Master Thesis

HOW TECHNOLOGY AFFECTS ENERGY CONSUMPTION IN THE REGGEFIBER FTTH NETWORK

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20 April 2017,
Rijssen

UNIVERSITY OF TWENTE.

Master thesis

Abstract: Using technology enables the gathering of more information, this information can be used to research topics or fields of interests more in-depth. One of such topics is the energy consumption in telecommunication networks. With the use of smart meters, data has become available to gather on a large scale. In this study it is examined how this data can be used in the budgeting process. Input for the energy consumption budget at KPN is researched with variables based on prior studies such as telecom equipment and cooling equipment. The variables are tested with the use of a multiple linear regression analysis. The results from the statistical analyses shows that a forecast can be made with input from the researched variables (location design, function of the location, homes activated, location equipment, active operators, outside temperature and HVAC equipment). One of the findings in this thesis is that telecom equipment has a positive relation with energy consumption and that location design does matter (more equipment results in more energy consumption). Another finding is that HVAC is negatively related to energy consumption (free cooling technology or also called VKU, results in less energy consumption). Additionally this thesis examines the current budgeting method for energy consumption at KPN (traditional budgeting) and researches different alternatives such as the rolling forecast method to achieve a more predictable forecast.

Keywords: *budgeting; electricity; energy consumption; forecast; FttH; HVAC; smart meters; telecom.*

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1. INTRODUCTION

Energy consumption is a topic which has become steadily more relevant over the past decades, recent summits of the European Union resulted in the climate treaty of Paris which aims to reduce the environmental impact of fossil fuels and stimulating renewable energy (European Commission, 2016). Energy and electricity are often used interchangeable, however the term 'Energy' is broader than only electricity. Electrical energy, after natural gas, is only the second greatest category of energy consumed in the Netherlands in the last 10 years (Eurostat, 2016). However the FttH network of Reggefiber is designed to only use electricity and therefore other energy categories are not relevant for this study. Similar focus on electricity can also be found in a study within the Chinese telecom network by Yang, Zhang, Huang, and Peng (2013).

The acquisition of Reggefiber by KPN introduced new practices and methods for the old Reggefiber organisation. Budgeting for energy consumption in the FttH network is designed according to the annual budgeting method. Different views on purposes of budgets are described in the literature review (Drury, 2012). The purpose of budgeting for energy consumption related to the Reggefiber FttH network is planning the annual operations. In order to prepare the budget input such as the costs should be known. As described above the input for the energy consumption budget is uncertain. However the data which is gathered by the smart meters introduces new opportunities to research the cost drivers related to energy consumption.

This study researches the gap between budgeting literature and energy consumption, in specific related to energy consumption in an FttH telecom network. This thesis contributes to the literature regarding energy consumption by adding variables in the prediction of energy consumption in an FttH telecom network such as PoP design (function, model type) and the influence of open access related to Active Operators. Other variables such as cooling equipment (HVAC) and telecom equipment (EQF) are important contributors to the energy consumption and corresponds with previous studies by Mandal et al. (2013) and Sorrentino et al. (2009).

New technology introduces new opportunities to change the budgeting process. Rolling forecasting can be used to improve the prediction according to literature and combined with technology this method can be implemented for the FttH network (Hansen, 2011). With the use of the regression equation the input of the budgeting process can be improved and subsequently can lead to an improved forecast. This study includes variables such as design of telecom locations, outside average temperature and network design. The main research question of this study focuses on identifying cost drivers related to the FttH energy consumption budget at KPN.

This study examines budgeting methods and existing alternatives to annual budgeting. In recent years criticism towards annual budgeting regarding the time-consuming and rigid planning aspects has been discussed (Hansen, Otley & Van der Stede, 2003; Libby & Lindsay, 2010; Hansen, 2011; Drury, 2012). Hansen (2011) identifies three different budgeting alternatives to an annual budget, namely rolling forecast, activity-based budgeting and beyond budgeting.

- The rolling forecast method generates an improved forecast.
- Activity-based budgeting takes into account the operational planning and generates greater flexibility for unforeseen events.
- Beyond budgeting approach involves changing the compensation of employees and improving performance evaluation.

Empirical research documents identify variables which are potential cost drivers for energy consumption such as telecom equipment (Mandal et al., 2013), HVAC equipment (Roy, 2008; Sorrentino et al., 2010; Mandal et al., 2013). The identified variables are subsequently entered into the multiple linear regression model in order to test the statistical relationships between energy consumption and the variables (location design, function of the location, homes activated, location equipment, active operators, outside temperature and HVAC equipment). All of the variables which are entered in the multiple linear regression models are significantly related to the energy consumption of the FttH network for the overall dataset. Differences between subsamples exist, however they correspond to the expected signs. Variables such as HVAC and telecom equipment corresponds with relationships found in previous research.

The results from the statistical analyses indicates that a forecast can be made with input from the researched variables. However the relevance of the variables can differ between different location designs and are not always statistically significant. One of the findings in this study is that telecom equipment has a positive relation with energy consumption (more equipment results in more energy consumption) and HVAC is negatively related to energy consumption (free cooling technology results in less energy consumption). Additionally this study researches the current budgeting method for energy consumption at KPN (traditional budgeting) and researches different alternatives such as the rolling forecast method to achieve a more predictable forecast.

The results suggests that the regression equation from the multiple linear regression analysis can be used as input for the budget in order to predict the costs for energy consumption. Aside from looking at the input for the budgeting model, the budget model itself can be evaluated in order to determine if it is suited for the desired purpose.

The remainder of this thesis is organised into seven sections. Section 2 explains the background and section 3 will elaborate on the used research methods. Section 4 will discuss the literature. Section 5 develops the hypotheses and explains the methods employed to test these hypotheses. Section 6 presents the descriptive statistics. Section 7 presents the results. Finally section 8 will discuss the conclusions of the results.

2. Background

Reggefiber was a company active in the Dutch Fiber to the Home (hereafter called FttH) market. Reggefiber was founded in 2005 and became a joint venture between KPN and Reggeborgh in 2008 (Reggefiber, 2016). In 2014 KPN bought the remaining shares from Reggeborgh and became the 100 percent owner of Reggefiber.

Different techniques can be used to connect customers to the network of the telecom provider. Examples of these techniques are VDSL, Hybrid Fiber Coax (HFC), Fiber to the Building (FttB), Fiber to the Cabinet (FttC) and Fiber to the X (FttX). FttX also contains FttH according to Vereecken et al. (2011). Three main domains can be identified in the network of KPN, these three domains are visualised below in figure 1. The focus in this study will be on the Reggefiber FttH network. The other two domains mobile and fixed contain different techniques compared to Reggefiber such as FttB, FttC and VDSL.

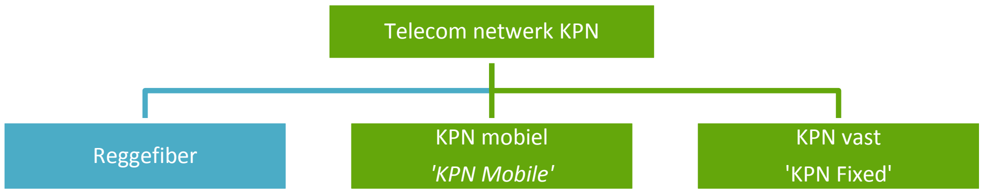

Figure 1: KPN Network structure 2016

2.1 Passive network Reggefiber

The FttH network of Reggefiber is organised by cities and villages, every city or village has a CityPoP (hereafter called CP), multiple CP's or a CityPoP/AreaPoP (hereafter called CP/AP) combination. For instance, where Reggefiber is headquartered, a combination of a CP/AP is used. This CP/AP is connected with the backhaul which connects the FttH network with the internet. Several AreaPoPs (hereafter called AP) are used to connect the customers with the CP/AP, the customers are connected via a distribution point or directly to an AP. The structure of the FttH network design of Reggefiber is visualised in figure 2.

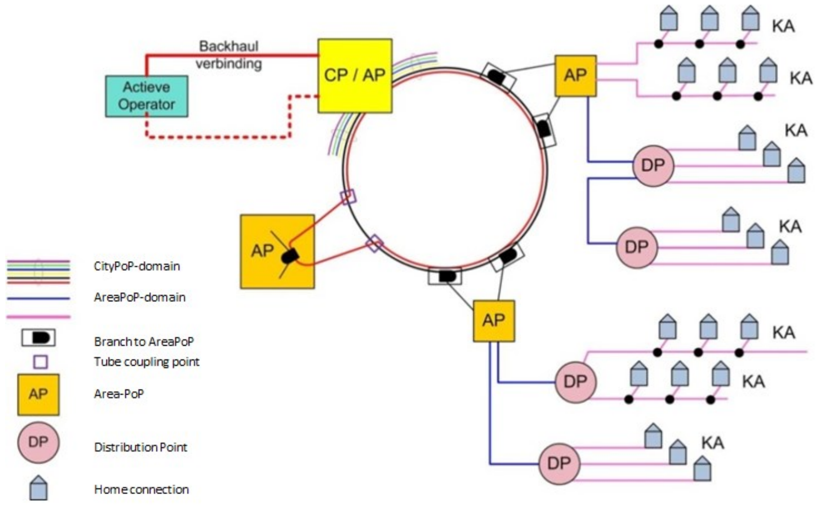

Figure 2: Passive network setup (Reggefiber, 2016b)

Customer with a connection to the FttH network can be defined into two categories: Home Passed (HP) and Home Activated (HA, visualised as KA in figure 2). HP means that the customer is connected to the passive network from Reggefiber. When the customer has an active subscription and uses the FttH Network the status is defined as HA. In a CP a section is reserved wherein the AO can utilise their hardware in order to deliver services to the customer which have a HA connection.

2.1.1 *Active operators & service providers*

Active operators are organisations which buy access to the FttH passive network. They gain access to optical fibers, data is delivered by providing light on the optical fibers. They use their own hardware to deliver the signal to the home of the customer with a HA connection. Service providers are providers that deliver services to the consumers, they deliver this service by using the services of an Active Operator. The service providers can buy access to the wholesale services of the Active Operators.

Access to the FttH network for outside organisations is regulated by the Dutch authority for Consumers and Markets. This regulation is based on a non-discrimination principle which ensures that all parties are treated equally and have access to the same services for fixed prices (ACM, 2014). Organisations which access the FttH network have access through Optical Distribution Frame contract. In this contract two categories of fees are listed: recurring and one-time fees. One of the listed recurring fees is energy consumption per HA. This recurring fee for Active Operators is a compensation for the costs related to energy consumption in the FttH network. The compensation for energy consumption is set at the beginning of the year and Active Operators are paying in advance for the energy consumption. At the end of the year the total energy consumption is analysed for discrepancies and will be adjusted at the end of the year.

2.1.2 Point of Presence (PoP)

Reggefiber is constantly changing and developing their network and introducing new types of Point of Presence (hereafter called PoP) models. The traditional PoP model can be categorised in six different types (Reggefiber, 2016b). In Appendix I the layouts of the different PoP types are shown, in this appendix the differences such as size and differences in layout can be seen. Two main different types of PoP's can be identified, a regular PoP and a street cabinet. The street cabinet is a new type of PoP in the FttH network, however in the KPN network this is a widely used type of PoP. The regular PoP can be divided into three categories, these categories are model 1, model 2 and model 3. The Mini-PoP contains two categories, version 1 and version 2, however the Mini-PoP is excluded from this research because the lack of sufficient data.

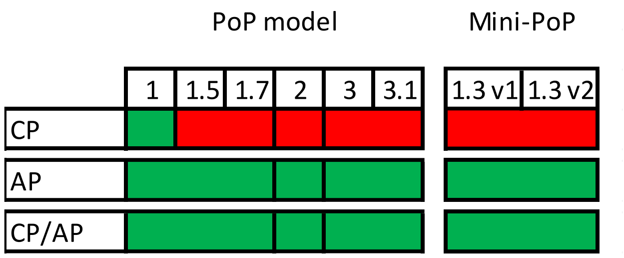

Figure 3: PoP models

In figure 3 the different combinations between the PoP domain (AP and CP) and the different PoP models are shown. All of the PoP models can have the combination CP/AP or the sole domain AP. Model 1 however is distinct in the way that locations can have the sole CP function without the AP domain. In figure 3 the green colour shows combinations between the PoP models and domain in the Reggefiber FttH network. In contrast with the green colour, red identifies combinations which are not present in the FttH network such as only CP domains for Model 2 and Model 3.

2.2 ENVIRONMENTAL FOCUS ON ENERGY CONSUMPTION

KPN is convinced that sustainability and technology are closely related and can complement and reinforce each other (KPN, 2016e). KPN has the ambition to provide services and networks that are part of a circular economy. In order to achieve this ambition in 2025, this goal is included in the Key Performance Indicators (hereafter called KPI) for 2016. This KPI about circular economy is focusing on reducing waste and raw material consumption and recycling (KPN, 2016b). VBDO concluded that KPN is amongst the top ten of large companies in the Netherlands with attention towards economic circularity. Nevertheless the transition of KPN to renewable energy can lead to additional costs which in turn can affect the price for energy consumption. On the other hand while the data volume is growing, the amount of electricity consumption which is needed to power the data volume is declining (see figure 4). KPN achieved one of the climate goals five years earlier than scheduled, since 2015 the operation is climate neutral (KPN, 2016b).

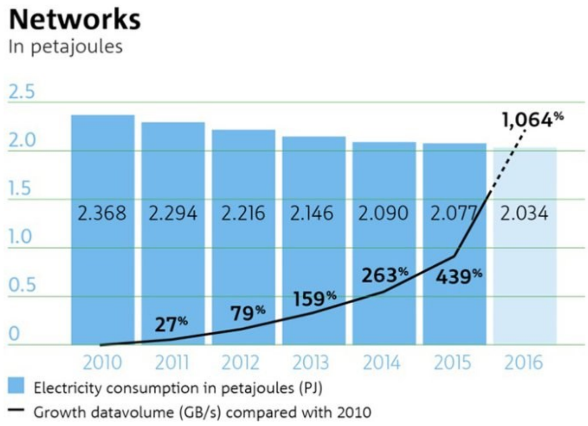

Figure 4: Electricity consumption compared to growth data volume (KPN, 2016c)

2.3 BUDGETING ENERGY CONSUMPTION

With the integration of Reggefiber into KPN the budgeting method rolling forecasting was introduced to produce budgets. However in the current situation annual budgeting is used besides annual budgeting to produce a budget for the energy consumption within the FttH network. An aspect to consider of the rolling forecast method is the frequency of adjusting the budget. A trade-off exists between the intensity of adjusting the rolling forecast and the accuracy of the budget. More labour is required if the frequency of adjustment is higher and subsequently lead to higher costs of the budgeting process.

The FttH network, previous Reggefiber, is situated in the Consumer Operations department in KPN. Within Consumer Operations the department Infra Services is charged with maintaining the current FttH infrastructure and managing the energy consumption is an example of one of the responsibilities. Of the total operating expenditures (also called OPEX) budget of Infra Services in 2016 approximately 25 percent has been budgeted for energy consumption. In the current situation the annual planning of the operations does not correspond to the actual energy consumption, this results in a surplus between the budget and the actual numbers. This surplus is evaluated and corrected after the year has passed. Because the budget is planned with a safety margin, the input for the planning is inaccurate, not all of the budget will be used. This money could have been spend on other projects with a positive net present value and the mismatch should therefore be as low as possible.

3. RESEARCH PROBLEM

This study will focus on two topics which are the aspects of energy consumption and the budgeting of energy consumption. The previous section introduces the design of the FttH network and the challenges that KPN faces related to energy consumption. In this section the main research question is discussed and a distinction is made between knowledge problem based research questions and practical problem based research questions. According to Wieringa (2007) every practical problem contains a knowledge problem. This distinction will be further elaborated in subsection 3.2. The third and fourth part of this section will discuss the knowledge problem based research questions and the methods which will be used to answer this research questions.

3.1 PROBLEM STATEMENT & RESEARCH GOAL

Reggefiber as a part of KPN has different types of energy consumption, for instance energy consumption within office buildings and energy consumption within the telecom network. This study will focus on the energy consumption within the FttH network. The challenge for the FttH domain is that the planning of the costs, related to energy consumption, cannot be accurately predicted or planned. The costs cannot be accurately planned because it is not known which cost drivers influences the costs of energy consumption.

The aim of this study is to research which cost drivers have an influence on the energy consumption and how this cost drivers can be used to enhance the process of budgeting. KPN uses annual budgets to plan for the costs related to energy consumption. In the current situation it occurs that the actual cost differs from the planned cost. The desired goal of KPN is to calculate an accurate cost for energy consumption and reduce the gap between the planned and actual costs by using relevant cost drivers. The costs are expressed in Euro's, however the price for electricity is fixed and therefore the measurement unit kilowatt hour (kWh) will be used instead of expressing the costs in Euro's.

The problem as stated above results in the following research question:

"Which cost drivers can be identified that play a role in the planning function for the budget of the energy consumption, in the FttH domain of KPN?"

3.2 PROBLEM INVESTIGATION

A practical problem can also be seen as an implementation problem (Wieringa, 2007). There is a difference between the way stakeholders experience the world and the way they would like to experience it. As described in the second section a discrepancy exists between the planning in the annual budgeting and the actual results. The answer to a practical problem is neither true nor false but is useful or useless, in order to achieve an answer criteria are used to judge the answer. The practical research questions will be researched with the use of empirical data.

As mentioned in the introduction of this section a practical problem often contains a knowledge problem. Wieringa (2007) describes a knowledge problem as a difference between what stakeholders know about the world and what they would like to know. In order to solve knowledge problems information needs to be gathered with methods such as literature review, desk research or consulting experts. The object of knowledge should not be disturbed during the study and finding the truth with the gaining of knowledge as goal. One of the differences between a practical problem and a knowledge problem is that practical problems involves criteria, by which the desired change is evaluated (Wieringa, 2007). In the paper by Wieringa (2003) a further distinction is made for practical problems, namely a classification into a design problem and an implementation problem. The design problem is focusing on specifying a change and the implementation problem focuses on implementing the specified change. This study will focus on the design problem and will not address the implementation problem. In order to solve a design problem the problem needs to be analysed and a solution has to be specified.

In order to answer the practical problem, the knowledge problem needs to be addressed and this will be addressed in the first three research questions in the next subsection. After the knowledge problem is addressed, the practical problem will be addressed in the fifth section.

3.3 KNOWLEDGE RESEARCH QUESTIONS

Several sub research questions have been defined in order to answer the central research question. These sub research questions will be discussed hereafter including the associated research methods to answer the sub research questions. The first three research questions are knowledge problem based and will be discussed in this section, the fourth and fifth research question are practical problem based and will be discussed in the fifth section.

- *How is the current process about budgeting energy consumption structured and which activities can be identified in the FttH network of Reggefiber?*

The current budgeting process for energy consumption will be researched by carrying out a literature review related to budgeting. Additional desk research will be conducted in order to match the current process to the literature. The literature review for this research question is closely related to the second sub research question and will be done simultaneously.

- *What are, according to scientific literature, the advantages and disadvantages of the current budgeting method for energy consumption in the FttH network of Reggefiber?*

In the current situation circa 25 percent of the budget for maintaining the FttH network is used for energy consumption. According to Reggefiber the current process is unpredictable and could result in additional payments. The process about budgeting energy consumption as researched and described in the first research question will be analysed with scientific literature. The advantages and disadvantages of the current process according to scientific literature will be discussed. A comparison will be made between the current process and alternatives researched in the first research question. Reggefiber expects that a significant deviation exists between the budget and the actual costs, however because of the lack of data this will not be researched in this study.

- *Which characteristics or cost drivers can be identified, according to scientific literature, in the energy consumption related to the FttH network?*

Literature review will be conducted to research potential variables which could be identified as cost drivers. Previous studies exist and will be analysed for potential use in this study. Additional desk research will be carried out to match if the researched variables of the literature are applicable to the Reggefiber FttH network. Based on the gathered information of the desk research and literature review several hypothesises are formulated in the fourth research question in the fifth section.

3.4 RESEARCH METHODS

Desk research is a method involving existing data in order to carry out research (Baarda et al., 2013). Baarda et al. (2013) make a clear distinction between a literature study and desk research. Desk research focuses on analysing collected data and documents and a literature study is used to gather information about the subject of the study, research methods and possible theories related to the subject. Several data sources are used for the literature review, such as google scholar, web of science, Scopus and desk research at KPN. The output of the desk research and literature review will be used to research the practical problem as will be further elaborated in the fifth section.

In order to answer all of the research questions and thereafter the main research question multiple methods are used. In the previous subsection the methods are specified for each research question related to the knowledge based research question. In order to determine the potential variables, which can affect the budgeting for energy consumption, multiple methods are combined in order to achieve the utmost list of variables. This list of variables will be tested with a multiple linear regression analysis and the results will lead to one or more conclusions. The regression analysis will be further elaborated in the seventh section.

4. LITERATURE REVIEW

Energy and electricity are often used interchangeable, however the term ‘energy’ is broader than only electricity. Electrical energy, after natural gas, is only the second greatest category of energy consumed in the Netherlands in the last 10 years (Eurostat, 2016). Other energy sources such as fossil fuels are not relevant for this study because only electrical access points are available in the PoP locations from Reggefiber. This conclusion corresponds with the research from Yang, Zhang, Huang, and Peng (2013) where the focus on their research of energy consumption within the Chinese telecom network is put on electricity, because between 80 percent and 90 percent of the total energy consumed by the telecom industry is of electrical nature. In the case of the FttH network it will be 100 percent with the exception of special locations which are excluded in this research.

With the current introduction of smart meters, more data is available than in the past, it is feasible to specific research energy consumption. Previous research is done on electricity consumption by using smart meter data in the scientific studies (Arora & Taylor, 2014). In this study they used large micro-level datasets, Arora and Taylor (2014) also argue that literature on modelling smart meter data is small. Past data can be used as the starting point for producing the budgets, however this does not mean that the assumption can be made that what has happened in the past will occur in the future (Drury, 2012). Changes in the future conditions must be taken into account, the information from the past can be used as guidance for the future. For this study this means that past data of energy consumption can be used as an input for producing a new budget, but also future conditions should be taken into account.

4.1 BUDGETING & ALTERNATIVES

According to Horngren, Datar, & Rajan (2012) a budget is a proposed plan of action by the management for a specified period. A budget is normally prepared for a particular period, usually one year (Zeller & Metzger, 2013) and designed with one or multiple purposes. Budgets can be designed by organisations to serve a number of purposes. Six different purposes are identified by Drury (2012): (1) planning annual operations, (2) coordinating the activities of the various parts of the organization and ensuring that the parts are in harmony with each other, (3) communicating plans to the various responsibility centre managers, (4) motivating managers to strive to achieve the organisational goals, (5) controlling activities and (6) evaluating the performance of managers.

In contrast with the six purposes as mentioned above by Drury (2012), another view is given by Hansen and Van der Stede (2004) who identifies four reasons used by organisations to use a budget. Two of these reasons are primarily short-term and operational in nature (operational planning & performance evaluation), while the other two reasons are long-term and strategic in nature (communication of goals & strategy formation). In contrast with the previous mentioned authors a later article by Hansen (2011) three different functions are enumerated instead of the six or four functions as mentioned above. These three functions are: (1) a common forecast (base demand forecast), (2) operational planning (hard capacity decision) and (3) performance evaluation. These different views on purposes of budgeting show that differences exist in the existing literature on budgeting. This difference between views in existing literature is confirmed by Hansen and Van der Stede (2004) who argue that there is no well-defined, stable and unitary meaning regarding the different uses of budgets.

When a budget is used to serve several purposes it is possible that these purposes may be in conflict with each other. Drury (2012) gives the example of a conflict between planning and motivation, these purposes can conflict with each other when demanding budgets are used to motivate for maximum performance but are not suited for planning purposes because the demanding budget cannot be achieved. This is contradicted by a study performed by Fisher et al. (2002), in this study it is suggested that a combination of budgeting reasons (e.g. performance evaluation & resource allocation) can create more value instead of only using the individual reasons.

Several different methods of budgeting are identified in scientific literature (Hansen 2011; Drury, 2012). The traditional budgeting is visualised in figure 5 and further elaborated in the next subsection. Alternatives to traditional are displayed in table 1 categorised by the function as argued by Hansen (2011) and will be discussed later in this section.

Table 1: Budgeting methods

Budgeting method	Function
Traditional/annual budgeting	
Rolling Forecast	Forecast
Activity-based budgeting	Operational planning
Beyond Budgeting	Performance evaluation

Drury (2012) describes a framework of how the overall traditional budgeting process is structured (see figure 5). In the previous paragraph it is enumerated that the budget can serve several purposes such as planning. The planning function of the budgeting process ensures that plans for the future operations are made and that conditions are considered which can impact future operations.

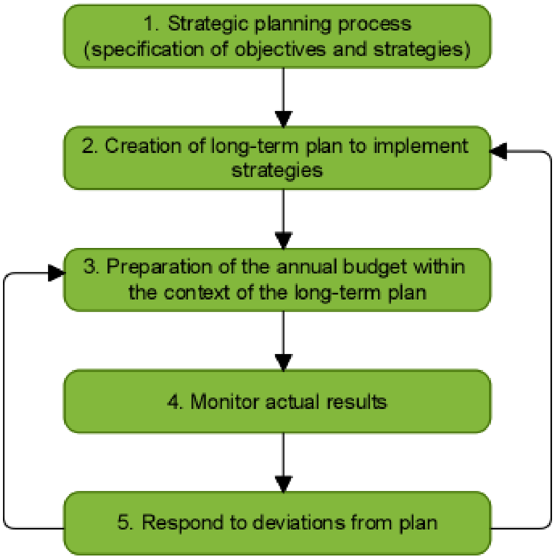

Figure 5: Strategic planning, budgeting and control process (Drury, 2012)

4.1.1 CRITICISM ON TRADITIONAL BUDGETING

Recent years traditional budgeting has been criticised in academic literature, one of the illustrating examples can be seen in the title of the article of Wallander (1999) which is named *"Budgeting – an unnecessary evil".* One of the recurring conclusions is that budgeting systems often result in dysfunctional behaviour and consuming large amounts of time (Libby & Lindsay, 2010). According to Drury (2012) the major criticism on traditional budgeting is that the annual budgeting process is not capable to meet the demands of the competitive environment in today's information age. Sources of criticism are not only from academic sources but also from practical sources. Drury (2012) has reviewed academic literature relating to annual budgets and identified the following criticism relating to the annual budgeting process:

1. Encouraging rigid planning and incremental thinking.
2. Being time-consuming.
3. Ignoring key drivers of shareholder value by focusing too much attention on short-term financial numbers.
4. Being a yearly rigid ritual that impedes firms from being flexible and adaptive in the increasingly unpredictable environment facing contemporary organizations.
5. Tying the company to a 12-month commitment, which is risky since it is based on uncertain forecasts.
6. Meeting only the lowest targets and not attempting to beat the targets.
7. Spending what is in the budget even if this is not necessary in order to guard against next year's budget being reduced.
8. Achieving the budget even if this results in undesirable actions.
9. Being disconnected from strategy.

Hansen, Otley and Van der Stede (2003) synthesise the sources of dissatisfaction into three categories. The first category contains the arguments that the assumptions in the budget are outdated by the time the budget is used. The second criticism category is that budgetary controls impose a vertical command-and-control structure with a centralised decision making with the focus on cost reductions rather than value creation. The third category contains organisational issues which occur when a vertical, command-and-control and responsibility centre-focus budgetary controls are incompatible with flat, network or value chain-based organisational designs (Hansen et al., 2003; Hope & Fraser, 2003).

To address the shortcomings of traditional budgeting two approaches are suggested by Hansen et al. (2003). The first approach is to improve the budgeting process and primarily focus on the planning problems. The second approach suggests that budgeting should be abandoned and the focus should be on performance evaluation. Hansen et al. (2003) link these two approaches to two groups which both originated in the same organisation: The Consortium for Advanced Manufacturing-International (hereafter called CAM-I). The first group is the U.S. based CAM-I Activity-Based Budgeting and this group argued that the budgeting system should be transformed into a more complete activity-based operational model with a detailed financial model. The focus should be on supporting to operational planning with improving the budgeting. The second group is the European based CAM-I Beyond Budgeting group which recommends a two-stage approach and either radically change the traditional budgeting or abolish the budgeting process. The first stage should address problems with budgeting when the budget is used for performance evaluation. This group argued that combining planning and performance evaluation results in both poor planning and dysfunctional behaviour. The second stage should lead to a decentralisation of the organisation and empowering lower management and employees.

4.1.2 Alternatives to traditional budgeting

Hansen et al. (2003) questions why most firms in the U.S. still retain a formal budgeting process when there are many problems and calls for change. Libby and Lindsay (2010) argue that it is difficult to accept that many organisations would continue using budgeting for control purposes (managerial motivation and performance evaluation) if it was fundamentally flawed. They also state that examples are present in literature in which highly successful firms utilize budgeting for planning and control.

Libby and Lindsay (2010) investigated organisations in Canada and the United States if budgets are used for control. Additional they asked if these organisations are planning to abandon the use of budgeting as a control mechanism. Of these organisations 79 percent indicated that they use budgeting for control. Of these organisations, that indicated that budgeting is used for control, 94 percent are not planning to abandon budgeting for control. One of the conclusions of their study is that the results suggest that traditional budgeting for control purposes will not soon be eliminated and have the potential to be useful if used appropriately. Libby and Lindsay (2010) argue that the focus should not be on *"either/or"* (alternatives such as beyond budgeting versus traditional budgeting) because examples exist of successful companies utilizing both approaches. Instead they suggest developing the possibilities for each model by seeking deeper understanding. Hansen (2011) identifies three different budgeting alternatives to an annual budget, namely rolling forecast, activity-based budgeting and beyond budgeting.

- The rolling forecast method generates an improved forecast.
- Activity-based budgeting takes into account the operational planning and generates greater flexibility for unforeseen events.
- Beyond budgeting approach involves changing the compensation of employees and improving performance evaluation.

According to Zeller and Metzger (2013) leading companies use the rolling forecast as a replacement to or in combination with a traditional budget. This corresponds to the suggestion made by Libby and Lindsay (2010) that the focus should not be on *"either/or"* but on seeking deeper understanding. Morlidge and Player (2010) define that a rolling forecast as a financial estimate of likely future outcomes, based on current assumptions and economic forecasts (as cited in Zeller & Metzger, 2013). Previous research has been done on rolling forecast by Doeven (2012), in this study a framework (figure 6) is presented which is based on research performed by Zotteri and Kalchsmidt (2007).

Traditional budgeting and the rolling forecast are both tools which are used to produce a forecast for organisations (Doeven, 2012). However several differences can be identified between traditional budgeting and the rolling forecast. The rolling forecast is used to produce an outlook for the organisation and obtain a planning whereas a budget can serve multiple purposes. Another difference is that the rolling forecast divides the annual budget down into smaller time frames which requires a constant flow of current business data and is regularly updated (Zeller & Metzger, 2013).

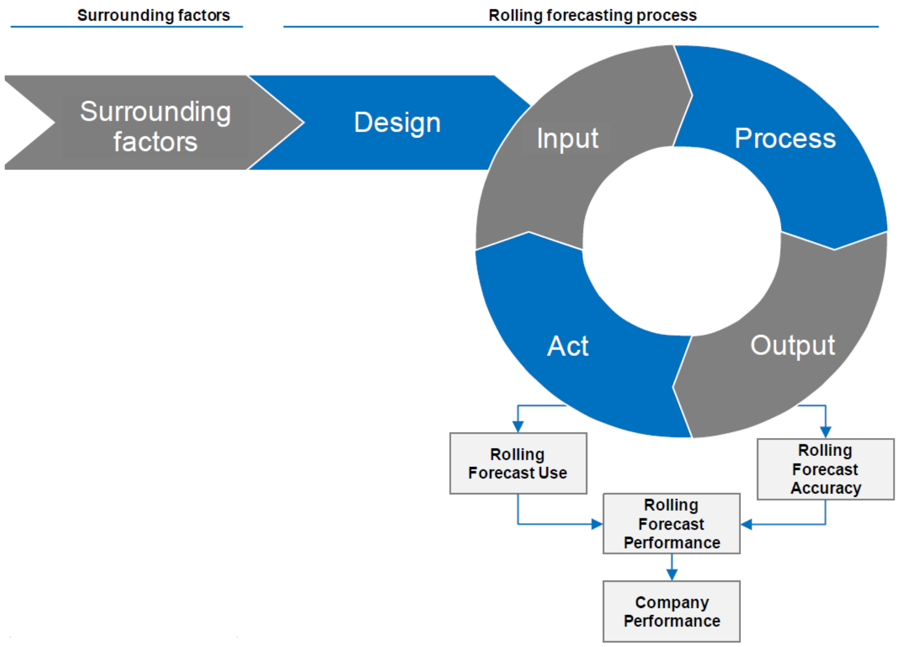

Figure 6: Rolling forecast Framework (Doeven, 2012)

4.2 BUDGETING PROCESS

Drury (2012) describes six stages which can be followed in order to complete the budgeting process: (1) communicating details of the budget policy, (2) determining the factor that restricts performance, (3) preparation of the sales budget, (4) initial preparation of budgets, (5) negotiation of budgets, (6) coordination and review of budgets, (7) final acceptance of the budgets and (8) budget review.

In these six stages it is important that the long-range plan of the organisation should be the starting point of the annual budget (Drury, 2012). The budget policies should be communicated (stage 1) by the top management in order to establish common guidelines that govern the preparation of the budget. Possible factors which can restrict performance for a given period and in result affect the budgeting should be communicated by the top management (stage 2). When the volume of sales the level of an organisations operations the sales budget is the most important (stage 3). This sales budget is an organisational budget and may be influenced by the economy or competitors. After the sales budget the managers should prepare the budgets for which they are responsible (stage 4). Initial preparation of the budget should be carried out through a bottom-up process which originates at the lowest levels of management and be refined and coordinated at higher management levels. Past data of previous years can be used as a starting point for producing budgets, but this does not take future conditions into account. After the budgets are prepared for the relevant areas it should be approved by the higher management and incorporate this budget with other budgets (stage 5). When the individual budgets move up in the organisation the relation between budgets must be examined (stage 6). Corrections should be made when budgets are out of balance when the relation is examined. When all budgets are in harmony with each other the master budget can be made (stage 7) and this master budget should be periodically compared with the actual results (stage 8).

4.2.1 COST MEASUREMENT & COST ALLOCATION

In order to prepare a budget the input such as costs has to be measured. The costs related to energy consumption in the FttH network of KPN is only influenced by the amount of energy that is consumed in kilowatt hour (hereafter called kWh) because the price for energy is yearly stipulated in the contract with the supplier. The costs are usually expressed in Euro's, however the price for electricity in this instance is fixed and therefore the measurement unit kilowatt hour (kWh) will be used instead of expressing the costs in Euro's. However cost measurement does nothing to manage cost (Geiger, 1999). In order to manage cost, managerial costing systems must provide measurements which are compatible with a cost management control mechanism. Hiromoto (1988) states that it is desirable to focus management attention on only a few main cost drivers (as cited in Homburg, 2001). However a high accuracy in allocating overhead costs requires a high number of cost drivers (Homburg, 2001). This requires finding the right balance between a few main cost drivers in order to focus management attention while ensuring at the same time that the accuracy stays reliable.

A cost driver is a measure that can be used to proportionately distribute the cost of activities to cost objects. Geiger (1999) argues that the choice of a cost driver can have considerable impact on the effectiveness of a managerial costing system. In some cases managers identify surrogate targets in cost drivers which are subsequently used to achieve reduction in costs (Geiger, 1999). When cost drivers are primarily selected for their behavioural impact instead of linking costs to cost objects it is possible that wrong cost drivers will be selected. One of the more common approaches is to select cost drivers that reflect the resource consumption by being correlated to resource usage (Geiger, 1999). Drury (2012) mentions different types of tracing costs to cost objects and how cost allocation can be applied such as cause-and-effect allocation, for allocating indirect costs to a cost object, which assumes that allocations are applied when significant determinants can be found (see figure 7).

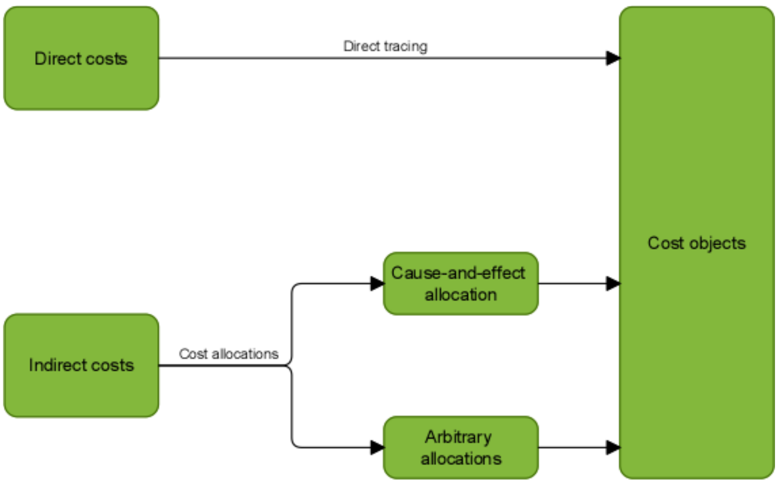

Figure 7: Cost allocation (Drury, 2012)

4.2.2 Cost drivers

Drury (2012) describes a regression equation which identifies an estimated relationship between a dependent variable (cost) and one or more independent variables (cost driver or activity measure) based on past observations. In a PoP multiple potential cost drivers can be identified according to existing literature which will be discussed below. Because multiple cost drivers are expected to be relevant multiple regression will be used to research relationship between the cost and cost drivers, this is called a cost function (Drury, 2012). A danger exists that cost functions which are derived from past data may contain a spurious correlation in the data. High correlation is only likely to continue if the relationship between the variables is economically plausible. An example of a regression equation which contains two independent variables and the relationship can be assumed to be linear, the regression equation will be (Drury, 2012):

$$y = a + b_1 x_1 + b_2 x_2$$

The equation as stated above contains several items:

- y represents the cost (in this study y will represent kWh)
- a represents the non-variable cost item (also called constant or intercept)
- b_1 represents the average change in y resulting from a unit change in x_1 assuming that x_2 will remain constant. In this study the unstandardized coefficients will be used which shows the average change in the dependent variable associated with a 1 unit change in the dependent variable.

As can be seen in the formula by Drury (2012) for researching a relationship between cost and cost drivers there is a non-variable cost part (represented by a) and a variable part (represented by b_1). This non-variable and variable part can also be recognised in theory on energy consumption. Two types of loads in energy consumption can be identified in the energy grid, namely essential and flexible (Hassan, Wang, Huan & Yuen, 2013).

4.3 ENERGY CONSUMPTION

The last three decades telecommunication plants have evolved dramatically, data traffic volume and speed have grown at an increasing rate (Sorrentino et al., 2010). This evolution of telecommunication plants have led to smaller equipment with a higher power density. Koutitas and Demestichas (2010) enumerate several power consumption units which correspond with other studies on this topic such as lights, cooling, ups and telecom equipment. They state that great losses occur in UPS due to conversions in the form of thermal heat.

In the study performed by Mandal et al. (2013) three categories are identified in energy consumptions related to telecommunications networks. These three categories are transmission energy, storage energy and energy consumed by heating, ventilation and air conditioning. One of the assumptions in their study is that HVAC energy can be reduced by reducing storage energy. Storage energy in the FttH network can be designated in the EQF equipment in PoP locations. This equipment is telecom equipment which is powered by electricity and is also mentioned in the paper of Roy (2008) as a contributor to energy consumption. They also raise the concern in higher power density of new equipment and the impact of this higher power density on environmental conditions. Another possible concern which is raised in the paper of Roy (2008) for predicting energy consumption is the presence of different power modes in telecom equipment such as ECO modes. This mode is currently not active in the Reggefiber FttH network, nevertheless this could become relevant in the near future.

HVAC equipment is an important contributor to the energy consumption. Mandal et al. (2013) make the assumption that when transmission and storage energy is being reduced the HVAC energy will also be reduced and because of that reason excluded this variable from their study. A study performed by Sorrentino et al. (2010) in the telecom switching plants of Telecom Italia shows that Telecom Italia could save energy on HVAC as high as 25 percent through improving climate control management (Sorrentino et al., 2010). Another study performed by Roy (2008) on energy efficiency at five telecom networks estimates that passive cooling or free cooling (VKU) energy savings of above 10 percent. This conclusion by Roy (2008) and Sorrentino et al. (2010) suggest that HVAC configuration does have the potential of affecting energy consumption and contradicts the argument from Mandal et al. (2013) mentioned above. The study by Sorrentino et al. (2010) shows that the variable should be further researched to reach a reliable conclusion.

5. PROBLEM ANALYSIS & HYPOTHESIS DEVELOPMENT

In the literature review in the previous section the knowledge problem of the main research question is addressed and the results of the first three research questions will be used as input for the analysis of the fourth and fifth research question. The research methods which are used to answer the practical problem will be discussed in this section including the corresponding data collection and selection of variables. Finally the scope of this study will be discussed in the last part of this section.

5.1 RESEARCH QUESTIONS & HYPOTHESES

With the use of the knowledge based research questions the practical problem research questions will be addressed. These research questions will be discussed hereafter and the results will be used to answer the main research question.

- *Which characteristics or cost drivers can be identified in the energy consumption in the FttH network of Reggefiber?*

In order to identify the relationship between the cost of energy consumption and the corresponding cost drivers multiple linear regression will be used (Drury, 2012). This corresponds with previous studies on energy consumption where regression is used to find out whether independent variables are able to predict the dependent variable; energy consumption (Erdogdu, 2007; Bianco, Manca, & Nardini, 2009; Kaytez, Taplamacioglu, Cam, & Hardalac, 2014). Possible variables are identified in the third research question with the use of desk research, literature review and consulting experts from KPN. Based on the gathered information in the third research question several hypothesises are formulated which will be researched in this study.

- *How can the researched characteristics of energy consumption be applied to enhance the process of budgeting energy consumption in the FttH network of Reggefiber?*

In the first and second research question the current budgeting process is researched with the corresponding advantages and disadvantages. One of the current known disadvantages is the unpredictability of the cost of energy consumption. In the third research question the cost drivers are researched related to energy consumption. The goal of this research question is to use the results of the third or fourth research question to enhance the current process. This research question will be answered in the eight section.

5.1.1 HYPOTHESES

As described in the second section different configurations for designs of PoP's are present in the FttH network. According to internal desk research it can be stated that Model 1 is the oldest PoP design and Model 3 is the most recent. The only exception is Model 1.3 which is excluded in this research and is vastly different from the other three models as described in the second section (Reggefiber, 2016b).

Throughout the construction and rollout of the FttH network in the Netherlands the requirements have changed, which subsequently resulted in different requirements of the PoP design. Changes in the requirements of PoP's and the introduction of different and more recent machinery it is expected that PoP models show a variation in the pattern of energy consumption. This study only contains three different types of PoP locations as a result of excluding the fourth category. A PoP location can only be Model 1, Model 2 or Model 3. Because of the differences in spatial design of PoP models and the variation between equipment the first hypothesis is defined.

Hypothesis 1: Newer PoP models shows a significantly negative relationship with energy consumption when compared with the older PoP models.

In the FttH network several hierarchical layers can be identified (see figure 2) in order to connect customers to the backhaul of KPN and ultimately to the global network (Reggefiber, 2016). The customer connected to the FttH network is connected to an AP domain which in turn is connected to the CP domain. The FttH network of Reggefiber is designed with AP and AP/CP PoP locations. Considering the different layers of connecting customers to the backhaul, different types of equipment are placed which are related to the according domain. Therefore it is assumed that a difference exists between the function and hierarchical layer of the PoP, with this assumption the second hypothesis is formulated.

Hypothesis 2: CP/AP PoP locations have a significant positive relationship with energy consumption when compared with AP PoP locations.

The variable Homes Activated is included as a control variable in the multiple linear regression analysis. The main objective of utilising the FttH network is to connect as many HA's as possible to the FttH network. It is expected that if the number of HA's per PoP increases the entire PoP is affected, more equipment is needed to facilitate the number of HA's. Furthermore in order to be able to compare PoP's with each other the number of HA's needs to be controlled and this variable has been included as a control variable. Based on this assumptions the third hypothesis is defined.

Hypothesis 3: The number of Homes Activated have a positive relationship with energy consumption.

Two PoP telecom equipment categories can be identified within the FttH network of Reggefiber, PoP equipment for connecting HA's and equipment for the functioning of PoP's. This variable focuses on equipment which is needed to connect HA's to PoP's, this equipment can be further categorised into equipment which consumes electricity and passive equipment which does not consumes electricity. Equipment which consumes energy is identified as EQF equipment and is researched in this multiple linear regression model.

It is expected that the number of HA's affects the amount of EQF equipment needed to connect HA's to the network. However because of the different EQF equipment types from different AO's it is expected that these variables are closely related but also shows differences. Because of the differences between AO's and various equipment types with other specifications it is expected that this variable has additional explaining and predictive power when compared to the number of HA's. With these assumptions the fourth hypothesis is formulated.

Hypothesis 4: The amount of PoP equipment is positively related with energy consumption, more equipment results in a significant higher consumption.

The second hypothesis describes the AP and CP domains, in these domains several AO's are operating in order to deliver services to the customers with the use of the FttH network. The regulation of the Dutch ACM ensures that access is ensured with the same conditions for all interested parties (ACM, 2014). Because of the regulated open access to the Reggefiber FttH network different regional and national AO's are present, which results in a varying amount of AO's per PoP. Each AO rents space within PoP's and install their own equipment in order to connect customers in the FttH network to their services. It is assumed that an increasing number of AO's present within PoP's results in more installed equipment, which in result leads to a higher energy consumption. According to this assumption the fifth hypothesis is defined.

Hypothesis 5: The number of Active Operators has a positive relationship with energy consumption, more AO's results in a significant higher consumption.

The energy consumption pattern for the FttH network shows fluctuation throughout the year between the seasons. This pattern is suggested to be the cause of the outside temperature which affects the cooling equipment in PoP's (Sorrentino et al., 2010). Because of the lack of data it is not possible to measure the direct effect of temperature on cooling equipment, therefore it is included as a separate variable on the total variation of energy consumption. It is assumed that the outside temperature has a significant positive effect on the energy consumption and explains a part of the variation between the seasons. The sixth hypothesis is formulated because of the expected significant impact on the total variation of the energy consumption.

Hypothesis 6: The outside temperature has a positive relationship with energy consumption.

As suggested in the literature review HVAC consumes energy and can be reduced by using different technology than the traditional AC (also called Airco) cooling equipment (Roy, 2008; Sorrentino et al., 2010). Mandal et al. (2013) assumes that HVAC energy consumption has an impact on energy consumption but excluded it in their research. In order to test if the HVAC energy consumption is relevant, for predicting energy consumption of the FttH network, the following hypothesis is formulated:

Hypothesis 7: The cooling equipment significantly influences the energy consumption, VKU cooling equipment shows a negative relationship with energy consumption when compared with Airco equipment.

Table 2: Variables Multiple Linear Regression

Variable		Description	Measure	Unit
Energy consumption		Energy consumption of a PoP measured by smart meters in kilowatt hour, measured bimonthly.	Ratio	Kilowatt Hour (kWh)
Model	Model 1	Dummy variables with a value of 1 for the PoP model 1 and a value of 0 for other models.	Ordinal (dummy variable)	0=Other model 1=Model 1
	Model 2	Dummy variables with a value of 1 for the PoP model 2 and a value of 0 for other models.	Ordinal (dummy variable)	0=Other model 1=Model 2
	Model 3	Dummy variables with a value of 1 for the PoP model 3 and a value of 0 for other models.	Ordinal (dummy variable)	0=Other model 1=Model 3
Function		Dummy variable with a value of 1 for a CityPoP/AreaPoP (CP/AP) domain and a value of 0 for an Area-PoP (AP) domain.	Ordinal (dummy variable)	0=AreaPop 1=CityPoP/AreaPoP
Homes Activated (HA)		The number of Homes Activated in a PoP location.	Ratio	
PoP Equipment (EQF)		The amount of space used by equipment in a PoP which consumes electricity.	Ratio	
Active Operators (AO)		The number of Active Operators present in a PoP.	Ratio	
Temperature		The bimonthly average degrees of Celsius as measured by the KNMI (weather station “De Bilt”).	Ratio	Degrees Celsius
HVAC		Dummy variable with a value of 1 for a VKU cooling and a value of 0 for the presence of an Airco cooling.	Ordinal (dummy variable)	0=Airco 1=VKU

5.2 RESEARCH METHODS

A multiple linear regression will be conducted on the data gathered through desk research. Hair et al. (2014) have defined six stages which can be followed in order to obtain valid results, these stages: (1) objectives of multiple regression, (2) research design of multiple regression, (3) assumptions in multiple regression analysis, (4) estimating the regression model and assessing overall fit, (5) interpretation of the regression results and (6) validation of the results.

The first two stages will be discussed in this subsection and later stages will be addressed in later sections. Hair et al. (2014) distinguishes two categories of objectives, prediction and explanation. This study has the objective to explain the regression coefficients in order to develop a reason for the effects which occurs from the independent variables on the dependent variable. With this objective it is important to demonstrate both statistical and practical significance and take measurement and specification errors into account (Hair et al., 2014). Practical significance can also be termed as economic significance. The assumptions, the third stage in conducting multiple regression will be discussed in the next subsection.

5.2.1 MODEL ASSUMPTIONS

The first assumption for conducting a multiple regression analysis which will be checked is the normality of the residuals, this will be done with a visual check of the normality plot (steam-and-leaf plot) of the residuals (see appendix IV). The graphical distribution as can been seen in appendix IV shows an approximately normal distribution. Altman and Bland (1995) argue that when large samples, which contain over hundreds of observations, the distribution of the data can often be ignored. The Central Limit Theorem (hereafter called CLM) states that when sampling is from a normal population, the mean of samples drawn from that population are themselves normally distributed (Kothari, 2004). However when the sampling is not from a normal population the size of the sample is crucial, in this case the sample size can be classified as a large sample. The dataset used for the analysis is many times larger than the required threshold according to the power analysis and because the sample size is greater than the required threshold of 30 which is required for the CLM to be effective (Cohen, 1992; Kothari, 2004). It can be assumed according to CLM that the sampling distribution of the mean approaches normal distribution. This in combination with the approximate normal distribution it can be concluded that this assumption is not critical and is satisfied for this study.

The second assumption the linearity assumption can be analysed in the scatterplot which shows the distribution of the standardised residuals versus the predicted values (see appendix IV). According to Hair et al. (2014) linearity of the relationship between dependent and independent variables represents the change in the dependent variable which can be associated with the independent variables. The multiple linear regression method is based on a linear relationship and thus it is important to satisfy this assumption. The scatterplot in appendix IV shows no curvilinear pattern, therefore it shows no linearity and the assumption of linearity is satisfied.

The scatterplot which is used for analysing the linearity assumption will also be used for analysing the third assumption of homoscedasticity. A violation of homoscedasticity will cause difficulties to determine the standard deviation of the forecast error. Subsequently the confidence intervals can be too wide or too narrow. The cases are evenly distributed amongst zero in the scatterplot which shows no pattern of increasing or decreasing residuals and therefore does not show a violation of homoscedasticity. With this conclusion it can be assumed that the assumption of homoscedasticity is satisfied.

5.3 RESEARCH VARIABLES

All the hypotheses will be simultaneous tested (confirmatory selection approach) as visualised in figure 8. The dependent variable, energy consumption, will be discussed in the first subsection and the second subsection will address the independent variables.

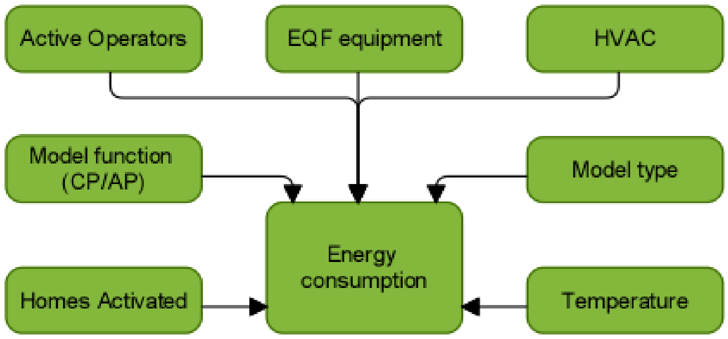

Figure 8: Input variables multiple linear regression

5.3.1 DEPENDENT VARIABLE

The dependent variable which is used for the multiple linear regression analysis is energy consumption. Energy consumption is measured with smart meters placed within the FttH network. The smart meters are not available in all PoP locations, however the smart meters that are placed are distributed throughout the Netherlands. The smart meters are matched with PoP's within the FttH network by matching EAN numbers, which are unique numbers for a smart meter, between sources from Reggefiber and the supplier of electricity. In the case no match was made based on these sources a geographical match is made based on address or location.

5.3.2 INDEPENDENT VARIABLES

In appendix II an overview is given of the selection which is made of the PoP locations. By comparing several registration systems multiple locations have been filtered by only administrative present (not build or removed locations), capacity (this category shows rented locations) and PoP model 1.3 (street cabinets are excluded as mentioned in the second section). Of the remaining PoP locations on average of 50 percent of the locations are equipped with smart meters and in May 2016 circa 65 percent of the PoP locations are equipped with smart meters. In the dataset which spans over two years, a selection will be made for twelve months in order to prevent possible season influence of the temperature. Further information on descriptive statistics and selection of observations will be discussed in the sixth section.

Within the PoP registration system (SIMA) different categories can be identified: the PoP is not owned by KPN, the PoP location is special (deviation from the normal model types) or the PoP location is a regular model as identified in the second section. Because of legacy in the system this category is defined in several different fields such as PoP model or PoP capacity. In the data source PoP capacity is included as a filter variable in order to exclude PoP locations which are rented. Rented locations can deviate from regular locations, energy consumption can be included in the renting contract or there is no energy meter present. The PoP registration system contains more information such as the function of a PoP, the amount of PoP equipment present, which type of HVAC equipment is placed and the numbers of Active Operators active in PoP locations. The information related to the average outside temperature is gathered from the KNMI public website.

UPS could be a potential variable as described in the literature review, however there is a lack of reliable data on how to measure this variable. However this variable consumes electricity and therefore could be a significant variable for the prediction of energy consumption in telecom networks. The lack of this variable is a limitation of this study and further research should take this variable into consideration.

5.4 DATA

Data for energy consumption is gathered from the suppliers of energy and the supplier of the smart meters. The data from third parties are combined with internal data available at KPN will result in a dataset with all PoP's and the available data on energy consumption. Of the measured periods with smart meter data an average of 50 percent of the PoP's in the FttH network are equipped with a smart meter and are randomly placed. Apart from determining an appropriate sample size potential outliers should be identified and be treated accordingly. Influential observations are observations that lie outside the general patterns of the dataset or strongly influence the regression results (Hair et al., 2014).

Hair, Black, Babin and Anderson (N.D.) describe four steps in order to identify influential observations. These steps are (1) analysis of the residuals, (2) identifying leverage points from the predictors, (3) single-case diagnostics and (4) selecting and accommodating influential observations. The analysis of the residuals are instrumental in detecting violation of the model assumptions, therefore this analysis is descripted in the previous section which discuss the multiple linear regression assumptions. Outliers are filtered based on the Cook's Distance. Several thresholds appear throughout the literature, observations greater than 1.0 or according to the formula $4 / (n - k - 1)$ are suggested as outliers by Hair et al. (N.D.). In order to detect outliers in this dataset the threshold of the formula as suggested by Hair et al. (N.D) will be used.

5.5 RESEARCH SCOPE

The focus in this study will be on the FttH network from Reggefiber and will not consider the influence of other business units on this research. The FTTH network design contains several different types of PoP's. There are two main different types of PoP's, a regular PoP and a mini-PoP (which is also called a street cabinet or model 1.3). The mini-PoP is a new type of PoP in the Reggefiber network design. This research will focus on the regular PoP model because there is only data available about this type of PoP locations.

6. Data analysis

This section discuss the descriptive statistics of the researched dataset. The overall dataset will be presented in the first subsection and in order to determine the variation between the different PoP model types the descriptive statistics of each model type will be presented. The second subsection will further elaborate on the differences between the different PoP models and will discuss the statistics results of these comparisons. The final subsection will discuss the descriptive analysis.

6.1 Descriptive statistics dataset

The descriptive statistics are used to describe the results and organise the data. In table 3 the descriptive statistics of the dataset will be given, the descriptive statistics categorised by Model type are given in table 4. Missing cases are excluded list wise because of the large dataset sufficient observations remain to conduct the analysis. After excluding missing or incomplete observations 615 outliers are identified and removed. As mentioned in subsection 5.3 these outliers can be classified in four categories. These outliers are influential observations identified by applying the Cooks Distance and can distort the analysis (Hair et al., N.D.) These observations are most likely caused by incorrect registration or invalid data.

Table 3: Descriptive statistics dataset (without the variable PoP model)

Variable	Descriptive statistics dataset *N =8238*				
	Mean	Median	Std. deviation	Min	Max
Energy consumption	3351.27	3109.00	1778.46	25	11955
Function	0.46	0.00	0.49	0	1
HA's	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
EQF	178.38	193.00	70.34	14	560
AO's	1.32	1.00	0.62	0	4
Temperature	10.71	9.74	4.81	3.76	18.45
HVAC	0.12	0.00	0.32	0	1

The variable Function is a dummy variable 1 denotes CP/AP locations and 0 denotes AP locations. The third and last dummy variable is HVAC, 1 denotes VKU equipment and 0 denotes Airco equipment. The variable Temperature is measured in Celsius temperature scale.
■ The numbers regarding the HA variable are removed because of the confidential nature of this variable.

Table 4: Descriptive statistics categorised by PoP model

Variables	Panel A: Model 1					Panel B: Model 2					Panel C: Model 3				
	Mean	Median	Std. deviation	Min	Max	Mean	Median	Std. deviation	Min	Max	Mean	Median	Std. deviation	Min	Max
Energy consumption	4577.11	3052	3320.09	249	11955	3377.63	3213	1478.08	263	9662	1187.81	964	747.41	25	4400
Function	0.35	0	0.47	0	1	0.47	0	0.49	0	1	0.49	0	0.50	0	1
HA's	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
EQF	204.75	132	204.75	23	560	181.55	193	62.60	29	403	90.83	75	27.10	14	189
AO's	2	2	2.00	0	4	1.27	1	0.54	0	4	1.03	1	0.24	0	2
Temperature	9.97	7.57	4.61	3.76	18.45	10.79	9.74	4.85	3.76	18.45	10.56	9.74	4.42	3.76	18.45
HVAC	0.48	0	0.50	0	1	0.03	0	0.16	0	1	1.00	1	0.00	1	1
N	*646*					*7139*					*453*				

This table shows the descriptive statistics categorised by the independent variable Model type. Function is a dummy variable 1 denotes CP/AP locations and 0 denotes AP locations. The last dummy variable included in this table is HVAC, 1 denotes VKU equipment and 0 denotes Airco equipment. The variable Temperature is measured in Celsius temperature scale.

■ The numbers regarding the HA variable are removed because of the confidential nature of this variable.

When analysing the distribution of the existing PoP's in the Reggefiber FttH network it can be concluded that of the Model types the PoP model 2 is the most common. This corresponds with the descriptive statistics table (see table 4) and can be recognised in appendix III that in the observations PoP Model 2 is the most occurring model type. The variable model type has been included in the regression model through a dummy variable. The model type in the descriptive table is the base variable for this dummy variable, this variable is coded in three dummy variables which are exclusive. A PoP location can only be assigned to one exclusive PoP model type, the descriptive statistics for each of the model type is presented in table 4. The mean of the CP/AP variable for the overall dataset is 0.46 (see table 3) and because this is a dichotomous variable (0=AP & 1=CP/AP) it can be concluded that around 55 percent of the observations is from an AP PoP. This corresponds with the design of the FttH network which consists of several layers as described in the second section.

The HVAC variable as previous mentioned is included in the regression model as a dichotomous variable (0=Airco & 1=VKU) which shows a mean of 0.12. The mean of 0.12 suggest that of the gathered observations the majority is equipped with the traditional Airco. This distribution is visualised in appendix III which shows the amount of observations equipped with a VKU (13 percent) and the observations equipped with an Airco (87 percent). Internal documents gathered with internal desk research shows that all new locations are equipped with VKU cooling equipment (all PoP Model 3 locations, see mean Panel C in table 4) and it is expected that this distribution will change with an increase for the VKU equipment.

The means of EQF and HA's are given in the descriptive statistics table (see table 3). The mean for these two variables are derived from multiple months. When looking at these variables in more detail a growth pattern can be found. This can be explained by the growth in PoP's in the FttH network. In appendix III the growth of the mean of EQF and HA's is plotted against the base values in July and August 2014. This graph shows that the average number of HA's in May/June 2016 is around 60 percent higher when compared to the average mean in July/August 2014. This leads to the assumption that the connected customer (HA's) will grow and in result will lead to a total higher energy consumption in the FttH network.

6.2 DESCRIPTIVE STATISTICS POP MODELS

In table 5 the differences between the means of the three PoP models are presented. The differences between the different panels (models) are presented in the right section of the table with the corresponding t-values. The results shows that almost all of the variable means shows a significance difference between the different PoP models. Exceptions are seen in the comparison between panel B (Model 2) and panel C (Model) 3 for the mean of the variable Function and the mean of the variable Temperature.

When comparing the overall differences it can be observed that the means for HA, EQF and AO are lower for the more recent Model 3 when compared to Model 2 and Model 1. The means for panel A (Model 1) are the highest of the three models for these variables. Another notable difference is the distribution of HVAC equipment across the different models, Model 1 is nearly 50 percent distributed with VKU equipment while the mean for panel B (Model 2) is only 3 percent for VKU equipment.

Comparing the mean for the whole dataset and the subsamples it can be seen that the means for panel B (Model 2) is the closest to the means of the overall dataset. This can be explained by the fact that of the observations of the dataset 86 percent can be assigned panel B. With these differences in variable means across the different models the multiple linear regression analysis will be performed for each model.

Table 5: Differences between PoP models

Variable	Panel A: Model 1	Panel B: Model 2	Panel C: Model 3	Differences Panel A and B		Differences Panel A and C		Differences Panel B and C	
	Mean	Mean	Mean	Difference	t-value	Difference	t-value	Difference	t-value
Energy consumption	4577.11	3377.63	1187.81	1199.48	9.10**	3389.30	25.05**	2189.82	55.81**
Function	0.35	0.47	0.49	-0.12	-5.97**	-0.14	-4.64**	-0.02	-0.91
HA's	[redacted]	[redacted]	[redacted]	[redacted]	2.19*	[redacted]	15.49**	[redacted]	21.56**
EQF	204.75	181.55	90.83	23.20	5.08**	113.92	24.33**	90.72	61.57**
AO's	2.00	1.27	1.03	0.73	16.60**	0.97	21.68**	0.24	18.49**
Temperature	9.97	10.79	10.56	-0.82	-4.33**	-0.59	-2.17*	0.22	1.05
HVAC	0.48	0.03	1.00	0.45	22.91**	-.051	-26.35**	-0.97	-495.10**
N	*646*	*7139*	*453*						

**, * Denote significance at the 1 percent and 5 percent, respectively. The table reports the mean of the different variables in PoP's divided by model type. The means of each variable are compared and tested for differences between two panels with a t-test. The sample consists of a total of 8238 samples measured by smart meters and other KPN systems.

[redacted] The numbers regarding the HA variable are removed because of the confidential nature of this variable.

6.3 DESCRIPTIVE ANALYSIS

The remaining dataset of 8238 observations exceeds the threshold for the required data sample size. Additional assumptions will be tested in order to confirm the appropriateness for the multiple linear regression technique for this data set. Hair et al. (2014) identifies three assumptions which are required to satisfy in order to conduct a valid analysis. These three assumptions are linearity, homoscedasticity and normality. Other considerations should be taken into account such as multicollinearity and independence of the residuals. This dataset does not contain longitudinal data and therefore the independence of the residuals is not relevant for this analysis. This subsection will address the three required assumption as defined by Hair et al. (2014) and the influence of multicollinearity.

Table 6: Pearson Correlations

	Energy consumption	Model 2	Model 3	Function	HA’s	EQF	AO’s	Temp	HVAC
Energy	1								
Model 2	0.03***	1							
Model 3	-0.29***	-0.61***	1						
Function	-0.35***	0.04***	0.01*	1					
HA's	0.83***	0.10***	-0.21***	-0.46***	1				
EQF	0.84***	0.11***	-0.30***	-0.40***	0.83***	1			
AO's	0.54***	-0.17***	-0.11***	-0.31***	0.36***	0.46***	1		
Temperature	0.14***	0.04***	-0.00	-0.00	-0.03***	-0.02**	-0.03***	1	
HVAC	-0.37***	-0.70***	-0.66***	0.03***	-0.28***	-0.33***	-0.09***	-0.01	1

***, **, * Denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.
The table reports the correlation between the dependent and independent variable in the first column. Correlations between the independent variables are shown with the according significance level if applicable. Temperature is abbreviated to Temp for readability.

It is necessary to assess if multicollinearity can be observed within the data considering that the ability to predict is decreased if multicollinearity is present within the regression model (Hair et al., 2014). The ability to predict decreases because of the shared variance between independent variables, as multicollinearity increases the total variance explained decreases. The first technique that will be used to assess the multicollinearity for the regression model is the Pearson Correlation (see table 6). When looking at the correlations between the independent variables none of the variables exceeds the threshold as suggested by Hair et al. (2014) with a correlation of greater than 0.9 (negative or positive). In the Pearson Correlation table the independent variables EQF equipment and HA's have the highest correlation of 0.830. Therefore according to the Pearson Correlation it can be assumed that there is no significant multicollinearity or singularity present in this dataset which requires corrective actions in order to obtain valid results. In order to confirm the Pearson Correlation and to further test the presence of multicollinearity the Tolerance and the Variance Inflation Factor (VIF) will be used. In the case of Tolerance values lower than 0.10 or VIF values exceeding the value 10 concerns for multicollinearity arise (Hair et al., 2014). When consulting the Tolerance and VIF values the concern for multicollinearity can be satisfies as none of the values exceeds the critical threshold (see appendix IV for the table containing the VIF and Tolerance values, only 1 table is included as this table can been seen as an example for the other PoP models). The conclusion can be made that there is no significant multicollinearity or singularity present in this dataset which requires corrective actions in order to obtain valid results.

7. RESULTS ANALYSIS

This section presents the results of the multiple linear regression analyses. The overall regression model analysis will be discussed in the first subsection. The differences between the overall model and the subsamples will be addressed in the second part of this section. The last part of this section will review all the formulated hypotheses.

7.1 REGRESSION MODEL ANALYSIS

The adjusted R squared (Adj. R^2 in table 7) indicates the total variation of y (energy consumption) which can be explained by the regression model consisting of the included variables (Hair et al., 2014). The adjusted R Squared indicates that 87 percent (see table 7) of the variation of the energy consumption can be generalised for data not included in this dataset. When looking at the model fit and considering the assumptions, as discussed in the previous sections, it can be concluded that the model has considerable capabilities in predicting energy consumption.

The hypothesis as formulated below will be used in order to verify if the regression slope differs from zero and that the regression model is significant. With the significant value it can be stated that the alternative hypothesis (H_a) is accepted in favour of the H_0 hypothesis ($p < 0.001$) because the $\beta's$ are not equal to zero. The alternative hypothesis suggests that at least one of the coefficients shows a predictive relationship with energy consumption.

H_0: β_1 *Model* = β_2 *Function* = β_3 *HA's* = β_4 *EQF* = β_5 *AO* = β_6 *Temp* = β_7 *HVAC* = 0

H_a: At least one β_j differs from 0

7.2 COMPARISON OVERALL MODEL & SUBSAMPLES

This subsection shows the multiple linear regression results for the overall dataset in the left segment of table 7. As mentioned in subsection 6.2 the different PoP models shows a significant difference between the means of the variables and therefore the regression analysis was conducted for each PoP model type (see the right segment of table 7). The results of the multiple linear regression analysis will be further elaborated and analysed in the next subsection.

Table 7: The relation between energy consumption and cost drivers

	Predicted sign	Results for dataset		Results for subsamples					
				Panel A: Model 1		Panel B: Model 2		Panel C: Model 3	
		Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Constant		259.78	5.15*	734.25	4.62*	-876.72	-23.79*	170.51	2.62*
Model 2	-	-1205.84	-37.09*						
Model 3	-	-448.22	-10.32*						
Function	+	293.90	18.23*	307.98	4.72*	291.81	16.87*	25.80	1.13
HA's	+	[redacted]	68.13*	[redacted]	18.74*	[redacted]	63.57*	[redacted]	44.45*
EQF	+	8.09	42.09*	10.34	20.01*	7.18	33.10*	6.24	13.47*
AO's	+	507.00	37.73*	380.02	9.04*	466.78	31.15*	136.72	3.23*
Temperature	+	65.98	45.72*	29.57	5.47*	72.72	47.52*	-12.00	-5.07*
HVAC	-	-1281.54	-36.55*	-1695.89	-15.78*	-899.40	-19.98*	-	-
N		8238		646		7139		453	
Adj. R^2		0.87		0.96		0.82		0.91	

*** Denotes significance at 1% level**

The table reports the results of the multiple linear regression for the overall dataset and for each of the three subsamples with energy consumption as the dependent variable. The variables Model 2 and Model 3 are included as dummy variables for the overall dataset with the dummy variable Model 1 as the control variable. The variable HVAC is included as a dummy variable for all the analyses with a value of 1 denoting VKU and 0 denoting Airco. T-values related to the coefficient are shown after each coefficient. The independent variable is not present in the analysis of panel C (subsample model 3) because this subsample only contains VKU as HVAC equipment (see mean of 1.00 in table 4 at panel C).

[redacted] The numbers regarding the HA variable are removed because of the confidential nature of this variable.

7.3 HYPOTHESIS TESTING

As is stated in subsection 7.1 the regression model is significant and at least one variable has an effect on the regression slope. In this paragraph the hypotheses of the third research question will be tested. The hypotheses which are tested with the multiple linear regression model are clustered in three groups. The first group is named '*PoP Model & Function*' and contains the variables related to the PoP design type and function. In the second group '*PoP utilisation'* the hypotheses are addressed relating to HA's, EQF equipment and AO's. The last group is called '*Temperature & HVAC'* and contains hypotheses related to managing temperature within PoP's.

The coefficients of the analysis (see table 7) shows that all included variables for this multiple linear regression model are significant for the overall dataset ($p < 0.001$). The variables will be used to formulate the regression equation which can be used to predict energy consumption in the FttH network of KPN. The regression equation for the overall dataset can be formulated as:

y = 259.789 + (293.9 * CP/AP) + (-1281.549 * HVAC) + (8.093 * EQF) + ([redacted] * HA's) + (65.98 * Temp) + (507.005 * AO) + (-1205.843 * Model2) + (-448.229 * Model3)

7.3.1 PoP MODEL & FUNCTION

We discuss results regarding H1, which predicts that, newer PoP models (model 2 & 3) shows a significantly negative relationship with energy consumption when compared with the older PoP model 1. In order to test this hypothesis with multiple linear regression the original variable has been recoded into a dummy variable. As can be seen in table 7 the dummy variables Model 2 and Model 3 are included with Model 1 as a control variable. The direct correlation of Model 2 (0.03) and Model 3 (-0.29) on energy consumption is rather low (see table 6), although the coefficients are both statistically significant ($p < 0.001$). Both dummy variables Model 2 and Model 3 are statistically significant and show negative coefficients when compared to Model 1.

This variable was included as a dummy variable for different type of design in the Reggefiber FttH network. Model 1 can generally be considered as the oldest PoP type and Model 3 is the latest design. When looking at the coefficients it can be concluded that both Model 2 and Model 3 are consuming less energy compared to Model 1. However it is interesting to conclude that the coefficient of Model 2 is greater than the coefficient of Model 3 which suggests that Model 2 has a different energy consumption pattern when compared to Model 3. Considering the average mean of energy consumption (3351.27) and the negative coefficient for Model 2 (-1205.84) and Model 3 (-448.22) it can be concluded that this variable is economically significant.

The results regarding H2 will be discussed, which predicts that CP/AP PoP locations have a significantly positive relationship with energy consumption when compared with an AP PoP location. This variable is included in this dataset as a dichotomous variable (1 denotes CP/AP and 0 denotes AP) and the t-value is statistically significant in the model for the complete dataset ($p < 0.001$). A difference can be observed between the different PoP models when the subsamples are analysed in the multiple linear regression analysis. For Model 1 and Model 2 this variable is significant, however this is not the case for Model 3. Nevertheless all the coefficients are in line with the expected positive effect, although the coefficients are declining with newer PoP models. With a positive beta in all the panels and the complete dataset it can be concluded that a PoP with a CP/AP function consumes significantly more energy than a PoP with an AP function.

When looking at the economic significance of this variable it can be concluded that this is not the case for Model 3 which is statistically insignificant. However this variable shows an increase of around 300 kWh (around 9 percent of the average energy consumption) if the PoP location is an AP/CP location and is economically significant for Model 1 and Model 2. Remarkable is that the difference between the mean of Function between Model 2 and Model 3 is insignificant. This would suggest that this variable has become irrelevant in Model 3 and requires further research to localise the cause of these results.

7.3.2 PoP utilisation

The results regarding H3 will be discusses, which predicts that the number of HA's shows a significantly positive relationship with energy consumption. The PoP is designed to facilitate the customers (HA's). With an increase in customers it is expected that the amount of equipment is adapted to facilitate this expansion. Therefore it is expected that this variable has a considerable influence for predicting the energy consumption. Looking at the coefficients and the corresponding t-values for this variable in table 7 the same conclusion can be made for all the samples, namely that the expected positive sign is significant for all PoP models ($p < 0.001$).

The coefficient for this variable is rather low compared to the other variables included in this study. It can be assumed that a single HA increase should not result in an economically significant change in energy consumption. However in the case of high variation in this variable it is economically significant. In the ideal situation this variable should be excluded from the model because it does not consume electricity, nevertheless customers are connected to the EQF equipment in PoP locations which does consume electricity. However because the equipment types are not known and the capacity varies between equipment configurations this variable is included to compensate for this deficit in data.

The results will be discussed regarding the fourth hypothesis (H4), which predicts that PoP equipment is positively related with energy consumption. PoP EQF equipment is used in PoP's to connect HA's with the FttH network and consumes electricity. The fourth hypothesis states that the amount of EQF equipment significantly influences the energy consumption, more EQF equipment leads to a higher consumption.

The coefficients related to EQF equipment are positive for all of the panels and corresponds to expected positive sign as stated in the fourth hypothesis. EQF has a significant t-value ($p < 0.001$) in all the panels and therefore it can be concluded that the amount of EQF equipment positively influences the energy consumption. Nevertheless a decline in the coefficient for EQF equipment can be recognised from Model 1 to Model 3. This suggests that equipment placed in Model 3 is newer and therefore consumes less energy when compared to equipment in Model 1 and Model 2.

The variables included in the regression model shows that HA's and EQF equipment contributes positively to energy consumption (see table 7). The acceptance of the alternative hypothesis for the EQF equipment corresponds with the expected signs and previous literature which suggests that the telecom equipment in telecom locations are significant contributors to energy consumption (Mandal et al., 2010). This variable is closely related to the variable HA and it could be discussed if this variable is economically significant. In the case of high variation in this variable it can be assumed that it would be economically significant.

The results regarding H5 will be discussed, which predicts that the number of AO's is positively related with energy consumption. The fifth hypothesis predicts that more AO's would lead to higher energy consumption. The variable AO contains statistically significant t-values ($p < 0.001$) and has a positive coefficient in the researched sample and subsamples. Therefore it can be concluded that more Active Operators would lead to a higher energy consumption. The coefficient of the dataset and the panels is around 8 to 15 percent of the corresponding energy consumption mean. Considering the impact of an Active Operator it can be concluded that this variable is economically significant.

With the conclusion that the number of Active Operators active in a PoP location is significant it can be assumed that reducing the number of Active Operators should lead to a lower energy consumption pattern. This variable is present in the Reggefiber FttH network because of the regulation by the ACM, which determines that open access for all parties should be ensured. This is in contrast with other telecommunication networks and it is not widely researched what the effect of open access is on the total energy consumption. It could be possible that open access of the network leads to an increased energy consumption.

7.3.3 Temperature & HVAC

Two hypotheses are formulated in order to test the outside temperature and HVAC equipment in the regression model. The results regarding H6 will be discussed, which predicts that the outside temperature has a positive relationship with energy consumption. In table 7 the variable outside temperature has a positive coefficient with a significant t-value ($p < 0.001$) for the overall dataset. With the positive and significant coefficient it can be concluded that the temperature has a significant impact on energy consumption.

When the subsamples are analysed, a positive statistically significant influence on energy consumption can be observed for Model 1 and Model 2. However this is not applicable for Model 3 which shows a statistically negative relationship with energy consumption. As stated in the sixth section, in the descriptive statistics analysis for table 4, Model 3 deviates from the other two PoP models. Model 3 is solely equipped with VKU equipment and has a negative significant coefficient which differs from the expected sign as stated in the sixth hypothesis. While the outside temperature is statistically significant, however it can be argued that this variable is not economically significant. The coefficient is rather low compared to the mean of energy consumption and is closely related to the next hypothesis. Therefore it is concluded that this variable is not economically significant.

The seventh hypothesis which is tested in the multiple linear regression analysis tests the variable HVAC type. The results regarding to H7 will be discussed, which predicts that VKU equipment shows a negative relationship with energy consumption when compared to Airco equipment. In table 7 the HVAC variable shows a negative beta with a statistical significant result for the t-value ($p < 0.001$). Because of the coding of this variable, dichotomous coding with a value of 1 for VKU equipment, it can be concluded that the cooling equipment affects the energy consumption. More specifically it can be concluded that VKU equipment leads to a lower energy consumption compared to Airco equipment. When looking at the subsamples both panel A (Model 1) and panel B (Model 2) shows a similar pattern as the overall dataset. The coefficient for HVAC equipment is significantly negative for panel A and B in table 7. However panel C (Model 3) as earlier stated is only equipped with VKU equipment and therefore contains no variation for this variable.

This conclusion corresponds with previous research done by both Mandal et al. (2013) and Sorrentino et al. (2009) that HVAC equipment is an important contributor to the energy consumption. The coefficients of HVAC equipment in the dataset, panel A and B is around 26 to 38 percent of the corresponding energy consumption mean. It can be concluded that the type of HVAC equipment has a significant economic impact on energy consumption. However the difference between these studies is the conclusion that HVAC equipment is not considered to reduce energy consumption in the study of Mandal et al. (2013) because HVAC energy consumption will be reduced if the storage energy (EQF) is consuming less energy. While the focus of this study is on the predictive ability of the regression model. It is interesting to note that HVAC equipment has the highest standardised coefficient (see table 7) next to the EQF and HA equipment. Therefore both arguments contain merit by stating that reducing storage energy (EQF equipment) should lead to a lower energy consumption and in result lower HVAC consumption, nevertheless is the HVAC consumption also an important contributor for the energy consumption. Based on these findings the energy consumption could be affected by both reducing EQF equipment and changing the type of HVAC equipment.

8. CONCLUSION

In this section the conclusion will be drawn based on findings in the earlier sections and the main research question will be answered through the research questions. The second part of this section will discuss the relevance of this research and the limitations of this study. Finally directions for future research are suggested.

8.1 RESEARCH QUESTIONS

In order to answer the main research question the research questions will be answered in this section. First the main research question will be addressed. The second subsection will discuss the first and second research question related to the budgeting process. Cost drivers of energy consumption and how this can be used to enhance the budgeting process will be discussed in the third subsection which covers the third, fourth and fifth research question.

8.1.1 MAIN RESEARCH QUESTION

This subsection will discuss the main research question regarding to which cost drivers can be identified, which can play a role in the budget for energy consumption. The current budgeting process can be classified as annual budgeting according to relevant literature. Alternatives for annual budgeting are suggested in literature which focuses on forecasting or the planning function, one of these alternatives is the rolling forecast budget method. Nevertheless the input which is required in order to produce a budget is vital and the cost drivers as mentioned below can be used.

The cost drivers that are identified for the overall dataset are: (1) function of the PoP (CP/AP), (2) HVAC equipment, (3) EQF or telecom equipment, (4) HA's, (5) outside temperature, (6) Active Operators active and (7) Model type of PoP's. These cost drivers are relevant for the energy consumption of PoP's and are all practical and economic significantly tested for their effect on energy consumption. With the use of the regression formula the cost drivers can be predicted and used in the planning function of the budget for the energy consumption in the FttH domain. When looking at the subsamples the variables are not always significant, however they all correspond to the expected signs with the exception of HVAC and temperature in subsample panel C (Model 3).

8.1.2 *Budgeting process*

The first two research questions analysed the budgeting process for the Reggefiber FttH Network as described in the third section. The first research question researched the current budgeting process regarding the energy consumption in the Reggefiber FttH network and the second research question researched literature regarding the budgeting methods. This study shows that two budgeting processes are in use at KPN, namely annual budgeting and rolling forecast. Relating to energy consumption annual budgeting is used in the FttH network and the rolling forecast method is used for other financial plans. With both methods used in the KPN organisation it can be assumed that a switch could be easily made between these methods. Literature on this subject shows that annual budgeting is mostly seen as a rigid process and is outdated by the time the budget is used.

Forecasting for energy consumption is currently inaccurate and therefore it is difficult to achieve an accurate budget. With the ambition of KPN to improve the predictability in their budgeting alternatives are investigated in literature. Alternatives mentioned in literature are activity-based budgeting, beyond budgeting and the rolling forecast method. Each of these alternatives shows different advantages and disadvantages. Nevertheless the alternative which corresponds to the goal of KPN is the rolling forecast method. This method improves the forecast accuracy and therefore increases the predictability of the budget. The rolling forecast is used to produce an outlook for the organisation and obtain a planning whereas a budget can serve multiple purposes. Another difference is that the rolling forecast divides the annual budget down into smaller time frames which requires a constant flow of current business data and is regularly updated.

8.1.3 *Cost drivers & budgeting process*

The results regarding the cost drivers and the budgeting process will be discussed. The three research questions are described in the fifth section. The third research question researched which cost drivers could be identified based on previous literature. The fourth research question researched which cost drivers could be identified in the Reggefiber FttH network and the fifth research question researched the relation between the cost drivers and the budgeting process.

Variables which are possible cost drivers for energy consumption in the Reggefiber FttH network are selected based on desk research and literature review. Results shows that all formulated hypotheses for this research question are statistically significant for the overall dataset and therefore can be seen as cost drivers for energy consumption. As mentioned in the literature review it is desirable to reduce the amount of cost drivers in order to focus the managerial attention, however with the statistical method a trade-off exists between the accuracy of prediction and the amount of cost drivers. The confirmatory method used in the regression analyses focuses on including all the variables simultaneous because the desired goal is to enhance predictability or planning function in the budgeting process.

With the use of cost drivers as input for the budgeting process the energy consumption costs can be forecasted. Through the introduction of smart meters in the FttH network new opportunities arise in the budgeting process. With the use of this technology it is possible to compare the forecasted energy consumption with actual results and adjust the budget accordingly. This corresponds with the rolling forecast method and was practically not feasible in the past. This adaptation in the budgeting process can reduce the deviations in the current process and in result lead to an improved forecast.

8.2 PRACTICAL IMPLICATIONS

With the use of the multiple linear regression analysis a prediction can be made for the energy consumption of the PoP locations in the FttH network. The current method for budgeting energy consumption in KPN leads to discrepancy between forecasted and actual results. As described in the literature review the rolling forecast method offers an improved forecast in comparison with the annual budgeting. The budget period can vary, nevertheless the current budget period is one year. With the use of the regression equation the yearly energy consumption in the FttH network can be forecasted.

As visualised in the adapted rolling forecast figure from Doeven (2012) the yearly predicted FttH energy consumption can be used as input for the rolling forecast method (see figure 9). With the use of technology such as smart meters the actual results can be compared with the forecast and adjusted accordingly. With the adjustments the yearly deviations are expected to decline compared to using the annual budgeting method.

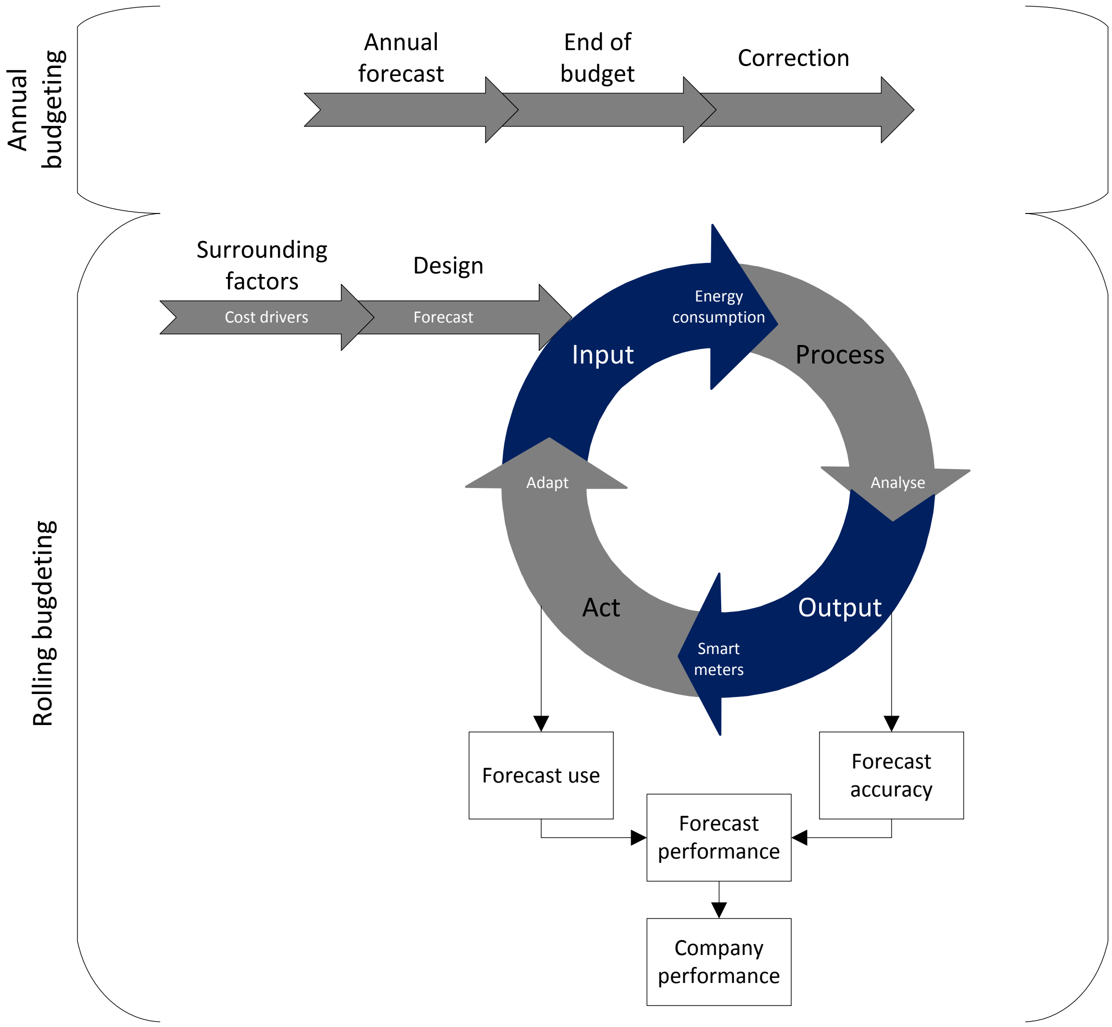

Figure 9: Adapted rolling forecast method from Doeven (2012)

8.3 RESEARCH CONTRIBUTIONS

Previous literature focuses on analysing energy consumption in telecom networks, such as comparisons between different network designs, configurations of hardware in telecom locations or saving potential of energy in telecom networks. This study is in line with research done by both Mandal et al. (2013) and Sorrentino et al. (2009) that HVAC equipment is an important contributor to the energy consumption. Another variable that is tested and corresponds with previous literature is the variable EQF equipment. The acceptance of the alternative hypothesis for the variable EQF equipment corresponds with the expected signs and previous literature which suggests that the telecom equipment in telecom locations are significant contributors to energy consumption (Mandal et al., 2010). Variables which are added in this model are related to PoP design (function, model type) and the influence of open access related to Active Operators.

However few articles are written which research how the variables related to energy consumption can be used as input for the budgeting process. This study aims to research this gap between budgeting literature and energy consumption, specifically for FttH telecom network design. With the introduction of new technology more information is possible to gather information in great amounts from telecom locations. New technology can influence the way how budgeting processes are organised and can be used to enhance or alter current methods.

8.4 LIMITATIONS & FUTURE RESEARCH

This study has performed a confirmatory selection of the independent variables with a direct link to the dependent variable. When looking at the Pearson correlation table (see table 6) a high correlation (correlation > 0.8) can be identified between the variables EQF and HA's. Future research could test the relationship between this variables by adding HA's as a moderator variable for EQF equipment. Another side of the spectrum is the relation of temperature with energy consumption which is relative low (correlation < 0.2). The variable temperature could possible included as an indirect variable for HVAC equipment. An altered model could be researched as visualised in figure 10.

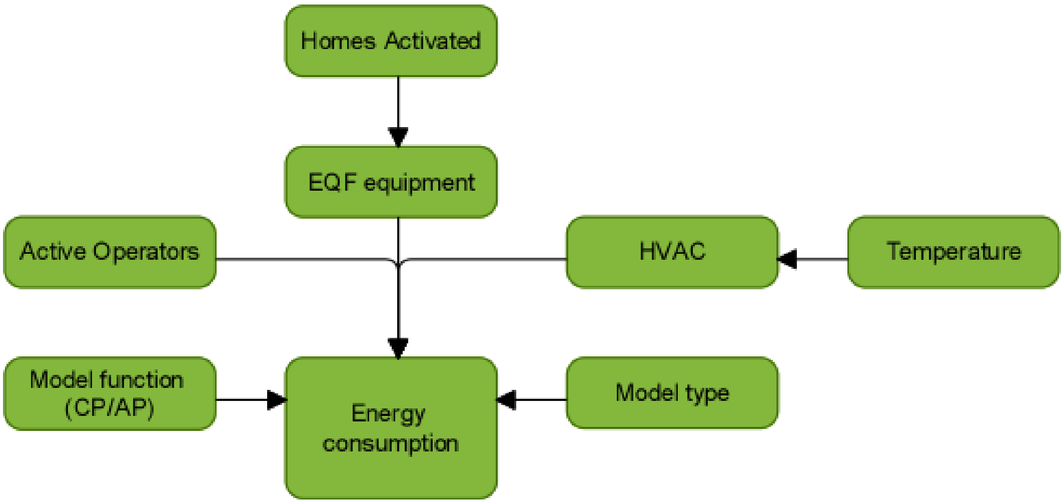

Figure 10: HA's & Temperature as an indirect variable

Nevertheless the results of this analysis will become more inaccurate as changes are made in the FttH network. New technology that is be placed in the PoP locations can vary in their energy consumption as older technology will be replaced. Further in-depth analysis is recommended for each individual model in order to compass a more complete model. In this research the mini-PoP or also called street cabinet is not included, however it is expected that because of the design variables will differ from the researched PoP locations in this study. Differences are expected in cooling equipment as a result of different isolation or as a result of a different ratio of equipment which is needed to facilitate a PoP which subsequently could lead to differences in the researched variables of this study.

One of the variables, not researched in this study, which could be a potential cost driver for energy consumption is the UPS variable. The UPS is a backup battery for electricity disruptions in PoP locations in order to ensure the equipment stays powered. UPS could be a potential variable but there is a lack of reliable data in this dataset to measure this variable. However this variable consumes electricity and therefore could be a significant variable for this study. Because lack of data it was not possible to include this variable in this study. Future research could focus on different types of configurations in telecommunication locations related to UPS equipment.

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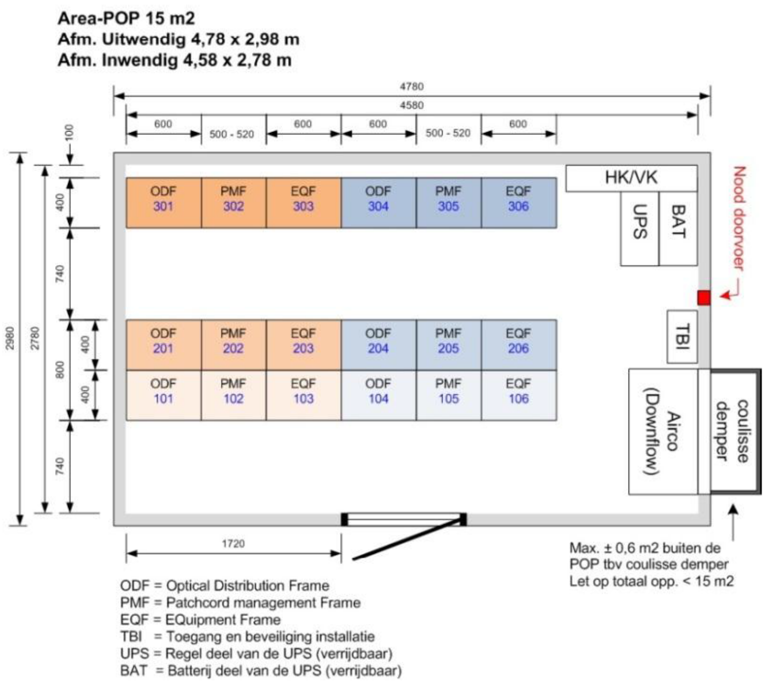
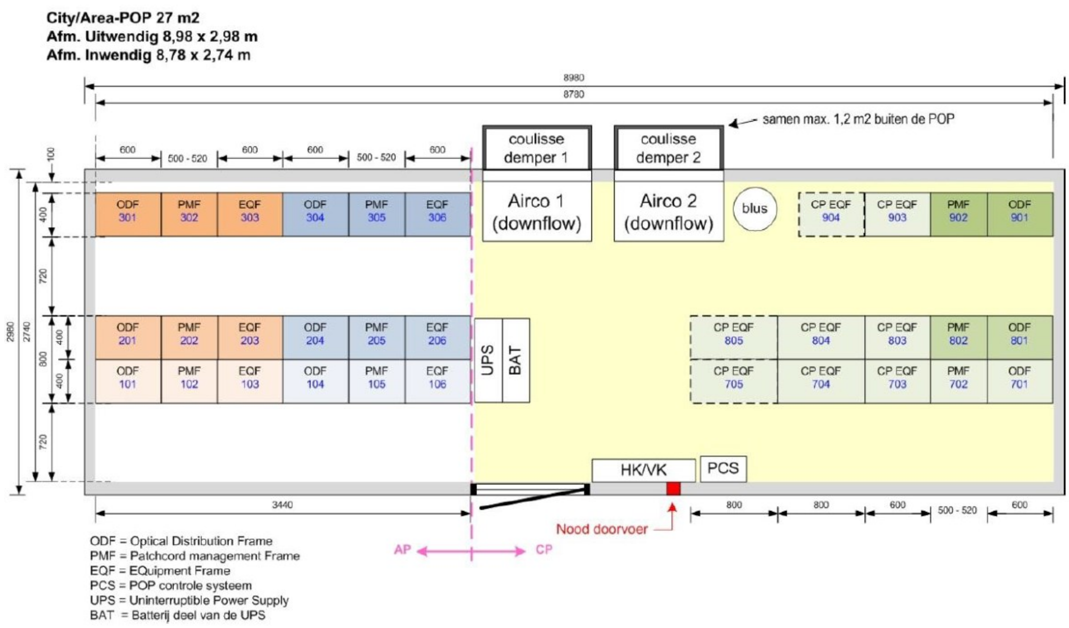
APPENDIXES

APPENDIX I: POP CP, AP & CP/AP LAYOUT

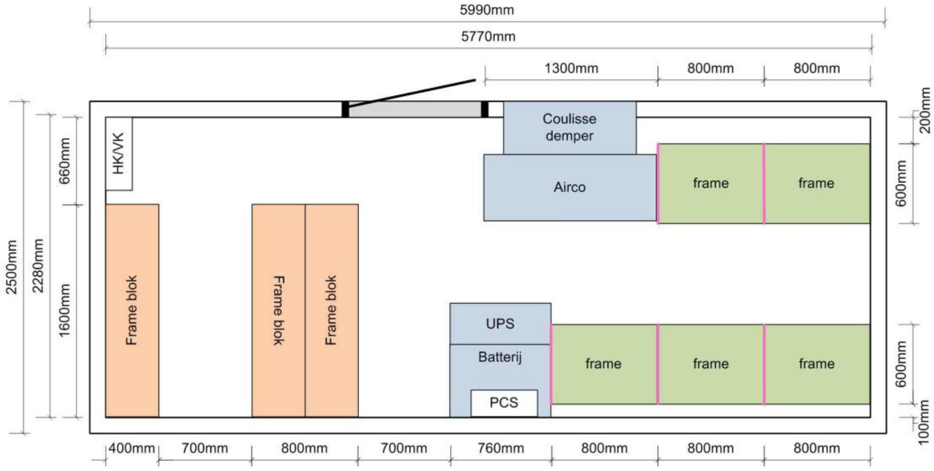
Model 1





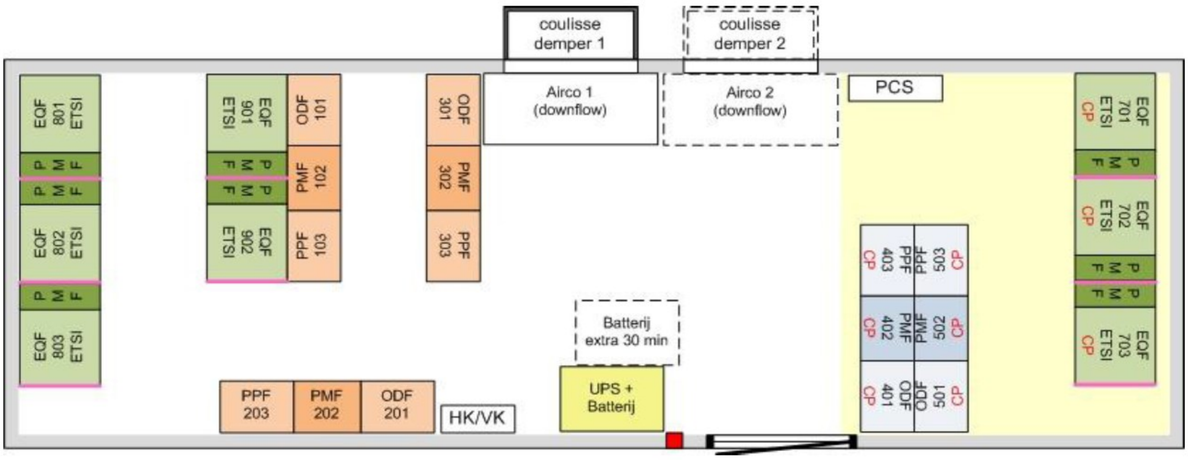
Model 2

AP model



Notes: Batterij=Battery

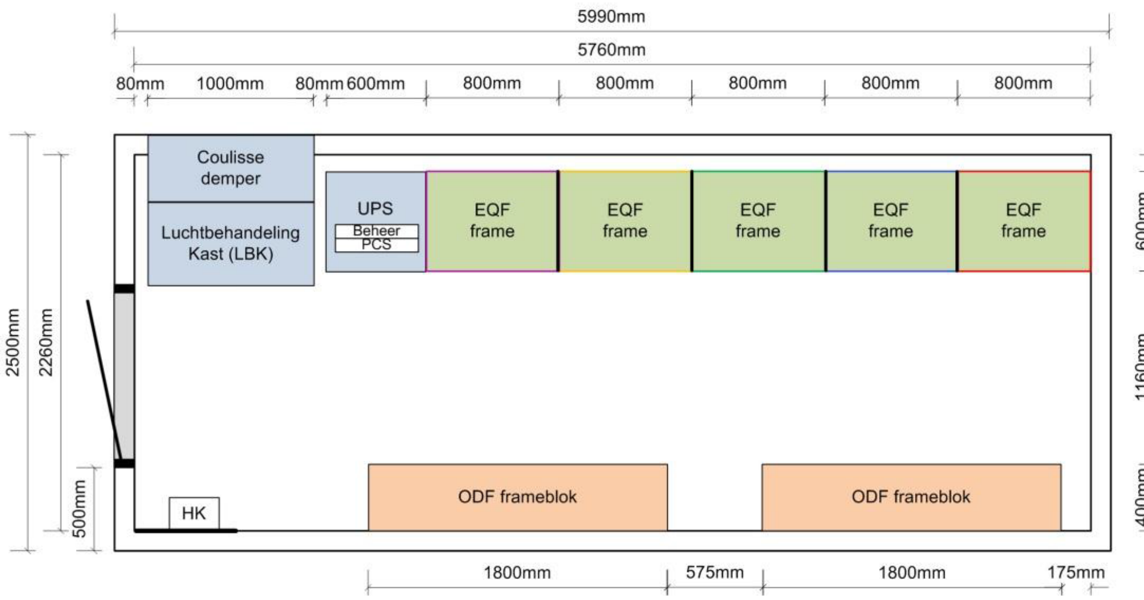
CP/AP model



Notes: Batterij=Battery

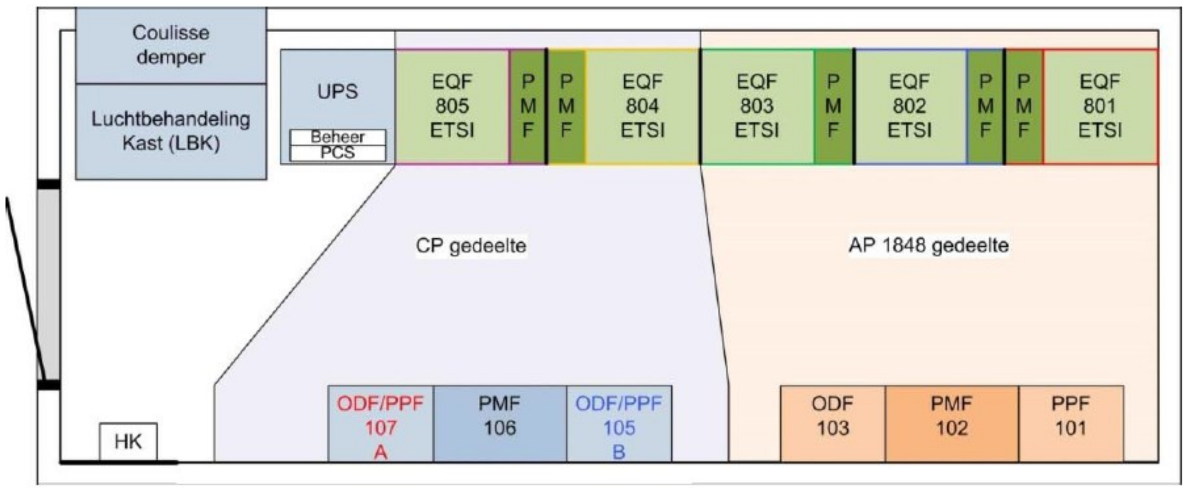
Model 3 & 3.1

AP model



Notes: Luchtbehandelingskast=HVAC equipment (airco(AC)/VKU(free cooling unit))

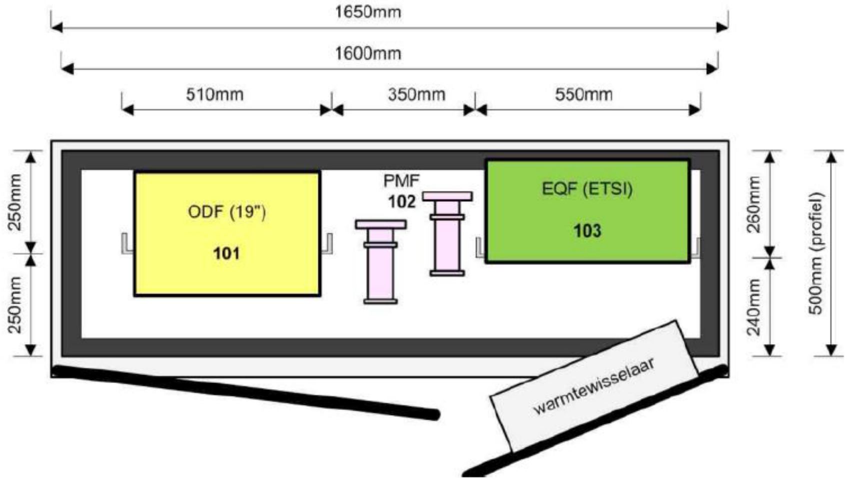
CP/AP model



Notes: Luchtbehandelingskast=HVAC equipment (airco(AC)/VKU(free cooling unit))

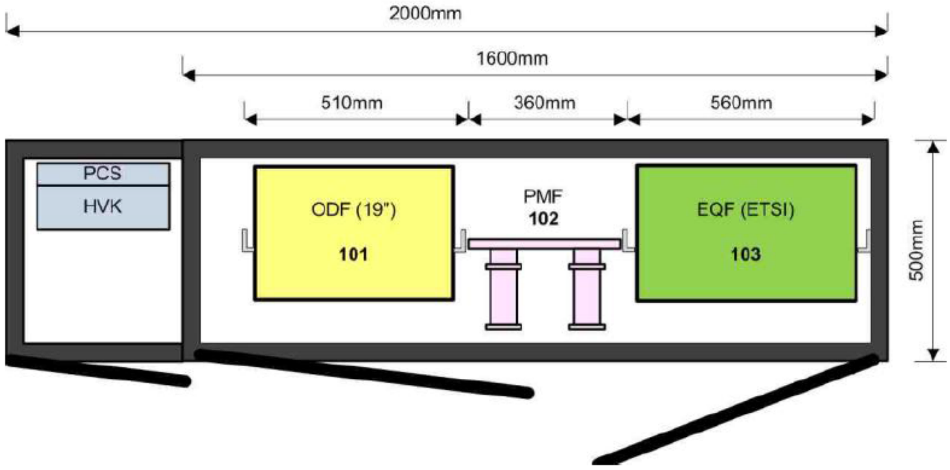
Mini PoP 1.3

Version 1 (2 doors)



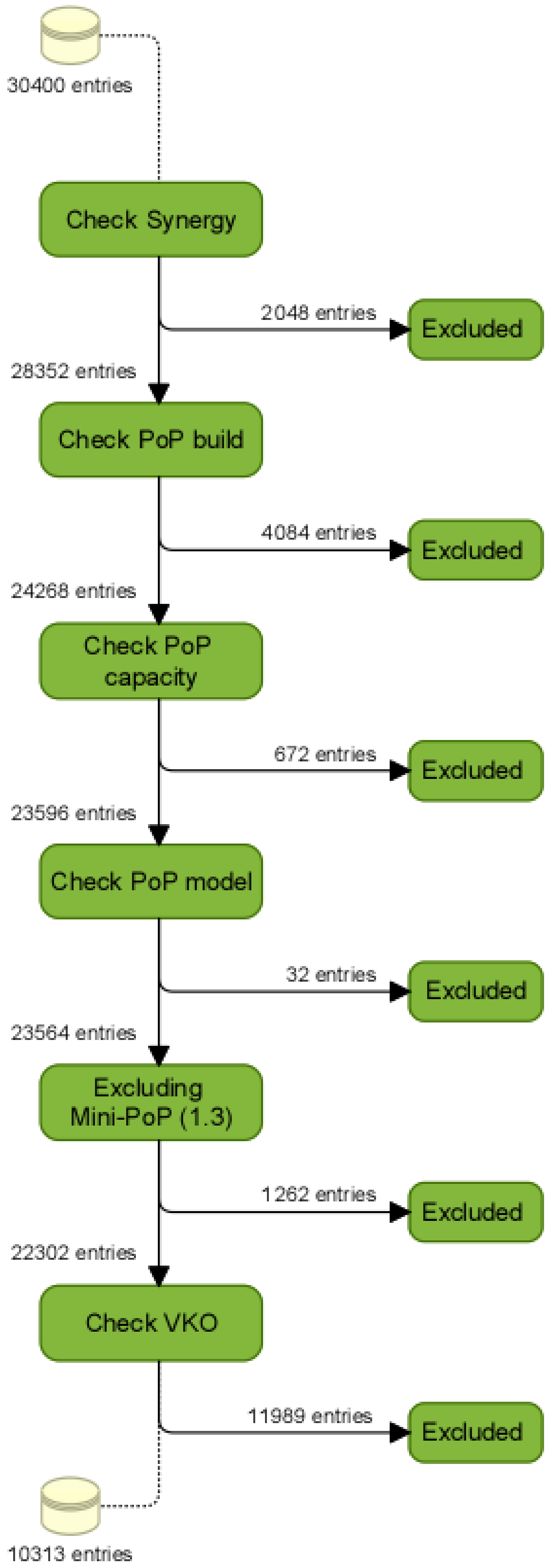
Notes: Warmtewisselaar=HVAC equipment (airco(AC)/VKU(free cooling unit))

Version 2 (3 doors)



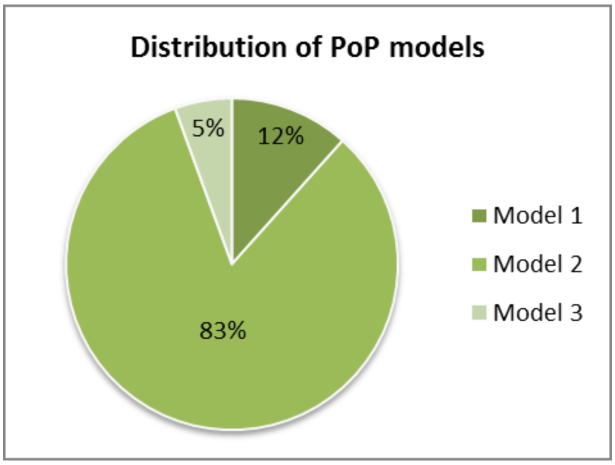
Notes: HVK=HVAC equipment (airco(AC)/VKU(free cooling unit))

APPENDIX II: SELECTION OF POP'S

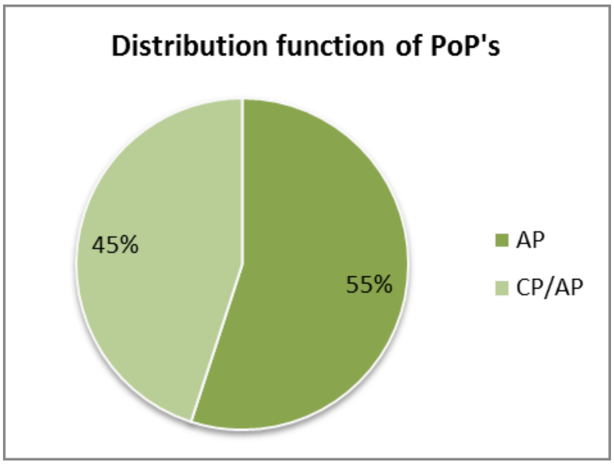


APPENDIX III: DESCRIPTIVE FIGURES

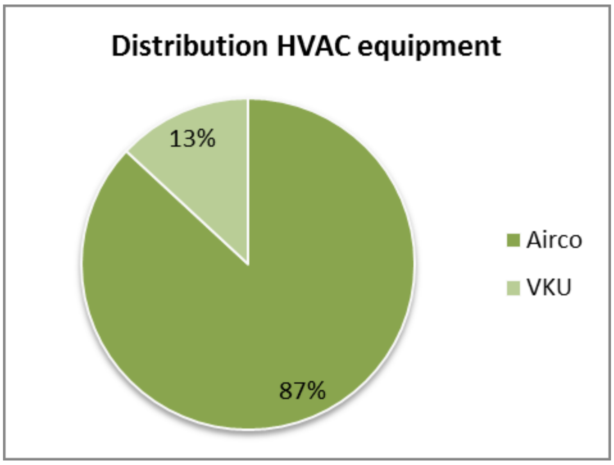
PoP model distribution



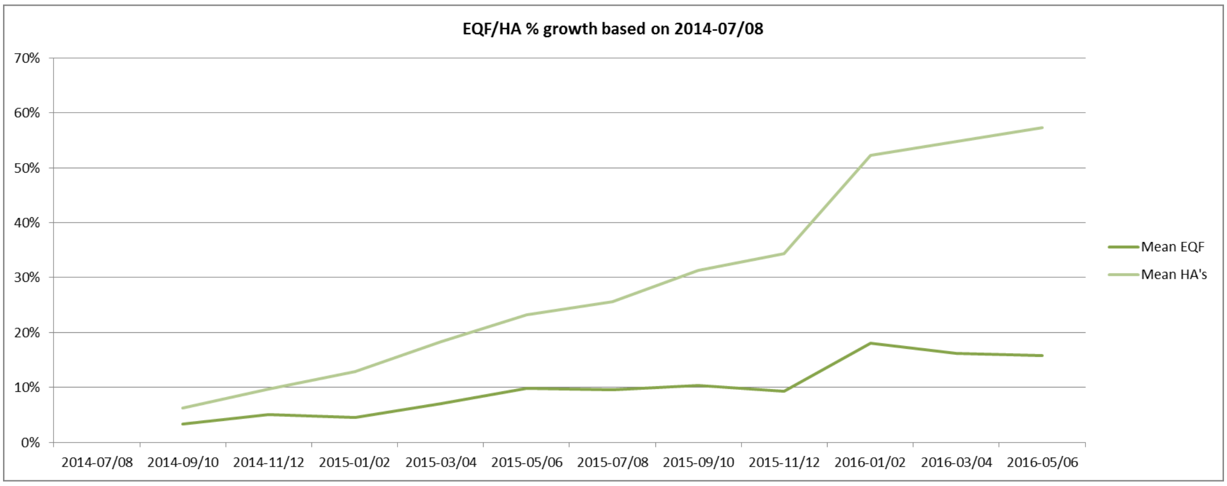
PoP function distribution



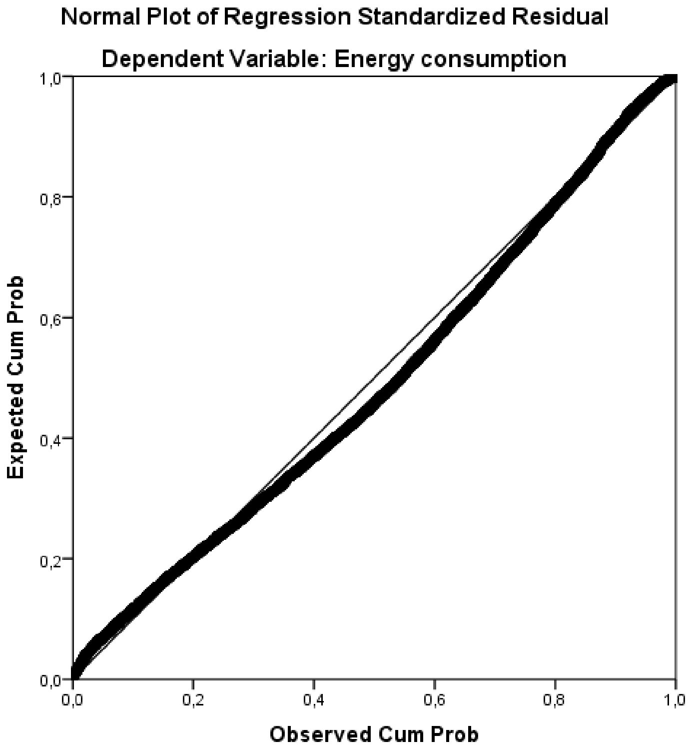
HVAC distribution

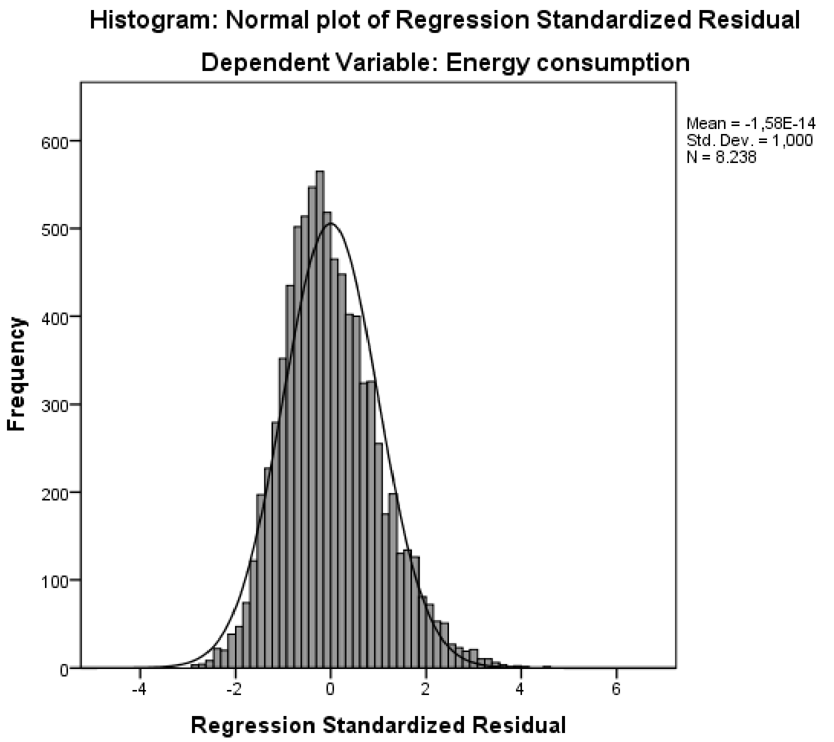


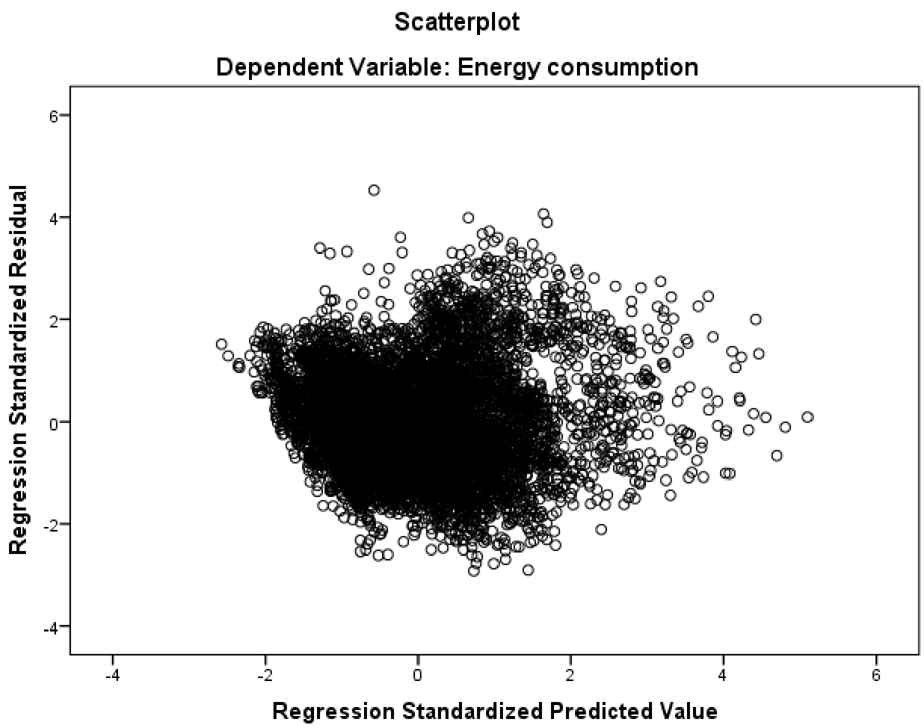
EQF & HA growth (% of value in 2014-07/08)



APPENDIX IV: ASSUMPTIONS OF MULTIPLE LINEAR REGRESSION







Tolerance & VIF scores

	Collinearity Statistics	
	Tolerance	VIF
Model 2	0.394	2.541
Model 3	0.491	2.038
Function	0.746	1.341
HA's	0.287	3.487
EQF	0.263	3.804
AO's	0.676	1.480
Temperature	0.995	1.005
HVAC	0.378	2.647

The columns shows the multicollinearity statistics for the independent variables. In the horizontal row Temperature is abbreviated to Temp for readability.