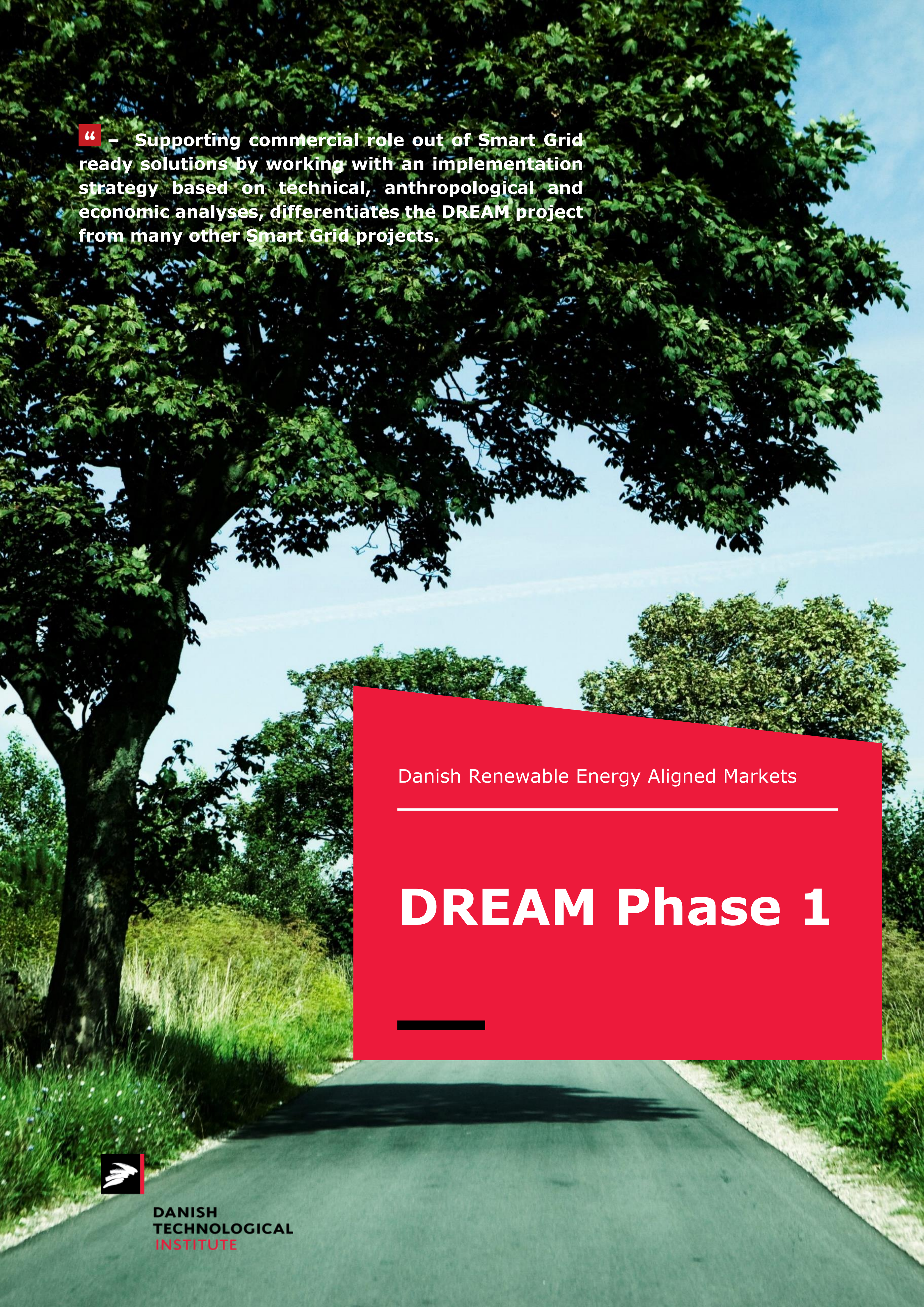

" – Supporting commercial role out of Smart Grid ready solutions by working with an implementation strategy based on technical, anthropological and economic analyses, differentiates the DREAM project from many other Smart Grid projects.

Danish Renewable Energy Aligned Markets

DREAM Phase 1

DANISH TECHNOLOGICAL INSTITUTE

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DREAM Phase 1

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1. Project details

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2. Project background and core challenge

The DREAM project – Danish Renewable Energy Aligned Markets – Phase 1, supported financially by ForskEL, has through the period from 2012 – 2014 gathered insights into the complex agenda of implementing flexibility in private homes, municipal buildings and industry. The focus was on areas outside collective heating systems like district heating or piped gas, were oil burners are still the dominant heat source.

The need for flexibility in sub urban grids has been investigated, and supported by anthropological, technical and economic analysis. An implementation strategy has been developed supporting a commercial role out of smart grid ready equipment and solutions such as heat pumps, electrical vehicles, solar cells and home automation. The objective of the first phase of the DREAM project has been to find commercially viable solutions for implementing smart grid ready equipment to entities with relative low energy consumption – like private houses, the public sector and small industries in areas where the only collective energy source available is electricity. To some extent, the flexibility in larger industries was investigated as well.

The background of the DREAM project is the Danish strategy for changing all electricity and heat consumption to renewable sources in 2035.[1] Most of the electricity will come from fluctuating renewable sources, which calls for much more flexible electric demand to absorb the renewable energy when available than nowadays. This change will increase the load on both transmission and distribution grids and require new resources and new solutions for balancing power and energy, as it is stated in the Danish 'Smart Grid in Denmark.[2] An electric grid enabling electric consumers to act flexible depending on certain conditions is in this context referred to as a "Smart Grid".

In relation to the transformation of the energy system the term "Smart Grid Ready" has been developed. Smart Grid Ready is a very general term used in different ways around the World to describe electric equipment that can be managed remotely and consequently support a Smart Grid. The DREAM project's view on Smart Grid Ready equipment is when an energy consuming- or energy producing component, such as a heat pump, has the ability to be remotely controlled via an interface that is in conformance with certain international communication standards and the chosen Danish implementation of those standards. Smart Grid Ready components offer the ability to regulate electric load down (or up where feasible) remotely controlled by an external aggregating facility. The primary purpose of a Smart Grid is to create demand side flexibility enabling:

- load reduction when electric power is scarce
- increase load when the renewable electric power generation is high
- reducing or increasing load at load or voltage problems in the grid

[1] See 'Danish climate policy plan' http://www.ens.dk/sites/ens.dk/files/policy/danish-climate-energy-policy/danishclimatepolicyplan_uk.pdf - visited 07.01.2015
[2] 'See Smart Grid in Denmark' http://www.energinet.dk/SiteCollectionDocuments/Danske%20dokumenter/El/Det%20intelligente%20elsystem%20-%20SmartGrid%20i%20Danmark%20rapport.pdf – visited 06.01.2015

An introduction of remotely controlled flexible loads may offer added value to many stakeholders as it can support some of the future needs of both TSO,[3] BRP[4], DSO,[5] aggregator, electricity brokers and the end user. The TSO can use the flexibility to stabilize the grid and for other purposes as well. The DSO will thus be able to transport more energy in the existing grid and can postpone reinforcing the local grid in some situations. The "Aggregator" is a new type of business offering the service to aggregate flexible components in thousands of homes and other entities optimizing the use of those components with respect to aspects as comfort, weather prognosis and energy exchange market. The Aggregator will buy flexibility from the end user, optimize the shopping for cheap electricity on the energy exchange market, and sell the accumulated flexibility to the TSO, BRP and DSO. The end user can consequently benefit from selling flexibility services as well as moving consumption to periods with low electricity cost. A major challenge is that the creation of flexibility adds cost, which cannot always be offset by savings.

However, the role out of Smart Grid equipment and solutions is in its initial phase also faced with a chicken and egg challenge. Commercially based aggregation requires a very large number of Smart grid Ready installations in private homes and a large part of the private homes will not invest in Smart grid Ready equipment without some incentive – be it monetary, legislative and ideological or something else. This is where the DREAM project has placed its primary focus.

Furthermore, for large energy consumers the matter of implementing flexible consumption is largely a pure matter of business and handling of risk. Analyses, in both the DREAM project[6] and other projects such as FlexEl,[7] indicate that the potential demand side flexibility in large industries is relevant but less than expected. To activate the majority of the potential demand side flexibility, it is consequently relevant also to focus on smaller industries, municipality buildings and private homes, as is the case with the DREAM project. These are typically supplied with electricity from the lower voltage (400V) electric distribution network. To support the roll out of Smart Grid solutions and the creation of flexibility in the low voltage grid, under commercial circumstances is THE core challenge for the DREAM projects.

Different equipment in private homes, municipality buildings and small industries do offer flexibility, but the potential differs a lot. For most equipment, the value added by connecting to a Smart Grid and aggregation service will not offset the cost. Consequently, DREAM focuses on three types of electrical equipment, characterized by the availability of certain flexibility and high continuous power meaning > 1kW for hours: Heat pumps, Electric Vehicles and Photovoltaics – solar cells.

[3] TSO: Transmission System Operator – Energinet.dk is the Danish TSO
[4] BRP: Balance Responsible Party
[5] DSO: Distribution System Operator
[6] Appendix 10 - Offentlige bygninger og industri
[7] http://www.teknologisk.dk/projekter/projekt-fleksibelt-elforbrug-hos-store-energiforbrugere/26974

Based on technological, financial and anthropological insights the primary goal of the DREAM project is to demonstrate how feasible business models can support a commercial implementation of Smart Grid Ready technologies and secure end user acceptance. The following report is the presentation of the findings and results from DREAM Phase 1.

3. Executive summary

DREAM Phase 1 has focused on creating the necessary analytic baseline for possible further DREAM phases and other R&D activities in this field. It has addressed challenges and possibilities involved by implementing flexibility, Smart Grid Ready equipment and aggregation on commercial terms. The DREAM Phase 1 final report compiles the results from several different surveys and analyses obtained or performed in the first phase of the DREAM project.

Even though DREAM Phase 1 is solely an analysis phase, the general lack of knowledge about the commercial feasibility of flexible technologies in different building types, has made the findings of this project relevant not only to later phases of DREAM, but also for the general Smart Grid agenda.

3.1 The socio-geographical profile

The DREAM Phase 1 geographical profile has evolved around areas outside the district heating or gas system, where the only collective heating source available is electricity. These areas are often rural in nature or characterized by small villages often with less than 1000 inhabitants. These are areas with a high degree of oil-fired boilers and other individualized heating systems and with at low population density. More specifically the project has worked within the distribution area of SE and with a primary, but not exclusive, focus within the Municipality of Billund.[8] The project results, though generated in a specific socio-geographical area, can be utilized in other similar areas of Denmark.

To support the ongoing electrification in Denmark it is important that as many heat pumps as possible will replace oil-fired burners. Estimations about the potential of heat pumps have been many and some have stated it as high as 300.000 heat pumps.[9] If the estimations come true it will likely create an open window for Smart Grid solutions as they reduce the need for reinforcement of the existing grid.

The project has originally focused on three overall consumer types: private, public and industrial consumers. The early intention of the project group was to find one single area, where all consumer types where represented, but since the combination of all consumer types and areas without collective heating systems could not be found within the Municipality of Billund, the analyses of consumer types were separated and the research was conducted in parallel.[10] During the project, focus on the private consumers increased. This was not only due to the difficulties in finding public buildings and industries with a relevant flexibility potential, but also due to already existing numbers of projects, which had focused on flexible energy use in industries. At the time when the DREAM project was initiated, very little was known about the private consumers and their incentives to do what they do,

[8] In Appendix 9 the discussion of area is elaborated.
[9] See 'Smart Grid in Denmark'
[10] For further documentation of the reasons behind this decision, see Appendix 9 and 10 on choice and area, industry and villages.

not to mention the business case of investing in heat pumps, electrical vehicles and solar cells and the ability of local grids to handle this amount of electrification.

The following is a short introduction of the analyses and research results.

3.2 Private consumers

As part of the category "private consumers", several analyses have been carried out:
1. A technical analysis on grid capacity[11] was done in a number of potential village areas. The project has carried out a more detailed analysis of the grids in each of the two chosen villages. The reason for the analysis was to understand how much control would be required, if large volumes of heat pumps, electrical vehicles and solar cells are deployed in these areas. It is a question of gaining insight into the actual grid down to the local substation, feeders and whether they may become overloaded with new load. When deploying heat pumps, photovoltaic and electrical vehicles in a high concentration, the monitoring of the distribution grids below 10-20 kV are often not sufficient to detect problems until it is too late.

As a scope of the DREAM project was to look at the consequences of new load in a smaller area, this degree of insight into the actual grids was needed. The capacity of an actual local grid is dependent on the historic development in that area and the development of consumption over time. After selection of one city, electro technical simulations for heat pumps were performed with details such as size of the houses, year of construction, and renovation and existing heat supply taken from the public BBR register. This data gave more knowledge of the individual house; and how big the heat pumps should be.

The analysis concludes that there is a potential for flexibility when working with a number of heat pumps in the area chosen for DREAM. The flexibility is established by varying the room temperature (store the heating in the buildings) or the utility water temperature to a certain comfort level. Since a large number of heat pumps connected to the system give a high load, the simulations show that flexibility does not have much influence on the 0,4 kV feeders, the available capacity before an overload is simply too small. On the other hand, massive use of flexible consumption (price signals or service for the balance or regulating power market) will cause problems for the 0.4 kV grid and make reinforcement necessary. The room for electrical vehicles in the grid has not been investigated since the load from the many heat pumps in the selected village is so high that the room for electric vehicles will be severely limited.

2. The project has carried out an ethnographic field research[12] in the chosen villages to figure out what motivates people in their daily lives and more specifically in their energy related behaviour. The results have showed that convincing end users to adapt to a specific solution takes much more than just showing a positive business model. Across the two villages, it became clear that a strong do-it-

[11] Appendix 1 – Grid Analysis
[12] Appendix 2 – Energi i landområder

yourself-culture, the social networks, interaction with neighbours, local business owners and others very much influence the individual decisions. The socio-material infrastructure – access to different materials and experience - in the local community thus influences decisions, meaning that what your neighbour does, you tend to do yourself. Furthermore, the analysis showed that biomass-fired boilers are for many currently more attractive not only because of equipment prices, but also due to the ease of access to materials – pellets, grains, wood etc. – which are often experienced as free or close to.

3. The project has created a dynamic business model for presenting the economic consequences of implementation of Smart Grid Ready heat pumps, electrical vehicles and solar cells in private homes.[13] This is an important tool for the further process, in subsequent phases of DREAM or under other circumstances, where the roll out of Smart Grid Equipment and aggregation will be supported. The question is whether there is a feasible business case and market for Smart Grid Ready equipment investments in private households. The answer is of course not black or white, but the preliminary use of the business model with data from some of the involved families, shows that the potential of investing in Smart Grid Ready equipment will vary from family to family depending on their energy consumption. Currently the model cannot incorporate the dynamic value of flexibility. Furthermore, the business model cannot stand alone in convincing private households to invest in Smart Grid Ready technologies. Economic challenges are not the only barrier when it comes to figuring out why so few heat pumps are installed in areas with primarily oil-fired boilers.

4. To identify possible equipment that can support the implementation strategy the project group have conducted an analysis[14] of the existing Smart Grid technology market, with the intention of compiling SG Ready products in a catalogue. Looking for commercially available and proven products experience has been collected from a number of relevant research projects.[15] Several projects have run demonstration of possible intelligent control of primarily heat pumps. The disappointing message consistent from all projects is that no commercially available standard equipment has yet been found to be Smart Grid Ready[16] for the Danish grid. If proprietary management and communication can be accepted several systems have demonstrated successful aggregation and VPP functionality with different suitable heat pumps. The best temporary Smart Grid Ready functionality may be the German Smart Grid system[17] where ripple signals can activate a basic functionality in PV systems and heat pumps with the German SG Ready certificate. Many modern PV inverters have functionalities built in that can offer local reactive compensation (VAR-compensation) and frequency stabilizing functions besides ordinary curtailment but a slightly more advanced communication is preferred for such advanced functions.

[13] Appendix 3 – Økonomisk model og finansieringsmetoder
[14] Appendix 4 – Smart Grid Ready equipment
[15] Appendix 4 – Smart Grid Ready equipment
[16] For project definition of Smart Grid Ready please refer to chapter "Project background and core challenge"
[17] For more information about the German Smart Grid Ready Label, see this website: http://www.waermepumpe.de/waermepumpe/qualitaetssicherung/sg-ready-label.html - visited 07.01.2015

5. The combined findings have resulted in an implementation strategy of how to deploy higher degree of heat pumps and other Smart Grid Ready equipment.[18] The implementation strategy contains a recommendation for creating a partnership in the given area, where local stakeholders and businesses join forces in getting the new equipment implemented. The strategy also contains a program for further education of relevant stakeholders such as energy auditors, plumbers and other professionals enabling them to be able to handle the roll out of Smart Grid equipment for the benefit of both energy system, local business and customer. Furthermore, the strategy contains a marketing plan and financial alternatives for overcoming some of the practical and financial obstacles in the deployment. The marketing plan will focus on creating an image of the heat pump, PV and EV as solid alternative to oil or biomass based solutions. It will also address the issues of the overall green transitions of the energy system focusing on renewables and electrification of energy consumption. The financial plan will focus on offering solid alternative solutions to private households who may not be able to finance the investments in an ordinary fashion. Both the marketing plan and the financial alternatives have local dynamics and community as part of their construction, where the local community plays a role in the individual household decision and where local community investments in one way or the other may be the best solution. Finally, the basic fundament was laid out for the definition of solid package solutions based on extended energy audit, idea catalogue, business case tool, financial schemes and contractual agreements.

3.3 Public consumers

By recommendation from Billund Municipality the category of "public consumer" has been centred on a study of an activity centre, Vorbasse Fritids Center (VFC) in the Municipality of Billund.[19] The purpose of the study was to identify accessible flexibility within the centre's complex energy system and assess the potential to shift from NGAS to electric heat pump. The study concludes that in the current system, there is almost no available flexibility potential, but some flexibility can be realized by installing Smart Grid Ready technologies such as a heat pump with a buffer system. The centre's current six gas-boilers are facing maintenance issues and the municipality has awaited the DREAM study before planning a refurbishment. The municipality is likely to choose a cheaper investment than the flexible heat pump based solution.

Early in the DREAM project, several other public buildings were taken into account, but it was also very clear that with a focus on flexibility, these buildings where not suitable. The primary energy consumption comes from light, ventilation and computer use with no flexibility. It may also be relevant to address the fact that the Municipality of Billund has either district heating or gas in large parts of its area. However, the geographical DREAM focus on public buildings was only within the Municipality of Billund and other parts of Denmark have consequently not been analysed yet.[20]

[18] Appendix 5 – Implementeringsstrategi
[19] Appendix 6 – Smart Grid potential analysis at Vorbasse Fritids Center
[20] Appendix 10 - Offentlige bygninger og industri

3.4 Industrial consumers

When DREAM started out in 2012, active projects had already worked with flexibility in industries and the results were the same – in general, it is almost impossible to find flexibility potential in large industries.[21] Due to the link to production process, changes in electricity consumption are unpopular and risks to high. The production process is more important than finding energy savings and flexibility.

The DREAM project concludes that strictly from a technical and theoretical point of view, flexibility in industries is possible, when installing of larger process heating or cooling buffers – where production of heat or cooling happens from electricity from e.g. a heat pump. This is though not the case in industries today, because in practice it is less complex just to produce heat or cooling when needed. Consequently, it is cheaper, because there is no investment cost in the maintenance of a buffer system and no loss of energy, which is inevitable when converting between energy sources.

Early on, the project met with Danish Crown, who showed an interest in the project objectives. With their building of a new slaughterhouse within SE's distributions area, the case was perfect for the DREAM project group. However, after a number of meetings the collaboration ended.[22]

Furthermore, it was discussed in the project group whether the focus should be directed towards smaller businesses with the same socio-geographical profile as the private households. Bigger industries can in many cases secure an acceptable business case when optimizing production system or facilities for higher flexibility due to their higher energy use. For smaller businesses, with lower energy consumption, the investment in flexibility and Smart Grid Ready equipment often has a very poor business case on its own but combined with energy savings and improved energy efficiency it could be a good business (e.g. switching from an old oil-fired boiler to a heat pump) – as with private households. After some debate, it was agreed that these types of businesses with low energy consumption should be viewed in the same manner as the private consumers.

Consequently, the distinction between small businesses, such as grocers, mechanics and small production companies and the private consumers in areas outside the district heating and gas system as two categories was dismissed.[23]

3.5 Aggregation and communication standards

As part of the DREAM project a couple of overall Smart Grid related analyses were conducted, analyses which were not specifically a part of either the three consumer categories, but relevant in an overall setting.

[21] Appendix 10 - Offentlige bygninger og industri
[22] Appendix 10 - Offentlige bygninger og industri
[23] Experiences from interviews in the villages supported this decision – the interviewees did not themselves differentiate between their energy system for private use and for the business. If the house had an oil-fired boiler so did the shop and vice versa.

An analysis of the role of the aggregator was conducted with input from leading industry stakeholders.[24] The question was raised on how the value chain for the aggregator looked like and how the development of an aggregator could be facilitated through the project. Thus, the analysis focused on one of the fundamental aspects of the DREAM project – how to organise and make money on flexibility. Furthermore, the analysis looked into the value, which an aggregator would create for the different stakeholders in the energy sector.

The "aggregator" can be described as the facility between the individual household, TSO, BRP DSO and the energy broking companies. The aggregator will aggregate Smart Grid Ready equipment in thousands of homes, and small industries, and strive to make the best value out of the available flexibility. The aggregation will take into consideration the actual available flexibility, the actual energy exchange market prices, weather forecast, DSO, BRP and TSO contracts and more information when remotely controlling the individual Smart Grid Ready equipment in his cloud.

While the analysis states some indications of the total value achievable from a single household with a heat pump, less is known about how the value should be distributed between stakeholders in the value chain being the consumer, the appliance supplier, the aggregator, the electricity dealer, the DSO, BRP and TSO.

An analysis on the topic of the communication needs for commercial power electronic products was carried out.[25] With the roll out of an intelligent grid or Smart Grid, the communication between entities will be fundament. With a lack of a common standard the communication between entities might become a bottleneck. This barrier is regulatory in nature; consumer oriented and addresses some specific technical aspects. The analysis addresses the need for an open holistic Smart Grid communication protocol – in the sense that it is not specialized for a particular kind of product, application or physical medium. It is pointed out that exactly because a Smart Grid deals with so many different products from a vast range of suppliers, the need for an open standard is so much higher. Prior to the Smart Grid agenda these products had no need to communicate at all.

DREAM is based on applying existing and proven technologies and solutions and has never intended to develop new technologies, equipment or even suggest a standardized communication protocol. With the analyses, DREAM highlights some of the main barriers of implementing Smart Grid and orchestrating flexibility in practice.

[24] Appendix 7 – Kommercielle aktører
[25] Appendix 8 – A Survey of Smart Grid Communication with focus on Embedded Systems

4. Project conclusions and perspectives

The DREAM projects has gathered many insightful findings in relation to working and talking about a Smart Grid on commercial terms. Further, the project has addressed some of the unknowns in regards to grid capacity, technology deployment, the business potential of buying new smart grid ready technologies, and end user behaviour. The project has also highlighted more in detail some of the experienced barriers of implementing Smart Grid equipment in areas outside the district heat and gas system and tried to turn these barriers into something useful.

Beneath, is a summary of the main conclusion in the DREAM project and how they will be part of a continuous discussion on Smart Grid in areas outside the district heating and gas system.

4.1 The grid

Results from the DREAM project have shown that the grids may be challenged with a severe penetration of heat pumps, electrical vehicles and solar cells and that the DSO may experience voltage problems or overload in some areas. These findings raise the question of the level of control, and whether the management of flexibility only will be realistic in the 10-20 kV grid since the problems with voltage and overload can be so big that only reinforcement is a solution on the 0,4 kV grid. The networks company will probably not use flexibility to mitigate issues in the 0.4 kV grids although the consumption from heat pumps is flexible. A 0.4 kV feeder covers a limited number of consumers. If the load or voltage on a 0.4 kV feeder must be controlled using household consumption, it requires that the flexibility is always available and in sufficient quantities. These two conditions will probably not always be met on a 0.4 kV feeder, except if you compromise the consumers comfort and switch off appliances.

Lots of heat pumps in 0.4 kV grids give a high load, much higher than the "evening peak" which therefore disappears. This means that request of flexibility, to smooth the "evening peak" and better utilization of the cable capacity, is not relevant when installing lots of heat pumps on 0,4 kV grids. Use of flexibility to use low prices or services for the system (balance or regulating power market) can therefore make reinforcement necessary in the 0.4 kV grid.

4.2 Private consumers

The challenges of implementing new Smart Grid Ready technologies, primarily heat pumps, and electrical vehicles in areas outside district heating and gas network should be understood as more than just a question of money. The everyday practice in these areas are based on a culture of doing things yourself – renovation of the house, fixing the car, gathering firewood etc. – and people here are not relying on public infrastructure to get things done. The different biomass boilers are popular, not only because of the lower up front price compared to the heat pump, but because of access to wood and biomass through the local community. Consequently, these Smart Grid Ready technologies are neither developed nor being marketed to fit the costumer types in these areas. Consequently, many of the Smart Grid Ready technologies are not suitable to the everyday practice in rural areas. The conclusion is that people here find value and freedom in being able to repair and handle their equipment themselves. However, this is not the only barrier. Lack of local experience is another barrier. The heat pump actually has a high success rate in one of the investigated villages – this tells us that these mentioned barriers are only challenging, when there is no local experience with the technology. The local community, the help and guidance you receive in the streets and over the garden fence are very important factors in your individual decision in relation to energy supply.

These insights can help to better understand why some technologies have not penetrated the market as fast as it may have been expected. Furthermore, it will also help to better direct and market Smart Grid Ready technologies and the heat pump especially to the areas outside the district heating and gas system.

The DREAM project concludes that even though there are many barriers for implementing Smart Grid Ready technologies, knowing these barriers will help the implementation and transformation process from primarily oil-fired boilers to heat pumps. The idea of consuming energy more efficiently and outside the peak load periods will not be problematic for many of the consumers in these areas – the whole idea of energy efficiency goes hand in hand with their anti-waste practice. The main barrier is therefore getting them to choose the heat pump in the first place and not renewing the oil-fired boiler or replacing it with biomass-based technologies.

4.3 The business model and alternative financing

The dynamic business model developed in the project will in the future make the financial consequences of investing in a heat pump combined with other energy related decisions more transparent. Eventually, the business model will be able to illustrate the financial consequence of flexibility at end user level and help break down some of the financial barriers of investing large sums of money in Smart Grid technologies.

The business model will be a dynamic tool for the aggregator, Smart Grid provider or other energy related personnel to use when in contact with the private households. During the research, the project has met many different households, which have chosen other solutions than the heat pump, not because they could not finance it, but because other aspects are part of their decision. This also means that the business model can in most cases not stand alone, but should be part of a larger implementation strategy, where communicational aspects are delicately thought about.

Furthermore, the DREAM project concludes a need for both alternative financial and technical concepts to accommodate the barriers of implementation of Smart Grid technologies, which are happening nowadays.

4.4 The existing technologies

Standardized Smart Grid devices has not yet emerged due to lack of suitable standards for embedded control in consumer's devices. Several R&D projects have demonstrated aggregation based on proprietary solutions and the overall conclusion is that Smart Grid is relevant and has potential for demand side flexibility. None of the Smart Grid research projects has yet identified any device that could claim to be Smart Grid Ready in a Danish context. In line with several R&D projects, DREAM recommend development of an open Smart Grid standard protocol. The Smart Grid Open project intended to develop a test method for Smart Grid ready devices have the same finding.

The immaturity of the Smart Grid raises the question whether the DREAM agenda is relevant under the current market conditions. The technology developers do not have the financial incentive to integrate 'Smart Grid readiness' into their equipment's, but at the same time, the ability to manage and control a number of technologies cannot be carried out, thus making it difficult to show the potential and the circle continuous. This is of cause not only a question of inefficiency of the technologies; it is also a flaw or a demand, which is not being met. The immaturity of the Smart Grid - readiness of current technologies is a result of many different things, but primarily a result of no request of flexibility.

So what is at stake here? The DREAM project concludes that in order to talk about a Smart Grid, there needs to be an implementation and thus instrumentation of technologies, which under the current market conditions are able to be remotely controlled. These technologies and the impact they will have on the grid, will pave the way for the next generation and if the need for flexibility has been proved in practice, the next generation of technologies may very well be more Smart Grid Ready than the current one. Since the DSOs have not yet experienced serious overload or voltage problems due to high power load there is only little interest in developing a Smart Grid control structure for power flexibility. Until it is possible to pay for power by the hour there will be no pull for Smart Grid from consumers. Some aggregators seriously look into possible energy trading on spot energy market or regulation energy market with Virtual Power Plants, VPP, based on many parallel units. Due to the lack of a common accepted Smart Grid standard all the way to the equipment all VPP currently use proprietary command methods. Demonstration of deployment seems essential to create both a push and create a market pull for Smart Grid Ready standard devices.

4.5 The aggregator

The Smart Grid agenda is still very much a question of the chicken and the egg and the DREAM findings support that. Many have a mental picture of an aggregator as a party that can start and stop equipment e.g. a heat pump. In the real world, an aggregator may consist of two or more business units. A technical aggregator that can handle the communication and command to the individual electric equipment e.g. a heat pump. A trading aggregator, which can trade on the electricity and regulation markets using the technical aggregator to compile information and relay commands. Additional could be a third aggregating business unit that sells energy to the consumer e.g. in the form of heat from a heat pump. The combinational range of aggregating possibilities are large and a single model would be much too simple for future use.

It is also important to underline that the findings of WP4 clearly shows, that all the market players expect to see aggregators functioning on market terms within a number of years. However it remains unclear who is going to organize and develop the aggregator role.

The conclusion on the topic of aggregation reveals some missing insights into the division of value generated by an aggregator. The question of the value, which an aggregator can provide and the question of how to divide this value between the different stakeholders in the energy systems, cannot be answered at this stage due to the premature market development.

5. Recommendations

The following is a list of different recommendations that evolved from the DREAM Phase 1 work.

1. A 0.4 kV feeder covers a limited number of consumers. If the load or voltage on a 0.4 kV feeder must be controlled using household consumption, it requires that the flexibility is always available and in sufficient quantities. These two conditions will probably not always be met on a 0.4 kV feeder, except if you compromise the consumers comfort and switch off appliances. Flexibility at household must be developed for demand from the 10-60 kV grid, the TSO and BRP. The network companies will probably not use flexibility to mitigate issues in the 0.4 kV grids.
2. Credible grid load monitoring in 10-20 kV feeder can be obtained from very few measuring points thus reducing cost of future detailed load monitoring in the low voltage grid. Network companies may include this in their strategic planning.
3. The local community in many rural areas play a direct or indirect part in the individual household's decisions, therefore, Smart Grid deployment initiatives may be strengthened by addressing the community as a whole.
4. Massive demonstration projects are needed to build up a critical mass of successful Smart Grid solutions to serve as "real people reference" for "real people", as well as commercial reference for potential financing partners and technical providers.
5. To lower cost of installed flexibility it is important to introduce the flexibility thinking and flexibility elements as early as possible when starting new building- and renovation projects both at household, municipality buildings and industry. A massive information campaign on how to plan for flexibility must be developed and deployed as soon as possible.
6. Use of open international standards is a necessity between the stakeholders in the flexibility market. International standards reduces the barriers for all stakeholders on the marked, but also for the component suppliers, that mainly are developing products according to international standards.
7. Massive demonstration projects are needed to create a market pull for Smart Grid ready components and solutions, which can lead to a commercial market. Operable standards must be found and smart grid ready equipment certified accordingly.
8. Roll-out of Smart Grid solutions can benefit from a holistic approach and package solutions taking into consideration both technical, economic and social matters.
9. Massive demonstration projects are needed to evaluate the DREAM tools and business concepts.

DREAM Phase 1 results and findings are highly relevant to support a future market for Smart Grid ready solutions and devices. It is important to demonstrate and validate the business model with its tools and implementation strategy.

6. Project results

DREAM Phase 1 is structured around a range of analyses – investigating aspects of the Smart Grid agenda, which the energy sector has not to this day highlighted. The project results are thus a range of individual existing reports and an overall perspective on the commercial feasibility of Smart Grid technologies in primarily residential areas.

The following chapter is organized into three sections: private consumers, public consumers and a section about the overall analyses on the topic of Smart Grid.

6.1 Private consumers

The private consumers have been given much attention in the DREAM project Phase 1. The primary reason for this is the lack of heat pump penetration in areas outside the district gas and heating system and an insufficient knowledge about the capacity of local grids when reaching a higher part of electricity consumption in the future energy system.

Five different project tasks was conducted to bring insight into the barriers and possibilities of implementing Smart Grid Ready technologies in private households in areas outside the district gas- and heating system:

1: The Project has carried out an analysis in relation to the local grids – grid capacity and levels of measurement points for optimized grid management[26].

2: The project carried out an anthropological analysis with ethnographic field research in two different villages on the topic of what motivates people in their daily energy related activities and dissections.[27]

3: The project has looked into the existing market for Smart Grid ready equipment to identify potential equipment for use in later phases of DREAM as well as by other stakeholders.[28]

4: The project has created a dynamic business model to show households the economic incentives of different energy related decisions[29] and 5: The project have developed an implementation strategy for roll out of Smart Grid Ready equipment.[30]

Two suitable villages were chosen to become research areas for the project group. Both cities are situated within the distribution area of SE. In both villages, the citizens primarily own oil-fired boilers, some have biomass-boilers and few have heat pumps or electric heating. The villages were chosen

[26] Appendix 1 - DREAM WP1a Grid analysis
[27] Appendix 2 - Energi i Landområder
[28] Appendix 4 - Smart Grid Ready equipment
[29] Appendix 3 - Økonomisk model og finansieringsmetoder
[30] Appendix 5 - Implementeringsstrategi

out of many, but represent in many ways other villages and areas without district heating or gas system elsewhere in Denmark.

6.1.1 Grid analysis

The purpose of the grid analysis[31] in DREAM was to investigate whether the local grids were suitable for the level of electrification, which would be the result of a massive implementation of heat pumps, electrical vehicles and solar cells. This analysis looked into the future grid scenario of new production and consumption units and addressed the question of whether reinforcements would become relevant.

The grid analysis was used to document whether one village was more suitable for a later demonstration than the other was and to calculate the grid impact from heat pumps, electrical vehicles and solar cells. With the investigation, the DREAM project wished to gain insights into the actual typical capacity, possibilities and challenges of the electricity network. It is of crucial importance in the Smart Grid agenda to have a detailed picture of the current network. When a grid is more likely to be reinforced, the need for flexibility becomes less relevant for the DSO. Even though the DREAM grid analysis is an investigation of a specific grid in a narrow local area, the findings are relevant for Smart Grid discussions in other parts of Denmark too.

The grid analysis was divided into five parts:

- Electro technical screening for 13 cities located in a selected area
- Modelling of the distribution network in three cities
- Overall simulation of new consumption in two cities
- Detailed network calculation of the impact from heat pumps in one city
- Analysis of measurements in a 15 kV feeders for Smart Grid

Electro technical screening

An electro technical screening of 13 villages in the area where the Municipality of Billund overlap with the SE distribution area, based on data quality and assessments of the low and medium voltage network gave an overall assessment of the distribution network's suitability for deployment of heat pumps, electrical vehicles and solar cells. Together with the 'qualitative' area screening conducted in the anthropological research the results were applied to find the most suitable cities for the more detailed analyses later on in the project.

The project wanted to find an area and a village, where a later demonstration phase would not overload the grids, but also an area, where the deployment of heat pumps, electrical vehicles and solar cells would challenge the grid to an extent where management of flexible consumption would

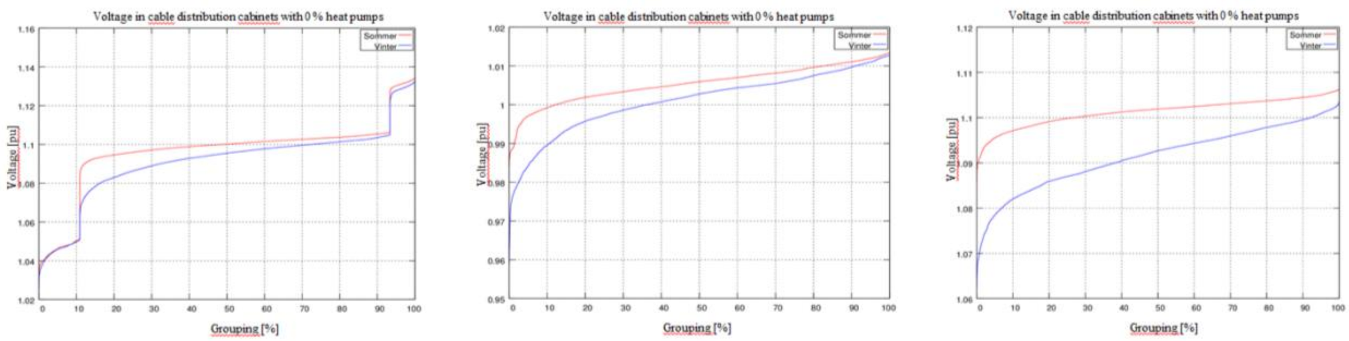
[31] Appendix 1 - Grid analysis

be relevant. In the end the project ended up with three potential villages, which all fitted the vast criteria of suitable size, supply source and suitable grid capacity.

Modelling of the distribution network and new consumption

Three small villages and a small city were selected for further electro technical studies. The distribution network was modelled in PowerFactory and the load and voltage quality of the existing consumption was calculated.

The calculations showed that the voltage variation for all three cities is the determining factor for the amount of new consumption that can be deployed in the villages. All three cities could be used in a later demonstration phase of the DREAM project, but two cities have the smallest voltage variation with the existing consumption and would be most appropriate for establishing new consumption and production like heat pumps, electric vehicle and solar cells respectively.



Graphs showing the voltage in cable distribution cabinets in three cities
(red= summer; blue=winter)

Overall simulation of new consumption in two cities

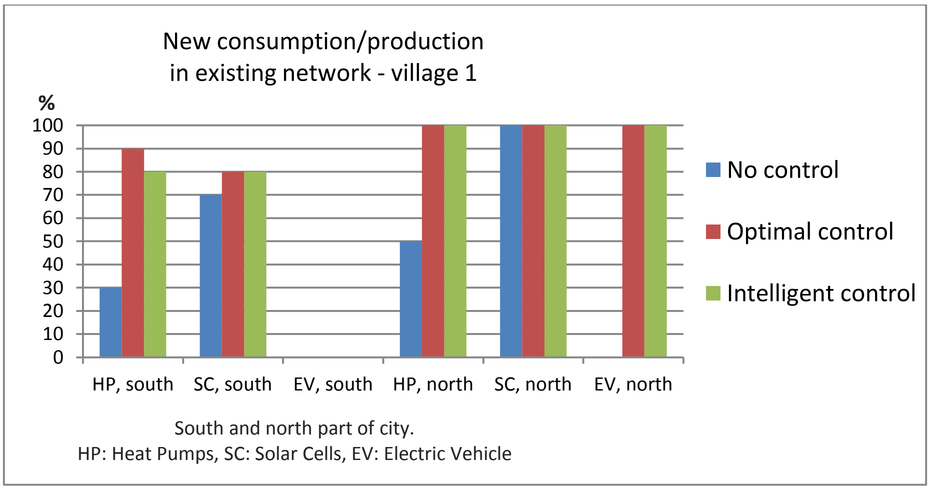
In the next part of the grid analysis, the consumption and production from heat pumps, electrical vehicles and solar cells were modelled and simulated in PowerFactory for two out of the three cities. The simulations were performed in four steps:

1. Simulation with dimensioned load and right voltage at the low voltage side of the secondary substation.
2. Simulation with no control of consumption
3. Simulation of Smart Grid with optimal (unrealistic) control of consumption
4. Simulation of Smart Grid with intelligent (realistic) control of consumption

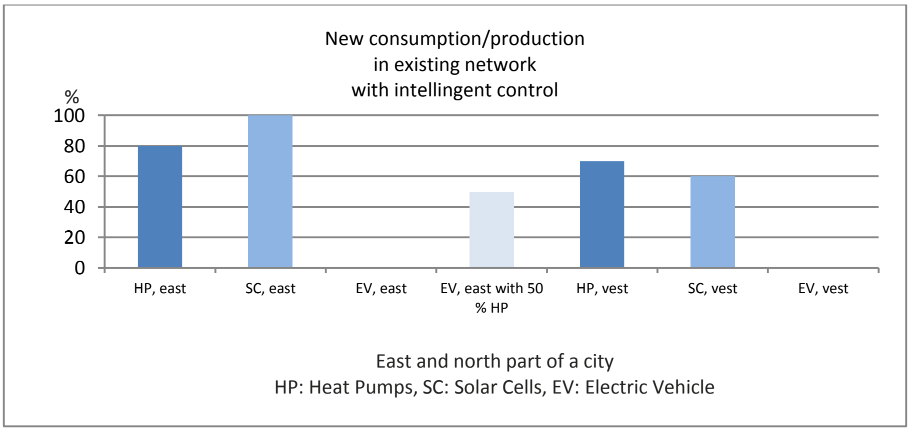
The simulations showed how many heat pumps and electrical vehicles that could be deployed in the existing network in different control situations. Simulation with no control is a scenario without any management and control of flexible consumption and production – in other words, no Smart Grid.

The simulation with optimal control was viewed as unrealistic, as the amount of knowledge and details about the consumption would be too difficult to obtain in a cost-effective manner. The fourth simulation, though, was named 'intelligent control of consumption' and describes a scenario, where exactly the needed amount of knowledge about the grids and consumption is known in order to control the flexibility to the benefit of all stakeholders involved, both grid operator, aggregator and the private households themselves.

The results showed that from an electro technical point of view none of the two cities was more suitable for demonstration than the other. The first of the two following graphs illustrates the three different control scenarios in one of the villages. The second illustrates the level of technology deployment with intelligent control of consumption.



Graph showing how many houses that can have heat pumps, solar cells and electrical vehicles before reinforcement in the electrical network will be necessary.



Graph showing how many houses that can have heat pumps, solar cells and electrical vehicles before reinforcement in the electrical network will be necessary.

Detailed network calculation of the impact from heat pumps

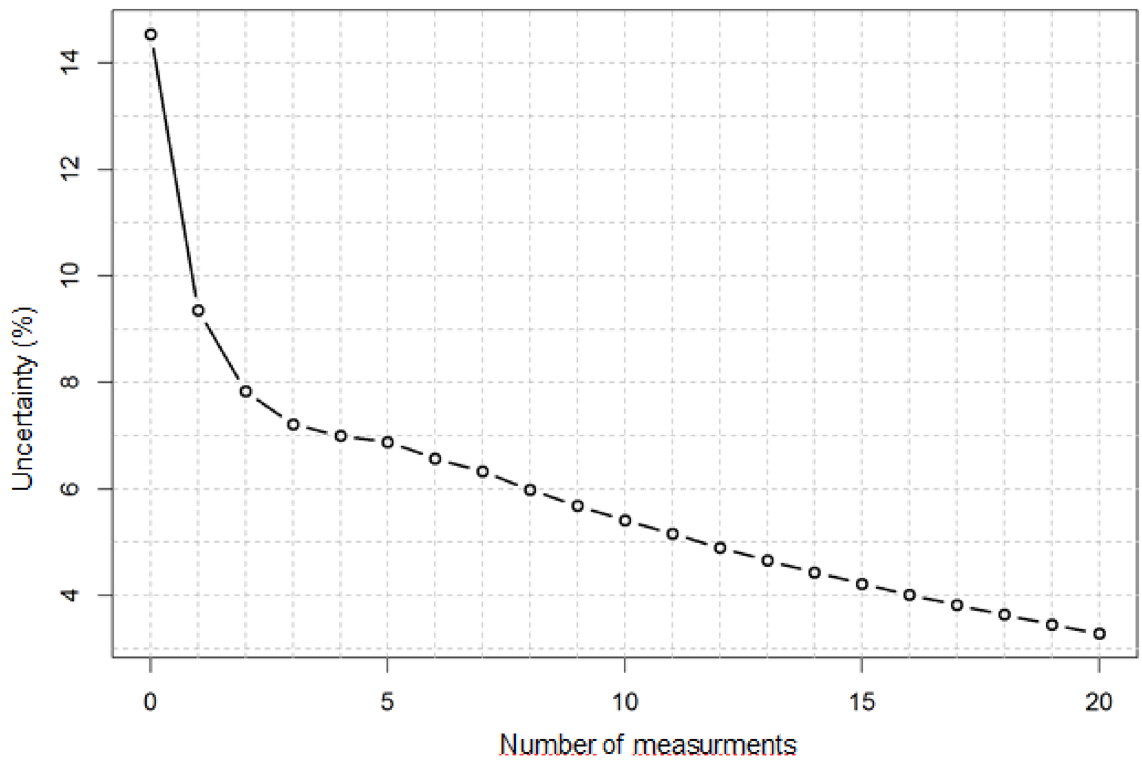
After selection of one city, the electro technical simulations for heat pumps were performed again, this time with details such as size of the houses, year of construction, and renovation and existing heat supply taken from the public BBR register. This data gave more knowledge of the individual house; which were suitable for heat pumps and how big the heat pumps should be.

Analysis of measurements in a 15 kV feeder for Smart Grid

The last step of the grid analysis is the investigation on measurement points. Establishment and control of consumption and production from heat pumps, electrical vehicles and solar cells thus requires measurement in the distribution network. The sufficient numbers of measurements in order to monitor the distribution network were investigated. Data from electricity meters and a 15 kV feeder was analysed for strategically locating of the sufficient number of measurement devices in the network.

The analysis was conducted in two main steps: 1) a power system state estimation; to obtain an estimation of the electric properties of the feeder (nodal voltage, injected power and branch power) for the different number and meter location on the feeder, 2) uncertainty assessment; estimated/measured states are combined into an overall score criterion for the state uncertainties. This procedure allows the uncertainties to be represented as a function in relation to the number of installed measurement devices, which ideally decreases with increasing number of installations. The results of the study verify this uncertainty reduction and, with the nodal voltage and the branch power applied to obtain the relevant score criterion, suggest the intermediate nodes for the optimal meter locations. For this particular feeder the first installation is located according to the majority of the voltage variations in the end nodes – in a branch node downstream covering almost all the end nodes - whereas subsequent installation are evenly allocated along the feeder, towards the transformer, according to the distribution of the load in the nodes.

The conclusion is that for this particular feeder, which includes 20 stations, only three installations are required to obtain the sufficient information about the feeder’s condition.



Graph showing the uncertainty by number of measurement

Conclusion on the grid analyses

The selected city:

The calculations contain estimates, general parameters, and data. It is uncertain if the data from the BBR-register of renovation year, heat supply etc. is updated. Furthermore, the number of residents and the consumption of heat and utility of water are unknown. It is estimated, however, that the model can be used to assess the impacts of the 0.4 kV grid by establishing a lot of heat pumps. The model provides an overall picture of what the simultaneity of consumption will be with a large number of heat pumps connected to the same 0,4 kV transformer.

The simulations have been made for a 3-phase balance grid. In reality, the 3 phases are unbalanced with different loads, which make problems with overload and voltage worse.

The detailed network calculations show that in the northern part of the selected city installation of heat pumps in all households (without existing electricity heating) will exceed the max. load in the transformer. Theoretic flexibility could solve the problem, if the heat pumps act like the model in the simulations. However, in practise replacing the transformer will probably be necessary and problems with low voltage will occur in situations with high load. Replacing a transformer is not a problem due to the fact, that it can be use another place in the grid. Reinforcement of cables is very expensive, the old cable cannot be used and the expenses to excavation are high.

There will only be room for a few electric vehicles in the north and only 66 % solar cells. 100 % if the transformer is replaced.

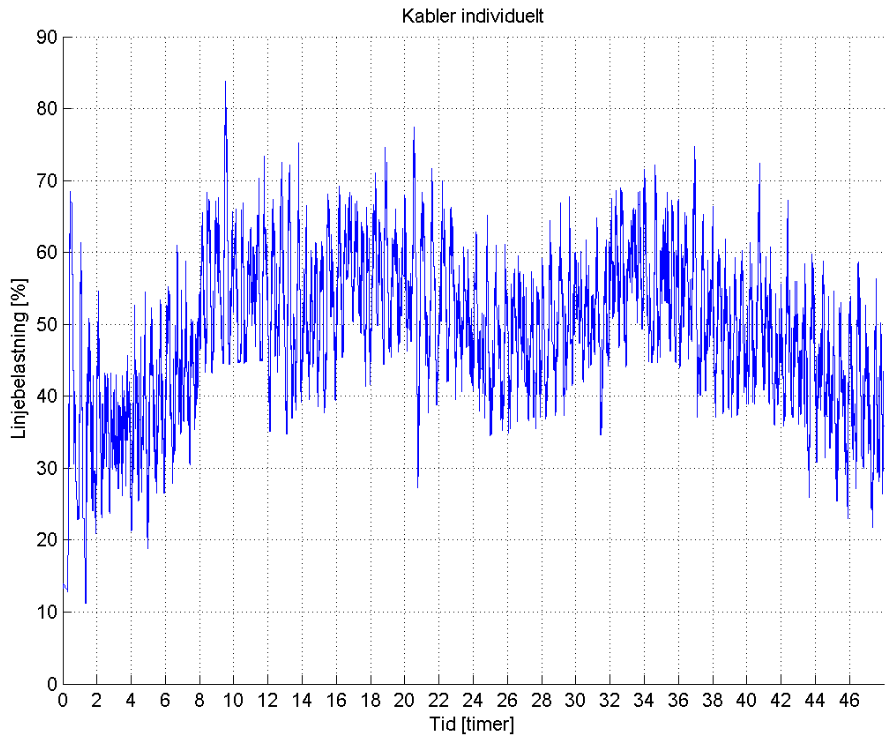


Figure 1 The maximum load in all cables in the northern part of the city in all the 0.4 kV feeders

In the southern part of the selected city, a few cables need to be reinforced if heat pumps are established in all households due to high load and voltage problems. The number of electric vehicles to be connected to the grid will be limited unless many of the cables are reinforced. About 65 % solar cells, perhaps a little bit more, can be connected by replacing a few cables. If flexibility is used this can cause overload problems for the transformer and require replacement.

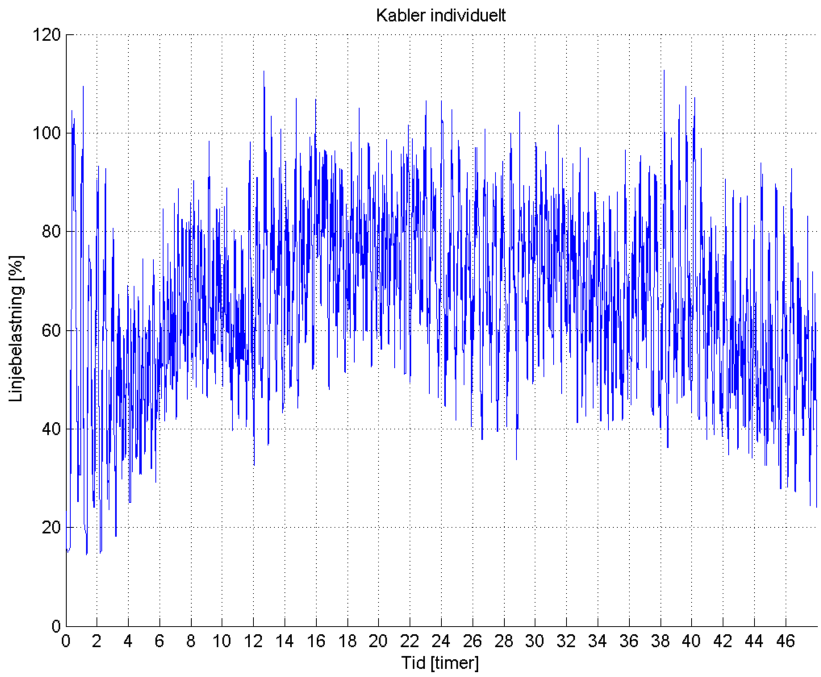


Figure 2 The maximum load in all the cables in the southern part of the city

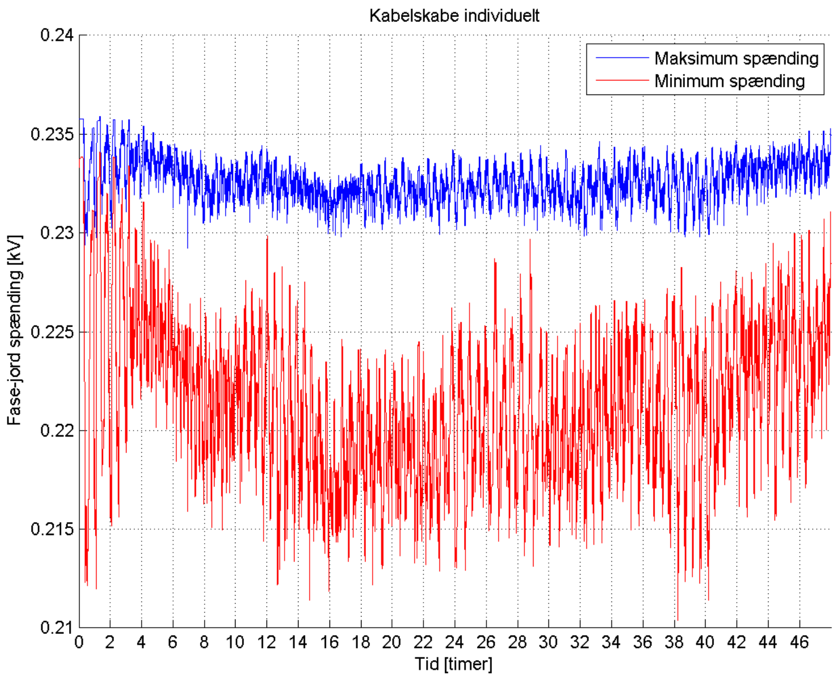


Figure 3 The maximum and minimum voltages in the southern part of the city

The room for electrical vehicles in the grid has not been investigated since the load from the many heat pumps is so high that the room for electric vehicles will be severely limited.

There is potential for flexibility in the heating system. You can vary the room temperature (store the heating in the buildings) or the utility water temperature to a certain comfort level. This kind of flexibility can spread the load, but only for 3-5 hours, after which a severe kick-back for heating will come, significantly increasing the load from the heat pumps while the temperature recovers. Since a large number of heat pumps connected to the system give a high load, the simulations show that flexibility does not have much influence on the 0,4 kV feeders, the available capacity before an overload is simply too small. On the other hand, massive use of flexible consumption (price signals or service for the balance or regulating power market) will cause problems for the 0.4 kV grid and make reinforcement necessary.

General:
Lots of heat pumps in 0.4 kV grids give a high load, much higher than the "evening peak" which therefore disappears. The "evening peak" will no longer necessarily give the highest load. This means that request of flexibility, to smooth the "evening peak" and better utilization of the cable capacity, is not relevant when installing lots of heat pumps on 0,4 kV grids.

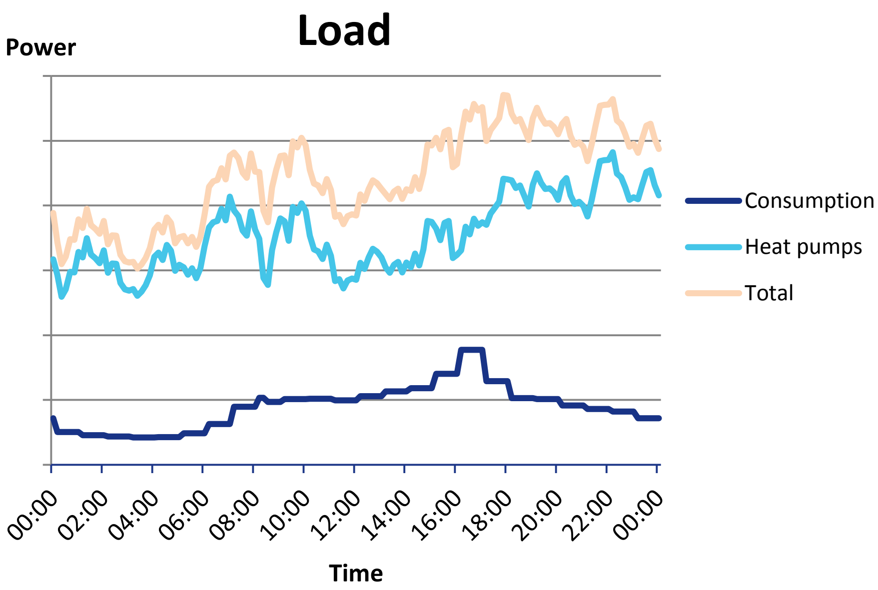


Figure 4 Illustration of consumption and load from heat pumps

In areas that are not designed for electric heating, lots of heat pumps can produce such a high load that reinforcement will be necessary. Due to the security of supply, cables cannot in normal operation operate close to 100 % load, because there needs to be room for new heat pumps, electric vehicles, or other increases in consumption during the expected operational life of the cables. Use of flexibility to use low prices or services for the system (balance or regulating power market) can also make reinforcement necessary in the 0.4 kV grid.

The network companies will probably not use flexibility to mitigate issues in the 0.4 kV grids although the consumption from heat pumps is flexible. A 0.4 kV feeder covers a limited number of consumers.

If the load or voltage on a 0.4 kV feeder must be controlled using household consumption, it requires that the flexibility is always available and in sufficient quantities. These two conditions will probably not always be met on a 0.4 kV feeder, except if you compromise the consumers comfort and switch off appliances.

Furthermore, it is difficult to estimate the amount and the timing for the number of heat pumps and electric vehicles that will be installed on a 0.4 kV feeder. The number of heat pumps or electric vehicles should not raise much before grid reinforcement is necessary. Therefore, it is not realistic that a network company will use a market for flexibility for 0.4 kV feeders to postpone reinforcements, when they see a rise in the consumption from heat pumps. It is considered more likely that network companies will make use of the flexibility of private household for the 10 kV feeders, since the feeders have many more consumers and the quantity and thus the reliability are higher even though the need also increases.

6.1.2 Anthropological analysis of private consumers

As part of the DREAM project, an anthropological analysis[32] in two villages was conducted to address the question of what motivates private households in their energy related behavior. In order even to talk about Smart Grid and flexible consumption, a large part of the Smart Grid agenda has to deal with the instrumentation of households with heavily consuming components such as heat pumps, PVs and electrical vehicles. The analysis looked at socio-material behavior in relation to energy consumption in the villages, but also more widely at the overall practice of everyday life in these villages. Because, the DREAM project differentiates from other Smart Grid projects by having a clear commercial focus, the barriers and challenges for getting especially the heat pump deployed, was therefore important to address.

The field research is case-oriented, but the results may be utilized in many rural areas all over Denmark. The motivations and barriers described in this analysis are not just typical for these specific two villages, but many characteristics are general.

The data basis of the analysis:

- 20 visits in people’s homes in two villages
- Citizens meeting
- Meetings with representatives from local associations
- Dialogue with the involved municipalities
- Systematic assessment of BBR
- General desk research about the two villages and local communities

[32] Appendix 2 Energi i landområder

The villages are very similar regarding demography, everyday life, financial income, employment, and the fundamental aspect that local experience, central ambassadors and social relations are pivotal to the many choices made in relation to house and home in the individual household. The villages are, therefore, demographically and socio-culturally comparable. Together they provide an image of the challenges and opportunities the project must address in the implementation processes in future phases, where the implementation of Smart Grid Ready technologies will be demonstrated. Even though the villages are from some perspectives very similar, there are also differences and these have proven important for understanding the social dynamics of village life in relation to energy behaviour.

Everyday life and energy practice in the two villages

The results from the anthropological analysis focused on four overall characteristics describing the lives in the two villages – similarities and differences between villages and citizen taking into account. These categories describe the general practice in these villages and are important to understand in order to address the Smart Grid agenda.

In both villages, there is a distinct do-it-yourself-culture. Most people do not hire craftsmen, but manage their renovation projects themselves, helped by family, neighbours and friends. They have great confidence in their own work, and there is a strong drive to make things happen. The do-it-yourself-culture is both social and material. There is a lot of experience in the villages, and there is easy access to help and guidance. At the same time, there is access to materials and tools, which influences everyday practice and choice of energy supply. Individually compounded heat supply solutions in both villages exemplify how access to materials and experience influence energy related behaviour. The many different solutions are not necessarily the cheapest or easiest, but they are built upon the local experience and material basis – and not least, the possibility for the people to handle them themselves.

Technologies like the heat pump and the electrical car face the challenge of being too obscure and different from the mechanical technologies the citizens are used to dealing with. Thereby the technology deprive them their possibility to act. This challenge the implementation of Smart Grid technologies in general and is something that the DREAM project must respond to in the future implementation strategy and future DREAM phases. This finding is not just relevant for the project group, but important for all stakeholders dealing with implementing new technologies in these areas.

Many of the citizens display a great deal of wilfulness and need of control. It has something to do with personal freedom, but it also concerns a lack of trust in the system and the necessity of being able to deal with things on your own - for example to build a heat supply solution, that can be dealt with locally and by need. The experience of being left on their own, derives e.g. from being outside of public heat supply and public transportation system. Heat supply and cars both symbolize freedom in many ways. By solving their own problems and not leaving it to the public sector or others, they experience greater freedom of action. An old car that you can fix yourself and a heating solution with an oil-fired boiler, supplemented with a solid fuel boiler and solar panels, may demand a greater deal of work, but that is not how it is experienced. On the contrary, it is a natural and necessary part of everyday life. Citizens in these areas do not always have the possibility to choose the easily accessible public solutions, but are often faced with choices, where it can be difficult to choose the best, cheapest or easiest solution. However, by local guidance and experiences they manage to find the best solution experienced from their point of view.

This influences the Smart Grid agenda, as many newer technologies are experienced as too complex (highly technological), but also automatic to some extent. So the need for control or freedom through interaction with the technology becomes challenged e.g. by the automatic nature of a heat pump.

The citizens have a pragmatic relation to their house and functionality is central. The house is seen as changeable and flexible, meaning that it is possible to mould it as you like – knowing that it may take some hard work. Even though many of the houses are described as being in somewhat bad condition at the time of moving in, this is always accepted and addressed over time. Most of the citizens have been through great and time-consuming renovation processes. In general, the houses seem to be in a constant condition of 'unfinished', and one renovation project takes over the other due to practical conditions, like having more children, becoming older or similar. Rarely renovation is done just for aesthetic reasons. If something works, there is no reason to change it. This category actually represents on opportunity, as the pragmatic relationship to their houses compliments the idea of Smart Grid implementation as a holistic approach with demands of potential renovations.

In both villages, "unnecessary" expenditure is not prestigious; instead, it is considered an unwise 'waste of money'. On the contrary, it is admired to strike a bargain. Many use the word "frås" – meaning being wasteful or to squander money. This approach is also expressed in their unsentimental and pragmatic relation to their house and car. Renovation projects often does not concern panorama-view windows, fancy floors etc. Investments have to make sense, and there must be "sanity in it", like several citizens describe it. It is all about striking the bargain or finding the smart solution.

Conclusion on the anthropological findings

Apart from the financial difficulties regarding investments and loans, which is already known, a number of socio-cultural circumstances challenge a Smart Grid technology deployment in practice as well. Central needs for self-regulation, freedom of action, and local anchoring, make constrains on future solutions and business models. However, these needs and insights will also be part of the solution.

The anthropological analysis breaks with a dominating assumption; that consumers predominantly make individual choices, that are (economically) rational and derives from knowledge and insight. For example: it is not enough to introduce an economic model with long term benefits to a household, as money is not the only determining factor in their decision. Furthermore, it is not always rewarding to talk to the individual household alone, when mechanisms of local community are motivating forces as well.

The anthropological analysis shows that there is a lack of local experience with heat pumps and electrical cars. Furthermore, limited knowledge of the energy system in general – combined with a need for empowerment, freedom of action and local anchoring, weakens the potential of a Smart Grid technology deployment on commercial terms, as there is simply not enough trust or local experience with these technologies. Two overall and overlapping conclusions can be drawn up:

1. The influence of local communities

People are influenced by the social contexts they engage in, and these affect the actions and decisions of the individual. The two villages in the project have strong social mechanisms, and therefore the community level is of great importance. When there is limited local experience with the heat pump, for example, this becomes a central challenge. People supervise and listen to each other and in the many situations where they are "left on their own" with significant decisions, like individual heat supply, comfort is found in the fact that 'others chose the same way'. Therefore, the messages, technologies and implementation strategies of the project must be directed towards the community as a whole, if the solutions are to be solidly anchored.

2. "Community power"

The power of social mechanisms shows in a conflicting tendency. In one of the villages, a citizen has experience with heat pumps through his professional life and other central citizens have recently invested in one. This creates a ripple effect. They are local ambassadors, positive stories about reduced consumption are told and the heat pump is now seen as an alternative to the oil-fired boiler. In the other village, trendsetting citizens choose the wood pellet boiler or even renewing their oil-fired boiler – and guide others to do the same. As a result, many other households reinvest in a new oil-fired boiler, as this is the recommendation they are receiving by local craftsmen and neighbours. Negative stories about inefficiency and bad durability of heat pumps are told, while there is no local experience and thus no one to tell the good stories. This also means that local stakeholders are crucial for a successful implementation of Smart Grid technologies. This is an important insight not only for the DREAM project, however, for other stakeholders working with heat pumps, PVs or overall the Smart Grid agenda.

The anthropological analysis concludes that despite of these challenges and barriers, the insight and understanding of the village practice, are the basis for actually implementing more heat pumps and other Smart Grid related technologies in areas outside the district heating and gas system successfully. The results are part of the implementation strategy introduced further down.

6.1.3 Economic consequences from Smart Grid ready appliances

An important step in the implementation of Smart Grid appliances is the development of a box of tools, which can support the implementation process for Smart Grid Ready technologies. A central part of this so called "tool box" is a business case tool developed on the MS Excel platform, which is able to calculate the economic consequences for a household when a heat pump, electrical vehicle and/or solar cells are installed. As a result, the model is also an important tactical element in convincing households to change from oil-fired boilers to heat pumps and/or to invest in other types of

Smart Grid Ready equipment. The business model and the research on the economic consequences carried out by the project is presented in the report "Økonomisk model og finansieringsmetoder".[33]

Specifically the model estimates the economic consequences of the installation of a heat pump, electrical car and/or solar panels by comparing total costs (operating, service and financing costs) of each equipment under the household's current setup to costs of the Smart Grid Ready equipment over the equipment's estimated lifespan. It is economically beneficial to scrap current equipment and install Smart Grid Ready equipment if accumulated total costs of the current equipment is higher than accumulated total costs of the Smart Grid equipment.

All case-specific input such as energy consumption, heating source, number of cars and car-specific info (model, year, kilometres driven each year, etc.), Smart Grid ready appliances to be analysed, etc. are to be entered in a single pedagogical worksheet – the model's cockpit (primary input sheet). The cockpit is divided into different input sections, which are illustrated below. It is also elaborated on in the report "Økonomisk model og finansieringsmetoder".

Input til eksisterende bil(er) og varmekilde

Eksisterende bil(er) og varmekilde	Vælg	Finansiering
Bil nr. 1 (vælg bil til/fra samt finansieringsform)	Ja	Lånefinansiering
Bil nr. 2 (vælg bil til/fra samt finansieringsform)	Ja	Lånefinansiering
Varmekilde (vælg varmekilde samt finansieringsform)	Oliefyr	Lånefinansiering

Specifikationer - bil nr. 1	Input	Kommentarer
Bilmodel	Ford Focus	
Købsår	2006	
Købspris (ved anskaffelse)	263.690	
Forbrug (km pr. liter) - eksisterende bil	20,8	
Forbrug (km pr. liter) - ved geninvestering i tilsvarende bil	23,8	
Forbrug (årlig kørsel i km)	25.550	
Forsikring (årlig præmie)	5.132	
Årlig betaling til grøn afgift	580	

Specifikationer - bil nr. 2	Input	Kommentarer
Bilmodel	Ford Focus	
Købsår	2006	
Købspris (ved anskaffelse)	263.690	
Forbrug (km pr. liter) - eksisterende bil	20,8	
Forbrug (km pr. liter) - ved geninvestering i tilsvarende bil	23,8	
Forbrug (årlig kørsel i km)	25.550	
Forsikring (årlig præmie)	5.132	
Årlig betaling til grøn afgift	580	

Varmekilde	Input	Kommentarer
Købsår	2002	

Input regarding the household's current car(s) and heating source

[33] Appendix 3 - Økonomisk model og finansieringsmetoder

Input til elektrificering af husstanden

Elektrificering af huset	Vælg til/fra	Input	Vælg finansiering
Elbil nr. 1	Ja		Lånefinansiering
Elbil nr. 2	Ja		Lånefinansiering
Solceller	Ja		Lånefinansiering
Varmepumpe	Ja	Væske/vand	Lånefinansiering

Specifikationer - elbil nr. 1	Input	Kommentarer
Bilmodel	Nissan Leaf Visia	
Købspris (ved anskaffelse)	253.690	
Energiforbrug (kWh/km)	0,22	
Forventet årlig kørsel (km)	25.550	
Køb eller abonnement på ladestander	Abonnement	
Optankningskort (vælg)	Basis	
Forsikring (årlig præmie)	2.768	

Specifikationer - elbil nr. 2	Input	Kommentarer
Bilmodel	Nissan Leaf Visia	
Købspris (ved anskaffelse)	253.690	
Energiforbrug (kWh/km)	0,22	
Forventet årlig kørsel (km)	25.550	
Køb eller abonnement på ladestander	Abonnement	
Optankningskort (vælg)	Basis	
Forsikring (årlig præmie)	2.768	

Input regarding the Smart Grid ready equipment to be analysed

Input til fremskrivning af energipriser og afgifter

Energi- og afgiftsscenarie	Vælg	Konsekvens
Fremskrivning af elforbrug (før elektrificering)	Medium case	Elforbrug fremskrives årligt med gennemsnitligt 1.45%
Fremskrivning af varmebehov	Medium case	Varmebehov fremskrives årligt med gennemsnitligt 0%
Fremskrivning af råpriser (el)	Medium case	Råprisen på el fremskrives årligt med gennemsnitligt 2%
Fremskrivning af afgifter (el)	Medium case	Afgifter på el fremskrives årligt med gennemsnitligt 2%
Fremskrivning af råpriser (fjernvarme)	Medium case	Råpris på fjernvarme fremskrives årligt med gennemsnitligt 2%
Fremskrivning af afgifter (fjernvarme)	Medium case	Afgifter på fjernvarme fremskrives årligt med gennemsnitligt 0%
Fremskrivning af råpriser (olie)	Medium case	Råpris på olie fremskrives årligt med gennemsnitligt 2%
Fremskrivning af afgifter (olie)	Medium case	Afgifter på olie fremskrives årligt med gennemsnitligt 2%
Fremskrivning af råpriser (gas)	Medium case	Råpris på gas fremskrives årligt med gennemsnitligt 2%
Fremskrivning af afgifter (gas)	Medium case	Afgifter på gas fremskrives årligt med gennemsnitligt 2%
Fremskrivning af råpriser (træpiller)	Medium case	Råpris på gas fremskrives årligt med gennemsnitligt 2%
Fremskrivning af benzinpriser	Medium case	Benzinpriser fremskrives årligt med gennemsnitligt 2%

Input regarding forecast of energy prices and taxes

The creation of the model has been an incremental process, where features have been amended and added as knowledge among project participants has increased. The model was initially created with a holistic view on the economic consequences from installing heat pumps, electrical vehicles and solar cells simultaneously. The model now shows and compares the effect from each instalment. This has been done to accommodate individual preferences and choices among households.

We have used the model to analyse the economic consequences of an installation of Smart Grid ready equipment in two interviewed households from the cell area and a typical household in Southern Denmark (the generic case). The first household uses an oil-fired boiler and has three cars; two Peugeot 207 and an old Talbot Solara which has not been included in the analysis. The second household also uses an oil-fired boiler but only has one car, a Peugeot 407. The third household has partly been defined based on data from Danmarks Statistik.

The following results were achieved for household one (input data and results are elaborated on in the report "Økonomisk model og finansieringsmetoder"):

- The calculations showed that it is economically sound to scrap the oil-fired boiler and invest in a heat pump. A ground source heat pump is repaid over a period of 10 years while an air heat pump is repaid over 8 years.
- The current cars are more economical than an electrical car (including operating, service and financing costs). Therefore the household should not invest in an electrical car for economic reasons
- Solar panels only provide cost savings when no heating pump is installed (the result is the same for the household two and three). Total savings over the lifetime of the equipment are small and therefore the conclusion changes when a heating pump is also installed. This is because the electricity price, including taxes, is lower for electricity consumption above 4000 kWh for a household that applies an electrical heating source.

The following results were achieved for household two (input data and results are elaborated on in the report "Økonomisk model og finansieringsmetoder"):

- It is also an economically good idea for household two to scrap the oil-fired boiler and acquire a heat pump. A ground source heat pump is repaid after 9 years while an air heat pump is repaid after 7 years.
- It will be economically better for the household to scrap the current car and invest in an electrical car. The electrical car is repaid over a period of 11 years.

The following results were achieved for the typical household/generic case (input data and results are elaborated on in the report "Økonomisk model og finansieringsmetoder"):

- In this case we analysed the economic consequences from installing a heat pump when the existing heating source is either an oil-fired boiler, a gas-fired boiler, a wood pellet fired boiler or district heating.
    - Cost savings from a heat pump are high when the existing source is an oil-fired boiler or district heating
    - Whether it is economically sound to scrap a gas-fired boiler and install a heat pump depends on the installation year of the existing boiler.
    - Economically is does not make sense to install a heat pump when the existing source is a wood pellet fired boiler. A wood pellet fired boiler is both cheaper to install and has lower operation and service costs during its lifespan compared to a heat pump.
- Economically it does not make sense to sell the existing car and purchase an electrical car.

Using traditional financing sources, financing costs typically constitute a large part of total costs involved in investing in a new car, heating source or other appliances. Therefore, untraditional financing is believed to be an important element in the roll out of Smart Grid ready appliances. Besides traditional bank loan financing, we have analysed alternative financing opportunities such as leasing, public private partnership, financing from electricity dealers selling Smart Grid ready appliances, as well as other types of financing. Especially financing from the commercial operator is believed to be an efficient tool, as the operator can lower financing costs in exchange for potential flexibility benefits in the household's electricity consumption for a number of years. This will be beneficial to both operator and household. Also it is concluded that financing in the form of public grants or the like will be important in the early stages of commercialization of smart grid due to the fact that the market and financing institutions do not want to invest in smart grid at this stage.

6.1.4 Smart Grid Ready equipment survey

Smart Grid Ready is a very general term used in different ways around the world to describe electric equipment that can be remotely managed. The DREAM project's view on Smart Grid Ready equipment in Denmark is the ability, of a piece of equipment, to regulate electric load down (or up where feasible) remotely controlled by an external controller using existing open communications and control standards.

It is important that new equipment in the kW-range, which is feed by electricity from the electric distribution network (400V level), becomes Smart Grid Ready. If the major share of electric loads in the consumer's installation (demand side) is flexible and can be remotely managed, it can increase the absorption of renewable energy and reduce the cost of balancing the energy and power in the grid and help the DSO in voltage and overload situations

There are three relatively new types of electric equipment characterized by high continuous power > 1kW for hours that calls for intelligent management:

- HP - Heat pumps – likely to substitute most existing oil boilers and to some extend to substitute gas boilers.
- EV - Electric Vehicles – likely to substitute most of the fossil fuel passenger cars before 2050
- PV – Photovoltaics – solar cells

Other energy consuming equipment in private homes could be managed through home automation systems. Typical home appliances use relatively little energy and for short periods only, so the cost – benefit of adding an intelligent remote control interface for the purpose of flexibility alone will be insignificant. DREAM keeps an eye on home automation systems though, because many home automation systems offer energy saving and additional functionalities like fire and burglar alarms, smart control of e.g. light and Window shades. The extra functionalities increase comfort and gives the customer values worth paying extra for.

To identify Smart Grid Ready equipment suitable for standardized roll out an analysis[34] of the existing Smart Grid Ready technology market has been conducted on Heat Pumps, PV systems, Home Automation and Electric Vehicles. Originally, the intention was to list relevant SG Ready products for future reference in DREAM follow-up projects but the list is very short.

The overall objective of the DREAM project is to deploy Smart Grid ready equipment, which is based on existing and proven technologies and solutions. DREAM has never intended to develop new technologies, equipment or suggest standardized communication protocols.

[34] Appendix 4 - Smart Grid Ready Equipment

To find suitable commercially available and proven products DREAM has looked to other research projects demonstrating different Smart Grid functionalities. Experience has been collected from a number of relevant finished and on-going research projects. Several projects have run demonstration of possible intelligent control methods for heat pumps. The disappointing message from all projects is that there are currently barely any commercial Smart Grid Ready equipment available, which fulfils the requirements for the Danish grid.

There is not yet any consensus among the electric system's stakeholders regarding control and communication standards for Danish Smart Grid functionality. For some time the IEC 61850, used for substation control, was the favourite and suggested for use as the possible Danish Smart Grid control standard having a lot of functionality and secure handshake. This standard is complex and carry a lot of overhead due to the wide applications range. Lately, a competing OpenADR standard from USA is being accepted in Europe via IEC as IEC PAS 62746 (originally designated as OpenADR 2.0b). OpenADR is simpler and based on lighter data packages but has less functionality for status feedback. The situation is currently completely open but both methods can be used. The Smart Grid Open project (SGO) is looking at a possible open test method for Smart Grid Ready equipment and has not yet decided which system to work with. The SGO project still awaits the first likely Smart Grid Ready equipment to apply the test method on.

If proprietary management and communication can be accepted as a temporary solution then several systems have demonstrated successful aggregation and VPP functionality with different suitable heat pumps. Several large heat pump manufactories offer their own aggregating system operating on their own proprietary servers. Some of these suppliers even offer to aggregate other brands of heat pumps to form a Virtual Power Plant (VPP). There is also a very relevant open Danish aggregating setup named "Intelligent Energistyring amba (IES amba)" nearly ready for commercial operation with different heat pumps using their own communication interface.

The Ecogrid.eu demonstration project, at the island of Bornholm, has nearly 1000 heat pumps installed in private homes. The heat pumps are mainly standard types but managed by dedicated interface hardware. The project has two different control setups. One system managed by Siemens hardware and software. The other system is based on Green Wave Reality hardware serviced by IBM software. Both setups use proprietary communication and control.

Another temporary Smart Grid Ready functionality is the German 2 bit interface where broadcast signals can activate a basic Smart Grid functionality in PV systems and heat pumps with the German BWP "SG Ready" certificate[35].

[35] Bundesverband Wärmepumpe (BWP) e.V., »www.waermepumpe.de«, 01 01 2013. [Online].

Many modern PV inverters have functionalities built in that can offer local reactive compensation (VAR-compensation) and frequency stabilizing functions besides ordinary curtailment but a slightly more advanced communication is preferred for such advanced functions.

Since Smart Grid Ready heat pumps are the most urgent product to find DREAM invited the major Danish heat pump suppliers to take part in a survey regarding control options on their products. A preparatory study on Smart Grid ready domestic heat pumps for use in the DREAM project was conducted as a questionnaire survey to 18 (9 answered) major Danish Heat Pump producers / importers.[36]

The survey included both existing and some new heat pumps currently available on the marked. The questionnaire gathered a range of information regarding heat pumps on the market. The recipients were asked which control and measurement options the company offers in their heat pumps, and through interfaces. The questionnaire had a particular focus on external communications capabilities and the receiving companies were asked about their approach to and thoughts on Smart Grid.

Based on the answers from the suppliers / subcontractors / dealers (importers), a scale from 1-10 in regards of "Smart Grid Readiness" was formulated:

1. The heat pump can respond directly to e.g. a price signal over the Internet, without modification.
2. The heat pump can be adjusted/upgraded to respond to e.g. a price signal over the internet.
3. The heat pump can be set to different "modes" over the Internet.
4. The heat pump can be set to different "modes" through a local connection (external box).
5. Start / stop and set points can be controlled over the Internet.
6. Only start / stop can be controlled over the Internet.
7. Start / stop and set points can be controlled via local connection (external box).
8. Only start / stop can be controlled via local connection (external box).
9. Remote control and sensor-values only available by physical modification and adding external equipment, but supplier has interest in development.
10. Remote control and sensor-values only available by physical modification and adding external equipment, and supplier indicates NO interest in development.

A product rated grade 1 is not necessarily better suited for Smart Grid purposes than a product rated grade 3. A product rated grade 1 may work autonomous where a product rated grade 3 works in connection with an aggregator controlling the heat pump. The level of "needed intelligence" in the heat pump will depend on how the heat pump in integrated in a Smart Grid system.

The different manufactures are rated according to whether their products are suited for use specifically in connection with the DREAM project. The rating is done according to the following:

[36] Appendix 4 - Smart Grid Ready Equipment

Evaluation	Rating	Description
Good candidate	App. 1-5	Very little or no change to the heat pump hardware is necessary for it to be part of a Smart Grid system. External systems may be necessary but is considered relatively simple.
Possible candidate	App. 6-7	There are opportunities to use the heat pump in a Smart Grid system, but modifications/additional equipment is needed for it to work. These modifications may be offered by the manufacturer.
A limited candidate	App. 8-10	The heat pump does not have the necessary external interface to be controlled in an appropriate manner in connection with Smart Grid, and / or the manufacturer has no interest in the project.

None of the heat pump manufacturers were rated grade 1 and thus none of the participants in the questionnaire have "plug-and-play" Smart Grid system solutions. With a 'plug and play' system we defined a system, where no modifications are needed. It is believed that one of the main reasons for this result is that it is yet unknown how the communication in a future Smart Grid system will take place. This conclusion is also supported by the analysis on standards and open communications systems, which will be summarized later. The analysis however, shows that several products are prepared to respond to a simple signal over the internet. This means that preliminary introduction of Smart Grid Ready equipment can take place once a standard is agreed. The next generation of heat pumps, from large suppliers like Bosch, will have high-level communication built into all models but not necessarily comply to open standards.

Conclusion on the equipment analysis

There is yet no agreed communication standard recommended for Smart Grid communication and control in Denmark. Consequently, no component supplier can claim that their equipment is Smart Grid Ready in Denmark.

Most heat pumps on the market can be managed by aggregators but only by using a dedicated interface box. In Germany more than 400 listed heat pump models claim to meet a Smart Grid Ready functionality agreed between members of the BWP[37] using only to discrete signals. This type of communication is still not used in Denmark, but a requirement for many PV systems in Germany. New future PV systems are likely to have a high-level communication enabling intelligent exchange of status and performance. EV charging can be intelligently managed and support a Smart Grid. Nevertheless, the EV penetration in Denmark is still poor and apart from grid load analysis, no analyses have been carried out in DREAM phase 1 on the Smart Grid communications barriers and potential of integrating EVs in a Smart Grid. No home automation system candidates have be nominated as Smart Grid Ready yet.

The DREAM initiative seems to be a bit early out when compared to the availability of Smart Grid Ready products.

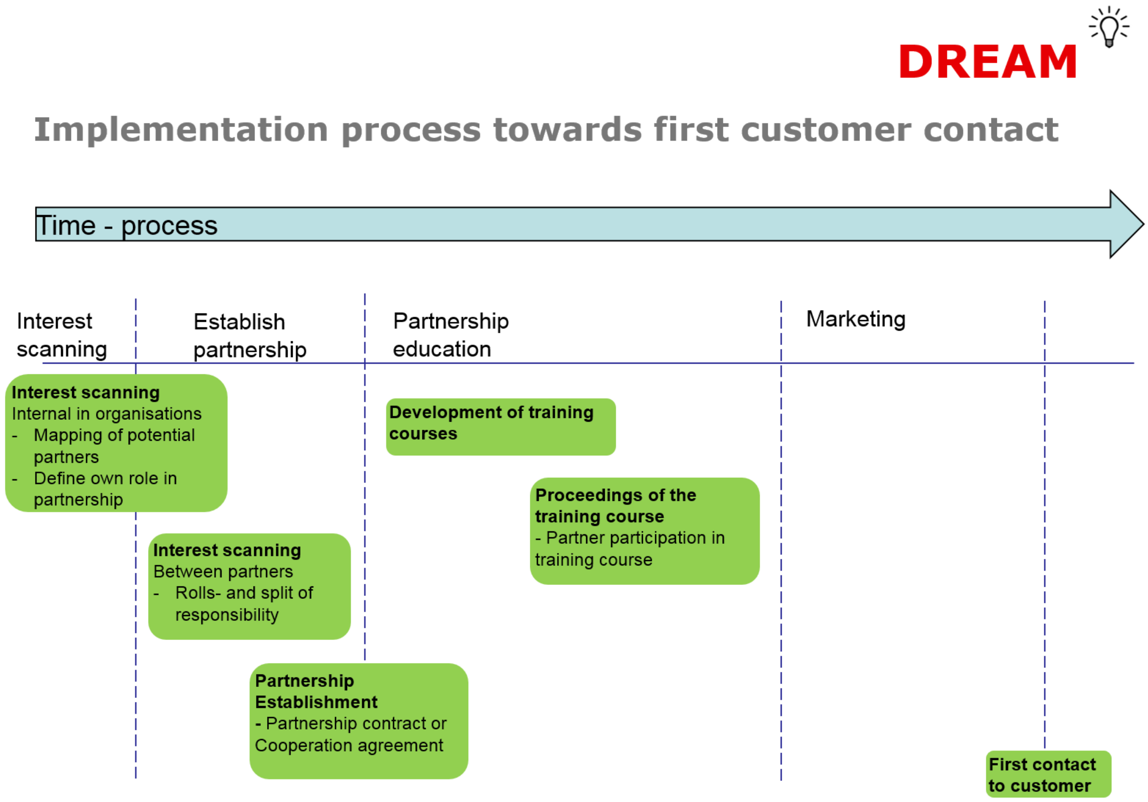
6.1.5 Smart Grid Implementation Strategy

Based on various analyses on private consumers, the current market for Smart Grid Ready equipment, the new business case model and other experience, the DREAM project group has created an implementation strategy[38] for Smart Grid Ready equipment, mainly heat pumps, in a similar sociogeographical area directed at private households. The strategy consists of two overall processes – one that is up to the time of first contact with the customers and the other is the process from first contact to full instrumentation of household.

Based on findings from the other DREAM analyses and especially the anthropological analysis, the implementation strategy has integrated a larger focus on the importance of the local community in the individual decision-making in the households and furthermore, integrated the idea of a partnership with more local stakeholders. The notion of partnership was integrated, as the Smart Grid agenda and the general transformation of the energy system is not only in the interest of one stakeholder, but involve a panorama of both local businesses, central energy industry stakeholders, the municipalities and of cause the willingness of the consumers.

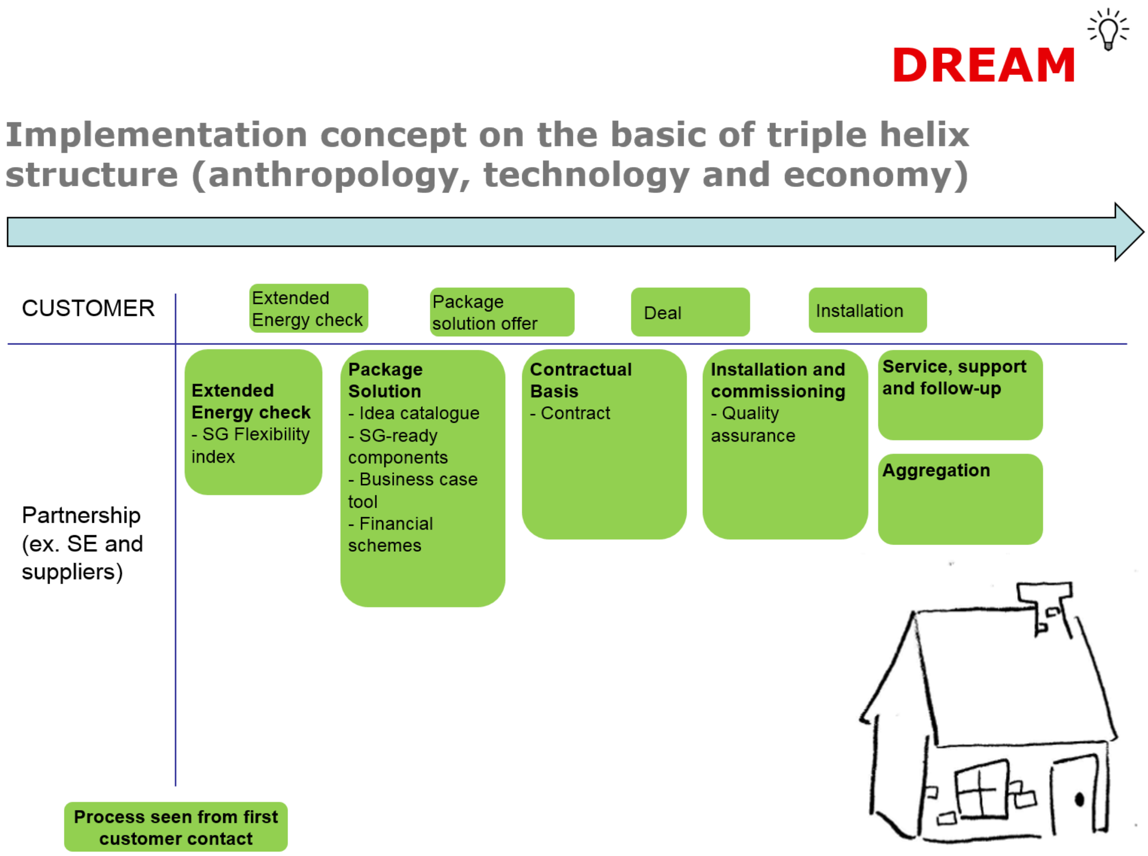
The illustration below describes the formulation of a partnership between local stakeholders, who have a common interest in implementing Smart Grid Ready equipment and solutions. For the utility or other stakeholder, owning an interest in the roll out of more heat pumps or other Smart Grid Ready equipment, it can be of great importance for the whole success that they are in alliance with local stakeholders. The illustration also focus on the education of the partnership group in order for them to work with the same Smart Grid mind-set and toolbox[39].

[37] Bundesverband Wärmepumpe (BWP) e.V., »www.waermepumpe.de,« 01 01 2013. [Online].
[38] Appendix 5 - Implementeringsstrategi
[39] Appendix 5 – Implementeringsstrategi



Not all parties need the same education; this all relies on the division of responsibility. The partnership is mutually beneficial and can be characterized as a collaboration. The nature of the partnership may vary from area to area and perhaps even in some area be unnecessary. To market Smart Grid Ready equipment, such as heat pumps, may be carried out in a joint effort, but can also happen individually. However, the partners will still have their own area of business, but can through the partnership benefit mutually from a Smart Grid Equipment roll out.

In the illustration beneath, the necessary steps in a full implementation is drafted, from the first extended energy check in the household to full instrumentation of a number of Smart Grid Ready equipment. The process is to some extent to be compared with a normal sale process with screening, offer, contract and installation. In this case, the personnel conducting the sale has been through the partnership educations program, they are familiar with integrating flexibility in the offered solutions and are aware of the social circumstances and practice of life in many of these areas. They are familiar with the new toolbox with its many tools and do know how to merge solid technical and community solutions with appropriate financing solutions.



The implementation strategy for larger industrial consumers has not been discussed, but it is viewed that it will differentiate profoundly from the private consumer strategy. The complexity and economic circumstances are very different between industries and private households. However, as earlier mentioned, some businesses like local grocers, craftsmen and other shops, can largely be approached the same way that private households are.[40]

6.2 Public consumers

In comparison to residential consumers, the group of public consumers deals with a higher concentration of energy consumption. Public consumers are often larger office buildings, schools, institutions and different activity centres. Buildings that all have medium to high energy consumption compared to private homes as many people make use of the facilities. These buildings often have complex energy systems, which may be individually energy optimized, in order to fit the many needs of the buildings, as well as to service the many users.

Municipality of Billund has helped screen their own buildings for suitable test buildings in DREAM context, preferably buildings within the same area as the anthropological analysis and the DSO SE

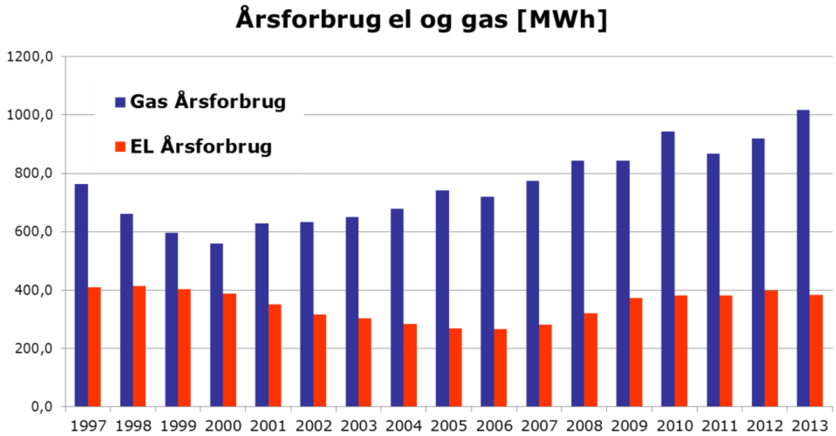
[40] This conclusion is based on conversations with citizens in the two villages, who also own smaller shops and businesses in the area.

supply area if possible.[41] An integrated institution and activity centre within the Billund Municipality area was chosen as test site. The office buildings of the employee in the Municipality of Billund was, at the time of research, already undergoing changes and they were thus viewed unfit for demonstration of Smart Grid in the DREAM context.

6.2.1 Flexibility study on Vorbasse Fritids Center

The analysis of Vorbasse Fritids Center (VFC)[42] was a case study conducted to address the question of flexibility in public buildings. The analysis is a specific analysis of a local activity and sports centre in the Municipality of Billund, but it still raises some overall perspectives of flexibility and Smart Grid in relations to existing buildings in the public sector and the variety of them.

The purpose of this particular study was to identify any accessible major flexibility within the large energy consumption and assess the potential to shift from NGAS to electric heat pump.



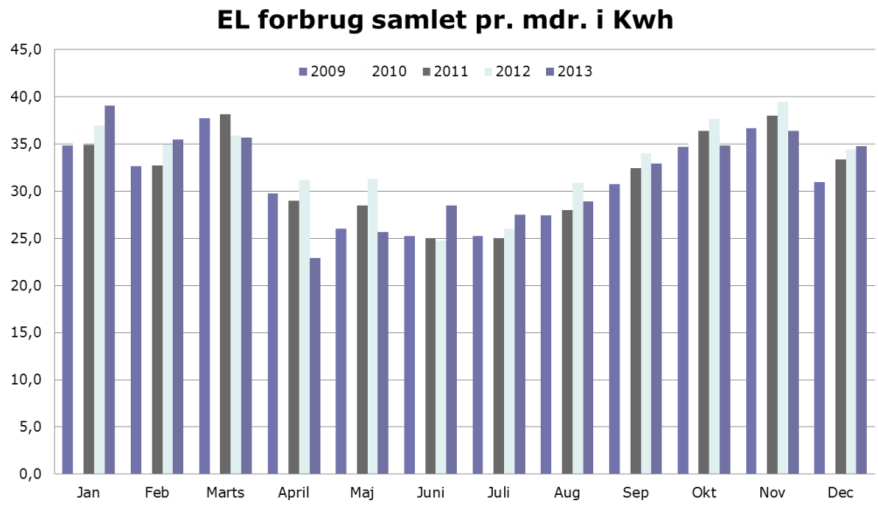
VFC Historic yearly energy consumption; Blue is NGAS [MWh] and Red is electricity [MWh]. The increase in energy match the extensions added to the institution and higher number of guests

An overview on the actual and historic energy consumption was compiled from monthly records of energy consumption from meters and networked climate controllers over the last 5 to 10 years. An overview over the gas and electricity consumption from 1997 to 2013 is shown in the figure above. Unfortunately, time resolution higher than month level was not available, but a primitive central logging by printing automatic reports every hour was initiated few weeks before the conclusion of this study.

The analysis of the data was done with assistance from the local caretakers with deep knowledge of the systems. It is obvious that the institution has a high energy consumption year round but nearly all the local air and water treatment systems is designed with focus on reducing energy consumption

[41] Appendix 10 - Offentlige bygninger og industri
[42] Appendix 6 – Smart Grid potential analysis at Vorbasse Fritidscenter

and best practice for the type of solutions. An overview over the yearly electricity consumption from 2009-2013 is shown in figure below.



VCF Last 5 years of electricity consumption per month. Only small sesonal variation; The lowest monthly consumption is 22.9 MWh

A relative high energy waste was identified at the exhaust from the swimming facility. The exhaust air is heat exchanged with the intake air through a heat pipe but still holds considerable energy in form of very humid air at temperatures well over ambient. The ventilation system of the swimming facility was also analysed for flexibility, but has to run around the clock year round to protect the buildings from aggressive vapours and humidity, so a buffer system is needed in order to create some flexibility.

It was analysed whether a heat pump could be installed with a buffer system. Even though a lot of energy is exchanged around the swimming facility and the pool holds a huge amount of heat energy, there is no available flexibility in energy consumption. A very fine balance must be kept with comfort temperatures, pressure, humidity, and requirement for air exchange in a room with a large warm water surface evaporating water proportional to temperature and humidity.

Conclusion on the institution Vorbasse Fritids Center Flexibility study

The study concludes that in spite of the high level of energy consumption year round, mainly for the swimming facility, the fine balance needed to maintain good comfort, safe environment and long life for the swimming hall building is critical. There is therefore nearly no available flexibility in the current system. This may also very well be the case for many other energy heavy public buildings in other parts of Denmark. Many existing systems have been designed to lower the energy consumption as much as possible and of cause uphold safety and health criteria, thus making the new focus of energy flexibility difficult to integrate. For good reason timing will become important. Cost – benefit analysis of current systems will be needed to estimate the optimal time for making changes to the system. In this particular case, the current energy system at VFC do not need any major renovations.

6.3 Smart Grid Ready equipment aggregation

Not all the analysis conducted throughout the DREAM project can be attributed to one of the consumer types. A couple of the analyses addresses more the overall agenda of Smart Grid and highlights some of the challenges related to the energy system transformation.

6.3.1 Research on a Smart Grid aggregator in Denmark

The analysis[43] on the topic of aggregation was carried out to better understand the business potential for this particular stakeholder in a Smart Grid. Moving consumption to other periods during the day or to turn on/off Smart Grid Ready equipment when needed by the grid makes little sense if not addressing the role of the aggregator.

The concept of an aggregator facility has been investigated through a research of related projects in Denmark, the rest of Europe and the USA. Furthermore, a number of relevant industry players in Denmark have been interviewed to get their views on the current and future flexibility market. This was carried out in order to relate existing experiences on the topic to the DREAM project and to understand how the development of an aggregator could be facilitated through the project. Finally, the research has looked into the potential value created by an aggregator.

The USA has a long history of using aggregators for TSO balancing services. The TSO gives a signal to the aggregators to turn off demand during peak hours to avoid blackouts. As a result, heavy investments in the grid are avoided. For now grid constraints is not an issue in Denmark and the results from US consequently cannot directly be transferred to Denmark due to differences in legal frameworks and energy profiles. Denmark applies much more renewable energy than the USA and so faces a different supply issue. An increasing amount of renewable energy creates a group of decentral production units which do not only need to be integrated, but are also of a less reliable nature in terms of production. As a result, it is more complex to estimate when balancing services are needed as well as where these needs will occur in the grid, than e.g. in the USA.

To facilitate a full deployment of Smart Grid aggregators in Denmark a number of legislative measures and heavy investments in dedicated aggregator software is needed to ensure full and close cooperation between the aggregator and the TSO and DSOs on the one side (demand for flexibility) as well as the aggregators and all Smart Grid Ready appliances in households on the other side (supply of flexibility).

The value of flexibility and the market for an aggregator

[43] Appendix 7 - Kommercielle aktører

Based on the research and interviews with relevant players in the Danish market, it can be concluded that the market for balancing services is not big enough to support this transition yet. Today around a few billion DKK are spent on balancing services each year. If every member of the value chain is to get a piece of this value, created by the flexibility, little is left to the aggregator. As a result commercial operators in Denmark currently make unilateral flexibility contracts with consumers, ignoring the TSO (balancing services).

Calculations from SE[44] show that a typical household with a heat pump can save around 1.000 DKK by simply shifting from fixed electricity prices to spot prices and dynamic taxes (nettarif). Savings are expected to increase to around 1.600 DKK if consumption is moved to hours with low spot prices[45]. These calculations provide an indication of the value that an aggregator is able to create for the electricity system with a flexible household with a heat pump installed. Naturally, the value creation from flexibility will be bigger if electric cars and solar panels are installed as well. This matter will be clarified as households are enrolled in the DREAM project later phases.

Conclusion on Smart Grid aggregation

The analysis of the role of the aggregator and the whole facilitation of the development of this stakeholder shows some difficult challenges in effectively organizing flexibility. The barriers of developing aggregation businesses are not just challenged by technical difficulties, but also by the question of value for the individual stakeholders and the energy system as a whole, as the market for flexibility is still immature..

6.3.2 Embedded Systems and Smart Grid communication

The report 'Embedded systems and Smart Grid communication'[46] was conducted by the project in the fall 2013/spring of 2014. The overall objective of the report was to address the challenge of communication standards for grid connected devices below substation level down to lightweight embedded systems such as communication between different household technologies and the grid. The report comments on several standards based on results from many referenced projects and makes detailed recommendations based on the observations.

Products in a Smart Grid setting, operated within a marketplace for flexibility, depend on the ability to connect and communicate with other system components and controllers. There is currently no European accepted standard for this communication besides the IEC61850 standard originally intended for grid control at substation level and above but to handle everything from power plants to substations the full implementation calls for large resources in hardware and software and are thus not suited for embedded usage. An ideal Smart Grid communication standard would be a light version of the IEC61850 with focus on embedded usage with less complex object and data models. A simpli-

[44] Appendix 7 - Kommercielle aktører
[45] In 2020 all household can expect to be billed based on hourly energy consumption
[46] Appendix 8 - A Survey of Smart Grid Communication with focus on Embedded Systems

fied subset of IEC61850 with ensured interoperability and a robust protocol with inherent communication security even accepting low-power low-resource wireless devices. OpenADR are a new contender winning support where IEC61850 has not yet been implemented. It is impossible to foresee whether OpenADR will 'overtake' IEC61850.

OpenADR has simpler communication with smaller data packages but lack the handshake and detailed process feedback IEC 61850 offer. OpenADR also lack the server to server communication IEC61850 can offer but this may be less relevant for Smart grid applications.

DREAM was never intended to do technology development, so any development of standards and technology has to be carried out in another context but the clarity of the conclusions and recommendations of the report highlight that further R&D is required before a full deployment of Smart Grid can be based on open standards. However, the recommendations of the report propose a top-level requirement specification for "An Open Smart Grid interoperability communication protocol" that can be developed combining existing technologies. It so seems to be primarily a development task that is required to propose an open Smart Grid standard. A major challenge working for open standards is financing the work.

7. Utilization of project results

The DREAM project is working with a very wide perspective on Smart Grid, thus making the utilization of results equally wide. As the current stage of the project is primarily a range of analyses, it is expected that results generated can be used and implemented in a variety of contexts, projects and not to mention energy related work conducted in the Regions, municipalities and energy related businesses. Besides the narrow socio-geographic profile in the project, the results can be utilized and the methodological approach can be adopted in many other areas, context and industries.

7.1 Utilization in future DREAM phases

DREAM was from the beginning on, thought to develop into a range of phases. The dynamic nature of the energy industry and energy system was the reason for this open and flexible structure. This mean that one of the prime utilizations of the results is to carry the results further in succeeding phases. This will be carried out either in a similar partner constellation or with only a number of the existing partners.

The project recommends that further deployment demonstration projects be lunched to identify the real world critical obstacles, to test the business concept proposed and to optimize the standard solutions in the DREAM toolbox[47]. Possible successive DREAM Phases have already been discussed but so far, none has been executed. The scope of the first successive project phases is to test the Smart Grid implementation strategy in a number of similar socio-geographical settings. The next DREAM Phase should primarily focus on the instrumentation of Smart Grid Ready technologies in a local area and strive to implement holistic package solutions to private households as close to market terms as possible. The process of further DREAM phases include usability evaluation and adjusting the implementation strategy accordingly and to other relevant areas. However, consecutive DREAM Phases will also further develop the business models, the Smart Grid Ready catalogue and the findings from grid analysis and anthropological analysis will be integrated into the work focusing on communication aspects and the need for flexible consumption.

Developing successive DREAM Phases is the prime utilization activity and the obtained results from DREAM phase 1 show that even getting the Smart Grid Ready technologies implemented on commercial terms is a massive challenge in itself. Increasing focus on flexibility and voltage problems in the local grids will be needed later and will however add further complexity. The results from DREAM Phase 1 have shown and underlined that creating successful alternative conditions for implementation of Smart Grid Ready technologies may very well be the first obstacle, which needs to be addressed, before the Danish society can even talk about flexibility and Smart Grid. This challenge will be the primary focus of the first successive DREAM Phases.

[47] Appendix 5 - Implementeringsstrategi

7.2 Utilization of results by project group

DREAM Phase 1 has generated a number of sub reports focusing on different aspects of the Smart Grid agenda. Because of the complex and wide focus on Smart Grid in DREAM Phase 1, the results obtained may in many ways be utilized either directly or indirectly in other energy related discussions and activities.

Throughout the project period, the project partners has focused on dissemination opportunities and the project has participated in national and international seminars.[48] These tasks will continue after DREAM Phase 1 has finished.

It is expected that the results from the project will be utilized within the field of Smart Grid deployment and will become a part of the complex, but productive debate about the future of a Danish Smart Grid. Examples of how the DREAM phase 1 partners intent to exploit the results.

Deloitte:

Financial Advisory Services will use the knowledge gathered at DREAM phase 1 about technical, financial and anthropological barriers when trying to implement smart grid ready appliances at end user level when conducting financial analysis and business cases in the energy sector, specifically when focusing on renewables energy.

Furthermore, the knowledge about the technological and economic value chain behind the smart grid aggregator will also be used in Deloitte's financial advisory work.

Danish energy association:

The grid analysis in the project shows that even heat pumps are flexible, they can cause so much consumption that it can cause voltage or overload problems at the 0,4 kV feeders and reinforcement can be necessary. This is interesting and cause more analysis of the heat pumps flexibility and impact on the grid.

The analysis of the sufficient number of measurements in a 15 kV feeder showed that that it is possible to develop a strategic approach to place measurement points in the distribution network. However, due to the large amount of data, and different request and development of devices it requires a lot more work than what was presented in this analysis. However, with the development of analytical procedure introduced in the DREAM Phase 1 is a starting point for how the matter should be addressed

[48] M. F. Bendtsen og m.fl., Interviewees, *Ecogrid.eu-Bornholm.* [Interview], 25 06 2014.

Danfoss

Danfoss will make use of the following results generated in DREAM:

Business Segments: Industrial examples of "energy flexibility" are hard to find; the private and commercial markets would be the first to target.

Business volume: The value identifiable in possible Demand/Response schemes in Denmark seems too limited to support a commercial aggregator structure; at least on the short term

Buying behavior: Economics is not the sole determining factor for the private consumer

Technology: SG ready technology is immature and products based on open standards are only in their early infancy

Models: The economic calculation models developed in DREAM may prove helpful towards possible customers in the future; especially in the private consumer market

The Municipality of Billund

The role for the municipality changed when the project moved from its socio-geographical focus. The municipality of Billund will primarily use the findings generated in the anthropological analysis in their tasks related to the strategic energy planning. Especially the challenges related to the facing out of oil-fired boilers in the areas outside distributed heating.

SE

SE has used the performed load calculations for a major study to estimating the free capacity of the entire grid. In addition, the SE used parts of anthropological studies to understand people's views on opportunities and constraints related to the use of electricity instead of gas and oil. These studies are also used to estimate the market potential for heat pumps and electric cars

In the future, anthropology can be an important factor in understanding the customers will to change the form of energy and behavior. It will be important for the customer's choice of products and important for SE's business development.

Danish Technological Institute (DTI)

DTI are planning use of the DREAM project results in a number of diverse activities. Smart Grid and Smart Energy are core focus areas for DTI so a significant part of the learnings from DREAM will be used indirectly as back ground information and directly in new and current energy related research projects. The foreground and background knowledge acquired through the DREAM project will be disseminated through future consulting, new energy related services and project participation. DTI employees will carry DREAM knowledge into e.g. Smart Grid Open; eButler; Smart Grid i forklædning; iPower; HPCOM; Smart grid in Agriculture; Intelligent Energistyring AmbA - and any further phases of DREAM.

Besides the utilization of DREAM results in R&D activities, the institute will include DREAM knowledge and results in e.g. presentations about topics like energy transitions and energy efficiency for strategic energy planning inputs to municipalities and regions. The anthropological results from DREAM will be of value to many other areas in Denmark.

7. References

Appendix list:

DREAM appendixes can be found on the Danish Technological Institute's website - www.teknologisk.dk/DREAM - under the following names:

Appendix 1 – Grid Analysis (in English)

Appendix 2 – Energi i landområder (both in English and Danish)

Appendix 3 - Økonomisk model og finansieringsmetoder (in Danish)

Appendix 4 - Smart Grid Ready Equipment (in English)

Appendix 5 – Implementeringsstrategi (in Danish)

Appendix 6 - Smart Grid potential analysis at Vorbasse Fritidscenter (in English)

Appendix 7 - Kommercielle aktører (in Danish)

Appendix 8 - A Survey of Smart Grid Communication with focus on Embedded Systems (in English)

Appendix 9 - Afrapportering_Celleområdet (in Danish)

Appendix 10 - Offentlige bygninger og industri (in Danish)

Further references:

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