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ICT AS A KEY ENABLER OF MICRO-GENERATION RENEWABLE ENERGY GROWTH. THE CASE OF DENMARK

Introduction

Energy production based on renewable energy sources is an important pillar in overall Danish energy supply. In 1973 Denmark was among the OECD countries most dependent on oil in its energy supply. More than 90% of all energy supply was imported oil. While the main objectives of Danish energy policy have varied, since the energy crisis in 1973 renewable energy has been a key focus area. Danish development in the area of wind energy has been an energy policy and commercial success story. Since the first wind turbines were industrially constructed around 1980, there has been tremendous growth in technological development and turnover. This development has been particularly rapid since 1990. The technological development has been driven forward by a favourable combination of market conditions, policy and research efforts.

By 2009, 43% of the 36 TWh of electricity used in Denmark came from Independent Power Producers (IPPs). Of the 43%, wind power accounted for 18-20% and local Combined Heat and Power (CHP) around 25%[1]. As a consequence the central power utilities had their share of the electricity market reduced to little over 50% of the domestic demand. It took 10 years to dramatically shift almost half of the power production from inefficient, centralized, fossil fuel power supply to local, municipal or consumer-owned companies. The liberalisation of the electricity system has opened up new options for consumer's involvement in the Danish electricity system. Consumers can switch their energy supplier and become active partici-

[1] *Energy statistics*, Danish Energy Agency, 2010.

pants in the electricity system. This Danish model shows that a decentralized heat and power system owned by the consumers can pave the way for a sustainable energy future.

The smart grid is an important tool on the road towards independence of fossil fuels by 2050. Micro-generation enabled by ICT technologies are the key to the success of future load management and sustained conservation. Two–way interactions will enable not only more efficient management of the grid but also is expected to encourage home and business owners to install their own renewable sources of energy such as wind turbines or photovoltaic panels.

Even though ICT-based applications are already in use at grid operators to monitor the status of national grid infrastructure, renewable energy production will raise the complexity of the system and make better and faster information provision a necessity. ICTs are seen as a key enabler of a wider integration of renewable energy sources, and inducting structural shifts in electricity consumption.

Innovative ICT applications for final consumers have the potential to balance traditional information asymmetries between electricity producers and consumers and to stimulate informed energy conservation choices.

1. Micro-generation. Small scale energy production

Micro-generation is widely defined to be the small-scale production of heat and/or electricity from zero or low carbon source technologies. The suite of technologies caught by this definition includes solar photovoltaic (PV) to provide electricity and thermal to provide hot water, micro-wind (including rooftop mounted turbines), micro-hydro, heat pumps, biomass, micro-combined heat and power (micro-CHP) including small-scale fuel cells.

Micro-generation is also seen as an additional way for citizens to help combat climate change with the potential advantage of achieving energy savings without having to sacrifice comfort and to contribute to demand shifting and a decentralized generation infrastructure[2].

For electricity generating technologies, micro-generation includes both grid-connected and off-grid systems. Typically, micro-generation refers to technologies on a scale of less than around 100 kW – a scale that involves meeting energy needs for single buildings or developments. Micro-generation is about enabling efficiencies, bringing renewable energy production close to the people who consume it, and empowering people to make sustainable choices.

Denmark has developed unique experience over several decades with the integration of renewables into the power supply, and has a very flexible electricity mar-

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[2] B.A. Price et al.: *When Looking out of the Window is not Enough: Informing The Design of In-Home Technologies for Domestic Energy Micro-generation*, 2010.

ket as a result. Thus, the country has already got a head start in the development of a new intelligent power grid that is planned to allow the integration of 100% renewable energy. This system also gives people more active ownership of their energy sources. By enabling local action and empowering individuals and communities as producers, decentralisation brings about a massive cultural change in attitude to the use of energy and thus helps to stimulate energy-use efficiency.

2. Empowering consumers as micro producers

The introduction of micro-generation creates a degree of independence for consumers. Micro-wind, solar photovoltaic can reduce the need for power from the grid significantly. As consumers become "consumer-producers" they will also gain a stronger sense of ownership and control over their energy use.

The literature provides evidence that micro-generation technologies encourage energy efficient behaviour. Keirstead[3] describes micro-generation as delivering a 'double dividend' – that is, not only does micro-generation produce green energy but also give rise to reduced electricity consumption behaviour. He highlights that the installation of PV encouraged households to reduce their overall electricity consumption by approximately 6% and shift demand to times of peak generation. He pointed out that from a household perspective, system performance monitors had the most notable influence on these behavioural responses; however evolving industry arrangements for metering and micro-generation tariffs will be central in determining the future of micro-generation.

The Green Alliance's Micro-generation Manifesto[4] argued that the small-scale nature of micro-generation means that individuals can play an active part in attaining country environmental goals.

A UK study[5] observed that 88% of consumers who installed micro-generation found that household behaviour was significantly altered to reduce energy consumption after installation (including lifestyle changes as well as traditional energy saving measures).

With the ability to generate electricity and sell it back to the grid, households are no longer restricted to being passive recipients of electricity. Indeed the literature[6] has suggested that micro-generating households might become actively engaged in the dynamics of electricity production and consumption.

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[3] J. Keirstead: *Behavioural responses to photovoltaic systems in the UK domestic sector*, „Energy Policy" 2007, Vol. 35, No. 8, p. 4128-4141.

[4] J. Collins: *A micro-generation manifesto*, Green Alliance, September 2004.

[5] K. Willis, R. Scarpa, A. Munro: *Element Energy – The growth potential for Microgeneration in England*, Wales and Scotland, Element Energy Ltd., Cambridge, 2008.

[6] A. Bahaj, P. James, in press. *Urban energy generation: the added value of photovoltaics in social housing*, Renewable and Sustainable Energy Reviews; J. Dobbyn, G. Thomas, 2005.

The transition from few big centralized, fossil fuels based power stations to thousands of wind turbines, solar installations for heat and electricity is a technological and structural challenge. In Denmark the shift to renewables has taken some time with a mix of conventional and renewable energy technologies. With more and more decentralized CO2 neutral capacity the centralized plants can gradually be phased out which will stabilize consumer energy prizes and fulfil international climate commitments.

The Danish Government has implemented different strategies to promote renewable energy technologies e.g. the economic support system utilized in the form of subsidies; and the ownership structure of a technology.

The government created incentives and support to technological innovations through which citizens (in the form of individuals or cooperatives) adopted the technology. This element could have been the stimulating factor for market and community acceptance. Some research suggest that the ownership have provided a basis for success in wind projects as it created a distribution of wealth, and portrayed a sense of ownership.

3. Applications of ICT solutions in micro-generation renewable energy systems in Denmark

The role of information technology is one of the major factors that are transforming the traditional grid into smart grid. ICTs are the cornerstone in development and adoption of micro-grid solution.

Recent technological innovations have made possible for home owners to retrofit their homes and generate their own electricity and heat by the use of micro-generation technologies such as photovoltaic (PV) panels, micro wind turbines, solar water heaters, wood pellet boilers, geothermal heat pumps or combined heat and power units (CHP), thus providing electricity and heat close to the source of consumption.

As the consumer will be able to feed the electrical network with excess power, the future network will have to manage not only the power flow from the power station to the consumer but will also need to handle the back flow of energy from the consumer to the distribution network.

Seeing the light: the impact of microgeneration on our use of energy, Tech. rep., Sustainable Development Commission, London; P. Schweizer-Reis, M. Schulz, X. Vallv, I. Vosseler, E. Ramrez, J. Serrano: *Successful user schemes for photovoltaic stand-alone systems: solar energy for rural electrification - lessons learned*, Tech. rep., Fraunhofer-Institut fur Solar Energiesysteme ISE, Freiburg, 2000.

The rapid increase in renewables sources of energy is imposing new challenges such as the real time power balance, grid connections, energy storage and backup methods, and micro grid management.

The main components of the systems which are necessary for the implementation of micro-grid are: connected hardware devices installed at the consumer-producer premises enabling real-time communication between electricity producer and operator; an integrated software management systems, databases and APIs include user interface for visualization of the system status; a communication network and protocol that allow exchange of relatively small amounts of data, embedded systems and software and sensor-based networks.

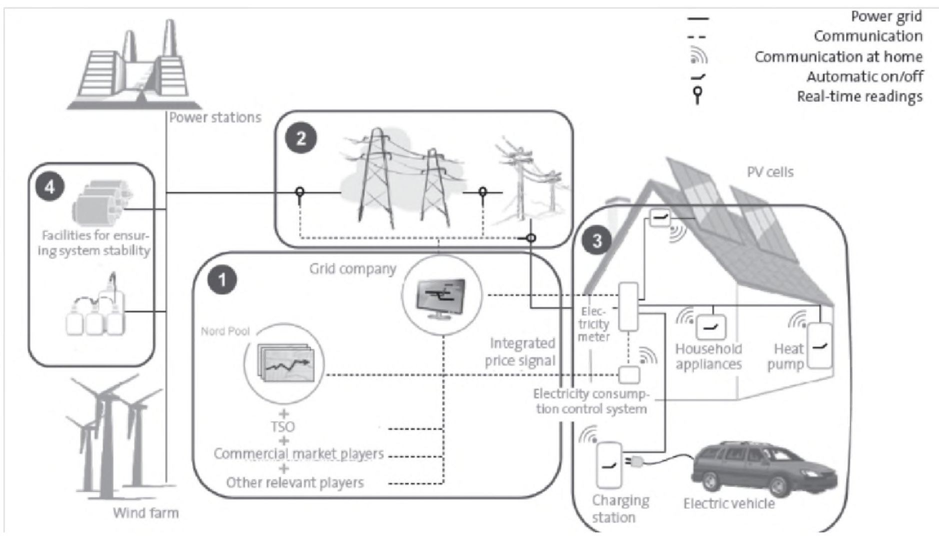

Fig. 1. Illustration of the elements of a Danish Smart Grid

Source: *Smart Grid in Denmark*, Danish Energy Association, 2010.

Rectangle 3 (figure 1) represents an effective interaction between wind power generation, PV cells, heat pumps in private households, electric vehicles and plug-in hybrid vehicles.

ICT will enable a dynamic interaction between the power system and the consumers through metering, controlling and automation in the power grid and in private households.

According to Danish Energy Association the electricity meter is an important element in the establishment of an intelligent power system, but it could not create the desired ambitious conversion to demand response and an intelligent power system alone. It is necessary to support the electricity meter data with a contractual relationship between consumer and electricity supplier that rewards the consumer for acting flexibly, e.g. settlement according to the hourly rates on the wholesale market.

Until now, the consumers have been primarily ‘passive’ with predictable and regular consumption patterns. Through ICT, the consumers will be able to interact with the power system and generation through automated and intelligent control of their electrical appliances, thereby acting as resources for the power system.

More metering, controlling and communication electronics will be present in households, which will afford the consumers an overview of their consumption and the possibility to achieve automatically controlled and intelligent electricity consumption.

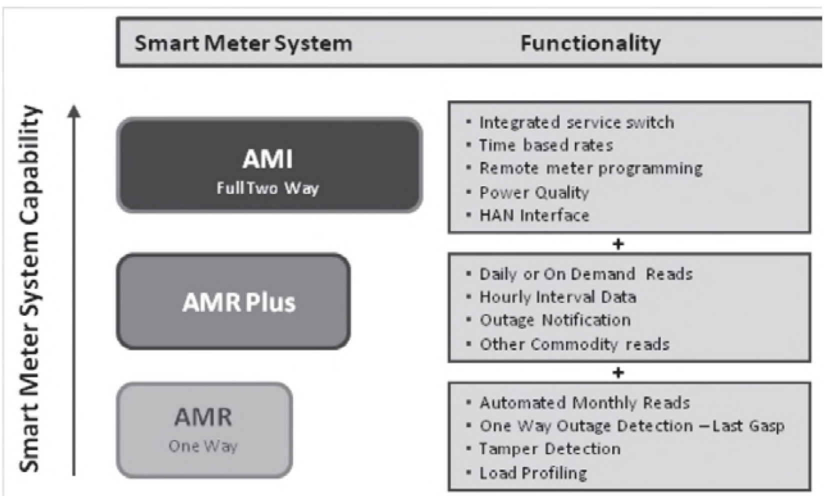

Fig. 2. Figure: Smart Meter Technology Evolution

Source: Smart Meters and Smart Meter Systems: A Metering Industry Perspective, White Paper, Edison Electric Institute, March 2011.

A flexible market supporting the development and expansion of the energy supply with renewable energy will demand old metering infrastructure to be replaced by new ones that will enable real-time monitoring and remote reading.

Advanced metering infrastructure (AMI) can be used to communicate data to consumers as well as to utilities. It will enable utilities to “collect, measure, and analyse energy consumption data for grid management, outage notification, and billing purposes via two-way communications”. AMI architectures can also enable additional consumer choice and flexibility in electricity rates and energy saving programs, increase the availability of information consumers can act on, facilitate distributed energy integration and enhance utilities’ ability to maintain power quality and respond to outages faster.

However systems for data exchange between the players in the micro-grid system requires close coordination across the interfaces of the power system, and it will therefore be necessary to establish IT systems capable of receiving and processing data about the status of the power system – for most of the parties involved – online. These IT systems should make it possible to fulfil the wishes and needs of the consumers without overloading the power system and thus reward the consumers for their flexibility.

Through IT system, it will be possible for consumers to reduce their electricity bills through intelligent consumption and automated energy-efficient solutions by letting their electrical appliances function automatically at predetermined comfort levels to the benefit of both themselves and the power system[7]. Smart appliances could communicate with the electric grid to recognize the source and cost of electricity, and provide and adjust services accordingly. Smart appliances could be programmed to respond to authorized commands from the utility to help regulate demand[8].

Mobile applications will provide remote control and management of consumers' smart thermostats and other appliances. We will also observe that utilities will embrace mobile platforms as being integral to their customer relationship and residential demand response programs.

The role of Home Energy Management and Demand Response systems for Smart homes and micro grid management will grow considerable. It will enable an environmentally-friendly and effective way to put flexibility back into the power system by complimenting the increasing penetration of variable renewable resources and supporting distribution automation systems.

Even though ICT-based applications are already in use at grid operators to monitor the status of national grid infrastructure, renewable energy production will raise the complexity of the system and make better and faster information provision a necessity. ICTs are seen as promoting a wider integration of renewable energy sources, and inducting structural shifts in electricity consumption.

Innovative applications for final consumers have the potential to balance traditional information asymmetries between electricity producers and consumers and to stimulate informed energy conservation choices; over 10% of an individual household's electricity consumption can be cut by simply providing better information.

Conclusions

The future electrical network will encourage new technologies and business services, which in turn will require interoperability and interfacing of different sys-

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[7] *Smart Grid in Denmark*, Danish Energy Association, 2010.

[8] Hammerstrom et al.: *Grid Friendly™ Appliance Project*, May 23, 2011.

tems from different providers. It is therefore, needed to develop an innovative ICT-based solution to handle such situations and make the real-time balance between the demand and supply of the electrical network. It is expected that ICT enabled technologies or tools would contribute to optimize an energy balance between the demand and supply side on the electrical network.

At the moment micro-generation technologies contribute partly to Denmark energy supply mix. But it is expected that the trends of decentralized production, close to or at customer premises, and re-feeding to the grid are expected to continue. The main advantages of this solution are wider diffusion of renewable energy generation, competition in energy supply and the potential of fostering new business models. Micro-generation may help to stimulate competitions in energy markets through the development of new energy services for the household sector.

Despite many benefits there are still some significant barriers to micro-generation technologies adoption, especially: high cost, lack of trust in unfamiliar technologies and scepticism regarding the performance of technologies like solar PV, micro-CHP and micro-wind. Additional reasons for the slow take-up of micro-generation, is that often equipment and systems have been designed and installed without taking sufficient account of user requirements and usability.

Standardized ways of measuring energy efficiency and ICT's enabling effect as well as harmonized standards of smart grids and other new technologies are important parts of the adoption. By closing the gap between policy and technology, ICT can play a significant role in this context.

The success of micro-generation therefore depends strongly on the interplay between technology development, policy support and, in particular, consumer priorities.

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Summary

The main focus of this paper is on the application of ICT solutions in micro-generation renewable energy systems.

This paper focuses on the vision that through ICT, consumers might also become producers of renewable energy in Denmark. Innovative ICT applications will be needed in order to balance traditional information asymmetries between electricity producers and consumers and to encourage energy efficient behaviour.

The paper present that the success of micro-generation depends strongly on the interplay between ICT, policy support and, in particular, consumer priorities.

Translated by Iwona Windekilde