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Introducing energy performance indicators for the residential sector in Curacao

Guus van Eldik

University of Curacao & University of Twente

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Company: University of Curacao
Willemstad, Curacao

Student:
Guus van Eldik
Civil Engineering & Management
University of Twente
g.vaneldik@student.utwente.nl
+31 (0)630721720

Supervisor University of Curacao
ir. Richenel Bulbaai
r.bulbaai@uoc.cw
+5999 7442182

Supervisor University of Twente
dr. ir. A.G. Entrop
a.g.entrop@stw.utwente.nl
+31 (0)534896860

Preface

This research has been conducted for the bachelor thesis of my study Civil engineering at the university of Twente, in the Netherlands. In the months February and March research has been conducted on the energy performance of buildings in order to deliver a research proposal. After this research proposal was approved, I travelled across the Atlantic ocean to conduct research in Curacao for a period of 10 weeks. In this period the research questions from the research proposal are answered and the findings of the research are documented in this rapport.

Curacao is a small island of 444 km^2 in the southern part of the Caribbean Sea. The official languages of Curacao are Papiamento, English and Dutch, and Curacao has a population of about 150,000. Currently Curacao does not have minimum requirements for the energy use of buildings, and is using building codes from other countries (Figaroa, 2002). For Curacao to become more energy efficient it is important to develop their own energy efficient building codes. In order to develop an energy efficiency building code it is important to establish an uniform method on how the energy performance of buildings can be determined.

The research consists of a study about energy performance indicators for buildings and how these can be customized and fitted to meet the standards of Curacao.

I hope the research contributes to raising awareness of energy efficient building in Curacao, and hope my research delivers an useful tool for the building sector in Curacao to assess the energy performance of houses.

Finally I want to thank ir. Bulbaai for all the help finding contacts in Curacao and answering my questions and I want to thank dr.ir. A.G. Entrop for supervising my bachelor thesis and delivering all kinds of useful thoughts and feedback. Lastly I want to thank Professor Halman for helping me to contact people in Curacao and doing my bachelor thesis there.

Guus van Eldik

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Abstract

This research aimed to find out how the energy performance of dwellings in Curacao could be assessed, and what the energy performance of the dwellings in Curacao are. First the energy sector of Curacao is unravelled in order to find the way of energy production, transfers and use. Next we have tried to determine how an energy performance indicator can be made suitable for Curacao. Therefore, research has been conducted on the legislation and goals on energy efficiency worldwide before researching them for Curacao to give us a sense of scale. In order to determine which energy performance indicator can be used for Curacao, research has been conducted on the climate and architectural specification of the buildings in Curacao before choosing an energy performance indicator to assess four dwellings.

In Europe the energy labelling system is already a common used method to increase the sustainability and energy efficiency of dwellings. In Curacao there is no energy performance indication system for buildings so the government is not able to set minimum requirements for the energy use of buildings. In order for Curacao to become more sustainable and energy efficient it is important to introduce minimum requirements for the energy use of dwellings and therefore an energy performance indicator to be able to assess the energy use of dwellings in Curacao.

Curacao has not the possibility to mine their own fossil fuels and therefore energy is mainly imported in the form of crude oil by ships. Curacao has a lot of refineries on the island where the crude oil is being processed in other oil products and energy carriers. The main energy carrier in Curacao is electricity. Electricity is being used in almost every dwelling and in a lot of other sectors. Gas is also being used in dwellings for cooking which is not a bigger share then 5% of the total energy use. The electricity in Curacao is mainly produced by diesel generators from the only electricity company on the Island Aqualectra. Aqualectra produces and buys electricity before they distribute the electricity to different end users. Also energy is obtained in a sustainable way in Curacao by wind farms and solar panels. Unfortunately despite the high potential for the winning of renewable energy, the biggest share of energy is produced by burning imported fossil fuels. Furthermore the energy sector in Curacao is relatively unreliable, inefficient and expensive. Therefore it is important that the energy sector has to be reformed and an energy performance indicators for dwellings can be introduced.

Before we can determine the way to assess dwellings in Curacao it is important to conduct research on the specific energy use in dwellings in Curacao and which factors influence the energy use of Curacao dwellings. Therefore we researched the energy use of buildings, architectural specifications and the climate. We found that energy in Curacao buildings is mainly being used for cooling, ventilation, lighting and the heating of water. Next we found that buildings in Curacao are constructed in order to let air flow through the dwelling as freely as possible. Therefore, the dwellings are really open and are not insulated. Because the last decades the use of air conditioning systems increased rapidly the energy use of dwellings increased significantly. Unfortunately the dwellings are not constructed in a way to use air conditioning systems efficient. This way a lot of energy is being lost for cooling, next to the already high energy demand for the cooling of dwellings. The necessity for cooling in Curacao is really high because the temperature on the island is always between the 25 and 35 degrees Celsius. The ideal temperature in Curacao is 23 degrees Celsius. This means the use of ventilation and cooling is necessary during the entire year.

Curacao currently does not have a building code with minimum requirements for the energy use of buildings. Because they want to introduce a building code and minimum requirements for the energy use of buildings in the nearby future it is important to create a way to assess the energy performance of buildings in Curacao. First we have determined the energy performance of dwellings in Curacao

using the Dutch energy performance indicator. The assessed dwellings received a really high energy label according to the Dutch labelling method. We assume this is due to the fact that the Dutch labelling system is not applicable in Curacao. The main reasons therefore are that the absolute average energy use in the Netherlands is almost three times as high as in the Netherlands. Also the numerical correction factors in the Dutch energy performance equation are based on assumptions of thousands of assessed Dutch buildings, which are not applicable for the tropical climate in Curacao. That is why we created a new Curacao energy performance indicator.

$$EI_{Cur} = \frac{Q_c + Q_v + Q_{hw} + Q_l}{Q_{adm;c} \times A_{fs} + Q_{adm;v} \times A_{fs} + Q_{adm;hw} \times A_{fs} + Q_{adm;l} \times A_{fs}}$$

For the determination of the energy performance of buildings in Curacao we needed information about the actual energy use, the floor surface and the admissible energy use. The top part of the equation is the actual energy use we have extracted from energy bills during the year of 2014 and 2015. The floor surface is measured next to a couple of other architectural specifications. We have chosen to use the floor surface of the building because it is simple to measure and it relates to a lot of other factors relating to energy use which are more difficult to determine. The botom part of the equation is the admissible energy use. Therefore we have determined the average energy use of the assessed dwellings per end use per square meter. This way we have created a simple to determine energy performance indicator which gives realistic energy labels to the assessed dwellings. Also a big advantages of this new Curacao energy performance indicator is that the energy performance per end use is easy to determine. Also the product of each energy performance indicator per end use gives the total energy performance of the dwelling. The energy labels from the Curacao energy performance indicator give an indication about the energy use in the building per square meter per end use in comparison to other buildings. This way it is possible to assess if dwellings use relatively more or less energy than other dwellings in Curacao. Using the Curacao energy performance indicator it is not able to say if dwellings in Curacao are more or less energy efficient than dwellings anywhere else in the world.

It is possible to assess the energy performance of dwellings in Curacao by using the new Curacao energy performance indicator. In order to set minimum requirements for the energy use of dwellings it is important to create an forecasting method for the energy use of dwellings. In order for Curacao to become more sustainable we strongly advise to implement an energy labelling system for the existing residential building stock.

Table of Content

1. Introduction

In this chapter I will try to motivate the importance and relevance of my research. Next I will state the problem and objective of the research. Finally I will discuss the research questions and methods I will use to reach my research objective.

1.1 Motivation

Sustainability has become a hot topic in the recent years for policy makers. Also the private sector slowly sees the relevance of sustainability. Brundtland a former commissioner of the United Nations describes sustainability as processes who meet the needs of the present without compromising the ability of future generations to meet their needs (Brundtland, 1987). In order to guaranty the needs of future generations it is important to use resources more efficient. When trying to save resources, it is important to focus on which sector uses most. Buildings account for 30-40% of total energy usage worldwide (Chedwal, 2015). And according to the European energy efficiency plan (European-commision, 2011) buildings have one of the greatest potentials for saving energy. Especially in Curacao there is a huge potential because the energy use of buildings account for more than two-thirds of the total electricity demand. To decrease the energy demand of buildings a lot of countries use buildings codes. Buildings codes are a legislative tool for policy makers to set requirements for the energy use in buildings and contribute to energy efficiency. Building codes can stimulate people to act sustainable while also thinking about their own social and economic situation. Also people who are involved in the process of designing and constructing buildings are forced to take sustainability of commercial real estate into account instead of only increasing profits.

The United Nations has an environment programme that aims to make the building sector more energy efficient. They especially motivate the use of energy efficient building codes for new buildings. Because the construction of a new building is a 'last opportunity' resource for energy efficiency, because any efficiency investments not made during construction will be much more expensive to achieve as retrofits. Furthermore investing in energy efficient buildings does not only have financial advantages. On the contrary energy efficient buildings generally provide not merely the same level of energy service, but a higher level of energy services than conventional buildings. But energy efficient buildings have higher levels of thermal comfort, greater ability to operate in the face of energy supply disruptions and encourage greater productivity of their occupants. These benefits may be substantially larger than (and an addition to) the benefits of direct energy savings (United nations enviroment programme, 2007).

The European Union aims to reduce energy use and eliminating wastage. There is significant potential for reducing use with cost-effective measures for the buildings sector. A key part of this legislation is the Energy Performance of Buildings Directive (EPBD), which required all EU countries to enhance their building regulations and to introduce energy certification schemes for buildings. The goal of this legislation is giving insides about the energy efficiency of a building, so when people purchases, rent or constructed a building they will know how much energy the house uses. Unfortunately, Curacao does not have minimum requirements for the energy use of buildings. For Curacao to be able to meet the needs of future generations it is important to be able to assess and compare the energy performance of buildings in order to become more energy efficient.

1.2 Problem statement

Curacao mainly depends on oil for the production of energy (The ministry of Health, Enviroment and Nature, 2014). Oil is a relatively expensive way of producing energy and the availability is limited. Additionally a lot of power plants need to be replaced or renovated in the nearby future which will lead to opportunities for other ways of producing energy. Curacao aims to produce 25% of their energy in renewable ways and therefore needs to reform its energy sector drastically (The ministry of Health, Enviroment and Nature, 2014). New legislation is required to decrease the demand for energy and make the use of energy more efficient. Energy use in residential buildings in Curacao accounts for more than half of the total energy demand in Curacao. Implementing energy efficient measures in the residential building sector in Curacao will lead to a significant decrease in energy demand. An effective strategy to reduce the energy demand in buildings is the implementation of an energy efficiency building codes (Brown, 1993). Curacao currently does not have minimum requirements for the energy use of dwellings recorded in a building code, and an uniform method for assessing the energy performance of dwellings and therefore:

"The problem is Curacao currently does not have their own energy performance indicator to determine the energy performances of dwellings in order to set minimum requirements for the energy use of residential buildings to become more sustainable"

1.3 Research objective

Curacao currently does not have minimum requirements for energy use of dwellings. In order to become more energy efficient it is necessary to implement a buildings code with minimum requirements for the energy use of dwellings. In order to create energy efficiency requirements for dwellings it is necessary to assess the energy performance of dwellings. There are a lot of ways to assess the energy performance of dwellings. But energy performance indicators are limited to a country or area because of differences in climate, building specifics, and the function of the building. In order to create an assessment method for the energy performance of dwellings in Curacao, existing energy performance assessment models will be customized to fit Curacao. When the energy performance assessment method is finished it will be used to determine the energy performance of three buildings in Curacao in a field study.

"The objective of this research is to find out how the energy performance of houses in Curacao can be assessed."

1.4 Research question and method

The main research question which arises from the research objective for the study is:

"How can the energy performances of houses in Curacao be assessed?"

Question 1(Chapter 2)
How does energy flow through various sub systems in Curacao?
To answer this question a Sankey diagram will be used to map the various energy flows on the Island of Curacao. In order to successfully create a Sankey diagram a lot of information and data has to be extracted from various companies in the energy sector. First will be discussed how a Sankey diagram works and how it can be helpful. Secondly the different companies in the energy sector of Curacao will be mapped in order to get an understanding on how the energy flows on the island of Curacao, before the companies can be approached for data. When the data is collected the energy flow and quantities will be discussed and visualized in a Sankey diagram.

Question 2(Chapter 3)
How can an energy efficiency indicator be customized to fit Curacao?
In this chapter we will focus on how energy efficiency can be achieved for residential buildings in Curacao. Therefore we will conduct research on global and international goals and legislation concerning energy efficiency in order to create a understanding about what needs to be accomplished in the nearby future. To use an energy performance indicator (EPI) that fits the tropical climate of Curacao, research will be conducted on differences in factors that influence the energy use of residential buildings as: climate, architectural specifications and energy use patterns in Curacao. To determine the energy use patterns the energy use of 4 houses is being assessed before the energy performance of these houses is being determined. Lastly the EPI will be discussed and customized before using it to determine the energy performance of four houses in Chapter 4.

Question 3(Chapter 4)
What is the energy performances of dwellings in Curacao using a customized energy performance indicator?
For the assessment of the energy performance of buildings is chosen to assess 4 dwellings in Curacao. The houses are relatively different in size, location on the island, expected energy performance and energy efficiency. There is even one house that creates renewable energy with the use of solar panels. There is chosen to assess 4 different types of houses because it gives a better understanding about the national energy performance of houses in Curacao. Also the different types of equipment will give useful insights about energy use of houses and how sustainable the residential sector in Curacao is.

For the assessment of houses a research template is created and can be find in Appendix B. The assessment of houses consists of residential specific questions, energy use of the house, questions about the appliances and architectural information. The architectural information consists of measuring the surface of the floor, walls and roof in order to find the thermal transmission area and the solar radiation area. Also questions about the natural ventilation of the house will be asked to determine the energy use of the buildings.

1.5 Reading guide

In Chapter 2 you will find the breakdown of the energy sector in Curacao. In Chapter 3 different types of global and national legislation and organisations will be discussed in order to get a better understanding about what legislation and goals already exist on energy efficiency. Before we choose an energy performance indication method we will discuss important factors which influence the energy use of dwellings in Curacao. In Chapter 4, four houses will be assessed by means of an energy performance indication method. Lastly the conclusions and recommendations of my research will be discussed.

2. Energy system in Curacao

Curacao is an island in the southern part of the Caribbean. If the island of Curacao wants to become more energy efficient it is important to identify the energy sectors with the highest potential for saving energy. Therefore, it is necessary to research the energy flows of Curacao from the production of energy to the use of energy.

2.1 Introduction on energy flows on Curacao

This research focuses on the energy performance of buildings. But before the energy of buildings will be assessed it is important to conduct research on how efficient energy is produced and transferred through the energy sector of Curacao before it is used in a building. This is relevant for my research because in order to create an assessment tool for houses to become more energy efficient it is important to know were the energy in a house is coming from, and how it is transferred before being used, so different sources of energy can be considered, depending on their efficiency. The energy sector can be considered as a black box with input going in the system throughput in the black box and output coming out the black box. The black box model is visualized in Figure 1.

Figure 1. Black box model

The aim of this research question is to provide insight to this black box. For the energy sector of Curacao the input of the black box can be described as the energy supply stage, the throughput can be described as the energy transformation stage and the output is the final stage were energy is used and exported. The energy flow stages are visualized in Figure 2.

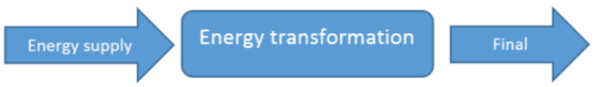

Figure 2. Energy flow stages

In order to map the energy sector as clear as possible a Sankey diagram will be used. A Sankey diagram is an useful tool to visualize energy transfers between different energy flow stages.

2.2 Sankey diagram

In order to map the energy production and demand of Curacao a Sankey diagram will be used. A Sankey Diagram is an energy flow diagram what can be useful to map energy transfers for a process, area or even a country. The strongest feature of a Sankey diagram is that a complicated energy network becomes insightful. An Sankey diagram has proven to be a useful tool in energy management and performance improvement, because the diagram traces energy use in various conversion, devices, products, and services, which can be helpful to identify the energy economics, the environmental impact and the energy security of a country (Soundarajan, 2014).

To create a Sankey diagram and trace the energy flows through the sub systems of my research area it is important to outline a clear boundary. The Boundary for my research will be the border of the Island of Curacao. Because the research area of my study will be an entire country, the level of relatively granularity won`t be high. The major energy transformations will be mapped and the small transformations will be neglected. The Sankey diagram will be primary constructed with recent data from the past 5 years so the diagram will be useful to identify current potential area for energy savings.

Three main stages can be identified in the Sankey diagram: primary energy supply, energy transformation and energy use (Subramanyam, 2014). The primary energy supply stage represents the various primary energy resources that enter the boundaries of the research area. The primary energy supply stage will be classified into various types of fossil fuels and renewables. Therefore every form of fuel and energy coming from outside the boundaries of my research area will be identified as imported energy. On the other hand every form of energy leaving the boundaries of the island will be identified as exported energy. Also energy will be produced on the island and will have to be traced through the energy system of Curacao.

Next to the production, import and export energy will be used on the island for various purposes. The use of energy is the final stage of energy transfer. In the process between import, export, production and the use of energy there can exist a variety of energy transfers. The energy transformation stage broadly refers to energy resources being converted to energy carriers and secondary forms of energy supply such as electricity, various types of fuel, and various forms of thermal energy.

The final stage in the energy flow is the energy use stage. The energy use stage incorporates the various activities and flows associated with energy use to provide desired energy services what enables the energy user to produce useful products and services. Because this research focuses on the energy performance of buildings, the energy use will be divided in services, households, and industries.

In all three stages of the Sankey diagram energy will be no longer usable. These losses are due to distribution and transformation of energy. Losses occur because these processes are not fully efficient and therefore energy will be no longer usable. The loss of energy highly depends on operating equipment and conditions. Representing energy losses can be challenging because it is difficult to identify what energy is useful and what energy is no longer usable. Energy used for a certain purpose can be identified as useful, but what energy is used for the purpose, and what energy is no longer usable is hard to determine. Furthermore, data collected at a national level is not from a desired level of granularity to give sufficient information to analyse the energy losses. Therefore the energy loss for use will be neglected and the energy losses for transformation, which depends on the conversion efficiency, will be approximated.

2.3 Companies in the energy sector

There are a lot of different companies on the island of Curacao who are involved in the energy production, transformation and the selling of energy. The importation of energy carriers is mainly done by the company of Petróleos de Venezuela S.A. PDVSA is a Venezuelan company who imports crude oil and refined petroleum. The crude oil transfers to the refineries on the island and are converted in other oil products. The refineries belong to the company of ISLA. ISLA produces gasoline, diesel fuels, jet fuels, lubricants, petrochemicals and other petroleum-based industrial products. The electricity and water company on the island is called Aqualectra. Aqualectra is responsible for the distribution of energy and water on the island of Curacao. Aqualectra mainly depends on the production of energy by diesel generators. Also Aqualectra gets energy from two small energy production companies on the island. Aqualectra gets wind energy from the company of NU Capital, steam energy from the company CRU. Finally Aqualectra gets energy from houses and companies who have solar panels and sell back energy to Aqualectra. There is also an LPG gas company on the island of Curacao called Curoil. Gas is only used for cooking in Curacao and a connection for gas is respectively expensive. Therefore not all the households have this connection with Curoil and a lot of people buy canisters of gas at the gas pump what makes it difficult to assess the amounts of gas used on the island. Curoil is also sole supplier of fuel for the transport sector on

Curacao and the island of Bonaire. In Figure 3 the major companies in the energy sector are visualized.

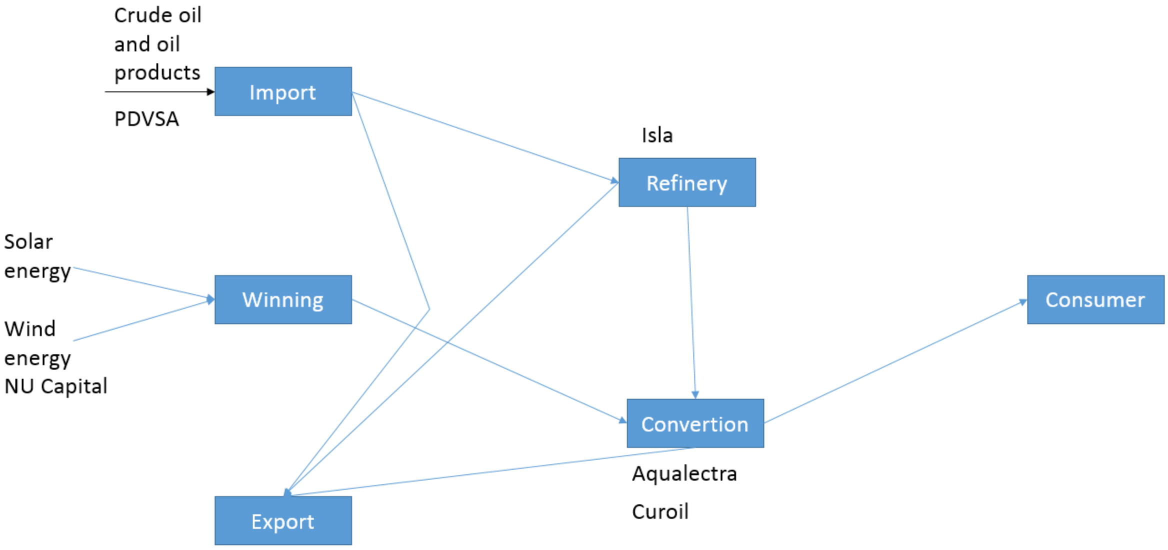

Figure 3. Important companies in the energy sector of Curacao

2.4 Primary energy supply

The primary energy supply of Curacao largely depends on the import of crude oil. The crude oil is being imported by the company of Petróleos de Venezuela S.A. Curacao currently does not have pipeline infrastructure to the mainland what lead to the importation of crude oil by ships. Curacao does not mine their own fossil fuels and therefore the production of energy resources mainly depends on the importation of crude oil.

Curacao aims to improve their renewable energy resources because the potential for green energy is really high on the island due to the relatively high amount of sun hours and wind capacity (The ministry of Health, Enviroment and Nature, 2014). Currently the company of NU capital has two wind farms on Curacao. One located at playa Kanoa and the other at Tera Kórá. Both wind parks have five Vestas 3.0 MW V-90 turbines who have a power of 30 MW of energy (NUcaptial,2015).

Furthermore the company called Curacao Refinery Utilities produces steam energy which it delivers to the refineries. Excessive energy from the refineries on the island is directed to the company of Aqualectra for use. The steam engines of the company currently have a power of 20 MW but the company is planning on improving its plant to have a power of almost 60 MW in the future (CHEEC,2015).

Curacao currently imports 41% of its total import of $3,840,000,000 on refined petroleum and 15% on crude petroleum. Furthermore Curacao exports almost 75% of their total export of $3,220,000,000 on refined petroleum and 7% on crude petroleum (Observatory of economic complexity,2015).

In Table 1 the imported and exported energy carriers are quantified. The average price of a litre crude oil is $ 0.34 and the average price of a litre refined petroleum is $1.10 (Nasdaq,2015). The amount of energy of 1 litre of crude oil and refined petroleum is respectively 37 and 38.6 MJ/l (Natural Gas, 2015).

Table 1. Import and export oil in Curacao per year (Observatory of economic complexity, 2015)

Import/export	Energy carrier	Price($)	Mega Litre	TWh
Import	Crude petroleum	576,000,000	1.69	17.37
	Refined petroleum	1,574,400,000	1.43	15.33
Export	Refined petroleum	2,415,000,000	2.20	23.59
	Crude petroleum	225,400,000	0.66	6.78

2.5 Energy transformation

The company of Aqualectra possess 145 MW of diesel generators. They buy diesel from the refineries of the company ISLA in order to transform energy carriers into electricity. The company of ISLA owns the refineries on the island of Curacao.

Isla is the only refinery who processes crude oil on the island of Curacao. Isla buys the crude oil from the Venezuelan company of PDVSA. In Table 2 is visualized how much barrels of crude oil were bought in the last 5 years per day.

Table 2. Crude oil barrels bought by Isla per day between 2010-2014(ISLA, 2015)

	2010	2011	2012	2013	2014
Import(Barrels per day by ISLA)	63,600	164,000	165,500	170,000	189,200
Total energy (MWh) per day	103,933	267,976	270,427	277,780	309,153
Total energy (MWh)	4330.54	11165.67	11267.79	11574.17	12881.38

The crude oil bought by Isla is converted to other oil products and energy carriers. These oil products and energy carriers are shown in Table 3.

Table 3. Average barrels of oil products created by Isla per day between 2010-2014(ISLA,2015)

	Oil products	2010	2011	2012	2013	2014
	LPG	500	1,900	700	900	800
	GASOLINE	15,300	33,200	38,000	47,700	52,600
	AVTUR	6,100	16,100	17,000	13,400	17,000
	GASOIL/DIESEL	19,500	33,000	35,000	35,400	39,700
	VAC. DISTILLATES	1,800	2,300	6,100	300	600
	FUELOIL/BUNKERS	35,000	64,500	60,200	65,800	61,100
	LUBES	2,300	3,500	3,200	2,200	2,100
	ASPHALT	200	800	1,000	700	3,100
	OTHERS	200	400	200	700	1,100
	OWN USE	12,000	18,400	18,800	20,600	26,500
Total production(Barrels per day)		**92,900**	**174,100**	**180,200**	**187,700**	**204,600**
Total energy (MWh) per day		**157,930**	**295,970**	**306,340**	**319,090**	**347,820**
Total energy (MWh)		**6580.42**	**12332.08**	**12764.17**	**13295.42**	**14492.50**

In Table 2&3 you can see that the company ISLA almost doubled its production in the last 5 years. Especially the production of Asphalt is grown because it is fifteen as high as five years ago.

The company of ISLA also has Bunkers where always has to be crude oil in order to run two months of production in case of scarcity. In 2015 these Bunkers consists of 6 million barrels of crude oil.

The refineries of ISLA deliver 7.6% of their total production to the local market of Curacao. The biggest client on Curacao is Curoil the company who sells fuel to the transport sector and a small amount goes to Aqualectra for the production of electricity by their diesel generators. This means almost 15.500 barrels of oil products are delivered for usage on the local market of Curacao.

2.6 Energy use

The energy use of households and businesses in Curacao mainly depends on electricity. Because buildings in Curacao mainly use energy for cooling, ventilation, appliances and lighting. In Curacao the company Aqualectra is fully responsible for the distribution of energy. The company Aqualectra is also responsible for the distribution of water. Data from Aqualectra show that households, businesses and standard industries are the main users of energy on the island of Curacao. In Table 4 and Figure 4 we see the electricity sales of Aqualectra to different types of energy users.

Table 4. Annual electricity sales in MWh of Aqualectra per energy user between 2005-2015(Aqualectra,2015)

Energy sales (GWh)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Households	305	309	322	322	232	349	348	350	269	272
Business	168	163	163	162	165	171	170	167	164	159
Standard industry	92	91	89	95	98	103	101	102	98	96
Export industry	71	78	85	87	82	93	90	97	100	101
Import industry	11	7	6	7	6	6	7	7	7	7
AMU	6	8	9	8	21	12	16	12	7	7
Hospitals	8	8	8	8	8	8	8	9	10	10
Public lighting	7	7	8	8	7	7	7	7	7	7
Total	**667.7**	**671.7**	**688.7**	**696.6**	**720.2**	**748.7**	**748.2**	**751.4**	**662.4**	**660.1**

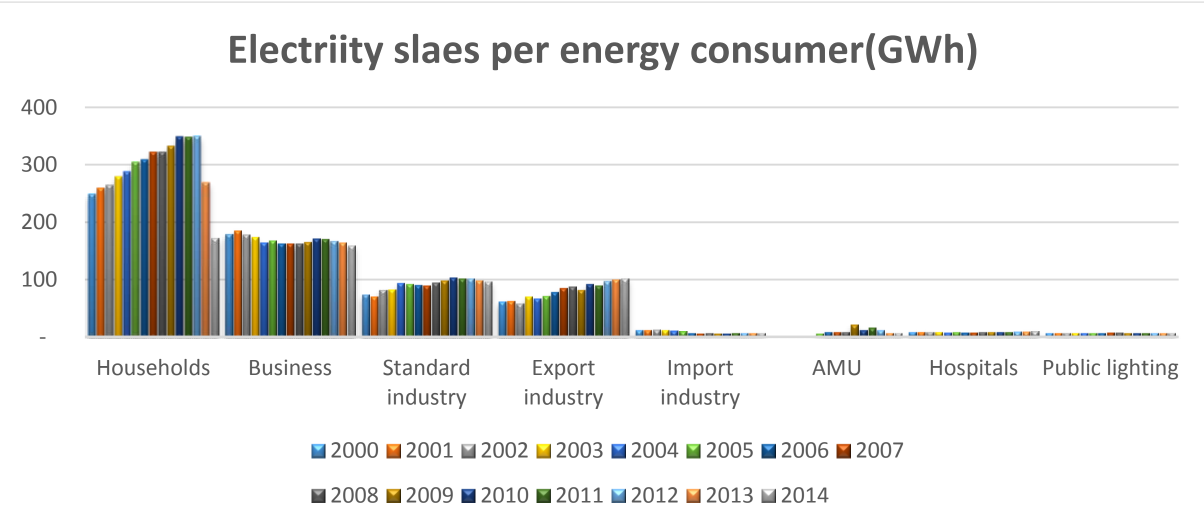

Figure 4. Annual electricity sales in MWh of Aqualectra per energy user between 2005-2010 (Aqualectra,2015)

The energy sales from Aqualectra show an increase in energy use of 10% between 2005 and 2010. This increase is mainly caused by the increase of the use of households. Curacao has around 70,000 energy connections (Appendix A Energy connections on the Island). According to the energy sales and amount of connections from Aqualectra an average household used 4.39 MWH in 2005 and 4.35 in 2010. This means the increase in energy use of households is mainly due to the increase of household connections.

2.7 Preliminary conclusions on energy system in Curacao

Now all the data is collected we can visualize the energy transfers on the island of Curacao. The energy transfers are visualized for the year of 2014 in Figure 5.

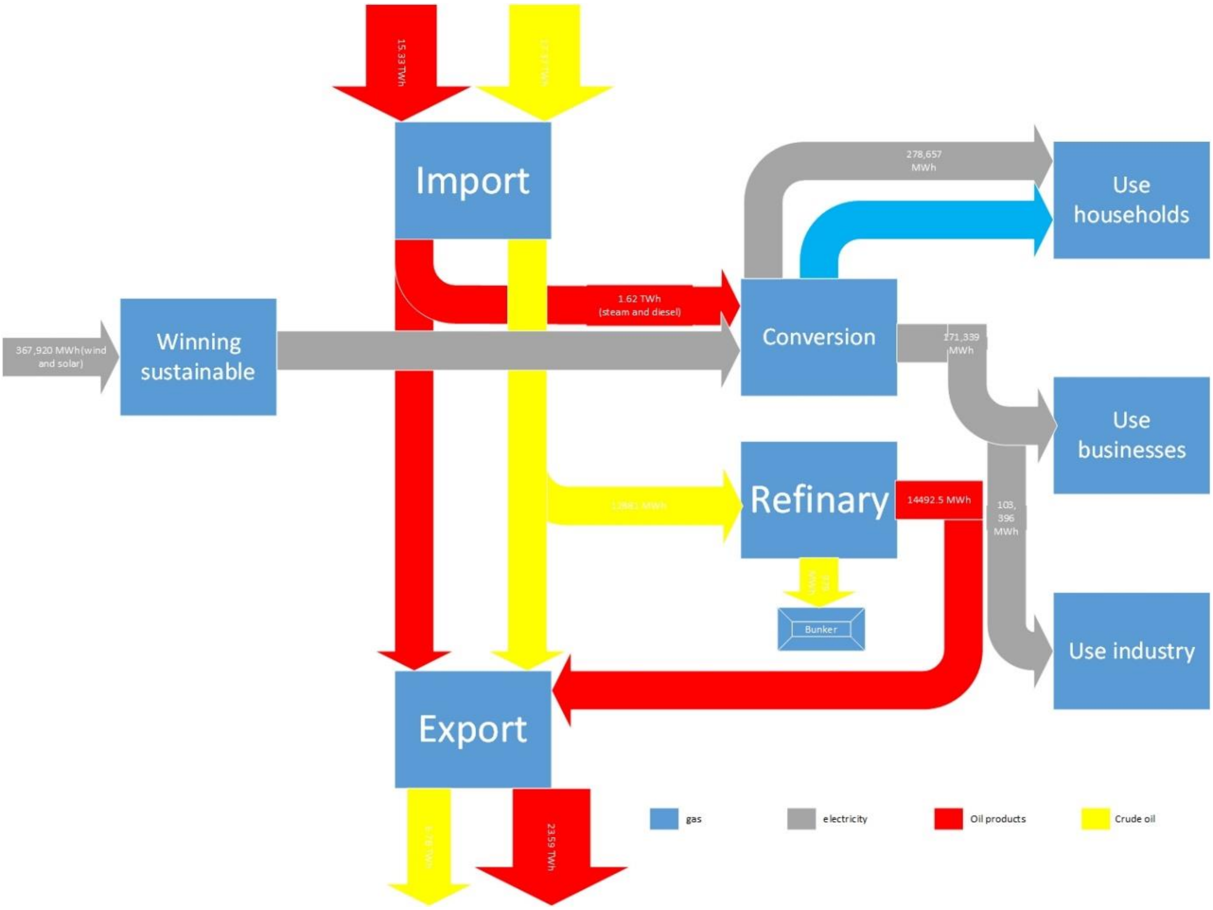

Figure 5. Sankey diagram for Curacao in 2014

In the Sankey diagram is clearly visible that the import and export of crude oil and oil products is the major part of the energy transfers in Curacao. Also the big refineries on the island play a crucial role in the energy transfers. The greatest share of energy is used in the households on the island, and in order to become more sustainable it is important to set minimum requirements for the energy use of households. Households use mainly electricity, and a relatively small amount of gas. This Electricity is being produced and distributed by the company Aqualectra. Aqualectra produces the biggest share of their energy with diesel generators.

Despite a high potential for the winning of renewable energy, the biggest amount of energy is produced by burning fossil fuels. In order to become more sustainable, Curacao has to replace the diesel generators by renewable energy resources.

Another issue is the high amount of energy carriers imported for the production of energy in Curacao, and the low amounts of energy winning on the island. Energy wining on the island is more efficient because this energy does not have to be transported. Therefore, Curacao has to produce more energy locally.

Because a lot of generators in Curacao are becoming old and unreliable, there have been quite some energy blackouts on the island of Curacao the last years (Aqualectra, 2015). In order to prevent these blackouts the capacity of produced energy has to match the energy demand in order to ensure energy security at all time. In order to guarantee energy safety, plants have to be renovated or new plants have to be build.

Solar panels have made it possible to produce energy on the premises of a house. The classical electricity grid is one way traffic and in order for users to deliver electricity back to the grid the infrastructure has to be adapted. The classical grid has a central energy production in a power plant. The power is increased by transformers in order to minimize the losses. The energy travels through high power cables to an area of usage. In this area the power is being decreased by transformers and is being delivered to the users. Because people are using solar panels the energy is not produced locally anymore and therefore it is recommended to redesign the energy grid of Curacao. Because energy is going the transfer in different ways and with different amounts it is recommended to use a smart grid. A smart grid is an electricity grid which is supported by various ICT systems in order to map the energy transfers. This is necessary because energy is going to transfer in different ways due to the decentralised energy production and this way the energy demand can always be determined, and the energy production can be fitted to the use in order to save energy.

Another point of improvement is the energy loss due to transportation and distribution. This energy loss is called Non-Revenue Electra (NVE). This means all the energy produced and distributed which cannot or is not sold. Energy is lost due to heat losses in the cables, transformers and other elements in the grid. The NRE is declining because the grid is getting more efficient. In Figure 6 the NRE of Curacao is visualized between 2004-2008.

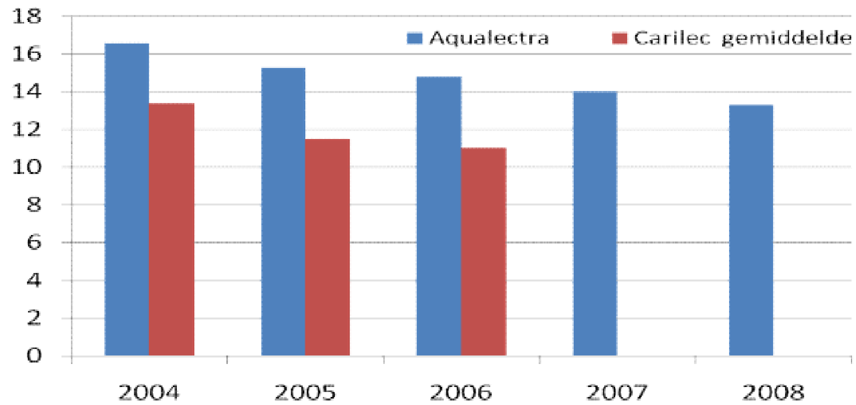

Figure 6. NRE between 2004-2008

In 2004 the NRE was 16,3% and in 2008 it was 13,1%. The NRE is still relatively high because the NRE of Aruba and the Netherlands are respectively 5% and 4%. In Figure 6 we see the average NRE of other Caribbean countries(Carilec) and we see Curacao its NRE is higher. These differences can be due to geographical differences and the density of the population. But Figure 6 gives a good visualization about the challenge for improving the NRE in Curacao. Also a NRE of 0% is impossible because energy will always be lost during transformation and distribution but according to the BTP a NRE between the 6-8% will be reasonable.

3. Energy efficiency indication method for Curacao

In this chapter we will focus on what aspects and features of an energy efficiency indication method are important to be successful in Curacao. We will focus on legislations and goals on energy efficiency, factors which influence the energy performance of houses and lastly an energy efficiency indication method in order to choose a suitable energy efficiency indication method for Curacao.

3.1 Introduction

In this chapter we will focus on how energy efficiency can be achieved for residential buildings in Curacao. Therefore we will conduct research on global and international goals and legislation concerning energy efficiency in order to create an understanding about what needs to be accomplished in the nearby future. To use an energy performance indicator that fits the tropical climate of Curacao, research will be conducted on differences in factors that influence the energy use of residential buildings as: Climate, Architectural specifications and energy use patterns in Curacao. The answer to this research question will consist of the choice for a specific EPI and the reason why this EPI is the best solution for Curacao. This EPI will be used to determine the energy performance of four residential buildings in chapter 4.

3.2 Legislation and goals

In order to honour the commitments countries have entered into by signing the Kyoto protocol they face big challenges. Each country is free in the method of honouring their commitments. Legislation and a compulsory buildings code can be used as tools for policymakers of countries to become more sustainable. In this chapter we will focus on how legislations and a buildings code can help a country in becoming more sustainable and which global goals and objectives exist on energy efficiency. First we will look at the United Nations and the European Union, and there role in influencing the world in becoming more sustainable and energy efficient. Next research will be conducted on the countries: the Netherlands and the United States of America in order to see how these countries tackle the energy efficiency and sustainability issues before researching the legislation and goals of Curacao.

3.2.1 Global legislation and goals

United Nations (UN)

The United Nations (UN) promotes the co-operation between countries all over the world. The UN is involved in peacekeeping, improving human rights and offering tools for economic development and humanitarian assistance. The United Nations is also involved in solving energy related issues worldwide. The United Nations mainly focuses on three aspects regarding to energy related problems. The UN focuses on global energy access, the production of renewable energy and energy efficiency(UN, 2015).

Energy access

The United Nations helps governments, the private sector, local communities and other stakeholders in order to ensure energy safety around the world. They support important institutional reforms to create transparent, well-governed energy markets and leverage private sector participation. The UN strongly focuses on expanding energy services in rural areas, urban slums and the poorest communities as a fundamental means of reducing poverty, because poverty and not having access to energy are related (United nations Energy Council, 2015). In Figure 7 the share of people without access to electricity in developing countries is shown.

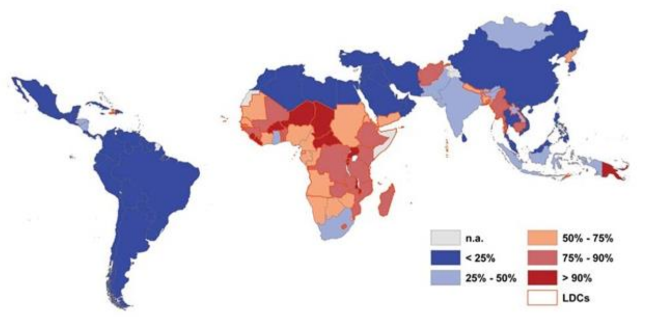

Figure 7. Share of people without access to electricity in 2008(UNDP&WHO,2009)

Renewable energy

Renewable energy has become a cornerstone of the United Nations strategy to become more green, because renewable energy technologies have developed tremendously the recent years. These innovations have a big impact on the financial and social aspects of producing energy. The challenge of implementing new renewable energy resources is the management and usage of them. As such, the UN promotes the building of capacities, stimulating sharing of scientific knowledge and best practises, promotes the development of energy policies, supports pilot initiatives and provide technical assistance when necessary(United nations Energy Council, 2015).

Energy efficiency

Producing energy in a sustainable way only solves half of the energy problem. Reducing wastage and promoting efficiency in energy usage solves the other half of the problem. Furthermore, reducing the demand of energy by introducing energy efficiency measures lessens the pressure on energy security. The United Nations strongly advises countries to invest in the energy efficiency of buildings. Buildings use about 40% of global energy, 25% of global water, 40% of global resources, and they admit approximately 1/3 of GHG emissions. Therefore, buildings offer the greatest potential for achieving significant energy use and emissions reductions at the relatively least costs. The potential for energy savings of buildings can be up to 80% using proven and commercially available technologies (UNEP, 2015).

European Union

The European Union published an energy performance of buildings directive (EPBD) in May 2010. The EPBD describes requirements for member states of the European union for the determination method for the energy performance of buildings (article three), energy performance of new houses (article four), energy performance of existing buildings which will be renovated drastically (article six) and the energy certification of existing buildings (article seven). This directive requires member states of the European Union to issue an energy performance certificate for buildings which are constructed, sold or rented out. This energy performance certificate has a crucial role in informing potential buyers and tenant about the energy performance of a building. The energy performance certificate is a tool to take the energy performance of buildings into account when deciding to buy or rent a house. Because the energy performance of buildings becomes more transparent the EPBD tries to stimulate the building sector to improve the energy performance of new houses by increasing the demand for buildings with excellent, energy efficient performance and a high share of renewable energy use on the one hand, and to influence buildings owners to energetically refurbish their buildings on the other (European-commision, 2011).

The implementation of the energy performance certificate is compulsory but voluntary. Every member state of the European Union has the freedom to implement the energy performance certificate as they see fit. The EPBD supports member states of the European Union by tackling barriers to transform the existing building stock.

3.2.2 National legislation and goals

Netherlands

The Netherlands is one of the first countries who implemented minimum requirements for the energy performance of new buildings in 1995. A compulsory certification for the energy performance of the existing building stock was implemented in 2008. The energy performance standard, established in 1995 is replaced in 2012 by a new standard, the energy performance standard for buildings (NEN7120). This energy performance standard for buildings combines both the residential and non-residential sector and the existing and new buildings stock. The Dutch buildings code sets an integral requirement for the energy efficiency of new buildings and major renovations of existing buildings. Furthermore the energy performance standard for buildings includes a calculation for the energy performance of a building. This calculation takes the current levels of insulation and installations into account. The energy performance requirement of buildings are evaluated yearly and if possible tightened. In Figure 8 the required energy performance of houses from the Dutch buildings code are visualized over the past 20 years.

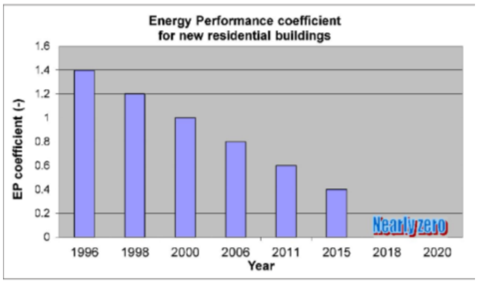

Figure 8 Required energy performance for residential buildings between 1996 and 2020 (European-commision, 2011)

The Dutch government aims to reach the goal of nearly zero-energy buildings in 2020 set by the EPBD.

The Dutch aim to issue an energy performance certificate (EPC) for all the buildings rented or sold in the nearby future. Between 2008 and 2012 over 2.4 million EPC`s were issued covering over 30 % of the residential buildings stock and 15,000 EPC`s were issued for the non-residential building stock (European-commision, 2011).

An energy performance certificate in the Netherlands assigns an energy performance indicator to buildings and thereby list individually tailored cost-effective measures for improving their energy performance. The Dutch energy performance certificate consists of three pages. On the first page the energy performance indicator shows the energy performance class of the building. The energy performance classes run from A++ to G. A label A++ means a lot of energy saving measures are taken and a label of G means a lot of energy saving measures possible. When a building has at least an energy performance of A the building meets the standards of a new building. Furthermore the energy performance certificate shows the standardized annual primary energy use, including a sub-division into different energy carriers as: Electricity, gas and heat. The specific recommended energy saving measures for the building are listed on page two and the last page describes how the EPI is calculated, according to a standardised methodology (RVO, 2015). The Dutch Energy performance certificate is shown in Figure 9.

Figure 9. Dutch energy performance certificate(EPC)(RVO, 2015)

United States(US)

In the United States (US) the Office of Energy Efficiency and Renewable Energy(EERE) and the Department Of Energy (DOE) is responsible for the acceleration of development and facilities deployment of energy efficiency, renewable energy technologies and market-bases solutions that strengthen U.S. energy security, environmental quality and economic vitality. The Office of Energy Efficiency and Renewable Energy focuses on three main goals:

- The generation of renewable electricity by using solar energy, geothermal energy, wind energy and water energy.
- Sustainable transportation by using efficient cars, bioenergy and hydrogen and fuel cells.
- Increasing efficiency and saving energy in houses, buildings and manufacturing processes.

Especially the last goal is really important because the building sector has been identified as the largest energy user as its account for a significant percentage of the nation's energy use as shown in Figure 10.

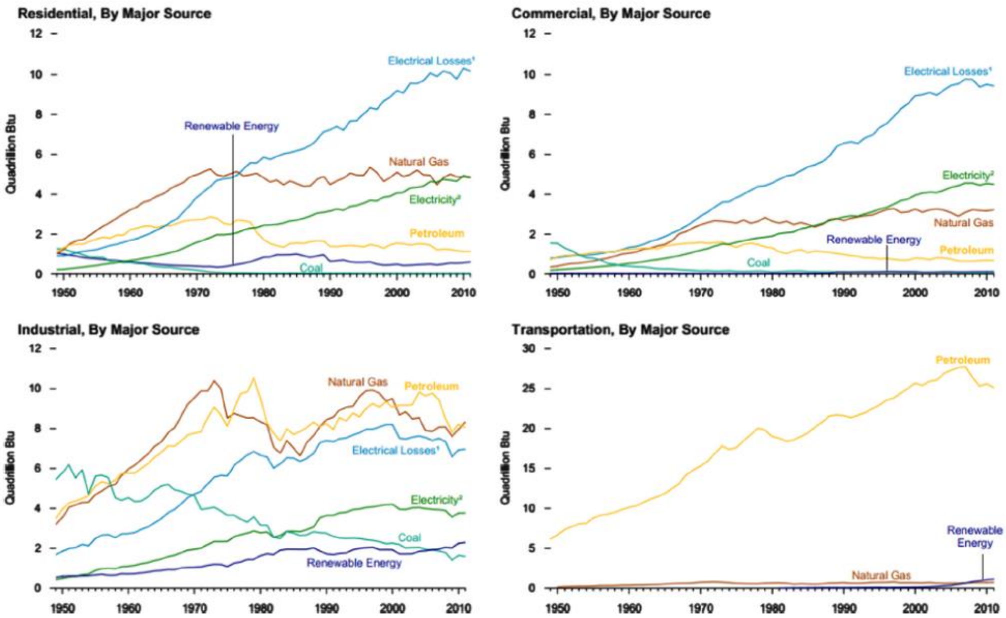

Figure 10. Energy source used by end user sector between 1950-2010 (Bakar, 2014)

Because the electrical losses in the residential sector increased significantly the last years, the need to optimize building`s energy efficiency increased. In order to optimize the energy use of buildings it is important to know for which activities energy is used and how much. In the pie chart in Figure 11 the residential buildings sector energy use of the united states is visualized.

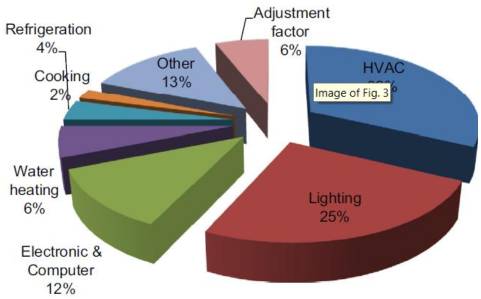

Figure 11. residential sector energy use in US (Bakar, 2014)

Figure 11 shows that most energy in the United States is used by heating, ventilation and air-conditioning systems(HVAC), and followed by lightning. The DOE highlight natural ventilation and daylighting as two strategies that should be used to reduce energy use (DOE, 2013) for houses. These strategies have to be implemented in the new building code in order to improve the energy performance of new houses in the United States.

In the Unites States the International Code Council (ICC) developed a model building code which is adopted through most of the United States. This International building code is divided in different topics as: Fire code, plumbing code, mechanical code, fuel gas code, existing building code, new building code and an energy conservation code (ICC, 2015). The International Energy Conservation Code (IECC) is a model code that regulates minimum requirements for new buildings. The IECC addresses energy conservation requirements for all aspects of energy use in both commercial and residential construction, including heating and ventilation, lighting, water heating and power usage for appliances and buildings systems. The IECC divides The United States in seven climate zones, which can be moist, dry and marine as shown in Figure 12.

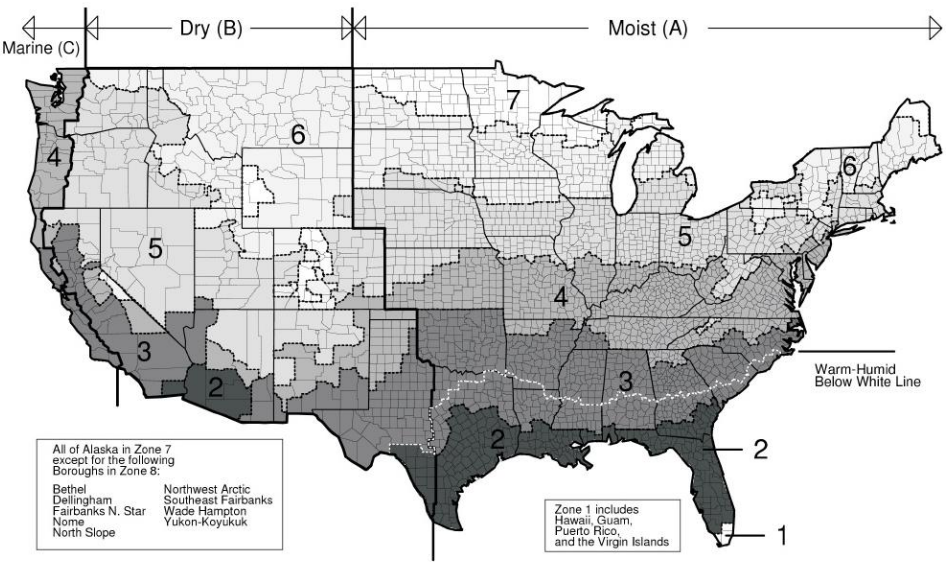

Figure 12. Climate zones in the United States(ICC, 2015)

For each climate zone there are different requirements for the buildings such as: insolation of the roofs and walls, lighting, materials and ventilation. After comparing the requirements to the energy performance of the building a mandatory energy performance certificate of a building can be issued.

The International buildings code is operational since 2012 and is not changed since. In order to meet goals related to energy efficiency the requirements for the buildings have to be tightened in the nearby future.

3.2.3 Legislation and goal Curacao

Currently there are no legislations or a building code which regulates minimum requirements for the energy use of houses in Curacao. Curacao does not has its own building code or legislation for the energy use of buildings because over the last years the prices of energy were really high. The government thought because of the relatively high energy prices people were aware of the importance of energy efficiency, because it effects their own financial situation. For example the energy price of one KWh for households in the Netherlands is €0,23(Nuon, 2015) and the price of energy on Curacao was in 2012 0.80 NAF(€0.40) and currently 0.60 NAF(€0.30)(Aqualectra,2015). Furthermore, Curacao has the highest electricity price in the Caribbean as shown in Figure 13.

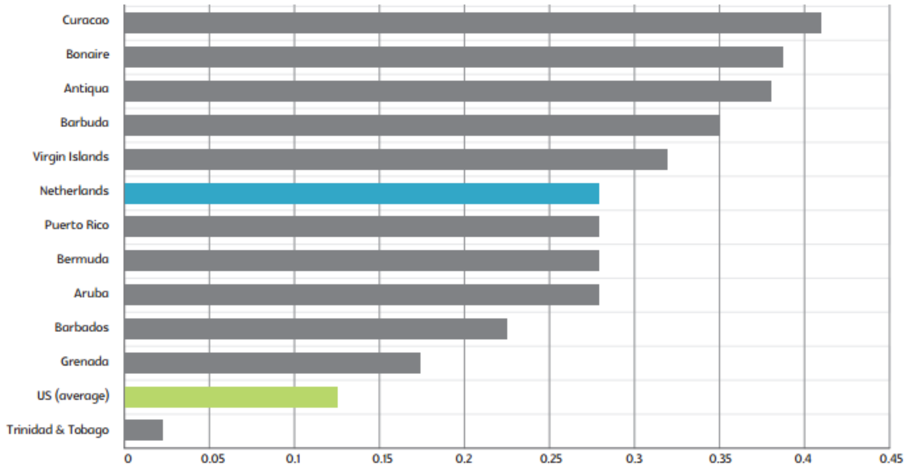

Figure 13. Electricity prices Caribbean per kWh in USD cents(Global Solar investments, 2015)

Also because a lot of houses in Curacao have pre-paid energy they are more often thinking about their energy use. But because the price of energy decreases, legislation and a building code become more desirable for Curacao in order to avoid an increase in energy use.

Therefore, the Bureau of Telecommunication Post and Utilities (BTPU) who supervises the electricity, water and fuel sectors in Curacao has advised a new policy on electricity to the government of Curacao. The new policy is mainly established because the energy sector in Curacao is a monopoly. Only the company of Aqualectra is distributing electricity on the island. Because they are the only company, the government has to set strict rules for Aqualectra and enforce them. The policy has three main objectives (Beleidsnota energie , 2011).

- Creating a transparent model for determining national energy prices.
- Producing energy in a sustainable way by using renewable energy resources on the island.
- Lowering the use of energy per capita.

The policy aims to reduce the energy use of Curacao by 40% in 2010 compared with energy use in 2010. Therefore, the policy introduces compulsory and stimulating measures. The policy aims to introduce an compulsory buildings code for the electricity use of houses and buildings in Curacao. Also fiscal stimulation by subsidies for energy efficient measures is on the agenda.

Also the production of energy will change in the future in Curacao. Because a lot of power plants are old and unreliable the energy sector has to invest in new sources for energy. Because the availability of fossil fuels is decreasing and so the prices of fossil fuels are increasing the production of sustainable energy will become more profitable. The policy aims to extract 45MW of power from wind energy by extending the windmill parks at Tera Kora and Playa Kanoa, and by burning garbage which is a form of bio mass in 2030. Curacao also aims to collect 55 MW of solar energy by public and private users. This means that 20-25% of the energy demand is produced in a sustainable way.

For further stimulation of producing energy sustainable the policy insists on legislative and fiscal incentives for energy producing companies. Because producing renewable energy needs big investments companies are not willing to invest in sustainable energy by themselves. But when legislative and fiscal incentives are used it becomes more profitable for companies to invest or the invest cost get lower. The policy aims to:

- Abolish Imports duties and other taxes for the importation of renewable energy production means as: solar panels, wind mills, etc.
- Introduction of a deductible investment for renewable energy production.
- Introduction of 'green credits' so companies can loan money from the government to invest in renewable energy without having to pay for interest.

This way Curacao tries to become more sustainable. Also the possibilities for a mandatory buildings code with requirements for the energy use of buildings will be researched.

3.3 Differences in factors that influence the energy use of residential buildings

In order to create an assessment tool for the energy performance of buildings in the tropical climate of Curacao it is important to research some factors that influence the energy use of buildings. The first important factor influencing the energy use of buildings in Curacao is the climate. The tropical climate differs from the climate in for example Europa and therefore the energy use of buildings will be different. This mainly influences the transportation of warm and cold air through a building. In order to create an assessment tool for the energy performance of buildings it will be necessary to research the climate specifications to be able to fit the assessment tool to the tropical climate of Curacao. Furthermore the architectural specification of buildings can have an influence on the energy use of buildings. Therefore, architectural specification for buildings will be researched and compared to architectural specification elsewhere in the world. One other factor which has the most influence on the energy use in a building is the behaviour of inhabitants and users of the building. This factor is also the most difficult to influence, and therefore the behaviour and customs of the people on Curacao have to be researched. After the big influences on the energy use of buildings in Curacao are listed we will present an energy efficiency indication method for residential buildings in Curacao. This energy efficiency indication method for residential buildings will be used to assess four buildings. Identifying the factors on the energy use of buildings will be crucial to customize an energy efficiency indicator for Curacao because it enables us to emphasize some key parts of the determination method of the energy performance of buildings in Curacao.

3.3.1 Climate in Curacao

Curacao has a tropical savannah climate according to Köppen. The temperature is relatively constant during the year with a temperature between the 25 and 32 degrees Celsius. There is a relatively low amount of precipitation and rain days on the island, the relative humidity is about 80% and the average wind speed is about 7 m/s which makes it ideal for ventilation. The average cooling degrees per month is 150 degrees celcius. This means that for an ideal temperature of 22 degrees Celsius the dwelling has to be cooled down 150 degrees Celsius during a period of one month. The climate in Curacao is so warm and dry that buildings don't need heating devices during the year. Buildings in

Curacao need to be cooled down 1800 degrees Celsius during the year for an ideal climate inside the dwellings. The monthly climate data of Curacao is available in Appendix G.

3.3.2 Architectural specifications residential buildings in Curacao

Because Curacao has a tropical climate the most important objective of a house is to keep warm air outside and the cold air inside the building. Therefore, two different methods are being used. One of the methods is to insulate the building as good as possible so no warm air can get inside, and use HVAC equipment to cool the inside temperature of the building to the desired temperature. The other more common used method is to keep the building as open as possible and let the air naturally ventilate the building. This is mainly done by windows which are constructed as blinds who can open and thereby create surface for air to flow inside the building. The first method is very common for commercial buildings as shops and offices because the desired temperature is hard to reach with only ventilation of the building. Natural ventilation is more commonly used in residential buildings on the island because these buildings have a higher potential for natural ventilation and the desired temperature is not as low as in commercial buildings.

Residential buildings in Curacao are built separate from each other to create space were air flows freely. To protect the building from the sun lots of artificial and natural shading are used to prevent the walls and windows from transferring warmth inside. Therefore most buildings in Curacao have eaves and transition spaces. These intermediate spaces between the inside and outside protect the walls and the inner space from climatic conditions, generating a shaded space with an air-flow and therefore a cooling effect. This strategy can also be used next to or joint with isolation for the roof of buildings. Also the height of the ceilings on the island is relatively high in order to keep the heat gained through the roof away from the users, given the fact that hot air rises. The roofs of the buildings are not often flat because these roofs attract the most sunlight and therefore pyramid and gable roofs are used. Also most buildings on the island are painted in bright colours in order attract less sunlight.

The foundation of most buildings are constructed with strip foundation, made by concrete block or reinforced steel because the bearing capacity of the ground in Curacao is often good or even excellent and this form of foundation is relatively cheap. The walls of the buildings are also constructed with concrete blocks, often without insulation and the walls are covered with plaster and a bright coloured painting to protect the buildings from the sun, precipitation and the humidity. The roofs of the buildings are often constructed with an angle so the roof attracts the lowest amount of sunlight as possible. The roofs are constructed of wood and covered with sheets, often without insulation. The buildings have big windows that enable cross ventilation and are often accommodated with mosquito screens to keep insects outside the buildings. A lot of windows are protected from the sun by shades. These shades can be provided by a constructed shade or natural shading by vegetation.

3.3.3 Energy use patterns residential buildings in Curacao

The biggest amount of energy used in buildings in Curacao is for cooling and the transportation of hot air out of the building. Next to the ventilation of the house this is mainly done by air conditioning systems. These air conditioning systems are often located in the bedrooms and are used during the night in order to sleep comfortable. Most other rooms in the house use fans for cooling. Houses in Curacao use gas for cooking from canisters. One other major energy use is the lighting of houses. Because Curacao is located close to the equator the sun comes up around seven and the sun sets around seven in the evening throughout the year. This means that during the evenings artificial lighting is needed inside the buildings. Water heating is often done by electrical devices or not done at all. Also the cooling of drinks and food by refrigerators and freezers use relatively lots of energy.

Currently the necessity for energy is largely constant during the day. This is mainly due to cooling appliances who work the entire day. There are three main peaks visible in the energy demand diagram which is visualized in Figure 14.

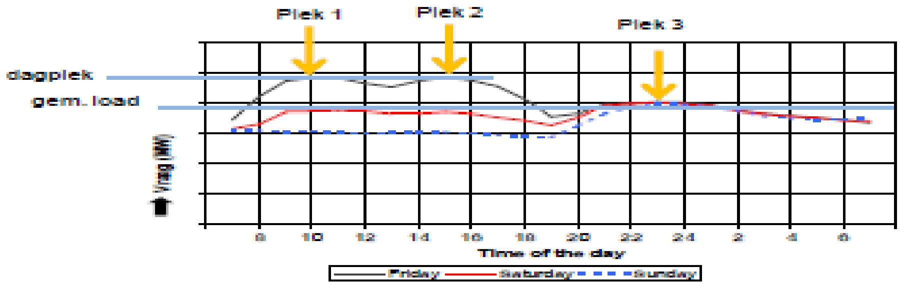

Figure 14. Energy demand in the day and in the week (Beleidsnota Energie, 2012)

The three main peaks occur at 10:00, 15:00 and 23:00. The maximum daily demand of energy occurs between 10:00 and 15:00 and is 135 Mega Watt (MW). Between Monday and Friday the energy demand is lower than the weekends, but the same peaks occur as during the weekends. Aqualectra expects the maximum peak load of energy to grow to 200 MW in 2020. Also the energy demand differs during the year in Figure 15 we see the relative average energy demand per month.

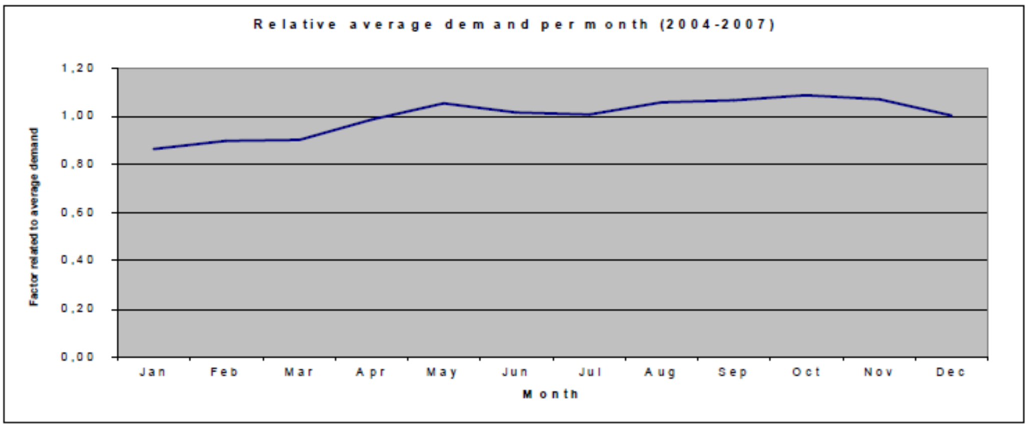

Figure 15. Relative average energy demand per month(Beleidsnota Energie, 2012)

To be able to assess the energy use patterns of residential buildings in Curacao it is necessary to examine the installations used in buildings and how many of them are being used. In this research the energy use of four houses are being measured in order to assess the energy performance of the buildings (Chapter 4). These measurements will give a good indication in how much energy is used and wherefore. In Appendix E the electronic appliances used in the case buildings are listed. The main energy users in the houses were: Indoor climate control, lighting, preservation of food and washing as shown in figure 16 and Appendix E.

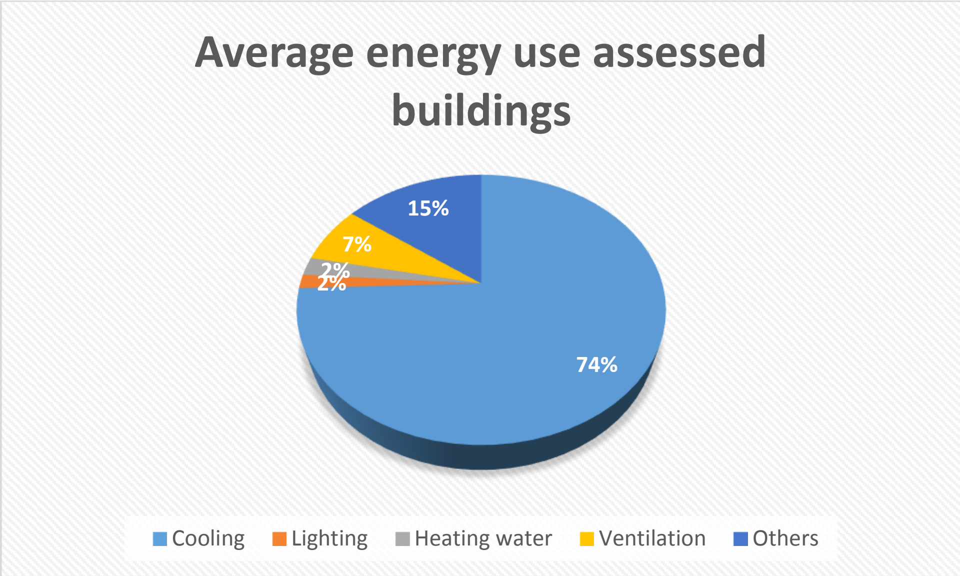

Figure 16. Average energy use assessed buildings

Energy used for cooling includes climate control with air conditioning and the use of refrigerators and freezers. For lighting we include all the lights inside the house, the heating of water with electricity is in dwellings in Curacao only used for showering and the energy for ventilation is calculated by the use of fans inside the house. Others are other equipment and appliances used in the house. Now we see that the average Curacao dwelling uses about 74% for cooling and 7 % for ventilation. These shares of energy use can be used to determine the amounts of energy used in the assessed dwellings by only looking at the energy bill and applying these average shares of energy used in Curacao dwellings

3.4 Energy efficiency Indicator

The goal of an energy performance indication method for buildings is to track the performance of energy in a building. Accurate forecasting of energy use in buildings is an important strategy in achieving the goal of reducing energy demand, as well to improve energy efficiency. To implement this strategy many methods and indicators have been proposed to monitor and measure energy performance in buildings. However, various factors influence the energy use of a building and contribute to the difficulty in accurately measuring a buildings energy system. The factors that can influence the energy use in a building can be: types of activities in a building, weather conditions, building materials, occupancy, electrical installations and the surface area. These factors make it difficult to use one uniform energy performance indication methods worldwide. There are a lot of different ways to assess the energy performance of buildings, but in order to create a successful energy efficiency indication method for Curacao it is important to focus on which parts of a buildings use most energy. In section 3.3 we have seen that dwellings in Curacao use energy for: cooling, ventilation, lighting and the heating of water. Therefore it is important to include these uses of energy in the energy performance indicator.

3.4.1 Dutch energy indicator

To assess the energy performance of buildings on: cooling, ventilation, lighting and the heating of water we will use the determination method used in the Dutch energy norm (NEN 7120). We will determine the applicability of the Dutch energy norm in Curacao. The Dutch energy norm gives calculations to forecast the energy use of a building. The Dutch energy norm could easily be implemented in Curacao because the population speaks Dutch, but the requirements for the energy use of dwellings must be determined separately because Curacao has its own goals on energy efficiency of dwellings and therefore the applicability has to be determined.

The energy system for a dwelling in Curacao exists on the input of energy by electricity and gas. Also energy in dwellings is being transferred by solar radiation, thermal transmission and ventilation. To forecast the energy use and performance of a building these energy flows in the dwelling have to be determined. These energy transfers depend on the ground surface and the thermal transmission surface of the building. The energy index for existing residential buildings can be determined by using the following equation. The energy index determines the ratio between the characteristic energy use and the maximum admissible energy use based on ground surface and the shell of the building. The characteristic energy use is the amount of energy used for a dwelling to function. The characteristic energy use is determined by looking at the energy meters and bills.

$$EI_{ned} = \frac{Q_{total}}{C_1 \times A_{gs} + C_2 \times A_{ts} + C_3}$$

EI = Energy index of the dwelling(-)
Q_{total} = Characteristic dwelling bounded energy use based on NEN7120(MJ/year)
A_{gs} = Total ground surface(m^2)
A_{ts} = Total transmission surface(m^2)
C_1,C_2,C_3 = Numerical corrections factors for: admissible energy use per area, transmission surface, and the admissible energy use. Respectively: 155, 106, 9560(MJ/m^2)(for Netherlands)

The Dutch energy index gives a numerical value. This value corresponds with an energy label from A-G were A is considered as energy efficient and G as energy inefficient as shown in Figure 17.

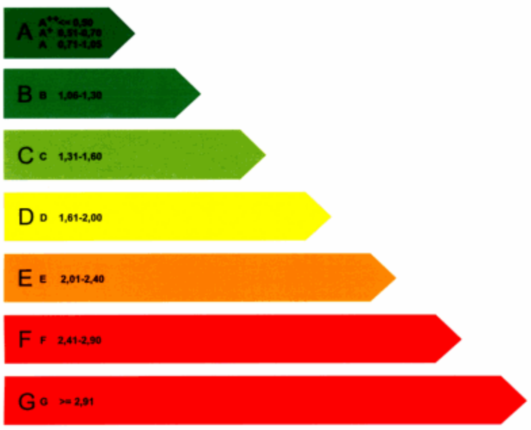

Figure 17. Dutch energy label

3.4.2 Curacao energy indicator

Because the admissible amounts of energy used in buildings in the Netherlands differ from Curacao we will create a new energy performance indicator based on the Dutch energy index. This energy performance indicator will rely on comparing different dwellings in Curacao, and give insight on how the energy performance of the buildings is in comparison to other buildings on the island. The biggest advantage of this energy index that is that it can be broken down and the energy index per end use can be determined in order to assess which end use is the less efficient. The new energy performance indicator largely depends on the assumption that a bigger surface area has more habitants and therefore use more energy.

The equation exist in the bottom part of the characteristic energy use, which is determined by looking at the energy meters and bills of the assessed dwellings. In the bottom part of the equation we see the floor surface and the admissible energy use, which we have determined in Table 5. The most important part of this new energy indicator is to determine the admissible amounts of energy used per end use. Therefore, we will use the range of the energy use per end use of the researched dwellings.

To determine the admissible amounts of dwelling bounded energy use per end use we will use amounts of energy used in the researched buildings. In order to get an average energy index of 1.5 the dwelling has meet the average amount of energy used per end use per square meter of the building. We have chosen the value of 1.5 because the energy labelling system gives values for the energy index between the zero and the three as showed in Figure 17, and the admissible energy use has to be the same as the average energy performance indicator in order to be suitable. In Table 5 the admissible energy uses per month are determined using the data collected from the four dwellings. First the amounts of energy for each end use are being determined for each house by calculating the energy used for appliances in Appendix E. When these used amounts of energy are calculated we can determine the admissible amounts of energy by sharing the average energy use per end use by the factor 1.5.

Table 5. Admissible energy use Dwellings Curacao

House	A_{fs} Surface area houses (m^2)	$Q_{adm;c}$ Energy used for cooling (MJ/m^2)	$Q_{adm;v}$ Energy used for ventilation (MJ/m^2)	$Q_{adm;hw}$ Energy used for heating water (MJ/m^2)	$Q_{adm;l}$ Energy used for lighting (MJ/m^2)
1	165	14	2	2	1
2	322	103	4	7	0.5
3	57	11	1	2	0.5
4	180	39	6	3	1
Average energy use	-	42	4	4	0.75
Admissible energy use(/1.5)	-	28	2	2	0.5

The Curacao energy performance indicator will be determined by the following equation.

$$EI_{Cur} = \frac{Q_c + Q_v + Q_{hw} + Q_l}{Q_{adm;c} \times A_{fs} + Q_{adm;v} \times A_{fs} + Q_{adm;hw} \times A_{fs} + Q_{adm;l} \times A_{fs}}$$

EI_{new} = New energy index
Q_c = Characteristic dwelling bounded energy use for cooling(MJ/year)
Q_v = Characteristic dwelling bounded energy use for ventilation(MJ/year)
Q_{hw} = Characteristic dwelling bounded energy use for water heating(MJ/year)
Q_l = Characteristic dwelling bounded energy use for lighting(MJ/year)
$Q_{adm;c}$ = Characteristic admissible dwelling bounded energy use for cooling(MJ/m^2)
$Q_{adm;v}$ = Characteristic admissible dwelling bounded energy use for ventilation(MJ/m^2)
$Q_{adm;hw}$ = Characteristic admissible dwelling bounded energy use for heating water(MJ/m^2)
$Q_{adm;l}$ = Characteristic admissible dwelling bounded energy use for lighting(MJ/m^2)
A_{fs} = Floor surface of dwelling(m^2)

3.5 Preliminary conclusions energy efficiency indication method for Curacao

Curacao aims to improve its energy sector. Therefore, the Bureau of Telecommunication, Post, and Utilities (BTPU) who supervises the electricity, water and fuel sectors in Curacao has advised a new policy on electricity to the government of Curacao. This policy aims on three objectives:

- Creating a transparent model for determining national energy prices.
- Producing energy in a sustainable way by using renewable energy resources on the island.
- Lowering the use of energy per capita

The policy aims to reduce the energy use of Curacao by 40% in 2030 compared with energy use in 2010. Therefore, the policy introduces compulsory and stimulating measures. The policy aims to introduce a compulsory buildings code for the electricity use of houses and buildings in Curacao. It is clear Curacao has set some challenging targets on making the island and energy sector more sustainable. Especially the introduction of a compulsory buildings code for the electricity use of houses and buildings in Curacao will be challenging because anno 2015 there is no legislation on the energy use of houses.

The main task of houses in Curacao is to keep hot air outside and cool air inside the building. The cooling of air can be done by two strategies. The first one is the cooling of the house by air conditioning systems and keeping the cold air inside. The second way is to transport hot air outside by ventilating the house and replacing the outgoing air with cooler incoming air.

To determine the energy performance of dwellings in Curacao we use the Dutch energy performance norm (NEN 7120). Because the climate and architectural specifications of buildings are different in Curacao in comparison to the Netherlands only the energy use for heating water, ventilation, lighting and cooling will be used. We will try to determine if the Dutch energy performance norm is suitable for Curacao.

After determining the energy performance of the buildings by the Dutch method we will also use a Curacao energy performance indicator by using the data collected of the four dwellings in Curacao we will have established the admissible amounts of energy used per end use and floor surface for dwellings in Curacao. In the next chapter we will use the Dutch energy performance indicator and the new energy performance indicator to determine the energy performance of dwellings in Curacao.

The reason why we use two different energy performance indicators is simple. We expect the Dutch energy label not able to determine the energy performance of Curacao buildings accurate because this method is calibrated using Dutch buildings. Also we need a lot of cases to successful use this statistical approach which we simply do not have. We use the Dutch energy performance indicator to improve the Curacao energy performance indicator. By changing data in the Dutch energy performance indicator we can see which parts of the equation are most sensitive and therefore most important. We predict floor surface being one of th

\e most important factors because this factor relates with a lot of other factors. For example the amount of residents have an influence on the energy use of a dwelling. When there are more residents in a dwelling most of the time the floor surface of a dwelling is larger than a building with less residents. In the Curacao energy performance indicator we compare the energy performance of buildings with eight other. We expect that comparison of energy use with other buildings give useful insights about the energy efficiency of a building. We have determined the average amount of energy use per end use per square meter. Using simple measuring and calculations the energy performance indicator can be determined. The simplicity of this equation may be its biggest strength because this way the equation is easily adaptable.

4. Assessment of four dwellings in Curacao

In this chapter the energy performance of four houses will be assessed. The houses differ in size, amounts of residents and of course in energy performance. First the assessed houses will be described before the energy performance can be determined.

4.1 Introduction

To determine the energy performance of houses an adaption of the Dutch energy labelling method for existing residential buildings will be used next to the Dutch energy label itself. This way it is possible to find differences and which energy performance indicator is better suitable for Curacao. For the assessment of the energy performance of the houses we need to know who and what uses energy in a house and how much. Therefore it is important to know the amount of residents of a building and how long these residents are inside the house and use electricity. In Curacao the most energy is used for cooling as we have seen in Section 3.3 and Appendix E. The necessity of cooling depends on three main architectural specifications. These architectural specifications are: losses due to transmission, losses due to ventilation and losses due to solar heating of a house. To determine these losses the surface area and the material of the floor, walls, windows and roof have to be determined. The surroundings of the buildings could also influence the energy performance of a building because trees and bushes could provide desirable shades. Also houses in Curacao use energy for lighting and the heating of water. The amounts of energy used for lighting and the heating of water will be assessed by assessing the appliances in a house. The power of the appliances and the time used by the residents can give a useful insight about the energy performance of a house.

In this chapter we will assess the energy performance of four dwellings in Curacao. These dwellings are picked in such a way that they differ in size, energy use and amount of inhabitants. This way we try to create a variety of energy efficiency of the assessed dwellings in order to make sure the Curacao energy performance indicator is applicable for all kinds of dwellings in Curacao.

We will use different assessment methods in order to find out which method can be used the best for Curacao. These methods will lead to two different energy performances of the houses but can give a good indication of the actual performances the buildings. The data that needs to be required can be found in Appendix B: Research template for assessment of houses.

4.2 Assessed houses

In this section the four assessed houses will be briefly discussed before the energy performance of these houses will be determined. The location of the houses is visualized in Figure 18.

Figure 18. Location assessed houses

The most relevant specifications of the houses are visualized in Table 6. Other relevant information about the building can be found in Appendix C, D, E and F.

Table 6. Relevant information assessed buildings

	House 1	House 2	House 3	House 4
				
Year of construction	1981	2007	2006	2004
Habitants (age)	2(63,64)	3(23,56,62)	3(1,38,45)	2(44,13)
Total floor surface(m^2)	165	322	57	180
Total shell surface(m^2)	433	401	163	321
Total surface of windows (m^2)	30	40	11	15

4.3 Energy performance index

In this section we will give the results for the energy performance of four buildings in Curacao. Therefore we will use the two energy performance indicators discussed in section 3.4. The results are shown in Table 7. The calculations are done by a model created by the author and in Appendix H an example calculation is done to get the reader of this report familiar with the calculations.

Table 7. Energy performance of dwellings

House	EI_{Ned}	Energy label	EI_{Cur}	Energy label
1	0.16	A++	0.56	A+
2	0.66	A+	1.74	D
3	0.27	A++	0.2	A++
4	0.45	A++	1.35	C

The advantage of the new energy performance indicator is we can determine the energy index per energy use. The energy index per energy use is shown in Table 8.

Table 8. Energy performance of dwellings per end use

House	EPI cooling	EPI ventilation	EPI heating water	EPI lighting
1	0.52(A+)	2.10(E)	0.28(A++)	1.18(B)
2	1.88(D)	0.53(A+)	0.59(A+)	1.21(B)
3	1.14(B)	5.47(G)	1.24(B)	0.21(A++)
4	1.27(B)	2.26(E)	0.53(A+)	3.24(G)

4.4 Preliminary conclusions assessments of four dwellings in Curacao

For this thesis 4 dwellings have been examined. The examined building differ in size, habitants and therefore also energy use. We know from chapter three that cooling dwellings in Curacao takes account for the largest part of the energy use. We see dwellings that use air condition systems use a significantly larger amount of energy than buildings that depend on ventilation and shading. The energy used to determine the energy indexes of the buildings are all kinds of energy which are directly related to the usage of the building. Therefore all kind of appliances which do not relate with cooling, ventilation, water heating and lighting are not taken into account.

The Dutch energy index gives almost all the assessed dwellings an A++ label. Using the new energy index the buildings received a significantly lower value varying from A++ to D.

5. Discussions

Research have showed that in order for Curacao to become more sustainable and energy efficient it is important to set requirements for the energy use of dwellings. The Dutch energy performance indicator gives the buildings in Curacao a really high energy label. Therefore we assume that the Dutch energy performance indicator cannot be used to accurate assess the energy performance of dwelling in Curacao. The main reason therefore is that the numerical correction factors used in the calculation are based on data collected from Dutch buildings over the last years. Also the absolute energy use in the Netherlands is almost three times as high as in Curacao, which makes the Dutch energy labelling norm not directly applicable for curacao. To make the Dutch energy labelling system suitable for Curacao it is important to conduct further research on these assumptions to make this EPI suitable for Curacao.

The Curacao energy performance indicator relies on comparing different dwellings in Curacao, and give insight on the level of energy performance of the buildings, in comparison to other buildings on the island. The energy labels determined by the Curacao energy performance indicator give realistic energy labels for the dwellings. This means that the Curacao energy performance indicator works. In order to improve this energy performance indicator, more buildings need to be examined to improve the accuracy of the average energy use of buildings and therefore the admissible amounts of energy used in dwellings. To make this energy performance indicator suitable for setting requirements for the energy use of dwellings research need to be conducted on ways of forecasting the energy use of dwellings.

The new energy performance indicator is constructed in such a way it can assess the energy performance by end use. This way it enables us to determine which part of the dwelling is the least efficient and therefore gives room for improvement. The energy performance indicator can give an overall energy label and an energy label for each energy end use of the dwelling.

It is clear that dwellings in Curacao use the most energy for cooling. On the one hand this is because the temperature on the island is relatively high and to create an desirable inside temperature there needs to be a lot of cooling. On the other hand do cooling appliances use relativity lots of power which resolves in more energy use. To decrease the energy used for cooling the appliances have to become more efficient and the cool air has to be hold inside the dwelling by using good insulation techniques. Also the time cooling appliances are used have to be reduced. The conducted research shows air conditioning systems are most commonly used in bedrooms. Air conditioning systems are commonly used during the night to increase the comfort temperature during sleeping. We recommend to cool the bedroom before people go to sleep so the bedroom has an comfortable temperature. The air conditioning system has to be shut down during the sleep to save lots of electricity.

6. Conclusions

Curacao is a small island in the Caribbean sea with no access to fossil fuel resources. Therefore Curacao largely depends on the importation of fossil fuels by ships from PDVSA. This crude oil is processed by the many refineries of the island owned by the company ISLA. The oil products are being sold to other companies as Aqualectra. Aqualectra is the only electricity company on the island of Curacao and mainly produces its energy by diesel generators. Aqualectra sells its electricity to end users. Electricity is the main energy source for dwellings on the island, gas is also being used but only a small amount for cooking. The electricity is relatively expensive in Curacao what results in people being aware of their energy use. The last years the prices of energy are declining because of government policies and the declining oil prices. In order to become more energy efficient an energy performance indicator can be used to keep track of the energy use of a dwelling and even improve the situation.

To determine what energy performance indication method can be used in Curacao we first focussed on legislation and goals of Curacao. Curacao currently does not have a building code which describes requirement for the energy use of houses. If Curacao wants to reach its target of becoming 40% more energy efficient by 2030 it is necessary to set requirements for the largest energy end user sector: residential buildings.

The most important factors which influence the energy use of dwellings in Curacao are: the architectural specification, the climate and the energy use patterns. The most important function of a dwelling is to provide a comfortable living environment. Because the climate in Curacao is relatively hot this means dwellings need to cool the inside temperature and transfer hot air from inside the house out. Cooling houses in Curacao is mainly done by using two strategies. The first strategy is using air conditioning systems to cool down the inside of a house and keeping this cool air inside. The other main strategy is to keep air flowing inside the house to transport hot air outside. Air conditioning systems are relatively expensive and use a lot of energy and therefore these systems often are only installed in the bedrooms. The most dwellings in Curacao have a lot of windows and eaves which enables air to flow through the house to improve the comfort level of the living environment. The reason for increasing the temperature inside the dwellings is the sun. The sun warms up the shell of the dwelling by solar radiation. To minimize the solar radiation dwellings are provided with a lot of shading of the windows and walls and roof to provide transition spaces . Also the roofs have a pyramid shape and the buildings have bright colours which attract a low amount of radiation.

Buildings in Curacao use energy mainly for four reasons: cooling, ventilation, water heating and lighting. We have chosen to use two energy performance indicators to assess the energy performance of dwellings in Curacao. First we have used the Dutch energy performance indicator to find out if the indicator can be suited to fit the tropical climate of Curacao. The second energy performance indicator focuses on the main energy users of dwellings in Curacao. This energy performance indicator is developed during this thesis and uses floor surface and admissible amounts of energy use per end use to determine the performance of dwellings. Using the data collected from four dwellings in Curacao we have determined the admissible amounts of energy use per square meter. This energy performance indication method is basically a comparison tool to determine the energy performance of a specific dwelling in comparison to other dwellings in Curacao.

The assessed dwellings in Curacao score relatively high, using the Dutch performance indicator. Almost every dwelling receives an A++ label. The new energy performance indicator assesses the dwellings with an energy label varying from A++ to D.

7. Recommendations

In order to improve energy efficiency the most important area to focus on is the efficiency of cooling inside a dwelling. We advise to set minimum requirements for cooling and use cooling certificates to raise awareness of the energy use for cooling inside a house. Furthermore it is important to improve the efficiency in air conditioning use. Because most buildings are constructed to enable air to flow freely through the house for ventilation the use of air conditioning is not very efficient because cold air from the air conditioning system gets lost very easily. Because air conditioning systems in dwellings are often only installed in the bedroom we advise during the construction of new dwellings to insulate the bedroom to decrease the energy use for air conditioning systems.

We recommend to introduce energy labels for dwellings in Curacao to raise awareness for sustainability and energy efficiency. After the energy labels are successfully introduced we advise to set minimum requirements for the energy use of new dwellings. In order to introduces these minimum requirements it is important to work on a method to forecast the energy use of dwellings. In order to implement minimum requirements for the energy use of new dwellings we strongly advise to conduct research on forecasting methods for the energy use of dwellings in Curacao.

When energy labels are being used in Curacao it can be useful to create an computer model which helps to determine the energy performance of dwellings. To make the determination methods for the energy performance of dwellings more simple we advise to conduct research on a computer model to help determine the energy labels of dwellings so this process is not as time consuming as it used to be.

The Curacao energy performance indicator gives logical energy labels to dwellings. In order to improve the accuracy of this energy performance indicator we need to conduct research on more dwellings to determine the average energy use more accurate and therefore the admissible energy use becomes more accurate. In order to improve the accuracy of the Curacao energy performance indicator we strongly advise to conduct research on more dwellings.

To decrease the energy use of dwellings it is important to focus on energy used for cooling. The efficiency for cooling appliances have to increase and the using time of these appliances have to be decreased. In order to decrease the energy use of dwellings in Curacao we strongly advise research to be conducted on how to decrease the energy use for cooling.

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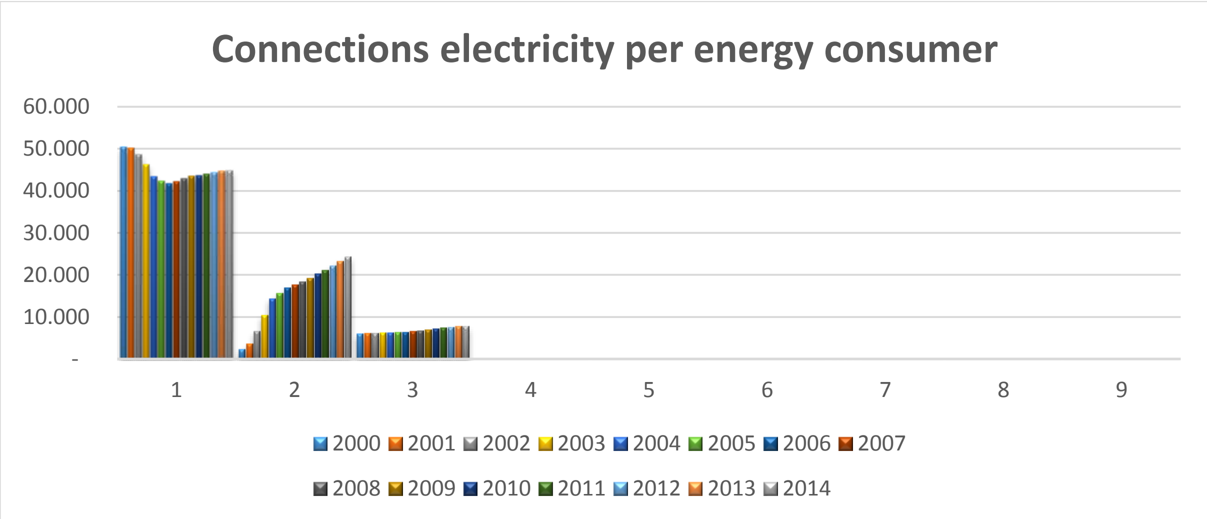
Appendix A: Energy connections on the island

Connections	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Households postpaid	42,259	41,694	42,236	42,968	43,485	43,592	44,005	44,342	44,670	44,810
Households prepaid	15,663	16,975	17,698	18,435	19,299	20,368	21,220	22,213	23,350	24,346
Business	6,355	6,434	6,615	6,806	7,050	7,308	7,486	7,613	7,808	7,844
Standard industry	151	151	155	163	167	171	167	167	168	177
Export industry	46	48	50	53	52	53	52	52	62	62
Import industry	12	11	11	11	11	11	12	12	13	14
AMU	3	2	2	1	4	4	4	4	1	1
Hospitals	2	2	2	2	2	2	3	3	3	5
Publix lightning	1	1	1	1	1	1	1	1	1	1
Total amount of connections	**64.491**	**65.317**	**66.769**	**68.439**	**70.070**	**71.509**	**72,950**	**74,410**	**76,076**	**77,260**



Appendix B: Research template for assessment of houses

In order to determine the energy performance of existing residential buildings data of these houses needs to be collected. For the assessment of the houses the characteristic energy use of the house will be determined by measuring the energy use of a house. Also the theoretical energy use of the house will be determined by calculating the need for cooling, lighting and heating water.

Next to the architectural specification as surface, it will be necessary to determine the materials of the components of the house and sun hours of the building to successfully assess the energy use and therefore the energy performance of a house.

The necessary data for the assessment of houses can be divided in:

- Resident specific information
- Energy use of a building
- Architectural information
- Appliance information

Resident specific information	
Amount of residents	
Age of residents	
How many of the residents work during the day	
How long do the residents work	

Energy use of the house	**Dimension**	**Quantity**	**How to measure**
Electricity use per month	KWh		Asking the residents how much energy they use by looking at electricity meter once I arrive, and one month later again.
Gas use per month	m3		Curacao does not have gas pipes, gas is used from canisters. Asking the residents how many canisters they use.
Alternative energy resources			Measure the amount of thermal, solar or wind energy produced on the terrain of the building.

Electronical devices	Amount of devices	Usage per day in hours	Capacity in Watt	Energy use of device in KWh	Model	Year
Washer						
Dryer						
Lighting						
Water heating						
Air conditioning						
Fans						
Stove						
Oven						
Microwave						
Refrigerator						
Freezer						

Architectural information				
Building component	**What to measure**	**Quantity**	**How to measure**	**Value**
Floor	Surface	m2	Measure Length and Width of the floor	
	Material		Observing, asking	
Walls	Surface	m2	Measure Length and Width of the walls	
	Material		Observing, asking	
	Sun hours	Sun hours*m2	Determining the surface of walls who collect sunlight during the day	
	Quality of ventilation		Asking the residents	Good or bad
Roof	Surface	m2	Measure Length and Width of the roof	
	Material		Observing, asking	
	Height		Measure height above the floor level	
Eaves	Surface	m	The length of the roof overhanging the wall	
Windows	Surface	m2	Measure Length and Width of the windows	
	Material		Observing, asking	
	Sun hours	Sun hours*m2	Determining the surface of windows who collect sunlight during the day	
	Quality of ventilation		Asking the residents	Good or bad
Surrounding of the building	Amount of plants			
	Open space			

Appendix C: Resident specific information Case buildings

House 1

Resident specific information	
Datum assessment	21-04-2015 15:00-17:00
Address	Kaminda Popo Royer 8, Barber, Curacao
Amount of residents	Two retired persons. A man and his wife
Age of residents	The woman is 64 years old and the man 63 years old
How long do the residents work during the day	The man works 4 hours a week at the university giving lectures, and the women is unemployed.
Building year of house	1981
Levels of the house	One

House 2

Resident specific information	
Datum assessment	21-04-2015 17:00-19:00
Address	161 Jan Sofat, Willemstad, Curacao
Amount of residents	Three, a man his wife and their daughter
Age of residents	56, 62, 23
How long do the residents work during the day	8 hours a day 7 days a week
Building year of house	2007
Levels of the house	2

House 3

Resident specific information	
Datum assessment	27-05-2015 16:00-17:30
Address	Kaya Livistona 5
Amount of residents	3
Age of residents	9 months(baby), man is 38, women 45
How long do the residents work during the day	Man from 6:30-15:00, women 6:30-17:00
Building year of house	2006
Levels of the house	1

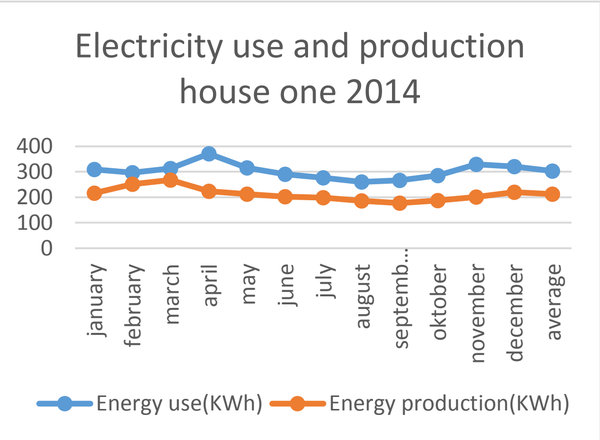
House 4

Resident specific information	
Datum assessment	28-05-2015 17:00-19:00
Address	Kaya Seru Mahoc 2
Amount of residents	A women and her daughter
Age of residents	44 and 13
How long do the residents work during the day	Mother works from 7:00-15:00
Building year of house	2004
Levels of the house	1

Appendix D: Energy use case buildings

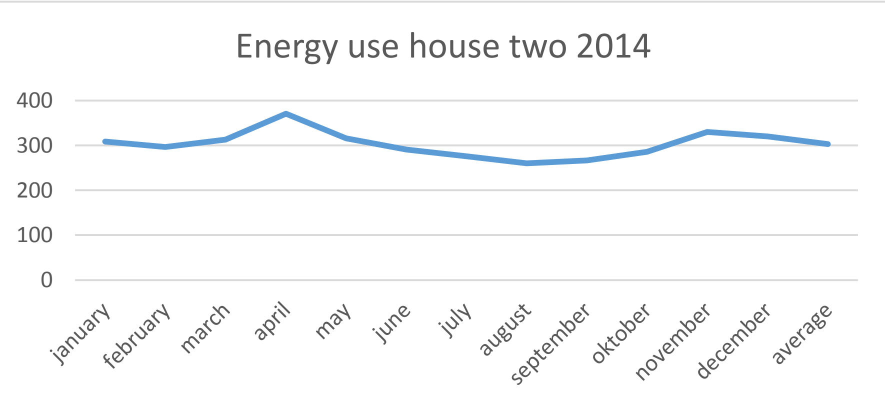
House 1

Energy use of the house	Dimension	Quantity	How to measure
Average electricity use per month	KWh	302 (post-paid)	Look at the energy bill
Gas use per month	m3	33.3	Curacao does not have gas pipes, gas is used from canisters. Asking the residents how many canisters they use.
Solar Panels (20)	KWh	216 KWh	Measure the amount of thermal, solar or wind energy produced on the terrain of the building.



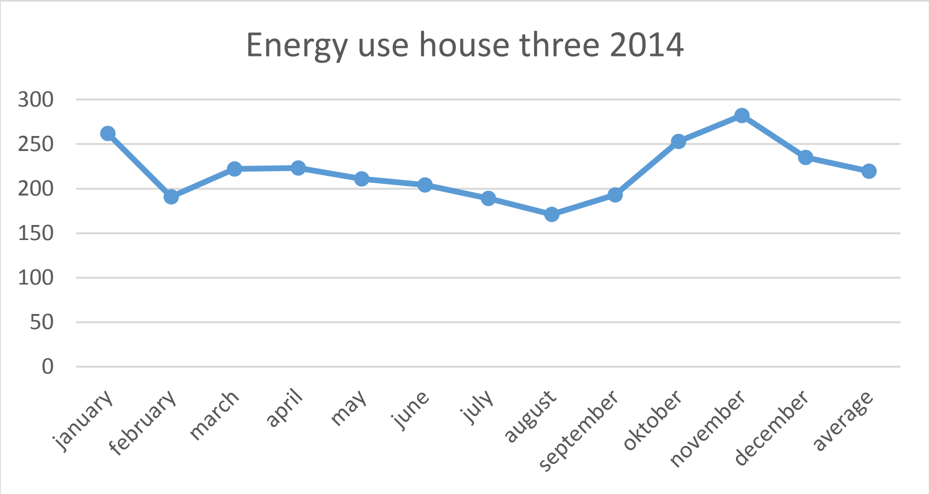
House 2

Energy use of the house	Dimension	Quantity	How to measure
Average electricity use per month	KWh	1577.4 (post-paid)	Look at the energy bill
Gas use per month	m3	33.3	Curacao does not have gas pipes, gas is used from canisters. Asking the residents how many canisters they use.
Alternative energy resources		-	Measure the amount of thermal, solar or wind energy produced on the terrain of the building.



House 3

Energy use of the house	Dimension	Quantity	How to measure
Average electricity use per month	KWh	220 (post-paid)	Look at the energy bill
Gas use per month	m3	12.5	Curacao does not have gas pipes, gas is used from canisters. Asking the residents how many canisters they use.
Alternative energy resources		-	Measure the amount of thermal, solar or wind energy produced on the terrain of the building.



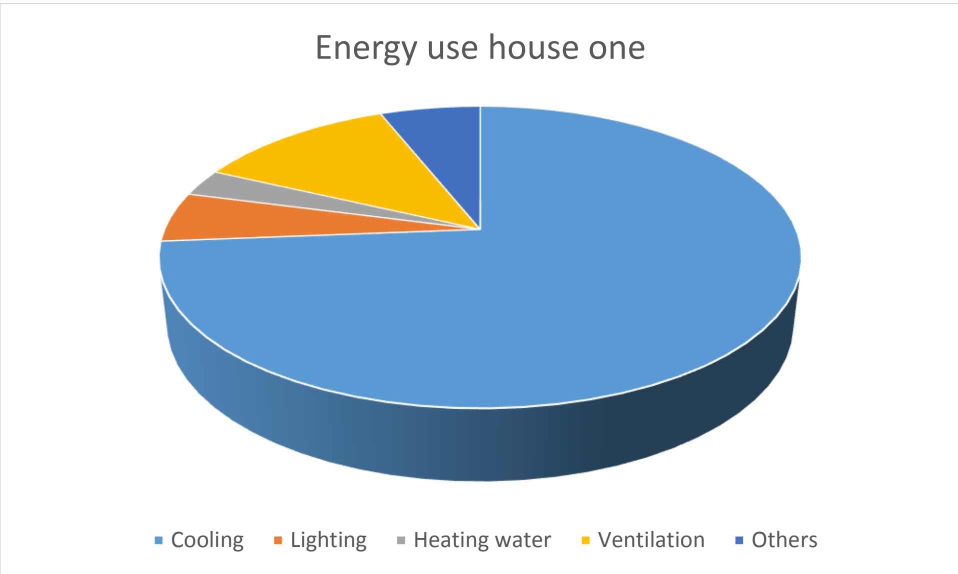
House 4

Energy use of the house	Dimension	Quantity	How to measure
Average electricity use per month	KWh	750 (pre-paid)	Look at the energy bill
Gas use per month	m3	20	Curacao does not have gas pipes, gas is used from canisters. Asking the residents how many canisters they use.
Alternative energy resources		-	Measure the amount of thermal, solar or wind energy produced on the terrain of the building.

Appendix E: Electronical divices case buildings

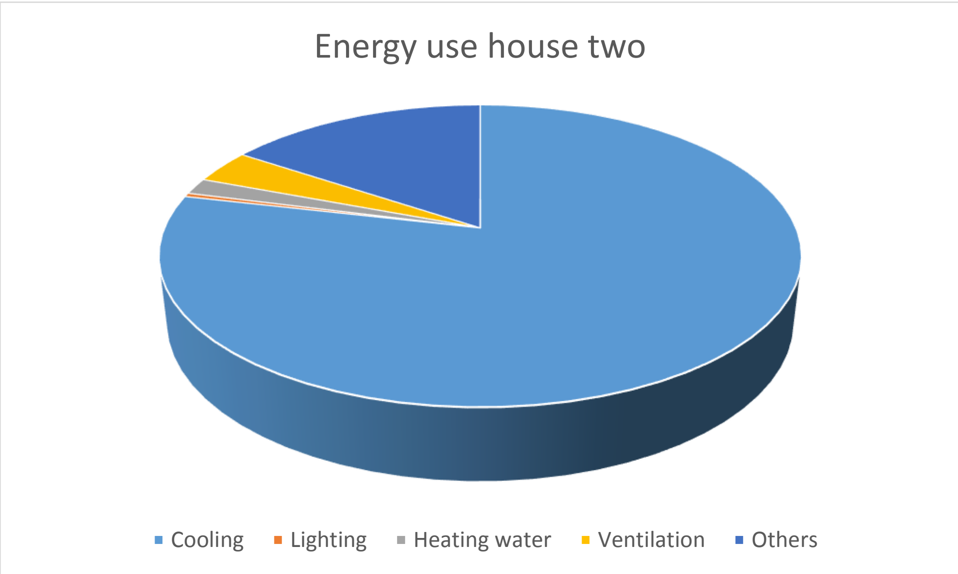
House 1

Electronical devices	Amount of devices	Usage per day in hours	Capacity in Watt	Energy use of device in Wh per day
Washer	1	1/2	400	200
Lighting (incandescent light bulbs)	10	4	40	1,600
Water heating (showering)	1	1/3	2610	870
Air conditioning	1	2	3500	7,000
Fans	3	12	100	3,600
Stove (gas)	-	-	-	-
Oven (gas)	-	-	-	-
Microwave	1	1/12	1250	105
Refrigerator/ freezer	1	24	630	15,120
Total energy use per day				28,392



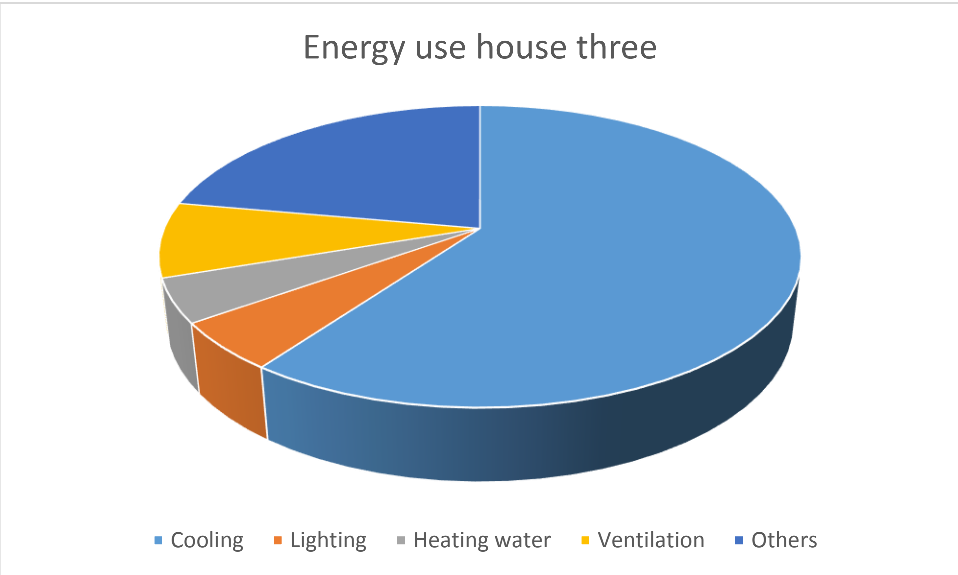
House 2

Electronical devices	Amount of devices	Usage per day in hours	Capacity in Watt	Energy use of device in Wh
Washer	1	1	1200	1200
Dryer	1	1	2000	2000
Lighting (led)	20	4	10	800
Water heating	1	1	3500	3,500
Air conditioning	6	4	3800	91,200
Fans	4	12	150	7,200
Stove (gas)	-	-	-	-
Oven (gas)	-	-	-	-
Microwave	1	1/2	1450	725
Refrigerator (wine)	1 1	24 24	1200 650	28,800 15,600
Freezer	1	24	900	21,600
Total energy use per day				172,625



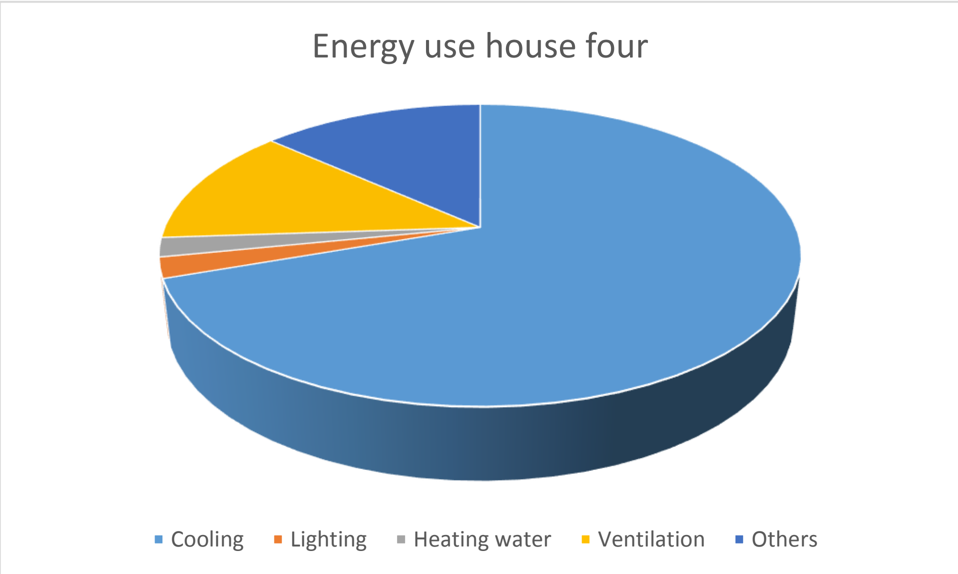
House 3

Electronical devices	Amount of devices	Usage per day in hours	Capacity in Watt	Energy use of device in Wh
Washer	1	1	1300	1300
Lighting (incandescent light bulbs)	9	4	40	1440
Water heating (showering)	1	0.5	2610	1305
Fans	3	6	125	2250
Stove (gas)	-	-	-	-
Oven (gas)	-	-	-	-
Microwave	1	0.5	1350	675
Refrigerator/freezer	1	24	700	16,800
Total energy use per day				23,770



House 4

Electronical devices	Amount of devices	Usage per day in hours	Capacity in Watt	Energy use of device in Wh
Washer	1	0.5	1200	600
Lighting (energy saving light bulb)	25	5	15	1875
Water heating	1	0.5	3500	1750
Air conditioning		4	3800	30,400
Fans	3	24	150	10,800
Stove (gas)			-	
Oven (gas)			-	
Refrigerator/freezer	1	24	1200	28.800
Total energy use per day				74225



Appendix F: Archtectitural specifications case buildings

House 1

Architectural information				
Building component	**What to measure**	**Quantity**		**Value**
Floor	Surface	m2		165.13 m^2
	Material			Dimension stone tile with concrete foundation
Walls	Surface	m2		228.1 m^2 incl windows
	Material			Concrete, cement
	Sun hours	Sun hours*m2		The walls catch legible amounts of sunlight
	Quality of ventilation			Good or <u>bad</u>
Roof	Surface	m2		Pyramid roof. 205.625 m^2
	Material			Corrugated asbestos sheets
	Height			Highest point 4.9 meter lowest point 3.5 meter
Eaves	Surface	m		1.7 m on three sides of the building. On one side there is a terrace where the eaves are 4.5 meters long
Windows	Surface	m2		29.22 m^2
	Material			Single glass with wooden window frames
	Sun hours	Sun hours*m2		The windows catch legible amounts of sunlight
	Quality of ventilation			Good or <u>bad</u>

House 2

Architectural information				
Building component	**What to measure**	**Quantity**		**Value**
Floor	Surface	m2		164 m^2(attic) 158 m^2(1^{st} floor)
	Material			Marble tiles with concrete foundation
Walls	Surface	m2		227.7 m^2
	Material			concrete
	Sun hours	Sun hours*m2		Neglectible amount of sun hours due to the eaves
	Quality of ventilation			<u>Good</u> or bad
Roof	Surface	m2		173.7 m^2
	Material			Wood
	Height			Pyramid roof Highest 5.6 m Lowest 3.6
Eaves	Surface	m		4.2 meter on the backside and 1 meter on the front side
Windows	Surface	m2		8 windows of 1.8mx2.7 m 10 windows of 0.3mx0.5 m Total=40.38
	Material			Wood ventilation windows
	Sun hours	Sun hours*m2		Neglectible amount of sun hours due to the eaves
	Quality of ventilation			<u>Very Good</u> or bad

House 3

Architectural information				
Building component	**What to measure**	**Quantity**		**Value**
Floor	Surface	m2		56.7 m^2
	Material			Dimension stone tile with concrete foundation
Walls	Surface	m2		102.26 m^2 incl windows
	Material			Concrete blocks
	Sun hours	Sun hours*m2		The small walls collect sun radiation the entire day
	Quality of ventilation			Good or <u>bad</u>
Roof	Surface	m2		Pyramid roof. 60.47 m^2
	Material			eternit sheets
	Height			Highest point 4.3 meter lowest point 3.1 meter
Eaves	Surface	m		1.0 m on all sides of the building.
Windows	Surface	m2		11.31m^2
	Material			Single glass with aluminium window frames
	Sun hours	Sun hours*m2		The windows catch legible amounts of sunlight
	Quality of ventilation			Good or <u>bad</u>

House 4

Architectural information				
Building component	**What to measure**	**Quantity**		**Value**
Floor	Surface	m2		179.2 m^2
	Material			Dimension stone tile with concrete foundation
Walls	Surface	m2		121.9 m^2 incl windows
	Material			Concrete, cement
	Sun hours	Sun hours*m2		The walls catch legible amounts of sunlight
	Quality of ventilation			Good or <u>bad</u>
Roof	Surface	m2		Pyramid roof. 198.6 m^2
	Material			Red roof tiles
	Height			Highest point 4.5 meter lowest point 3.7 meter
Eaves	Surface	m		1.0 m on all sides of the building.
Windows	Surface	m2		14.6 m^2
	Material			Single glass with aluminium window frames
	Sun hours	Sun hours*m2		The windows catch legible amounts of sunlight
	Quality of ventilation			Good or <u>bad</u>

Appendix G: Climate data Curacao

Month	Duration month	Sun hours	Temperature	Minimum temperature	Maximum temperature	Precipitation	Rain days	Relative humidity	Wind speed	Cooling Degree days	Sun altitude*	Solar radiation
	[days]	[hours]	[Celsius]	[Celsius]	[Celsius]	[mm]	[days]	[%]	[m/s]	[Celsius/day]	[degree]	[kWhr/m^2]
January	31	260	26	22	28	46	9	80	7	248	57.9	165.85
February	28	230	26	22	28	28	5	80	8	224	67.1	161.28
March	31	265	27	23	28	15	2	80	8	279	78.1	184.76
April	30	225	27	24	30	19	2	80	8	270	89.6	162.00
May	31	230	28	25	30	25	3	80	8	310	81.9	196.85
June	30	255	28	25	30	21	4	80	8	300	78.8	184.50
July	31	285	28	25	30	34	5	80	8	310	81.7	189.10
August	31	290	29	25	32	41	6	80	7	341	89.2	202.12
September	30	250	29	25	31	45	4	80	7	330	78.2	179.10
October	31	240	28	25	31	83	7	80	6	310	66.7	145.39
November	30	220	28	23	30	96	10	85	6	300	57.6	131.70
December	31	230	27	22	28	99	10	80	6	279	54.4	124.62
Annual	**365**	**2980**	**27,6**	**23,8**	**29,7**	**552**	**67**	**80,4**	**7,3**	**3501**		**2027.27**

*at solar noon on 21 day

(TuTiempo,2015)
(Weather and climate,2015)
(Climatetemps,2015)
(Weatherbase,2015)

Appendix H: Example calculation energy labels

The calculations to determine the energy labels for the dwellings in Curacao are done by a model made in Excel. The model needs some input which has to be introduced manually. The input needed for the calculations are listed in Table 9.

Table 9. Input energy label calculations

EI_{Ned}	EI_{Cur}
Characteristic dwelling bounded energy use(MJ)	Characteristic dwelling bounded energy use for: cooling, ventilation, heating of water and lighting(MJ)
Total ground surface(m^2)	Total ground surface(m^2)
Total transmission surface(m^2)	Admissible energy use(MJ/m^2)
Numerical correction factors (MJ/m^2)	

To get the reader of this report familiar with the calculations used to determine the energy index of the dwellings we will calculate the Dutch and Curacao energy index for the first dwelling manually.

Dutch energy index

For the Dutch energy index we use the total yearly energy use of a dwelling. The total energy use of a dwelling can be found on the energy bills of the dwelling. The ground surface and the shell surface of the building are determined by measuring the architectural specifications and can be found in Appendix F. The Total energy use of the first dwelling is 3,624 Kwh which is the same as 13,050 MJ. The surface area and the surface of the building shell are respectively 165 and 403 square meters. Furthermore the numerical corrections factors of the Dutch energy indicator are 155, 106, 9560.

$$EI_{ned} = \frac{13050}{155 \times 165 + 106 \times 403 + 9560} = 0.167$$

After submitting these values to the equation the Dutch energy index of the first dwelling is 0.17. This Energy index corresponds with an A++ energy label and therefore is very energy efficient.

Curacao energy index

For the Curacao energy index we have determined the amounts of energy used per end use of the buildings by assessing the devices used for various purposes. By measuring the amounts of devices used, the time used and the power of the used devices we can determine how much energy is used for a certain purpose. In Chapter 3 we have determined that the biggest sources of energy use are cooling, ventilation, heating of water and lighting. The amounts of energy used in the first dwelling are respectively: 2310, 330, 330, 165 MJ. After comparing the energy use of different buildings we have determined the admissible energy use per square meter which is respectively: 28, 2, 2, 0.5 MJ/m^2. The floor surface of the first dwelling was 165 square meters.

$$EI_{Cur} = \frac{2310 + 330 + 330 + 165}{28 \times 165 + 2 \times 165 + 2 \times 165 + 0.5 \times 165} = 0.56$$

After submitting these values to the equation the Curacao energy index of the first dwelling is 0.56. This Energy index corresponds with an A+ energy label and therefore is energy efficient.