DREAM Phase 1 – Appendix to main report

Appendix 4

Smart Grid Ready Equipment (in English)

ForskEL projekt nr. 10744

Project partners:

DREAM WP3a
Smart Grid Ready Equipment

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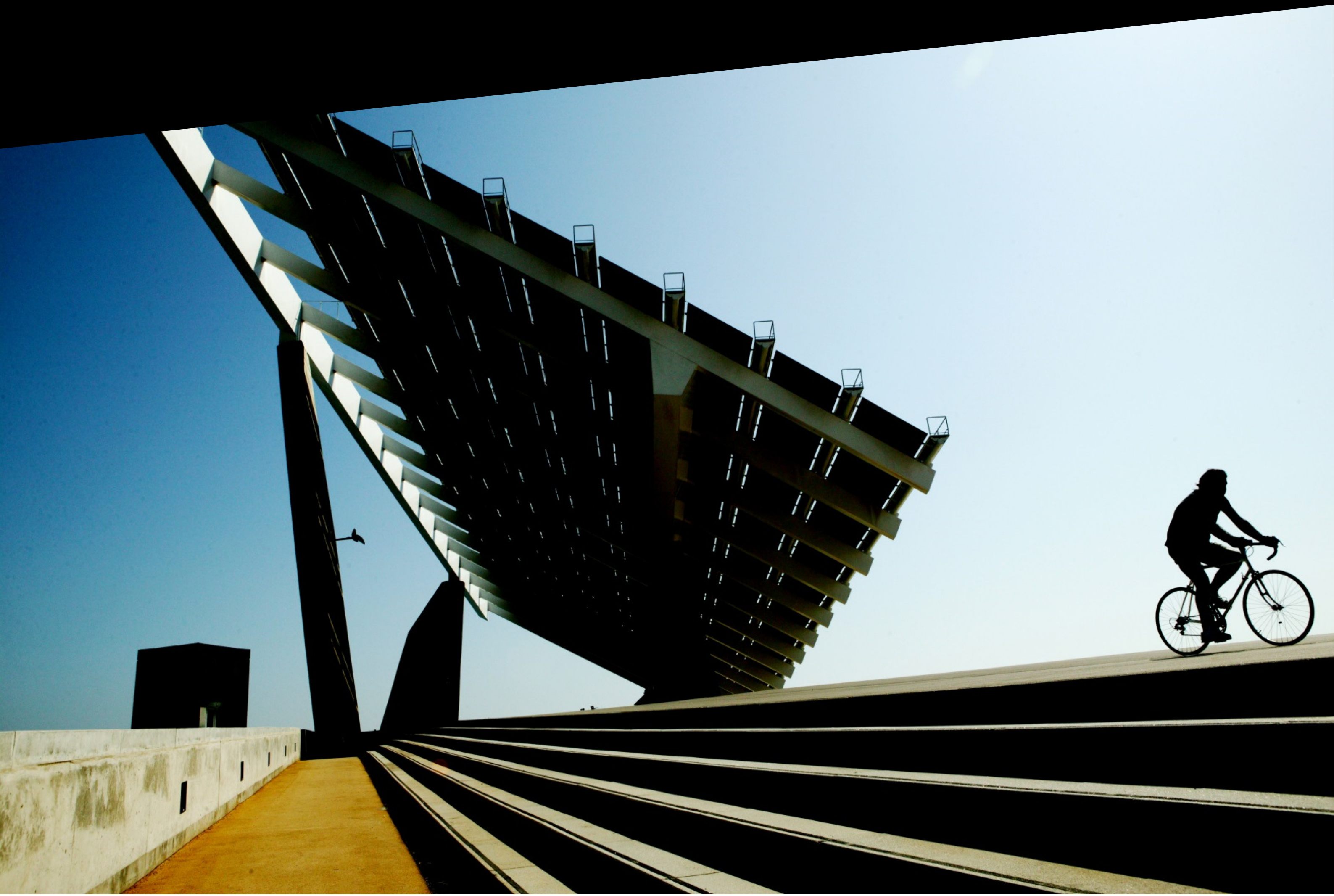

1. Indholdsfortegnelse

1. Introduction

The primary task of WP3a is to map Smart Grid Ready equipment.

The DREAM project has a practical approach to Smart Grid roll out. The focus should be on practical solutions that has the largest impact at the lowest cost. The DREAM project is not developing equipment but is based on using existing knowledge and commercially available equipment.

A survey has been made into a number of research projects to find relevant the existing knowledge and to identify the Smart Grid ready equipment.

Below there is a description of the types of relevant equipment, the challenges that should be handled and the results of the survey into other projects.

2. Relevant types of equipment.

Typical home appliances use relatively little energy and for short periods only, so the cost – benefit of adding a Smart Grid interface alone for flexibility will be insignificant.

Of potential interest is therefore three new types of electric equipment characterized by high continuous power > 1kW for hours. The critical equipment types:

1. HP - Heat pumps – likely to substitute most of the already banned oil boilers and soon also gas boilers.
2. EV - Electric Vehicles – likely to substitute most of the fossile fuel car fleet by 2050. In this context, it is actually the charging of the EVs that are critical. When there is a reference to EV it generally means EV charge.
3. DER – Distributed Energy Resources – E.g. PV system or other domestic energy production like a house windmill. PV is considered the critical equipment in this context. Producing maximum at midday – when there are nearly no other equipment loads in domestic areas.

Other equipment in homes could be managed through Smart Grid Ready home automation systems. Home automation systems could maybe also serve as Smart Grid gateways to the critical equipment types and therefore of potential interest.

3. Smart Grid relevance.

The three new types of equipment will challenge the energy balance but in particular the DSO's distribution grid. Distribution grids in domestic areas are planned with very little coinciding consumption. Even though most private houses has 20 kW power available the local distribution grid is typically designed for approximately 1 kW to maximum 2 kW continuous load per house.

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The load of this new equipment are very different from other home appliances regarding load patterns and actual load and could easily create overload in critical peak load situations. Charging an EV at home can easily load 3 kW for several hours. PV systems can source more than 4 kW for several hour on sunny days. On cold days heat pumps will run almost continuously with 1 to 2 kW load and may even add 2 to 6 kW electric boiler power to supply enough heat. Combining EV and heat pump could even make the situation worse.

Enabling 100% renewable energy in the electric supply within 20 years is a significant challenge. Considering that the largest part of the current fossil energy consumption will shift to electric supply will only double the trouble.

Smart Grid management can help equal out the load from large loads to avoid critical peak load. In the research community, many have for some time assumed that Smart Grid management would have a lower cost than reinforcing the grid. At the time of this report the saving potential in the distribution grid is being questioned and cannot be confirmed by the involved parties.

Domestic investments in PV and heat pumps is expecting the equipment to live for 15 to 20 years or longer. A ban on oil burners in areas with possible collective energy supply and a law[1] that allows further limitations later means that many will shift to heat pumps. These heat pump installations will be optimized economically based on today's price and tax setup and optimal comfort. The installations will not be prepared for any flexibility e.g. because:

- There is no obvious good business plan in it
- There are no serious official recommendations regarding need for future flexibility on these types of equipment – thus no recommendation to prepare new systems for flexible operation.
- There are no recommend standards to look for even if the customer wants to prepare the installation for future flexibility. (No Smart Grid Ready label).
- Many heat pump sellers cannot guide the customers because they have no information themselves on future needs from the grid.
- The sellers of heat pumps, PV and electric vehicles has little short term interest in increasing cost on their products due to unsure future maybe needs of the electric grid.

Another huge challenge the largely unpredictable fluctuating energy production coming from sun, wind and waves. Today there are no relation between consumption and production. Traditionally the production has always adapted to the demanded consumption. The energy is used when there is a demand. There is no built in flexibility in the consumption and even if people had incentives to vary their consumption, it would be difficult to handle. Without flexibility on the demand side the future need for energy storage and balancing power from other countries will be huge (and expensive).

The background for the DREAM project is to start preparing the electricity consumers for a future where they can actively work with the electricity production rather than against it – i.e. applying Smart Grid to

[1] LOV nr 577 af 18/06/2012

enable demand side flexibility. Getting Smart Grid technology out into all homes are the core idea behind DREAM.

4. Smart Grid functionality

Smart Grid Ready is a very general term used in different ways around the World. Some countries define electronic meters with remote reading as Smart Grid because it reduce losses due to meter manipulation. In northern Europe Smart Grid equipment, describe an electric equipment that can be remotely managed to assist the electric grid working more efficient or stable. Remote management of domestic equipment has to respect agreed comfort limitations. The DREAM project’s view on Smart Grid Ready in Denmark is the ability to regulate electric load down (or up where feasible) by an external controller using existing open communications and control standards. It is a base assumption in the DREAM project that Smart Grid management can benefit both TSO, DSO and BRP. TSO and the Danish Energy Association has recognised a potential for Smart Grid for a long time and invested in research. Until now the best business case seems to be in creating more flexibility in the energy balance and maybe offer aggregated regulation services.. The DSOs has not yet seen a credible documented business potential and are therefore hesitant taking responsibility for any Smart Grid implementation at distribution level. Balance Responsible Parties are monitoring the situation and preparing to handle e.g. VPP (Virtual Power Plants). The actual formation of aggregating parties trading many consumers flexibility to enable participation at energy og regulation markets are unsure. Nobody currently claims to have interest in becoming an aggregating party. BRPs operate highly competitive at the financial and legislative conditions of the markets as it is. If Smart Grid comes to exist, BRPs work with it as another finesse of the markets but they are not likely to invest in the implementation. If Smart Grid is a good idea, who is then responsible for implementing it? The approved scope of the DREAM project does not include responsibility for implementing Smart Grid, but only trying to setup structures to help deployment of existing solutions on a large scale. Since existing Smart Grid solutions are not yet ready, the DREAM project seems to be a bit early.

The DREAM projects view on Smart Grid Ready in Denmark is the ability to regulate electric load down (or up where feasible) by an external controller using existing communications and control standards. Since DREAM has focus an large scale deployment, it is important to have flexible solutions that enable flexibility rather than limit customers options. The equipment must be open for any aggregator to manage. An aggregator may choose to work only with specific types of systems (like EVs) but cannot be allowed to dictate a specific product to customers, which would limit the customers’ flexibility to work with other aggregators later on (like SIM-locking on mobile phones). The customer should also have freedom to implement own home automation solutions on his own equipment at a later stage.

5. Acquiring existing knowledge

The DREAM project is not developing equipment but is based on using existing knowledge and commercially available equipment. A survey has been made into a number of research projects to find relevant the existing knowledge and to identify the Smart Grid ready equipment.

Criteria used in the survey.

A research project could be relevant if it has addressed some of the demand side challenges in the distribution end of the electricity supply grid with Smart Grid technology.

Relevant knowledge relates to test or implementation of Smart Grid technologies in the related equipment areas.

Commercially available equipment means that it exists as product with a description and specification. The equipment has a known price and can be ordered in large quantity. There must be a service and warranty organisation behind the product.

Smart Grid Ready in DREAM context means that the equipment as a minimum has ability to reduce power by external command. A heat pump should also be able to increase load by command until all buffers are filled. The command interface should follow open information structure and protocol based on open standards. The equipment must be able to indicate the current operational status.

Using proprietary Smart Grid setups, many projects have demonstrated that demand side management is possible. There is no clear winner regarding the control mechanisms.

Projects contacted for Smart grid Ready equipment or systems.

The following projects has been contacted in person and interviewed regarding Smart grid relevant results:

- EcoGrid.eu – Proprietary solutions, not quite ready for commercial roll out
- iPower – no SG Ready equipment identified ready for commercial roll out
- TotalFlex – no SG Ready equipment identified - Proprietary solutions used. Learning also used in SDVP2
- Smart Grid in Agriculture – no SG Ready equipment identified - Proprietary solutions used
- STVP + STVP2: StyrDinVarmepumpe – no directly SG Ready heat pump identified – but aggregating is functioning in the demonstration. Proprietary solutions used (partly open source). The results from this project will be carried into a new aggregating project: HPCOM, and this project is expected to come out with relevant results in 2016.
- Smart Grid Open – looking for equipment with standardized Smart grid Ready interface to develop conformance test. No commercially available equipment with standard SG Ready interface identified.

Other smart grid related project investigated via their web-sites:

The following projects has been surveyed via internet only regarding Smart Grid relevant results – without positive outcome:

- **Fra vindkraft til varmepumper** –suggests direction and information interchange needed to implement a SG interface but no SG Ready equipment identified

- **Smart City Kalundborg** - no reference to SG Ready equipment identified. Project terminated halfway.
- Middelfart/Føns demo project- no reference to SG Ready equipment identified - Proprietary solutions used
- **Improsume**- no reference to SG Ready equipment identified - Proprietary solutions used
- **eFlex-** no reference to SG Ready equipment identified - Proprietary solutions used
- **TWENTIES**- no reference to SG Ready equipment identified - Proprietary solutions used
- **Varmepumper, et aktiv i fremtidens energisystem** (VAFE)
- **Intelligent Fjernstyring af Individuelle Varmepumper** (IFIV)
- **SDVP Connect**
- **READY** – Smart Grid Ready Controller for Heat Pumps
- **READY** - Resource Efficient cities implementing ADvanced smart citY solutions
- Insero Live Lab
- DSO challenges from introduction of heat pumps
- Sommerhuse og smart grid - et plug 'n play-koncept

From several Smart Grid R&D projects the response is that the roll out of a Smart Grid is a good idea[2] because it provides a needed flexibility but also needed to optimize solutions for large scale roll out. It is also stated the there is no reason to stop the preparation for a Smart Grid future but it may be necessary to look at some interim Smart Grid solutions depending on proprietary control and communication.

If proprietary management and communication can be accepted as a temporary solution then several systems have demonstrated successful aggregation and VPP capability with different suitable heat pumps. Several large heat pump manufacturers 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 (IESamba)" nearly ready for commercial operation with different heat pumps using their own communication interface. See more under the heat pump section below.

The Ecogrid.eu demonstration project, at the island of Bornholm, has several hundred heat pumps installed in private homes [1]. 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.

[2] E.g. EcoGrid Bornholm; iPower; Styr din varmepumpe

6. Smart Grid Ready standards

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 favorite 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 but the information structure is stringent and well accepted by control people.

Lately, a competing OpenADR standard from USA is being introduced 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 for demand side management.

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.

At the time of this report, there is no push for agreeing any standards. It could seems that the different stakeholders are waiting for someone else to take initiative. Maybe because initiating activity could involve at least moral if not economical responsibility for getting to a result.

7. Heat pumps and other equipment.

Currently only Electric vehicles can be assumed to be smart grid ready via the suppliers of charging services. Politicians and researchers have been nervous that black outs because of too many electric vehicles would be used as another argument against the EV. Because the introduction of the EVs has happened at a very modest rate all the standards needed to handle EV charging with demand side management is in place. There is even proposed standards for V2G (Vehicle to Grid) where energy is taken from EV batteries and fed back into the grid. The SG Ready functionality can be tested by the NEVIC centre at DTU, where also compatibility between EV and charge station can be verified. There are a number of companies offering charging infrastructure or charging service e.g. the company Clever, that offer access to a number of fast chargers and home charging on subscription base.

In DREAM context also PV systems are considered Smart Grid Ready. Most PV systems has control inputs that can reduce power or interrupt production. Eventually the connection to the grid can be disconnected to reduce power. In Germany, any larger PV system must be able to react to control signals (ripple signals). Since the control algorithms from larger inverters tend to be inherited by the smaller systems almost all PV inverters will be able to react to high-level commands e.g. via RS485. In Denmark there is no focus on PV systems since the netto-tariff was changed to a much less attractive feed-in tariff. Even though many modern PV inverters have functionalities built in that can offer local reactive compensation (VAR-compensation) and frequency stabilizing functions besides ordinary curtailment. Slightly more advanced communication is preferred for such advanced functions. Because there is very little interest in PV nobody seems to show any interest in Smart Grid manage Danish PV. But if somebody decide to go for Smart Grid management of PV, most systems could be retrofitted at a marginal cost.

No home automation candidates have be nominated as Smart Grid Ready yet. E.g., the iPower project has monitored the home automation area and they have not found a Smart grid Ready candidate worth looking into. Home Automation is still an interesting component when it comes to adding extra value to some of the Smart Grid investments needed to enable control of other Smart Grid equipment in the house. Home automation systems offering the necessary control of PV and/or heat pumps might be able to serve as a smart grid gateway to these along with other energy functions in the house. Currently Home Automation is ignored as Smart Grid Ready equipment on it own.

That leaves the heat pump to be looked at. Many heat pump research projects has been done and several is still under ways. Heat pumps cannot be assumed to have any standardized interface for Smart Grid management.

7.1 Heat Pump Smart Grid survey

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.

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:

2. The heat pump can respond directly to e.g. a price signal over the Internet, without modification.
3. The heat pump can be adjusted/upgraded to respond to e.g. a price signal over the internet.
4. The heat pump can be set to different "modes" over the Internet.
5. The heat pump can be set to different "modes" through a local connection (external box).
6. Start / stop and set points can be controlled over the Internet.
7. Only start / stop can be controlled over the Internet.
8. Start / stop and set points can be controlled via local connection (external box).
9. Only start / stop can be controlled via local connection (external box).

10. Remote control and sensor-values only available by physical modification and adding external equipment, but supplier has interest in development.
11. 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.

Evaluation	Rating	Description
Good candidate	Ca. 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	Ca. 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	Ca. 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.

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:

None of the heat pump manufacturers was rated grade 1 and thus none of the participants in the questionnaire has "plug-and-play" Smart Grid system solutions. The 'plug and play' is understood as 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 for reducing power. 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 and Nibe, will often have high-level communication built into all models but not necessarily comply to open standards.

Forhandler / produkt	Typer	Ready -ness	Åbent system	Kommenter
Heat Pump Supplier #1	V/V, L/V	2	Nej	Deres VP'er er klar til styring efter et pris signal gennem deres lukkede system, men det er usikkert hvordan. Der er kun mulighed for eksternstyring af start/stop og setpunkt for FL-temp. Alle målinger kan trækkes ud gennem deres kommunikations-modul. De er åbne overfor en anden styring.
Heat Pump Supplier #2	V/V, L/V, L/L	2	Ja	Deres VP'er kan sættes til at hente en datafil online med 24 timers pris information (Nordpool), som VP'en kan reagere efter. Derudover kan VP'erne styres eksternt, og en del målinger kan udlæses, bl.a. varmeeffekt. #2 virker desuden meget interesseret i et samarbejde.
Heat Pump Supplier #3	V/V, L/V	4	Ja	Deres VP'er er Smart Grid ready efter den tyske definition, hvor der er 4 "modes" som aktiveres med to kontakter (2bit). Der skal altså en ekstern enhed til at vælge en af det 4 "modes" i hht. en elpris. Der er mulighed for eksternstyring af start/stop og setpunkt for FL-temp og BV-temp. #3 forventer at videreudvikle Smart Grid løsningen, så driftsindstillinger kan ændres over internettet.
Heat Pump Supplier #4	V/V, L/V	4	??	Deres VP'er er også Smart Grid ready efter den tyske definition, hvor der er 4 "modes" som aktiveres med to potentialefri kontakter (2bit). Der er mulighed for eksternstyring af start/stop og setpunkt for FL-temp. Der kan tilsluttes et GSM-modul.
Supplier #5	-	5	Nej	De levere "kun" styringen, som bl.a. bruges på xxx VP'er. De har mange forskellige produkter, men med udgangspunkt i en standard xxx VP vurdere de sig til delvis Smart Grid ready. Deres system er lukket, så det vil altså kræve arbejde fra deres side at få VP'en gjort Smart Grid ready. Det er de dog villige til.
Heat Pump Supplier #6	V/V, V/L	5	Ja	Der er kun mulighed for eksternstyring af start/stop, setpunkt for FL-temp og BV-temp kan ændres med deres eget online system. Målinger af FL-temp og Ude-temp kan trækkes ud gennem dette system. Det vides ikke om online systemet kan tilgås eksternt, men de virker umiddelbart åbne overfor samarbejde.
Heat Pump Supplier #7	V/V, L/V	5	Ja	Deres VP'er har mange interface-, styring og informationsmuligheder. Der er bla. WEB-interface og usb. De er ikke åbne over en anden styringsenhed. Det vurderes at der kræves et eksternt system som kan indstille setpunkter og/eller starte/stoppe VP'en, udfra et pris-signal.
Heat Pump Supplier #8	V/V, L/V, L/L, BV	7	??	Informationen var mangelfuld, og videre opfølgning er ikke blevet besvaret. Det vides at deres varmepumper kan startes/stoppes og SET-punktet kan ændres via eksternt signal. Det gives intet information om kommunikationsplatformen.
Heat Pump Supplier #9	L/V	10	Nej	Varmepumpen har ikke mange funktioner, og ingen mulighed for ekstern styring. Der kan dog trækkes enkelte målinger ud. #9 virker umiddelbart ikke interesseret i at klargøre deres produkter til Smart Grid eller i at indgå et samarbejde.

Forkortelser: V/V = Væske/Vand, L/V = Luft/Vand, L/L = Luft/Luft, BV = Boligventilation, FL-temp = Fremløbstemperatur, BV-temp = Brugsvandstemperatur, VP = Varmepumpe

*Ikke oplyst, men vurderet ud fra information på hjemmesiden og/eller Inseros rapport (Insero Energy A/S, 2013).

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 [2].

Looking for a potential standard interface allowing both up and down regulation, the SGO project is attempting lab verification of the German BWP SG Ready label. First finding at time of this report is that Bosch in Denmark may be able to source an air-to-water heat pump for test but currently unable to source a water-water heat pump compliant with the BWP SG Ready label. It has been very difficult to get any third party assessment of the BWP label arrangement, so it has yet to prove itself as a future standard heat pump interface.

7.2 An interim solution for DREAM?

Several heat pump brands actually offer existing proprietary solutions for aggregation, which have some potential for demand side management. They use high level communication with their own heat pumps and some even invite other brands through a dedicated interface box. The purpose of these systems may partly be to monitor their products in operation but to the customer they can offer extra services like time scheduling, energy price depending demand side management. Some advanced hybrid heating units with combined NGAS and heat pump on the German market offer automatic preference for either NGAS or electricity hour by hour depending on actual energy cost.

Systems exist to offer services to domestic customers and it might be acceptable to use such a service in DREAM context as an interim solution, until an open standards solution is available for commercial roll-out. But before going down that route there are a couple of projects working actively on creating a platform of interest to DREAM. It is not yet a fully commercial ready product but it is based on open standards and open source software. (See 7.3)

7.3 Heat Pump aggregating platform for DREAM

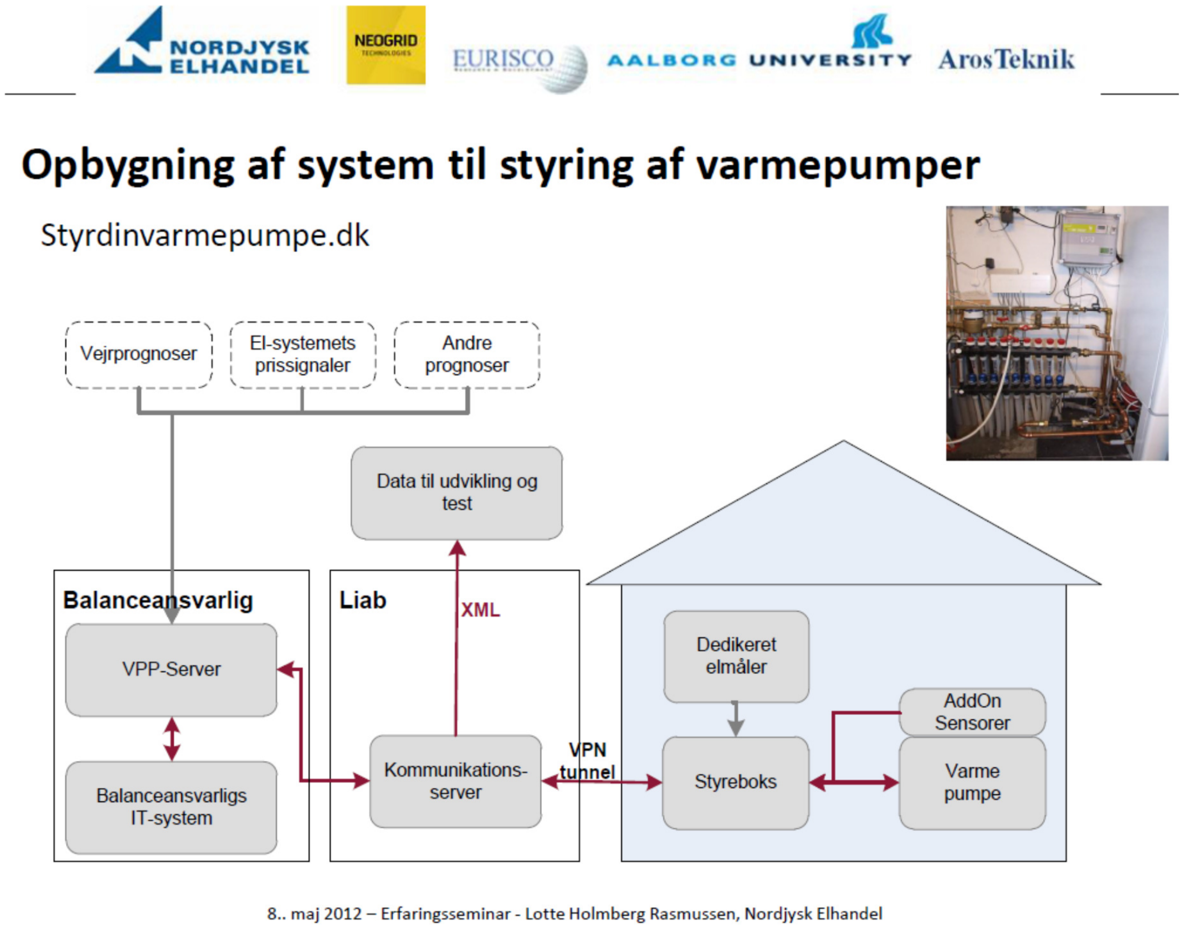

Figure 1 Example on SDVP setup

If the intentions of IES a.m.b.a. and the Projects SDVP Connect and HP-COM succeed, there should soon (in 2016?) be a software platform commercially ready to support many heat pumps (and other equipment). IES amba is establishing an IT platform for future heat pump aggregation where both server and client software are Open Source based on open standards (SSL, IEC 61850, XMPP). This should enable others to either use the platform or implement a similar platform and make a competitive offer to customers. This is currently the best option that has been identified.

Awaiting better open solutions, in the future an interim solution for the next phase of DREAM could be to take e.g. Bosch in as a partner or supplier and use their proprietary server solution as aggregating service. Bosch can connect also to other brands via an interface box Bosch provide. This solution is semi proprietary but for heat pump owners, it is possible to switch to another interface box and work with another aggregator at a later stage.

One of the interesting extra values this could add to the customer is monitoring for less optimal operation. In the SDVP2 project the central accessible data was used to locate a defect 3-way valve stuck in winter position when the customer had ordered summer mode. The installation used too much energy for summer operation. It would be difficult for the customer to locate such a problem.

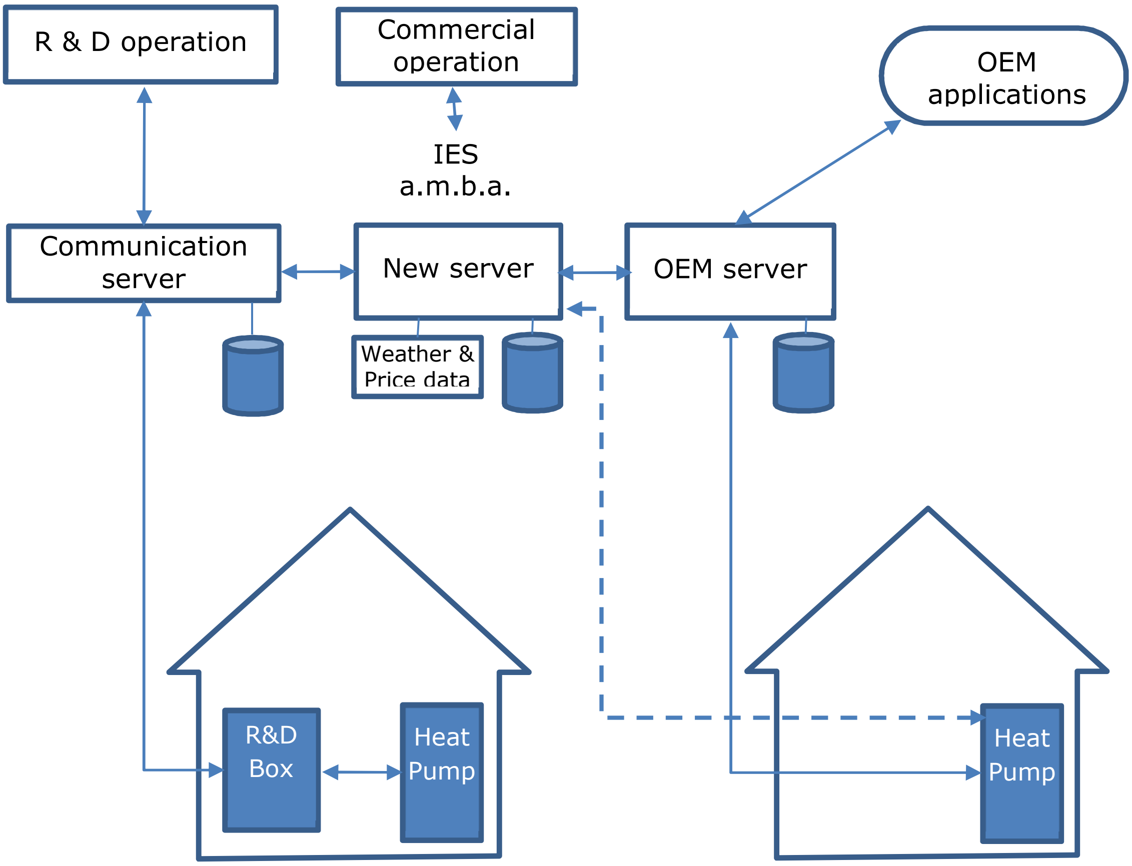

Figure 1 Illustration of the offered IES a.m.b.a. server setup.

8. Embedded Systems and Smart Grid communication

The report 'Embedded systems and Smart Grid communication' 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. A very brief summary below.

Products in a Smart Grid setting, with at market 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 simplified 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 too early to foresee whether OpenADR can win support to 'overtake' IEC61850.

OpenADR has simpler communication with smaller data packages but lack the handshake and detailed process feedback IEC 61850 offer. The built-in handshake in 61850 makes it the preferred system by some experienced Communication and Control people. 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. Financing the work is a major challenge working for open standards.

9. Conclusion

A planned Smart Grid equipment catalogue (see A1.1) with available equipment ready to use for demonstration is very short compared to the expectations prior to the project: Zero Smart Grid Ready Equipment identified.

At time of project start, general Smart Grid Ready equipment suitable for Danish homes and small business including minor DER systems was in reality non-existent and the situation has not improved much. The challenges remain the same - balancing an increasing amount of fluctuating Renewable electric energy requires more flexibility in the electric consumption. To activate possible flexible consumption within the majority of smaller consumers, cost effective solutions is needed. Components that can be switched off or powered down for shorter or longer periods should have a Smart Grid interface to manage this. Components or utilities that have potential for both decreasing and increasing its consumption should have a Smart Grid interface to enable management. Where no relevant general Smart Grid Ready components seems to exist, cooperation with an aggregator offering the required functionality can be an acceptable temporary route to demand side flexibility - even using proprietary solutions.

Large energy consumers will implement dedicated Smart grid solutions. It is relevant that new equipment in kW-range in the electric distribution network (400V level) is Smart Grid Ready. A major challenge is that the Smart grid interface often adds up-front cost to the products, which cannot be fully offset by later savings. Even though that Smart Grid may save some energy, its primary purpose is to create demand side flexibility.

Currently only Electric vehicles can be assumed to be smart grid ready via the suppliers of charging services. EV charging can be intelligently managed and supports Smart Grid management by aggregators already. 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. For any first next phases of DREAM the EV aggregation could be handled by the current suppliers of charging services like e.g. Clever.

In DREAM context PV systems are considered ready for Smart Grid. Most PV systems has high-level communication or control inputs that can reduce power or interrupt production (because of the German market). Some PV systems may even have IEC 61850 interface capability inherited from high power applications. New future PV systems are likely to have a high-level communication enabling intelligent exchange of status and performance. Even though the systems might be able to react to Smart Grid signals, there are no indications that Smart Grid control of domestic PV systems are near. Nobody express interest in the management of PV to be willing to invest in it.

No home automation candidates have be nominated as Smart Grid Ready yet. Home Automation may be considered to add extra value to some of the Smart Grid investments needed to enable control of other Smart Grid equipment in the house.

There is yet no recommended communication standards 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 to stop by aggregators using the German EVU blocking signal input, but only by using a dedicated interface box. Per July 2014 more than 440 heat pump models claim to meet a German BWP Smart Grid Ready agreement, which require the ability to operate in one of four modes from fully off to fully on. Using such an interface on the heat pumps, an aggregator should be able to offer both up- and down-regulation to the grid. The Germany Smart Grid Ready functionality agreed between members of the BWP use only to discrete signals typically communicated as ripple-signals on the grid supply cables. This type of communication is still not used in Denmark, but is a requirement for many PV systems e.g. in Germany.

Modern high-end heat pumps actually also have advanced communication built-in that allow the manufacturer to pull health and statistic information. Some suppliers offer remote controlled management e.g. based on electricity price. Such a platform could also enable the supplier to sell aggregated services. The communication is often based on standard protocols like e.g. XML/XMPP but still proprietary.

In DREAM context, the best contester for a support platform for heat pump aggregation based on open standards and open source seems to be the IES amba server with the expected extension being developed currently.

The DREAM initiative seems to be a bit early out judged by the lag of both Smart Grid Ready equipment and agreed Smart Grid standards for use in Denmark. Several Smart Grid R&D projects confirm that the roll out of a Smart Grid is a good idea[3] because it provides a needed flexibility. Demonstration is needed to verify studies and optimize solutions for large scale roll out. It may be necessary to look at some interim Smart Grid solutions based on proprietary control and communication pending common agreed standards.

[3] E.g. EcoGrid Bornholm; iPower; Styr din varmepumpe

A1. Appendix

A1.1 Smart Grid Ready equipment catalogue

Type of equipment	Supplier	Equipment – type and model	SG Ready Load-reduction	SG Ready Load-increase	Operational status feedback	Service and warranty organization	Lead time	Price level	Smart Grid potential	

The list of commercially available Smart Grid Ready equipment found in the DREAM project is empty – not by intention but because no equipment was identified during the project period.

There is yet no 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.

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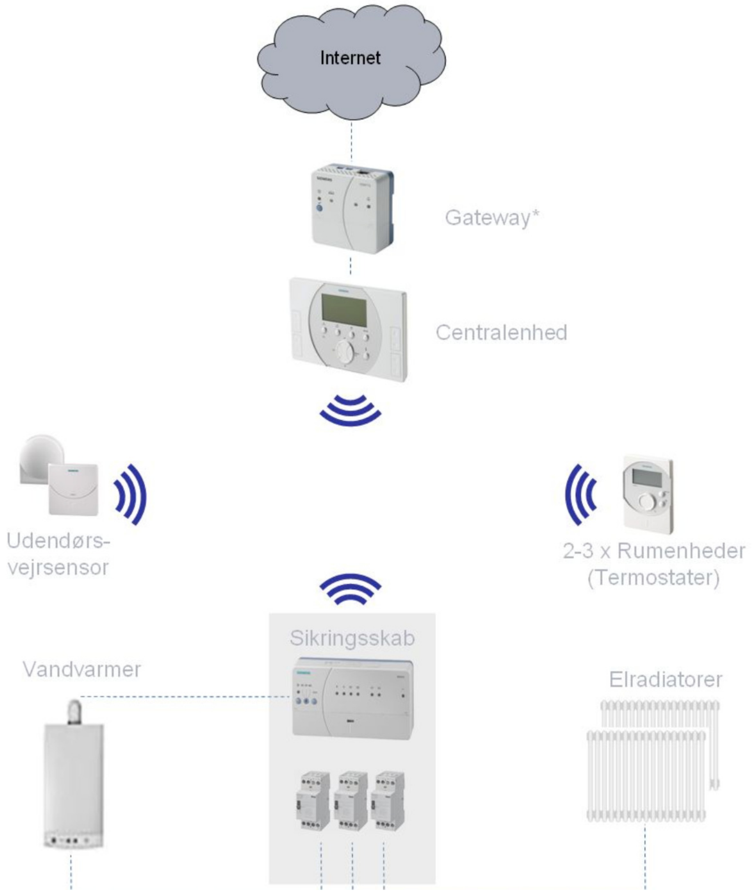
A3. Components opting for Smart Grid systems

The examples of systems and components below have interesting elements but are not yet ready for standard roll out solutions

A4. EcoGrid Bornholm

It was the hope that **DREAM could reuse** some of the experience and **hopefully** the system solutions from the large demonstration project EcoGrid Bornholm**. EcoGrid Bornhom include Smart Grid management of both electric heating heat pumps and for industys**

A4.1 Siemens EcoHome-system (EcoGrid Bornhom)



EcoHome-equipment from Synco Living gives posibility for automatic heating control in a private domestic house. The heating can be remotely controlled either by agreement with the electrical contractor or by individual set up of the accepted flexibility. Communication protocol from dedicated gateway to aggregator not public (Proprietary)

Figure 2 Nice system presentation drawing of the Siemens system used at EcoGrid Bornholm.

The Siemens Ecohome Smart Grid system is tested in domestic homes on Bornholm for electric heating control.

The Siemens hardware in each house is too expensive – requiring too many complex standard components. There is potential for a development of a dedicated solution. Problems with stable contact to wireless sensors.

A central element in the EcoGrid Bornholm project is the Aggregators Smart Grid reaction to price forecast. The consumption and the prices is updated at 5 minute frequency. Even reading modern electronic meters at 5 minutes interval turned out to be a challenge requiring additional external equipment.

The major delays getting the systems operational has disappointed some private participants.

Figure 3 The real world system has a high number of required components driving the price too high to be competitive.

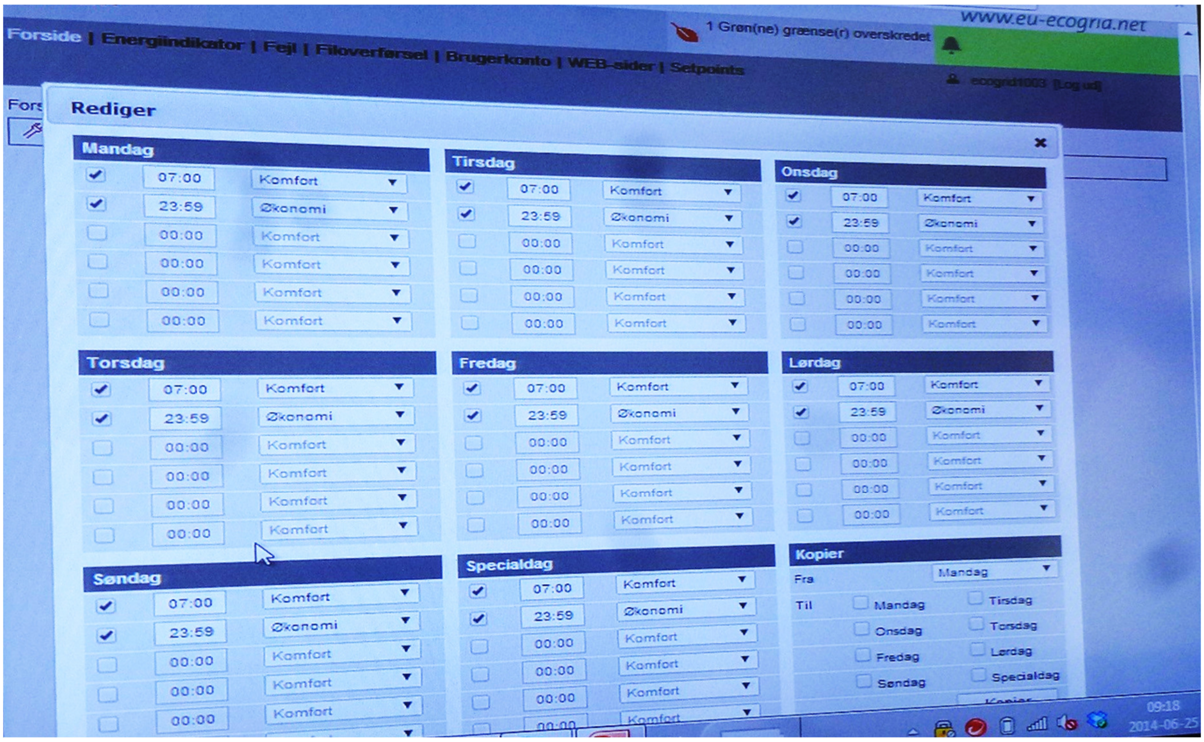


Figure 4 EcoGrid Bornholm Siemes system; Each family has an internet log-in to a common server where they can set schedules for heating priorities.

A4.2 GreenWave-system / IBM (EcoGrid Bornhom)

A system solution for heat pump control from GreenWave reality and IBM is tested in domestic homes on Bornholm.

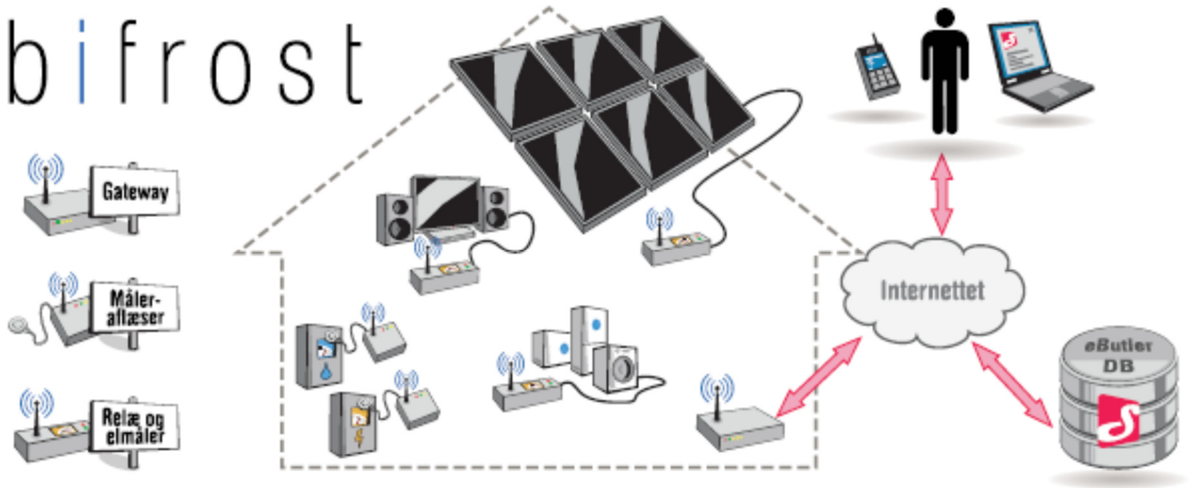
Figure 5 EcoGrid Bornholm demo setup og heat pump control

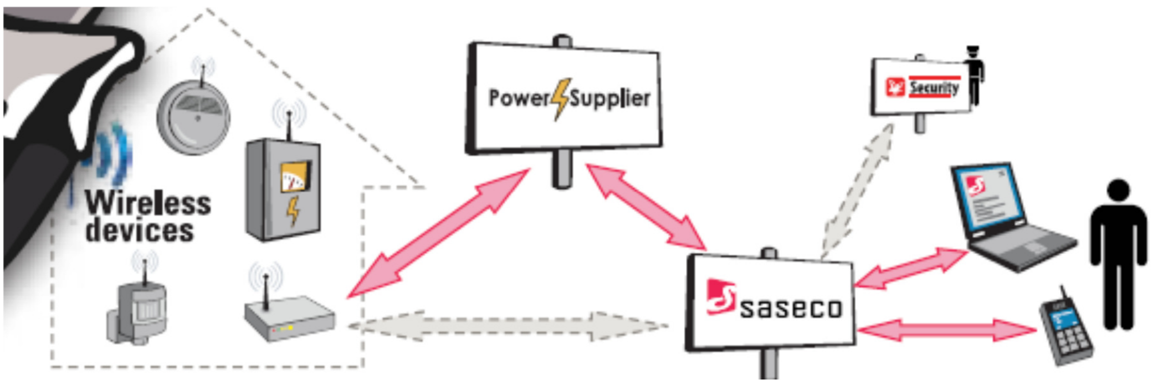
The user friendliness and reliabillity needs to improve before a larger roll out is recommended.

The EcoGrid Bornholm technologi partners had no solution for air – air heatpumps.

A4.3 Saseco eButler-system (iPower)

Bifrost hardware with eButler control. DREAM had hoped that eButler in the iPower project would develop into a homeautomation system that could function as a Smart Grid gateway to no Smart Grid ready equipment in the homes. Saseco focused on systems sale to





Saseco became part of Kamstrup by October 2014. Kamstrup is Denmark's leading producer of energy and water meters. This may streghten the basis for the Saseco product range but that will have to show over the next year.

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A4.4 Develco components (several projects)

Develco offers hardware components to system vendors. Only.
Develco has a components range potentially very relevant to future Home Automation with Smart grid control. Currently the products are sold only through a few DSO's
TDevelco use both eiter ZigBee or Z-Wave in their products, as these protocols have different advantages.

A4.4.1 ZigBee

Fordele ved at bruge en standard som ZigBee:

- Interoperabilitet
- Silicium (chips) kan fås fra en række forskellige leverandører
- Kontinuerlig optimering af silicium
- Pris, størrelse, strømforbrug osv. falder hele tiden

ZigBee bruges, når der ønskes interoperabilitet. ZigBee er f.eks. velegnet til:

- Automatisk måleraflæsning (integration i måleren eller via ekstern gateway)
- Displays til visualisering af strømforbrug
- Låsesystemer
- Lyskontakter
- Lysdæmpere
- Sensorer af enhver art (lyssensor, temperatursensor, fugtighedssensor, bevægelsessensor (PIR), CO2-sensor...)
- HVAC (pumper, ventilation, osv.)
- AC/DC motorer
- Fjernbetjeninger
- Home Automation af enhver art

Fordelen ved en åben standard, er at man kan købe en kontakt fra en producent og en lysdæmper fra en anden, og så "snakker" de sammen uden problemer.

A4.4.2 Z-Wave

Z-Wave er en trådløs protokol, der drives af organisationen Z-Wave Alliancen. Produkter baseret på Z-Wave skal have en certificering for interoperabilitet.
Den trådløse standard Z-Wave bruges primært inden for home automation. Her anvendes den bl.a. til:

- Lysstyring
- Varmestyring (HVAC)
- Adgangskontrol
- Fjernstyring
- Sensorer
- Styring, måling og overvågning af forskellig art

Z-Wave er en let tilgængelig standard, der er forholdsvis simpelt at anvende.

More information on Z-Wave: http://www.z-wavealliance.org/

A4.4.3 Gateways

Develco has developed several gateways. A gateway is a bridge between different system protocols:

- Ethernet - ZigBee
- IP - Z-Wave/ZigBee
- GAM - ZigBee
- Bluetooth - Proprietære protokoller
- Ethernet - RS485, RS232, CAN m.v.

A4.4.4 ZigBee Home Automation products

Develco Products provides a wide range of ZigBee HA certified products. The products are available in different versions depending on the actual needs and technical environment. Develco Products also provides a wide range of ZigBee HA compliant products.

Overview ZigBee HA certified products:

- ZigBee - Ethernet gateway - ESI serves as data concentrator.
- ZigBee - GSM gateway - ESI serves as a data concentrator.

- ZigBee - Wall plug meter relay enables you to switch your equiment on/off remotely.
- ZigBee - DIN meter relay enables you to switch your equiment on/off remotely.

Overview ZigBee HA compliant products:

- USB gateway serves as a data concentrator.
- Occupancy, temperature & light sensor enables you to detect movement and light as well as measuring temperature.
- Magnetic sensor enables you to detect door and window status.
- Optical smoke sensor enables you to detect smoke and temperature.
- Key fob enables you to adjust various settings depending on your needs.

Some interesting Develco products with potential relevance for Smart Grid upgrade of an existing heat pump. They all require a ZigBee gateway. The gateway with a local controller can form a standalone system but to enable Smart Grid functionality there must be a Smart Grid ready communication option. The system in the house will be a client. There must be a server application somewhere to aggregate / relay information.

Few examples of ZigBee products:

ZigBee Example: Smartplug with Schuko connector
ZigBee based on/off wall plug relay
ZigBee Wall Plug Meter Relay HA

Smartplug with Schuko Connector

ZigBee Example DIN Relay w. Meter HA

ZigBee based
ZigBee based on/off Relay for DIN Rail Mounting

The ZigBee based on/off relay for DIN rail mounting enables you to switch your equipment on or off remotely, e.g. by SMS, GPRS, Ethernet or by another communications path depending on the gateway.

Zigbee Example Multisensor (PIR,Temp,Light)

ZigB
ZigBee based Home Automation multi sensor for occupancy, temperature, and light
The multi sensor enables you to detect movement and light as well as measuring temperature.

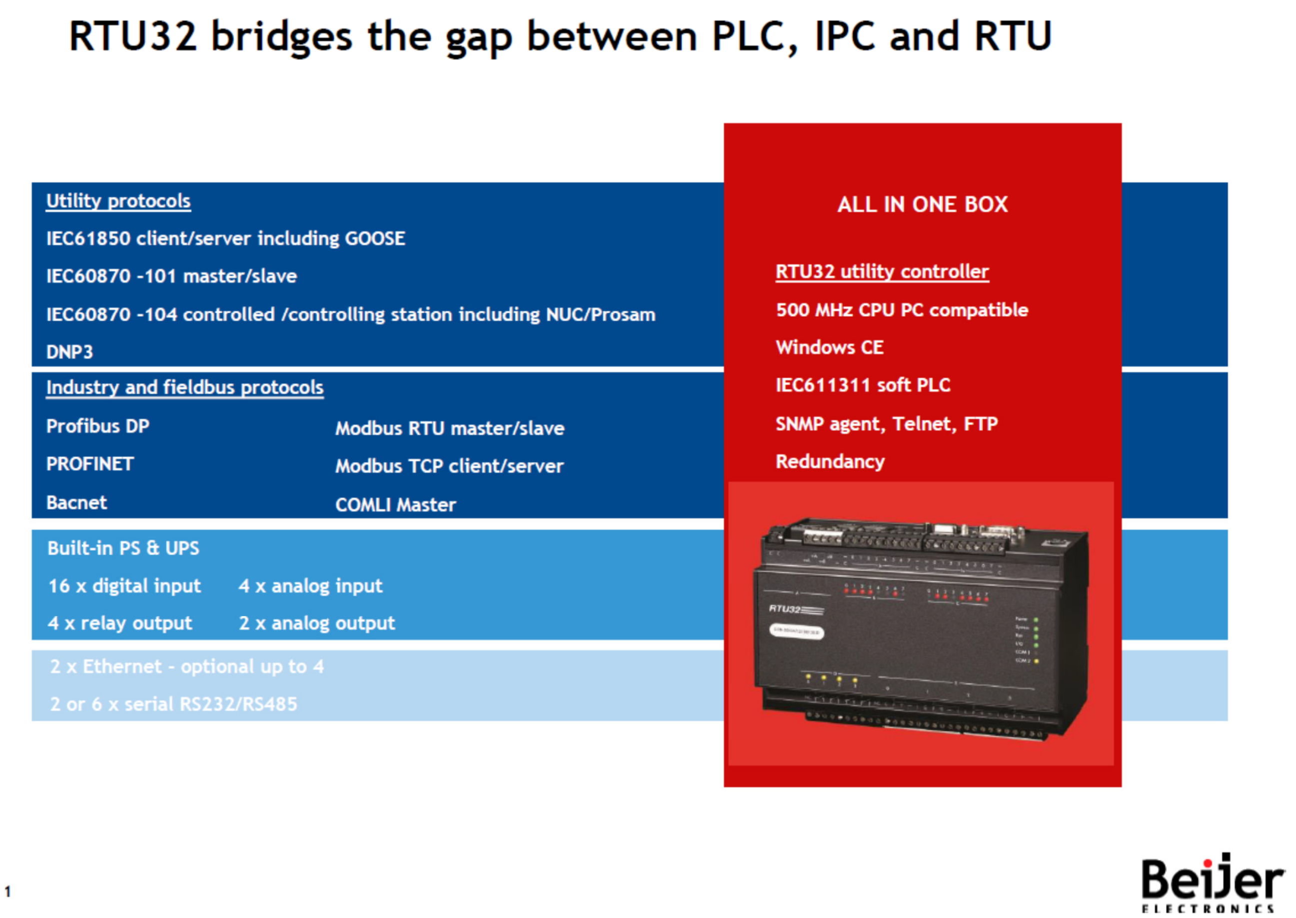
Combinational products like this can help drive the price down on home automation systems offering diversified services.

A5. Smart Grid back-up solution?

If IEC 61850 becomes the agreed Smart Grid communication standard and no equipment offers built in support for this standard, there may be a back-up solution. Using a RTU that has the proper protocol support can bridge the technology gab for limited demonstration. RTU units are still too expensive for massive roll out but could be an acceptable solution in the first limited DREAM campaigns.

Communication between systems always pose a challenge. Not only protocols but more important the interchanged information are often dedicated the actual applications. Some attemps have been made to develop gateways that can bridge different HBES. In the professional sector a unit like the Beijer RTU32 can serve as Smart grid gateway.

A5.1 RTU32 gateway - IEC 61850 compliant



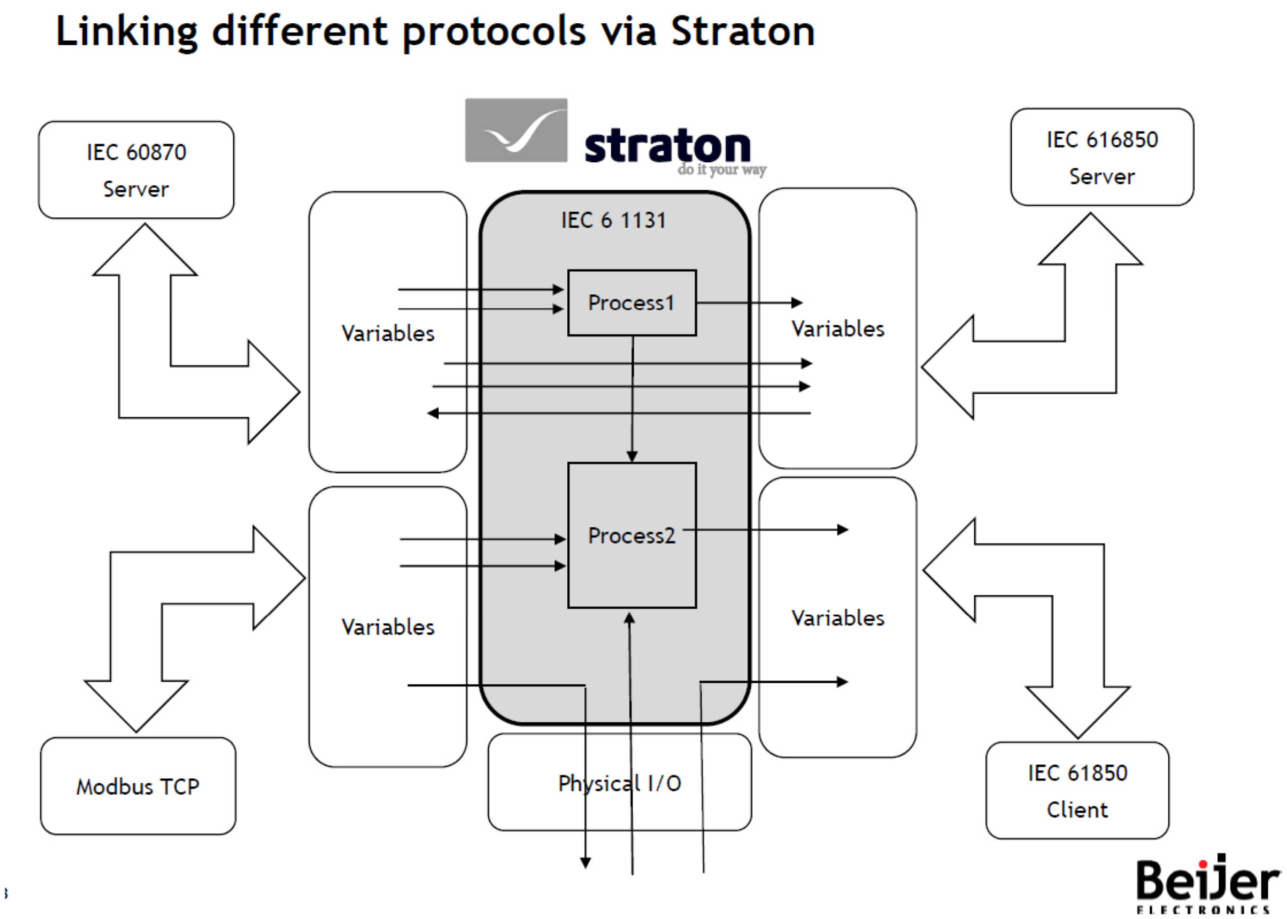


Figure 6 Example of gateway functionality of a RTU.

Example: Excerpt from Brodersen RTU32S data

The Brodersen RTU32S Series is a small and compact RTU, PLC and Industrial Controller.
RTU32S comes standard with 28 built in I/O. 16 digital IN, 8 digital OUT, 4 analogue IN.

The RTU32S Series also features:

- WebServer configuration
- Advanced PLC function support with full IEC61131 language compliance
- Ethernet and serial communication ports for flexible connectivity to SCADA, field devices and remote systems
- Multiple communication driver support
- Support for wide range of communication medias - radios, PSTN, GSM, GPRS, 3G etc.
- Flexible I/O support provided via integrated and expansion I/Os
- Several integrated power supply options

Supported Drivers & Protocols:

- IEC61850 Server, inclusive GOOSE
- IEC61850 Client
- IEC60870-5-101 Master & Slave
- IEC60870-5-103 Master
- IEC60870-5-104 Server & Client
- DNP3 Slave & Server
- Modbus Full Suite
- COMLI Master
- SNMP Agent for network management etc.

- IEC 60870 standards define systems used for telecontrol (supervisory control and data acquisition).

A6. Peaceful Co-existence at the network.

As "Internet of things" evolve, it can be assumed that more and more networked equipment will have some level of Smart Grid functionality. It is relevant to ensure that these can coexist at the same network without interfering each other. It is relevant for all Smart Grid ready components to meet three levels of integration but especially relevant for Home automation systems where many different types of equipment is likely to share the same network and the same field for wireless operation:

Co-existence - where different systems can operate in the same environment without hindering each other's' operation;

Interworking - where different technologies are connected together to transfer data end-to-end. It is primarily a technical solution encompassing connectors, protocols, bridges, etc.;

Interoperability - where different application functions are able to use the shared information in a consistent way. This requires interworking as a building block as well as coexistence, and adds business rules, processes, and security provisions that enable applications to be joined together.

As part of standardization preparation the Home Automation definitions has be thoroughly described and for information interoperability level illustrations are enclosed below.

Central standard for Home Automation: EN 50090

Interoperability Framework Requirement Specification for service to the home. (IFRS)

Some illustrations on Home and Building Electronic Systems (HBES) Interoperability levels follows below.

Level 0	A single system of supplier-defined structure built from devices using a single HBES specification and locally defined interoperability verified by the supplier for one or more application domains. No assurance of coexistence is provided.
Level 1	A Level 0 system operating across one or more application domains Verified coexistence is required.
Level 2	Multiple Level 1 systems that interwork to exchange information and interoperate across specification and application domains verified by the suppliers using conformance specifications agreed by each HBES specification used.
Level 3	As Level 2, and the interoperability is verified with respect to international standards applicable to the HBES specifications used in the system.
Level 4	As Level 3, but conforming to IFRS so that the applications and devices can be installed, managed and changed during the operation of the system by a qualified installer.
Level 5	As Level 4, and changes of application and devices will be done automatically.
Level 6	As level 5, and with remote management, diagnostics and maintenance. (automatic installation, operation and support).

In the SGO project levels up to "Interchangeable" are addressed.

SGO compatibility levels						
	Incompatible	**Coexistent**	**Interconnectable**	**Interworkable**	**Interoperable**	**Interchangeable**
Application interface						
Information interface						
Service interface						
Protocol interface						
Physical interface						

A6.1 Interoperability model examples from level 0 to 5 and 6.

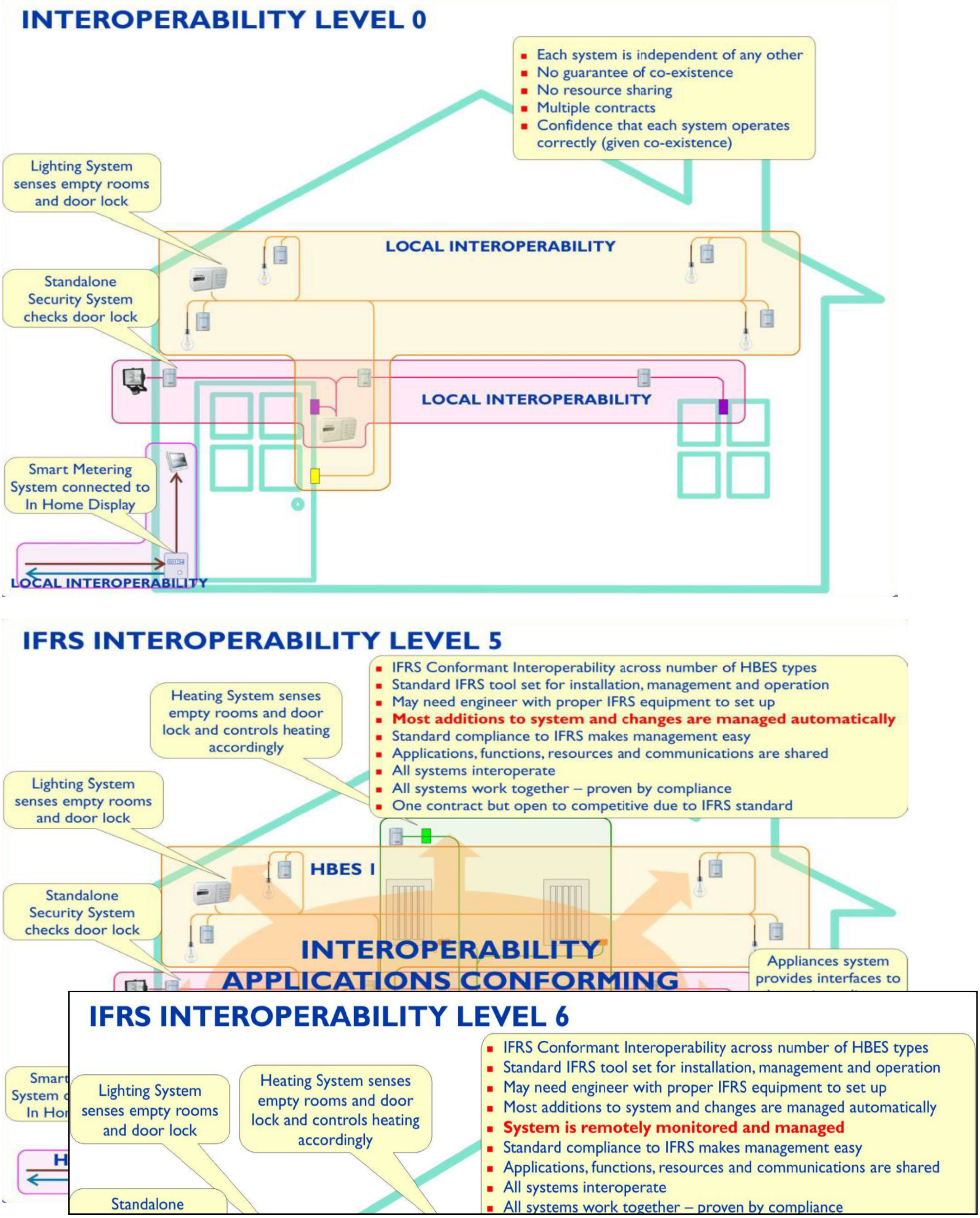


Figure 7 Examples from HBES standardization initiatives

A7. List of standards relevant to the Smart grid area

Recommendation regarding standards; Excerpts from DanGrid workgroup 23 final report 14. Sep. 2012:

To be ready for integration in a smart grid environment in Denmark include the information used models, data, objects, protocol stacks, and the electrical interfaces and protocols used must within a time frame of 3 - 5 years meet the following requirements:

- All information and data objects created as well as derivative and / or aggregated information must follow, but are not limited to, the specifications listed in IEC 61850 and IEC 61400 standard series.
- Where information or data objects are found in the IEC 61850 series of standards, specifications must follow the domain specific definitions in IEC 61850-7-x in general. Eg. must DER units comply with the specifications in IEC 61850-7-420 standard and wind power plants must follow the specifications of IEC 61400-25-2 standard.
- Any protocol stack must follow, but are not limited to, the specifications of one or more of the following standards IEC 61850-8-1 (mapping to MMS), IEC 61850-8-2 (mapping to Web Services), IEC 61850- 80-1 (mapping to IEC 60870-5-104); IEC 61400-25-4 (mapping to WebServices, OPC / XML, MMS, DNP3, IEC 60870-5-101 / 104).
- In time security precautions must follow, but are not limited to, the specifications given in IEC 62351 standard series with a preferred focus on the use of role-based access control as specified in IEC 62351-8 (RBAC).
- Within a time frame of 5 - 7 years required compliance with the requirements of IEC 61970 (CIM EMS) and the requirements of IEC 61968 (CIM DMS) standard series of services and applications being developed for use in transmission and distribution systems.
- Any compliance tests for check of interoperability must be performed as indicated in the test scenarios / or testing standards as required by / or relevant to the above standards. The above standards developed under the IEC Technical Committee 57 (IEC TC57) assigned to communication within the power systems, and IEC Technical Committee 88 (IEC TC88) that specifically focuses on standards for wind power, including communications with wind turbines and wind power plants.

A7.1 IEC 61850 standard series for substations

IEC 61850-1: Introduction and overview

IEC 61850-2: Glossary

IEC 61850-3: General requirements

IEC 61850-4: System and project management - Ed.2

IEC 61850-5: Communication requirements for functions and device models

IEC 61850-6: Configuration language for communication in electrical substations related to IEDs -Ed.2

IEC 61850-7: Basic communication structure for substation and feeder equipment

IEC 61850-7-1: Principles and models - Ed.2

IEC 61850-7-2: Abstract communication service interface (ACSI) - Ed.2

IEC 61850-7-3: Common Data Classes - Ed.2

IEC 61850-7-4: Compatible logical node classes and data classes - Ed.2

IEC 61850-7-420:

IEC 61850-7-10: Communication networks and systems in power utility automation – Requirements for web-based and structured access to the IEC 61850 information models

IEC 61850-8: Specific communication service mapping (SCSM)

IEC 61850-8-1: Mappings to MMS (ISO/IEC9506-1 and ISO/IEC 9506-2) - Ed.2

IEC 61850-9: Specific communication service mapping (SCSM)

IEC 61850-9-1: Sampled values over serial unidirectional multidrop point to point link

IEC 61850-9-2: Sampled values over ISO/IEC 8802-3 - Ed.2

IEC 61850-10: Conformance testing

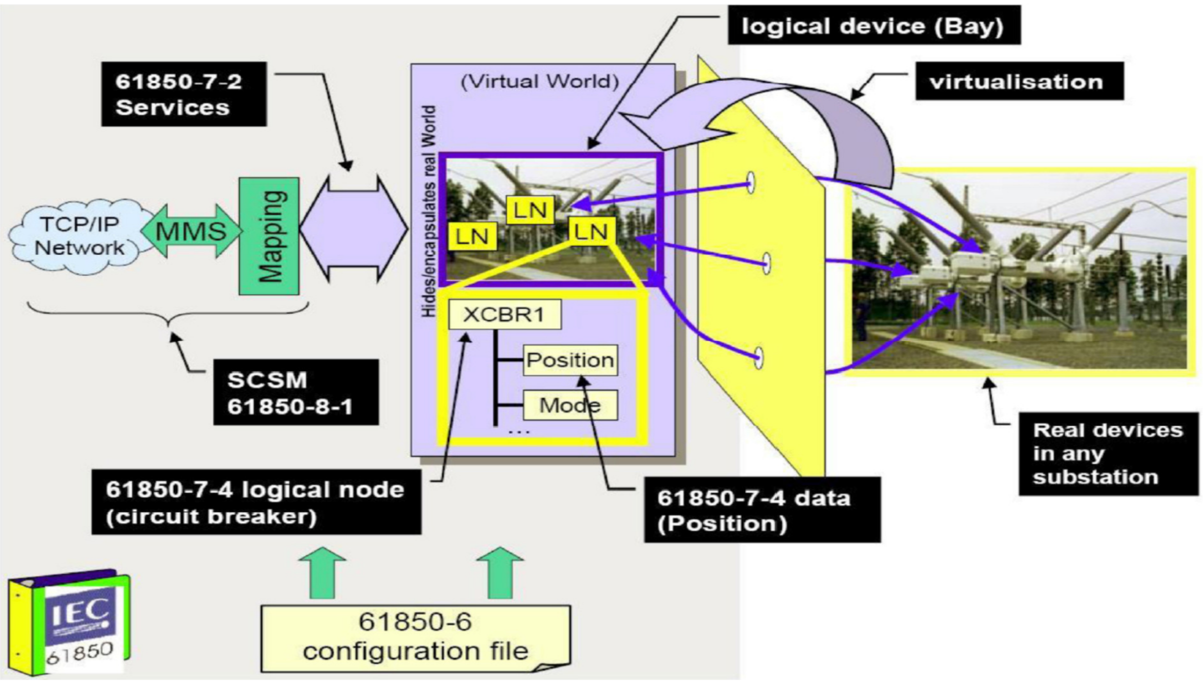


Figure 8 The IEC 61850 standard series include diverse areas of substation management.

There are similar standards families for:

- Wind turbines and Wind parks: IEC 61400-25 standard series
- Distribution Management: IEC 61968 standard series
- Energy Management: IEC 61970, 62056 and 62325 standard series (information interchange at transmission at control room level)
- Market information: IEC 62325 standard series; (information interchange at market based concepts)
- Data Security IEC 62351 standard series

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A8. Terms and abbreviations

Terms and abbreviations	English Definitions and explanations	Definitioner og forkortelser in Danish
DER	Distributed Energy Ressource	Distributed Energy Ressource - generator-, kompenseringsenheder, batterier eller forbrugsenheder
BRP	Balance Responsible Party	Balance Responsible Party (DK: BA =Balanceansvarlig)
DSO	Distribution System Operator	Distribution System Operator (netselskab)
TSO	Transmission System Operator	Transmission System Operator (I Danmark Energinet.dk)
CIM	Common Information Model,	Common Information Model - en informationsmodel baseret på software udviklingsværktøjet UML
LNs	Logical Nodes,	Logiske knudepunkter
kW el. MW	kilo-Watt or Mega-Watt; active power	kilo-Watt el. Mega-Watt, enhed for aktiv effekt
kWh el. MWh	kilo-Watt-Hour or Mega-Watt-Hour; active energy	kilo-Watt-Hour el. Mega-Watt-Hour, enhed for aktiv energi
kvar	kilo-Volt-Ampere- Reactive	kilo-Volt-Ampere-Reaktivt - Enhed for reaktiv effekt
Mvar	Mega-Volt-Ampere-Reactive	Mega-Volt-Ampere-Reaktivt - Enhed for reaktiv effekt
Bottleneck	Restriction in the grid that limit the power capacity between areas	Restriction in the grid that limit the power capacity between areas (DK: Flaskehals)
Regulerkraft	Primary reserve	Op- eller nedregulering der leveres inden for 15 minutter på foranledning af TSO'en
Up-regulation	Up-regulation	Increase in power production (DK: Op-regulering)
Down-regulation	Down-regulation	Reducing the power production (DK: Ned-regulering)
Kommando	Command; a message that cannot be rejected	En besked som ikke kan afvises
Ordre	Order; a message that must be acknowledged	En besked som skal bekræftes
Netzone	Netzone; a specific limited area in a distribution grid	Et specifikt afgrænset område i et eldistributionsnet
Markedsplads	marketplace	Et fysisk eller virtuelt sted for indgåelse af forretningsmæssige aftaler om at udveksle specifikke ydelser
Køreplan	Schedule; for production or consumption	En plan for produktion eller forbrug af elektricitet
Aggregator	Aggregator	En service udbyder der samler styringen af (små) producenters eller forbrugeres DER-enheder overfor en BA
Elhandler	Electricity trader; trade services on a marketplace	En serviceudbyder der handler ydelser på en markedsplads
Elleverandør	Electricity supplier; selling to the domestic customer	En serviceudbyder der køber el en gros og sælger det til slutkunder
Serviceudbyder	Service provider	Serviceudbyder udbyder ydelser til kunder i et marked
Fleksibilitetsprodukt	Flexibility product	Produkter og ydelser som definerer fleksibilitet i produktion og/eller forbrug
Prosumer	Prosumer	En forbruger som samtidig producerer elektricitet
Ydelser	Services provided by an	Service, som ydes af en aktør, og hvor der er en modydelse, dvs. Betaling eller en form for afregning.
Tjenester	Services	Service, som ydes af en aktør, og hvor der ikke er nogen form for modydelse eller afregning – typisk baseret på obligatoriske vilkår i tekniske forskrifter, tilslutningsbetingelser, netbenyttelsesaftaler, leveringsbetingelser for netprodukt eller lignende.
Aktør	Legal entity	Aktører i elsystemet er juridiske enheder, anvendelsesprogrammer eller personer som indgår i værdikæden fra produktion til forbrug af elektricitet, dvs. DSO, TSO, BA, Aggregatorer, DER-enheder og Markedsplads.
Energinet.dk's forskrifter	Grid codes	Tekniske forskrifter er tekniske krav til operationsområde, funktioner, reguleringsmuligheder, el-kvalitet, beskyttelse og dokumentation som produktionsenheder i Danmark skal opfylde. De tekniske forskrifter udgør sammen med markedsforskrifterne alle krav til produktionsenheder for afregning af leveret produktion. Markedsforskrifterne specificerer endvidere krav til dataudveksling til en række forskellige formål der involverer f.eks. BA og DSO.
DMS	Distribution Management Systems - DSO level	Distribution Management Systems - DSO level
EMS	Energy Management Systems - TSO level	Energy Management Systems - TSO level
Web Service	Web Service; software that supports cooperation between systems or applications	En Web Service er en software løsning der understøtter samarbejde imellem systemer eller applikationer
RTU	Remote Terminal Unit	Remote Terminal Unit,
HBES	Home and Building Electronic Systems	Bygningsautomatisering og f.eks. alarm systemer