Preliminary Report II

June 2010

Promoting Sustainable Energy in The Bahamas

FICHTNER

7399P02/FICHT-6116950-v4

FICHTNER

Sarweystraße 3
70191 Stuttgart • Germany
Phone: + 49 711 8995-0
Fax: + 49 711 8995-459

www.fichtner.de

Please contact: **Ole Langniß**
Extension: **584**
E-mail: **Ole.Langniss@fichtner.de**

Rev No.	Rev-date	Contents/amendments	Prepared/revised	Checked/released
0			Basteck	Langniß
1				
2				

Table of Contents

Table of Contents I

List of Tables V

List of Figures VIII

1. Summary 1-1

1.1 Energy Efficiency 1-1

1.2 Renewable Energy 1-7

1.2.1 Potential of Renewable Energy 1-7

1.2.2 Solar Water Heaters 1-8

1.2.3 Wind Power 1-9

1.2.4 Ocean Energy 1-9

1.2.5 Bio Energy 1-11

1.3 Scenarios on Power Demand and Renewable Energy Deployment 1-13

2. Introduction 2-1

2.1 Energy Efficiency Program 2-1

2.2 Renewable Energy Program 2-2

2.3 Next steps 2-4

2.4 Envisaged Reporting Schedule 2-5

3. Energy Efficiency Program 3-1

3.1 General 3-1

3.2 Hotel audits 3-1

3.2.1 Selection of hotels 3-2

3.2.2 Methodology 3-3

3.2.3 Findings from hotel audits 3-3

3.3 Public buildings 3-12

3.3.1 Selection of public buildings 3-12

3.3.2 Methodology 3-13

3.3.3 Findings from public building audits 3-13

3.4 Household audits 3-28

3.4.1 Selection of households 3-28

3.4.2 Methodology 3-28
3.4.3 Main findings from household audits 3-32
3.4.4 Power measurements of different appliances 3-34
3.4.5 Electricity consumption 3-35
3.4.6 Saving potentials 3-45
3.4.7 Good practice 3-48

4. Solar Water Heaters 4-1

4.1 Introduction 4-1
4.2 Potential of Solar Water Heaters 4-2
4.3 Conditions for SWH use in the Bahamas 4-3
4.3.1 Climatic conditions 4-3
4.3.2 Bahamian roof characteristics for SWH purposes 4-5
4.4 SWH technology overview 4-7
4.4.1 Collector types 4-7
4.4.2 Active and Passive Systems 4-11
4.4.3 Indirect and Direct Heat Transfer 4-12
4.4.4 Open Loop or Closed Loop Systems 4-12
4.4.5 SWH systems 4-13
4.5 SWH technology choice 4-17
4.5.1 Technical criteria and restrictions for SWH options 4-17
4.5.2 Costs and profitability of different SWH systems 4-24
4.5.3 SWH system choice for Bahamas 4-27

5. Photovoltaic Power Generation 5-1

5.1 Potential of Photovoltaic Power Generation 5-1
5.1.1 Building Integrated Photovoltaic 5-1
5.1.2 Open-field power plants 5-3
5.2 Initial Environmental Examination of Photovoltaic Plants 5-5
5.2.1 Construction Phase 5-6
5.2.2 Operation Phase 5-7

6. Wind power 6-1

6.1 Potential of Wind Power 6-1
6.1.1 Initial land suitability screening 6-1
6.1.2 Potential of wind power 6-4

6.2 Technology overview small wind turbines 6-6
6.3 Pre-feasibility study of wind power plants on The Bahamas 6-7
6.3.1 Turbine selection 6-8
6.3.2 Wind farm design and feasibility calculations 6-10
6.4 Initial Environmental Examination of Wind Energy Implementation 6-20
6.4.1 Construction Phase 6-20
6.4.2 Operation Phase 6-22

7. Ocean Power 7-1

7.1 Potential for Ocean Power 7-1
7.1.1 Introduction to the Ocean Resources 7-1
7.1.2 Ocean Energy Resource Estimates for the Bahamas. 7-6
7.2 Technologies for Ocean Power 7-9
7.2.1 Wave Energy Technology 7-10
7.2.2 Tidal Stream Technology 7-17
7.2.3 Ocean Thermal Energy Conversion (OTEC) Technology 7-21
7.3 Potential Sites 7-24
7.4 Coastal Bathymetry 7-24
7.5 Initial Environmental Examination 7-25
7.6 Conclusions 7-27

8. Bio Energy 8-1

8.1 Energy crops for The Bahamas 8-1
8.2 Potential of Bio Energy 8-11
8.3 Technical solutions for electricity production from biomass 8-14
8.3.1 General Assessment of potential feedstock 8-14
8.4 General considerations 8-15
8.4.1 Technical Options 8-16
8.4.2 Potential plant sizes 8-23
8.4.3 Generic plant configuration for the Bahamas 8-24
8.4.4 Electricity generation cost 8-24
8.5 Initial Environmental Examination of Biomass Cultivation 8-26
8.6 Conclusions 8-27

9. Deployment Scenarios 9-1

9.1 Current and Future Power Demand 9-1

9.2 Deployment Scenario for Renewable Power Generation 9-3
9.3 Conclusions 9-12

10. Annexes 10-1

List of Tables

Table 1-1: Potential of Renewable Energies for Power Generation 1-8
Table 9-2: Prospective power demand for 2020 on The Bahamas under two different scenarios 1-14
Table 1-3: Power supply from renewable energies by 2020 with an power consumption according to the EFFICIENCY scenario. 1-16
Table 3-1: Classification of hotels 3-2
Table 3-2: List of audited hotels with respective classification 3-2
Table 3-3: Average annual energy consumption of the Bahamian hotels 3-4
Table 3-4: Energy consumption of the large hotels (sample of 7 hotels) 3-4
Table 3-5: Energy consumption of the mid-sized hotels (sample of 5 hotels) 3-5
Table 3-6: Energy consumption of the small hotels (sample of 4 hotels) 3-5
Table 3-7: Calculation of the total electricity consumption of the Bahamian hotels 3-7
Table 3-8: Share of electricity consumption in air conditioned hotels 3-8
Table 3-9: Share of electricity consumption in ecological hotels 3-9
Table 3-10: Overview of good practice in hotels 3-9
Table 3-11: Total electricity saving potential of the hotel sector 3-11
Table 3-12: List of audited public buildings with respective use 3-12
Table 3-13: Summary of public buildings´ total floor area 3-19
Table 3-14: Estimated no. of inhabitants and households 2008 3-32
Table 3-15: Distinctive elements between normal houses and luxury homes. 3-32
Table 3-16: Electricity consumption of different devices in Watts 3-35
Table 3-17: Electricity consumption of different devices in kWh per cycle 3-35
Table 3-18: Annual electricity consumption in kWh (of 12 houses sample) 3-36
Table 3-19: Annual electricity consumption in kWh/sq ft (of 12 houses sample) 3-37
Table 3-20: Annual electricity consumption in kWh/(sq ft*inh.) (of 12 houses sample) 3-39
Table 3-21: Annual electricity consumption in kWh/inhab. weighted with census data 3-41
Table 3-22: Annual electricity consumption in kWh/inhab. weighted with census data 3-41
Table 3-23: Coverage ratios of electrical appliances in the audited households (sample of 15) 3-42
Table 3-24: Consumption and saving potentials in normal houses 3-46
Table 3-25: Consumption and saving potentials in luxury homes 3-47
Table 3-26: Consumption and saving potentials in small households 3-48
Table 4-1: Roof area in square meter suitable for solar energetic uses on Grand Bahama and New Providence. 4-3
Table 4-2: Most relevant SWH systems for Bahamas 4-13
Table 4-3: Approximate rating of suitability of different SWH systems (-- means least suitability and ++ best suitability) and preferable backup 4-24
Table 4-4: Specification of prototype systems for which profitability was calculated 4-25
Table 4-5: Economic key figures of different SWH prototypes for existing buildings with either heat tank or instantaneous heater installed and for new buildings 4-26

Table 5-1: Simulation of the annual yield of a PV set (Module type SPR 215) under Bahamain conditions depending on orientations and tilt 5-1
Table 5-2: Roof area in square meter suitable for solar energetic uses on Grand Bahama and New Providence. 5-2
Table 5-3: Potential peak power in kilowatt from building integrated PV on Grand Bahama and New Providence 5-2
Table 5-4: Potential annual electricity yield in MWh from building integrated PV on Grand Bahama and New Providence. 5-3
Table 5-5: Technical potential of open field pv installations on nine islands of The Bahamas........ 5-4
Table 5-6: Structural potential of open field pv installations on nine islands of The Bahamas........ 5-5
Table 6-1: Suitable sites for wind farms........ 6-3
Table 6-2: Technical potential of wind power........ 6-4
Table 6-3: Structural potential of wind power on The Bahamas........ 6-5
Table 6-4: Typical properties of small wind turbines........ 6-7
Table 6-5: Using a 49m tower maximum lift is limited to 50 ton – the tower can be installed in sections, further decreasing the demands to crane capacity........ 6-9
Table 8-1: Comparison of energy yield from ethanol production vs. utilization of the whole plant........ 8-1
Table 8-2: Energy crops for solid biofuel production with annual rotation and harvesting cycle........ 8-5
Table 8-3: Perennial crops for solid biofuel production........ 8-6
Table 8-4: Total Pinus caribaea plantation area required to produce enough biomass to operate a 5MWel power plant........ 8-8
Table 8-5: Potential biomass production from Pinus Caribaea on 4000 acres of land (= ~ 1,600 ha)........ 8-9
Table 8-6: Theoretical potential........ 8-11
Table 8-7: Structural potential........ 8-12
Table 8-8: Theoretical potential for electricity generation on The Bahamas 8-12
Table 8-9: Structural potential for electricity generation on The Bahamas........ 8-13
Table 8-10: Potential for electricity generation from Pinus if only planted on Pine forest stand........ 8-14
Table 8-11: Properties of energy crops........ 8-15
Table 8-12: Key characteristics of biomass power plants (5 - 20 MWe) 8-23
Table 8-13: Matching of biomass potential and electricity demand........ 8-23
Table 8-14: Key data biomass power plant 8-24
Table 8-15: Calculation of power generation cost........ 8-25
Table 9-1: Present status of power supply on The Bahamas........ 9-1
Table 9-2: Prospective power demand for 2020 on The Bahamas under two different scenarios 9-3
Table 9-3: Existing desalination capacities and resulting power demand........ 9-6
Table 9-4: Maximum renewable energy capacity and generation by 2020 which could be absorbed with power demand according to the BAU scenario........ 9-7
Table 9-5: Maximum renewable energy capacity and generation by 2020 which could be absorbed with power demand according to the EFFICIENCY scenario. 9-8

Table 9-6: Power supply from renewable energies by 2020 with an power consumption according to the BAU scenario.. 9-10
Table 9-7: Power supply from renewable energies by 2020 with an power consumption according to the EFFICIENCY scenario. 9-12

List of Figures

Figure 1-1: Assessment of the electricity saving potential in the different hotel classes ... 1-1
Figure 1-2: Consumption and potentials in normal houses ... 1-3
Figure 1-3: Present power demand and reduced power demand in Bahamian households due to savings. ... 1-3
Figure 1-4: Illustration of Site A for a long row of wind turbines at the southern coast of Grand Bahama ... 1-9
Figure 1-5: Annual Averaged Wave Power Levels ... 1-10
Figure 1-6: Tide Height Curve for Nassau – June 2010 ... 1-11
Figure 3-1: Specific energy consumption in kWh per rented room ... 3-5
Figure 3-2: Specific energy costs in $ per rented room ... 3-6
Figure 3-3: Share of the different sources in the energy supply of the hotels ... 3-8
Figure 3-4: Assessment of the electricity saving potential in the different hotel classes ... 3-11
Figure 3-5: Aerial view and front view of the Ministry of Works & Transport ... 3-14
Figure 3-6: Aerial view and front view of the Cabinet Office ... 3-14
Figure 3-7: Aerial view and front view of House of Assembly ... 3-15
Figure 3-8: Aerial view and front view of the Main Post Office ... 3-15
Figure 3-9: Aerial view and front view of the Elisabeth Estate Clinic ... 3-16
Figure 3-10: Aerial view and front view of Uriah McPhee Primary School ... 3-16
Figure 3-11: Aerial view and front view of the Geriatric Hospital ... 3-17
Figure 3-12: Aerial view and front view of the Ministry of Education ... 3-17
Figure 3-13: Aerial view and front view of McPherson Junior High School ... 3-18
Figure 3-14: Aerial View and front view of the Bimini Administration Building ... 3-18
Figure 3-15: Split of electrical usage in smaller public buildings ... 3-20
Figure 3-16: Electrical load curve of public buildings ... 3-21
Figure 3-17: Electrical load curve of small public buildings ... 3-21
Figure 3-18: Electricity consumption of audited public buildings ... 3-22
Figure 3-19: Specific electricity consumption per square foot ... 3-22
Figure 3-20: Specific electricity consumption per square foot for small public buildings ... 3-23
Figure 3-21: "Light coloured office building with partial shading by eaves" ... 3-24
Figure 3-22: "Light coloured school building shaded by a tree" ... 3-25
Figure 3-23 "Building with hurricane shutters and shaded decentralized A/C system" ... 3-25
Figure 3-24 : “Power outlet strip with on/off switch" ... 3-26
Figure 3-25: Typical load curve of a household with cooling demand in summer ... 3-29
Figure 3-26: Calculated monthly electrical load of a typical household ... 3-30
Figure 3-27: Households per income group ... 3-31
Figure 3-28: Power meter ‘Kill A Watt P4460’ from P3 International ... 3-35
Figure 3-29: Annual residential electricity consumption (sample of 12 households) ... 3-36
Figure 3-30: Load curves of the audited households (sample of 12 households) ... 3-37
Figure 3-31: Specific annual electricity consumption in kWh / sq ft ... 3-38

Figure 3-32: Specific load curves of the audited households (sample of 12 households) 3-38
Figure 3-33: Specific annual electricity consumption in kWh/(sq ft * inh.)........ 3-39
Figure 3-34: Specific load curves of the audited households (sample of 10 households) 3-40
Figure 3-35: Yearly consumption in six normal houses in relation to the household size 3-40
Figure 3-36: Typical split of the residential electricity consumption in ‘normal houses’ 3-43
Figure 3-37: Split of the residential electricity consumption in ‘normal houses’ with energy saving bulbs 3-43
Figure 3-38: Split of the residential electricity consumption in ‘luxury houses’........ 3-44
Figure 3-39: Split of the consumer types within the population........ 3-45
Figure 3-40: Split of the residential electricity consumption........ 3-45
Figure 3-41: Consumption and potentials in normal houses........ 3-46
Figure 3-42: Consumption and potentials in luxury homes........ 3-47
Figure 3-43: Open windows promoting natural cross and stack ventilation........ 3-48
Figure 3-44: Example for a wall partially shaded by plants and trees........ 3-49
Figure 3-45: Light colored and reflecting roof but dark and absorbing walls 3-49
Figure 3-46: Security lights without (l) and with motion detector (r) 3-50
Figure 4-1: Monthly course of daily global irradiation in Nassau........ 4-4
Figure 4-2: Relative yearly global irradiation in Bahamas at given tilt and orientation (Calculated with GetSolar simulation program)........ 4-4
Figure 4-3: Yearly specific solar yield of a thermosiphon in Bahamas at given tilt and orientation (Calculated with GetSolar simulation program)........ 4-6
Figure 4-4: Solar fraction of a thermosiphon in Bahamas at given tilt and orientation. (Calculated with GetSolar simulation program)........ 4-6
Figure 4-5: Flat plate solar collector........ 4-7
Figure 4-6: Heat pipe scheme: The heat liquid is vaporized under low pressure. 4-8
Figure 4-7: Heat pipe scheme: Heat is transferred from the heat pipe to the solar fluid via a heat exchanger........ 4-8
Figure 4-8: Sydney vacuum tube 4-9
Figure 4-9: ICS tank type........ 4-10
Figure 4-10: ICS tube type........ 4-10
Figure 4-11: Formed plastic collector used for pool heating........ 4-11
Figure 4-12: The Thermosiphon concept........ 4-14
Figure 4-13: Concept of an open-loop thermosiphon 4-14
Figure 4-14: ‘Jacketed’ closed loop thermosiphon 4-15
Figure 4-15: Schematic functionality of an open loop evacuated tube thermosiphon........ 4-16
Figure 4-16: Thermosiphon with tank under the roof but above the collector 4-19
Figure 6-1: Sample for a 1 kW micro wind turbine (Source: Zephyr) 6-6
Figure 6-2: The V52 construction........ 6-10
Figure 6-3: To the right, one long row along the south coast, to the left a square at the island north of Port facility 6-11
Figure 6-4: Basic finding from simulation calculations for Site A, south coast........ 6-12

Figure 6-5: Financial feasibility based on first 15 years of operation, where the investment is fully paid back, lead to a cost of wind electricity of round 16 US$c/kWh. The interest rate is set to 6%, there are not included inflation and tax in this simple calculation setup ... 6-13
Figure 6-6: Noise map for the layout ... 6-14
Figure 6-7: There seem to be some houses close to the wind farm in western part - this might require the wind farm location is moved some towards east, but there should all in all be enough space ... 6-14
Figure 6-8: Also in the eastern part is seen something that might be houses at Google Earth. It is informed that this location was used for recording parts of the movie "Pirates of the Caribbean" ... 6-15
Figure 6-9: A 54.4 MW wind farm with expected production of round 70 GWh/y, corresponding roughly to 15% of present electricity consumption at Grand Bahama ... 6-16
Figure 6-10: Based on 15 year payback time, the wind electricity costs will be 17.8 US$c/kWh. The cost changes relative to the previous proposal are slightly increased turbine costs due to larger hub height, and reduced main grid connection due to closeness to the power plant ... 6-17
Figure 6-11: Noise map for the layout. Normally 45 dBA is considered maximum allowed by settlings. In some countries 40 dBA ... 6-18
Figure 6-12: Photomontage from the bridge at Queens Hwy. The dead trees at the island are supposed to be removed ... 6-19
Figure 6-13: Photomontage from Queens Hwy at the Port facility ... 6-19
Figure 6-14: Google Earth visualization - there will be a need for fine tuning of the layout due to the water canals etc. but the site seems suitable for a project round 50-60 M ... 6-20
Figure 7-1: Wave Energy Propagation ... 7-1
Figure 7-2: Scatter Diagram – Wave Climate ... 7-2
Figure 7-3: Average annual wave power ... 7-3
Figure 7-4: Tidal Energy Distribution ... 7-3
Figure 7-5: Typical semi-diurnal tidal rise and fall over nine months ... 7-4
Figure 7-6: Tidal Currents in Puget Sound ... 7-4
Figure 7-7: Typical Temperature Profile ... 7-5
Figure 7-8: Ocean Surface/Deep Water Temperature Difference ... 7-6
Figure 7-9: Annual Averaged Wave Power Levels ... 7-7
Figure 7-10: Tide Height Curve for Nassau – June 2010 ... 7-7
Figure 7-11: Locations of XBT measurements 2007 ... 7-8
Figure 7-12: Typical XBT profiles for 2002 ... 7-9
Figure 7-13: SST from NOAA satellite ... 7-9
Figure 7-14: O.W.C. Principle of Operation ... 7-10
Figure 7-15: Mutriku OWC Breakwater – Bilbao, Spain ... 7-11
Figure 7-16: Limpet 500 kW Islay-Scotland ... 7-12
Figure 7-17: OE Buoy Floating OWC, Ireland ... 7-12
Figure 7-18: Pelamis – Three 750 kW machines in Portugal ... 7-13
Figure 7-19: Wavebob - Ireland ... 7-13
Figure 7-20: OPT Device deployed in Spain ... 7-14
Figure 7-21: Oyster 200 kW device in Orkney, Scotland ... 7-15
Figure 7-22: Seabased -10 kW units, Lysekil, Sweden ... 7-15

Figure 7-23: 500 kW Tapchan, Toftestallen, Norway 7-16
Figure 7-24: The Wave Dragon Nissum Bredning Prototype........ 7-17
Figure 7-25: The basic principle of the Wave Dragon........ 7-17
Figure 7-26: Seagen 1.2 MW device Strangford , Northern Ireland........ 7-18
Figure 7-27: Open Hydro – 1 MW device, Bay of Fundy, Canada 7-18
Figure 7-28: Enemar 40 kW turbine – Messina, Italy........ 7-20
Figure 7-29: Gorlov 1 MW turbine – Uldolmok, Korea........ 7-20
Figure 7-30: Open Cycle OTEC System........ 7-21
Figure 7-31: Closed Cycle OTEC System 7-22
Figure 7-32: India 1 MW Floating OTEC Pilot Plant........ 7-23
Figure 7-33: Saga University OTEC Research Centre 7-23
Figure 7-34: Lockhead proposed 10MW floating OTEC 7-24
Figure 7-35: GEBCO Bathymetry Chart 7-25
Figure 8-1: Comparison of energy yield from ethanol production vs. utilization of the whole plant........ 8-2
Figure 8-2: Total plantation area to be managed in order to produce 40,000 t of dry biomass to feed in a power plant of 5 MWel........ 8-9
Figure 8-3: Simplified flow schematic of a typical biomass power plant 8-19
Figure 8-4: Scheme of a typical biomass power plant........ 8-19
Figure 8-5: Scheme of a water-cooled vibrating grate for biomass fuels [17] 8-20
Figure 8-6: Scheme of a bubbling fluidized bed boiler for biomass fuels........ 8-21
Figure 8-7: Scheme of a circulating fluidized bed boiler for biomass fuels........ 8-22
Figure 8-8: Sensitivity analysis regarding cost of biomass........ 8-26
Figure 9-1: Investment in renewable energy technologies in million USD by 2020 under BAU scenario for power consumption........ 9-11

3. Energy Efficiency Program

3.1 General

In this report an update of the analysis of the current energy consumption of the Bahamian sectors hotels, households and public buildings is presented.

For each object group (i.e. for hotels, households and public buildings) sample energy audits had been performed. The audits contain a representative number and selection of objects, so that the audit insights are transferable to the entire group.

For the hotels additional audits have been added to this report. Especially in the group of smaller hotels the number of samples has increased (in contrast to the first preliminary report). In addition, hotels for each class (large, mid-sized and small) have been supplied by the Bahamian Hotel Association.

The audits for public buildings were lacking input data to confirm the consistency of the energy consumption figures provided by BEC. A good indicator for consistency checks is the specific consumption per sq ft. For this Fichtner has requested floor plans from the Ministry of Works. As these floor plans were not provided, Fichtner estimated to floor area of the public buildings on the basis of satellite pictures and photos taken during the audits. In addition best practice and potentials of public buildings are presented in this report.

The description of the households has also been extended. A distinction is now made between small houses, normal households and luxury homes. Specific consumption figures and potentials for these three consumer groups are presented. Statistical data have been used to calculate the total electricity consumption of The Bahamas on the basis of the figures determined during the audits. A cross check of the audit data of the household sector shows that the figures match with the BEC annual consumption figures has been extended.

3.2 Hotel audits

Tourism is a major consumer of power in The Bahamas. The hotels consume about 40% of all electricity. Therefore energy audits for a sample of 18 hotels have been performed.

Major tourism resort development has been concentrated in the two main vacation destinations in The Bahamas: New Providence (Nassau/Paradise Island) and Grand Bahama Island. Among the Family Islands there are six Islands which alone account for 80% of total electricity consumption in the Family Islands: Bimini, Abaco, Andors, Eleuthera, Exuma and Long Island.

The sample of hotels was intended to consider the two main destinations but also hotels from the Family Island in order to get representative results.

3.2.1 Selection of hotels

Searching for the most relevant efficiency measures requires a distinction between large, medium sized and small hotels in order to identify general trends for each size category. Together with the Hotel Association the following classification and split of sample audits was agreed upon:

Classification	Number of rooms	Number of audit samples
Large	more than 350 rooms	7
Mid-sized	50 to 350 rooms	6
Small	less than 50 rooms	5
Total		**18**

Table 3-1: Classification of hotels

The list of audited hotels, see Table 3-2 with respective classification has been updated.

Hotel Name	Island Location	Number of Rooms
Large Hotels – More than 350 rooms		
Wyndham Nassau Resort	Nassau	559 rms
Sheraton Nassau Beach Resort	Nassau	694 rms
Bimini Bay Resort and Marina	Bimini	481 rms
Our Lucaya – Radison	Freeport, Grand Bahama	752 rms
Atlantis – Beach Towers	Paradise Island	423 rms
Atlantis – Coral Towers	Paradise Island	693 rms
Atlantis – Royal Towers	Paradise Island	1201 rms
MID – Sized Hotels – 50 to 350 rooms		
British Colonial Hilton	Nassau	288 rms
Blue Water Resort	Nassau	105 rms
Pelican Bay	Freeport, Grand Bahama	186 rms
Grand Isle Resort	Exuma	72 rms
Cape Santa Maria Beach Resort	Stella Maris, Long Island	56 rms
Viva Wyndham Fortuna Beach	Freeport, Grand Bahama	276 rms
Small Properties – Under 50 rooms		
Small Hope Bay Lodge	Central Andros	20 rms
Emerald Palms Resort	Driggs Hill, Andros	40 rms
Tiamo	South Andros	10 rms
Marley Resort and Spa	Nassau	16 rms
February Point	Exuma	38 rms

Table 3-2: List of audited hotels with respective classification

{

3.2.2 Methodology

After the selection of the hotels, an agenda, a brief questionnaire and a schedule for the audits have been submitted to the Hotel Association, which forwarded them together with a short description of the project to the relevant contact persons of the hotels.

The brief questionnaire is the basis for the collection of basic data (name of the hotel, location, number of rooms, year of construction, indoor area, etc.) and energy consumption data (electricity demand, fuel oil demand, LPG demand, energy costs, etc.).

While for the household audits a detailed data sheet was used to collect the required data, for the hotel audits this approach was not suitable. This is because the hotels and also the individual requirements are so different. A brief questionnaire has been used and notes have been taken during the site visit and meetings with the relevant contact persons.

At the end of each hotel audit an individual energy audit report was generated which was handed over to the manager and discussed in a close out meeting. Each energy audit report comprises:

- General information
- Data
- Observations and good practice
- Potentials

For the evaluation of the hotel audits the data gathered during the audits have been analyzed according to the classification of the hotels. Indicators which are in use in the hotel industry are used. These indicators are for example:

- Energy consumption per rented room
- Energy costs per rented room
- Electricity consumption per rented room
- Electricity costs per rented room

To refer to the number of rented rooms is a common practice in hotels (kWh/rr; with rr = rented room). This is because the costs in a hotel are related to the occupancy and can only be recovered by the rented rooms. This approach is different from the household sector or the public buildings where the indicator usually is a figure which refers to the area (kWh / sq ft).

3.2.3 Findings from hotel audits

For the findings a sample of 16 hotel audits has been evaluated. This sample comprises:

{

- 7 large hotels,
- 5 mid-sized hotels and
- 4 small hotels.

Unfortunately the needed data for Tiamo Resort and Grand Isle Resort was not submitted as agreed, so these two hotels could not be taken into account for our evaluation.

3.2.3.1 Consumption

Average energy consumption
Based on the above mentioned sample of 16 hotels, for each of the three classes (large, mid-sized and small) the average annual energy consumption in kWh per year was determined. From Table 3-3 it is obvious, that the a typical large hotel consumes about 6 times more energy than a mid-sized hotel, while the small hotels use more than 35 times less energy than the large hotels.

Hotel class	Average energy consumption	of which electricity consumption	
Large	21,448,297 kWh	19,112,593 kWh	89%
Mid-sized	3,436,393 kWh	2,507,326 kWh	73%
Small	608,703 kWh	529,427 kWh	87%

Table 3-3: Average annual energy consumption of the Bahamian hotels

A large part of the energy consumed by the Bahamian hotels is electricity. Especially in large hotels, where electricity counts for almost 90% of the overall energy consumption (see Table 3-3). In mid-sized hotels electricity has a share of about three fourth of the overall energy consumption (see Table 3-5). This means that especially in mid-sized hotels more than 25% of other energy sources are used. These energy sources are LPG and diesel. From Table 3-5 and Table 3-6 it is obvious that it is mainly LPG which is used in a significant amount for the, not by electricity covered, share of energy consumption.. Small hotels show a quite similar share of electricity consumption as in large hotels, but their LPG demand is almost double as high, compared in relative shares.

Large Hotels		
Energy Source	**Energy consumption**	**Shares**
Electricity	133,788,153 kWh	89%
LPG	7,621,651 kWh	5%
Diesel	8,728,278 kWh	6%
Total	**150,138,082 kWh**	**100%**

Table 3-4: Energy consumption of the large hotels (sample of 7 hotels)

{

Mid-sized Hotels		
Energy Source	**Energy consumption**	**Shares**
Electricity	12,536,628 kWh	73%
LPG	3,961,337 kWh	23%
Diesel	684,000 kWh	4%
Total	**17,181,965 kWh**	**100%**

Table 3-5: Energy consumption of the mid-sized hotels (sample of 5 hotels)

Small Hotels		
Energy Source	**Energy consumption**	**Shares**
Electricity	2,117,708 kWh	87%
LPG	284,983 kWh	12%
Diesel	32,120 kWh	1%
Total	**2,434,810 kWh**	**100%**

Table 3-6: Energy consumption of the small hotels (sample of 4 hotels)

Specific energy consumption per rented room

The specific energy consumption per rented room varies a lot (see Figure 3-2). It is between 47 kWh/rr and 335 kWh/rr. This wide range comprises small and large luxury hotels with spa, pools, casino, several kitchens but also simpler and energy efficient hotels. According to the chosen methodology the total energy consumption of the hotel is considered, that means that the energy consumption of all the additional features (pool, spa, etc,) has to be added to the actual energy consumption of the guest in the guest room itself.

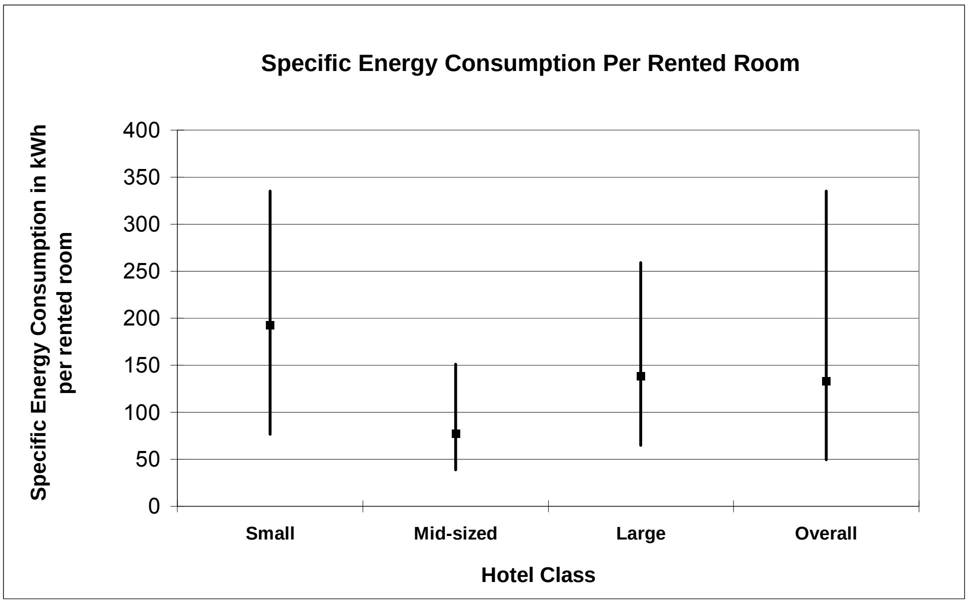

Figure 3-1: Specific energy consumption in kWh per rented room

From the preliminary evaluation one could draw the conclusion, that the small hotels are the less efficient ones, while the most efficient hotels are the mid-sized hotel.

Nevertheless smaller hotels might have a higher specific energy consumption due to the following reasons:

{

- base load from kitchen, pool, spa, etc;
- lower occupancy;
- they usually do not have specialized staff which cares for energy, their staff usually has multiple functions.

For mid-sized hotels the average specific energy costs per rented room are in the range of 10 to 30 $/rr. Large hotels range between 20 to 70 $/rr and for small hotels we have found an even wider range.

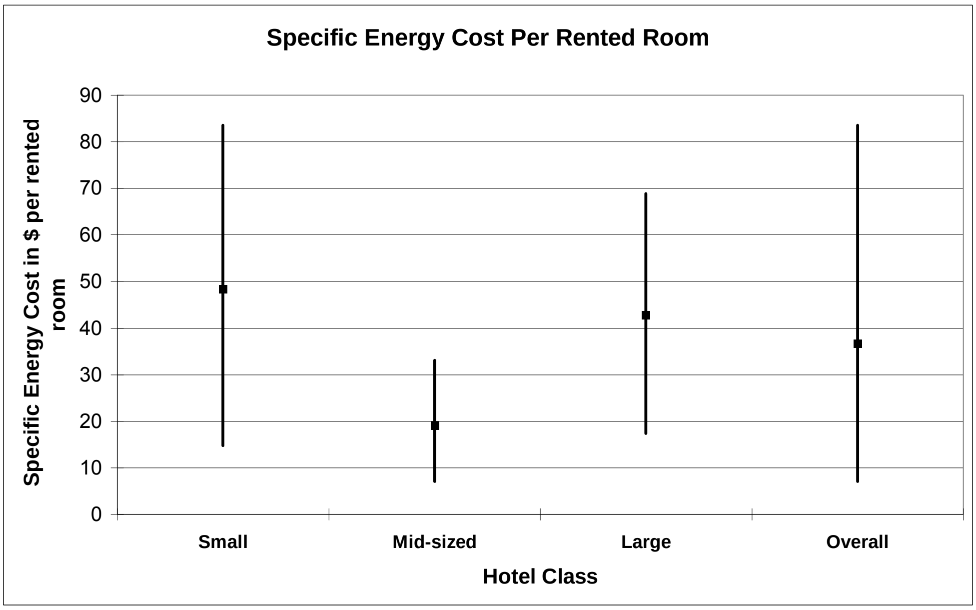

Figure 3-2: Specific energy costs in $ per rented room

Plausibility check

Having analyzed the average and specific energy consumption of the audited hotels according to the selected classification, a plausibility check of the calculated figures is required. This plausibility check is intended to answer the question, how representative the sample of audited hotels is for all hotels on The Bahamas.

For the plausibility check the average electricity consumption per class is used. By multiplying this average figure with the respective number of hotels in this class, the total electricity demand for the Bahamian hotels can be determined.

Comparing it with the figures from BEC the reported consumption allows checking the plausibility of the calculated figure. The assumption is that all hotels belong to the group of large consumers of BEC.

{

Plausibility check	Average electricity demand per hotel	Number of hotels	Total calculated electrcity comsumption
Large	19,112,593 kWh	11	210,238,526 kWh
Medium	2,507,326 kWh	37	92,771,047 kWh
Small	529,427 kWh	229	121,238,783 kWh
Total		**277**	**424,248,357 kWh**

Table 3-7: Calculation of the total electricity consumption of the Bahamian hotels

On the basis of the average electricity consumption of the audited hotels a total annual electricity consumption of The Bahamian hotels of 424,248,357 kWh per year can be calculated.

The annual electricity consumption of the group of large commercial consumers in the period of October 2008 to September 2009 amounts 524,752,934 kWh. If the calculated electricity consumption is divided by the reported consumption figure, it can be seen that the calculated figure accounts for 81% of the reported figure. This is plausible, as hotels might not be the only consumers which fall into the category of large commercial consumers. Nevertheless, hotels represent the majority of large consumers.

The plausibility check indicates that the audited hotels are representative for the other hotels on The Bahamas and therefore can be seen as a good indicator for defining energy saving potentials for this sector.

Contribution of the different energy sources

While most of the energy consumption in the Bahamian hotels can be assigned to electricity consumption for

- air conditioning,
- lighting,
- cooling purposes (fridges, freezers),
- and other appliances

also LPG (liquefied petrol gas) and diesel is used. LPG is often used in kitchens and for water heating. In some cases also diesel is used for water heating and steam generation (e.g. for the laundry).

Figure 3-3 shows the contribution of the energy sources for the energy supply of the 16 sample hotels which have been evaluated. 87% of the energy consumed in the 16 hotels is electricity, 7% is LPG and 6% is diesel.

{

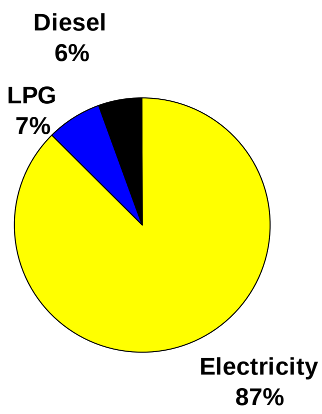

Figure 3-3: Share of the different sources in the energy supply of the hotels

Typically small and mid-sized hotels have a higher LPG share. In some of those hotels LPG contributes with 20% to sometimes even more than 30% to the overall energy consumption. In those cases LPG is mainly used in the kitchen (stove, oven, grill, deep fryer), for hot water preparation and in the laundry (dryer).

There is only one mid-sized and one large hotel which have a significant share of diesel in the range of 10% to 20% of their energy consumption. These hotels use diesel for hot water and steam generation. In all other hotels diesel is only used for the emergency generator and counts for only a few percent of the hotels' overall energy consumption.

Share of the biggest electricity consumers

Most of the hotels do not distinguish between the different appliances. They also do not have separate meters for the different appliances. Therefore, we were not able to get metered data for the electricity consumption of the appliances, not even the main appliances. These main appliances are: air conditioning, lighting, hot water generation and the kitchen.

During the energy audits we therefore asked the responsible technical personnel about their estimate of how much electricity is used for what. A result of that survey is presented in Table 3-8.

Appliance	Share of electricity consumption
Air conditioning and ventilation	about 50%
Hot water generation	17% to 25%
Lighting	n. a.
Kitchen	10% to 15%

Table 3-8: Share of electricity consumption in air conditioned hotels

There are some ecological hotels which do not use air conditioning at all or only very limited. For those hotels the share of electricity consumption looks very different (see Table 3-9).

{

Appliance	Share of electricity consumption
Air conditioning and ventilation	about 5%
Hot water generation	40% to 45%
Lighting	n. a.
Kitchen	25% to 35%

Table 3-9: Share of electricity consumption in ecological hotels

3.2.3.2 Good practice

Table 3-10 gives a comprehensive overview about the good practice which we have found during the hotel energy audits and also an indication of how often this good practice is applied.

		Observations and good practice																												
No.	Classification	Natural ventilation	Sun curtains	Roof eaves	Natural shading	Light colored roofs	Fans	Energy Saving Bulbs	Use of time glocks for lighting	PV lights für path lighting	Seawater cooling	PV - installed capacity (kW)	PV - actual production (kWh)	Solar water heaters	Cold water washing	LPG/Propane Dryer	Some Appliances are running on LPG	Non heated pools	Efficient hot water generation (propane,	AC: good set point / good calibration	Non-permanent usage of AC	AC: motion detectors	Awareness of staff	Maintenance	Monitoring of appliances	Monitoring of electricity consumption	Energy Management System
01	M		x	x				x								x		x		x							
02	L		x	x	x			x	x	x	x												x	x	x	x	x
03	L							x		x	x						x			x		x	x	x			
04	L							x		x	x						x			x		x	x	x			
05	L							x		x	x						x			x		x	x	x			
06	S	x	x				x	x								x		x	x				x				
07	L		x		x			x										x					x			x	
08	M	x	x		x	x		x		x					x	x	x						x			x	
09	M							x	x		x						x		x	x		x	x	x			x
10	L							x			x						x		x	x	x	x	x	x			
11	M	x						x								x	x	x		x			x		x		
12	M	x	x					x									x									x	
13	L		x					x									x						x			x	
14	S				x	x	x	x						x		x	x	x		x	x	x	x				
15	S	x	x		x	x	x	x																x			
16	S	x			x	x		x						x			x				x		x				
17	S	x			x	x						12.96	0	x		x	x	x	x				x				
18	M	x	x		x	x	x		x						x		x						x	x			

L = Large Hotel, M = Mid-sized Hotel, S = Small Hotel

Table 3-10: Overview of good practice in hotels

3.2.3.3 Potentials

The following potentials have been identified during the energy.

Use of passive measures

- Improve the usage of natural shading and natural ventilation
- As new buildings are planned the measures for new buildings described in section 3.4.7.1 should be considered

{

No invest measures

- Reduction of circulation of pool pump if possible
- Awareness campaign (in house and for guests)
- Regular check of temperature of cooling devices (fridges, freezers)
- Increase of standard set point of the A/C unit in guest rooms – of course the guest can change the setting, but after he leaves, the standard set point should be chosen (requires training of housekeeping)
- Switching off appliances which are not in use (e.g. fridge in the guest room if not rented)
- Regular maintenance of all technical appliances

Small installations (low cost measures with payback period up to 1 year)

- Installation of switches to allow appliances to be easily switched off during off season
- Replacement of incandescent bulbs (with a daily usage of more than 6 hours) with CFL's
- Shading of chillers to improve efficiency of air conditioning system

Installation of intelligent systems and monitoring

- Installation of motion detectors
  - to switch off lights if guest leave the room
  - to switch off air conditioning if window is open
  - to increase set point if room is not occupied
- Monitoring of technical appliances
- Monitoring of energy consumption

Change of energy source

- Usage of solar absorbers for pool heating (instead of electrical heating)
- Usage of solar hot water heaters, e.g. for preheating of the water or for laundry
- Usage of LPG or diesel for hot water generation (instead of electrical heating)
  - In 2009 LPG costs were 60% of electricity costs
  - In 2009 diesel costs were only 25% of electricity costs
- Seawater cooling for chillers of the central air conditioning system

Reduction of electricity demand for desalination

- Water saving by the usage of special fittings, e.g. mixing in air at the faucet or in the shower
- Grey water reuse for the garden and parks

An assessment of the electricity saving potentials for the three classes of hotels is presented in Figure 3-4. The basis for this rough estimation of the minimum electricity saving potential is the difference between the average electricity consumption and the benchmark.

{

For the benchmark the best practice can be used. As hotels are very different (some have spa, restaurants for external guests, water park etc., while others don't have), the best practice we have seen is most probably not achievable for all other hotels without loss of comfort and quality. Therefore as benchmark a 10%-quantile has been applied. The 10%-quantile defines the one value of a sorted list which just covers the lowest 10% of the observation's mass.

Taking e.g. the best practice for mid-sized hotels, it would result in a benchmark of 22 kWh per rented room, which is a very low figure. The 10%-quantile defines a benchmark of 31 kWh per rented room. According to our experiences the 10%-quantile benchmark is a more realistic figure.

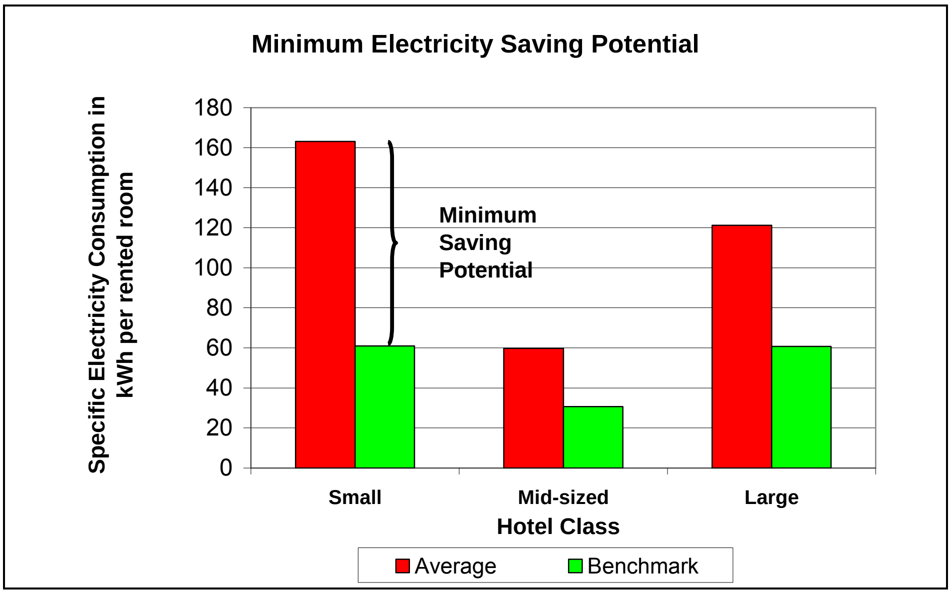

Figure 3-4: Assessment of the electricity saving potential in the different hotel classes

The electricity saving potential of the three different hotel classes in percentages are presented in Figure 3-4. They are between 49% and 63%. A prognosis of the electricity saving potential for the Bahamian hotels is also presented in Table 3-11. For this prognosis the total electricity demand per class is multiplied with the percental saving potential.

Saving Potential	Total calculated electrcity comsumption	Saving potential [%]	Total saving potential
Large	210,238,526 kWh	50%	105,005,485 kWh
Medium	92,771,047 kWh	49%	45,238,363 kWh
Small	121,238,783 kWh	63%	75,987,428 kWh
Total	**424,248,357 kWh**	**53%**	**226,231,276 kWh**

Table 3-11: Total electricity saving potential of the hotel sector

On the basis of the hotel audits for the Bahamian hotel sector an electricity saving potential of more than 53% has been identified. As a result more than 226 million kWh of electricity could be avoided every year.

{

3.3 Public buildings

Public buildings count for about 10% of the electricity consumption in The Bahamas. It was foreseen that Fichtner performs a sample of ten energy audits to analyse the energy efficiency of government offices and institutions.

For the selection of the public buildings and the arrangement of the audit program Fichtner was supported by BEST.

3.3.1 Selection of public buildings

On November 26, 2009 the Ministry of Public Works & Transport sent a list of recommended buildings for energy audit to BEST. This list comprised 40 public buildings on different islands and for different use.

On December 7, 2009 an energy audit for the Anatol Rodgers High School was performed. On this day also Minister of State for the Environment Phenton Neymour was present. This first energy audit of a public building was in the news and on TV.
During the hotel audit on Bimini Fichtner was asked also to visit the local governmental administration building on Bimini, which in 2009 was the second public building. Mainly at the end of the hotel audit campaign in 2010, ten additional public buildings have been visited by our expert Dr. Sven Eckardt. This means, that in total 12 public buildings have been audited.

The following list gives an overview about the 12 audited public buildings.

DATE OF AUDIT	NO.	USE	BUILDING
12/7/2009	1	School	Anatol Rodgers High School
12/10/2009	2	Office	Bimini Administration Building
1/13/2010	3	Office	Ministry of Works
5/2/2010	4	Office	Churchill Building - Cabinett Office
	5	Office	House of Assembly/Senate
6/2/2010	6	Post Office	Main Post Office
	7	Clinic	Clinic Elisabeth Estates
8/2/2010	8	School	Uriah Mc Phee School
	9	Hospital	Geriatrics Hospital
9/2/2010	10	Office	Ministry of Education HQ
10/2/2010	11	Clinic	Clinic Gambier
	12	School	S C Mc Pherson School

Table 3-12: List of audited public buildings with respective use

3.3.2 Methodology

BEC has provided monthly energy consumption data for selected meters. These data are intended to be used to visualize the monthly energy consumption of the public buildings.

To make the energy consumption of the very different public buildings comparable, the specific energy demand in kWh/sq ft can be used as an indicator.

To determine the specific energy demand in kWh/sq ft the effective area of the public buildings is required. Unfortunately no floor plans to determine the effective area was provided by the Ministry of Works. To estimate the floor area of each of the public buildings Fichtner did some additional effort.

Based on satellite pictures, the roof area for each building was measured and was equated to the base area. The total floor area of a building could be determined by multiplying the number of stories with its base area. To avoid an over estimation a reduction factor needed to be introduced,. To calculate the total floor area one needs to take into account, that the outer walls and the interior layout reduce the total space significantly. Regarding to the German Energy Saving Directives a reduction factor of 25% must be applied. A reduction factor of the same size has been applied for The Bahamas. The total floor area of a building is an important indicator to get an idea of the dimension of energy consumption and it is also needed to calculate the energy efficiency of the total sector.

3.3.3 Findings from public building audits

As described in the methodology one main input for the energy audits are the floor plans. Unfortunately until today Fichtner still has not received the floor maps of most of the public buildings. Therefore, the evaluation of the collected data can only be based on a rough estimation.

3.3.3.1 Estimation of floor area

<u>Ministry of Work & Transport</u>

Figure 3-5: Aerial view and front view of the Ministry of Works & Transport

The roof area of the building of the Ministry of Works & Transport amounts to 11,630 square feet which is equal to its base area. To get the total floor area, the obtained base area must be multiplied with the 4 levels of the building, as seen in the picture on the right. Subsequently the total area needs to be reduced by 25%.
Finally the estimated total floor area of the Ministry of Works & Transport adds up to 34,891 square feet.

Cabinet Office (Churchill building)

Figure 3-6: Aerial view and front view of the Cabinet Office

The roof area of the building of the Cabinet Office amounts to 14,741 square feet which is equal to its base area. To get the total floor area, the obtained base area must be multiplied with the 4 levels of the building, as seen in the picture on the right. Subsequently the total area needs to be reduced by 25%.
Finally the estimated total floor area of the Cabinet Office adds up to 44,222 square feet.

House of assembly

{

Figure 3-7: Aerial view and front view of House of Assembly

The roof area of the building of the House of Assembly amounts to 5,926 square feet which is equal to its base area. To get the total floor area, the obtained base area must be multiplied with the 2 levels of the building, as seen in the picture on the right. Subsequently the total area needs to be reduced by 25%.
Finally the estimated total floor area of the House of Assembly adds up to 8,889 square feet.

<u>Main Post Office</u>

Figure 3-8: Aerial view and front view of the Main Post Office

The roof area of the building of the Main Post Office amounts to 37,133 square feet which is equal to its base area. To get the total floor area, the obtained base area must be multiplied with the 7 levels of the building, as seen in the picture on the right. Subsequently the total area needs to be reduced by 25%. Finally the estimated total floor area of the Main Post Office adds up to 194,948 square feet.

<u>Elisabeth Estate Clinic</u>

Figure 3-9: Aerial view and front view of the Elisabeth Estate Clinic

The roof area of the building of the Elisabeth Estate Clinic amounts to 9,191 square feet which is equal to its base area. To get the total floor area, the obtained base area must be multiplied with the number of levels of the building which in this case is only the floor level, as seen in the picture on the right. Subsequently the total area needs to be reduced by 25%.
Finally the estimated total floor area of the Elisabeth Estate Clinic adds up to 6,893 square feet.

Uriah McPhee Primary School

Figure 3-10: Aerial view and front view of Uriah McPhee Primary School

The roof area of the building of the Uriah McPhee Primary School amounts to 22,148 square feet which is equal to its base area. To get the total floor area, the obtained base area must be multiplied with the 3 levels of the building, as seen in the picture on the right. Subsequently the total area needs to be reduced by 25%.
Finally the estimated total floor area of the Uriah McPhee Primary School adds up to 49,832 square feet.

Geriatrics Hospital at the Sandilands

{

Figure 3-11: Aerial view and front view of the Geriatric Hospital

The roof area of the building of the Geriatric Hospital amounts to 29,635 square feet which is equal to its base area. To get the total floor area, the obtained base area must be multiplied with the 2 levels of the building, as seen in the picture on the right. Subsequently the total area needs to be reduced by 25%.
Finally the estimated total floor area of the Geriatric Hospital adds up to 44,452 square feet.

<u>Ministry of Education</u>

Figure 3-12: Aerial view and front view of the Ministry of Education

For the Ministry of Education the floor plans were provided by the Bahamian administration indicating a floor space of 32,000 square feet per level. The building has 3 levels, so that the total floor space adds up to 96,000 square feet.

<u>McPherson Junior High school</u>

{

Figure 3-13: Aerial view and front view of McPherson Junior High School

The roof area of the building of the McPherson Junior High school amounts to 46,949 square feet which is equal to its base area. To receive the total floor area, the obtained base area must be multiplied with the 2 levels of the building, as seen in the picture on the right. Subsequently the total area needs to be reduced by 25%.
Finally the estimated total floor area of the McPherson Junior High school adds up to 70,424 square feet.

<u>Bimini Administration building</u>

Figure 3-14: Aerial View and front view of the Bimini Administration Building

The roof area of the building of the Bimini Administration building amounts to 5,000 square feet which is equal to its base area. To get the total floor area, the obtained base area must be multiplied with the number of levels of the building which in this case is only the floor level, as seen in the picture on the right. Subsequently the total area needs to be reduced by 25%.
Finally the estimated total floor area of the Bimini Administration building adds up to 4,000 square feet.

Table 3-13 gives an overview about the estimated floor area of the public buildings.

Public building	**Floor area [square feet]**
Ministry of Work & Transport	34,892

{

Cabinet Office (Churchill building)	44,222
House of assembly	8,889
Main Post Office	194,948
Elisabeth Estate Clinic	6,893
Uriah McPhee Primary School	49,832
Geriatrics Hospital at the Sandilands	44,452
Ministry of Education	96,000
Mc Phearson Junior High school	70,424
Bimini Administration building	4,000
Anatol Rodgers High School	50,232
Clinic Gambier	n.a.

Table 3-13: Summary of public buildings´ total floor area

It should be mentioned here, that it would be better to have to accurate figures from the Ministry of Waste on the basis of the floor plans.

3.3.3.2 Consumption

One of the findings for **small public buildings** is that these buildings are not so different from residential homes. In comparison to residential buildings besides air conditioning the small public buildings usually do not have any significant cooling demand (refrigerator, freezer). Also the energy demand for hot water preparation is very low. As end energy in small public buildings mainly electricity is used for the following main appliances:

- Air conditioning (mainly wall mount units)
- Lighting
- Computer, printers, Fax
- Other electronic devices

A split of the use of electricity in small public buildings is presented in the figure below.

{

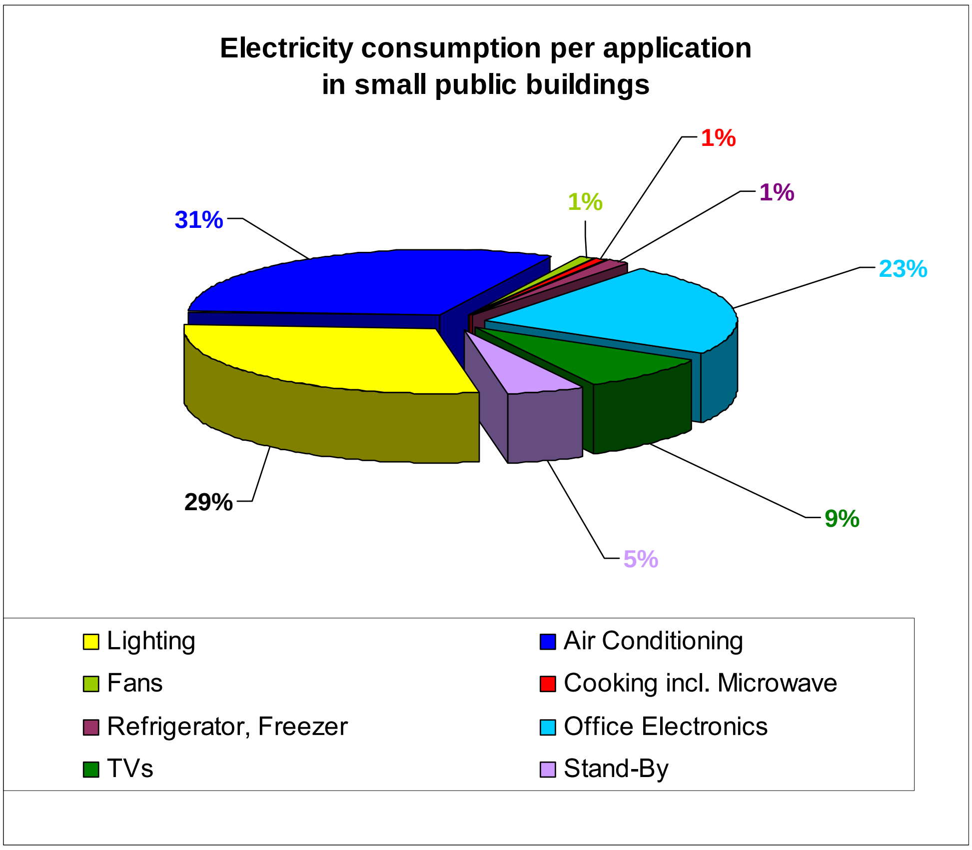

Figure 3-15: Split of electrical usage in smaller public buildings

According to our findings the largest consumers are:

- Air conditioning (31%)
- Lighting (29%)
- Office electronics – mainly computers (23%)

These three appliances account for more than three fourth of the overall electricity consumption.

The specific electricity consumption of the small public buildings is between 16 to 20 kWh/sq ft and year.

As most of the floor plans are still missing, useful indicators, as for example the energy consumption per sq ft were not included in the preliminary findings of the last report. For this report the floor areas have been estimated by Fichtner, which allows to roughly assess the specific energy consumption per sq ft.

The monthly consumption data from BEC were assigned to the respective public buildings.

Figure 3-16 and Figure 3-16 show annual electrical load curves of the several public buildings.

{

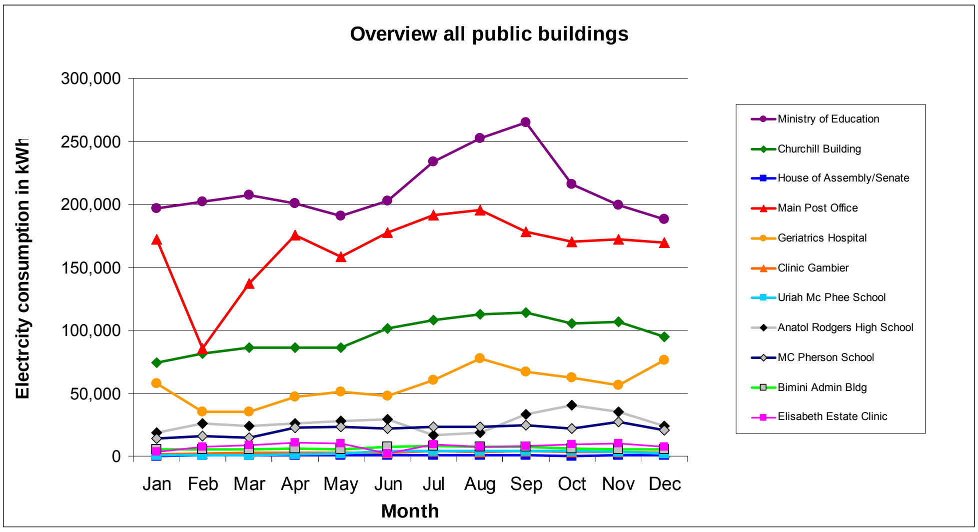

Figure 3-16: Electrical load curve of public buildings

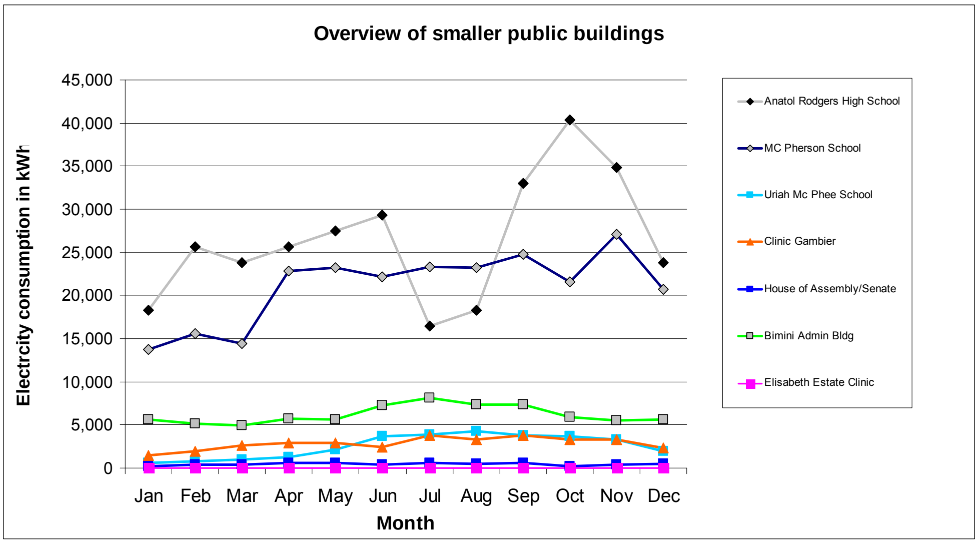

Figure 3-17: Electrical load curve of small public buildings

The annual electricity consumption in KWh per year of the audited public buildings is presented in Figure 3-18.

{

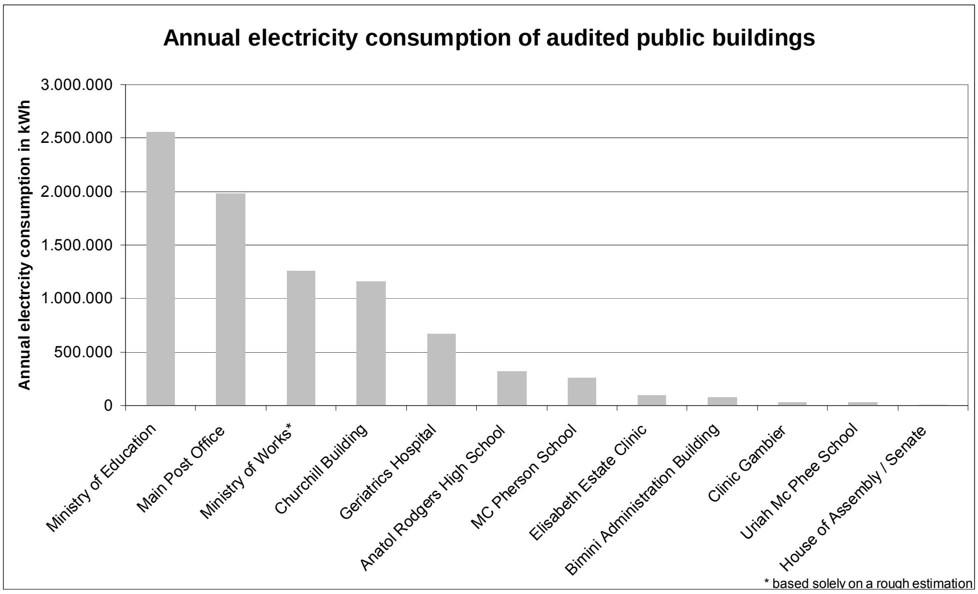

Figure 3-18: Electricity consumption of audited public buildings

For the Ministry of Works only the consumption of one month from August to September has been supplied. On the basis of this solely figure the annual consumption was estimated by Fichtner. It therefore has to be taken in mind, that the electricity consumption figure of the Ministry of Works has to be treated with care and that there is a certain uncertainty with this estimated figure.

Specific consumption figures have been determined by dividing the monthly consumption in kWh by the estimated floor area in sq ft. This is presented in Figure 3-21 and Figure 3-22.

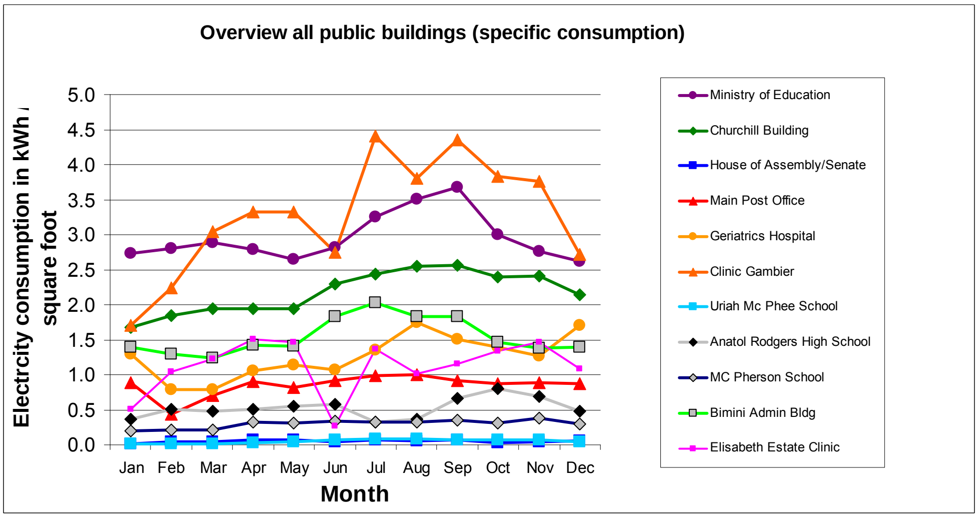

Figure 3-19: Specific electricity consumption per square foot

{

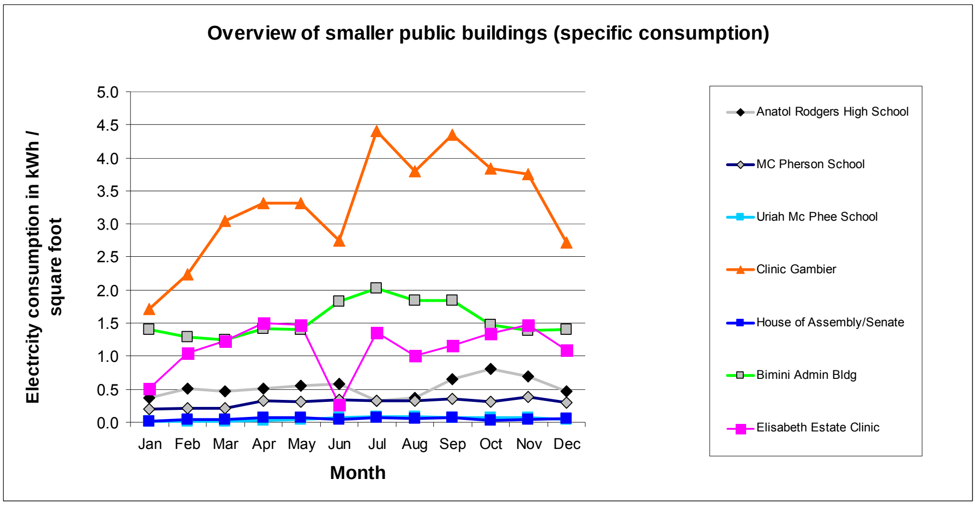

Figure 3-20: Specific electricity consumption per square foot for small public buildings

Figure 3-22 compares the specific annual consumption figures of the audited public buildings. They range from about 1 kWh/sq ft for the House of Assembly (which is very seldom used) to more than 25 kWh/sq ft. The specific annual consumption of the Ministry of Works is only based on every rough estimation. As this figure is very uncertain, it is not considered in the following evaluation. An average figure is between 10 and 20 kWh/sq ft. It is also obvious that schools which are not in use the whole summer and which are usually only partly cooled consume much less than fully air conditioned buildings with many windows exposed to the sun.

From Figure 3-22 it is also obvious that the Uriah Mc Phee School does fall completely out of the other specific figures. This confirms our concern that the consumption figures for this building are not consistent.

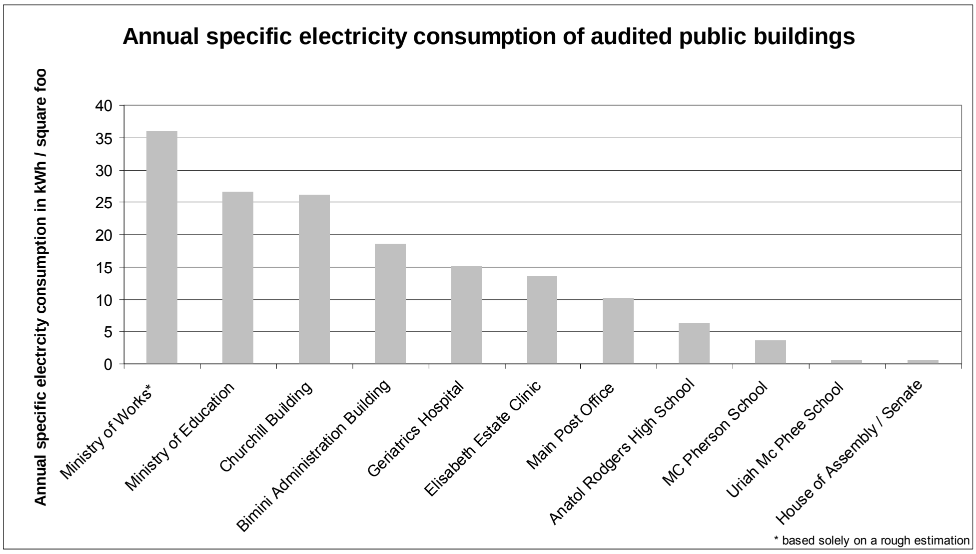

Figure 3-22: Specific electricity consumption per square foot of audited public buildings

{

While taking a closer look on Figure 3-22 and Figure 3-23, one can see that the three audited schools show some of the lowest monthly and lowest annual consumption figures of all surveyed public buildings. The specific monthly figures are ranking between 0.3 to 0.9 kWh / sq ft. Only Uriah McPhee Primary school shows a significant lower consumption per square foot which should be focused on. When having a look on Figure 3-17 the discrepancy in energy consumption becomes even more obvious. While Anatol Rodgers High school and McPherson Junior high consume 317,166 kWh and 252,640 kWh in 2009, McPhee Primary school comes to an alleged energy consumption of only 30,263 kWh in the same timeframe. Fichtner came to the conclusion that there must be some inconsistencies in the supplied load patterns.

One reason to explain this immense difference of almost ten times lower consumption figures compared to the other schools, could be a mistake in the supplied data. It is conceivable that in McPhee Primary school might be more than one power meter installed and BEC might accidentally missed to send data for all of them.

As the school building is 100% air conditioned it could be that the air conditioners, which are assumed to contribute the majority to the buildings energy consumption, have their own meters, which are not scheduled by BEC.

3.3.3.3 Good practice

Good practice was found in some of the audited public building. The following section shows some of the applied good practices in the public buildings of The Bahamas.

Figure 3-21: "Light coloured office building with partial shading by eaves"

Colouring, shading and planting to minimize heat gains:

- Several buildings had light coloured walls and light coloured, reflective roofs to minimise heat gains due solar radiation what reduces the cooling load.

- Roof eaves were used in some buildings for partial shading of walls. This measure to reduce heat gains is most effective when applied on the south side of the building.

Figure 3-22: "Light coloured school building shaded by a tree"

- Within the direct surrounding of some buildings trees and other medium and tall plants have been planted to shade the building, absorb solar radiation and cool the area by evapotranspirational effects.
- Most buildings used devices such as hurricane shutters or curtains to reduce heat gains through the windows. These measures are most effective when applied on the outside of the windows

Air conditioning:

- Some of the audited buildings placed the chiller of centralised air conditioning system in a shaded or partially shaded area. One building shaded even the chiller of a decentralised unit. Shading the A/C system reduces its energy consumption.

Figure 3-23 "Building with hurricane shutters and shaded decentralized A/C system"

{

- Operating the A/C system only when necessary also saves electricity. For example at least one of the audited schools switches the air conditioning off during the summer break but keep operating it during the weekend because of difficulties to restart the system.
- The temperature control should be covered to prevent a change of the default temperature by unauthorised staff. Still should the possibility to activate and deactivate the air conditioning according to personal needs be provided.

Lighting and electrical consumers

- One of the audited buildings used at least for the outer lighting partially energy saving lights. These bulbs can save several percent of the total electricity used for lighting.

Figure 3-24 : **"**Power outlet strip with on/off switch"

- Power strips equipped with an on/off switch as applied in some of the audited buildings can reduce electricity costs caused by standby consumption.

3.3.3.4 Potentials

The following summary shows some potential of our preliminary findings. Most of them are not quantified until now:

- Shading of windows - if possible - to avoid too much heat influx
- Natural ventilation during night - if possible
- Awareness of employees
- Energy saving competition between departments (if they do have separate meters) or between different buildings
- Temperature setting of the air conditioning at about 72°F to 73°F
- Adjustment of the temperature profile and control dependent on occupation, season, and time of the day
- Insulation of ceilings
- Insulation of air ducts to reduce cooling demand
- Fluorescent T12 tubes to be replaced by conventional T8 tubes (-15%)

{

- Fluorescent T12 tubes to be replaced by efficient T8 tubes with good reflectors (-40%)
- Energy saving bulbs instead of incandescent bulbs
- Presence detectors for lighting (-10% to -30%)
- Clock timers for lighting
- Daylight control
- Switchable multi socket outlets, to switch of electronic devices during night and to avoid stand by losses (-5% to – 10%)
- Energy saving electrical devices e.g. computers reducing also the heat load in air-conditioned areas.

- "50:50 project" in schools. The objective of a so called "50:50 project" is to sensitize the students for the energy topic. E.g. they should lean to close the window if the AC is in operating, they should switch off lights during times when they are not in the class room to save energy. As an incentive 50% of the achieved annual energy savings (measured against the baseline) should be given to school for its disposal. The remaining 50% are for the board of education which is paying the energy bills. To start such a project a training of the students is required.

- A calculation of the annual energy consumption with measures to reduce the energy consumption should be a mandatory part of the design phase of all new public buildings to avoid design errors. One bad example is the new gym of the Anatol Rodgers Junior High School.

If the air conditioning in the gym is running, it will waste a lot of energy, because the flow of the cold air was not taken into account. A portion of the cool air from the top will directly disappear through the hurricane shutter which are mounted only about 4 to 6 ft above the ground.

3.4 Household audits

Besides tourism the residential sector is another major consumer of power in The Bahamas. Households consume another 40% of all electricity. Therefore energy audits for a sample of 18 representative households have been performed.

Sample audits have also been undertaken with households in a similar manner as for hotels and public buildings. In principle similar options of efficiency improvements can be considered.

3.4.1 Selection of households

In order to obtain a representative picture about energy consumption patterns and efficiency options in Bahamian households a sample of 18 household audits from several islands was foreseen. During the kick-off it was agreed to consider only households on New Providence, as part of the selection of households will also be representative for Grand Bahamas and the family islands.

The Ministry of Environment provided a map of New Providence with 40 stochastically selected households in four different zones. Our local partner CCG contacted the listed persons by phone and tried to arrange the audits. Unfortunately the response was very disappointing. In accordance with Fichtner our local partner CCG contacted additional other home owners in the predefined four zones. Based on these contacts CCG was able to identify the required number of households.

For each zone five households were audited.

3.4.2 Methodology

A questionnaire has been designed for the data collection during the energy audits. This questionnaire is split into the main issues:

- General information
- Building information
- Electricity consumption
- Additional information

In addition to the questionnaire a help file has been developed to help the auditor to fill in the questionnaire. This help elaborates for example how the living area can be estimated and what types of material for walls, roofs, floor and windows to select. Another important issue is the electricity consumption. Many households do preserve their electricity bills. If the electricity consumption of one month or even only the average monthly

{

costs are available, the help file provides methods to estimate the annual electricity consumption.

In addition most of the audited home owners signed a “no objection agreement” with CCG that allows CCG to access the historical electricity consumption data from BEC. After receipt of the BEC data Fichtner was not able to assign all of the data to the audited households. In those cases were it was not possible, Fichtner has used the data which were received during the audits.

The monthly consumption figures allow to distinguish between ‘base load’ for lighting, hot water production, computers, TV, washing machine, refrigerator, freezer, etc. and ‘cooling load’ for the air conditioning system.

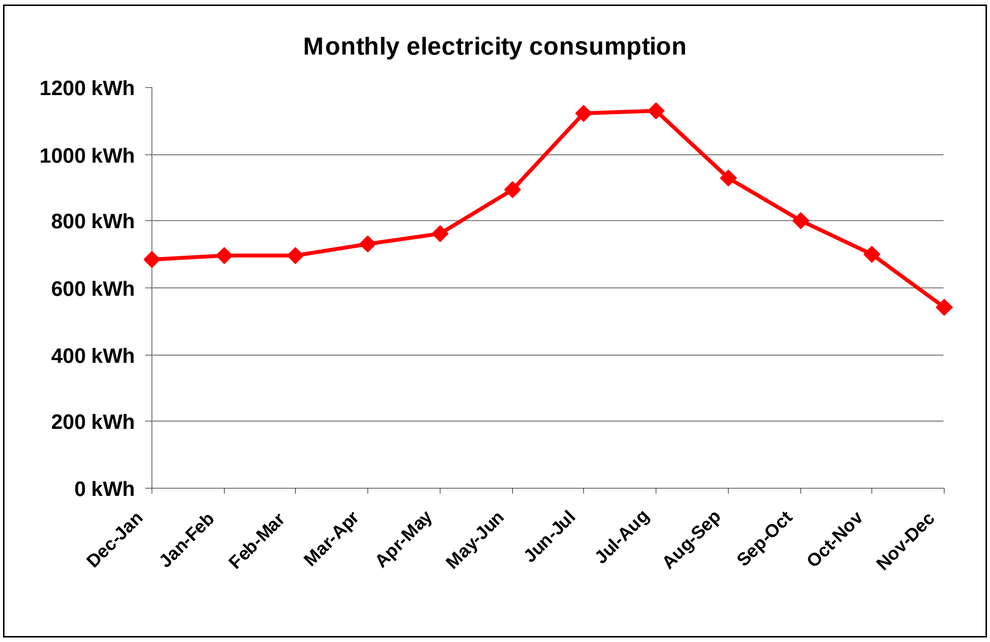

Figure 3-25: Typical load curve of a household with cooling demand in summer

3.4.2.1 Analysation of the audits

Based on the information gathered in the questionnaire Fichtner calculates the theoretical electricity load of each household. This calculation starts with the determination of the ‘base load’, which is based on average electrical power figures (in Watt) per appliance and individual usage hours.

The calculated electricity consumption figure for ‘base load’ is then adjusted with the actual ‘base load’ consumption. This is a recursive process, as each new audit allows to improve the quality of the average power figures. If for example home owner A uses appliance X while home owner B does not have this kind of appliance at all, our methodology allows to determine the consumption of the appliance X. Dividing the consumption in kWh by the average usage hours results in the average power in Watt.

{

Another approach to quantify the average electrical power of the different appliances is the provision of power meters. These power meters have been purchased by Fichtner in the United States. The power meters are available at CCG and they allow to determine:

a) the electrical power in Watt (in operation / in stand by),
b) the electricity consumption in kWh (e.g. per washing cycle).

CCG lend the power meters to the audited households together with a data sheet for the measured figures.

The ‘cooling load’ is the difference between the ‘calculated base load’ and the total consumption (see Figure 3-26).

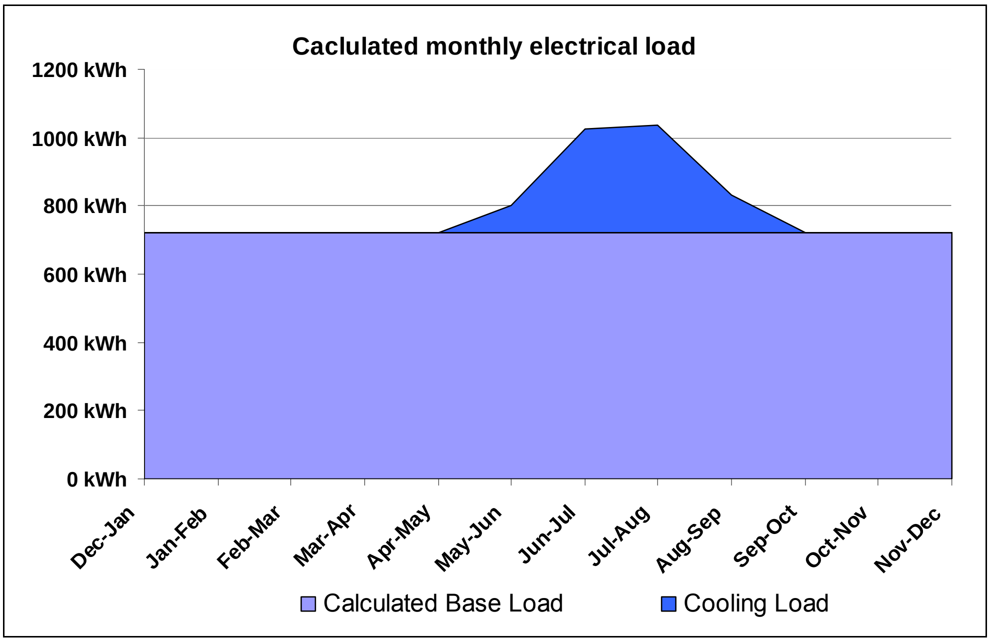

Figure 3-26: Calculated monthly electrical load of a typical household

This cooling load can then be cross checked with the information from the questionnaire about the cooled area, the cooling period and the characteristics of the house (shading, etc.).

A useful indicator for the evaluation of the data and the presentation of the results is the specific energy consumption per sq ft, but also per sq ft and inhabitant.

At the end of the evaluation of all households audits for each household an individual report is generated showing the actual load curve and the split of the consumption according to the different appliances. Also individual energy saving measures are presented. These reports will then be submitted to the home owners.

{

3.4.2.2 Interpretation of the collected data

The results of the audits suggested a division of all households into three consumer types:

a) Luxury homes
b) Normal houses
c) Small households

Furthermore, the category of normal houses is divided into three categories corresponding to the number of inhabitants per household:

I. 1 to 2 inhabitants;
II. 3 to 7 inhabitants;
III. 8 and more inhabitants

Households with less than 6 members and an annual income above 100,000 $ and those with one or two members and more than 80,000 $ per year are considered as "Luxury homes". Small households comprise all of those that dispose of less then 15,000 $ yearly. All other households are considered to be "Normal houses".

To identify total saving potentials, these different consumer types are than correlated with adopted data from the last published census of the Bahamian population from 2000. We estimate that even though the population has grown in the order of about ten per cent, the categories itself have stayed unchanged as seen in Figure 3-27. In 2007 the incomes were higher than in 2000 but they changed back until 2009, probably due to the economic crisis. Within the group of households between 20,000 and 80,000$ there have been changes of the distribution which are not further investigated in regard to our calculations since they all take place within the group of normal houses.

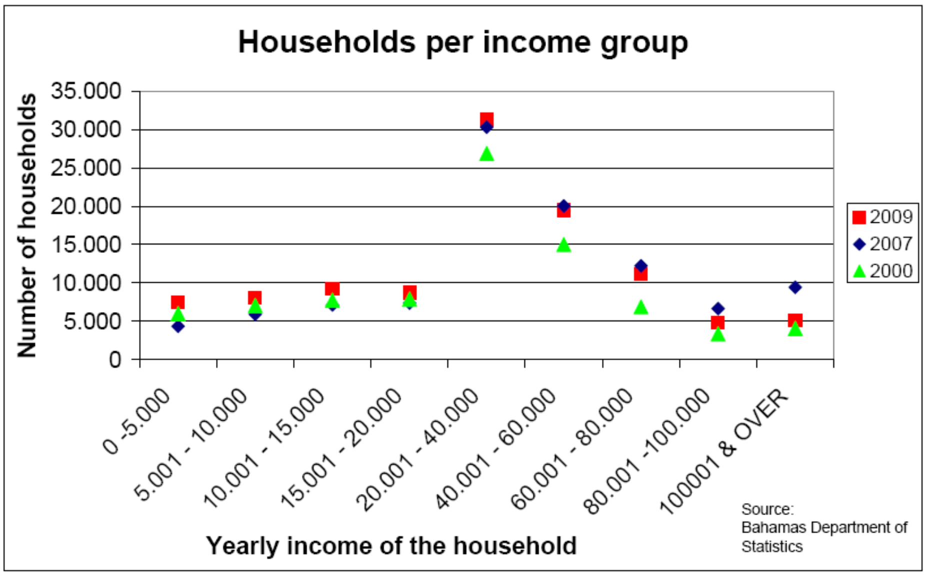

Figure 3-27: Households per income group

{

The calculated numbers of households are than broken down to the inhabitants leading to a number of inhabitants per consumer type and category. These inhabitants are multiplied with the average consumption attributes found in the audits in order to estimate the total consumption characteristics of the whole population.

Type	**Households**	**Inhabitants**	**Inhab./Household**
Luxury homes	3,099	12,176	3.93
Normal houses	63,888	265,344	4.15
Small households	20,755	54,772	2.64

Table 3-14: Estimated no. of inhabitants and households 2008

To quantify saving potentials the “best user” is identified for each application and used as a benchmark. Furthermore, a theoretical saving potential is proposed which is based on state of the art techniques and expedient use of passive measures.

3.4.3 Main findings from household audits

The houses are very different in size and in standard. A large luxury house consumes about 3 to 5 times more electricity than a smaller normal house. We distinguish between luxury homes and normal houses according to following criteria.

		Luxury Homes	Normal living Houses
Hard Criteria	Typical Specific Yearly Electricity per sq ft and pp	> 2,50 kWh / (sq.ft.* inhab.)	< 1,50 kWh/ (sq.ft.* inhab.)
	Yearly Electricity Consumption	> 20.000 kWh	< 15.000 kWh
	Specific Electricity Consumption pp	> 5.500 kWh pp	< 4.000 kWh pp
	Living Area pp	> 400 sq.ft. pp	
	Share of Cooled living area	> 90%	partial
Soft Criteria	Building/ Refurbishment	relatively recent	last 10 years
	Cooling	often central cooling or several units	rarely more than two units
	Pool	yes	none
A house is considered luxury if at least three out of the five criteria are met.			

Table 3-15: Distinctive elements between normal houses and luxury homes.

Regarding the building envelope there are some common issues in almost all Bahamian residential buildings:

- Houses do neither have a basement nor a crawlspace. Bahamian houses have a concrete foundation which rests on the soil surface

Wall:

- The outer wall is made of brick (about 8 to 12 inches) and is not insulated
- The color of the outer wall in most cases is a light and reflects large parts of the solar radiation

Roof:

- Roofs are usually cooled by natural ventilation (cross ventilation with inlets and outlets at the eaves, convection ventilation with inlet at the eaves and outlets at the gable)1
- The space under the roof is used for installation purposes and usually uninhabited
- The upper ceiling of the houses is not insulated, which allows the heat from the roof to be easily transmitted into the house
- Roof colors are from light colors to black
- The typical roof pitch is about 15°

Windows:

- Many windows are hurricane shutters and therefore also openable
- Not many buildings have eaves which allow effective shading of windows. The typical eave is about 2 to 4 ft

Regarding the energy consumption of the households the following is evident:

Air conditioning / cooling:

- As The Bahamas have a hot humid climate, there is a need for cooling. In most cases air conditioning systems are used for cooling purposes.
- In luxury homes a large part of the indoor area is air conditioned
- In normal houses air conditioning is usually used only in a small part (bed room and / or living room) of the building
- Some households use natural ventilation and fans to cool the house during summer

Hot water / lighting:

- Almost all households (more than 90%) use electricity to produce their hot water
- Because of the high electricity prices by the end of 2008 many home owners are sensitive to electricity costs. As a consequence of that energy saving bulbs (CFL – compact fluorescent lamps) gain market. Even in a warehouse on Eleuthera they offered more CFLs than incandescent bulbs. But still incandescent bulbs and halogen lights (for outside lighting) are dominating.

Other devices:

- For cooking LPG and electricity is used (about 50:50)
- Washing machines are typically vertical axis machines, which consume much more water than horizontal axis machines.

Some new luxury homes have:

- An insulated upper ceiling

[1] Cooling here means to reduce the heat load. The heat is accumulated inside the roof during a sunny day.

{

- Large eaves to cover outside terrace. As a side effect the large eaves reduce the heat load because they are shading part of the windows

The awareness of passive measures which could reduce the heat load of the houses by the use of light colors for the roof and the outer walls, insulation, shading of windows and natural ventilation seems to be not so extensive on The Bahamas.

Nevertheless from many discussions with home owners, hotel staff and other people it is obvious that the high electricity prices have increased the sensitivity for energy costs and energy conservation. As a consequence of people tend to exchange their lights (replacement of incandescent bulbs with CFL) and reduce the use of their A/C system. A useful indicator for home owners and decision makers would be the knowledge of how much energy they spend on what. In this respect the use of individual plug-in power meters could be very helpful.

3.4.4 Power measurements of different appliances

Unfortunately these meters seem to be almost unknown on The Bahamas. We had to purchase the power meters in the United States (see Figure 3-28), because we were not able to buy them on The Bahamas. This might also be a good explanation why Bahamian people are not used to them. As a consequence the power meter measurement by the home owners shows some inconsistencies and demonstrates the deficit in the use of the power meters. It turned out, that it was not that easy for the home owners to take measures. Unfortunately, the data sheets we received from the home owners were not very helpful, as the figures were partly inconsistent. It appears that e.g. the meters were not reseted or other mistakes in the usage have occurred.

If the power meters – which in general are very helpful for energy audits – will be used in other projects, they should only be used by trained staff.

{

Figure 3-28: Power meter 'Kill A Watt P4460' from P3 International

Despite of these difficulties and with the help of the CCG staff we were able to derive some reliable results. We corrected these with Fichtner estimations and results from other sources. According to their use, for some appliances the Wattages and for others the consumption per cycle or period have been collected. We also differentiate between devices switched on (fulfilling their primary technical function) and in stand by mode (plugged-in but not switched on).

Results were as follows:

Device	Mode	Minimum [Watt]	Maximum [Watt]	Average [Watt]
TV	switched on	60	590	180
	stand by	11	54	30
Computer	switched on	90	290	190
	stand by	10	40	30
Laptop	switched on	27	60	40
	stand by	14	14	14
Microwave	switched on	800	1400	1000
	stand by	3	5	4
Recharger for mobil	switched on	3	7	5
	stand by	0,5	3	1

Table 3-16: Electricity consumption of different devices in Watts

Device	Minimum [kWh/cycle]	Maximum [kWh/cycle]	Average [kWh/cycle]
Washing machine	0,22	0,44	0,3
Dryer	3,5	6	4
Dishwasher			1,7

Table 3-17: Electricity consumption of different devices in kWh per cycle

Measuring the electricity consumption of refrigerators led to a separation of the devices in two groups, one group for the refrigerators with an in-built freezer and one for those without. In both categories the result was a function that takes into account the size and the age of the refrigerator.

3.4.5 Electricity consumption

The electricity consumption of twelve households was gathered during the energy audits. For some households consumption data were provided by BEC, unfortunately only they could only be allocated partly to the audited households.

{

The evaluated houses have a total living area in the range of 980 sq ft to almost 5,700 sq ft. The average living area of these houses is about 2,600 sq ft. In this regard it has to be considered that the audits contain a share of luxury homes that is disproportionally high.

3.4.5.1 Absolute consumption figures

The annual electricity consumption of the evaluated households is in the range of 3,600 kWh to 48,600 kWh per year, with an average consumption of 21,000 kWh per year (see Table 3-18 and Figure 3-29). This calculated average consumption figure is of course not representative for the households in The Bahamas – it is simply the average of the twelve sample buildings. According to BEC data the average electrical Bahamian household consumption is about 7,500 kWh per year.

Type	Minimum	Maximum	Average
Luxury homes	24,356	48,580	34,528
Normal houses	3,626	10,462	7,416
Total sample	3,626	48,580	20,972

Table 3-18: Annual electricity consumption in kWh (of 12 houses sample)

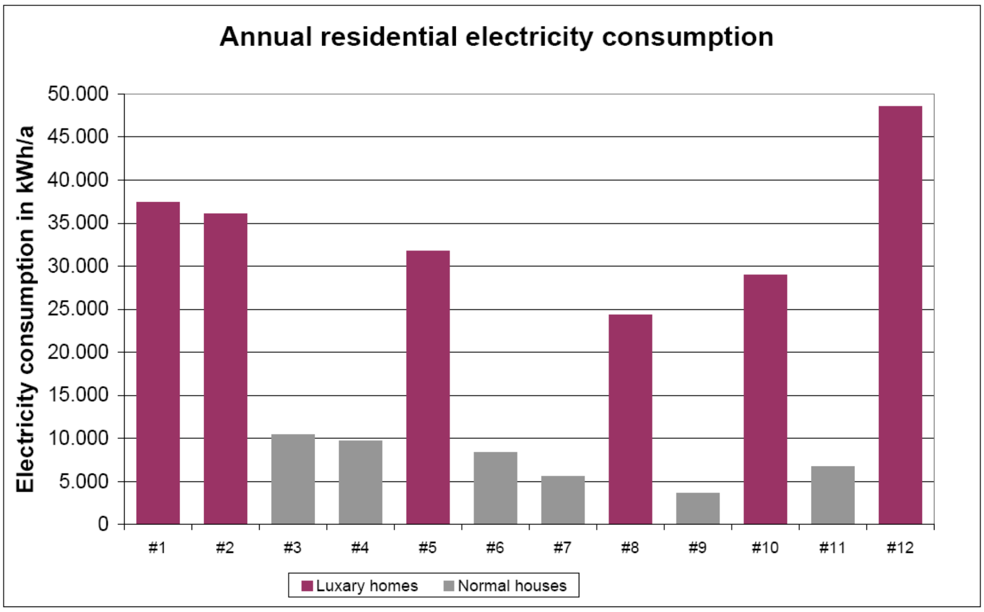

Figure 3-29: Annual residential electricity consumption (sample of 12 households)

In the next step we take a look at the load curve of the households. In the analysis of the monthly consumption figures we have distinguished between ‘luxury homes’ and ‘normal houses’. In Figure 3-30 there are two corridors describing the minimum and maximum of the load curves for ‘luxury homes’ and for ‘normal houses’.

{

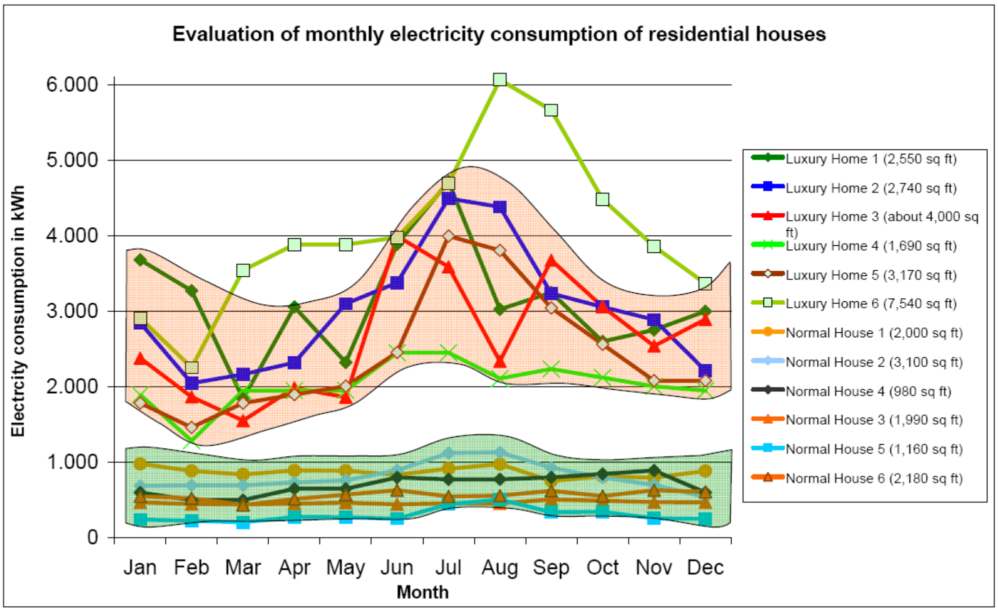

Figure 3-30: Load curves of the audited households (sample of 12 households)

By reduction of the cooling load of the air conditioning system (e.g. by increasing the set point or by only partly cooling the house) the electrical peak load in summer can be reduced.

3.4.5.2 Specific consumption in kWh/sq ft

In the following evaluation the absolute consumption figures and the load curves are related to the living area. Table 3-19 and Figure 3-31 present the specific annual electricity consumption of the sample of twelve households in kWh per sq ft.

Type	Minimum	Maximum	Average
Luxury homes	7.9	14.7	11.3
Normal houses	2.8	8.6	4.3
Total sample	2.8	14.7	8.2

Table 3-19: Annual electricity consumption in kWh/sq ft (of 12 houses sample)

{

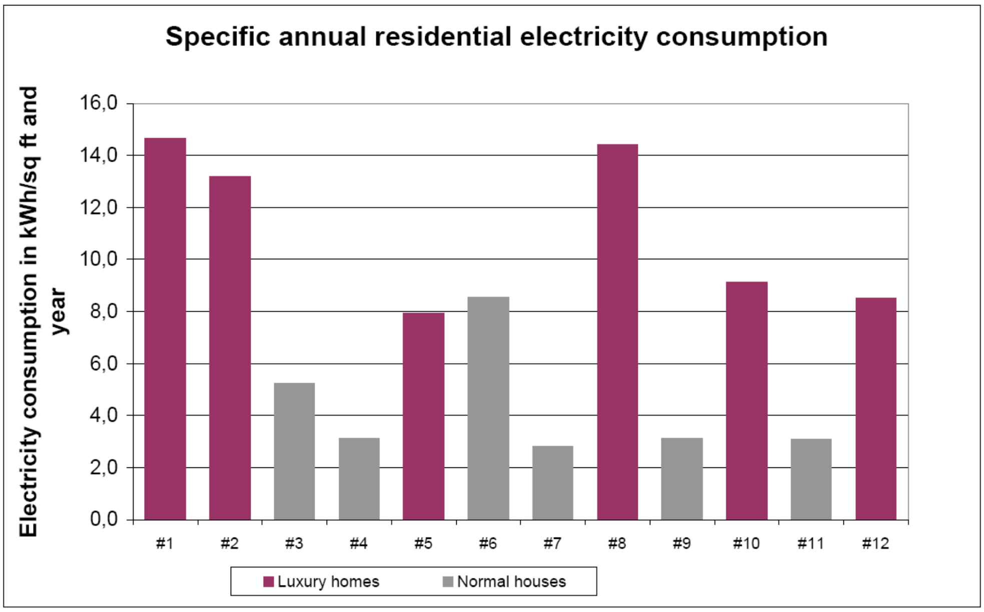

Figure 3-31: Specific annual electricity consumption in kWh / sq ft

For luxury homes the specific annual electricity consumption in kWh/sq ft is typically in the range of 8.0 to 14.0 kWh/sq ft. In Figure 3-31 the values #5 and #12 are that small, because these houses have an extraordinary large living area.

For typical normal houses, we have found a specific annual electricity consumption in kWh/sq ft in the range of 3.0 to 5.0 kWh/sq ft. There is one outlier #6 value because that house has a large number of inhabitants and therefore consumers on a relatively small living area.

Also a load curve with the specific annual electricity consumption in kWh/sq ft can be generated. This load curve is presented as Figure 3-32.

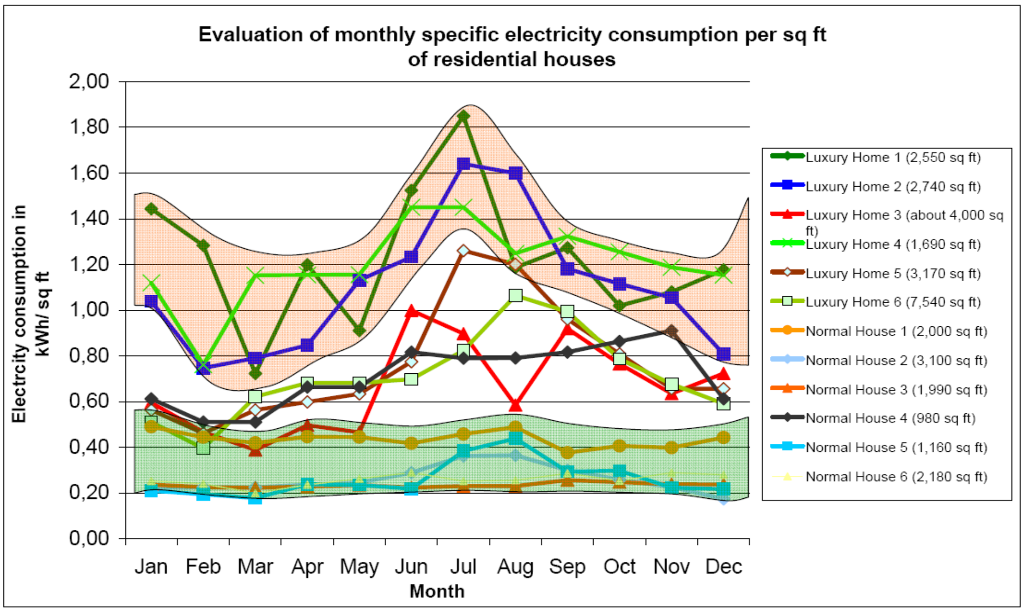

Figure 3-32: Specific load curves of the audited households (sample of 12 households)

{

3.4.5.3 Specific consumption in kWh/(sq ft * inhabitant)

In the following evaluation the absolute consumption figures and the load curves are related to the living area and the number of inhabitants, because also the number of people living in the house have an influence on the electricity consumption. Table 3-20 and Figure 3-33 present the specific annual electricity consumption of the sample of 12 households in kWh per sq ft and per inhabitant.

Type	Minimum	Maximum	Average
Luxury homes	2.0	3.7	3.1
Normal houses	0.4	1.5 (3.1)	1.0 (1.3)
Total sample	0.4	3.7	2.2

Table 3-20: Annual electricity consumption in kWh/(sq ft*inh.) (of 12 houses sample)

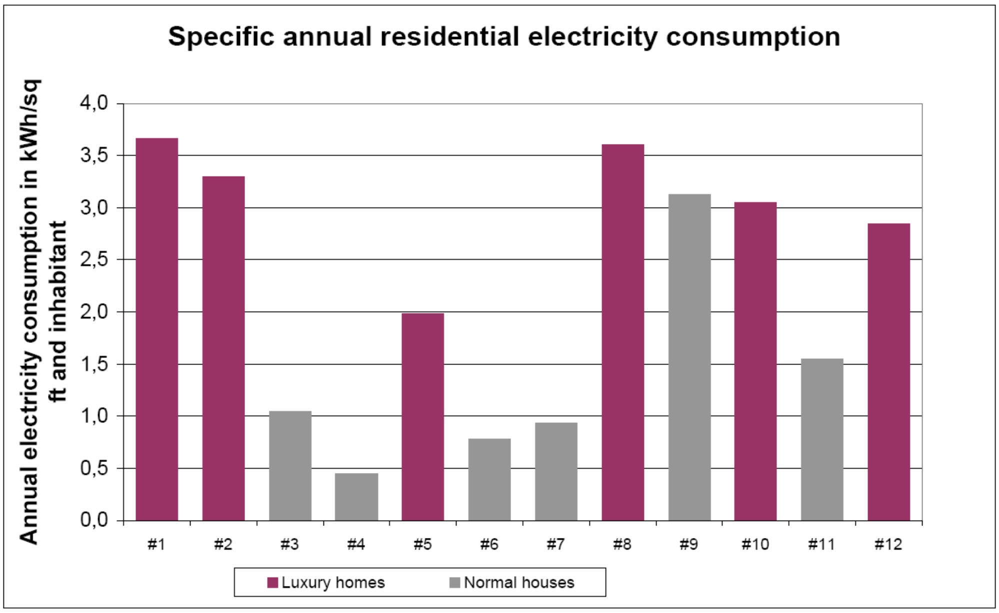

Figure 3-33: Specific annual electricity consumption in kWh/(sq ft * inh.)

For luxury homes the specific annual electricity consumption is typically in the range of 2.5 to 3.7 kWh/sq ft. In Figure 3-33 there is one outlier #5 value, because one of the houses has an extraordinary large living area.

For typical normal houses as a preliminary result, we have found a specific annual electricity consumption in the range of 0.5 to 1.5 kWh/sq ft. There is also one runaway value because one of the normal houses has only one inhabitant.

For this evaluation as well a load curve with the specific annual electricity consumption in kWh/sq ft and per inhabitant can be generated. This load curve is presented in Figure 3-34.

{

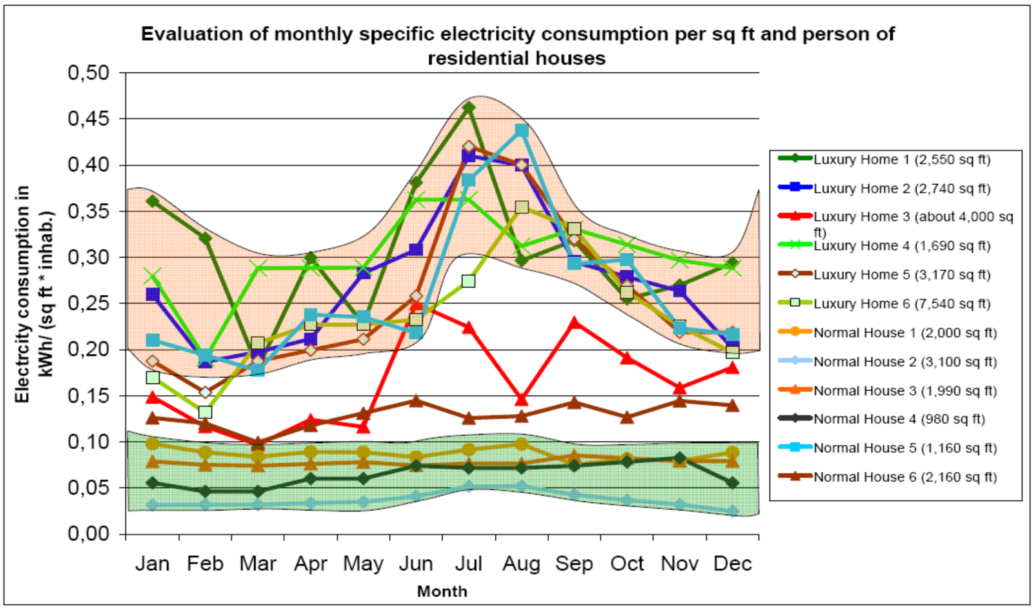

Figure 3-34: Specific load curves of the audited households (sample of 10 households)

3.4.5.4 Specific consumption in kWh / inhabitant

Since the group of normal houses is very inhomogeneous, not all sizes of households show the same characteristics. The electricity consumption per year and inhabitant strongly depends on the number of members of the household as shown in Figure 3-35.

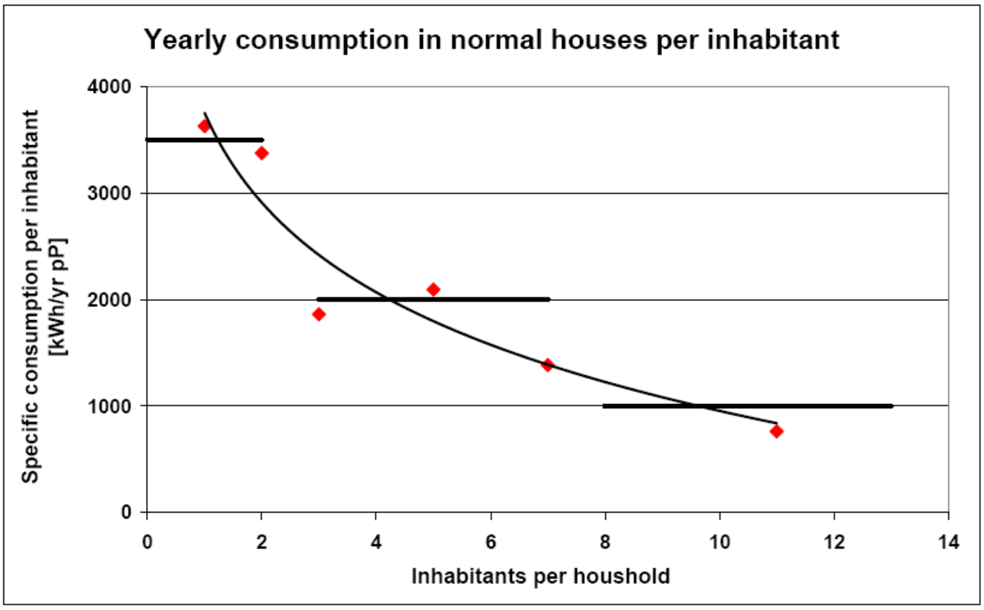

Figure 3-35: Yearly consumption in six normal houses in relation to the household size

Typical consumptions were attributed to the different size-categories:

I.	1 to 2 inhabitants:	3,500 kWh / year*inhab.
II.	3 to 7 inhabitants:	2,000 kWh / year*inhab.
III.	8 and more inhabitants:	1,000 kWh / year*inhab.

{

If those values are weighted with the adapted data of the 2000 census an overall average for normal houses of 1843 kWh per year and inhabitant is found.

As was to be expected, the luxury homes show a much higher electricity demand which is typically at about 10,000 kWh per year and inhabitant.

Type	Minimum	Maximum	Average
Luxury homes	6,089	16,193	10,000
Normal houses	763	3,626	1,843
Small households	-	-	932
Total	-	-	7,574

Table 3-21: Annual electricity consumption in kWh/inhab. weighted with census data

The small households which are typically less equipped with electricity consuming devices are estimated to have a demand of 932 kWh per year and inhabitant.

3.4.5.5 Plausibility check

To verify our findings an analysis of the available data is indicated.

- According to BEC the average electricity consumption per household is in the order of 7,500 kWh per year. This must be found also when averaging the total consumption of the three household types
- The total consumption of our calculations has to be in accordance with the total consumption real electricity demand in The Bahamas
- The average consumption of a small household has to coincide with a model household that has a basic equipment and 2,64 inhabitants. The model household has a consumption of 964 kWh/yr and per person.

	Value	Calculation	Consistency
Average electricity demand per household	7500 kWh / yr	7574 kWh / yr	✓
Total residential consumption of BEC in 08/09 plus 16% for the population on Grand Bahama	664,588 MWh / yr	664,588 MWh / yr	✓
Small household Avarage – modeled	964 kWh / yr pP	932 kWh / yr pP	✓

Table 3-22: Annual electricity consumption in kWh/inhab. weighted with census data

3.4.5.6 Coverage ratio of electrical appliances

To determine the coverage of electrical appliances (except of air conditioning) 18 samples have already been analyzed. The coverage ratios are presented below.

Appliance	Coverage ratio in %	Remark
Electrical hot water	83%	7% solar; 7% propane
Electrical fans	100%	In average 6 fans per house
Refrigerator	100%	
Freezer	44%	
Electrical cooking	44%	56% LPG
Washing machine	100%	
Dryer	61%	
Dishwasher	39%	
Computer	100%	In average 2 computers per house; Average usage: 3 hours per day
TV	100%	In average 3.6 TV per house; Average usage: 5.2 hours per day
HIFI	78%	
Microwave	100%	
CFLs	83%	In 22% of the households as main light source

Table 3-23: Coverage ratios of electrical appliances in the audited households (sample of 15)

It is obvious that about 83 per cent of the households in The Bahamas have electric water heaters. Only one household of the sample (7%) already uses a solar water heater. Two households applie water heating with LPG. And one an electrical continuous flow water heater.

3.4.5.7 Electricity consumption per application

The split of the electricity consumption per appliance in ‘normal houses’ is presented in Figure 3-36. According to our findings the largest consumers in ‘normal houses’ are electronics in use (TV, computer), stand-by appliances, cooling purposes (fridge, freezer) and hot water production followed by lighting, with shares of 16%, 15% and 14 % of the electricity respectively.

The electricity consumption for cooling of the house (air conditioning) only counts for about 4% as the air conditioning is usually limited to only one or two rooms and is in operation only during a period of about 100 days in summer and then also only a few hours per day. Cooling with fans on the other hand is responsible for a 10% share of the electricity consumption in this category.

{

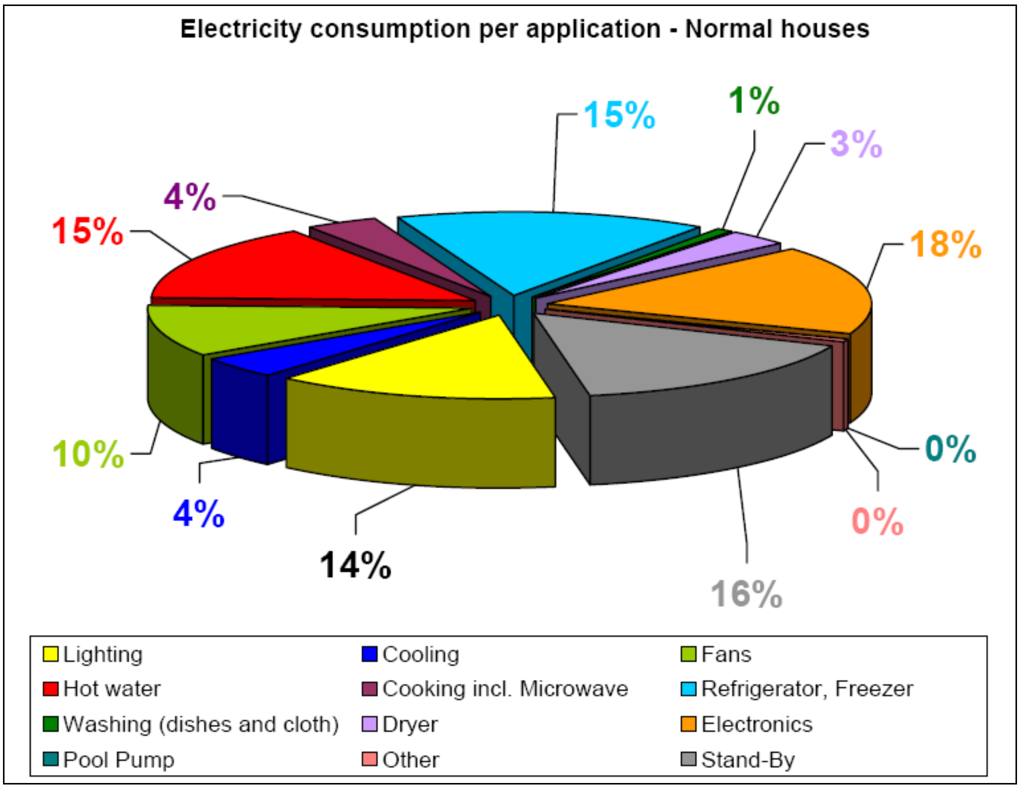

Figure 3-36: Typical split of the residential electricity consumption in 'normal houses'

For those normal houses that have at least half of their bulbs replaced by energy saving bulbs the split of the electricity consumption per appliance looks slightly different (see Figure 3-37). In those houses which have been analysed the consumption for lighting is significantly reduced.

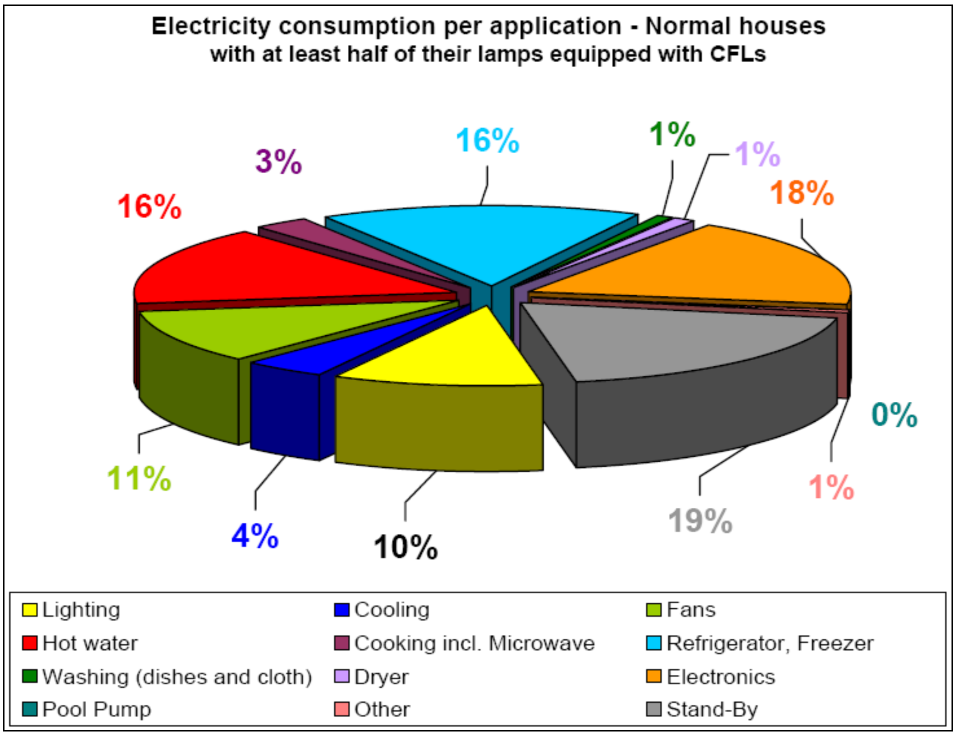

Figure 3-37: Split of the residential electricity consumption in 'normal houses' with energy saving bulbs

{

Figure 3-38 shows the split of electricity consumption in luxury homes. Those houses have a high electricity consumption for cooling of the house. More than one third of the electricity is used for the air conditioning system. Lighting also has a large portion. This is mainly because of the security lights, which are switched on the whole night (no one has motion detectors which switch them on only if required). The low share of electricity consumption for hot water, electronics, stand by and others does not mean that the consumption of these appliances is little but only that the total consumption of the luxury homes is very high.

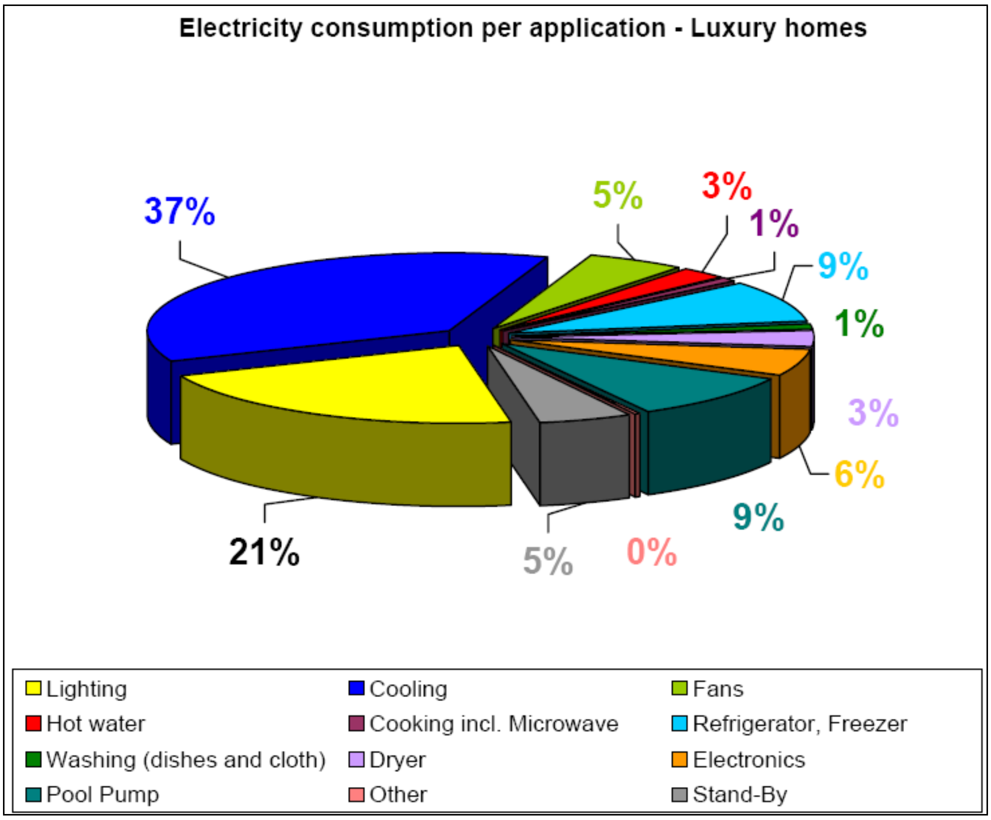

Figure 3-38: Split of the residential electricity consumption in 'luxury houses'

3.4.5.8 Shares of residential electricity consumption of consumer types

As shown above the electricity demand of the different consumer types is not proportional to their share of the population.

{

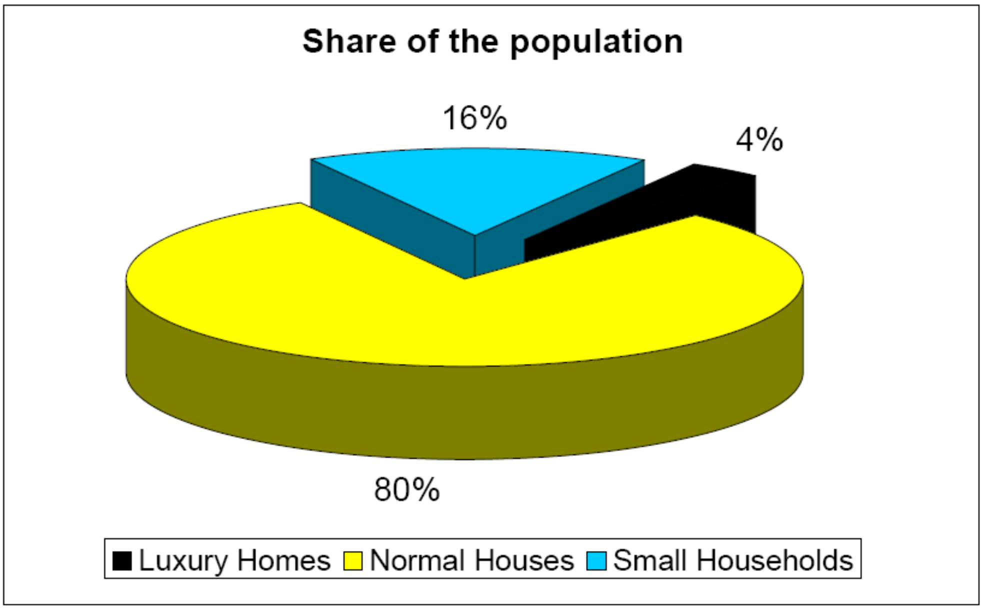

Figure 3-39: Split of the consumer types within the population

The normal houses have the biggest share of both, the population and the electricity consumption. Not surprisingly, the luxury homes consume 18% of the total residential electricity demand even though they represent only 4% of the population.

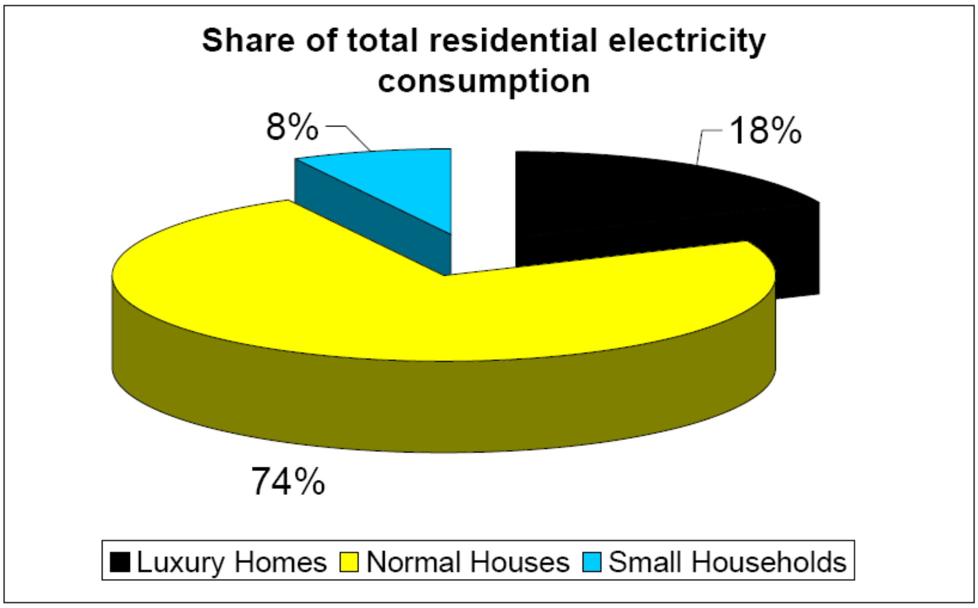

Figure 3-40: Split of the residential electricity consumption

The small households have a share of only 8% of the demand but represent 16% of the population.

3.4.6 Saving potentials

The identified saving potentials are significant and could attain, if all measures to meet the benchmark were applied, up to 57% of the total

{

residential electricity consumption. They could be even higher when taking into account the theoretical saving potentials.
The electricity demand for water heating is about 80,800 MWh/yr representing 12% of the total residential demand. When applying solar water heaters with a relatively low solar fraction of 85%, more than 10% of the electricity demand for residential use on The Bahamas could be saved.

3.4.6.1 Normal houses

Normal Houses						
	Share	Electricity Demand [MWh/yr]	Saving Potential with Benchmark	Saving Potential [MWh/yr]	Theoretical Saving Potential	Theoretical Saving Potential [MWh/yr]
Lighting	14,7%	72.370	85%	61.840	85%	61.840
Cooling	4,3%	21.241	100%	21.241	100%	21.241
Fans	9,4%	46.438	64%	29.492	100%	46.438
Hot water	14,2%	70.036	23%	15.912	88%	61.917
Cooking incl. Microwave	4,1%	20.157	89%	17.866	91%	18.439
Refrigerator, Freezer	16,5%	80.983	67%	54.475	74%	59.777
Washing (dishes and cloth)	1,0%	4.760	91%	4.340	91%	4.340
Dryer	4,0%	19.582	100%	19.582	100%	19.582
Electronics	16,2%	79.592	49%	38.770	66%	52.377
Pool Pump	0,0%	0	0%	0	0%	0
Other	0,4%	1.776	100%	1.776	100%	1.776
Stand-By	15,2%	74.854	28%	21.187	100%	74.854
		491.788 MWh/yr	58%	286.481 MWh/yr	86%	422.581 MWh/yr

Table 3-24: Consumption and saving potentials in normal houses

Since the normal houses represent the biggest share of the electricity demand in The Bahamas, there is an enormous saving potential. 58% could be avoided by meeting the benchmark requirements, representing 43% of the total demand for residential electricity. More savings are nevertheless possible when applying additional measures.

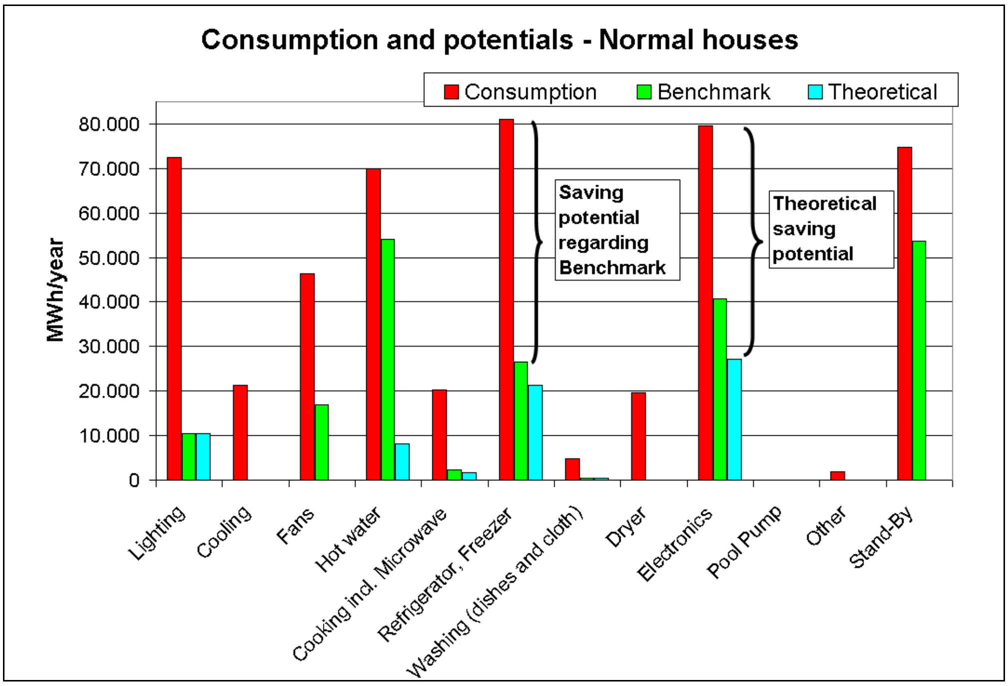

Figure 3-41: Consumption and potentials in normal houses

{

3.4.6.2 Luxury homes

Luxury Homes							
	Share	Electricity Demand [MWh/yr]	Saving Potential with Benchmark	Saving Potential [MWh/yr]	Theoretical Saving Potential	Theoretical Saving Potential [MWh/yr]
Lighting	25,1%	30.557	60%	18.312	90%	27.593
Cooling	35,9%	43.728	53%	23.380	69%	30.162
Fans	4,2%	5.165	73%	3.760	82%	4.228
Hot water	2,2%	2.718	100%	2.718	79%	2.157
Cooking incl. Microwave	0,8%	927	87%	809	87%	809
Refrigerator, Freezer	8,2%	9.942	57%	5.711	85%	8.477
Washing (dishes and cloth)	1,1%	1.351	94%	1.271	94%	1.271
Dryer	3,1%	3.736	100%	3.736	100%	3.736
Electronics	5,3%	6.405	46%	2.924	64%	4.085
Pool Pump	8,8%	10.748	26%	2.770	51%	5.429
Other	0,4%	462	100%	462	100%	462
Stand-By	4,9%	6.019	68%	4.069	100%	6.019
Total:		121.759 MWh/yr	57%	69.923 MWh/yr	78%	94.429 MWh/yr

Table 3-25: Consumption and saving potentials in luxury homes

On one hand within the luxury homes there are also vast potentials for energy efficiency measures as well as sufficient funds for applying them. On the other hand, home owners may not feel the pressure of rising energy prices quite as heavy as owners of normal houses. Since the luxury homes have a share of 18% of the total residential electricity demand it is important to motivate concerned home owners since their consumption could be cut in half. Luxury homes are typically equipped with security lighting.

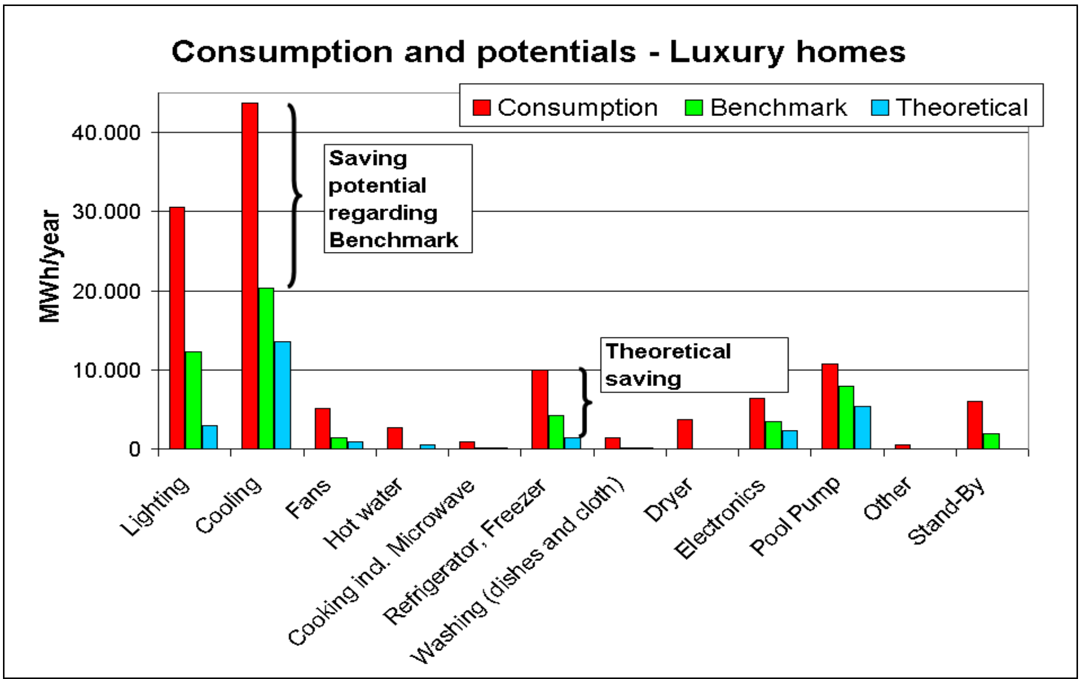

Figure 3-42: Consumption and potentials in luxury homes

{

3.4.6.3 Small households

Small Households						
	Share	Electricity Demand [MWh/yr]	Saving Potential with Benchmark	Saving Potential [MWh/yr]	Theoretical Saving Potential	Theoretical Saving Potential [MWh/yr]
Lighting	8,6%	4.393	32,6%	1.431	32,6%	1.431
Cooling	0,0%	0	0,0%	0	0,0%	0
Fans	14,1%	7.221	63,3%	4.573	100,0%	7.221
Hot water	4,3%	2.189	0,0%	0	79,5%	1.740
Cooking incl. Microwave	2,4%	1.220	47,2%	576	60,4%	737
Refrigerator, Freezer	31,6%	16.107	53,7%	8.652	58,3%	9.397
Washing (dishes and cloth)	1,8%	939	87,4%	821	87,4%	821
Dryer	0,0%	0	0,0%	0	0,0%	0
Electronics	31,0%	15.814	41,9%	6.629	61,3%	9.691
Pool Pump	0,0%	0	0,0%	0	0,0%	0
Other	0,0%	0	0,0%	0	0,0%	0
Stand-By	6,2%	3.158	0,0%	0	100,0%	3.158
		51.041 MWh/yr	44%	22.683 MWh/yr	67%	34.196 MWh/yr

Table 3-26: Consumption and saving potentials in small households

In the small households the saving potentials are, even though existent, more limited. This is due to the relatively small number of appliances that are present, additionally it can be assumed that in these households rising energy prices lead to a necessity for saving. The most realistic potentials lay in the replacement of incandescent bulbs with CFLs and a more conscious and focused use of fans. It is probably faire to estimate that a big share of these households are situated in rented dwellings. Therefore, measures that affect the building, like solar water heating are in the responsibility of the landlord. This can pose a problem in the way that the landlord has no direct advantage from these investments.

3.4.7 Good practice

Good practice was found in some of the audited households. In the following a short list of some of the good practices in the household sector of The Bahamas is shown.

Figure 3-43: Open windows promoting natural cross and stack ventilation

Use of natural ventilation

- One audited household was exclusively using natural ventilation to cool the house. This works, as the house has enough windows to allow cross

{

ventilation and also has a second floor which creates a natural air flow from the open windows in the ground floor to the open windows in the upper floor.

Figure 3-44: Example for a wall partially shaded by plants and trees

Colouring, shading and planting – minimising heat gains

- In several houses light colours of the walls and especially the roofs minimised heat gains
- Large roof eaves where found in some houses, these shade the walls and windows and are most effective on the south side
- Some home owners who disposed of a garden greened it in a way that the surrounding plants, shrubs and trees not only shaded the house and absorb light radiation but also cool the area by evapotranspirational effects

Figure 3-45: Light colored and reflecting roof but dark and absorbing walls

Cooling only parts of the house and when required

- Some of the audited households with decentralized cooling system reduced their electricity consumption for air conditioning by cooling only the bed room and/or the living room.

{

- Running the A/C system only when really required also saves electricity. For example the A/C system can be shut off, if no one is in the house.
- The use of mechanical ventilation (fans) reduces the need for A/C in some households especially in the transitional periods

Replacement of incandescent bulbs by CFL's

- In those households where CFL's are in use, most of the incandescent bulbs have been already replaced.

Reduction of energy consumption for security lighting

- Some security lights are equipped with motion detectors which saves a lot of energy due to non-continuous lighting

Figure 3-46: Security lights without (l) and with motion detector (r)

Reduction of electricity consumption for hot water

- One household was already using solar water heaters for hot water preparation
- Two households use a propane fired water heater, reducing the electricity consumption for hot water to zero
- Flow water heaters instead of hot water storage tanks to reduce radiation losses of large and badly insulated storage tanks (reduction potential of 100 to 200 kWh per month)

Non-electrical cooking

- In some households the use of a gas stove saved the electricity that would be needed when using an electrical stove

3.4.7.1 Potentials

Looking at potential energy savings in households it is necessary to distinguish between existing buildings and new buildings. In the following two text boxes preliminary findings of potentials in the household sector of The Bahamas are presented.

New buildings:
New buildings allow to already implement many passive measures which first of all prevent the living space from heating up too much. This of course reduces the cooling load.

{

Structural Measures

Passive measures to reduce the heat influx

- To maximize the natural ventilation in a building it should be shaped with an extended breadth facing the wind and little depth. If a building is cooled only by technical means (air conditioning) it should be build as compact as possible.
- Buildings should be positioned in a way that they have the largest façade and large openings in an angle of 30 to 120 degrees (optimum 90°) towards the prevailing wind direction.
- In buildings with an opening in the attic (or roof) and an open space for the air to circulate vertically the stack effect can be used for ventilation.
- It is useful to ventilate the attic of a building since it is likely that heat accumulates in this area.
- South-North orientation of the building (the windows face to the South and the North. Windows facing to the East and the West gain too much heat in the morning and in the evening when the sun is low above the horizon – in this case also shading by extensive eaves is almost useless)
- The construction of a building should be done in a way not to accumulate too much (thermal) mass since heat will accumulate and be radiated during the night.
- Shading of windows with eaves (**50 %** reduction of heat influx, outside shutters (**70 %** reduction of heat influx) or trees
- Use of light colors for outer walls and roof
- Insulation of upper ceiling, the first layer should be a reflective foil insulation, additionally bulk insulations can be added.
- Planting middle and high growing plants, trees and shrubs in the surroundings of a building helps shading it, absorbs light radiation and lowers the temperature due to evapotranspiration from the leaves and soil

Active measures for cooling of the house

- Installation of a high efficient central cooling system with single room control
- In larger buildings even solar cooling can be an option

Structural land use measures

Advantageous arrangement of buildings

An adapted arrangement of the rooms as well as the neighborhood can be of great impact.
The house should be used in a way that the rooms are placed according to their use and time of use. A bedroom is best placed in the east, this way it is not heated by the sun in the afternoon. Rooms which are occasionally used like laundries or storage rooms can be located in the south.
Also a whole neighborhood can be optimised for example by leaving

{

enough space between two houses in the windward and leeward direction, with the objective not to block the wind for the buildings alee. This can be achieved with pattern of the roads, the form of the lots, arrangement of open spaces etc.

New and existing buildings:
There are also measures which can be taken in new and in existing buildings.

Passive measures to reduce the heat load

- In existing buildings a dark colored roof could be repainted with a light color
- Planting middle and high growing plants, trees and shrubs in the surroundings of a building helps shading it and lowers the temperature due to evapotranspiration from the leaves and soil
- Sun curtains could be easily used to reduce the heat load from the sun by **10 %** if venetian blinds with reflective slats are used the reduction can be up to **30%.** But: shading from outside is much more effective than the use of sun curtains (the temperature behind sun curtains is much higher than behind a window which is shaded from outside).
- A more effective, but also more cost intensive measure is the use of outside shutters that keep out the sun. They reduce heat gains from the sun significantly by up to **70%.**
- Usage of natural ventilation to cool down the house during night

A/C unit

- The use of digital controllers for the A/C unit allows an accurate setting of the temperature
- Shading of the outside chiller of the A/C unit increase the efficiency and reduces the electricity consumption of the A/C unit

Reduction of electricity consumption for hot water

- Use of solar water heaters for residential homes could save about 10 to 15% of the electricity used in the household sector
- Flow water heaters instead of hot water storage tanks to reduce radiation losses of large and badly insulated storage tanks (can reduce the electricity consumption for hot water preparation up to 50%)
- Use of horizontal axis washing machine which has a lower water demand.
- If solar hot water is produced the washing machine should have a hot water intake

Reduction of electricity consumption for lighting

- The replacement of incandescent bulbs with CFL's usually has a payback period of about 1 to 2 years, depending on the usage of the

{

lighting. A CFL saves about 60% to 80% of electricity if compared to an incandescent bulb. If a bulb with 60 W that is installed for example in the living room and lighted for five hours per day, is replaced by a CFL with 14 W, the annual savings would be of 84 kWh. This represents with rate of 0,25 $ / kWh savings of approximately **21 $ per year** and bulb.

Ecomomic security lighting

- Use of motion detectors for outside security lights. A motion detector that runs on 4 W and reduces the lighted time of a security light to ten minutes per hour saves at least 310kWh per security light with 150 W and a runtime of 7 hours per day. This represents **77$ per year** and security lamp.

Training of energy awareness

- Turning off a light when it is actually not needed for one hour a day can save **22 kWh** per year representing **5.50 $** per bulb**,** supposing it is equipped with a 60W bulb
- Switching off the TV when nobody is really watching. On average there are 3.6 TVs in one household being switched on for 5.2 hrs per day. That are almost 19 television hours per household. If only one TV would be switched on for 5 hrs per day this could save **920 kWh** per year, representing **230 $. Each hour in which the TV is on costs about 5 cents** of electricity even when no one is actually watching**.**

Usage of efficient electrical devices

- The replacement of old inefficient appliances (e.g. fridge, freezer, computer) can save up to 50% to 70% of energy.
- In the case that an electrical device needs to be replaced the Bahamian people should be informed about the possibility to buy high energy efficient appliances
- Using laptops instead of desktop computers saves up to 90% of the needed energy
- Pool pumps should be used in a discontinuous way and not all the time through

Reduction of stand by losses

- To avoid stand by losses e.g. TV and computers should be plugged in a multi switch, which allows to really switch them off. The costs for these multi switches are about 15 $. The more appliances are connected the shorter the payback period. As an average a payback period of about 1 year can be assumed.

Reduction of electricity demand for RO water

As most of the potable water on The Bahamas has to be produced with RO plants – which consume electricity – the saving of water can also

{

3. Energy Efficiency Program

3.1 General

In this report an update of the analysis of the current energy consumption of the Bahamian sectors hotels, households and public buildings is presented.

For each object group (i.e. for hotels, households and public buildings) sample energy audits had been performed. The audits contain a representative number and selection of objects, so that the audit insights are transferable to the entire group.

For the hotels additional audits have been added to this report. Especially in the group of smaller hotels the number of samples has increased (in contrast to the first preliminary report). In addition, hotels for each class (large, mid-sized and small) have been supplied by the Bahamian Hotel Association.

The audits for public buildings were lacking input data to confirm the consistency of the energy consumption figures provided by BEC. A good indicator for consistency checks is the specific consumption per sq ft. For this Fichtner has requested floor plans from the Ministry of Works. As these floor plans were not provided, Fichtner estimated to floor area of the public buildings on the basis of satellite pictures and photos taken during the audits. In addition best practice and potentials of public buildings are presented in this report.

The description of the households has also been extended. A distinction is now made between small houses, normal households and luxury homes. Specific consumption figures and potentials for these three consumer groups are presented. Statistical data have been used to calculate the total electricity consumption of The Bahamas on the basis of the figures determined during the audits. A cross check of the audit data of the household sector shows that the figures match with the BEC annual consumption figures has been extended.

3.2 Hotel audits

Tourism is a major consumer of power in The Bahamas. The hotels consume about 40% of all electricity. Therefore energy audits for a sample of 18 hotels have been performed.

Major tourism resort development has been concentrated in the two main vacation destinations in The Bahamas: New Providence (Nassau/Paradise Island) and Grand Bahama Island. Among the Family Islands there are six Islands which alone account for 80% of total electricity consumption in the Family Islands: Bimini, Abaco, Andors, Eleuthera, Exuma and Long Island.

{

save energy.

- Water saving by the usage of special fittings, e.g. mixing in air at the faucet or in the shower
- Grey water reuse for the garden and the toilet flush
- Use of horizontal (water consumption of about 13 to 16 gals) instead of vertical washing machines (water consumption of 40 to 60 gals)

{