Assessing the Energy Use of Supermarkets and Shopping Malls in Curaçao

Civil Engineering Bachelor Thesis

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Preface

This thesis is submitted to fulfill final requirements for the Bachelor's Degree in Civil Engineering at the University of Twente, the Netherlands. It contains work done from April to June 2016. My supervising lecturer on the project has been Bram Entrop from the University of Twente Department of Construction Management and Engineering. The external supervisor has been Richenel Bulbaai from the University of Curaçao. This thesis has been made solely by the author, a significant part of the text, however, is based on research of others and I have done my best to provide references to these sources.

In November 2015 I have approached Joop Halman about the possibility of doing my bachelor thesis project in the Dutch Antilles. I thought it could be an excellent opportunity to gain knowledge abroad and at the same time familiarize myself with the islands where both my parents have grown up. Joop Halman provided me with several possible assignments, but my immediate preference went to the topic of building-related energy use. In consultation with Bram Entrop and Richenel Bulbaai the research project was specified to assessing the energy use of commercial real estate in Curaçao.

Writing this thesis and living abroad have been of great personal experience for me. Not only have I learned a lot about myself, but I also learned more about the Curaçaoan culture. I have experienced firsthand how relevant the subject of energy efficiency currently is in Curaçao. During my stay I experienced several power outages, noticed the increase of gasoline and electricity prices and saw people demonstrating against the air polluting oil refinery. Contact with the Curaçao government, utility company and business owners revealed that there is a growing awareness of their impact on the environment. I hope my thesis succeeded to present this subject from different perspectives.

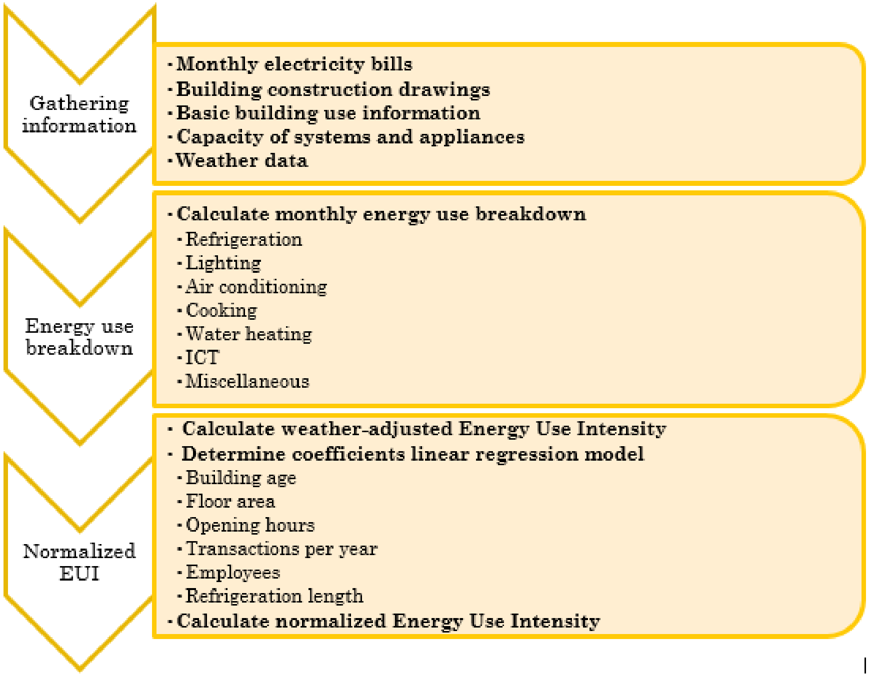
I would like to thank my supervisor Bram Entrop for the useful ideas and comments he provided in person and across different time zones via Skype. In the earlier stage of the project he had already helped me in the right direction to such an extent that it was possible for me to continue my research independently for several weeks. I was pleased that despite health issues he was still able to supervise me during the completion of this project.

Thanks also to Richenel Bulbaai from the University of Curaçao, who supervised me during my stay. He made sure I felt at home on the university campus and was always available to answer questions about my thesis or help with other unrelated matters. I am also grateful he shared his connections on the island to further aid me in my research.

Finally, lots of thanks are due to Joop Halman for bringing me into contact with Richenel Bulbaai and making this research project possible.

Summary

The commercial sector has been growing the past few years and as a result the amount of commercial buildings have been steadily increasing. Buildings have a significant contribution to the total energy use. In Curaçao electricity is relatively expensive and still only a small fraction of the total energy supply comes from renewable energy sources. To diminish the impact on the environment and reduce costs for business owners, energy efficiency of commercial buildings should be increased. Research has been done on the energy use of a shopping mall and eight supermarkets in Curaçao. The goal of the research was to determine how to assess the energy performance of these buildings. For this purpose the assessment framework below was created.



In a case study the framework was tested. An estimation was made of the energy use breakdown in supermarkets. Refrigeration contributed the most to total energy use on average with 32%, air conditioning and ventilation contributed with 28% and lighting 24%. Based on basic building information a normalized Energy Use Intensity was calculated for eight supermarkets. The resulting benchmark table is shown below.

Building	EUI_{norm}
Mangusa supermarket	45,71
Albert Heijn	74,76
Esperamos	52,77
Van den Tweel	53,53
Best Buy	22,81
Centrum	42,69
CostULess	57,37
Mangusa hypermarket	47,72

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1 Introduction

Energy use of buildings account for 30-40% of total energy usage worldwide (Chedwal, 2015). Commercial real estate can attribute significantly to the energy use. In this research project the focus will be on the energy use of commercial real estate in the island of Curaçao. First the problem will be introduced with its background, problem definition and relevancy. Then the research setup will be outlined, followed by a reading guide.

1.1 Background

The island of Curaçao, one of the ABC-islands, is officially a constituent country of the Kingdom of the Netherlands. It is located in the southern part of the Caribbean sea and near the coast of Venezuela. The climate in Curaçao can be characterized as semi-arid and tropical, which means a small amount of precipitation and temperatures that are relatively constant around 31 °C throughout the year (Meteorological service of Netherlands Antilles and Aruba, 2016).

In 2015 the University of Curaçao in collaboration with the University of Twente did research on the energy use of residential real estate in Curaçao. This resulted in better insight of the categorization and magnitude of energy use in this sector. In 2015 Guus van Eldik designed an energy prestation coefficient model fitted to Curaçao. This model enabled the assessment of energy efficiency in dwellings (Eldik, 2015).

However, there is still a great deal unknown about the energy use of commercial real estate in Curaçao. Because the buildings in this category are in general more substantial in size than residential buildings, they require more energy to provide a comfortable indoor climate. Consequently, it is believed that there is some room for improvement concerning the energy usage.
Commercial property is also a relevant research subject since this type of property is used for business purposes. An increase in energy efficiency will diminish business expenses and therefore increase profits. This makes the research valuable for business owners as well as for the environment.

Problem definition

The energy use of buildings in a tropical climate is distinctive because compared to milder climates a larger part of energy use is related to the cooling of the building. Previously houses in Curaçao were built to provide natural cooling by the wind. More recently the usage of air conditioning has increased significantly which has led to an overall increase in the energy usage of the average household. Especially on an island where energy usage is relatively expensive, this raises the question if energy sources are being used in a sustainable way. The government of Curaçao wants to diminish its negative impact on the environment in the future and has set sustainability goals. Business owners are also interested in restriction of energy use as this can lead to monetary savings.

Unawareness of current energy use prohibits improvement. In the current situation there seems to be limited insight in to what extent and for which purpose energy is being used in commercial real estate. A better understanding of this sector will contribute to the greater objective of comprehending energy behavior in Curaçao and improving energy efficiency. The research problem is defined below.

"There is currently limited insight into the energy usage of commercial real estate in Curaçao, but this knowledge is needed in order to reduce the island's energy use and its negative impact on the environment."

Relevancy

Energy is a very important subject for the technological and economic development of a country. Worldwide energy usage has risen by 30 percent in the last 25 years (Tverberg, 2016). With increasing oil prices and a growing awareness of the exhaustibility of fossil fuels, it is important to diminish energy use. Since the first oil crisis in 1975 many different countries have been trying to increase energy efficiency with energy policies. However, not all these policies have had the desirable effect and many countries still see their energy usage rising yearly.

This research will contribute to current research that Richenel Bulbaai (associate professor at the faculty of engineering) is performing commissioned by the University of Curaçao. His research subject covers how the present energy system in Curaçao that depends mainly on oil can be transformed to use more sustainable energy sources. For this purpose it is necessary to achieve a better understanding of the island's energy use. Information is still absent on energy use in the commercial real estate sector.

1.2 Research setup

Goal definition

The objective of this research is to achieve a deeper understanding of the current system, where particularly the quantity and purpose of energy use in commercial real estate are of interest. This is the assessment of the system. Another goal is to investigate possibilities to enhance energy efficiency and conservation. This can be summarized in one goal definition.

"The goal is to develop an assessment framework for the energy use of supermarkets and shopping malls in Curaçao."

Research questions and methods

The main goal as defined above can be disaggregated into several research questions. The order of the research questions is similar to the order in which the research will be performed. The sequence of the research is based on the concept of first gaining a general understanding of the concept of energy use in commercial real estate before zooming in on the more specific object of interest. The level of detail increases with every research question.

1. *What is known about the energy use of commercial real estate?*

The purpose of the first research question is to get an overview of the theories and concepts in energy use of commercial real estate. Previous research on this subject can be valuable to place the commercial sector of Curaçao into a broader context. Considering which factors influence the energy use and to what extent is crucial for the purpose of determining which factors to take into account when assessing a commercial building. A literature study will be performed to create a theoretical overview on the subject.

2. *What are characteristics of commercial real estate energy use in Curaçao?*

The literature study performed for the first research question will comprise what is internationally known about commercial real estate. The situation in Curaçao is expected to contrast with this view, as most countries have a mild climate whereas Curaçao has a tropical climate. The island of Curaçao has a population of only 155,000 (The World Bank, 2016) which elucidates why the amount of research performed on the island is limited and relatively few articles on Curaçao can be found in scientific databases. Hence a case study is viewed as the most appropriate method to gather information on typologies and energy use constitution of commercial buildings. During this case study several commercial buildings will be visited. Visual inspection will provide insight into some building characteristics. Also available energy bills and building drawings will be studied to gather information on respectively monthly energy usage and building architecture. Finally, building users will be asked to complete a survey to map the building's occupational characteristics.

3. *What assessment framework is suitable for commercial real estate in Curaçao?*

Information about commercial real estate in general and specifically on Curaçao as gathered in the first two research questions can be used to determine what type of assessment method is suitable. First common assessment method, as described in literature, will be compared. Then the results from the case studies will be compared to each other to determine how they perform.

1.3 Reading guide

In this Bachelor Thesis first a literature study on global energy use will be presented in Chapter 2. Then the literature study is made more specific and zooms in on the Caribbean and Curaçao in Chapter 3. In Chapter 4 the factors that influence building energy use will be outlined. The information from chapters 2, 3 and 4 will be used to develop a new assessment method which is presented in Chapter 5. This method will be used in Chapter 6 in a case study on supermarkets and shopping malls in Curaçao. Results from this case study will be presented and analyzed. The discussion follows in Chapter 7 and finally in Chapter 8 conclusions and recommendations will be given.

2 Literature study on global and commercial building energy use

Internationally energy markets are constantly evolving and have been changing rapidly for the past years. This paragraph is an examination and discussion of energy market trends that serves as a starting point to understand the impact of commercial building energy use.

2.1 Global trends in energy use

It took hundreds of thousands of years for the population to grow to 1 billion, but in the past 200 years it grew in sevenfold. In 2011 the global population reached the 7 billion milestone (UNFPA, 2016). In the meantime rapid advancements in Information and Communications Technology have been made, making it one of the main drivers for economic growth (Pilat, 2014). ICT and specifically the rise of the internet have significantly changed human activities and as a result the electricity demand.

The total energy use worldwide has been steadily increasing the previous years (Shell, 2008). The upcoming economy and population increase in Asia have resulted in a notable growth of the continents energy use. In 2013 Asia accounted for approximately 30% of global energy demand (Konrad Adenauer Stiftung, 2016). Asia is expected to continue to be a key actor in the increase of world energy use, especially the developing countries will play a key role (Figure 1). After Asia, North America and Europe are the largest contributors to the global energy use (EIA, 2016).

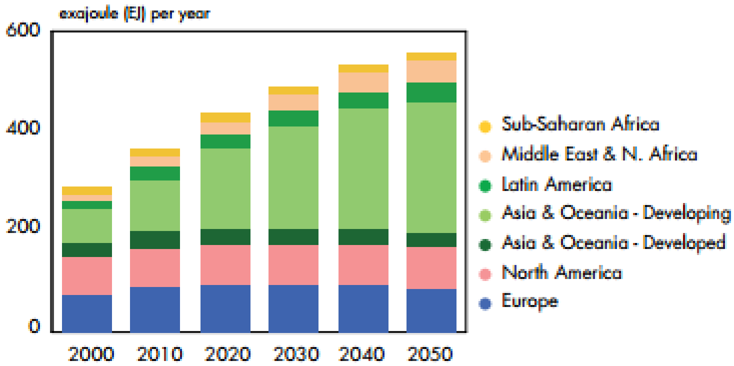


Figure 1: Final energy use by region (Shell, 2010)

2014 was a notable year because it was the first year that global energy use has almost stagnated entirely by growing only 0,3% (BP, 2016). The energy use of China, which is a significant contributor to the global energy use, stabilized for the first time in 30 years. Europe had the largest fall ever in energy use since the economic crisis. The stagnation in world energy use was not directly linked to a lack of economic growth, because the world economy increased with 3,5% which was similar to 2013. CO_2 emissions also stabilized with a decrease of 0,2% (Enerdata, 2015).

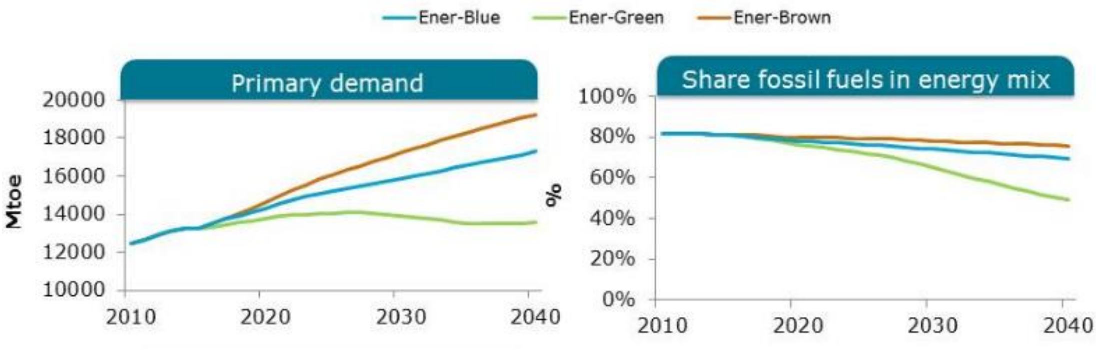


Figure 2: Three scenarios for primary demand and share of fossil fuels in 2040 (Enerdata, 2015)

Enerdata (Enerdata, 2015) made three scenarios for the future (Figure 2). The Ener-brown scenario assumes that OPEC output continues to rise while oil and gas remain weak. A lack of global agreement on energy policies results in CO_2 emissions increasing throughout the world and a temperature increase of +5-6°C. In the Ener-Blue scenario fossil fuels remain the dominant energy source, but energy efficiency and renewable energy sources slows down CO_2 emission growth. The Ener-Green scenario displays a clear transition to decarbonisation and renewable energy technologies. Renewable energy sources become dominant in the energy mix and nuclear energy also acquires a bigger share. This would reduce the world's emissions with 50% by 2050 (Enerdata, 2015).

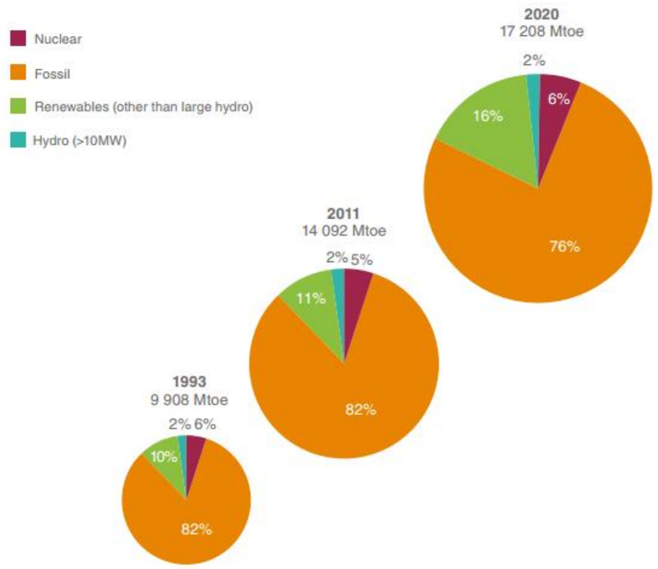


Figure 3: Global primary energy supply by resource (World Energy Council, 2013)

Whereas Enerdata takes on three different extreme scenarios, the projections of the World Energy Council (WEC) consist of single aggregations of different outcomes. As seen in Figure 3, the WEC also foresees an increase in renewable energy sources (World Energy Council, 2013). However, fossil fuels are still expected to make up 76% of the energy supply in 2020. The reserves of fossil fuels are limited and electricity generation with these sources cause high emissions of CO_2 and other pollutants. Clean technologies on the other hand require financing, which means consumers all over the world should be prepared to pay higher prices for their energy use than today. Despite these drawbacks the electricity production per year is forecasted to grow from 22,202 TWh to 23,000 TWh to meet the increasing demand (World Energy Council, 2013).

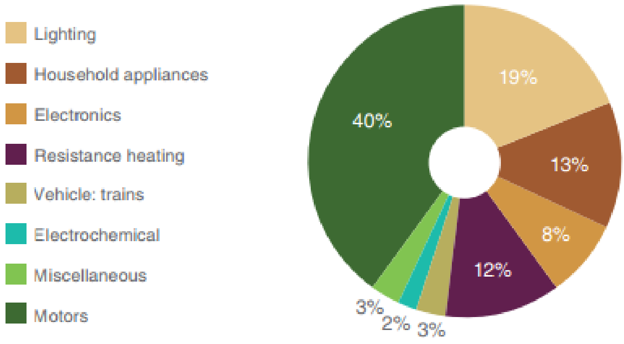


Figure 4: Global electricity demand by application 2013 (World Energy Council, 2014)

Energy efficiency can play an important role in solving this problem and provides an immediate solution to decrease energy density. Improvements in efficiency can achieve energy savings and reduce environmental impact (Shell, 2008). There is potential for efficiency improvements along the entire energy chain. Global electricity demand by application is dominated by motors, but this is closely followed by building related applications (Figure 4). The largest contributor to greenhouse gas emissions is the building sector. Buildings account for approximately 40% of global energy, 25% of water, 40% of resources and they emit approximately one third of Greenhouse gas emissions (UNEP, 2016). Residential and commercial buildings consume approximately 60% of the world's electricity. But there is a lot of potential for increasing the energy efficiency, especially in existing buildings because their performance is often lagging behind on technological development. It is estimated that potential energy savings in buildings could reach 20-40% (World Energy Council, 2013).

2.2 Developments in commercial building sector energy use

The commercial building sector encompasses a heterogeneous selection of buildings and there are several different definitions for the term. In this research project the term commercial building refers to all buildings that mainly serve a purpose which is not residential, industrial or agricultural. This definition does not only include traditional commercial buildings such as offices, restaurants and retail, but also hospitals and schools.

In the U.S. the survey Commercial Buildings Energy Consumption Survey (CBECS) has been conducted several years on a national level by the independent Energy Information Administration. It is the largest known survey on this subject and has been conducted ten times between 1979 and 2013 (EIA, 2003). Utility companies do not have information of energy use categorized by building function readily available, which explains why there is limited research available on the subject. Additionally there is no universal agreement on the classification of functions, which makes comparison between different surveys treacherous.

In the previous paragraph it was argued that buildings contribute significantly to the total global energy use. Figure 6 illustrates that this is also the case in the U.S., where energy use of the building sector exceeds transportation energy use. In 1998 the building sector surpasses the industrial sector as number one energy consumer. Both residential and commercial building energy use are increasing every year. Residential is the biggest contributor to energy use, but the commercial sector has been growing most rapidly. With a fraction of 14% of the total energy use in 1980 to 18% in 2005, which is an increase of 70% (U.S. Department of Energy, 2008).

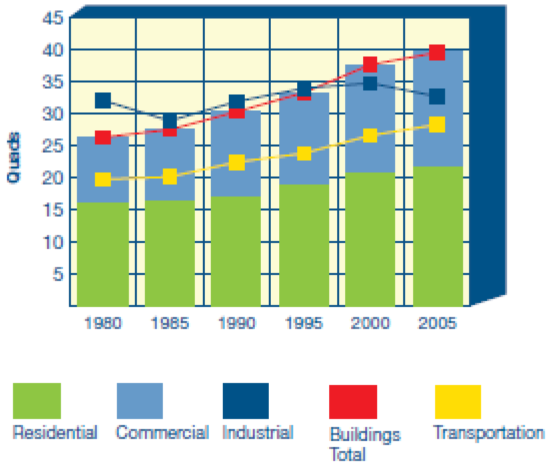


Figure 6: Growth in buildings energy use compared to other sectors US (EIA, 2010)

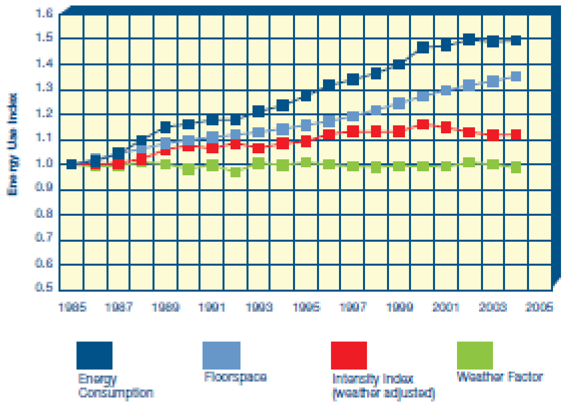


Figure 5: Commercial energy use intensity and factors US (EERE, 2008)

The economic growth is directly linked to the growth of the commercial sector, which influences the energy use and indirectly the commercial floorspace (see Figure 5). Since 1980 however, the growth in the number of buildings has overtaken the growth in floorspace, which indicates a trend toward smaller commercial buildings. 53% of commercial buildings are small with a floorspace less than 5,000 ft^2 (±500m^2). But 35% of total commercial floorspace is located in buildings larger than 100,000 ft^2 (±9 million m^2). Even though the large commercial buildings only make up around 2% of commercial buildings, they have a notable impact on energy efficiency (BLS, 2016).

Commercial building energy use is sensitive to weather circumstances, but less so than residential buildings. The correlation between the factors economic growth and energy intensity is clearly visible in Figure 5. Since the start of the recession in the late 2000s, energy intensity has been declining. This was among others the result of increasingly vacant office and retail spaces (EERE, 2016).

Energy intensity can also be linked to the function of the building. The functions retail and offices account for over 50% of the total energy use in the U.S. commercial sector (Pérez-Lombard, 2008). Restaurants, hospitals and supermarkets are the functions with the highest energy use intensity, which is related to the amount of technology needed for activities (Table 1).

Table 1: Average energy use intensity by building type US (Pérez-Lombard, 2008)

Building type	kWh/m² per year	Ratio
Dwellings	147	1
Retail	233	1.6
Schools	262	1.8
Offices	293	2
Hotels	316	2.1
Supermarkets	631	4.3
Hospitals	786	5.3
Restaurants	814	5.5

2.3 Preliminary conclusions

Buildings in the commercial sector make up a significant part of the global energy end use. Based on several future scenarios, the energy production will shift towards renewable sources. The likely increase in energy prices and a growing awareness of the impact on the environment, will demand energy to be used more consciously in the future. There is a lot of potential for energy savings in increasing the energy efficiency of commercial buildings. Energy usage and savings potential are closely linked to the building function. The energy use of buildings with the function shopping malls has not been researched often, so this could be investigated more. The energy use of supermarkets form an issue due to high energy use per m^2.

3 Literature study on Caribbean and Curaçaoan energy use

In this chapter the literature study zooms in on energy use in the Caribbean region and finally on energy use in Curaçao.

3.1 Energy use in the Caribbean

In this research project the term Caribbean is used to refer to the group of islands that border or are surrounded by the Caribbean Sea which includes the Greater Antilles and Lesser Antilles (depicted in Figure 7). Because of location near the equator the island group has a tropical climate and experiences wet and dry climate periods. In prehistoric communities the only sources of energy on the islands were those acquired by wind or human muscle (Parry & Sherlock, 1971). Nevertheless the demand of food could be met relatively easy by utilizing human labor and natural resources in the direct environment. Colonization by European countries followed and the islands were used for their resources and strategic access (Williams, 1970). This resulted in a shift from self-sufficiency on the island to serfdom and sugar plantations (Brereton, 1981). Export demand required more human labor and slaves were imported from African and Asian continents. Later a shift in energy use took place from human labor to predominantly exosomatic sources such as renewables, coal, oil and gas. The largest shift took place during the industrial revolution in the late 1800s. In this period fossil fuels became dominant over renewable energy technologies such as water and wind mills (Heinberg, 2007).

Figure 7: Caribbean islands (Kmusser, 2011)

The dependency on fossil-fueled energy in combination with the geographical isolation made small islands among the most vulnerable countries during the oil crisis in 1973. During this period attempts were made to transition to renewable energy sources, but when oil prices declined again interest in this change was lost (Weisser, 2004). This resulted in an ongoing reliance on oil for transport and on electric power generation.

Since 2003 oil prices have been increasing significantly again which triggered new interest in renewable energy sources. Additionally, there are also concerns for resource depletion. However in 2009, still 98% of commercial primary energy use in the Caribbean was found to be fossil-fuel based (KEMA, 2010) (Figure 8). In the past few years a lot of countries have made the shift towards more sustainable energy and the Caribbean would be an ideal location for renewable energy sources such as solar, wind and geothermal. Nevertheless most Caribbean nations still use imported diesel or oil to generate 90-100% of their energy (RMI, 2014). The majority of islands do not produce their own diesel and oil, which means they rely on import from other countries. Heavy reliance on imported petroleum means Caribbean islands are subjected to the inconsistent international energy prices. The small amount of energy that the islands demand and their geographical position makes it difficult for them to negotiate discount prices with exporters (Briguglio, 1995). Thus the islands in the Caribbean have little influence on the prices they pay for their energy. As a result Caribbean island residents pay some of the highest retail electricity prices in the world (RMI, 2014). The negative effect from higher oil prices will also be four times greater in the Caribbean compared to South American countries (CC-Energy, 2013).

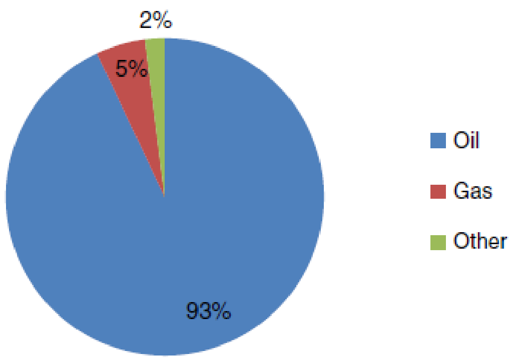


Figure 8: Energy mix in the Caribbean (Kema, 2010)

To add to this situation, the islands often rely on donor agencies to invest in energy related equipment and to draft energy policies. The financial and technical dependence of Caribbean islands on other countries means they might not withstand the future, when the price of oil is likely to be influenced by resource constraints and environmental regulations (Niles, 2013).

3.2 Energy use in Curaçao

In this paragraph the most important actors and recent developments regarding energy use in Curaçao will be evaluated.

For energy supply the island of Curaçao is mainly dependent on the import of crude and refined oil, which is imported by the Venezuelan state oil company Petróleos de Venezuela S.A.(PdVSA). But recently the country Venezuela is spiraling into extreme recession. Worldwide oil-prices have decreased considerably and oil makes up 95% of Venezuela's export (BBC, 2015). As a result the Venezuelan economy has collapsed with inflation rates of 180% over 2015: the highest in the world. The current economic crises in Venezuela poses a threat to the energy supply of Curaçao, because PdVSA is an important shareholder in the Isla refinery and oil-terminals Bullenbaai and Bopec (Antilliaans Dagblad, 2015). The energy supply of Venezuela itself is also under pressure, which resulted in drastic measures from the Venezuelan government. In the end of April 2015 they decided to ration electricity in the most metropolitan areas of the country (Curaçao Chronicle, 2016). Electricity outages and the dropping oil prices have had a negative effect on the crude oil production (Financial Times, 2016). The effects of the crisis in Venezuela can also be felt in Curaçao. In the beginning of May a delay in fuel shipments from Venezuela resulted in a shortage at gas stations on Curaçao (PanAm Post, 2016). In the meantime fuel and utility tariffs in Curaçao are rising and falling as an effect of changing fuel prices (Curaçao Chronicle, 2016). On April 1st the price per liter of gasoline increased with 11% and on May 31st prices increased with an additional 12%. The prices of electricity and water have remained more stable during the same period.

Imported crude oil products are transported for processing to the ISLA refinery which is located in the centre of Curaçao and operated by the Curaçao Refinery Utilities (CRU). Recently the ISLA refinery has been featured in the news multiple times because the future of the refinery is uncertain. In 1985 the Dutch oil company Shell decides to retreat from the refinery, while the refinery provides labour to thousands of inhabitants of Curaçao. Closing it down would have unforeseeable consequences. The government buys the refinery from Shell for the symbolic price of 1 NAF, under condition that Shell cannot be held accountable for environmental and health damages (NPO, 2015).

But concerns about the environment and health are increasing. Yearly the ISLA produces 30 million kg of Sulphur dioxide emissions, which is more than all refineries in the Netherlands added together. Yearly also 1,2 kg fine dust is emitted into the atmosphere. The result is that air quality has reached critical values and this has negative effects on the health of people living in the vicinity of the refinery (Ministerie van Sociale Ontwikkeling, Arbeid en Welzijn, 2012). On average 16 people are victimized each year as a consequence of the activities of the ISLA (Stichting SMOC, 2016). In November 2015 thousands of inhabitants protested against ISLA, because research from TNO showed that one and a half times the legally acceptable amount of sulfur dioxide had been emitted. The future of the refinery is still uncertain and remains a contentious subject on the political agenda (NOS, 2015). In 2019 the leasing contract for the Venezuelan state oil company PvdSA will come to an end and some government officials don't want to see it renewed (BBC, 2012).

Apart from the PdVSA, another important actor in the energy sector is Curoil. Curoil is the purchaser and distributor of oil and gas on Curaçao (Bureau Telecommunicatie en Post, 2014). They supply fuel for aviation purposes and to gas stations for vehicles. Indirectly they contribute to the production of electricity by supplying local power plants. The division Curgas supplies LPG to households (Curoil, 2016). There is no central gas network for small use in Curaçao, so households and businesses buy separate gas canisters of 20 or 100 lbs at the local gas stations or other suppliers to meet their gas demands.

Since 2009 Bureau Telecommunicatie en Post (BT&P) has supervision over the energy sector, including electricity, water and fuels. BT&P is a multi-sectoral supervisor and also supervises the telecommunications, broadcasting and postal sector. It does not only supervise the quality of the services, but also determines the rates for the end user (BT&P, 2016).

Finally another key energy-related actor is Aqualectra. Aqualectra is the utilities company of Curaçao. Aqualectra is responsible for the production and distribution of power and water on the island. Most electricity is produced by diesel generators and a small fraction by wind (20%), solar (2,6%) and steam energy (Aqualectra, 2016). There are also gas turbines for cases of emergency. Nevertheless electricity outages occur regularly.

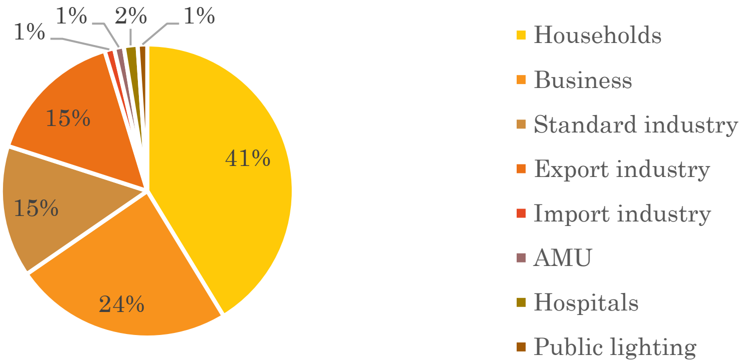


Figure 9: Curaçao electricity sales per sector 2014 in percentages (Aqualectra, 2015)

The most widely used primary source of energy on Curaçao is electricity. The electricity sales per sector as were provided by the utilities company Aqualectra are given in Figure 9. 41% of energy is being used by the residential sector in 2014. With 24% of the electricity use in 2014 being accounted to businesses, the commercial sector is the second most important contributor to the total energy usage of the island. Businesses used 159 GWh in 2014.

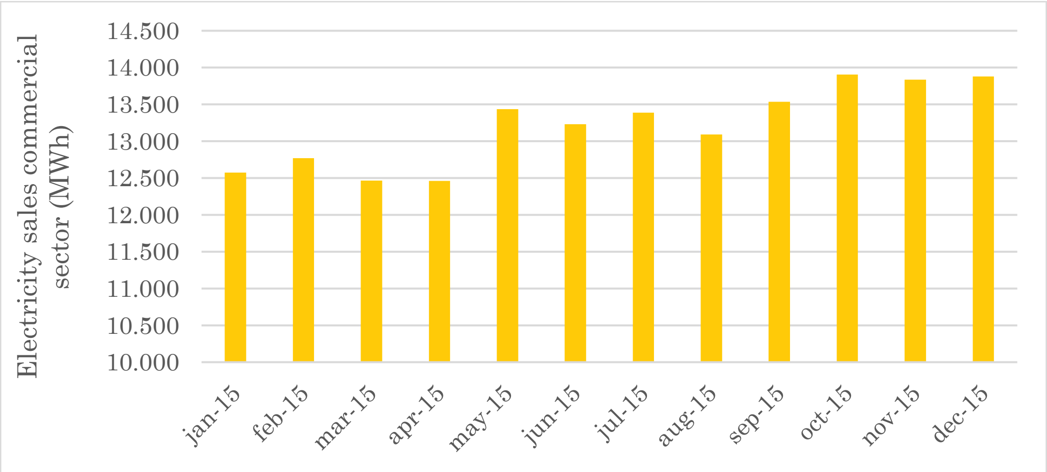


Figure 10: Curaçao electricity sales of commercial sector in 2015 (Aqualectra, 2016)

When we take a closer look at the electricity use of the commercial sector over the year 2015 it is notable that the electricity demand seems to be gradually increasing. The data from Figure 10 is based on 7.950 accounts and the average electricity use per account is 19,947 kWh.

3.3 Governmental energy policies in Curaçao

Contact with the governmental Department of Urban Planning learned that currently no policy exists to stimulate building in a sustainable or energy use reducing way. There is also no standard to measure the energy performance of a building, like the Energy Prestation Coefficient that is used in the Netherlands. Occasionally there are advertisements on the television or radio to save electricity, commissioned by the utilities company Aqualectra.

In 2011 the 'Policy Regulating Electricity Supply Curaçao' was drafted by the government for the years 2011-2015 (Gobiernu, 2011). The policy cited that there had been a lot of complaints from consumers concerning increasing electricity prices and frequent interruptions in the electricity supply. Hence urgently measures had to be taken to improve policy and control in the energy sector. The governmental policy consisted of four focus points.

- A transparent and stable system to determine energy prices
- Trustworthy and effective control mechanisms for functions of the energy sector
- Energy supply based on local renewable resources as much as possible
- A drastic decrease in energy use per head

It is noteworthy that it is not made specific how the goal of decreasing the energy use per head will be reached. Also the stimulation of renewable resources mainly focuses on a decentralized production model based on solar energy. The 'Policy Small-scale Sustainable Electricity Supply' discloses the possibility for owners of solar panels to sell produced energy back to the central network for a reversed supply charge (Gobiernu, 2011). This made producing solar energy lucrative and prompted residential and commercial building owners to buy solar panels on a large scale. In early 2015 however the governmental policy was modified (Gobiernu, 2015). The reverse supply charge was changed and a monthly standby charge was introduced. Before the modification approximately 200 requests for photovoltaic panels were issued per month, but afterwards requests have dropped to 20 per month (Bulbaai R. , 2016). In 2016 the reverse supply charge dropped even further by approximately 24%. The recent drastic changes in solar energy policies have made it an uncertain and risky investment.

3.4 Preliminary conclusions

In 2015 24% of electricity in Curaçao was being used by the commercial sector and the total electricity demand in this sector is increasing. Despite governmental policies, electricity prices remain high compared to neighboring countries and electricity supply is not reliable as there are frequent power outages. Meanwhile the current political and economic instability of Venezuela might form a threat to the import of petroleum and also to the future of the refinery. Also citizens are protesting against the refinery because there is a growing awareness of its air pollution and negative effects on national health. The dependency of Curaçao on fossil fuel import from other countries makes the energy sector vulnerable, so the government is investing more in local renewable energy sources. However, the policy in small-scale solar energy has been unstable for the past two years, discouraging investments in photovoltaic panels. Furthermore, the Curaçaoan government has not been promoting efficient energy use to end-users through standards, energy performance indicators or building codes.

4 Variables influencing building energy use

The building energy use is influenced by an innumerable amount of variables. Firstly different categorizations of influence factors will be evaluated and compared. Secondly a closer look will be taken at the energy use breakdown to see how the energy end-use is built up.

4.1 Categorizing of energy use influence factors

There are various ways to categorize the relevant factors that influence building energy use. In this paragraph several methods from literature and simulations will be compared.

Guerra Santín et al. (2009) did research on dwellings in the Netherlands and made a distinction between building characteristics, household characteristics and behavior. The focus of the research was on the effect of user-related characteristics which must have influenced the categorization choice. Janda (Janda, 2011) makes a distinction between architectural and user characteristics, arguing that the role of buildings users is often overlooked but plays a critical part. Kavgic (Kavgic, 2015) approaches buildings within an engineering context and concludes that commercial and industrial buildings are often classified by function, envelope type and Heating Ventilation Air Conditioning (HVAC) system. The U.S. Department of Energy (EIA, 2015) evaluated results from the Commercial Buildings Energy Consumption Survey and made a ranking of the checklist completion rates during this survey. This provides valuable information about availability of energy-linked data in practice. General building information (square footage, occupant metrics, building activity and schedule), principal opaque building characteristics (wall and roof characteristics), principal fenestration and lighting characteristics had a completion rate of 100%. Other categories that were also deemed relevant and for which it was possible to obtain information about were HVAC, energy sources/utility and miscellaneous loads (e.g. office equipment).

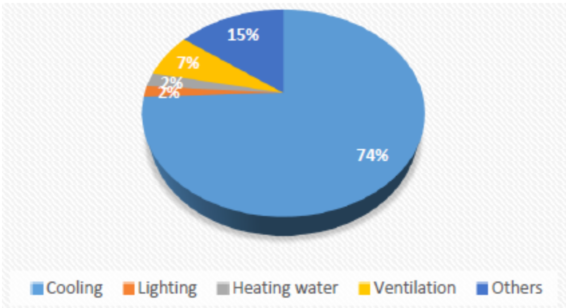
The chosen categorization of influence factors is mainly dependent upon the purpose of the energy use related research. In literature a distinction can be made between three different goals: monitoring energy use, simulating energy use and improving energy use. For the first goal the aggregation of energy use loads forms the main problem, which is why a distinction should be made between user/appliance loads, whichever is the main focus of the research. Secondly for simulation purposes categories in the most widely used building simulation software EnergyPlus (University of Illinois, 2010) and the software Vabi Elements (Vabi Software BV, 2014) were inspected. Both programs require the user to input building data, contain heat and mass balance simulation as well as a building systems simulation. In both computer programs a differentiation is made between user variables, architectural variables, HVAC and domestic hot water. In third place the goal of improving energy use is mainly focused on the economic variables related to energy use. In attempt to estimate the costs of over-cooling in the United States, Derrible (2015) deemed aggregated electricity use, CO_2-emissions and energy costs to be the most important cost factors. In research done on supermarkets in South

Africa (Pather-Elias, 2012) the economic benefits of reducing energy use turned out to be the main driver for supermarket owners. For this purpose variables such as investment costs and savings per year are meaningful.

4.2 Building energy use breakdown in Curaçao

The energy use of a building can be broken down into different categories. This disaggregation of energy use can provide more information on what systems or appliances have the biggest influence on total energy use.

Previously two research projects concerning building energy use have been done at the University of Curaçao. Both projects resulted in an estimation of the breakdown of energy use.



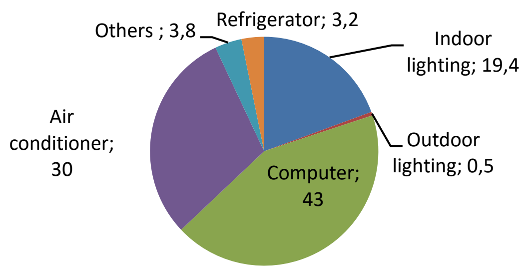


Figure 11 & 12: Energy breakdown dwellings (Eldik, 2015) and businesses (Bulbaai & Martha, 2011)

The first research was done in the residential sector and a case study was performed on five houses (Eldik, 2015). By investigating the capacity and usage hours of electric systems and appliances an estimation of the usage per category was made. Results showed that the energy use of dwellings in Curaçao is mainly constituted of cooling, ventilation, lighting and the heating of water (Figure 11). The cooling of air made up 74% of energy use on average. This high percentage was partially caused by the poor insulation that was found in the residential buildings.

The second research was more closely related to this research project, as it also focused on the commercial real estate sector (Bulbaai & Martha, 2011). A survey was conducted among approximately 300 offices on the island of Curaçao and the purpose was to uncover how business owners and employees use energy. A secondary goal was to uncover if they are aware of their energy use taking into account that energy is expensive on the island. The energy constitution of large businesses had the biggest penetration rate for the computer (43%), followed by air conditioning (30%) and then indoor lighting (19%). In comparison to the residential sector it is notable that devices have a more significant contribution. The results of the awareness part of the survey showed that 84,8% of the respondents were aware of their energy use. 93% listed saving money as their main incentive. The most popular ways of saving energy were outdoor photocell systems and turning off lights indoor when the room was not being used. Notable was that saving energy by turning off air conditioning systems when not in use was only done by 18% of the respondents.

4.3 Commercial building energy use breakdown per function

The energy use breakdown of commercial buildings are not only linked to the location of the building, but also show patterns depending on the building function. In this research project the commercial building functions shopping mall and supermarket will be evaluated.

In literature an energy use breakdown estimation has been done often for supermarkets. The varieties in the results of different research projects could be caused by environmental differences, building differences and a difference in the research method. When looking at the climate, Curaçao could be best be compared to research done in the climate zone 5 of the USA (the most southern part) (EIA, 2003). Geographically this research is closest to the island and it is also the most reliable research because of the large sample size. Secondly research done one supermarket energy use in the subtropical climate in South-Africa (Pather-Elias, 2012) is also comparable to that of Curaçao. Regarding economical development Curaçao shows more similarities with South-Africa than the USA. To get a more complete picture also of supermarkets in a mild and cold climate, supermarket energy use research performed in the UK (Tassou, 2011) and Sweden (Arias, 2005) are also examined. An overview of the data is given in Table 2.

Table 2: Supermarket energy use breakdown

	USA climate zone 5	South-Africa	UK	Sweden
Refrigeration	62%	45%	29%	47%
Lighting	15%	8%	23%	27%
HVAC	8%	18%	9%	13%
Water heating	12%	12%		
Ovens/bakery		16%	12%	3%
Office	1%		4%	
Misc	2%	1%	23%	10%

Even though different categorizations were used in the different researches, the main categories were similar. In the UK and Sweden studies water heating was included in HVAC, in the others it was not. In the miscellaneous categories different topics are aggregated such as external lighting/outdoor, ATMs, warehouse, restaurant and point of sales. Table 2 shows that in all studies refrigeration made up the largest percentage of energy use. In most cases the lighting category ranked second, but in South-Africa HVAC was the first follow-up. The energy use of the ovens or bakery varies strongly, in South-Africa and the UK it is a significant category, whereas it is not even mentioned separately in the US research.

Compared to supermarkets, less research has been done on energy use breakdown in shopping malls. The heterogeneity of functions and larger scale make it harder to break down the energy use. In subtropical Hong Kong four fully air conditioned shopping malls were selected for a case study on energy use (Lam, 2003). A breakdown of main electricity end uses was made through estimation and the use of energy analyzers. In the case study on average 50% of the mall building electricity was used by HVAC systems, 35% by lighting, 11% by electrical appliances and 3% by lifts and escalators. Research on a larger scale was done on enclosed shopping malls and strip malls in the United States (EIA, 2003).

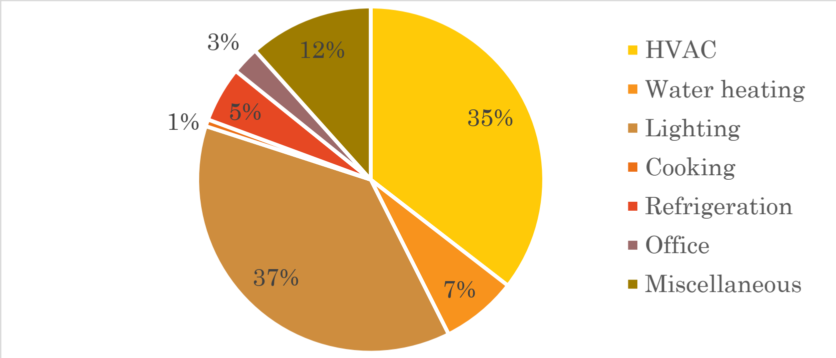


Figure 13: Energy use breakdown shopping malls USA (EIA, 2003)

The energy use breakdown in Figure 13 shows that lighting contributes the most to the total energy usage in enclosed malls, closely followed by HVAC. Shopping malls often fulfill several functions, so the building does not only contain retail businesses, but also cafés and restaurants. As a result cooking and refrigeration are also mentioned as relevant factors.

4.4 Preliminary conclusions

The literature study in the previous paragraphs aided in choosing and naming variables that are relevant and measurable for this research. The main variables that will be evaluated are listed below. One of the main goals is to uncover the relationship between actual energy use and building-related or user-related factors. In the use of the building a distinction is made between building use (defining characteristics such as opening hours and number of employees) and energy saving measures (how is the energy use awareness?). The building-related factors are divided into building architecture and installations/appliances. Especially the building envelope and HVAC systems are relevant factors.

Table 3: Selected research variables

Actual energy use	Energy use in kWh from energy bill
Building use	Opening hours, number of employees
Energy saving measures	Implemented saving measures by management
Building architecture	Building size and envelope materials
Installations and appliances	HVAC, water heater, lighting and appliances

The energy use breakdown will be calculated according to the categories below. In all supermarket research refrigeration turned out to use the most energy and lighting was also one of the most relevant energy users. HVAC also used a substantial part of the total energy. However in Curaçao most buildings don't have a heating system, so this was disregarded. In all studied cases the ventilation was integrated into the air conditioning system, so the term HVAC was changed into only air conditioning. All remaining factors cooking, water heating and ICT were also expected to have a significant influence on energy usage.

Table 4: Energy use breakdown categories

Refrigeration	Display and walk-in freezers and coolers
Lighting	In-store and storage lighting
Air conditioning	Integrated ventilation and air-conditioning system
Cooking	Heating appliances used in bakery or delis
Water heating	Main water heating system
ICT	Computers, monitors and points of sales
Miscellaneous	All energy use that does not fit the categories above

5 Developing a method for building energy assessment

In this paragraph several commonly used methods for building energy assessment will be discussed and finally one method will be presented for the case studies.

5.1 Current methods for energy assessment

A recent article by Yan (Yan, 2015) proposes a method to diagnose the energy performance of a building with limited energy information.

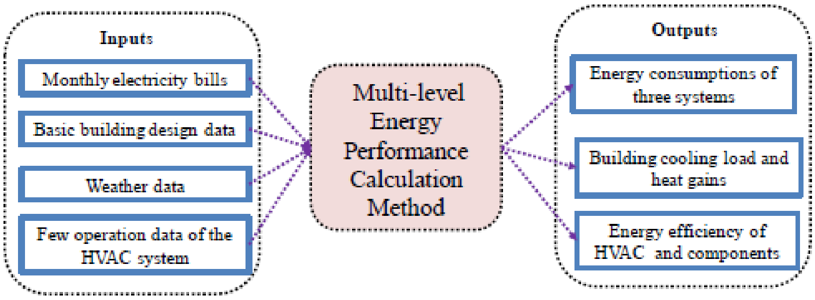


Figure 14: Energy performance calculation method (Yan, 2015)

His method consist of a top-down approach, where it is possible to evaluate the building energy use on different levels. At every level a check is performed to see if the assessment is detailed enough. The top level looks at the building as a whole, the second level looks at the building systems and the lowest level looks at components of the buildings system. For this type of evaluation four types of input are required. Monthly electricity bills are needed, basic building design data, weather data and the operation data of the HVAC system (Figure 14). Except for weather data which might have to be requested from an observatory, all data can be easily obtained as it is directly available or can be measured in the field. This input can be compared to a generic or customized benchmark in order to check the performance of the building.

Building energy benchmarking is commonly used to assess energy performance. A combination of energy use data and floor area can be used to determine the Energy Use Intensity (EUI) for example in MJ/ft or kWh/m^2. The calculated EUIs can then be ranked in a benchmark table. This method was used by Fillippín (Fillippín, 2000) in a study on school buildings in Argentina and is also used in the Singapore e-Energy Benchmark System (National University of Singapore, 2003), among others.

Monts & Blissett (Monts & Blissett, 1982) argued that the benchmark system mentioned has limitations because there are other factors apart from the floor area that have an influence on the energy use. These factors are not accounted for in the previous method. For the same reasons Chung et al. (Chung, Hui, & Lam, 2006) proposed a benchmarking based on a normalized linear regression analysis.

5.2 Constructing new method for energy assessment

The knowledge gathered from the literature review and also from visiting commercial buildings in Curaçao on site, lead to the construction of a new method for energy assessment. This method is designed for a research project to be completed within a limited timeframe of several months and with constraints on data availability.

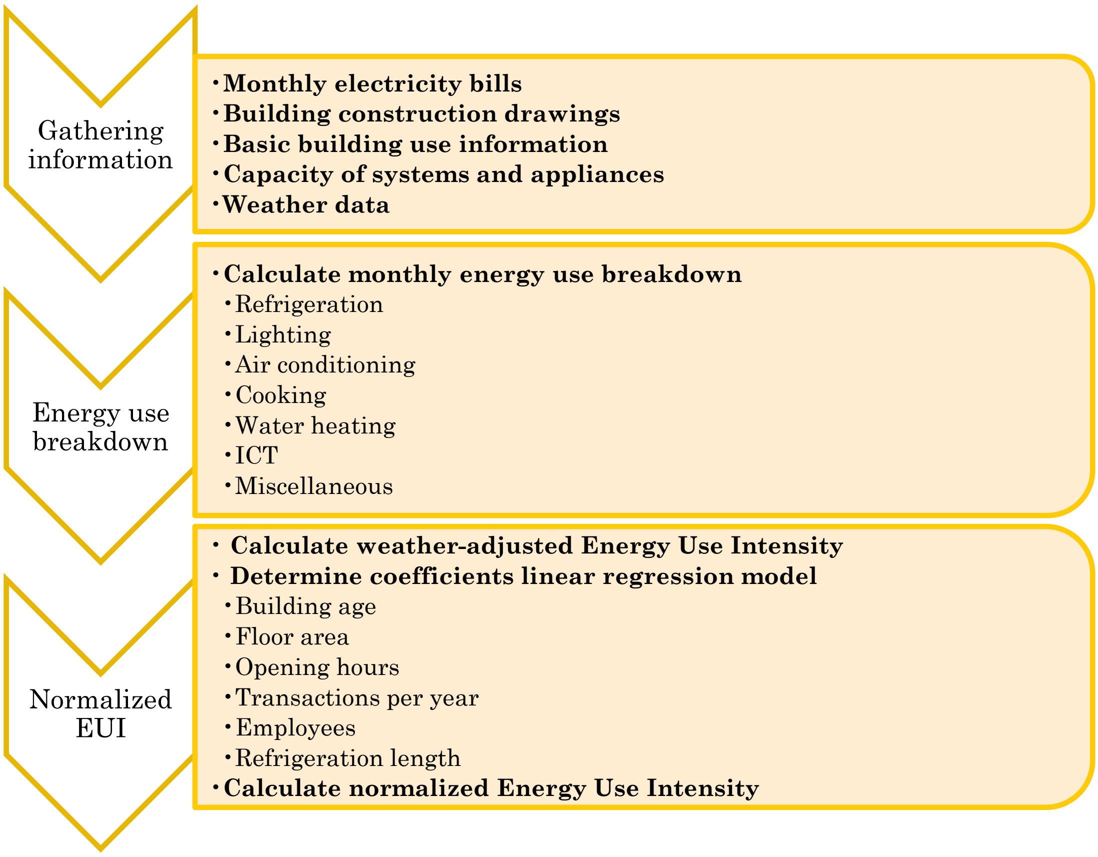


Figure 15: New energy assessment framework

An overview of the newly constructed assessment framework is presented in Figure 15.

5.3 Operationalization of new method

The use of the assessment framework in the field will be explained in more detail in this section.

Gathering information
The first step is to gather information from the business owner. The monthly electricity bill from the utilities company are gathered and an addition is made of high and low-rate energy use to get the total energy use. Building constructions drawings are gathered to determine building floor area, if not available the total floor area is derived from aerial photos. Basic building use information is gathered through a survey (Appendix B). The capacity of systems and appliances is communicated by the technical manager, determined by inspection or estimated if no exact values are available. Finally, weather data is requested from the local meteorological institute.

Calculate monthly energy use breakdown
First the average monthly energy use is determined by correcting the energy bills for the amount of days in the month and also correcting for the number of Cooling Degree Days. The capacity is multiplied with the estimated time of use of the system or appliance. For the first six categories mentioned above the monthly energy use is calculated in this way. The category miscellaneous is determined by subtracting the categorized monthly

energy use from the average actual energy use as found in the monthly energy bills. What remains is the energy use of the miscellaneous category.

Normalized EUI

The Energy Use Intensity (EUI) is calculated by dividing the monthly energy use (adjusted for the amount of Cooling Degree Days) by the total floor area of the building. It is assumed that the EUI follows the linear regression formula below.

$$\begin{aligned} EUI &= a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + \epsilon \\ &= a + b_1\left(\frac{x_1 - \overline{x_1}}{S_1}\right) + b_2\left(\frac{x_2 - \overline{x_2}}{S_2}\right) + b3\left(\frac{x_3 - \overline{x_3}}{S_3}\right) + b4\left(\frac{x_4 - \overline{x_4}}{S_4}\right) + b5\left(\frac{x_5 - \overline{x_5}}{S_5}\right) + \epsilon \end{aligned}$$

In the formula a is the intercept and the values for b are the coefficients. The values for x are the explanatory values (mentioned in Figure 15) and ϵ is the random error. By using the basic building information from the survey and using the software Microsoft Excel, the intercept and coefficients of the linear regression model can be determined. A check is performed to see if the y-intercept corresponds with the average value from the EUI's. Finally the normalized EUI is calculated for all case studies using the formula below.

$$\begin{aligned} EUI_{norm} = EUI_0 &+ b_1\left(\frac{building\ age - \overline{x_1}}{S_1}\right) + b_2\left(\frac{floor\ area - \overline{x_2}}{S_2}\right) + b_3\left(\frac{opening\ hours - \overline{x_3}}{S_3}\right) \\ &+ b_4\left(\frac{transactions - \overline{x_4}}{S_4}\right) + b_5\left(\frac{refrigeration - \overline{x_5}}{S_5}\right) + \epsilon \end{aligned}$$

All normalized EUI scores make up the benchmark table which can serve as a tool to assess relative energy use performance.

6 Case study: energy assessment of commercial buildings in Curaçao

In this chapter the method to assess commercial buildings will be applied to a case study in Curaçao.

6.1 Introducing the cases

The research is geographically limited to the island of Curaçao. Because of a need for better understanding of the commercial real estate sector as mentioned in Chapter 1, the research only comprises business buildings. Due to the limited timeframe the study is focused on two functional building types: supermarkets and shopping malls. Supermarkets are readily comparable as a result of their typically straightforward architecture and have a high cooling load to sustain freshness of products. All twelve supermarkets on the island were approached to participate in the research. Of these eight were willing to cooperate. Shopping malls also significantly contribute to the energy use on the island and are rarely studied. Of the three shopping malls on the island, only the two enclosed shopping malls were approached. Of these shopping malls one (Sambil Curaçao) was willing to cooperate in the research.

Table 5: Building areas

Building	Area
Sambil Curaçao	42.000 m²
Mangusa Supermarket	4.500 m²
Albert Heijn	3.000 m²
Esperamos	4.200 m²
Van den Tweel	750 m²
Best Buy	2.400 m²
Centrum	3.100 m²
CostULess	2.200 m²
Mangusa Hypermarket	5.000 m²

Figure 16: Geographical location of case studies

6.2 Results

In this paragraph the results from the case study will be discussed. First general findings, followed by actual energy use, energy use breakdown and finally a benchmarking model.

6.2.1 Characterization of buildings

The relevant building characteristics can be generalized for Curaçao based on the case study results.

Environmental characteristics

Curaçao only has one city called Willemstad and all buildings, with the exemption of the Van der Tweel supermarket which is in Jan Thiel, are located in this city. All buildings are located in a built-up environment. The tropical climate of 30-32 degrees Celsius which is very constant has a large influence on the way buildings are designed as well as on the energy use. There is a constant northeastern Passat wind and most buildings are designed with this concept in mind. Older buildings have an open design to let wind pass through and often buildings are built on raised ground to catch more wind for cooling.

Occupational characteristics
All buildings are open 7 days in the week from early in the morning until on average 8pm. Only in the weekend there are remarkable differences in the opening times. The supermarket buildings compared to other types of commercial buildings have high internal heat gains, because of the large density of people. The Sambil shopping mall is more spacious compared to its number of visitors.

Building characteristics
Only the biggest supermarkets were considered, which are all large in size. The Sambil shopping mall is of a different order of size with approximately 38,000m$^{2.}$ it is very likely the largest commercial building in Curaçao. Architecture in Curaçao can be characterized by a lack of glazing in the outer shell. Most buildings don't have windows except for at the entrance door which makes natural lighting impossible. The thermal shell is made up of thick concrete bricks and insulation use is limited.

System characteristics
In Curaçao there is no system for central heating, but all buildings in the case study have an air conditioning system. For tap water a heating and cooling system is found consistently. Ventilation systems are often combined with air conditioning system to provide air handling. The age of the systems vary greatly between the different buildings.

Appliances
The appliances that were deemed relevant in this case study based on visual inspection were lighting, cash registers, cooling units, refrigeration units and ovens.

6.2.2 Actual energy use

Actual energy use was requested from business owners and acquired by looking at the energy bills. Unfortunately not in all cases energy bills were available for an entire year, so the results are averaged and display the average monthly energy usage of businesses.

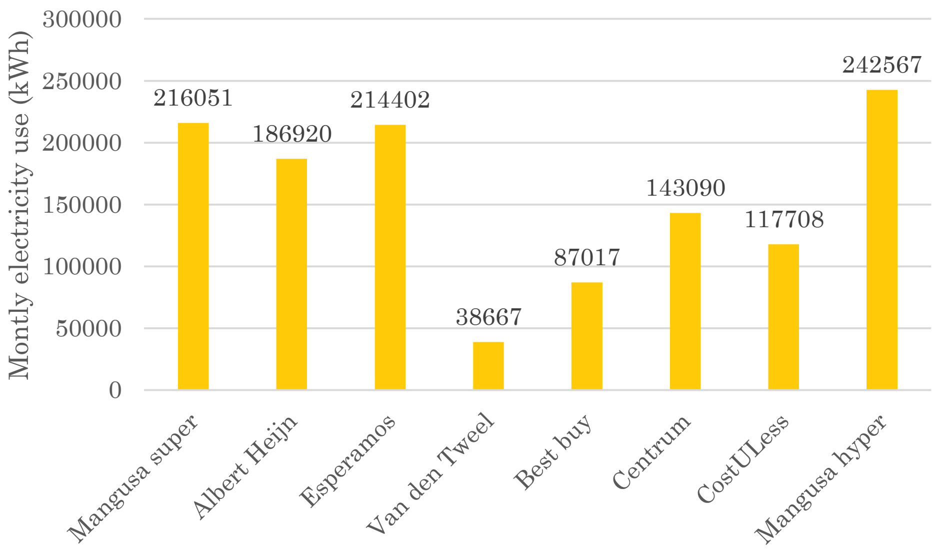


Figure 17: Average monthly electricity use

The average monthly electricity use of supermarkets is 155.803 kWh. The standard deviation is 71.339 kWh. An overview is displayed in Figure 17. The van der Tweel supermarket is significantly smaller than the other supermarkets and this is reflected in its energy use. The Mangusa hypermarket is the largest energy consumer and also has the largest store area. The Sambil shopping mall (not depicted) has a monthly electricity use of 9.135.143 kWh.

6.2.3 Energy use breakdown

For all supermarkets where enough data was accessible, an estimation of the energy use breakdown has been calculated. All energy constitution calculations can be found in Appendix B. The average energy use breakdown is shown in Figure 18.

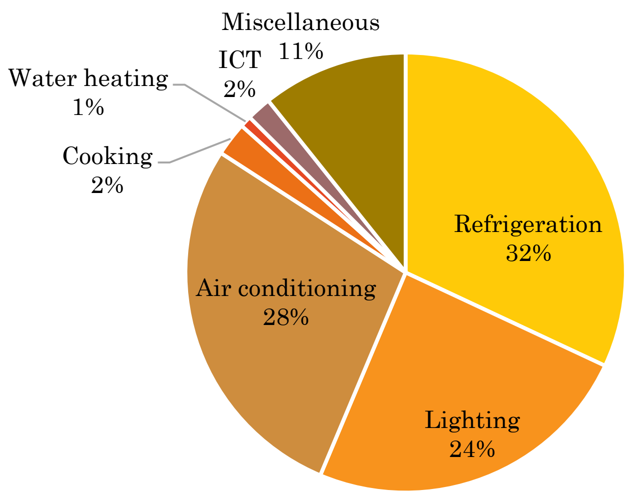


Figure 18: Average energy use breakdown supermarkets

Table 6: Average energy constitution of supermarket

Category	kWh/month
Refrigeration	76.143
Lighting	58.050
Air conditioning	66.257
Cooking	5.900
Water heating	2.008
ICT	4.307
Miscellaneous	25.546
Total	**238.210**

Refrigeration contributes the most to the total energy use in Curaçaoan supermarkets with 32%, followed by air conditioning (28%) and lighting (24%). Cooking and water heating both account for 2% of the total energy usage and ICT accounts for 1%. The results also show that the average Curaçaoan supermarket uses 238.210 kWh per month.

6.2.4 Benchmarking

A common way to benchmark energy use intensity is by comparing the energy use per floor area. An overview of the monthly electricity use per area is given in Figure 19. In comparison, the Sambil shopping mall uses 261 kWh/m^2.

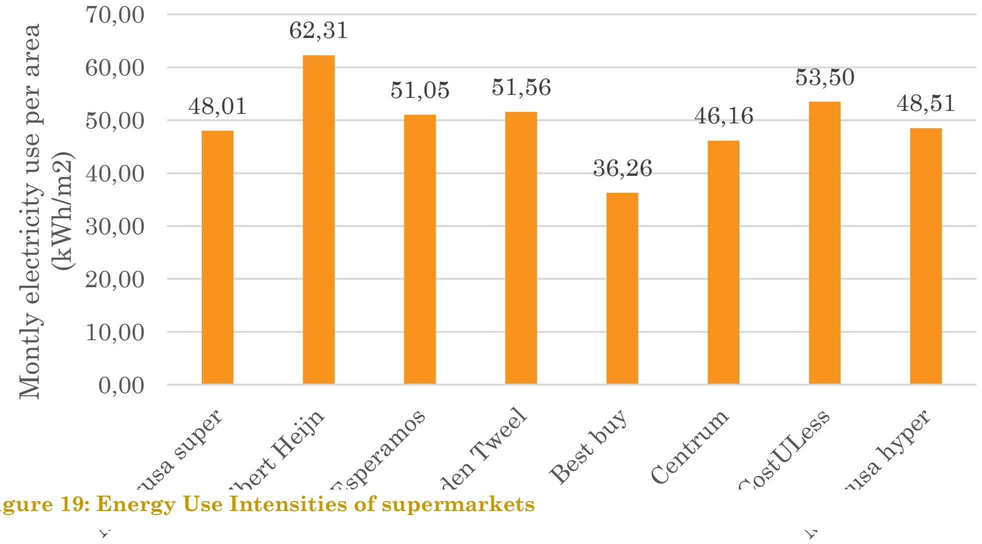


Figure 19: Energy Use Intensities of supermarkets

To get a benchmarking score that is a more accurate representation of energy performance, a multiple regression model for the supermarket Energy Use Intensity (kWh/m^2) was normalized for the significant factors building age (x_1), floor area (x_2), hours open per week (x_3), transactions per year (x_4) and energy use of refrigeration in the store (x_5). An overview of the data from the case study that was used is given in Table 7.

Table 7: Building data from supermarket case study

	Building age	Floor area	Opening hours	Transactions	Refrigeration
Mangusa super	20	4500	72,5	1833583	84910
Albert Heijn	36	3000	84	1127183	57791
Esperamos	34	4200	75,5	1277500	89941
Van den Tweel	5	750	84	159687	17066
Best buy	11	2400	79	185826	103763
Centrum	19	3100	78,5	898318	81598
CostULess	23	2200	77	674409	92227
Mangusa hyper	17	5000	72,5	2436601	81849
Mean	20,625	3143,75	77,875	1074138,375	76143
Standard dev	9,84	1303,71	4,20	732567,98	25441,13

In Excel the coefficients of the linear regression model were determined. The y-intercept from the calculated model corresponds with the mean value of the EUI's in the dataset and is 49,67 kWh/m². This is to be expected because if all significant factors are average, the normalized EUI will be equal to the average EUI. The formula to calculate the normalized EUI is given below.

$$EUI_{norm} = EUI_0 + 6{,}62\left(\frac{building\ age - \overline{x_1}}{s_1}\right) - 11{,}55\left(\frac{floor\ area - \overline{x_2}}{s_2}\right) - 0{,}78\left(\frac{opening\ hours\ per\ week - \overline{x_3}}{s_3}\right) + 9{,}41\left(\frac{transactions\ per\ year - \overline{x_4}}{s_4}\right) - 1{,}79\left(\frac{energy\ use\ refrigeration - \overline{x_5}}{s_5}\right) + \epsilon$$

The normalized EUI was calculated for the case study dataset and from these values a normalized benchmark table of the energy intensity can be made.

Table 8: Benchmark table with normalized EUI scores

Building	EUI_{norm}
Mangusa supermarket	45,71
Albert Heijn	74,76
Esperamos	52,77
Van den Tweel	53,53
Best Buy	22,81
Centrum	42,69
CostULess	57,37
Mangusa hypermarket	47,72

The benchmark table shows that the Albert Heijn supermarket has the largest Energy Use Intensity whereas the Best Buy supermarket is the most energy efficient. In average the normalized EUI is 49,67 kWh/m².

7 Discussions

In every research there are uncertainties to consider. In this research the used method for assessing the energy use of buildings only considers the energy use on a system level. This system level approach does not take into account the several components of which the system is made up of. To get a more accurate estimation of the energy use breakdown, information about the component level is also required.

The possibilities for acquiring information in this research were limited. The main cause was not the willingness of businesses to cooperate, but a poor administration of building properties and energy bills in Curaçao. The assessment of energy performance could be improved if more monthly energy bills were available to provide a better average monthly energy use. Also this would give a better view on how the climate changes throughout the year influence the energy use of buildings. Due to limited availability of data the Cooling Degree Days were unknown. Fortunately the temperature remains fairly constant throughout the year in Curaçao, but CDD calculations would make results even more accurate.

A similar problem occurred with the installations: not in every case information about the type of installations and specifications were readily available. Because buildings are relatively old the building drawings either often do not exist or have been lost. This restricts the amount of information available about the thermal shell and makes information only possible via visual inspection which decreases reliability of construction data.

Usually a linear regression model is based on a larger dataset, which makes the results more reliable. In this case only eight subjects were used. In Curaçao there are only a limited amount of supermarkets, making it difficult to expand the research scope. The results of eight out of a total of fourteen supermarkets does however give a fairly complete image of the island's supermarkets.

The normalized benchmarking results were mostly in line with expectations, but the Van der Tweel supermarket scored higher than expected. It was expected that this supermarket would have the lowest EUI, because it is by far the smallest in size, is situated in the newest building and has the most energy-efficient systems and appliances. However, the supermarket has a shared energy supply with the Papagayo hotel which is situated in the same building. It is suspected that the energy use on the bill of the Van den Tweel supermarket are higher than the actual use.

8 Conclusions and recommendations

In this chapter the conclusions and recommendations from this research will be presented.

8.1 Conclusions

Because the worldwide economy is trending towards service-oriented business instead of industrial activity, the commercial sector has been growing. The number of commercial buildings has increased and as an effect the energy used also has. The energy use of commercial real estate is mainly influenced by building characteristics and usage characteristics. The building's envelope has a big influence on how heat is transferred to the environment. Also the energy use of HVAC systems take up a relatively large chunk of total energy use. The energy constitution of commercial buildings is mainly dependent on its function. In supermarkets refrigeration is an important contributor to the height of energy use. In shopping malls lighting has the most influence.

The energy supply in Curaçao is mainly dependent upon import of fossil fuels from other countries, which makes the system vulnerable. Also power outages occur regularly and electricity prices are high compared to many neighboring countries. The government of Curaçao acknowledges these problems, but despite changes in policies citizens don't experience a lot of effect. The increase of energy efficiency in new buildings is also not stimulated by the government. The buildings in Curaçao are often outdated and a lot of cooling is lost because of poor insulation and building materials. Typically in Curaçao more energy is used for air conditioning compared to other countries with a similar climate.

Literature research suggests that normalized energy use intensities are a more correct way to assess the energy use. Based on a case study a linear regression model for supermarket energy use in Curaçao was designed.

8.2 Recommendations

The case study in this research has been limited by the functional types of commercial real estate buildings that were looked at: supermarkets and shopping malls. Previous research has been done on office buildings by the University of Curaçao. However both researches combined do not cover all aspects of the business building sector in Curaçao. Other commercial building types include restaurants, hotels, warehouses or recreational facilities. It is recommended that further research is done on these types of buildings as well to get a complete overview of the energy use in commercial real estate.

The governmental policies could be adjusted to stimulate energy efficiency in new buildings. In new buildings the use of sustainable building materials and technologies could be made mandatory or subsidized. The installation of solar panels is currently unattractive because the governmental policies keep changing. Fixing these regulations over a longer period of time will stimulate small-scale renewable energy production. Also the benchmarking system as presented here, can be used to inform business owners on how well they score on energy performance. This will raise more awareness and hopefully result into the implementation of energy saving measures.

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Appendix A DOCUMENTS SENT TO BUSINESS OWNERS

UNIVERSITY OF TWENTE.

UNIVERSITY OF CURAÇAO
DR. MOISES DA COSTA GOMEZ

PARTICIPATION IN RESEARCH: ENERGY USE OF COMMERCIAL REAL ESTATE CURAÇAO

Dear Sir/Madam,

You have been approached to participate in the research about energy use in the business sector of Curaçao. This research is focused on the characterization of energy use in supermarkets and shopping malls on the island. The research is conducted on behalf of the University of Curaçao. If you take part in the research, you will receive a short advice report about the energy use of your building afterwards. Participation is completely free of charge.

Purpose of the research

Map the energy use of supermarkets and shopping malls in Curaçao and determine which factors have the most influence on the energy use.

Needed information

Your cooperation is needed to obtain the following information about the building:

- Monthly energy use (found in energy bills)
- Building dimensions (found in building drawings)
- Type of installations
- Opening times of the building

Confidentiality of information

All information, documents and data with reference to your business and with inclusion of discussions between the business and undersigned, will be treated confidential. This means that information will solely be used for the educational purpose of research at the University of Curaçao. No confidential information will be revealed to third parties without prior written consent from the other party.

Advice report for your business

To thank you for your cooperation in you will receive an advice report free of charge after the research is completed. In this report an overview of your building's energy use will be given. Also you will receive an indication of how well you score on energy use compared to other businesses. Finally recommendations will be given on how to improve your energy efficiency.

I hope for a successful collaboration.

Kind regards,

Caithlin Ann Marugg

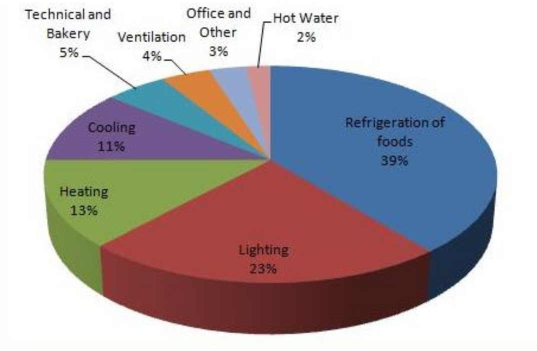
Telephone: (+5999) 6760322
E-mail: c.a.marugg@student.utwente.nl
Website: www.uoc.cw

Example energy use advice report

UNIVERSITY OF CURAÇAO
DR. MOISES DA COSTA GOMEZ

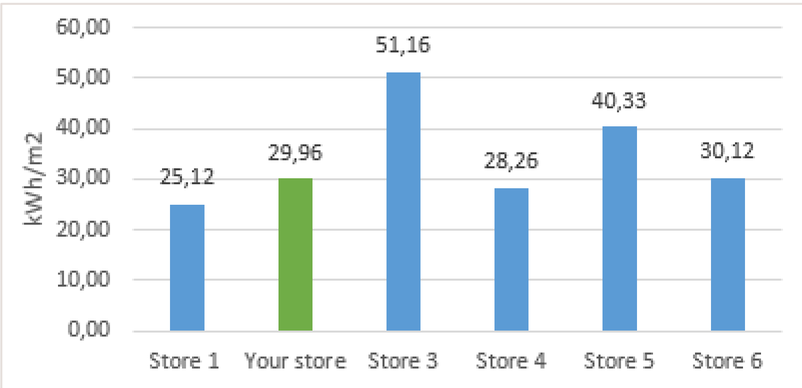
Energy use per category

By making an inventory of all the systems and appliances used in your building, an overview of the end-use energy use can be made per category.



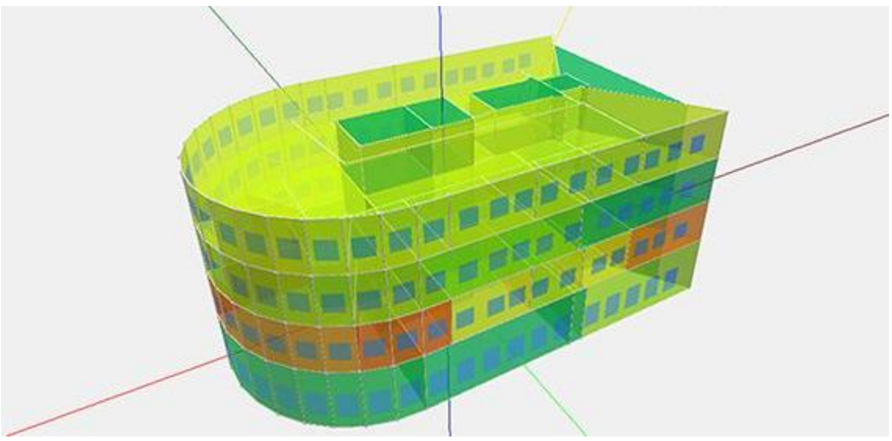
Energy performance compared to other businesses

By inspecting your energy bill and comparing it anonymously to those of other businesses, you can see how well your business scores on energy performance.



Building simulation

Using building drawings and material information, a simulation of your building can be made. This gives direct visual insight into the building cooling load.



Appendix B CASE STUDY

Sambil

Figure 20: Aerial views of Sambil (Curinvest, 2015)

Sambil Curaçao is the biggest shopping mall and commercial building in Curaçao with an area of approximately 42,000 m². The shopping mall and entertainment center first opened its doors to visitors in May 2015. The building which is shaped like a fish was constructed by the company Sambil Group who have opened several large malls in Venezuela. They have also expanded business to the Dominican Republic and are currently constructing large shopping malls in Spain and the USA. The construction in Curaçao started in October 2012 and took longer than expected. A section in the rear side of the mall is still closed for the public because the eight shops that are going to be there are still in construction. If the mall is finished, it will contain 156 stores, 8 cinemas, 4 restaurants and a food court. The mall is surrounded by 1400 parking spaces. The entire building is air conditioned. The floor plan is designed so that during the day natural light can enter through the raised rooftop which runs along the oval-shaped main walking alley (see Figure 21). The building has an entrance on six sides which all have sliding doors. The food court (depicted in orange) and toilets are in the center of the building. The Cinemark cinema (depicted in purple) is situated in the south. Offices (depicted in grey) are spread out across the building.

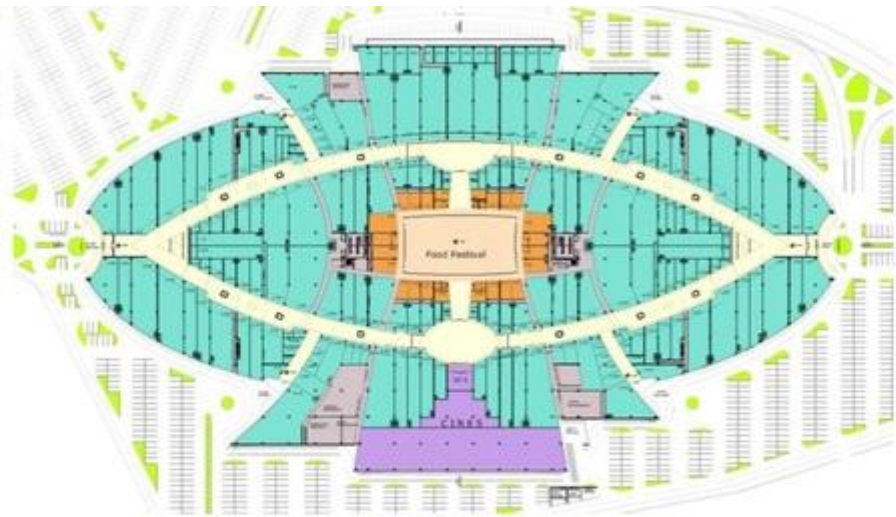


Figure 21: Floor plan of Sambil (source: skyscrapercity.com)

Figure 22: Food court and main walking alley of Sambil

Building specifications

An interview was conducted with the technical manager of Sambil (2016). Most of the energy use in the building is going to the cooling. For this purpose a compressor water chiller is used which cools the air to 5°C and air returns in 10-15°C. Cold and hot air is combined to create an air temperature in the building between 22 and 24°C. For some time the machines had broken down and the building was extremely hot, because there is no natural ventilation possible. The technical manager was appointed to fix this situation and through trial and error the current comfortable climate was reached. The building has three 700 A/phase air conditioning units.

The Sambil building has only been open for little more than a year and the stores have been filled up in several stages. The energy use of the building has been increasing simultaneously at a rapid rate. In the beginning the water use was about 20m^3 a day, but now it is up to 300m^3 a day. In early stages it was possible to use a well to extract ground water, but after calculations it turned out more convenient to get all water supplied by Aqualectra. Water is mainly used for watering plants, sanitation and cleaning. The building has its own water tank of 490m^3 that is filled up to 300m^3 at all times for cases of emergency. In case of emergency the water tank will be filled up to its full capacity so it can be used for putting out fires or flushing down all pipes. Gas is used by the restaurants and retailers at the food court. Three large gas tanks are filled up weekly to provide gas.

Energy is monitored at different locations in the building. All store owners have separate energy monitors. The technical manager suspects that a lot of energy is lost through because different voltages are needed (in Curaçao outlets can be 230V like in Holland or 120V like in Venezuela). However there is no direct insight into this matter.

The air conditioning and ventilation systems are checked daily at the front end and two times a week the back end pumps are checked. Maintenance is outsourced to an external party. Electrical circuits are thoroughly checked once every year. The climate in the building can be controlled directly by the technical, operational and general manager. The technical manager suspects that they have the most advanced system in Curaçao for this matter. Climate installations can be controlled via mobile phone, as well as fire safety systems.

The Sambil building has two own electricity generators of 1 MW but they are currently not in use because of steep diesel prices. The technical manager would like to investigate the possibility of using these generators in the future, but more research will be needed. Currently all lighting inside the building are energy-saving incandescent lights. In the parking lot LED lighting is used. In the future the move to LED inside will also be made, but it needs to be calculated when would be the right time to make this investment because the lighting is still relatively new. Exploratory research is also being done into powering the lights of the entire building with solar energy.

Basic information	
Company name:	Sambil
Address:	Weg naar westpunt, Willemstad, Curaçao

Energy use		
Month:		
Days measured:		
Electricity use	**High rate:**	
	Low rate:	
Water use (m^3):		300 m^3 per day
Gas use (cylinders):		Used for restaurants and food court, filled every week
Own energy sources?:		Two 1MW dieselgenerators and water well, both not in use

Building use	
Opening times:	Monday-Saturday: 10am-9pm. Sunday: 12pm-8pm.
Number of employees:	
Transactions/year:	
Store temperature:	22-24°C

Building architecture	
Construction year:	2014
Complete building floor area:	42,000 m^2
Building height:	

Windows:	Single / double / triple

Installations and appliances			
	Amount	Capacity	Type
Lighting:			LED outside, energy-saving inside Regular / reflective fixture
Air conditioning:			Inverter airco SEER-value: EER-value:

Energy saving measures	
Implemented energy-saving measures?	LED parking lights, airco low as possible
Adjust A/C temperature during closed hours?	Yes
Turn-off lighting/computers when not in use?	Yes
Effective energy-monitoring system?	Electricity meters at every store and various other locations
Who is responsible for operation/ maintenance of HVAC?	Technical manager for operations and regular maintenance, others external
Regular maintenance and inspection for HVAC?	Daily front end, 2 times a week back-end
Regular maintenance and inspection for lighting?	Yearly inspection of electrical circuits

Appendix C: Energy use breakdown calculations

Table 9: Energy use breakdown calculations Mangusa

Subject	Capacity		Amount		Factor		Total kWh per month
Refrigeration - back freezer	*21400*	*kWh/year*	*6*		*0,08*	*year/month*	*10700*
Refrigeration - back cooler	*16200*	*kWh/year*	*4*		*0,08*	*year/month*	*5400*
Refrigeration - store freezer closed	*20*	*kW/day*	*33*	*units*	*30,42*	*days/month*	*20077*
Refrigeration - store freezer open	*13*	*kW/day*	*54*	*m*	*30,42*	*days/month*	*21355*
Refrigeration - store cooler open	*6*	*kW/day*	*150*	*m*	*30,42*	*days/month*	*27378*
Refrigeration - total							84910
Lighting - Fluorescent T8	*0,04*	*kW/m2*	*3375*	*m2*	*365,04*	*hours/month*	*49280*
Lighting - LED	*0,0135*	*kW/m2*	*1125*	*m2*	*365,04*	*hours/month*	*5544*
Lighting - total							54824
Air conditioning	78,15	kW			730,08	hours/month	57056
Cooking	214	kWh/day			30,42	days/month	6510
Water heating	5,5	kW			365,04	hours/month	2008
ICT - ATM machine	*5,52*	*kW*			*730,08*	*hours/month*	*4030*
ICT - Computer + monitor + printer	*0,158*	*kW*	*9*		*365,04*	*hours/month*	*519*
ICT - Cash register	*0,2*	*kW*	*17*		*365*	*hours/month*	*1241*
ICT - total							5790
Total							211098
Miscellaneous							4953
Actual total							216051

Table 10: Energy use breakdown calculations Albert Heijn

Subject	Capacity		Amount		Factor		Total kWh per month
Refrigeration - back freezer	*21400*	*kWh/year*	*4*		*0,08*	*year/month*	*7133*
Refrigeration - back cooler	*16200*	*kWh/year*	*6*		*0,08*	*year/month*	*8100*
Refrigeration - store freezer closed	*20*	*kW/day*	*16*	*units*	*30,42*	*days/month*	*9734*
Refrigeration - store freezer open	*13*	*kW/day*	*47*	*m*	*30,42*	*days/month*	*18587*
Refrigeration - store cooler open	*6*	*kW/day*	*78*	*m*	*30,42*	*days/month*	*14236,56*
Refrigeration - total							57791
Lighting - Fluorescent T8	*0,04*	*kW/m2*	*3000*	*m2*	*365,04*	*hours/month*	*43805*
Lighting - LED	*0,0135*	*kW/m2*	*0*	*m2*	*365,04*	*hours/month*	*0*
Lighting - total							43805
Air conditioning	91,43	kW			730,08	hours/month	66751
Cooking	214	kWh/day			30,42	days/month	6510
Water heating	5,5	kW			365,04	hours/month	2008
ICT - ATM machine	*5,52*	*kW*			*730,08*	*hours/month*	*4030*
ICT - Computer + monitor + printer	*0,158*	*kW*	*6*		*365,04*	*hours/month*	*346*
ICT - Cash register	*0,2*	*kW*	*11*		*365*	*hours/month*	*803*
ICT - total							5179
Total							182044
Miscellaneous							4876
Actual total							186920

Table 11: Energy use breakdown Esperamos

Subject	Capacity		Amount		Factor		Total kWh per month
Refrigeration - back freezer	*21400*	*kWh/year*	*3*		*0,08*	*year/month*	*5350*
Refrigeration - back cooler	*16200*	*kWh/year*	*2*		*0,08*	*year/month*	*2700*
Refrigeration - store freezer closed	*20*	*kW/day*	*69*	*units*	*30,42*	*days/month*	*41980*
Refrigeration - store freezer open	*13*	*kW/day*	*64*	*m*	*30,42*	*days/month*	*25309*
Refrigeration - store cooler open	*6*	*kW/day*	*80*	*m*	*30,42*	*days/month*	*14601,6*
Refrigeration - total							89941
Lighting - Fluorescent T8	*0,04*	*kW/m2*	*4200*	*m2*	*365,04*	*hours/month*	*61327*
Lighting - LED	*0,0135*	*kW/m2*	*0*	*m2*	*365,04*	*hours/month*	*0*
Lighting - total							61327
Air conditioning	46,44	kW			730,08	hours/month	33905
Cooking	214	kWh/day			30,42	days/month	6510
Water heating	5,5	kW			365,04	hours/month	2008
ICT - ATM machine	*5,52*	*kW*			*730,08*	*hours/month*	*4030*
ICT - Computer + monitor + printer	*0,158*	*kW*	*9*		*365,04*	*hours/month*	*519*
ICT - Cash register	*0,2*	*kW*	*13*		*365*	*hours/month*	*949*
ICT - total							5498
Total							199188
Miscellaneous							15214
Actual total							214402

Table 12: Energy use breakdown Van den Tweel

Subject	Capacity		Amount		Factor		Total kWh per month
Refrigeration - back freezer	*21400*	*kWh/year*	*1*		*0,08*	*year/month*	*1783*
Refrigeration - back cooler	*16200*	*kWh/year*	*1*		*0,08*	*year/month*	*1350*
Refrigeration - store freezer closed	*20*	*kW/day*	*10*	*units*	*30,42*	*days/month*	*6084*
Refrigeration - store freezer open	*13*	*kW/day*	*0*	*m*	*30,42*	*days/month*	*0*
Refrigeration - store cooler open	*6*	*kW/day*	*43*	*m*	*30,42*	*days/month*	*7848,36*
Refrigeration - total							17066
Lighting - Fluorescent T8	*0,04*	*kW/m2*	*550*	*m2*	*365,04*	*hours/month*	*8031*
Lighting - LED	*0,0135*	*kW/m2*	*0*	*m2*	*365,04*	*hours/month*	*0*
Lighting - total							8031
Air conditioning	12	kW			730,08	hours/month	8761
Cooking	53,5	kWh/day			30,42	days/month	1627
Water heating	5,5	kW			365,04	hours/month	2008
ICT - ATM machine	*5,52*	*kW*	*0*		*730,08*	*hours/month*	*0*
ICT - Computer + monitor + printer	*0,158*	*kW*	*2*		*365,04*	*hours/month*	*115*
ICT - Cash register	*0,2*	*kW*	*4*		*365*	*hours/month*	*292*
ICT - total							407
Total							37900
Miscellaneous							767
Actual total							38667,4

Table 13: Energy use breakdown Best Buy

Subject	Capacity		Amount		Factor		Total kWh per month
Refrigeration - back freezer	21400	kWh/year	1		0,08	year/month	1783
Refrigeration - back cooler	16200	kWh/year	1		0,08	year/month	1350
Refrigeration - store freezer closed	20	kW/day	146	units	30,42	days/month	88826
Refrigeration - store freezer open	13	kW/day	16	m	30,42	days/month	6327
Refrigeration - store cooler open	6	kW/day	30	m	30,42	days/month	5475,6
Refrigeration - total							103763
Lighting - Halogen	0,06	kW/m2	2400	m2	365,04	hours/month	52566
Lighting - LED	0,0135	kW/m2	0	m2	365,04	hours/month	0
Lighting - total							52566
Air conditioning	55	kW			730,08	hours/month	40154
Cooking	214	kWh/day			30,42	days/month	6510
Water heating	5,5	kW			365,04	hours/month	2008
ICT - ATM machine	5,52	kW	1		730,08	hours/month	4030
ICT - Computer + monitor + printer	0,158	kW	3		365,04	hours/month	173
ICT - Cash register	0,2	kW	8		365	hours/month	584
ICT - total							4787
Total							209788
Miscellaneous							6263
Actual total							216051

Table 14: Energy use breakdown Centrum Piscadera

Subject	Capacity		Amount		Factor		Total kWh per month
Refrigeration - back freezer	*21400*	*kWh/year*	*3*		*0,08*	*year/month*	*5350*
Refrigeration - back cooler	*16200*	*kWh/year*	*4*		*0,08*	*year/month*	*5400*
Refrigeration - store freezer closed	*20*	*kW/day*	*75*	*units*	*30,42*	*days/month*	*45630*
Refrigeration - store freezer open	*13*	*kW/day*	*25*	*m*	*30,42*	*days/month*	*9887*
Refrigeration - store cooler open	*6*	*kW/day*	*84*	*m*	*30,42*	*days/month*	*15331,68*
Refrigeration - total							81598
Lighting - Fluorescent T6	*0,08*	*kW/m2*	*3100*	*m2*	*365,04*	*hours/month*	*90530*
Lighting - LED	*0,0135*	*kW/m2*	*0*	*m2*	*365,04*	*hours/month*	*0*
Lighting - total							90530
Air conditioning	225	kW			730,08	hours/month	164268
Cooking	214	kWh/day			30,42	days/month	6510
Water heating	5,5	kW			365,04	hours/month	2008
ICT - ATM machine	*5,52*	*kW*	*1*		*730,08*	*hours/month*	*4030*
ICT - Computer + monitor + printer	*0,158*	*kW*	*6*		*365,04*	*hours/month*	*346*
ICT - Cash register	*0,2*	*kW*	*12*		*365*	*hours/month*	*876*
ICT - total							5252
Total							143090
Miscellaneous							72961
Actual total							216051

Table 15: Energy use breakdown CostULess

Subject	Capacity		Amount		Factor		Total kWh per month
Refrigeration - back freezer	21400	kWh/year	7		0,08	year/month	12483
Refrigeration - back cooler	16200	kWh/year	9		0,08	year/month	12150
Refrigeration - store freezer closed	20	kW/day	96	units	30,42	days/month	58406
Refrigeration - store freezer open	13	kW/day	14	m	30,42	days/month	5536
Refrigeration - store cooler open	6	kW/day	20	m	30,42	days/month	3650,4
Refrigeration - total							92227
Lighting - Halogen	0,1	kW/m2	2200	m2	365,04	hours/month	80309
Lighting - LED	0,0135	kW/m2		m2	365,04	hours/month	0
Lighting - total							80309
Air conditioning	120	kW			730,08	hours/month	87610
Cooking	214	kWh/day			30,42	days/month	6510
Water heating	5,5	kW			365,04	hours/month	2008
ICT - ATM machine	5,52	kW	0		730,08	hours/month	0
ICT - Computer + monitor + printer	0,158	kW	4		365,04	hours/month	231
ICT - Cash register	0,2	kW	9		365	hours/month	657
ICT - total							888
Total							117708
Miscellaneous							98343
Actual total							216051

Table 16: Energy use breakdown Mangusa hypermarket

Subject	Capacity		Amount		Factor		Total kWh per month
Refrigeration - back freezer	21400	kWh/year	5		0,08	year/month	8917
Refrigeration - back cooler	16200	kWh/year	4		0,08	year/month	5400
Refrigeration - store freezer closed	20	kW/day	48	units	30,42	days/month	29203
Refrigeration - store freezer open	13	kW/day	72	m	30,42	days/month	28473
Refrigeration - store cooler open	6	kW/day	54	m	30,42	days/month	9856,08
Refrigeration - total							81849
Lighting - Fluorescent T8	0,04	kW/m2	5000	m2	365,04	hours/month	73008
Lighting - LED	0,0135	kW/m2	0	m2	365,04	hours/month	0
Lighting - total							73008
Air conditioning	98	kW			730,08	hours/month	71548
Cooking	214	kWh/day			30,42	days/month	6510
Water heating	5,5	kW			365,04	hours/month	2008
ICT - ATM machine	5,52	kW	1		730,08	hours/month	4030
ICT - Computer + monitor + printer	0,158	kW	10		365,04	hours/month	577
ICT - Cash register	0,2	kW	28		365	hours/month	2044
ICT - total							6651
Total							241574
Miscellaneous							992
Actual total							242566