). The total water production for the city of 159,500 m^3/d.[6]

Both water sources suffer poor quality. Surface water intake is affected by canals pollution by industrial waste and sewage, while groundwater wells are affected with high percentage of Manganese. The direct disposal of sewage and solid waste into canals and drains has caused a serious contamination of water.

A chemical and biological study conducted in 2013 to measure tap water quality in Tanta city, showed that sixty three species of green algae, diatoms and blue-green algae were present in samples of surface water origin, while Fe, Mn and hardness were found in samples of groundwater origin. Concentrations of iron and manganese were higher than admissible values according to Egyptian guidelines amounting to 1 mg L-1 for iron and 0.5 mg L-1 for manganese[7]. The reason of these high concentrations was due to the existence of some wells located in this zone with high concentrations of Iron and Manganese[8]. See fig(299).

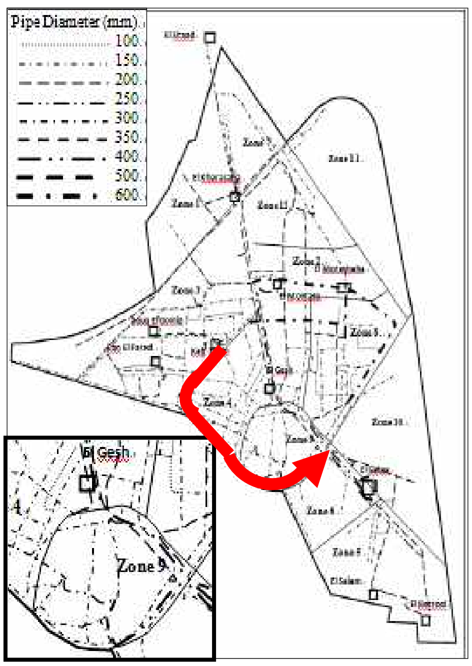


Fig(298): Municipal water intakes in Tanta City, 2013
Gharbeya Governorate Main Beareau Information Center



Fig(299): Chemical analysis measures for municipal water supplied from groundwater wells in Tanta city, Feb., 2013
Source: Maha Abdelfattah et.al. 2013 –Reference No. 7

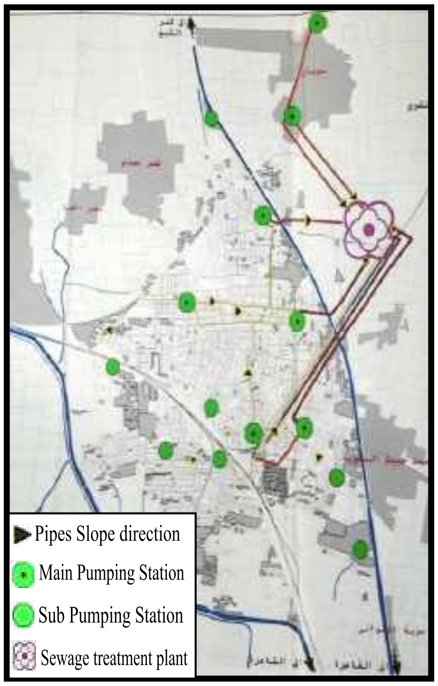
There are 2 water towers in Tanta shown in the previous map, the main one is located in Ganabeya area, Al-Hamouly street, and installed at the highest contour level as shown in fig(..). The Tower's total capacity is 350 m3 and its height is 50 meters. The tower is old and needs renewal, and hasn't been in service since 2011, so it needs maintenance and disinfection to be in service again. The main well feeding Ganabeya network is located at "Kafret El-Segn" area in Tanta city, through the main pipe coming from Al-Nahas st. (the supply path is illustrated as red path in fig (300)[9]. Both well and pipes are located in lower area so water needs continuous pumping to flow against gravity. As pumping needs power, the mentioned water tower was used to store pumped water and assure steady flow. After the tower has stopped working, water cuts became a daily trend in Ganabeya, see fig(300).



Fig(300): (left) Water distribution network for Tanta City with main line supplying study area (middle) Storing water for drinking and washing in houses uphill Tall El-Haddadeen, Gannbeyah (right) Unused water tower in Ganabeya. Source: (left) Mahmoud A. Elsheikh, et.,al.2013– Refe. No. 9

(3-3-7-B) Sanitation:

All Tanta's sewage is delivered to one treatment plant located to the north east of the city as shown in fig (301). Several pumping stations serve to deliver the city's wastewater to the mentioned plant. Ganabeya had no municipal sewage network, so the dwellers have installed local pipes and manholes as shown in the same figure. This network drains into nearest municipal manholes located in neighbor districts as illustrated in fig (301).



Fig(301): (left) Sewage network in Tanta City (middle) Locally installed manholes in Haret Abdelmou'ty, Gannbeyah, (right) Local sewage network in Gannbeyah draining into main neighbor municipal network. - Source: Gharbeya Governorate Main Beareau Information Center, 2013 (middle and right) imaged and illustrated by the researcher.

As a result of draining their sewage into neighboring network which is not designed to carry such loads, sewage recurrently overflows causing serious environmental and constructional problems. But these overflows don’t take place in Ganabeya itself because it has a higher contour level than its neighbors, these neighbors are always the affected part by overflowing problems as shown in fig(302).

Fig(302): Occasional sewage overflow in surrounding low-contoured areas around Ganbeyah
Source: Gharbeya Governorate Main Beareau Information Center& Administration of slum development special report, 2013

The sewage of Ganabeya is not causing problems only to its neighbors, but to the hall sewage system of Tanta city. The 132 metal workshops in the district drain industrial sewage full of hydraulic oils, tallow and particulate solids that the treatment plant is not designed to deal with. These non-degradable contaminants find their way to waterways without proper treatment, causing additional environmental problems.

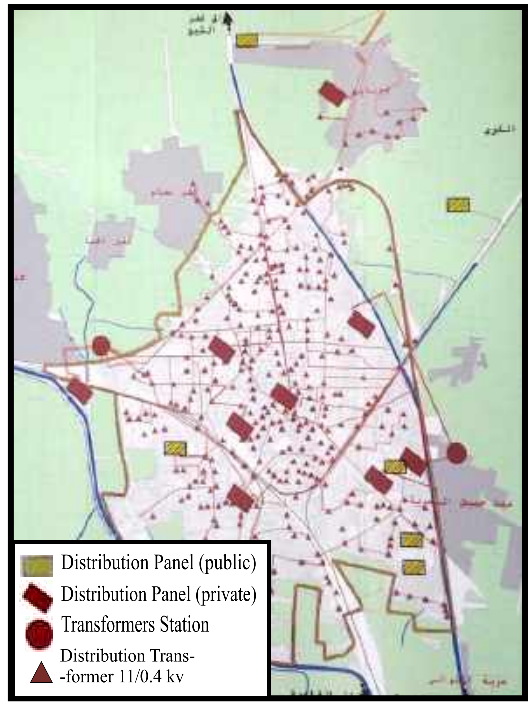
(3-3-7-C) Electricity:

Tanta city is 100% covered by electricity. The network is connected to the National Grid and all districts are well covered with the service as shown in fig(303). Ganabeya dwellers had no complains about electrical supply, except the seasonal cut-offs that occur on a national scale.

(3-3-7-D) Natural Gas Supply

Natural gas network was first installed in Tanta city in 1995 in limited areas. After 21 years of installation, Tanta's gas network is barely covering 50 percent of the city. Many districts are still deprived because of the shortage of finance. The local authority is planning to expand the service to cover 100% of the city by 2027.

Ganabeya is still depending on LPG canisters for cooking and steel welding. No serious complaints were recorded about this point during our visit, except the hiking price of canisters during winter season.



Fig(303): Electricity network in Tanta City
Gharbeya Governorate Main Beareau Information Center, 2013

(3-3-7-E) Solid waste disposal: Tanta is generally served by several private companies that collect the city's solid waste. Waste is recycled and turned into organic manure by a factory located in Difra village, that can process 320 tons per day. The unusable refuse was regularly buried in solid waste landfills (three units) on an area of three Feddans near the factory. Due to waste accumulation, a new landfill was constructed in Sadat city, with a total cost of 12 million Egyptian pounds (EGP), to be used as the current landfill of Gharbeya Governorate.

Some of Ganabeya dwellers work on garbage collecting from nearby districts. Gathered garbage is sorted as shown in fig(..). Valuable contents like metals, papers and plastics are sold to recycling factories, while other residues are disposed beside the walls of Municipal Garage. People living near the garage regularly burn up this heap to get rid of it, causing air pollution and respiratory ailments, fig(304).



Fig(304): (left) Sorted garbage stored in Ganabeya streets before being sold (middle and right) Regular burning of refused waste near the walls of the main Municipal Garage- impaged by the researcher.

(3-3-8) Data Analysis:

- Ganabeya is well supplied by municipal electricity. The main shortage is in gas, waste disposal and recurrent water-cuts.
- Sanitation in Ganabeya is not a problem, but it causes a chronic overflow problem in nearby districts which are lower in land level than Ganabeya.
- Soil in Ganabeya is not suitable for leaching systems being of low permeability nature. Leaching systems may cause wall dampness for nearby districts' constructions with lower contour.
- Temperature in Ganabeya is high and suitable for both solar systems and biogas generation systems.
- Ganabeyah is rich in solid waste gathered from all Tanta city, so it can get benefit from the organic waste in generating biogas and producing slurry fertilizer.
- The main animal hospital in Tanta is located in Ganabeya, which can be a good source of manure to be used in biogas production.
- Groundwater in Ganabeya is suitable for extraction and consumption, but needs a proper treatment due to high manganese ratio. High water tower in the area can be used to assure a continuous water supply.

- Education level in Ganabeya is low to medium, so it is difficult for them to treat with advanced technologies like solar systems.
- Many Ganabeya houses are owned by Government and Awqaf, which means that the inhabitants can't perform a significant modification in these houses without permission.
- People in Ganabeya have strong relations and good neighborhoods, so installing a group facility like the ABR can be suitable for them.
- Industrial wastewater from the blacksmith shops is harming the main sewage network and can't be treated by Tanta's main treatment plant, so the proposed sanitation system must be able to deal with industrial waste properly.

(3-3-9) Proposed model for Ganabeya Area:

The proposed model aims to solve the water, sanitation problem for Ganabeya's neighbors, as well as solving its water, gas and waste disposal problem.

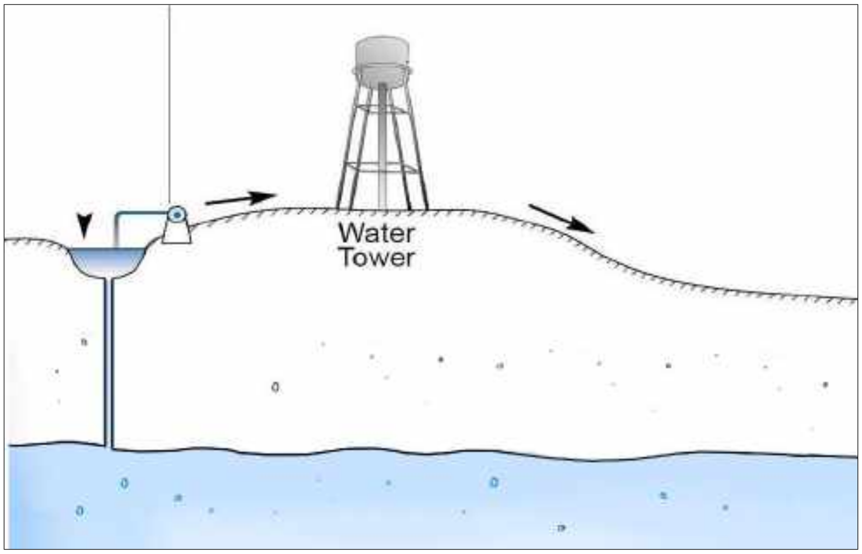
(3-3-9-A) Groundwater extraction well:

Water supply in Ganabeya comes from a ground well located in lower area. With water flowing against gravity and with insufficient pumping system, Ganabeya suffer recurrent water cuts as illustrated before. The proposed water supply is to dig new water well beside the existing water tower in Ganabeya. This well can supply the area independently, making the area independent from the city network. The municipal water distribution network in the city will suffer less loads and no continuous pumping will be required.

The proposed location for the well is in the vacant land located beside the water tower and owned by the municipality, shown in fig(305).

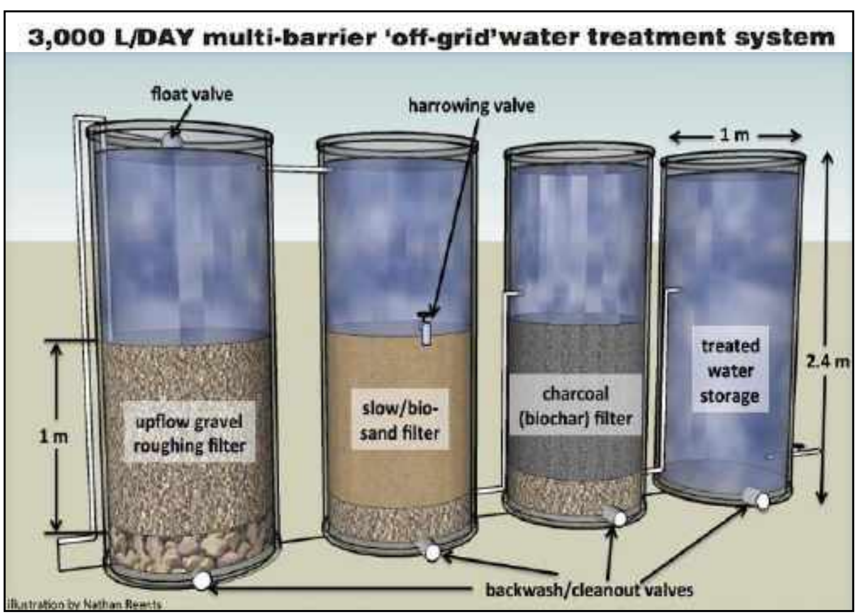
Fig(305): Ganabeya water tower and vacant land beside it

Water tower is suggested for repair and reoperation. As Ganabeya's dwellers have strong social consolidation, they can work together on tower renewal after municipal permission. Groundwater pump and re-operated tower will solve the problem of water continuity in the area.



Fig(306): Proposed water supply system for Ganabeya slum area in Tanta- Designed by the researcher

Extracted groundwater will need purification before human ingestion (e.g. drinking and cooking) which forms about 3% of total household water consumption. Grouped filtration systems are suggested for each street. As public taps is present in every street in Ganabeya, the proposed system will be installed on top of these taps. Ladies will gather their drinking and cooking water daily from this tap. The system is formed of layers of sand, gravel, charcoal and date palm-leaf. These layers will filtrate water from solids, heavy metals and living microorganisms. Layers will be replaced periodically by one family in turn, while the coast will be divided on the families of the street as all. Replaced layers will be thrown with the refused waste in the public garbage collection points.

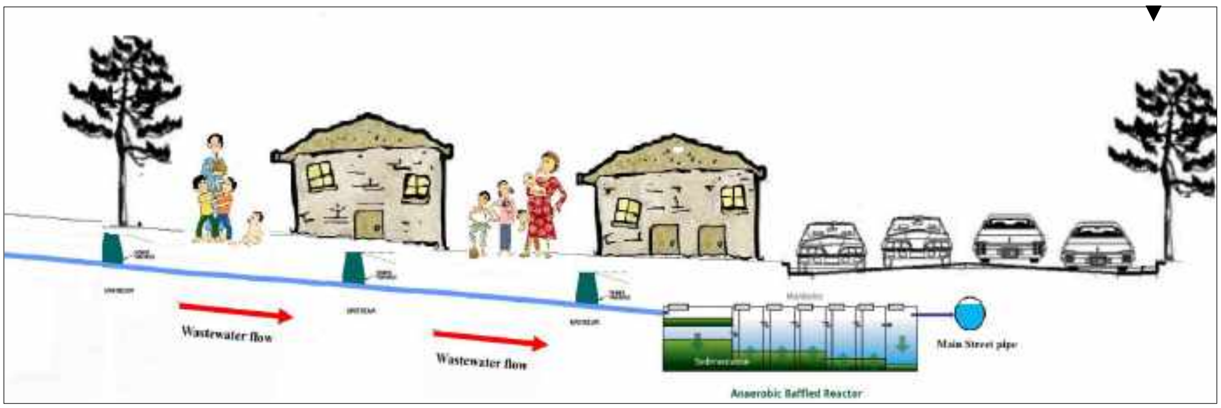


Fig(307): Proposed water treatment for Ganabeya slum area in Tanta, suggested by the researcher

(3-3-9-B) ABR System for residential sewage:

Ganabeya houses drain sewage into a locally installed sewage pipes that pours the effluent into adjacent municipal sanitation system. Local pipes are installed along with the natural topographic slope of the area. Anaerobic Baffled Reactor is suggested to be installed at the end point of the sloping streets just before the municipal grid system. This ABR will receive raw wastewater before reaching the municipal grid. ABR will perform the following tasks:

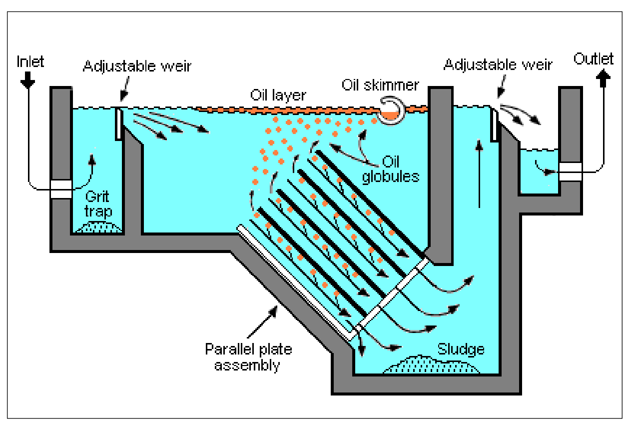
- Primary treatment of sewage by sedimentation and digestion.
- Physical filtration of wastewater from food, sludge and tissues.
- Delay of hydraulic loads in peak hours so the main grid won't receive massive amounts of sewage at the same hour.
- Reduce the final wastewater volume discharged.
- Protect the municipal grid from deterioration, and extend its lifetime.



Fig(308): Proposed Anaerobic Baffled Reactor system for residential sewage treatment in Ganabeya- Designed by the researcher

(3-3-9-C) Separation system for mixed residential/industrial sewage:

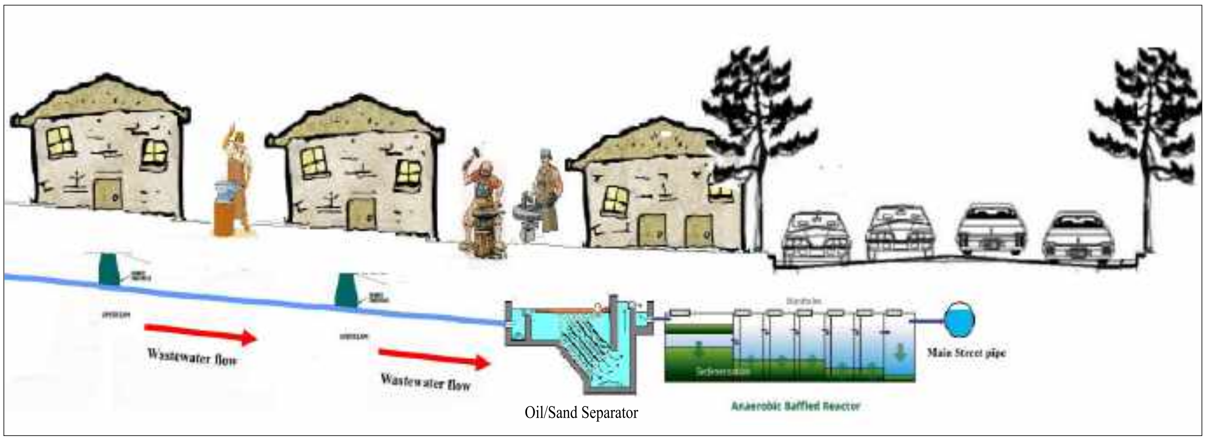
The 132 blacksmith shops in Ganabeya produce industrial wastewater that needs special treatment. The conversion of iron or steel into sheet, wire or rods requires hot and cold mechanical transformation stages frequently employing water as a lubricant and coolant. Effluent water contains contaminants like hydraulic oils, tallow and particulate solids, which are disposed into sewage network without prior treatment.



Fig(309): Oil, sand and grit separator suggested for Ganabeya for industrial wastewater treatment
Source: Beychok, Milton R. (1967):-Reference No.10

High temperature of drained water also affects the sewage network, so water needs temperature adjustment before it's drained into the sewage system. Oil/sand treatment system must be cheap and easy to deal with.

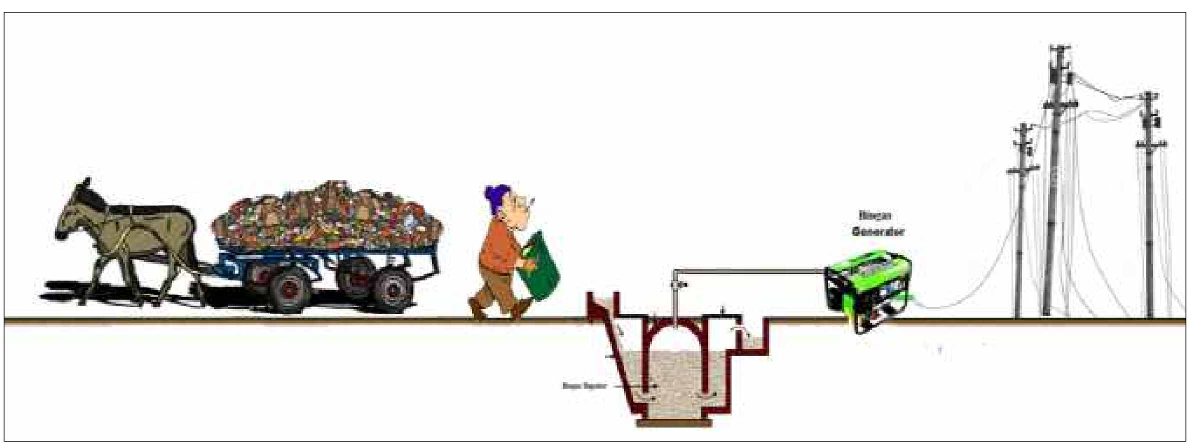
The proposed system for Ganabeya sewage is to install an Oil/Grit separator to collect oil, grease and lubricants from the surface, and trap sand, grit and small particulates in the bottom. This separator will be installed before the ABR system to assure that delivered sewage to ABR is oil-free, in moderate temperature and degradable, see fig(310).[10]



Fig(310.): Proposed wastewater primary treatment system for Ganabeya industrial water- Designed by

(3-3-9-D) Solid Waste Digesting System:

Ganabeya collects solid waste from all Tanta city, this waste can be a source of money and electric power. A digester can be built beside the animal hospital as seen in fig(311). This digester will be fed with all daily refused organic waste which the collectors throw away or burn up after sorting the garbage.

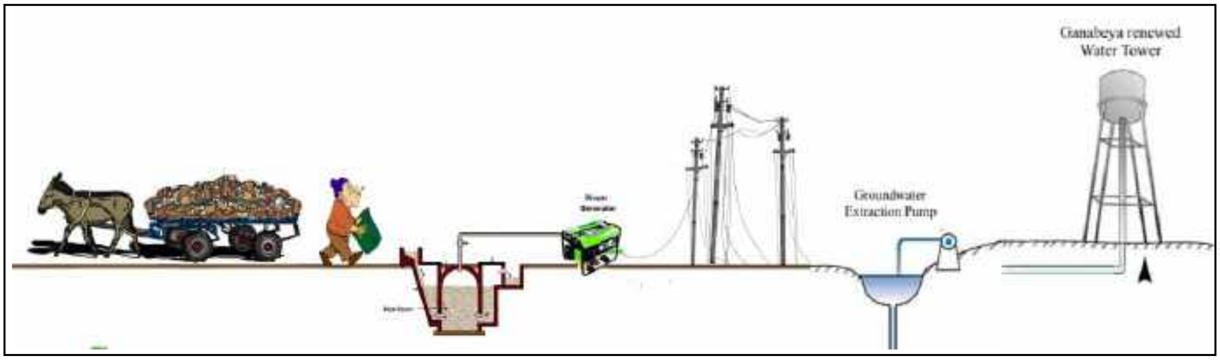


Fig(311): Sorted organic waste disposal in digester to generate electric power in Ganabeya - Designed by the researcher

Other sources for organic waste feeding the digester are:

- Manure produced by the animals in the hospital and in donkey-cart station located in the area.
- Sludge evacuated from the ABR's periodically.
- Date-palm leaf used in water treatment (after replacement).

Generated power can be used in running the grouped water pump installed beside the water tower as shown in fig (312).



Fig(312): Suggested Use of generated electricity in running water pump in Ganabeya- Designed by the researcher

(3-3-10) The advantages of this system are:

- Burning refused garbage will be reduced significantly, as most burnt waste is organic waste that can't be sold. As a result, air quality of the study area will be improved.
- Water tower will reduce the frequency of water cuts in the area.
- Groundwater extraction in Ganabeya will reduce the power needed for pumping water against gravity from Tanta's northern station which has lower level than the served study area.
- Groundwater will be treated in an acceptable manner using simple and cheap materials.
- Loadings over the sewage system will be reduced by the application of ABR system, so less overflows will occur in the neighbouring areas.
- Industrial contaminants will be physically blocked before reaching the public sewage system. This will elongate the lifetime of the system and improve its performance and quality of treatment.
- High sun exposure and high sky clearance will augment the gas yield from the proposed digester without using special heating systems.
- The proposed systems will improve the environment of the area which will positively affect tourism in the "Badawy-Shrine" area and attract more visitors.

(3-3-11) Disadvantages and concerns of this system are:

- Some inhabitants may not co-operate in applying grouped systems, which may cause social problems and create bad relations.
- Due to bureaucracy, municipality may not approve water pump installation in its state-owned land. It may also refuse renewal of water tower, even if the dwellers are ready to pay for the cost.
- If layers of filtration system are not replaced regularly, treatment will be of low quality and may cause health-related problems due to consumption.
- Garbage collectors may not pay effort in adding organic residues into the digester, they may find it easier to burn it as they used to. It is the rule of social leaders in the area to encourage those collectors, using regular advice and monetary incentives.

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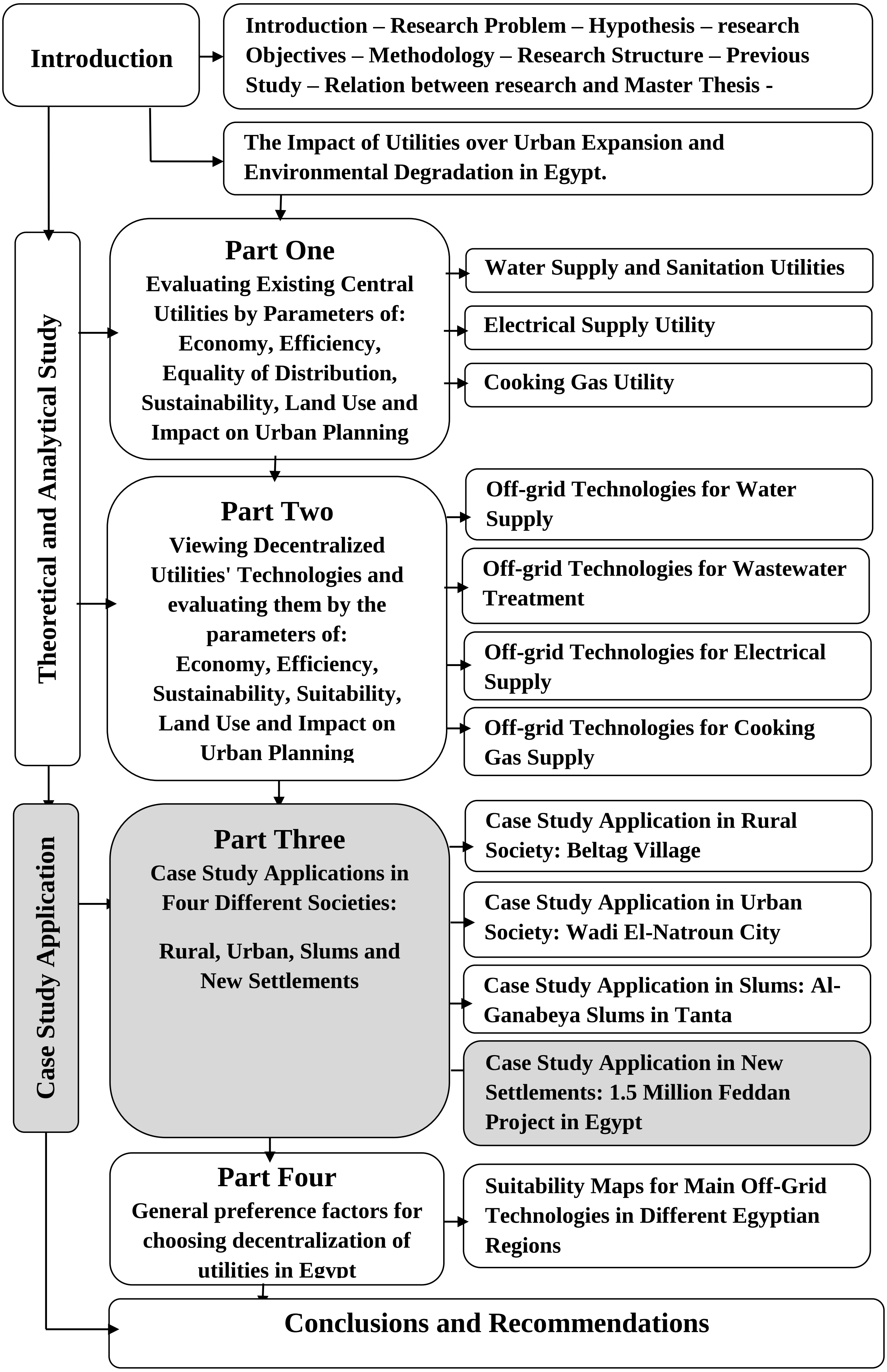
Part (III)- Chapter (4)

(3-4) Application Model in New Settlements: 1.5 Million Feddan Project in Egypt:

Introduction to Chapter 4

This chapter discusses the applicability of decentralized utilities in new settlements in the Egyptian desert. The 1.5 Million Feddan project is a national ambitious project aiming to expand both urban and agricultural area in Egypt to get out the old valley. This chapter introduces an application model for totally isolated houses in the desert which can be applied in the Million Feddan Plan.

End of Introduction to Part III- Chapter (4)


Introduction
Introduction – Research Problem – Hypothesis – research Objectives – Methodology – Research Structure – Previous Study – Relation between research and Master Thesis -
The Impact of Utilities over Urban Expansion and Environmental Degradation in Egypt.
Theoretical and Analytical Study
Part One
Evaluating Existing Central Utilities by Parameters of: Economy, Efficiency, Equality of Distribution, Sustainability, Land Use and Impact on Urban Planning
Water Supply and Sanitation Utilities
Electrical Supply Utility
Cooking Gas Utility
Part Two
Viewing Decentralized Utilities' Technologies and evaluating them by the parameters of: Economy, Efficiency, Sustainability, Suitability, Land Use and Impact on Urban Planning
Off-grid Technologies for Water Supply
Off-grid Technologies for Wastewater Treatment
Off-grid Technologies for Electrical Supply
Off-grid Technologies for Cooking Gas Supply
Case Study Application
Part Three
Case Study Applications in Four Different Societies:
Rural, Urban, Slums and New Settlements
Case Study Application in Rural Society: Beltag Village
Case Study Application in Urban Society: Wadi El-Natroun City
Case Study Application in Slums: Al-Ganabeya Slums in Tanta
Case Study Application in New Settlements: 1.5 Million Feddan Project in Egypt
Part Four
General preference factors for choosing decentralization of utilities in Egypt
Suitability Maps for Main Off-Grid Technologies in Different Egyptian Regions
Conclusions and Recommendations

(3-4) Application model in New Urban Settlements (1.5 Million Feddan Project):

In June 2015, the Egyptian governemtn had announced the establishment of the "1.5 Million Feddan Project" as a part of its developmental plan. The project aims to increase the arable lands in Egypt by several new settelments located in 10 different locations in the Egyptian desert, with each site having a surrounding zone planned for reclamation as, fig (313).

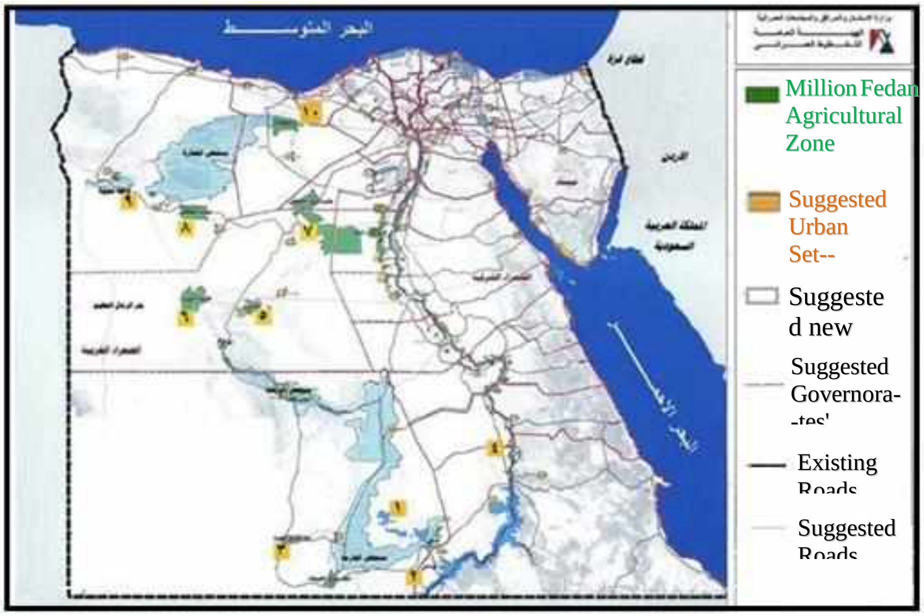


Fig (313): Suggested sites for the 1.5 Million Feddan Project, 2015

Source: The General Organization for Physical Planning GOPP

Each site is planned to contain a service central village with a total population of 25,000 people, surrounded by four agricultural villages with 15,000 capita for each, as well as 8 peripheral villages of 6,000 capita for each. The total population for each site is planned to be 133 thousand people over 50,000 Feddan as shown in fig(314). Lands that cannot be used

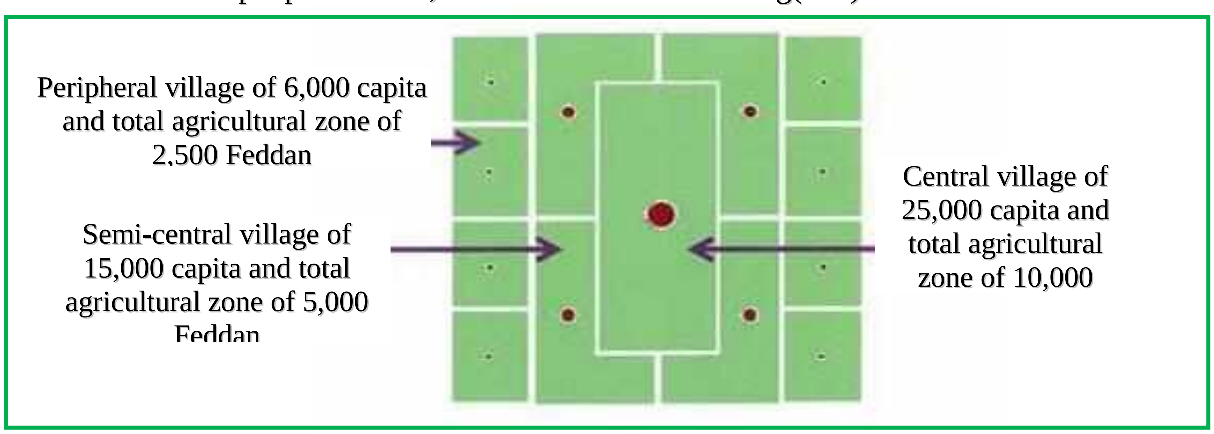


Fig (314): Suggested layout for each site in the 1.5 Million Feddan Project

Source: The General Organization for Physical Planning GOPP

for agriculture-related activities will be used for fish-farming, urban housing, and other services.

The Ministry of Housing has suggested a unified design model for houses in the project as shown in fig (315). Houses are planned to follow "Hassan Fathy" design school, using natural ventilation techniques, bearing walls, vaults and inner courts. Each family will have a 320 m^2 total housing area fromwhich 56 % will be a private garden. Houses will be separated by private gardens, while the outer agricultural frame will be used for cultivating different crops. However, the actual design was different due to technical and economic limitations. Vaults, domesand arabesque screens were cancelled as seen in the figure below.

Fig (315): (left & middle) Planned design for houses in the Million Feddan Project (right) Actual design applied in the project in Al-Farafra, December 2015 - Source: (left & middle) The Ministry of Housing main bearua (right) www.youm7.com/

(3-4-1) Climate:

Climate is variable in different sites of the project. As most sites are located in the subtropical climatic region, they would have a dry climate. In winter (December to February) the general climate will be cold, moist and rainy with minimum mean temperature of (8-13) C, while during summer (June to August), it is expected to be hot, dry and rainless with maximum mean temperature of (28-44)°C. Dust and sandstorms are expected to blow frequently in spring and autumn.[1]

(3-4-1-A) Rainfall, Precipitation & Relative Humidity: Most of the selected locations have an extremely arid region where the mean annual rainfall duration start with 47 days/year and the precipitation is between 14 mm in wettest months and zero mm in May and June. The evaporation rate is usually higher than precipitation, meaning that soil needs continuous irrigation to keep humid.[2] The relative humidity ranges between 51 % in summer and reaches 72% in winter. High relative humidity maximizes the feeling of high temperature in summer months and minimizez the chilliness feeling in winter.

(3-4-1-B) Sun Exposure: The selected sites almost enjoy a relatively high sun exposure, especially during summer season. High exposure is also maximaised by the absence of shading factor. Vacant lands, wide streets and sandy soil will augment sun exposure and reflection impact. The annual direct normal irradiation in is expected to start with (7.0 – 7.3) $kWh/m^2/day$, which allows the settlement to get benefit from high sun power either in biogas production or solar systems application.

(3-4-1-C) Wind Speed: Wind speed in general is expected to be moderate to high due to abundance of vacant land and vast bare areas. The average speed may start from 7 km/hour, compared to 4 km/h in Delta region. The highest speed will be during February while the lowest will be during June. High wind speed increases both evaporation rate and solar systems efficiensies, meaning better performance for both solar systems and leaching fields as well

(3-4-2) Sloping & Topography: New sites are chosen in locations with minimum slopes to suit reclamation. Housing areas will be especially chosen in flat-bed areas.

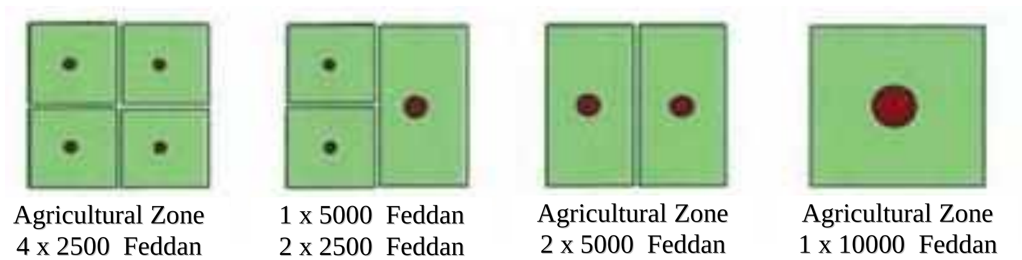
(3-4-3) Soil Properties: Soil properties are different in each site, but the main feature of desert soil is being sandy or loamy with sand stone or gravel, underlain with basalt, limestone, dolomite or conglomerate. These soil types are fairly suitable for leaching systems as it rapidly drains down liquids. The hydraulic conductivity of sandy or loamy soil is generally (0.005 to 20) $m^3/m^2/day$.

(3-4-4) Population Characteristics: Most new settelments suffer slow population growth as a result of their distance from populated areas, which in turn affect the resultant density. As a reclamation project, the planned density for it is to have 133,000 people over 50,000 Feddan, with a total density of 2.66 capita/ Feddan. Hoever, the starting population is expected to be far less than planned. But if the project succeeds to attract benefiters, the density is expected to increase to reach the planned.

(3-4-4-A) Age: The project is basically targeting youth, so the expected society is youthful, aged 18 to 45 years, as well as children below 5 years. The average family size in the first five years is expected to be 2.9 which is less than the National average family size of 4.2.

(3-4-4-B) Profession, Employment and Economic Standard: The main profession planned in the project is farming, followed by birds and cattle breeding. Secondary professions like trading and craftsmanship are less expected in the first 10 years. The unemployment rate is expected to be extremely low compared with national unemployment rate. As farming needs no special skills, almost everyone can find a daily job in the new project.

(3-4-5) Zonning and Urban Pattern: The official zoning of the project is to locate residential blocks at the core of reclamated areas, which makes the residential spots somehowisolated from each other by vast vacant lands as shown in fig(316).



Fig(316): Official zoning for the residential and agricultural areas in the Million Fddan Project
Source: New Urban Communities Authority (NUCA) , 2015 http://www.newcities.gov.eg/english/New_Communities/

No data could be obtained about suggested urban pattern in the project. However, houses in reclamation projects are either scattered among farms or clustered as nuclear housing spots as applied in most previous reclamation projects in Egypt, see fig(317).

Fig(317) Expected urban patterns in reclamation sites: Scattered houses or nuclear housing spots
Source: (right) Sada El-Balad website www.el-balad.com (left) http://www.skyscrapercity.com/showthread.php?t=1812411/

(3-4-6) Utilities and Infrastructure: The government has an ambitious plan aiming to adapt renewable energy resources in running the main utilities of the project. However, the only renewable utility applied so far is solar pumps technology for irrigation as shown in fig (318). Groundwater is planned to be the sole source for both irrigation and municipal uses.
For sewage and electricity, the official data from both ministries of housing and agriculture assures the installation of central utilities for electrical supply and sewage treatment in the

project. Using central utilities in serving scattered housing spots is extremely expensive and unfeasible. The previous attempts for reclamation in "Desert Backyard Villages Project" (مشروع قرى الظهير الصحراوي) has cost a fortune in utilities' provision. Though installed many years ago with full utilities provided, the new villages were barely inhabited, fig(319) .

Fig(318): Using solar pumps for groundwater extraction in Million Feddan Project www.akhbarmasr.com

Fig(319): Central Electricity and sewage utilities installed in new villages of the (desert backyard villages project)

(3-4-7) Data Analysis:

- With very low population density and with scattered housing areas of low-rise nature, using central utilities is not feasible. Decentralization of utilities must be considered.
- Gradual inhabitance is expected with low to moderate pace, so installing utilities is preferred to be gradual as well. Each house will have its utilities at the time of actual use.
- Expected society is youthful so it is more adaptable to new technologies.
- Expected family size is small in the first few years, so less pressure is expected on utilities which may elongate its operational life time.
- Unemployment rate is expected to be very low but with low monthly income, so chosen utilities must be of low to moderate cost.
- All houses in the project have a unified design model, so utilities may have a unfied design model, which allows mass production thus less cost.
- Residential sites are isolated by surrounding vast lands, so minimum help is expected in emergency. Chosen utilities must be of minimum need for spare parts or mentainence.
- No rock faults or flash floods are expected in the selected sites, so installing utilities can be applied safely at ground level.
- Dry air, high evaporation rates and low humidity, all make the soil dry and needs continuous irrigation for gardening. Water use should be wisely managed and greywater reuse is preferred.
- The sites of the project enjoy high temperature rates, high sun exposure and reflection impact, which maximizes the benefits of solar systems application. However, rainy climate in winter season aquires diversity in power generation systems as solar systems may not work adequately in rainy and cloudy days of the year.
- High wind speed increases both evaporation rate and solar systems efficiensies, meaning better performance for both solar systems and leaching fields.
- Leaching systems are also applicable due to high soil permeability and vacant lands available around each house.
- High temperature rates accelerate the fermentation process in biogas systems. In summer season with temperature exceeding 40, the anaerobic digestin will be "Thermophilic", with shortest treatment time and highest removal efficiency.

However, cold weather in winter season requires temperature adjustment for biogas systems to assure high performance around the year.

- The main profession planned is farming, so the resulting fertilizer from biogas will be valued.
- Secondary proffesions are birds and cattle breeding, which will provide massive amounts of organic matter to feed biogas digesters and maximize their gas yield.
- As water is valuable and non-renewable, water reuse should be maximized and leaching systems must be the last option. However, leaching systems are useful for groundwater recharge, especially in winter season by redirecting rainwater towards groundwater aquifers.

- Dust and sandstorms are expected to blow frequently in spring and autumn, so solar systems must be properly fixed and regularly cleaned.

(3-4-8) Average Water Needs: The average per capita water consumption is suggested to reach 120 L/day for residential use, fromwhich 4 L/day/capita needs treatment to be used for drinking and cooking. Average family size is 2.9, so 3 people/house need 360 L/day of water, classified into 3 categories:

- 11.52 L (3.2 %) for cooking and drinking, so it must be fresh (< 1000 ppm) and purified.
- 280 L (77.8 %) for bathing, washing and cleaning, which needs fresh or mildly brackish water (1000 - 5,000 ppm).
- 140 L (39 %) for toilet flushing, pavements cleaning, carwash, etc., which may be done with greywater recycled from the house.

(3-4-9) **Average irrigation needs for private gardens:** According to the Egyptian Code, the designed irrigation need for new settelments is 20 m^3 / Feddan /day with duration of 16 hour/day. Knowing that each family will have a 320 m^2 total housing area fromwhich 56 % will be a private garden so the total gardening area is 179.2 m^2. We can assume that the total irrigation need for each family is 853.33 L/day (equals 0.8 m^3/day).

(3-4-10) Expected wastewater flow: We assume tht wastewater is 85% of consumed water, which equals (0.85 x 360)= 306 L/day for each family. This water is calssified into:

Fig(320): International per capita household water uses

Source: www.fryslanleeftmetwater.nl

- 110 L/day of black water (from toilet flushing and kitchen sinks), based on 36 % of total consumed water as shown in fig (320).
- 196 L /day of greywater (from bathing, washing and cleaning uses), based on 64% of total consumed water.

(3-4-11) Average needs of electricity and cooking gas in the project: According to the statistics of International Energy Agency (IEA), and knowing that the average family size in the project equals 2.9 capita/family, the average expected needs of electricity in the project equals 750 kWh/family/month.[3] If solar water heaters are applied, the electrical needs are expected to decline to reach 560 kWh/family/month, which equals 18.6 kWh/family/day.

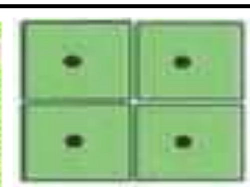
Concerning the average gas consumption, each cubic meter of biogas can serve up to 1.3 capita/day for cooking uses, meaning that a family of 3 needs 2.25 m^3/day of biogas for cooking.

If biogas is used for electrical generation, knowing that each cubic meter of biogas can generate (4 – 6) kWh of electricity according to gas quality, the daily needed gas for electricity equals (3 – 4.5) m^3 for one family in the project.

So, if biogas is used for both cooking and electrical supply, each family needs 6.75 m^3 of biogas per day. This amount can be generated by adding the manure if 3 cows, or any equal amount of similar organic matter.

(3-4-12) Proposed model for the houses in the 1.5 Million Feddan Project: The proposed model for the project is totally decentralized and can be applied in other sites that are totally isolated from any grid utilities in the Egyptian desert.

(3-4-13) Suggested layout: Housing areas are planned to be evenly distributed at the cores of rectangular reclamation areas as shown in fig(321). As People tend to live in groups to feel safe, we suggest the layout shown in the same figure. This layout allows private gardening, smooth movement, sharing semi-central utilities and strenghthening social relations.



Fig(321): Suggested layout for the Million Feddan project: (up) Zoning of housing spots (left) layout of housing area- inspired from "May Fair" compound in October city

(3-4-14) Suggested Utilities: The following model is suggested for application in the project, this model consists of nine parts:

(3-4-14-A) Water extraction by solar pump:

A solar pump will be installed in the front yard, with solar panels above roof of cow shed or parking shade. Extracted water will be pumped towards the storage tank installed above the house. Water will flow by gravity towards the house's fauctes for consumtion.

(3-4-14-B) Greywater treatment:

Greywater will be directed towards a septic tank with removable mesh for clarification and filtration. Filtered water will be pumped up to a recycled water storage tank installed above the house beside the raw water tank. Recycled water will flow by gravity to be used for toilet flushing, car washing, garden irrigation, as well as street and pavements' sprinkling. This recycle process will help reducing the needed groundwater by about 50%, saving power needed for extraction and decreasing aquiefer withdrawal.

(3-4-14-C) Blackwater Treatment:

Blackwater from toilets (and kitchen sinks supplied with grinders to mince food waste) will be directed to a biogas digester installed underground. The digester will perform fermentation and biological treatment for blackwater and kitchen waste, producing biogas and liquid fertilizer.

(3-4-14-D) Biogas filter and storage:

Generated gas will be stored in an underground storage tank, from which it will flow by nature up for use when needed. It will pass through a carbon filter to improve the odour and a tissue filter to dry the gas for quick ignition.

(3-4-14-E) Electrical Generator:

An electrical generator will be installed in a small room in the house front. The generator will be supplied from the gas storage. Another spare motor will be available for emergency. Electricity generated will be as much as the house needs.

(3-4-14-F) Solar Water Heater:

Groundwater storage tank will supply solar water heaters where raw water will be heated and then flows by gravity towards kitchen and bathrooms. An optional path can be added towards the biogas digester to heat it through a hot water jacket as shown in fig(323). This jacket will help speeding up the fermentation process and make the digestion "Thermophilic" as illustrated in chapter 2. Solar heaters will help reducing needed electricity by one third as mentioned before.

(3-4-14-G) Soak Pit or Infiltration trench:

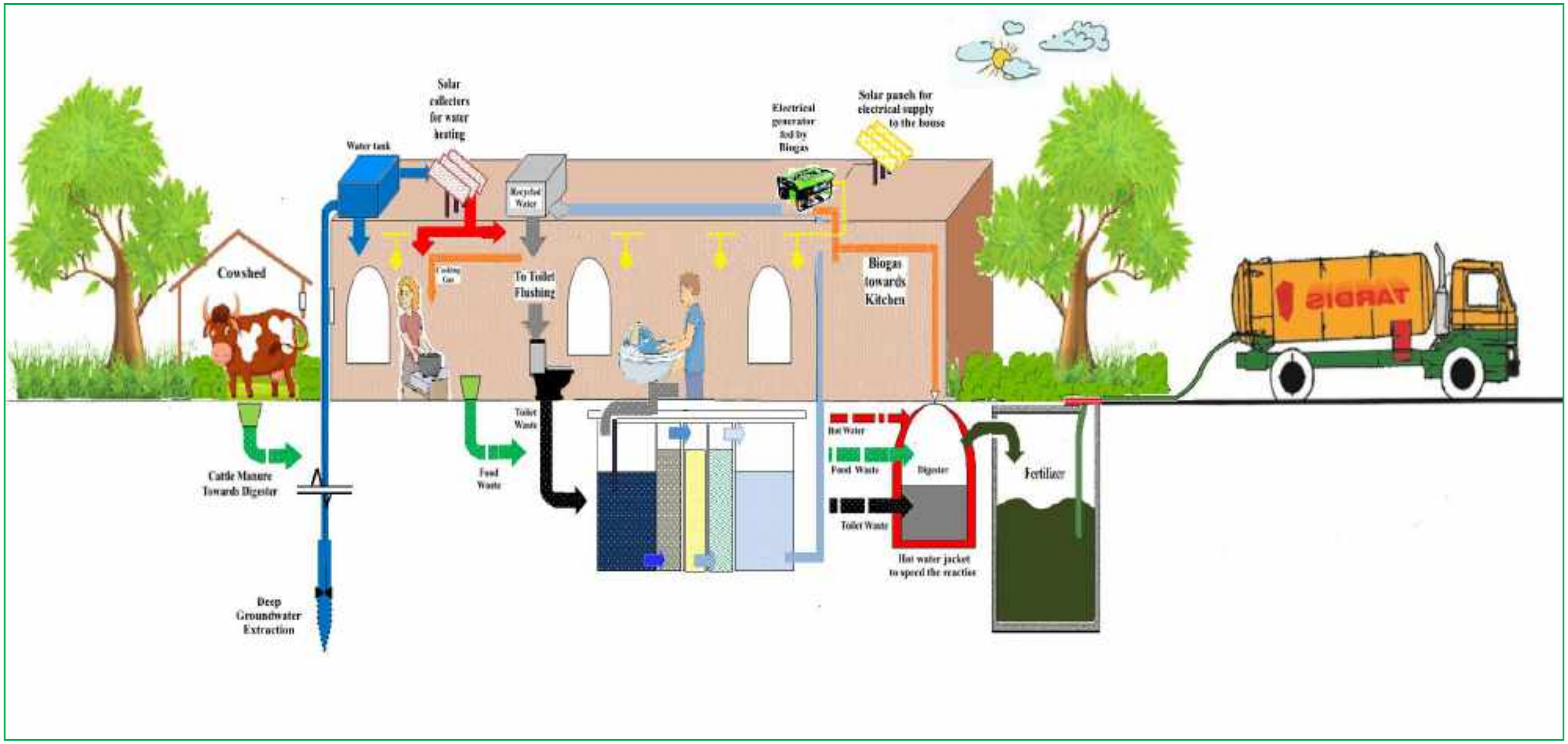
Extra raw water which the house didn't consume, as well as extra recycled water that the dwellers don't need, both will be directed towards an infiltration system to be used in groundwater recharge. The trench will be filled with sand and gravl to perform further filtration before water reaches the groundwater table. Rain water can be directed as well towards this trench to avoid traffic problems in rainy days or storms.

(3-4-14-H) Fertilizer tank:

Produced liquid fertilizer will flow towards a tank where gardeners or landscaping workers can evacuate regularly to use in fertilizing trees and non-edible soft-scape elements. If not needed, fertilizer can be dried though a spinning dryer, after which the dried ash will be buried and the water will be directed towards the infiltration trench.

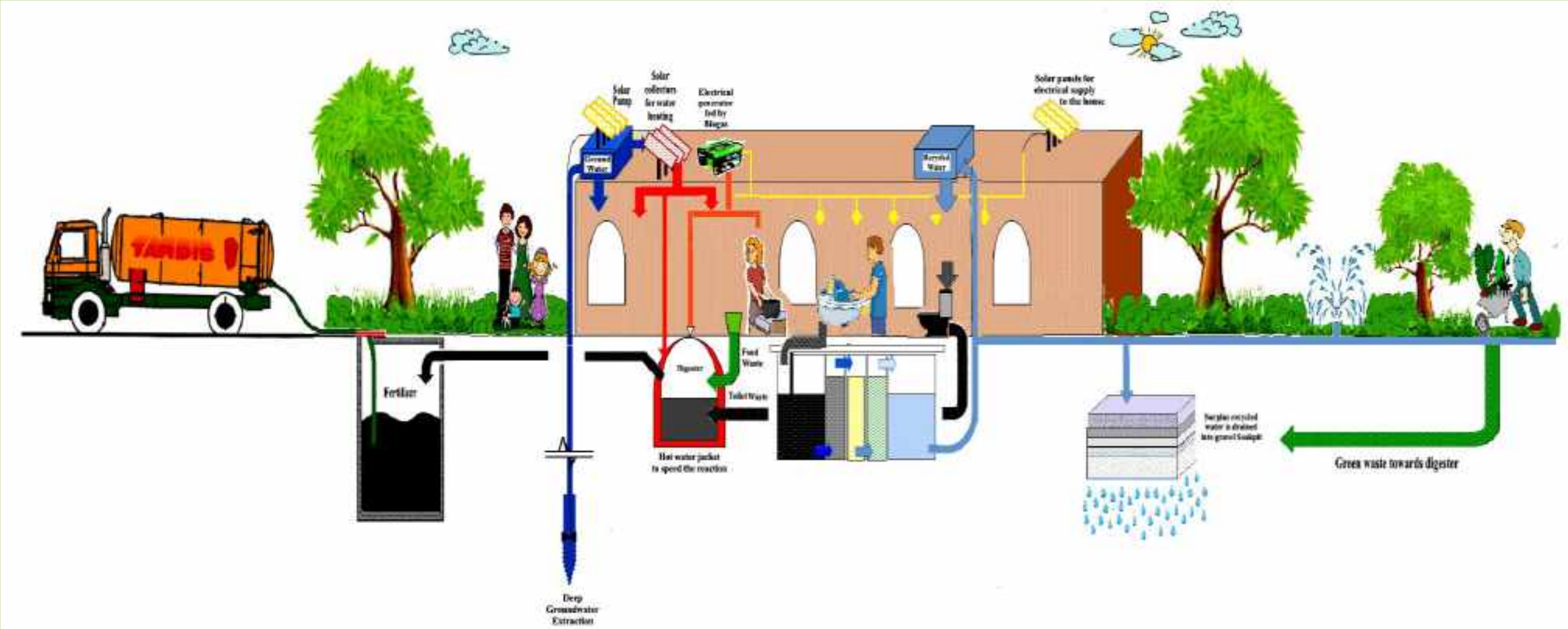
(3-4-14-I) Solar panels:

Solar panels can be applied for electrical generation if the generator is not suitable or making so much noise. Users may combine the use of solar panels during day time and motor generator during night time to avoid using solar batteries which are expensive and need replacement frequently. About 560 kWh will be needed for monthly consumption for a family using all modern applicances.

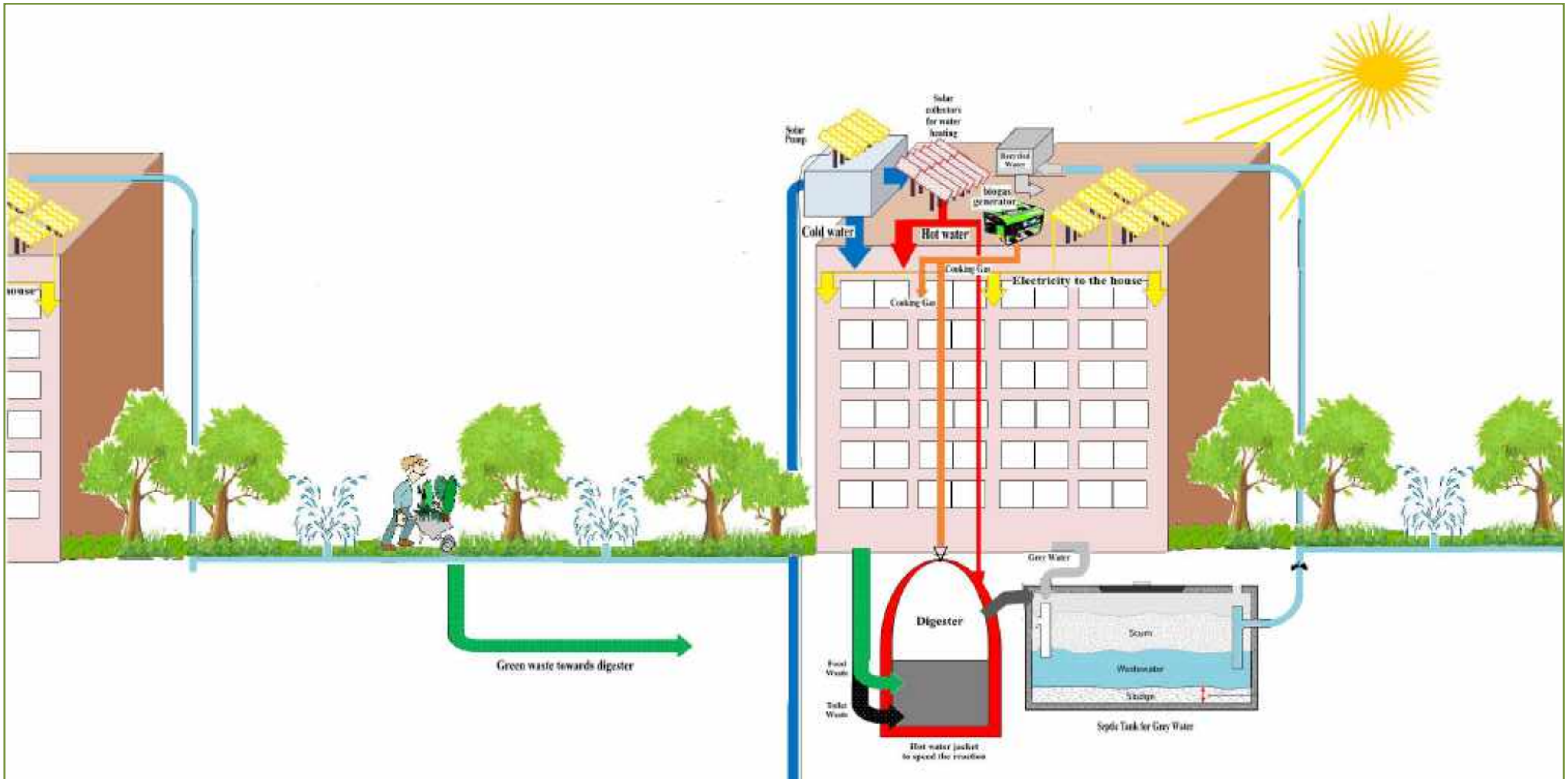


Fig(322) : The integrated model of utilities for houses in 1.5 Million Feddan Project is formed of of 10 elements:

1- Ground water pump for water extraction.
2- Filtration system inside the house.
3- Solar collectors for water heating.
4- Septic tank with gravel, sand and leaf-palm layers for greywater treatment.
5- Biogas digester for blackwater treatment as well as kitchen waste and cow manure.
6- Food grinder installed beneath the kitchen sink to help grinding food waste before directed towards digester.
7- Electrical generator fed by biogas if to use surplus generated gas.
8- Solar PV cells for electrical generation.
9- Greywater reuse in toilet flushing, pavements washing and cow-shed cleaning.
10- Underground tank for effluent slurry, which will be regulary pumped and used as soil amender.



Fig(323) : Biogas digester can be fed by grass from the private gardens.
Recycled greywater can be used in garden irrigation.
Underground tank for effluent slurry will be regulary evacuated and buried in nearby vacant lands, where sun and air will perform further treatment for the slurry.



Fig(324) : If the residential units are located at the commercial core of the project, housing units will be located in multi-storied buildings. These buildings will have the following utility modifications:

1. Solar PV cells will be increased to generate all electrical needs. The main cause is the lack of available organic matter in this area meaning less biogas available. No cattle breading will be practiced in the commercial core.
2. No leachimg systems will be applied because less vacant land is available per housing unit.
3. Treated blackwater will be directed towards the septic tank where water will be clarified and residues will be evacuated and buried regularly.
4. Water from the septic tank will be used for irrigation of non-edible plants and landscaping.
5. Grass from landscape will be added to digesters to increase the gas yield for cooking purpose.

(3-4-15) Average cost for different proposed technologies:

If 10 families share the same utilities, or if a multistory building formed of 10 apartments use a grouped utilitu system, the average cost of these systems will be as follows:
(the following products and prices are adapted from the official websites of the manufacturing companies, as well as Amazon and Alibaba sites, visited in Dec. 2015. US Dollars are assumed to equal 8 LE/dollar as in Dec. 2015 declared price):

- A solar water pump for groundwater extraction, with capacity of 1000 m^3/hour from a water depth up to 1000 meters, and a 400 kilowat power. The price equals US100 dollars (**800 LE**), enough for 200 capita consumption.[4] Fig 325.
- 2 prefabricated septic tanks for greywater treatment, with capacity of 1.8 m^3 and price of US50 dollars **(400LE) for each**. Both tanks can serve up to 30 capita.[5] Fig 325.
- 2 Prefabricated biodigesters for blackwater and kitchenwaste treatment, supplied with gas filtation systems and gas storage tanks which can hold up to 1.3 m^3 of gas. Each digester can receive up to 1.7 m^3 of wastewater /day and can serve up to 5 families. The cost of each digester = US200 dollars (**1600LE**) **for each**.[6] Fig 325.
- Electrical generator working by biogas, with 500 kilowat.hour capacity and gas consumption equals 0.7 m^3 gas / hour. The expected lifetime of the generator is 10 years and it can serve the needs of 10 families, with a price of US1150 dollars (**9200 LE**).[7] Fig 326.
- 10 stanless steel solar water heaters, with capacity of 60 liters for each. And price of US75 dollars (**600 LE**) **for each**.[8] Fig 326.
- 10 waste minicers to be installed under kitchen sinks to help mince all organic waste from kitchen before being added to the digester. Each mincer costs US32 dollars (**256 LE**) **for each**.[9] Fig 326.
- 2 Solar PV systems for electrical generation, with capacity of 100 kilowatt.hour/day and operational life time of 5-6 years, and operational efficiency up to 90 %. Each system can serve 5 families with a cost of US2900 dollars (**23,200 LE**) **for each**.[10] Fig 327.
- Leaching system for rainwater and surplus raw water, built in site with an average cost of **(500-1000) LE**, according to size, capacity and used materials.[11] Fig 328.

(3-4-15-A) The total cost for different proposed technologies serving 10 familis are:

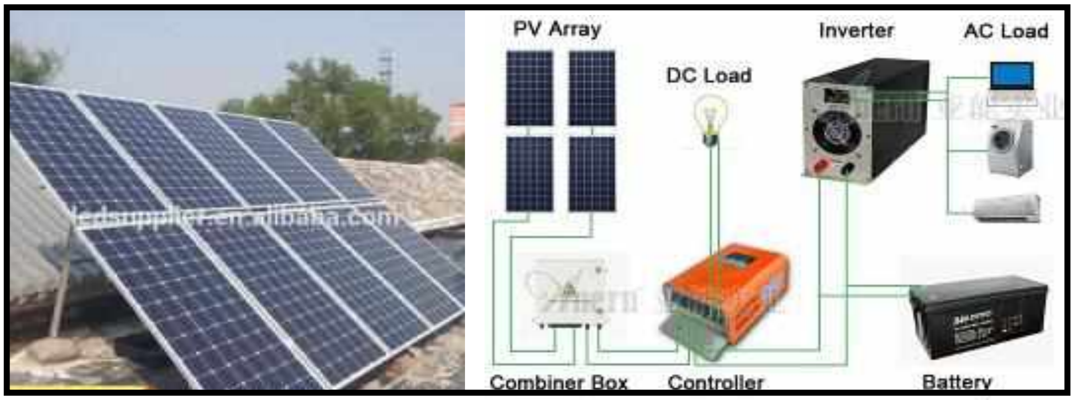
Solar pump (800 LE) + 2 septic tanks (800 LE) + 2 Digesters (3200 LE) + Electrical generator (9200 LE) + 10 Solar wate heaters (6000 LE) + 10 waste mincers (2560 LE) + 2

Solar PV systems (46,400 LE) + Leaching system (1000 LE) = **69,960 LE as total**. See table (50).

Dividing this cost on 10 families, **each family will pay 7000 LE for utilitis installation** (Dec., 2015 prices). The running cost is nearly zero because these sytems require no fuel for running like traditional utilities do.

Fig(325): (left) Prefabricated biodigester for wastewater treatment (up)Solar water pump for water ext raction (down) Prefabricated Septic Tank - Source: (left) Ref. No.6 - (up) Ref. No.4 - (down) Ref. No.5

Fig(326): (left) mincer for kitchen waste (middle) Solar water heater (right) Biogas generator for electrical supply



Fig(327): Solar PV System with all its components (as shown in the site of the manufacturing company).
Source: Ref. No.10

Fig(328): Leaching system built in site with local materials- cavity will be filled with gravel and clean aggregates
Source: Ref. No.11

The following table shows the cost and specifications for each system:

Utility	Cost (LE)	No. of Users	Cost for 10 houses (LE)	Operational life-time (year)
Solar water pump 1000 m^3/hour capacity 400 kilowat power	800	200	800	20
Septic tank 1.8 m^3 capacity	400	10-30	800	15
Biodigester 1.7 m^3 wastewater capacity /day 1.3 m^3 gas storage capacity	1600	20 **(five families)**	3200	15
Biogas electrical generator 500 kilowat.hour capacity 0.7 m^3 gas consumption / hour	9200	40 **(Ten families)**	9200	10

Stanlessteel solar water heater 60 liters capacity	600	One family	6000	20
kitchen sink waste mincer	256	One family	2560	20
Solar PV system 100 kilowatt.hour/day capacity 90 %.operational efficiency	23,200	20	46,400	5-6
Onsite leaching system	500-1000	40-60	500 - 1000	Works for decades, with gravel renewal every 2 years

Table (50.): Cost and specifications for proposed offgrid systems for the 105 Million Feddan Project Egypt.

Designed by the researcher, based on data from official websites of the manufacturing companies

(3-4-16) Advantages of this system:

- Most blackwater contaminants are removed during fermentation. Extra treatment is provided by soil and sun after using liquid fertilizer as soil amender.
- As hot water jacket helps speeding up the fermentation process, less stay time is needed in the digester, which minimizes the digester's size needed.
- As 40 % of household electricity is used in water heating, solar collectors can reduce monthly electrical needs by the same share.
- Solar pumps provide clean energy for water extraction.
- Recycled water is used in irrigation and toilet flushing which saves water resources and lessens the extraction needed.
- As extraction is minimized, leaching is also minimized, and the needed power for extraction will be reduced so smaller solar panels are needed.
- Raw water storage will save water for night time use, meaning that no solar batteries are needed for solar water pumps.
- Surplus water, as well as rain water and storm water, all will be directed towards ground water table across the leaching systems to help recharging aquifers. It will be furtherly filtered and treated by gravel and natural soil particles.
- Organic waste from the kitchen will be minced and directed towards the digesting system, which will increase its productivity and gas yield.
- Non organic waste will be sold to local garbage collectors (Rubabikya buyers).
- Biogas can be used both for cooking and power generation, which will solve the problem of gas shortage and offer electrical supply as well.

(3-4-17) Disadvantages of this system:

- Solar systems can be destroyed by storms.
- They need regular cleaning to stay efficient, especially during seasonal samd storms.
- Safety rules must be followed to assure that no source of ignition may reach the biogas storage tank. If not, tank may explode and cause disastrous damage.
- Surplus biogas must not be released to the environment to protect the atmosphere from green gas effects caused by Methane (CH_4).
- New technologies need well training to assure good results.
- No mentainance from outside can be offered due to isolation from populated areas.
- Sharing the same utilities by number of families may cause social problems, especially if no strong relations are present.

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Part (III) :

Case Study Applications in Four Different Societies: Rural, Urban, Slums and New Settlements

Summary of Part (III)

This part has introduced four application models of decentralized utilities in different Egyptian societies: Rural, Urban, Slums and New settlements. In each case, analytical study was introduced to cover main data of the studied society. Climate, topography, economy, people, urban services and available utilities, all these features were analyzed and then the most suitable off-grid utilities had been suggested for application in each case.

End of Summary of Part (III)

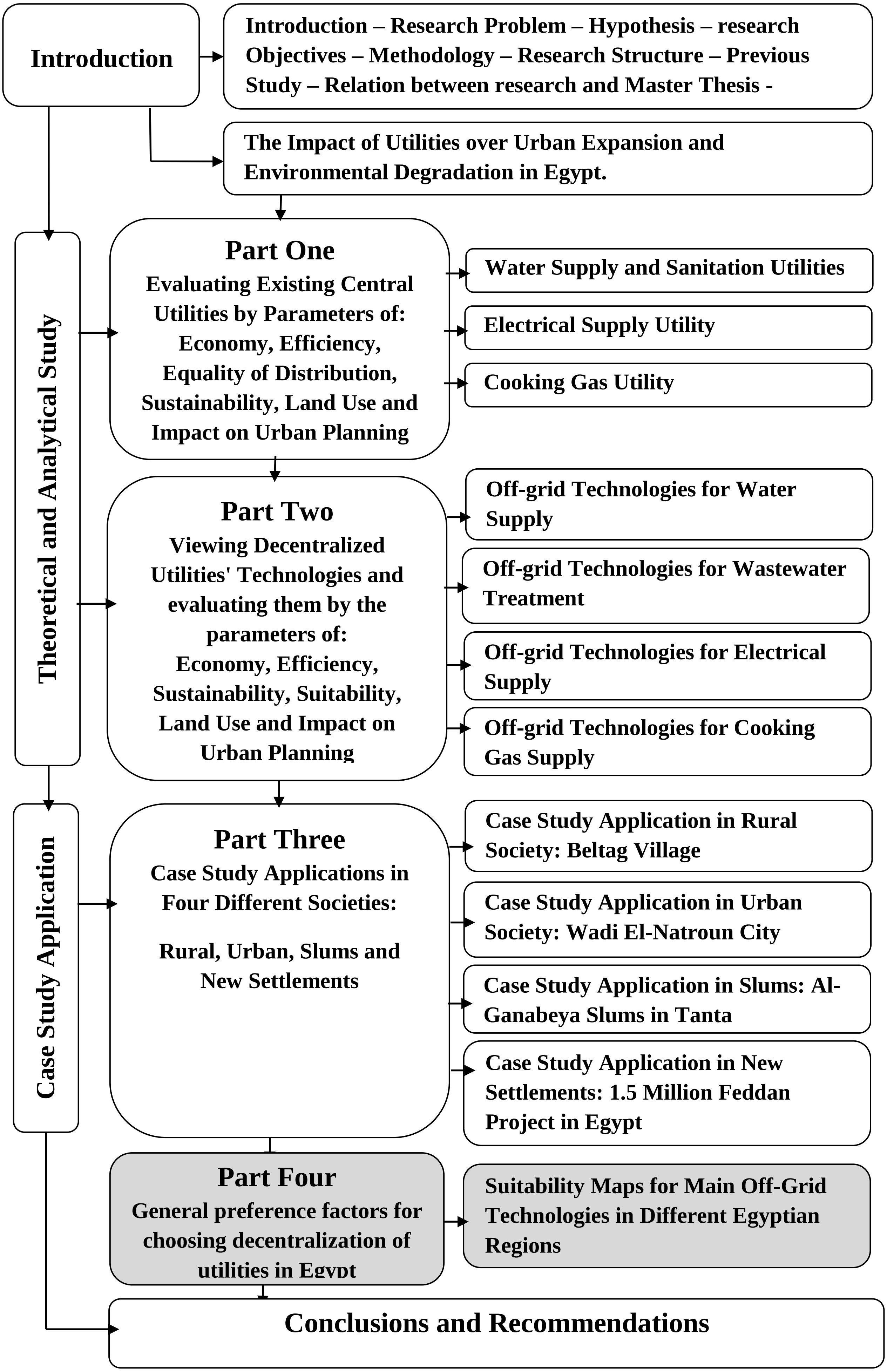
Part (IIII)

General preference factors for choosing decentralization of utilities in Egypt

Introduction to Part 4

After viewing samples of different rural and urban communities in Egypt and how the suggested models have dealt with their problems using decentralized utilities, this part introduces a manual for architects and urban planners to help them make the right choice in their future projects. Suitability maps are introduced for each technology among Egypt's different regions to help choosing the best technology for each location.

End of Introduction to Part IIII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(4-1) Making the decision whether to choose centralized or decentralized utilities:

As seen in chapter three, off-grid utilities have certain conditions to work properly. Every site has different preferences for utilities that are compatible with it. When the architect/urban planner try to choose the utility type for his project, he must consider many factors and parameters, considering the site data and conditions. Here we sum some of these parameters to be taken into consideration during the decision-making process:

- **A- Groundwater extraction Systems:** are suitable for sites with plentiful groundwater with small depth and low salinity. Water is preferred to be far from any source of contamination. Sites with high annual precipitation are preferred to assure natural recharge.
- B- **Septic tanks** are suitable for sites with limited land, remote sewers, light traffic, low economy and good ventilation. It isn't suitable for sites with heavy traffic, earthquakes or recurrent soil sliding. Almost all street types and urban patterns can host this technology, and almost all communities can get familiar with.
- C- **ABR systems** are suitable for sites with available land, remote sewers, accessible traffic, low economy and good ventilation. Not all street types and urban patterns can host this technology as it requires central vacancy for installation. Not all communities can get familiar with it as it requires strong relations and good sharing of responsibility.
- D- **Leaching systems** are suitable for sites with cheap land, low traffic, deep groundwater and high soil permeability. They don't suit sites with earthquakes, rock faults or soil sliding. They also don't suit sites with heavy rain fall, high humidity or low sun exposure.
- E- **Wetland Systems:** are suitable for sites with hot climate and existence of nearby water bodies to receive the treated effluent water (e.g. river, lake, sea).
- F- **Biogas Plant Systems** are suitable for sites with hot climate, high sun exposure, plentiful organic waste and nearby agricultural activities. Minimum space is required for installation and running.
- **G- Solar Heaters Systems:** are suitable for sites with hot climate, high solar intensity and high wind speed. Water is preferred to be of low salinity and high purity for quick heating.
- **H- Solar Panels PVC:** are suitable for sites with hot climate, high solar intensity and high wind speed. Good insulation in the building is preferred to assure wise electrical consumption.

(4-2) Suitability Maps of decentralized utilities in Egypt Using GIS program tool:

The Geographic Information System (GIS) software is used to develop a decision making tool for the implementation of different technologies of decentralized utilities. The tool is developed to analyze the suitability in different Egyptian regions based on the main parameters of suitability mentioned for each technology. A wide variety of maps and data sets are handled by the tool using advanced data management methods and incorporating important geographic characteristics of the regions under consideration. The following maps define the suitability of decentralized utilities in different regions in Egypt based on maps and data mentioned in chapter2.

(4-2-1) Suitability of decentralized water supply using groundwater extraction, desalination and treatment in Egypt:

Choosing off-grid water supply requires good knowledge about the availability of groundwater in the site of the project. The main parameters of making this decision are to know both depth and salinity of groundwater in the site. Groundwater depth identifies the cost of extraction, while salinity defines water quality and suitability for consumption. The following maps show both factors separately.

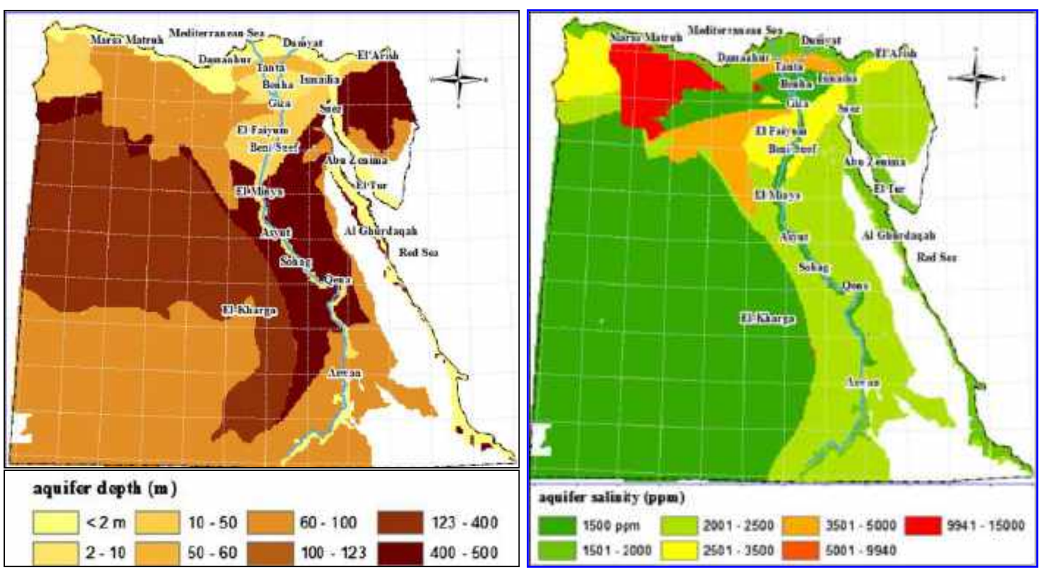
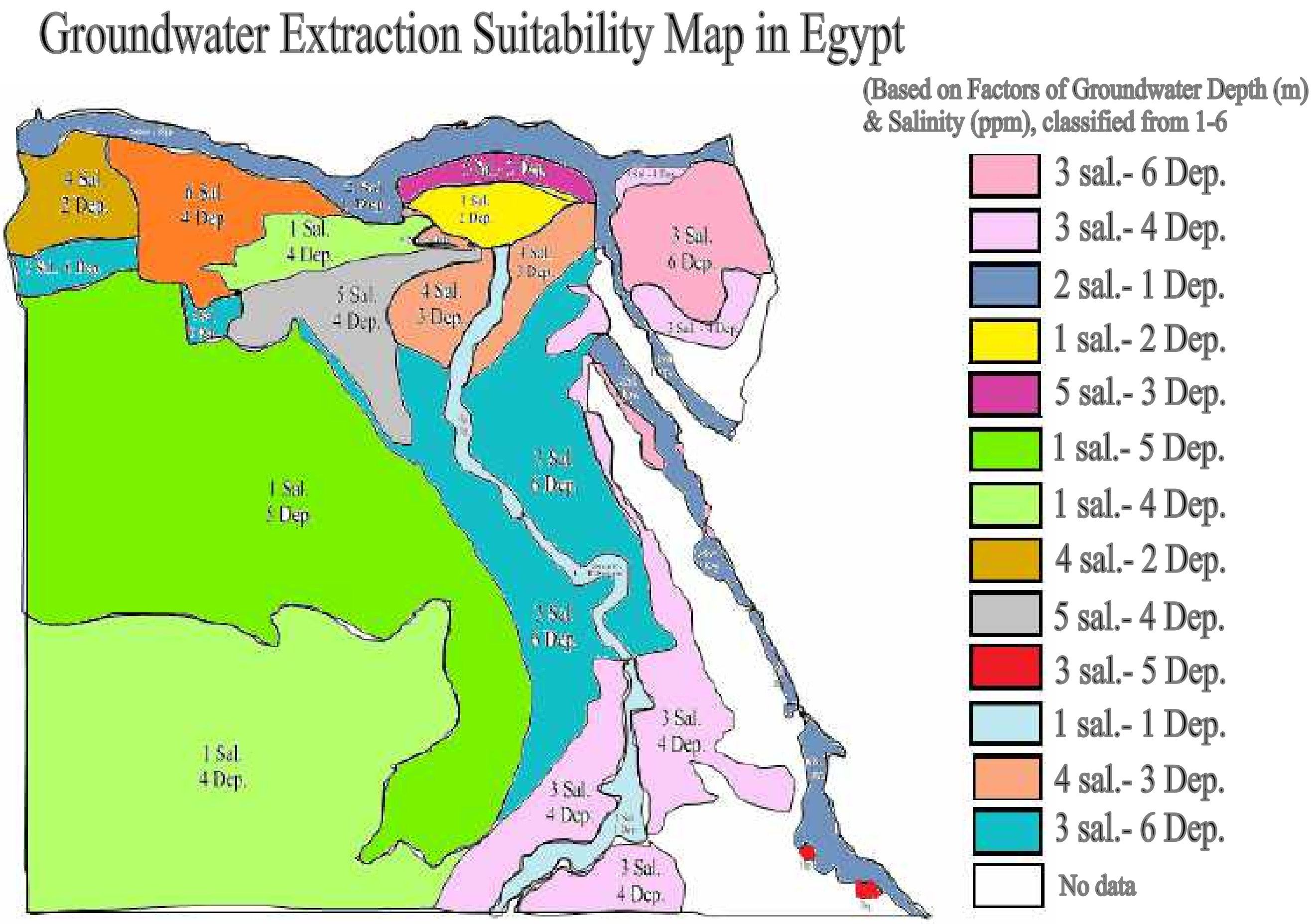


Fig (328): Groundwater classification map in Egypt (left) By depth (right) By salinity

Source: www.hydrologicalmpas.com retrieved 25/3/2014

Based on these maps, the following map was designed to help the architect/urban planner in choosing whether to use off-grid water supply from groundwater or not in his project, based on factors of depth and salinity, and according to site of his project:

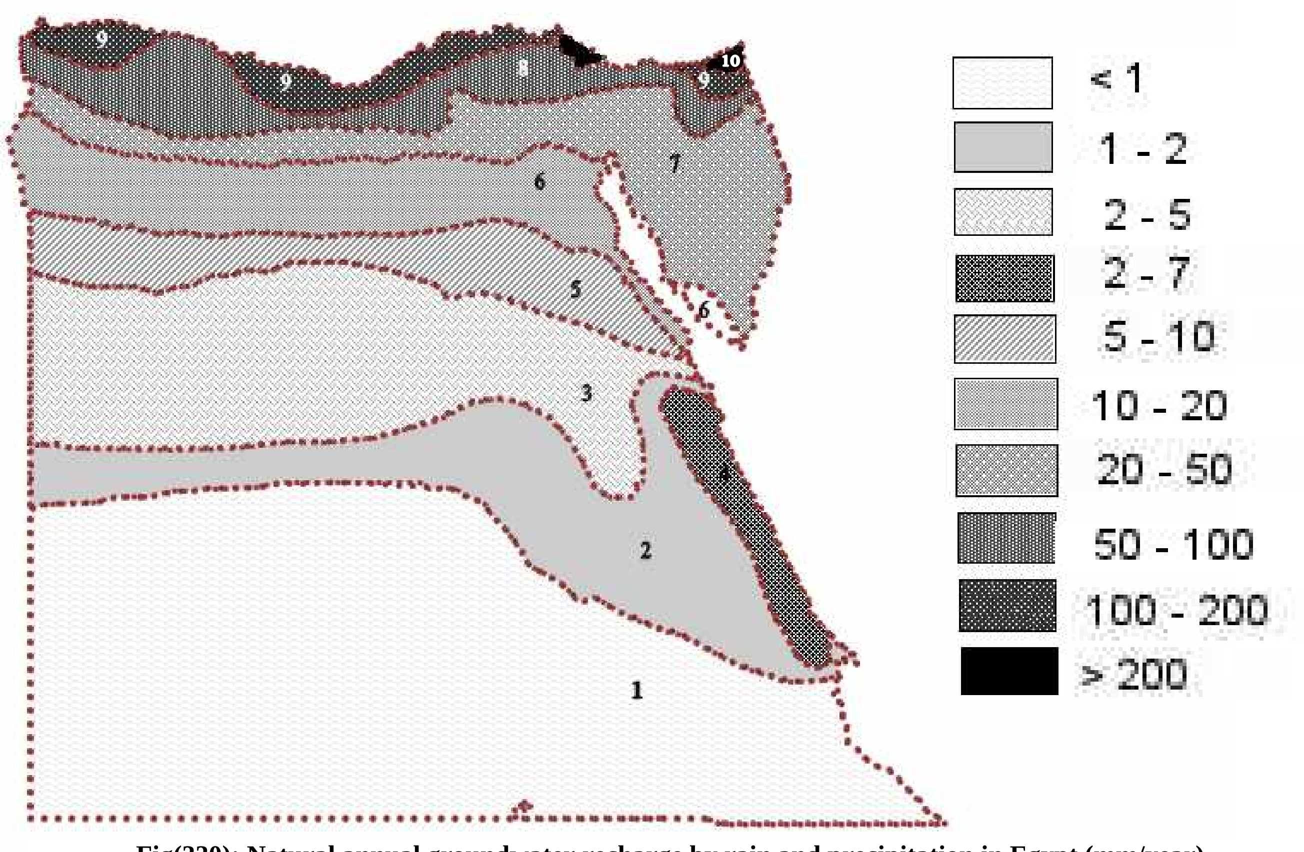


Fig(329): Groundwater extraction suitability map, based on depth and salinity – Designed by the researcher

Salinity Classification	PPM	Depth Classification	Meters
1	1500	1	< 2 – 10 m
2	1501 - 2000	2	10 - 50
3	2001 - 2500	3	50 - 60
4	2501 - 3500	4	60 - 123
5	3501 - 5000	5	123 - 400
6	9941 - 15000	6	400 - 500

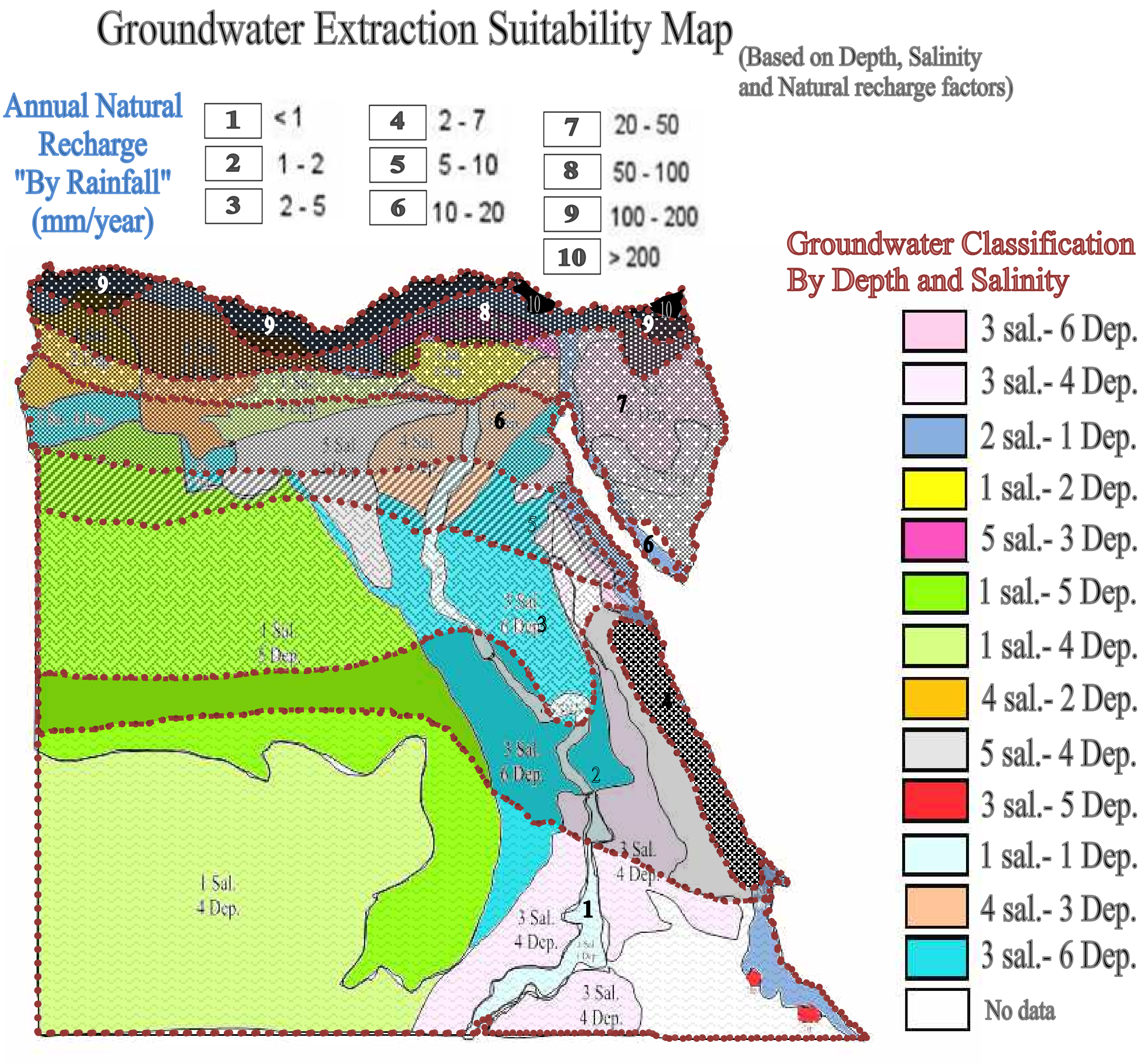
Table (51): Key of map (329), showing the values of depth and salinity in the map- Designed bu the researcher

However, water recharge must be carefully measured in site to maintain a sustainable consumption. Natural recharge by rain and precipitation are shown in the following maps.



Fig(330): Natural annual groundwater recharge by rain and precipitation in Egypt (mm/year)
Source: Designed by the researcher based on data from Ministry of water resources & irrigation in Egypt: Climate change risk management in Egypt, Prepared by UNISCO, Mohamed M. Nour El-Din, January, 2013

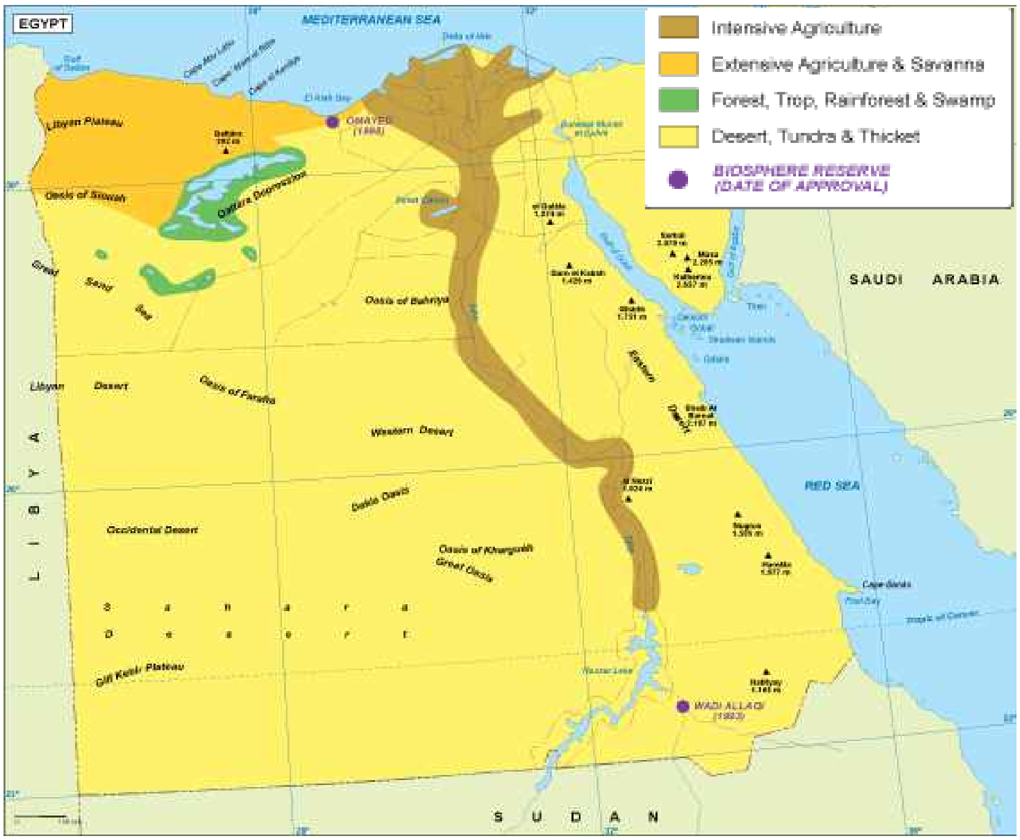
By merging the three factors: depth, salinity and natural recharge, we can define the suitability of groundwater extraction and use in off-grid houses according to site of the project as shown in the following map:



Fig(331): Groundwater extraction suitability map, based on depth, salinity and annual recharge rate

Designed by the researcher based on data from chapter 2

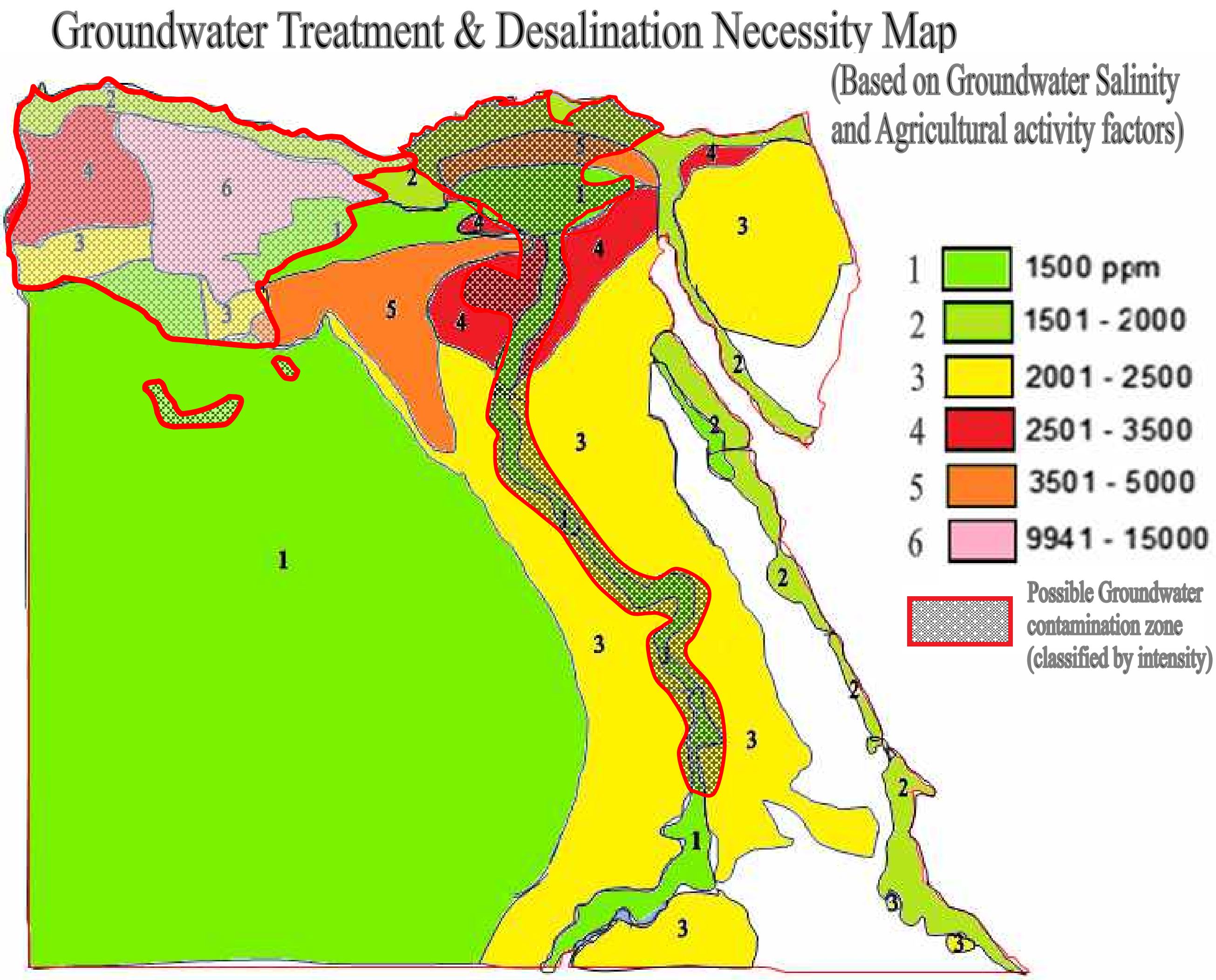
The need for desalination or treatment of the extracted water must be taken into consideration as well. The main factors controlling this are water salinity and contamination rates. Both factors vary from site to another, but generally, Nile valley and Delta region are depending on Intensive open irrigation which leads to groundwater contamination with herbicides and pesticides. Fig(332) shows the region of intensive agriculture activity boundaries in Egypt.



Fig(332): Region of intensive agriculture activity boundaries in Egypt which may lead to groundwater contamination

Source: Ministry of Agriculture www.moa.org.eg retrieved at 21/5/2013

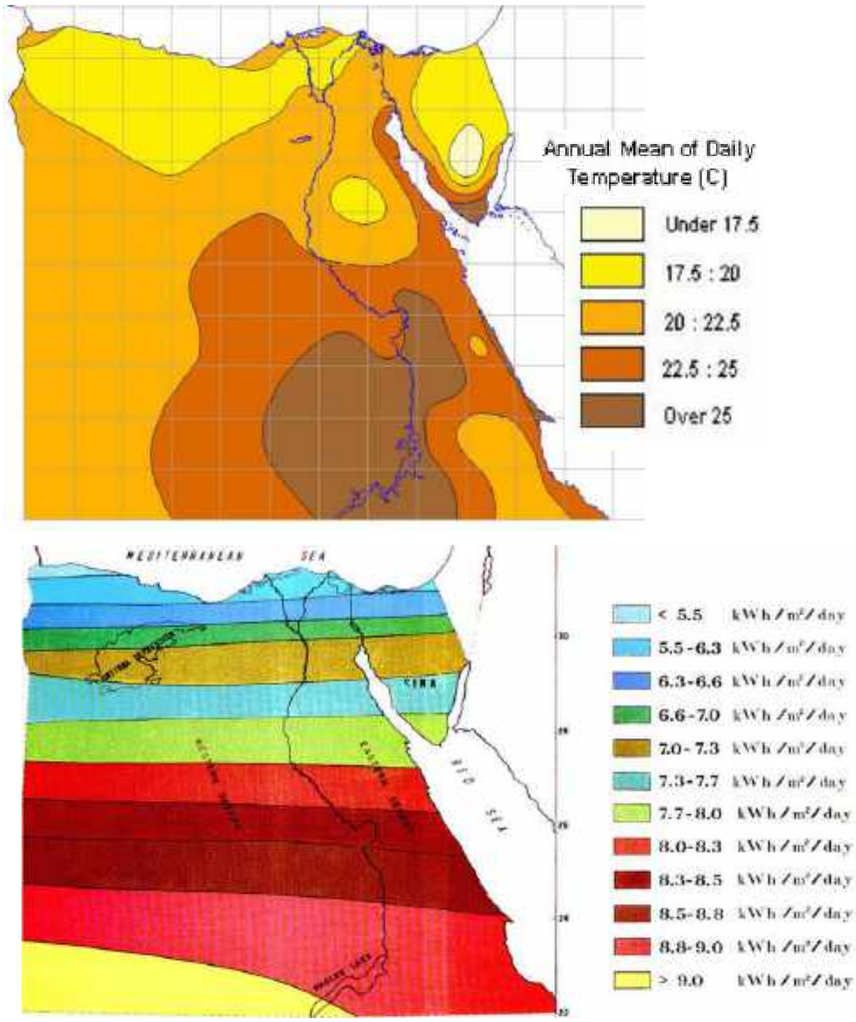
Considering this factor, as well as salinity factor, the following map can help the architect/urban planner to define the need for treatment or desalination in his project site before choosing the needed technology:



Fig(333): Groundwater Treatment & Desalination Necessity Map
Designed by the Researcher based on data from chapter 2

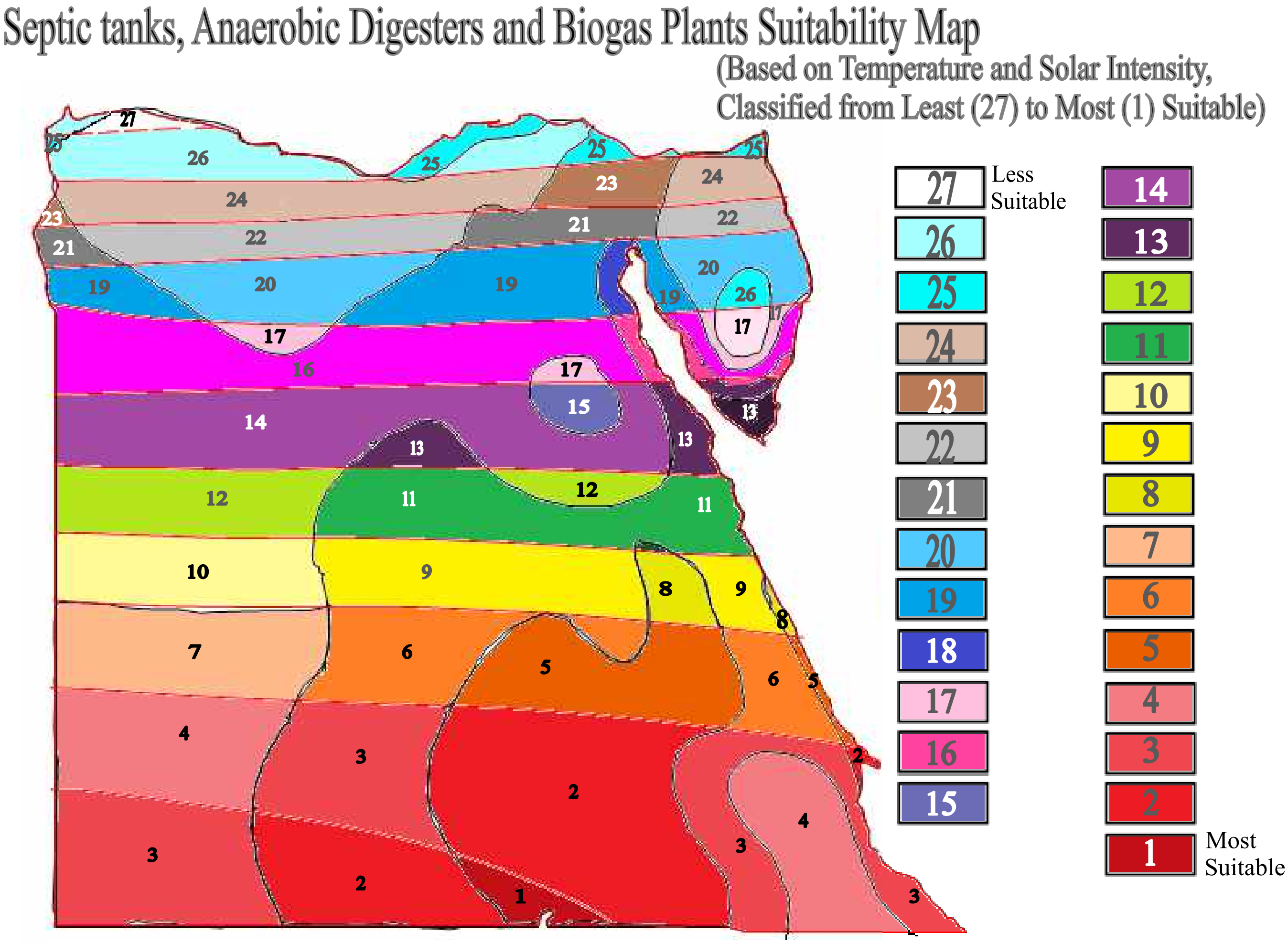
(4-2-2) Suitability of decentralized wastewater treatment in Egypt using Septic tanks, Anaerobic Digesters, and Biogas plants:

Choosing off-grid wastewater treatment technology requires good knowledge about the factors that speeds the treatment and improves its performance. Septic tanks, Anaerobic digesters and biogas plants all depend basically anaerobic digestion for wastewater fermentation and treatment. The activity of anaerobic bacteria correlated with high temperature and sun exposure for best performance. These technologies are most suitable in hot climate with high sun exposure. The following maps show these two factors separately classified in Celsius and kWh/m^2/day.



Fig(334): (Up) Average temperature rates in Egypt, measured in Celsius (Down) Average solar radiation in Egypt, measured in kWh/m2/day
Source: (left) UNESCO, SNC, 2010 (right) Solar GIs http://solargis.info/

The two factors are merged in one map using computer-based tools to define the areas for best suitability for septic tanks, anaerobic digesters and biogas plants technologies. Suitability is classified from 1 to 27, where 1 defines the most suitable locations, and 27 defines the least suitable ones. The following map can help the architect/urban planner to define the potentials of his site in applying these technologies:

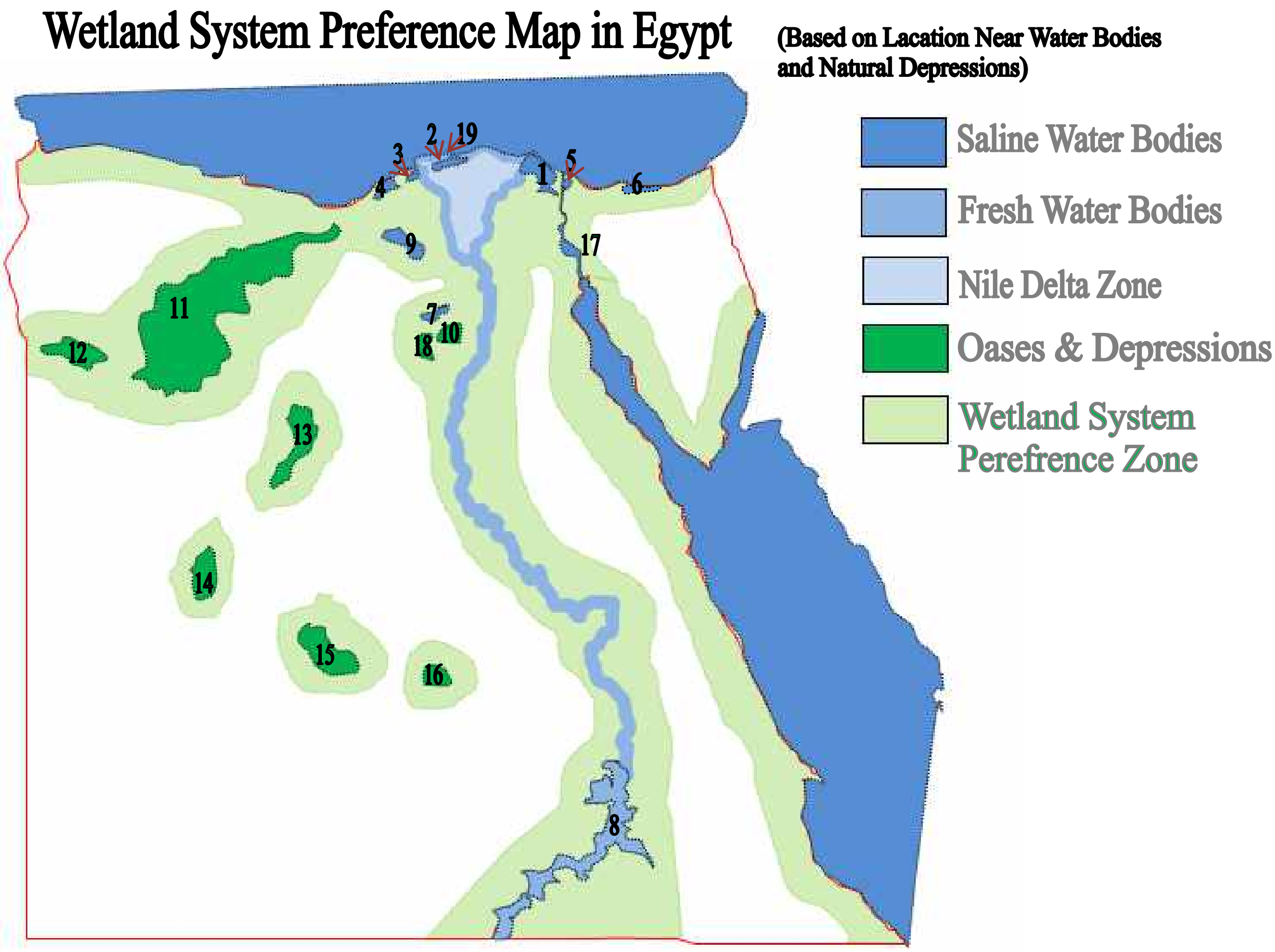


Fig(335): Septic tanks, Anaerobic Digesters and Biogas Plants Suitability Map
Designed by the researcher based on data from chapter 2

(4-2-3) Suitability of decentralized wastewater treatment in Egypt using Wetland Systems:

The previous map also defines the areas of suitability for wetland systems as well. Wetland systems depend basically on temperature for high removal efficiency. It is most suitable in hot climate with high sun exposure. The same previous map shows these two factors classified from least suitable (27) to most suitable (1).

However, wetland system is preferred in areas that are located near an existing water body (e.g. sea, river, lake etc.) as well as natural depressions of normal slopes (e.g. oases, depressions). These factors are available in Egypt in areas clarified in the following map:

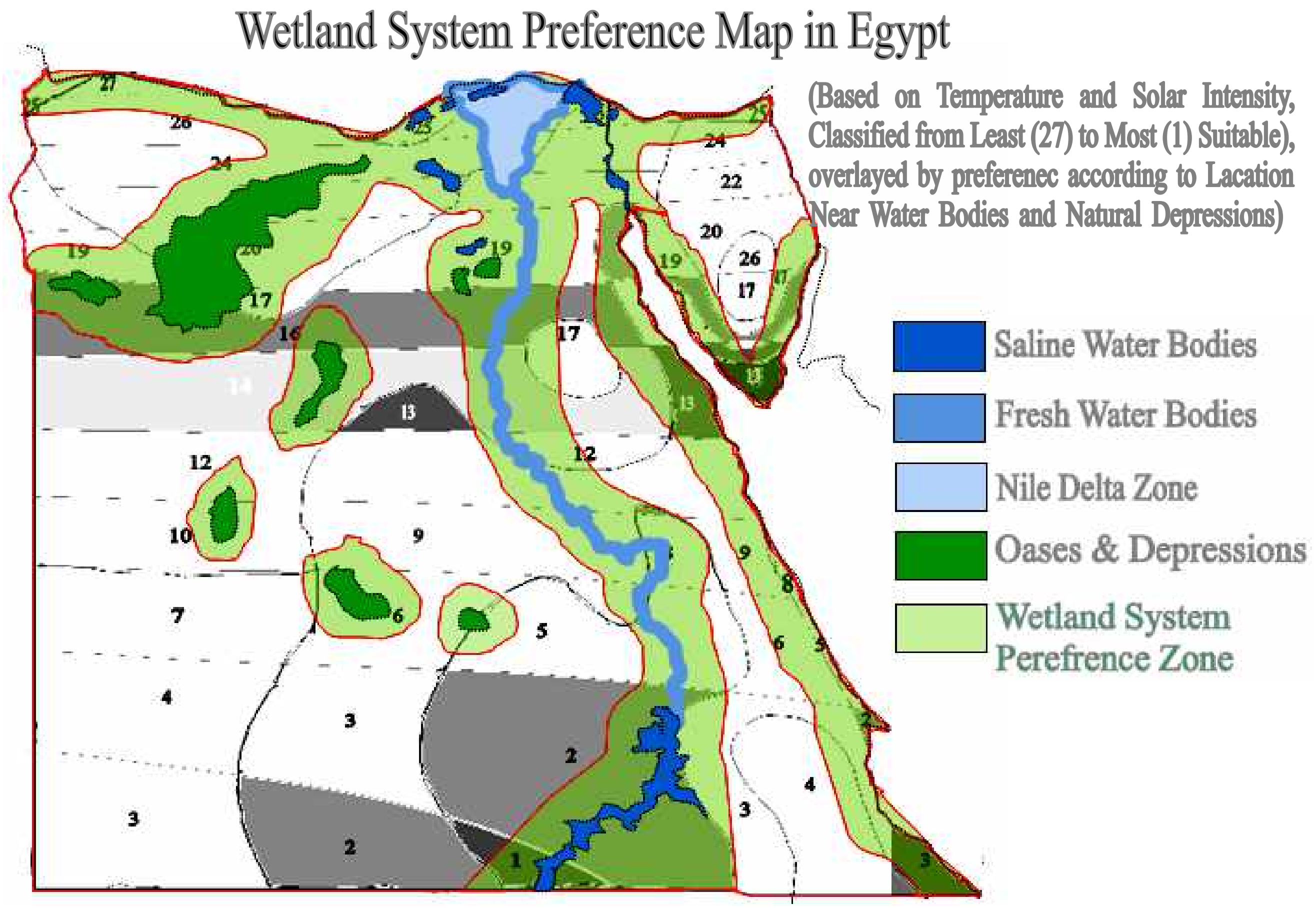


Fig(336): Wetland System Preference Map in Egypt, based on location near water bodies and natural depressions

The previous map is classified into regions by number; the following table defines the name of each region, with definition of the water body's depth, area, salinity and altitude. As well as water temperature in the receiving body:

No	Name (date constructed)	Description			Salinity (ppt) (‰)	Water temp. (°C)
		Area (km^2)	Altitude (m)	Mean depth (m)		
Natural Brackish Water Lakes						
1.	L.Manzalah	900	0–0.6	1.1	2–15	19.4–26.8
2.	L.Burullus	472–560	0–0.6	1.0	16–19	15.8–27.2
3.	L.Edku	130	0–0.6	0.75	5–15	14.5–28.5
4.	L.Mariut	27.3	-3	0.9	5–8	12.7–29.0
Natural Saline Lakes						
5.	Port Fouad depr.	96–200	0	0.7–12		
6.	Bardawil depr.	600–726	0	6	40–55	12.7–30.5
Artificial Brackish Water Lake						
7.	L.Quarun	220	-45	3.5–8	34	15–30
Artificial Freshwater Lakes						
8	L.Nasser (1964)	2 500–5 250	183	25	0	16–32
9.	Wadi Natrum					
10.	El Faiyum Oasis					
11.	Qattara depression					
12.	Siwa Oasis					
13.	Bahariya Oasis					
14.	Farafra Oasis					
15.	Dakhla Oasis					
16.	Kharga Oasis					
17.	Amer					
18.	Ruwayan					
19.	Nozha Hydrodrome	4.8	-3.6	3		15.5–27.5

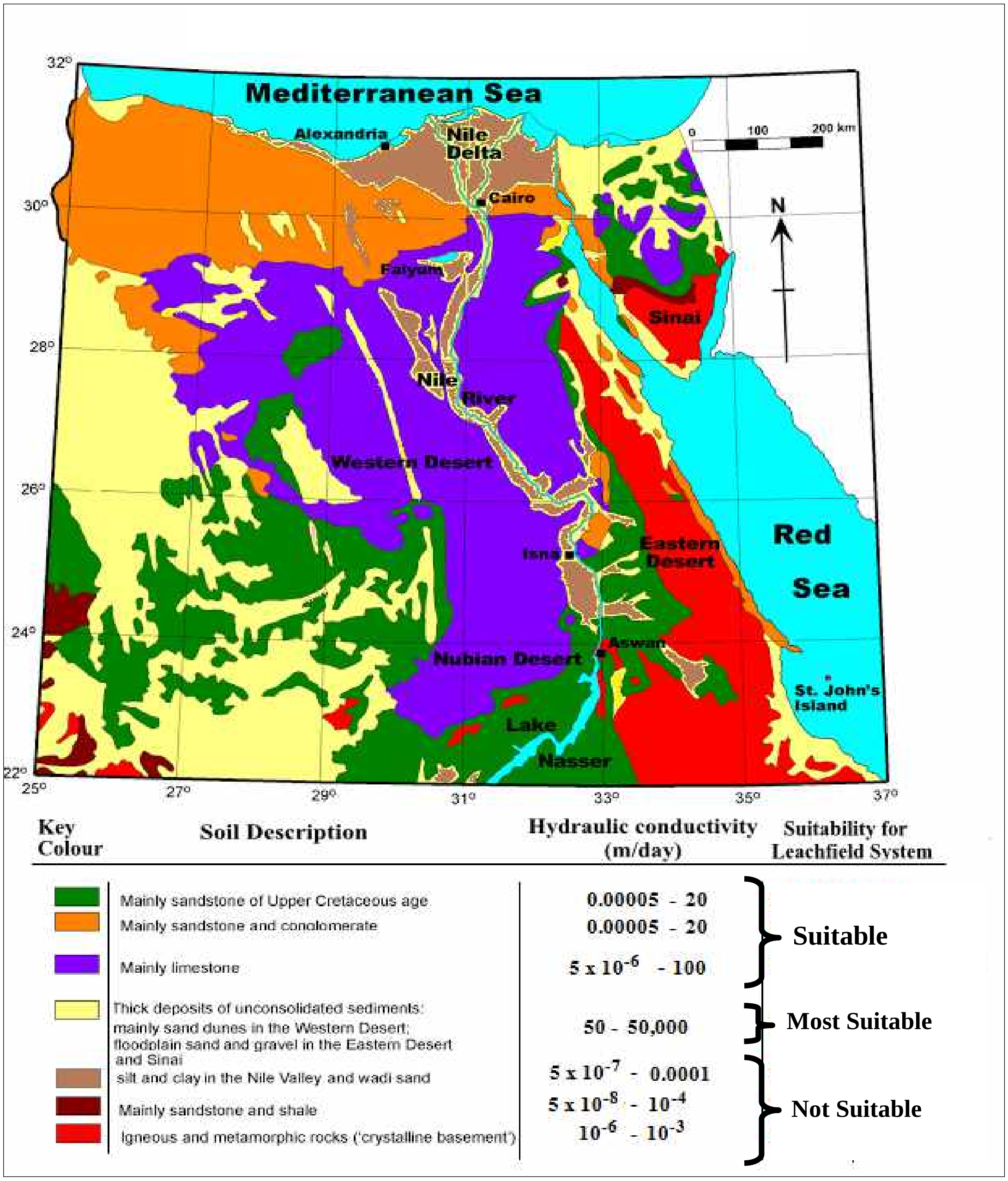
Table (52): Morphological data for major lakes and depressions in Egypt
Source: Modified, after Balarin, 1986, http://www.fao.org/docrep/005/t0361e/T0361E03.htm



Fig(337): Wetland System Preference Map of Egypt , Based on Temperature and Solar Intensity classified from least to most suitable, over-laid by preference according to Lacation Near Water Bodies and Natural Depressions)

(4-2-4) Suitability of applying Leaching Systems technology for residential uses Egypt:

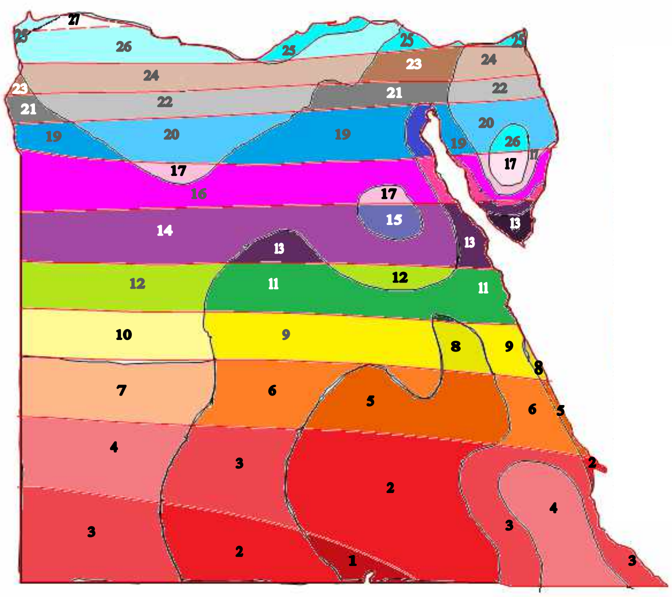
The suitability of leaching systems depends basically on soil permeability and hydraulic conductivity properties. The following map has classified the suitability of leaching system applications in different regions in the country based on data from the British Geological Survey and Information Products Program, 2006, to sort the country regions according to soil permeability and hydraulic conductivity, measured in m3/day. The data showed that most suitable soils for leaching systems are located in the south western desert and North Sinai, with a hydraulic conductivity reaching 50,000 m/day. Suitability is also fair in the Eastern and Western fringes of the Nile Valley, with a hydraulic conductivity reaching 100 m/day. Soil becomes moderately permeable in the Western North Coast, New Cairo, and Qattara Depression with a hydraulic conductivity reaching 20 m/day, while suitability is nearly absent in Delta and Nile Valley due to the dominance of clay in this fertile soil. The southern east quarter of Egypt is also non suitable due to crystalline based rocks, with permeability less than 10^{-3} m/day as shown in the map.



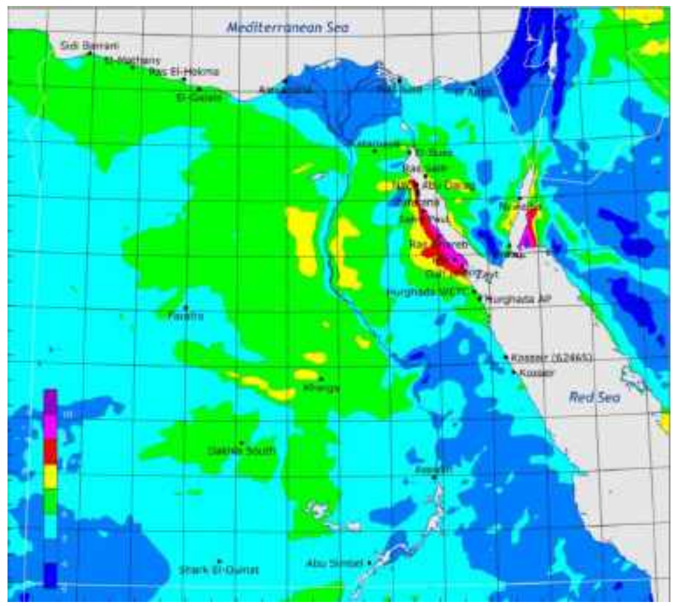
Fig(338): Leaching System Suitability Map for Egypt, based on Soil Permeability

Designed by the researcher referring to data from: BRITISH GEOLOGICAL SURVEY, INFORMATION PRODUCTS PROGRAMME, OPEN REPORT CR/06/160N, Guide to Permeability Indice: Keyworth, Nottingham,2006 as well as base map from http://soilsofegypt.blogspot.com/

However, leaching systems are also preferred in areas with high temperature, high solar intensity, and high wind speed as they speed up the evaporation rate of the soil as illustrated before in chapter 2. The following maps show the preference zones for leaching systems based on these 3 factors:



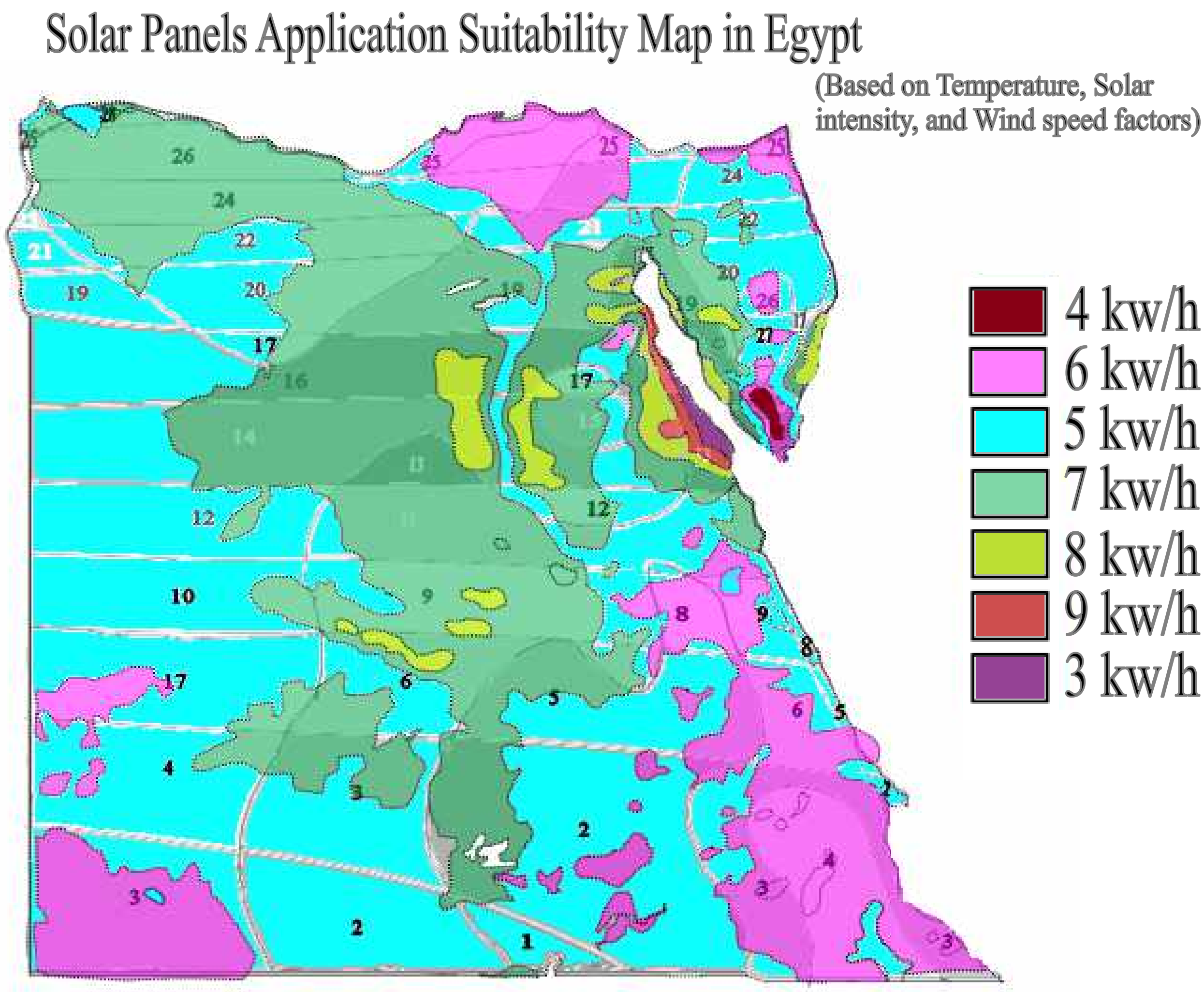
Fig(339): Temperature and solar intensity map in Egypt
Designed by the researcher based on data from chapter 2



Fig(340): Average Wind Speed in Egypt measured in kw/h.Source: Wind Atlas of Egypt www.wasp.dk/ retrieved in 22/4/2016

(4-2-5) Solar panels technology's suitability for application for residential uses Egypt:

The same two maps can help defining the preference zones of solar systems application in Egypt, based on temperature, solar intensity and wind speed. Solar panels work best in high sun-radiation areas and are positively correlated with high temperature and high wind speed. By merging the 3 factors together, the following map defines the preference zones of solar panels application in Egypt, based on these 3 factors: temperature solar intensity, and wind speed. This map can help the architect, the designer or the urban planner to expect the electrical yield of the PVC systems according to the site of the project in the following map:



Fig(341): Solar Panels Application Suitability Map in Egypt, based on Temperature, Solar intensity, and Wind speed factors) - **Designed by the researcher based on data from chapter 2**

After viewing the preference zones for some of the proposed decentralized utilities in Egypt, we need to define some other factors which generally affect the decision making process and must be considered while choosing whether to apply decentralized or decentralized utilities in Egypt as general :

(4-3) General preference factors for choosing decentralization of utilities in Egypt:

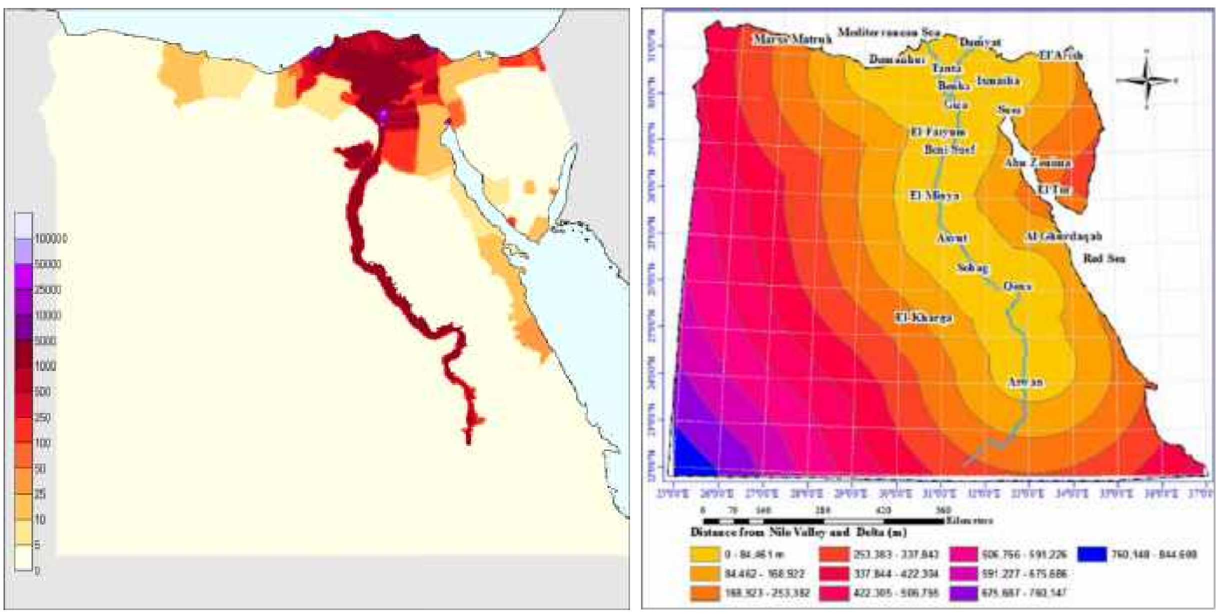
The main general factors that affect the preference of decentralized utilities in Egypt are:

(4-3-1) Population density in the served area:

As mentioned before, decentralization is preferred when population density is low. The following map shows the classification of population density in Egypt. Using this factor alone, we can assume that decentralized utilities are suitable for about 93% of Egyptian lands.

(4-3-2) Being far or near the existing urban spine of Egypt:

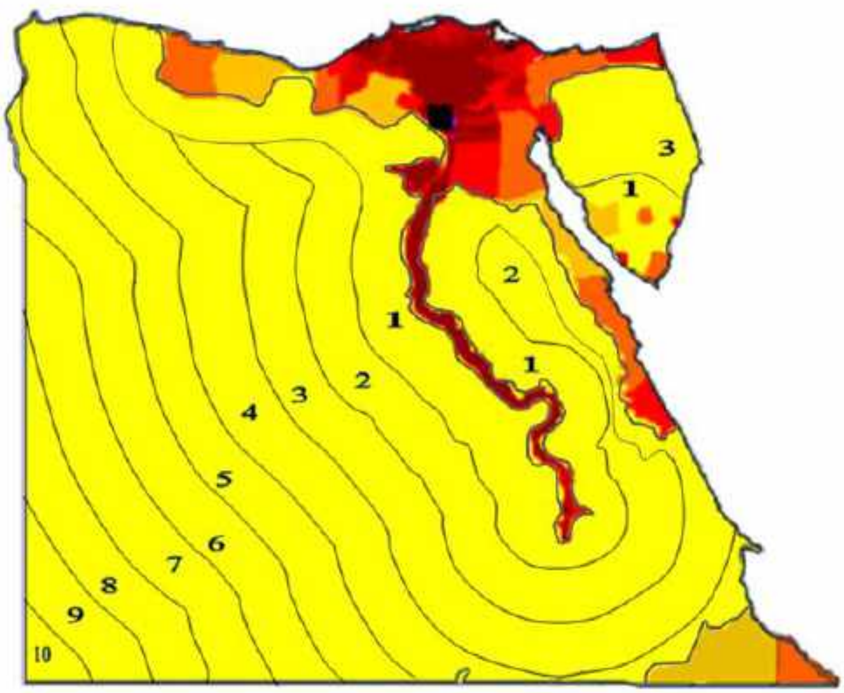
The old valley and Delta form the main urban spine of Egypt, where utilities and grid networks usually exist. If the project is located near this spine, it may be more economical to extend the grid to serve the project rather than establishing new systems. Decentralization preference is classified by this parameter as shown in fig(..).



Fig(342): (left) Population density in Egypt (0- 100,000 capita) referred to 2006 census (right) The classification of Egyptian land according to distance from Nile Valley and Delta (Kilometers).

Source: (left) http://www.mappery.com/Egypt-Population-Density-Map/ (right) Ab-Zeid and Biswas 1990)

The two parameters are used for preference by merging the previous two maps. Map(..) defines the preference of decentralization in Egypt. The existing urban spots are colored by red and orange, while the yellow zones are classified by nearness as shown in map(343).



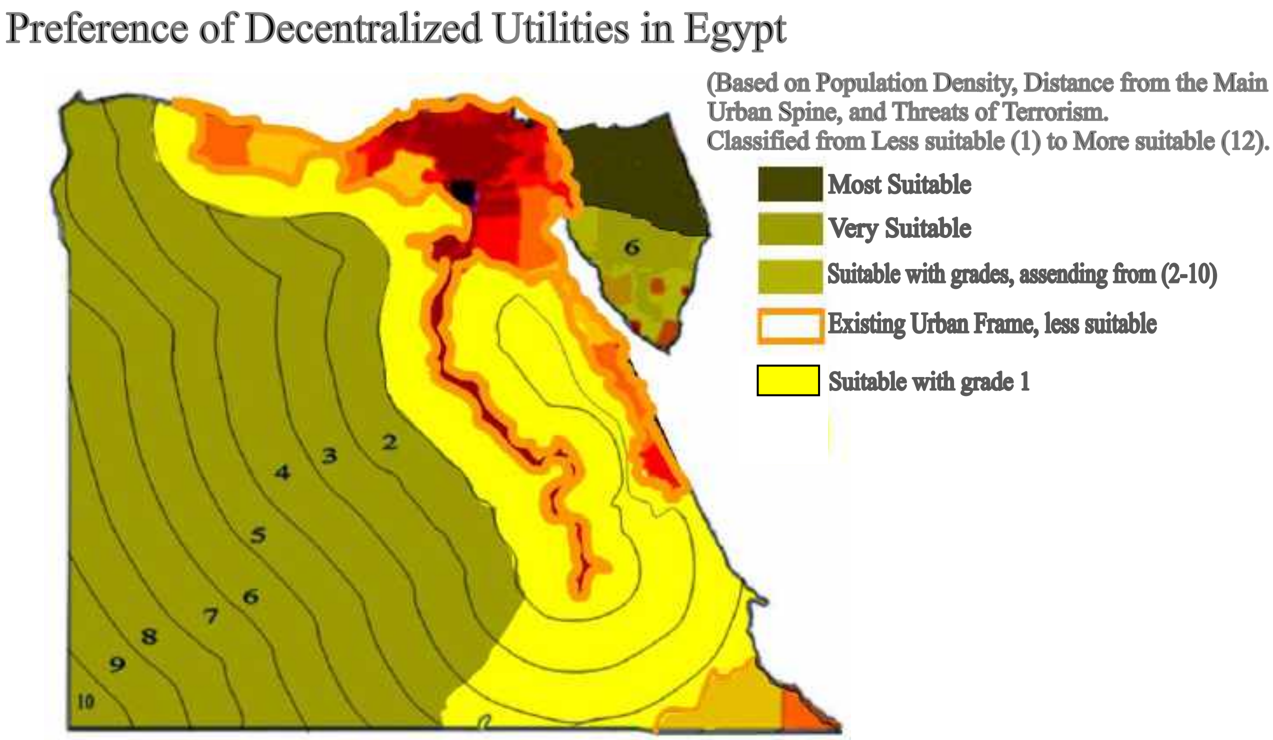
Fig(343): preference of decentralization in Egypt according to population density and distance from the main urban spine – **Designed by the researcher based on data from chapter 2**

(4-3-3) Safety of the served area:

Centralized utilities are not preferred in areas which suffer threats or recurrent terror attacks because utilities can be used as a mean of mass damage. The British Government has classified the Egyptian lands into 3 categories according to safety against terrorism as shown in map(344).

Fig(344): Egypt's classification according to threat from terrorism, as defined by the British Government 2016
Source: https://www.gov.uk/foreign-travel-advice/egypt/

Using the previous 3 parameters (density, safety, and nearness from the urban spine), we can classify the areas of preference for decentralized utilities in Egypt as shown in Map (345).



Fig(345): Preference of decentralized utilities in Egypt, based on population density, distance from the main urban spine, and threats of terrorism- **Designed by the researcher based on data from chapter 2**

(4-3-4) Elevation and Topography:

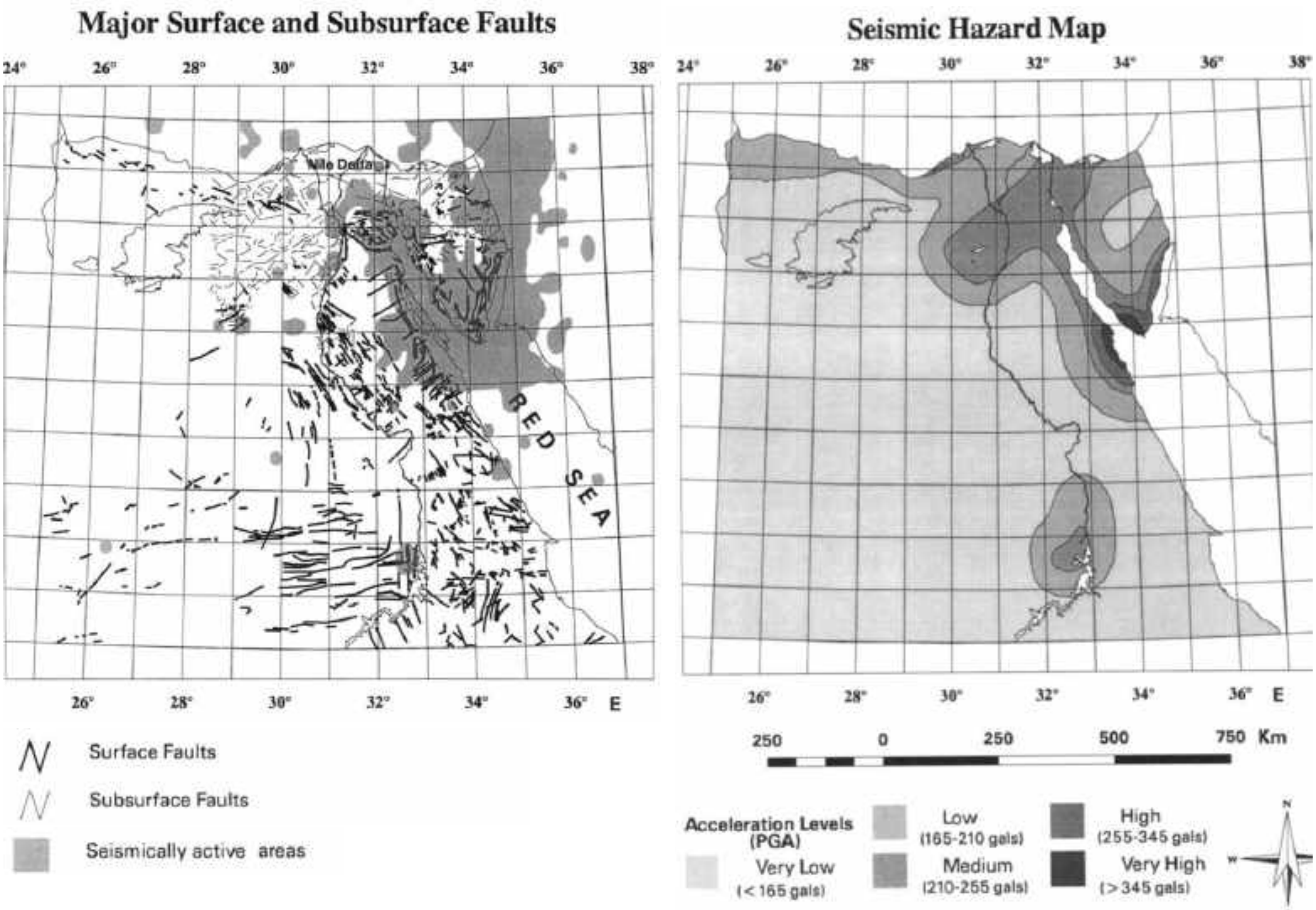
Decentralization of utilities is preferred in areas with special topography and steep slopes to avoid power consumption in pumping water/wastewater against gravity. The following map shows the main topography of Egypt where decentralization is favoured in the Eastern Coast, Sinai Peninsula, South west Quarter and Qattara Depression as shown in map(346).

Fig(346): Egypt's Elevation and Topography Map

Source: **http://www.lahistoriaconmapas.com/atlas/egypt-map/egypt-elevation-map.htm/** **retrieved 22/4/2016**

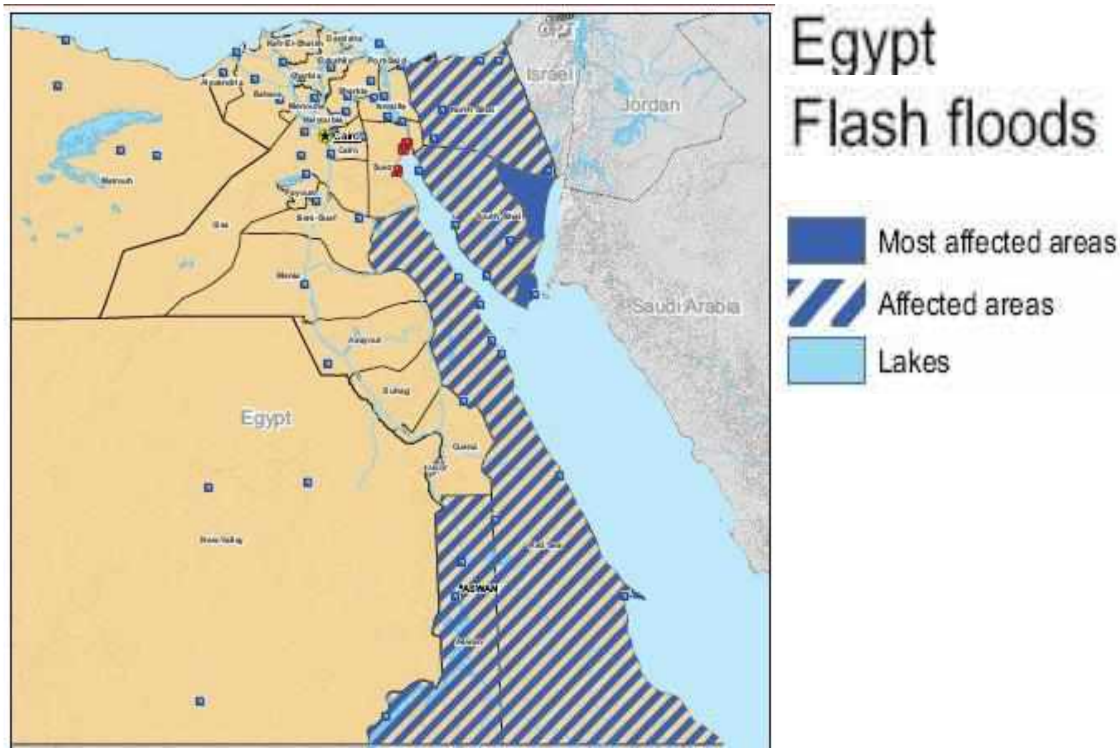
(4-3-5) Earthquakes, rock faults and flash floods:

Decentralization of utilities is preferred in areas with earthquakes and rock faults because the damage, if occurred, will be individual and not massive. The following maps show the areas to avoid for centralized utilities according to earth stability in Egypt:



Fig(347): (left) Major surface faults in Egypt (right) Siesmic hazard map of Egypt
Source: www.srl.geoscienceworld.org/ retrieved 22/4/2016

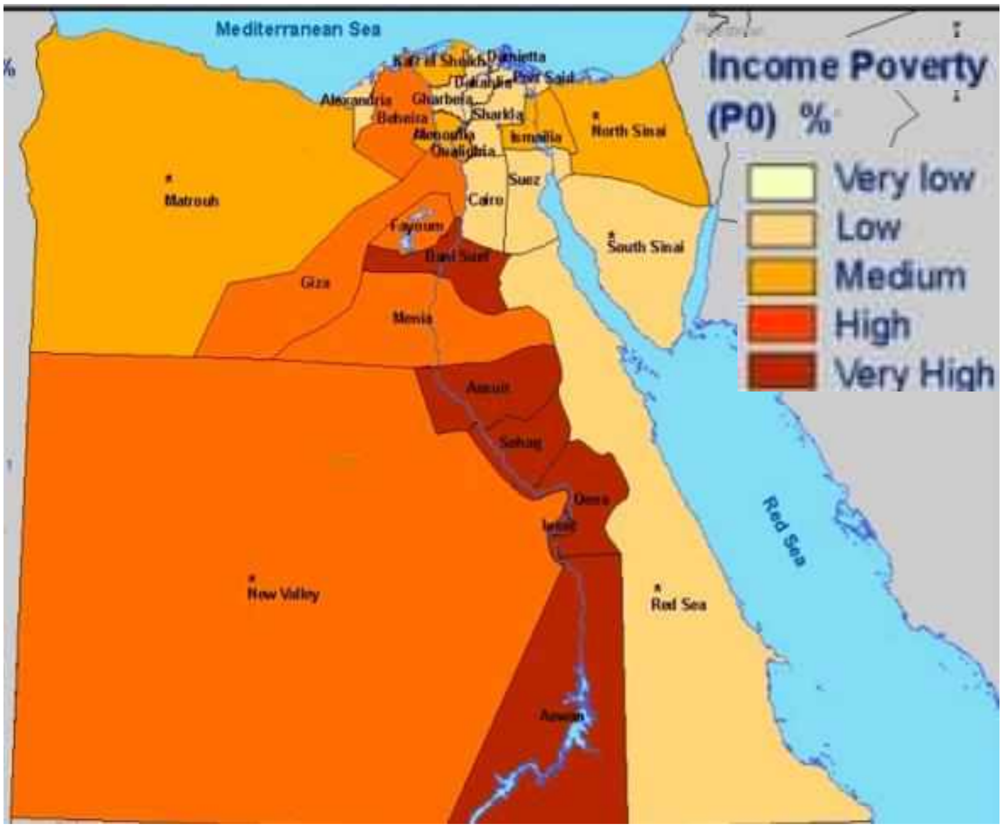
Flash floods' areas are preferred to have decentralized utilities to avoid mass destruction. Some exceptions are present, like leaching systems, which are not preferred due to soil erosion. Other exceptions are solar systems when they are located within reach of floods. The following map shows areas of floods in Egypt.



Fig(348): Areas of seasonal flash floods in Egypt
Source: http://www.accuweather.com/mt-news/ retrieved 20/4/2016

(4-3-6) Economic Status:

The economic standard affects the acceptance of new technologies of decentralization. Very wealthy people, as well as very poor ones, usually reject off-grid technologies, as the rich prefer not to worry about new technologies, and the poor can't afford to try new systems.



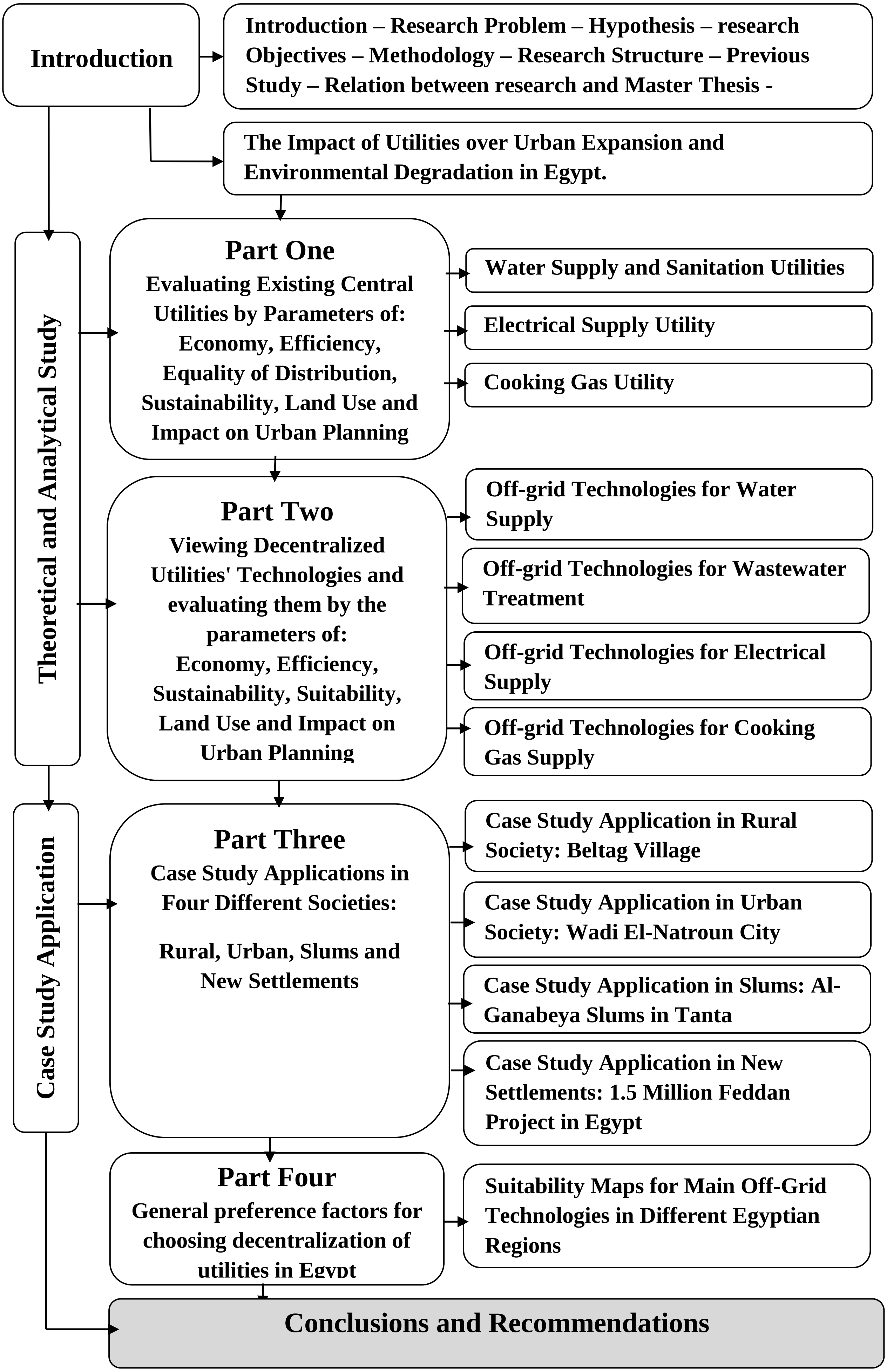
Fig(349): Septic tanks, Anaerobic Digesters and Biogas Plants Suitability Map
Source: http://rebeleconomy.com/commodities/egypt-rising-hunger/ retrieved 18/4/2016

Conclusions and Recommendations:

Introduction to Conclusions and Recommendations:

At the end of the Research, the researcher introduces some general findings, conclusions and recommendations. Main advises are given for architects and urban planners to help them take the proper decision concerning the use and application of decentralized utilities in different regions of Egypt.

End of Introduction to Conclusions and Recommendations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Conclusion and Recommendations:

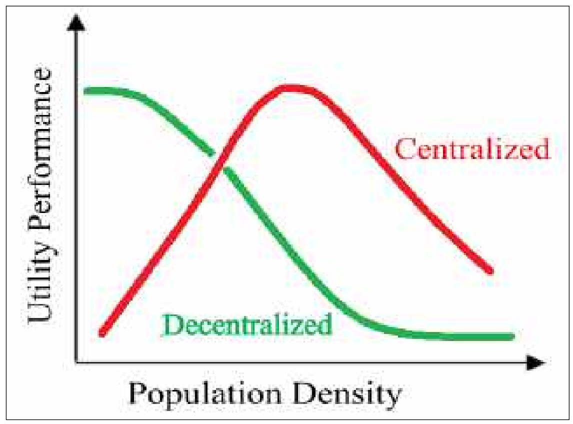
Egypt suffers extreme accumulation of population over 5% of its land, so urban shifting towards the Egyptian desert is being a must. However, building new cities with adequate utilities had cost billions of pounds so far, with poor utilities achieved. New cities and new rural settlements had failed in attracting new dwellers and the fortune spent over their establishment was not recovered.

(5-1) Possible Advantages of Decentralized Utilities:

Decentralization of utilities can be a good option for new settlements due to the following reasons:

(5-1-1) Compatibility with low density:

Unlike central utilities, decentralized utilities don't require high urban and population density to be feasible, which makes it suitable for new settlements, rural areas and bedwin communities with low density. In fact, the performance of decentralized utilities deteriorates with increasing density as shown in fig(350). Most of these utilities depend on natural resources (e.g. sun, air rain and soil) in working, so they require more space with less density for best performance.



Fig(350): The performance of centralized and decentralized utilities in relation with population density- **designed by the researcher**

(5-1-2) Installation comes with occupation:

Decentralized utilities have an economic advantage considering the needed fund. Unlike central utilities, off-grid utilities don't need to be installed totally at the same time. Every house owner will install his new utilities just as much as he needs. When the family grows bigger, he will increase the capacity of the system, meaning that "installation comes with occupation". This privilege is most appreciated in new settlements where the total occupation capacity is reached in decades. In some new settlements, central utilities where installed totally before occupation started, so when some occupants came, they found the utilities old and out-dated, and they had to make some replacements.

(5-1-3) Flexibility and ability of renewal: Decentralized utilities are more flexible and capable for replacement, development and renewal. If new technologies appear, they can be replaced or modified according to the desire of the owner and conditions of the organizing authorities.

(5-1-4) Ability to shrink or expand: Decentralized utilities have the advantage of ability to shrink or expand according to number of users or growing family size. This flexibility reduces the needed capital investment at the time of establishment.

(5-1-5) Ability to get moved, rent or sold: Most decentralized technologies are portable and capable of being moved from place to another. The owner can rent certain utilities and deliver them back. He can also take his own utilities wherever he settles, though some utilities may not suit the new environment or comply with the conditions of local authorities in this new place.

(5-1-6) Compatibility with different slopes and topography: Unlike central utilities, decentralized utilities are more compatible with most difficult site conditions. They would be especially useful for sites with topographic challenges (e.g. mountains and hills).

Fig(351): Difficult site conditions in Al-Dweiqa, Cairo

(5-1-7) Negotiable land use and flexible urban planning: Land use of decentralized utilities is negotiable and able to change. For example, solar systems can be installed at ground level or above the roof of the house with zero land use. Leaching systems can occupy vast or small land area according to site conditions and availability of vacant land. Biogas plant can be installed above ground or underground or be vertically attached to building façade. This flexibility gives freedom of design, according to terms of authorities, priorities of the site and desire of the owner. Decentralized utilities also give urban planners the freedom to use free form shapes and organic patterns. They comply with almost all patterns which allow planners to use their creativity.

(5-1-8) Saving Public money and Shifting of Responsibility: Utilities have always been considered as responsibility of the government and municipalities. People are not usually allowed to install or modify their own utilities unless no central utilities are available. This situation has caused the augmentation of public spending and raised the sense of irresponsibility and negligence among users, causing wrong attitudes that may negatively affect the durability and efficiency of the system. The concept of decentralization will raise the feeling of responsibility as the users are asked to install, run and maintain their utilities by their own. They will be keener to keep them efficient and will make their children use them properly.

(5-1-9) Enhancing social relations and activating the rule of civil society: As people will install their utilities for their own, neighbors may share some utilities to reduce its cost. This situation will enhance social relations and create zone of mutual interest which will positively affect the served society. Different charitable and academic organizations will be able to help people istall and run their utilities properly and protect the environment. They may help poor families by teaching them how to build their utilities and will provide them with needed materials.

(5-1-10) Activating industry and creating jobs: When off-grid utilities were allowed in Asia and Western World, thousands of factories started to manufacture, develop and improve these utilities which made these utilities improved and affordable. The same may occur in Egypt if these utilities are allowed for use. New factories and small workshops will be devoted for utilities production and marketing which will activate the industry and create new jobs. If all our utilities will be imported, new companies will be specified in running and maintaining them and new jobs will be created as well.

(5-1-11) Resistance against terror attacks: Decentralized utilities are less prone to terror attacks and mass damage. Each unit is separately installed and operated, so if any problem occurred it will cause minimal damage to the community.

(5-2) Possible Negative Impact of decentralized utilities:

However, we must not rush into applying decentralized utilities before understanding their possible drawbacks in our society. Decentralized utilities, like every system, have advantages and disadvantages as well. Applying decentralized utilities in Egypt may have negative impacts:

(5-2-1) Urban Impact:
Utilities supply in Egypt is only permitted to legal and authorized buildings, so the availability of decentralized alternatives may encourage the illegal building process. As a result, fertile agricultural lands may face the threat of diminishing.

(5-2-2) Environmental Impact: Some users may not comply with the proper use for decentralized utilities due to negligence or lack of money, knowledge or interest. This behavior, by time, may cause a serious environmental threat.

(5-2-3) Social Impact: As decentralized utilities may be shared among group of households, the misuse of shared utilities by one or more houses may cause bad relations among neighbors and affects the social harmony. Good relationship between neighbors is a prerequisite for installing group utilities.

(5-3) General Recommendations of the Research:

Finally, we have some recommendations for owners, developers, policy makers and urban planners, concerning the use and application of decentralized utilities:

(5-3-1) Use central utilities wherever they exist: Central utilities are favored where they exist. The further we go far from it, the more favored off-grid utilities become. As shown in map(331), central utilities in Egypt are "centralized" in the old valley and part of the northern and eastern costs. This is the "spine" of the Egyptian urban presence. As far as we go from this spine, off-grid utilities become more favored and more economic.

(5-3-2) Don't fight culture: The main factor of success for off-grid utility is the cultural acceptance. People tend to do things the way they used to, as seen in fig (352). So, the designer must introduce this technology to the inhabitants gradually and thoroughly to assure proper acceptance. He must explain the advantages and drawbacks of the system, and enlighten them about how to use and maintain the utility and the sequences of not doing so on their health and their children.

Fig (352): Sudden application of technology without prior change in culture
Duncan, 1996 pp.167)

(5-3-3) It's a matter of priority and interest: The adaptation to new and advanced technologies is easy to all users just if they believe it is a priority. We can easily note the commonness of dish plates over the roofs of slum areas although people in these slums may have no private bathroom! So, it is a matter of interest, if we can make them interested in better and hygienic life of their own, life where they don't need to beg for utilities or steel them. They would live a life of peace and dignity. So, people must be oriented towards right priorities.

Fig(353) : Two models for adaptation to new technology: (left) Dish plates over slums in Cairo (right) Solar panels in rural India –(left) www.akhbarmisr.com (right) www.greenenergy.com/

(5-3-4) Development is required: Scientists and engineers are invited to start developing and improving these utilities to comply with our climate, economy, needs and habits. The government and academic entities must provide academic and financial support for these developers to help them perform their task.

(5-3-5) Don't over or under estimate the users: Designers must not be so optimistic or so pessimistic about the served society. They must neither overestimate the users by installing very developed utilities that they can't operate, nor under estimate them by denying their right of proper technology. The best choice is let them choose after illustrating different technologies for them and all

Fig(354): Users should take the decision by their own to assure success of applied utilities

advantages and possible drawbacks of each system. If they choose their own utilities, they will be keen to make it succeed.

(5-3-6) Laws and enforcements are required: Finally, laws and legislations must be set to organize and control the use of new suggested utilities. As EPA did, we must have our own Environment Protection Act that suits our own society and solve our main problems expected from future application. Strong surveillance is required by the government to assure compliance with these legislations. However, civil authority must be activated by allowing neighbors and non-governmental entities to share in this surveillance.

Finally, if we can apply decentralized technologies in our new urban societies, we will be able to expand all over the Egyptian lands with minimal cost and effort. We will have a sustainable architecture with minimal use of the resources and maximal performance and compliance with our needs. New housing designs will be created to comply with new technologies, and new urban patterns will arise with more creativity and less limitations. Decentralization can have a revolutionary impact over our architecture, environment, economy and urban style.

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استخدام المرافق الذاتية للعمارة المستدامة كبديل للمرافق الرسمية

Using Decentralized Utilities for Sustainable Architecture as an Alternative to Formal Utilities

بحث مقدم من المهندسة

هالة محمد السيد رسلان

كجزء من متطلبات الحصول على درجة العالمية (الدكتوراة) في الفلسفة من قسم الهندسة المعمارية جامعة الأزهر

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