Integration of Demand Side Management, Distributed Generation, Renewable Energy Sources and Energy Storages

State of the art report

Vol 1: Main report

International Energy Agency Demand-Side Management Programme

Task XVII: Integration of Demand Side Management, Distributed Generation, Renewable Energy Sources and Energy Storages

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DSM REPORT - EXECUTIVE SUMMARY

TASK XVII: INTEGRATION OF DEMAND SIDE MANAGEMENT, DISTRIBUTED GENERATION, RENEWABLE ENERGY SOURCES AND ENERGY STORAGES

Background

Energy policies are promoting distributed energy resources such as energy efficiency, distributed generation (DG), energy storage devices, and renewable energy resources (RES), increasing the number of DG installations and especially variable output (only partly controllable) sources like wind power, solar, small hydro and combined heat and power.

Intermittent generation like wind can cause problems in grids, in physical balances and in adequacy of power.

Thus, there are two goals for integrating distributed energy resources locally and globally: network management point of view and energy market objectives.

Solutions to decrease the problems caused by the variable output of intermittent resources are to add energy storages into the system, create more flexibility on the supply side to mitigate supply intermittency and load variation, and to increase flexibility in electricity consumption. Combining the different characteristics of these resources is essential in increasing the value of distributed energy resources in the bulk power system and in the energy market.

IEA has several Implementing Agreements dealing with distributed generation (DG) (such as wind, photovoltaic, CHP), energy storage and demand side management (DSM). However, the question of how to handle the integration of various distributed energy resources is not actually studied.

This Task is focusing on the aspects of this integration.

Objectives The main objective of this Task is to study how to achieve a better integration of flexible demand (Demand Response, Demand Side Management) with Distributed Generation, energy storages and Smart Grids. This would lead to an increase of the value of Demand Response, Demand Side Management and Distributed Generation and a decrease of problems caused by intermittent distributed generation (mainly based on renewable energy sources) in the physical electricity systems and at the electricity market.

Approach The first step in the Task was to carry out a scope study collecting information from the existing IEA Agreements, participating countries with the help of country experts and from organized workshops and other sources (research programs, field experience etc), analyzing the information on the basis of the above mentioned objectives and synthesizing the information to define the more detailed needs for the further work. The main output of the first step is this state-of-the art report and the proposal for the future work to be carried out as a second step of the Task.

Results **Overview of the situation**: The main topics discussed are DER and electricity supply, flexibility in electricity demand, communications and IT, integration analytics, regulation, policy and business opportunities as well as market in participating countries.

Pilot case studies: more than 50 case studies, experiments and research projects in the participating and some other countries have been collected and categorized.

Although a general conclusion of the case studies is difficult, some elements can be pinpointed:

Most of the case studies are still in research, pilot or field test level and only very few were actual business cases. Integration technologies with different characteristics exist; metering and communication technology are still expensive to install and maintain, optimization algorithms for aggregated portfolio exist but are not public available yet, market rules which allow the integration of different generation units - especially aggregation of production and consumption – differ between countries.

Vision and Conclusion: As a conclusion of this analysis it can be said that the increased penetration of DG and the technology and market development results in:

- new roles of the different stakeholders meaning new business environment and possibilities; on the other hand new tools are also needed in this new business area
- metering and ICT technologies are developing rapidly
- the above development will result in new products, services and

pricing policies which can activate the more deep participation of final consumers in the market

Successful integration means that different technologies in supply and demand side as well as in ICT are developed to the level where their integration is feasible both technically and economically and that regulation, policy and market give the successful framework for the integration

The summary on the situation of integration was developed on the basis of analysis and expert group opinions. The status of each item was assessed among the following:

- Early: R&D
- Young: Pilots / Field tests
- Existing: Available, at least one vendor; early adopters involved
- Mature: Widespread commercial

Implications

On the basis of the analysis, it was noted that there are some needs for the future work inside this Task XVII to be defined. Especially topics which are at the level of young/existing give possibilities to mutual development and sharing experiences.

The list of the interesting topics was produced by the expert group including about 15 items.

It was decided that as the first priority topic – which is related to the assessment of the effect of DER penetration to the costs and benefits of different stakeholders and the whole system – will be further elaborated.

International Energy Agency Demand-Side Management Programme

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Contents

Glossary

Some of the terms used in the report are described. The terminology used is not necessary standardized, and it is produced to explain how the terms are used in this document.

Active and passive grids

A passive grid is the most commonly used way to manage low and medium voltage networks where a feeder is connected to a transformer and that transformer is the only source of control on the feeder (e.g. voltage control). In an active grid, the loads, generators and grid nodes can be controlled in real time by means of ICT technology.

Aggregation

Aggregation of flexible energy resources means that a third party, named DER aggregator, collects and implements a portfolio of flexible energy resources and operates them combined as a flexible resource on the energy market such as the whole sale electricity market. The aggregator may also offer the aggregated flexible resources to the market for system reserves or as ancillary services for the operators of energy distribution networks. The term Virtual Power Plant has roughly the same meaning as DER aggregation.

Bridging power

Application area for energy storages, where stored energy is used for seconds to minutes to assure continuity of service when switching from one source of energy generation to another.

Centralized power generation

Way of operating a power system where almost all electrical energy is generated or almost all capacity lies in large central power plants, which are not considered distributed generation units.

Common information model

Common Information Model (CIM) is a standard developed by the electric power industry that has been officially adopted by the International Electrotechnical Commission (IEC). It aims to allow application software to exchange information about the configuration and status of an electrical network from utility and system operation point of view. A related language is Substation Configuration Description Language (SCL) which specifies the information model in the substation automation system (SAS).

Congestion

A condition that occurs in the network when insufficient transfer capacity is available to bring electricity from generators to consumers.

Cyber security

Information security within the internet, telecommunications networks, computer systems, integrated sensors, system control networks and embedded processors and controllers.

As the grid becomes increasingly dependent upon distributed intelligence, communications and controls with multiple points of generation and consumption, cyber-security becomes a greater vulnerability for the bulk power system.

Demand response (DR)

or Demand Side Response (DSR). Programs and activities designed to encourage consumers to change their electricity usage patterns, including timing and level of electricity demand, covering all load shape and customer objectives. DR includes time-of-use and dynamic rates or pricing, reliability programs such as direct load control of devices and instantaneous interruptible load, and other market options for demand cahnges (like demand side bidding).

Direct Load Control (DLC)

Loads are externally controlled for the set of DR/DSM actions when the end-users are provided with the required hardware and communication infrastructure to allow direct load control. In DLC programs customers' load is interrupted by remotely shutting down or cycling consumers' electrical appliances such as air conditioners and water heaters.

Distributed energy resources (DER)

Common term for distributed generation (including small combined heat and power, small renewables), energy storages and flexible loads (recently called also active demand) connected to the distribution or transmission network. Flexible loads are usually utilised through demand response activities.

Distributed generation (DG)

Low capacity power generation connected to the distribution or transmission network including renewable resources and combined heat and power units. The definition of low capacity varies usually between 1 and 50 MW. In this report 20 MW limit is used in some tables..

Distribution System Operator (DSO)

A distribution system operator delivers electricity to the final consumer through a distribution system. The European directive 2003/54/EC defines DSO as follows:*"DSO means a natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems and for ensuring the long term ability of the system to meet reasonable demands for the distribution of electricity"* [It has to be noted the distinction between Retailer (in the US the Retail Electric Provider) who is the entity that sells electricity to the end user and DSO who delivers the electricity]

Dynamic Pricing (DP)

Pricing model where the energy price charged to customers can vary significantly according to the time and location of the electricity consumed; this can include real-time pricing.

Energy Management

The operations related to reducing cost of energy consumption and/or increasing income from electricity and heat generation.

Energy management is also an application area for energy storages. In these applications the electric storage is used to decouple the timing of generation and consumption of electric energy. A typical application is load levelling, which involves the charging of storage when energy cost is low and utilization as needed. This would also enable consumers to be grid-independent for many hours. Heat storages can be used to decouple electricity generation from a CHP unit and its associated heat consumption.

Energy Service Company (ESCO)

"Energy service company" (ESCO) is a natural or legal person that delivers energy services and/or other energy efficiency improvement measures in a user's facility or premises, and accepts some degree of financial risk in so doing. The payment for the services delivered is based (either wholly or in part) on the achievement of energy efficiency improvements and on the meeting of the other agreed performance criteria. [1]

Flexibility

Customer flexibility means the ability to quickly and inexpensively adapt his own power generation and demand in response to varying electricity prices, electricity market conditions, transmission and distribution system conditions, and of regulation.

Network flexibility is defined by either having enough capacity for transmission or distribution or increase the available energy storage in the network, or by being able to use tools such as real-time monitoring and analytics to manage grid assets in ways that increase its throughput and operational flexibility without compromising its reliability.

High-speed digital monitoring

Used for monitoring the status of a grid or of some elements on it in real time and allowing a quick response (automated or not) when needed. It is common in European countries to monitor the status of the high-voltage grids in such a way.

Independent system operator

An independent organization that is responsible for coordinating, controlling and monitoring the operation of the electrical power system in a particular geographic area

Indirect Load Control

Indirect Load Control is classified as the set of initiatives that require end-use customers to modify their load consumption with actions executed by the customers themselves. These include all the cases in which the system operator does not have the capability of directly control the load.

Intelligent agent

An entity (computer program or physical device) which can observe and act upon an environment and directs its activity towards achieving certain goals.

Interoperability

The ability of two or more systems or components to exchange information and to use the information that has been exchanged effectively without intervention on the part of the user or operator.

Liberalization

In the electricity sector, liberalization means the removal of the monopolies for electric utility sales to retail customers and the opening of competition in electricity generation and supply and sales to retail customers while keeping the monopoly in transmission and distribution. In order to guarantee a fair competition, the rules for accessing transmission and distribution grids must be transparent and non-discriminatory.

Micro-CHP

A cogeneration unit generating less than 16A per phase.

Power exchange

also known as spot or pool market, conducts auctions for generators seeking to sell energy and for loads which are otherwise served by bilateral contracts. The power exchange determines the market clearing prices and those generator units which have bid at or below the clearing price are scheduled for generation (known as 'merit order'). The power exchange is often also responsible for the settlement and billing (not in the UK). Depending on the closing time of the power exchange, it is either called a day-ahead market (like Nord Pool) or real-time market if it closes just before delivery. In addition, the term is also often used for other related markets, e.g. financial market or ancillary service market, because the entity operating the power exchange also operates those markets. Hence, the entity functions as a market operator (See market operator). Finally, in some cases, e.g. Pennsylvania-New Jersey-Maryland Interconnection, the entity operating the power exchange also functions as the system operator. [2]

Power quality

The conformity of voltage to certain standards. Deviation from these standards is regarded as degradation of power quality. Requirements can be set for variations in the peak or RMS voltage, voltage spikes, waveform shape, symmetricity of the waveform between different phases, etc.

When energy storages are used to assure continuity of quality power, stored energy is only applied for seconds or less, as needed.

Power system protection

Power system protection is that part of electrical power engineering that deals with protecting the electrical power system from perturbations by isolating the faulted part from the rest of the network. The main objective of a protection scheme is to keep the power system stable by isolating only the components that are under fault, whilst leaving as much of the network as possible still in operation.

Smart metering

Smart metering has the following features:

- Measures energy use in regular intervals as short as five to 15 minutes in length
- Stores energy use data to communicate to the utility meter data management system
- automatic processing, transfer, management and use of metering data;
- automatic management of meters;
- two-way data communication with the utility meter data management system

Advanced meters may provide meaningful and timely information about electricity rates and individual electricity consumption information to the relevant actors and their systems, including the energy consumer; they also support services that improve the energy efficiency of the energy consumption and the energy system (generation, transmission, distribution and especially end use).; they may also deliver information and signals that trigger customers' on-premise equipment operation. Advanced or smart meters do not include meters that have only automated meter reading.

Smart grid

The management of transmission and distribution networks which uses robust two-way communications, advanced sensors, and distributed computers to improve the efficiency, reliability and safety of power generation, delivery and use. Additionally it can support services, such as demand response, to consumers. The concept encompasses a wide range of technologies, such as advanced meter reading, substation automation and energy management systems. Smart grid development for the most part can use existing technologies, applying them in new ways to grid operations.

Time-of-Use (ToU) tariff

A method of pricing electricity using different prices at different times of the day and seasons of the year. Opposed to dynamic pricing, the prices have been agreed beforehand and the number of tariffs is fewer.

Variable-output power generation

Power generation whose output power is determined externally and varies with time. In [3] it refers to renewable electricity technologies, such as wind, wave, tidal, solar, and run-of-river hydro sharing a characteristic that distinguishes them from conventional power plants: their output varies according to the availability of the resource. The same characteristics can be related also to CHP. Often also the term "intermittent type generation” is used in quite a similar way: however, intermittent generation may be more stochastic and less predictable than variable generation

Virtual power plant

A portfolio of smaller generators and demands. The concept is closely related to DER aggregation. *Commercial virtual power plant*, CVPP, is one type of VPP operation. CVPP is related to the market (seeking to obtain a maximum benefit from the generation and demand portfolio without further considerations). Services provided by a CVPP include trading in the wholesale energy market, balancing or trading portfolios and provision of services to the system operator. *Technical virtual power plant*, TVPP, is another type of VPP operation. The TVPP takes into consideration also the operation of the grid and tries to solve possible contingencies (it probably will receive an income but it will come mainly not from the market but from the system operator)The TVPP consists of DER from the same geographic location. In this case the impact of operation on the distribution network is considered. Services from a TVPP include local system management for DSO, as well as providing TSO balancing and ancillary services. The operator of a TVPP requires detailed information on the local network, typically this will be the DSO.

References

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2. Distributed Resources in a Re-Regulated Market environment Thomas Ackermann Doctoral Thesis Stockholm, Sweden 2004-12-09

3. Empowering Variable Renewables. Options for Flexible Electricity Systems. IEA 2008, 36 p.

   (http://www.iea.org/textbase/publications/free_new_Desc.asp?PUBS_ID=2040)

List of abbreviations

AMM	Advanced metering management
AMR	Automatic Meter Reading
CAES	Compressed Air Energy Storage
CENELEC	European Committee for Electrotechnical Standardization
CHP	Combined Heat and Power
DER	Distributed Energy Resources
DG	Distributed Generation
DR	Demand Response
DS	Distributed energy Storage
DSM	Demand-Side Management
DSO	Distribution System Operator
EN	European Standard (developed by European Committee for Standardization)
GHG	Green-House Gases
HV	High-voltage
IA	Implementing Agreement
ICT	Information and Communication Technologies
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IT	Information Technology
LV	Low-voltage
PCC	Point of Common Coupling
PV	Photovoltaic (power generation)
RES	Renewable Energy Source
SMES	Superconducting Magnetic Energy Storage
ToU	Time of Use
TSO	Transmission System Operator
UPS	Uninterruptible Power Supply
VPP	Virtual Power Plant
VTT	Technical Research Centre of Finland
UCA	Utility Communications Architecture
µCHP	Micro Combined Heat and Power

1 Introduction

All around the world, there is increasing use of renewable energy sources and more efficient use of energy. These are motivated by a will to reduce green-house gases (GHG) emissions and the increase of fuel prices that drives up the prices of energy. Behind the will to reduce GHG large number of countries have ratified the Kyoto protocol which has, in turn, been transposed into national laws and energy policies. At the same time the role of electricity as an energy carrier is increasing and the construction of new transmission lines and large central power plants is becoming more and more difficult.

Energy policies are promoting energy efficiency, distributed generation (DG) and renewable energy resources (RES), increasing production from DG and especially variable output (only partly controllable) types of DG like wind power, solar, small hydro and CHP. The production from wind and photovoltaic units is governed by the availability of the primary energy source. There is therefore often no correlation between the production and the local consumption as can be seen in Figure 1. [1].

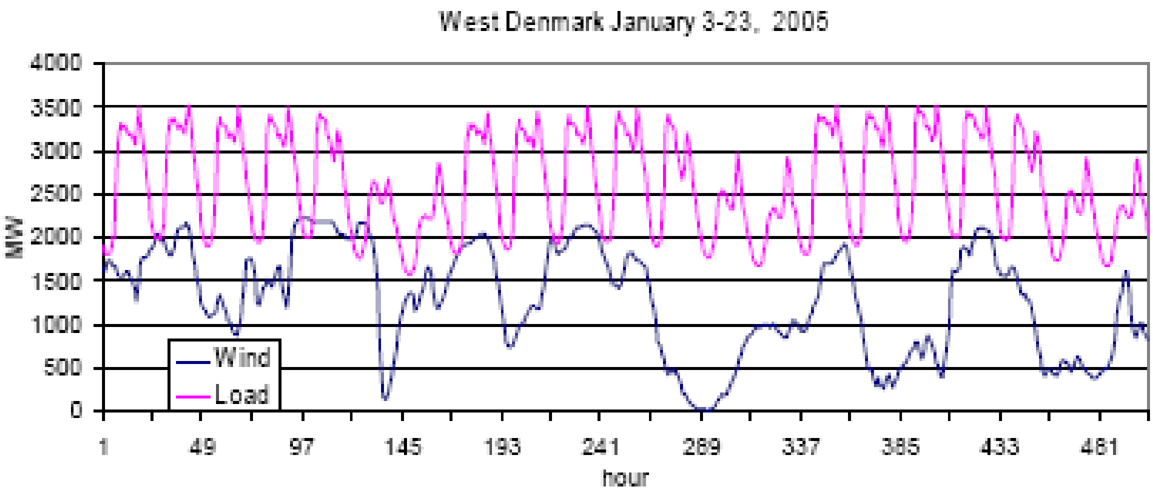

Figure 1. Wind power production (2400 MW wind power) and load in Western Denmark

Large amounts of variable generation from renewable sources are not fully forecastable and is causing increasing problems in electrical networks (both in local distribution networks and transmission networks including cross-border networks). In some places, we can already observe an increase in the network stresses and needs for upgrades to provide greater capacity and flexibility to integrate the variable generation. It also increases the need for flexible, dispatchable, fast-ramping generation for balancing variations in load, intermittent resources and contingencies such as the loss of transmission or generation assets.

The challenges caused by renewable energy sources are shown in Figure 2; the time scale of the problems varies from milliseconds to years. System integration costs (such as the amount spent on ancillary services) increase with higher use of renewable resources, but those increased integration costs usually net out against the lower energy costs of the renewable generation.

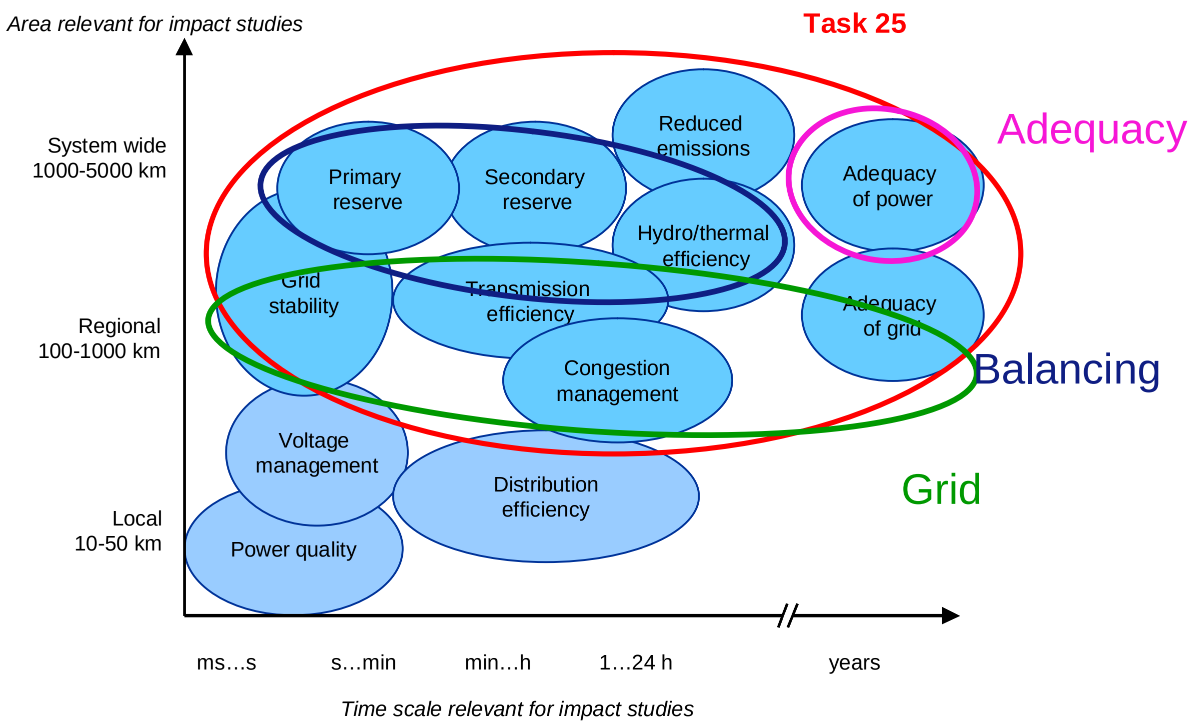

Figure 2. Impacts of wind power on power systems, divided into different time scales (from Task 25 of IEA Wind Agreement)

Similar problems can be seen at market: national and local balances between supply and demand are more complicated to manage with high levels of variable generation, which can increase total financial electricity costs. There are two tasks for integrating variable generation and distributed energy resources, both locally and globally: integrating them into the electricity network and into the energy market.

One solution to decrease the problems caused by the variable output of some DG is to add energy storages into the systems (centralised or distributed energy storages DS). Another way is to use flexibility in electricity consumption (demand response DR). In this sense distributed generation (DG), distributed energy storages (DS) and demand response (DR) can be seen as an integrated distributed energy resource (DER). Combining the different characteristics of these resources is essential in increasing the value of DG in the energy market.

The following Table 1 indicates some DER based solution options to the network and market problems at different time scales. It has to be noted that this kind of table is only very indicative because lot of work is going on in clarifying the role of DER in the connection of power systems.

	< One minute	15 minutes	30 minutes	Hour ahead	Day ahead	Year ahead
Frequency control (primary, secondary, tertiary)	Local automated DG Local automated DR Load shedding	Centralized signals to DG and DR	Direct load control DR Manual DR	DG DR		
Voltage control	Power electronics	Power factor corrections, DS	Power factor corrections DS, DR			
Meet system peak load				DR	DR	Energy efficiency Demand response
Portfolio balancing		DR, DG, DS	DR,DG, DS	DR,DG, DS		
Relief of HV network congestion		DR	DR	DR		
Network restoration		DR, DG, (DS)	DR, DG, (DS)	DR, DG, (DS)		
deferring network investments						Energy efficiency, DR, DS

Table 1. DER related solution options at different time scales

The idea behind this work, as well as behind several other projects around the world, is that better coordination between local energy sources, controllable loads, storage possibilities – the smart-grid concept – can reduce significantly the costs of integrating renewable sources into the networks.

The vision for the integration of DER is a smart-grid platform that would link a web of diverse generation sources, including a variety of fossil fuels and renewable and distributed sources, across the grid to a large set of consumers with possibilities for improved energy efficiency, local generation, controllable loads or storage devices. The grid, along with analytics, communication technologies and distributed intelligence, is used to coordinate and balance sources, storage and loads to produce a reliable power system for more moderate costs than a traditional and centralized approach. It is expected that the costs of a system with a better DER integration would be reduced compared to the present situation, because of the inclusion of more energy efficiency and renewables, but also of a lesser use of expensive peaking power and a better use of the transmission and distribution assets. This vision for the future grid can lead to a lower adverse environmental impact.

In the future system a proportion of the electricity generated by large conventional plants will be displaced by distributed generation, renewable energy sources, demand response, demand side management and energy storage. Additional stand-by capacity might be required, which could be called upon whenever the variable output type of RES ceases to generate power and there is not enough demand response or energy from storages. Efficient integration of distributed generation is unlikely to occur without changes to the transmission and distribution network structure, planning and operating procedures. Indeed, it is envisaged that there will be less of a distinction between these network types, as distribution networks become more active and share many of the responsibilities of transmission.

Several models for the future electricity system recognise the fundamental fact that with increased levels of distributed generation and active demand-side penetration, the distribution network can no longer act as a passive appendage to the transmission network. The entire system has to be designed and operated as an integrated unit. In addition, this more complex operation must be undertaken by a system where ownership, decision-making and operation are also dispersed.

Three conceptual models can be mentioned: microgrids (or minigrids), active networks supported by ICT and an ‘Internet’ model - all of which could find applications, depending on geographical constraints and market evolution.

Microgrids are generally defined as low-voltage networks with distributed generation sources, together with local storage devices and controllable loads (e.g. water heaters and air conditioning). They can have a total installed capacity in the range of a few hundred kilowatts to a couple of megawatts. Although microgrids operate mostly connected to the distribution network, they can be automatically transferred to isolated mode in case of faults in the upstream network and then resynchronised after restoration of the upstream network voltage. Within the main grid, a microgrid can be regarded as a controlled entity capable of operating as a single aggregated load or generator and, given attractive remuneration, as a small source of power or as an ancillary service supporting the network.

Active networks are a possible evolution of the current passive distribution networks and may be technically and economically the best way to initially facilitate distributed generation in a deregulated market. Active networks have been specifically conjectured as facilitators for increased penetration of DG and demand-side resources, building on new ICT technology and strategies to actively manage the network.

The internet model effectively takes the active network to the global scale but distributes control around the system. The flow of information around the internet uses the concept of distributed control where each node, web host computer, email server or router, acts autonomously under a global protocol. In the analogous electricity system every supply point, consumer and switching facility corresponds to a node.

The internet-type systems also enable new types of concepts in the electricity market, such as virtual power plants or virtual utilities. A conventional power plant generates electricity in one location, using (usually) one type of generating technology and is owned by one legal entity. A virtual power plant is a multi-fuel, multi-location and multi-owned power station.

Based on the characteristics of smart grids, it is possible to reach energy infrastructures and systems having a lower total capacity and emissions compared with the structures based on the existing technology and systems (Figure 3.). “Fit and forget” approach means that networks and central generation are build on the basis of present technologies where centralised control is applied to central generation and transmission and passive control to distridution systems. The ”Integrated DG & DSM/DR” approach is based on distributed control and efficient integration of DER. This means that the same demand needs less generation and network capacity than the “Fit and Forget” alternative.

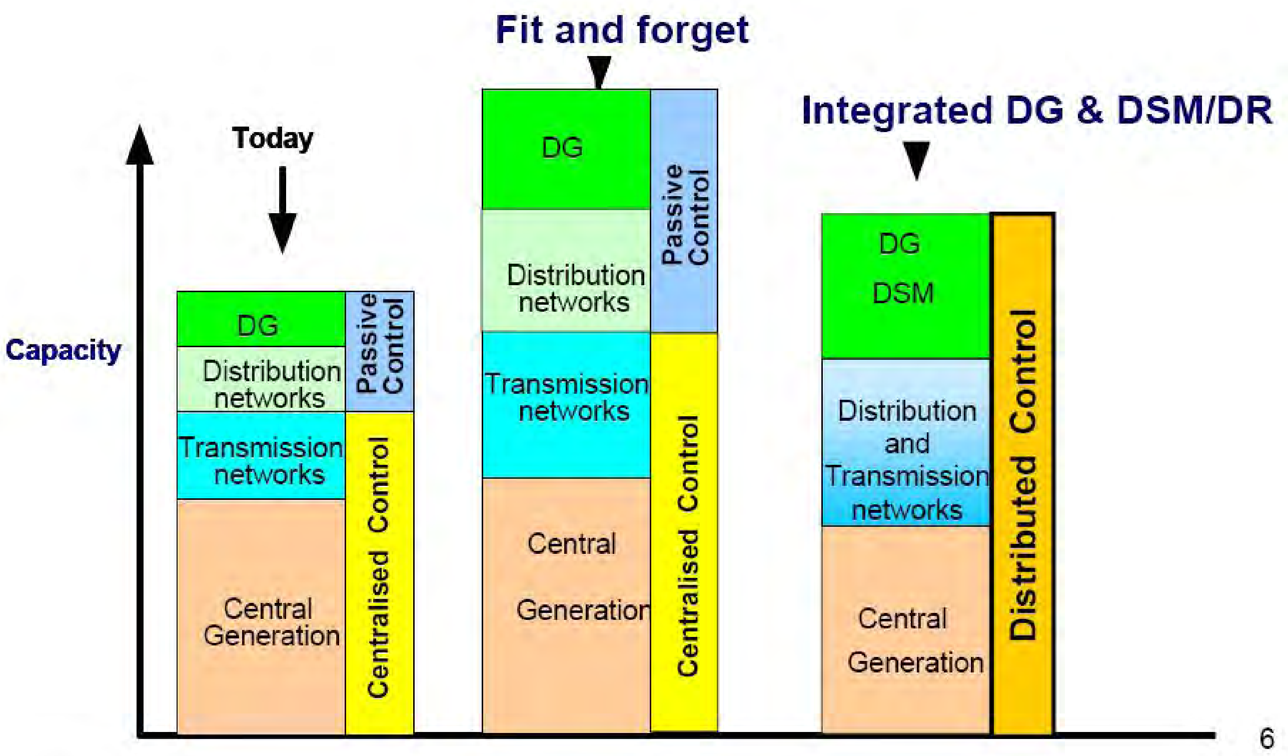

Figure 3. Impact of a smart grid on the need for energy system capacity. Two basic alternatives for the future electric systems: “Fit and forget” and “Integrated DG&DSM/DR”

Several initiatives related to smart grid concepts have been developed all around the world [2, 3, 4, 5 , 6, 7]. Figure 4. and Figure 5. show examples of the present concepts [8].

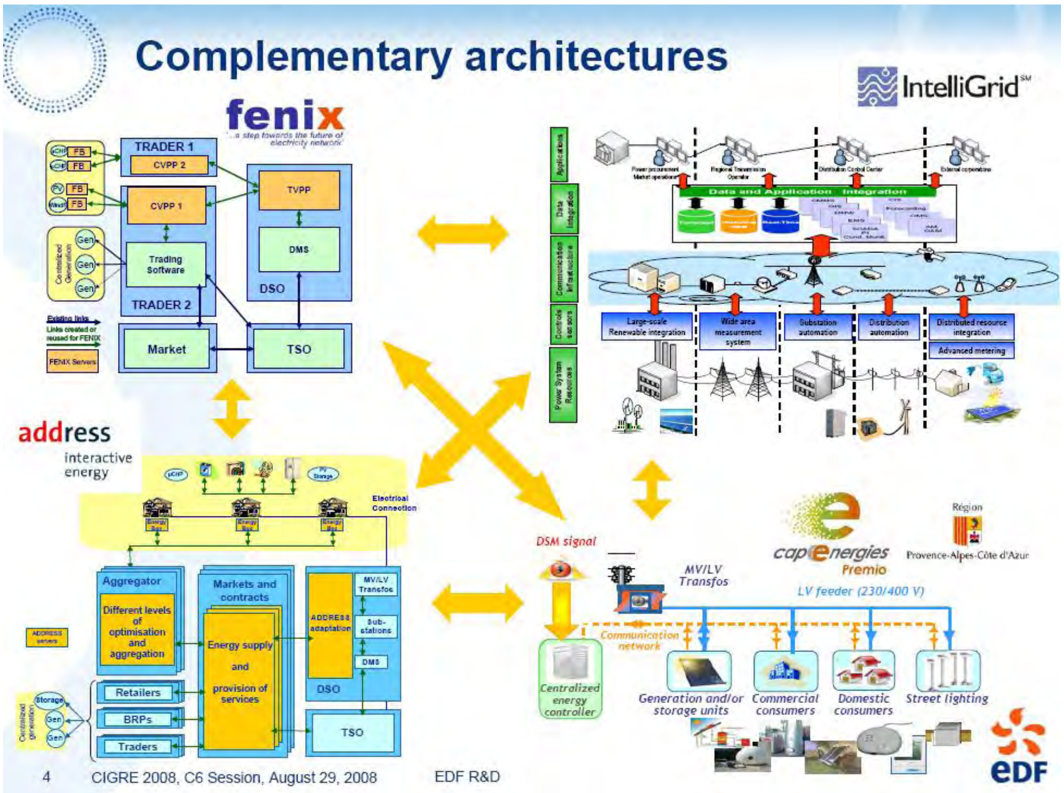

Figure 4. Examples on some smartgrid related architectures

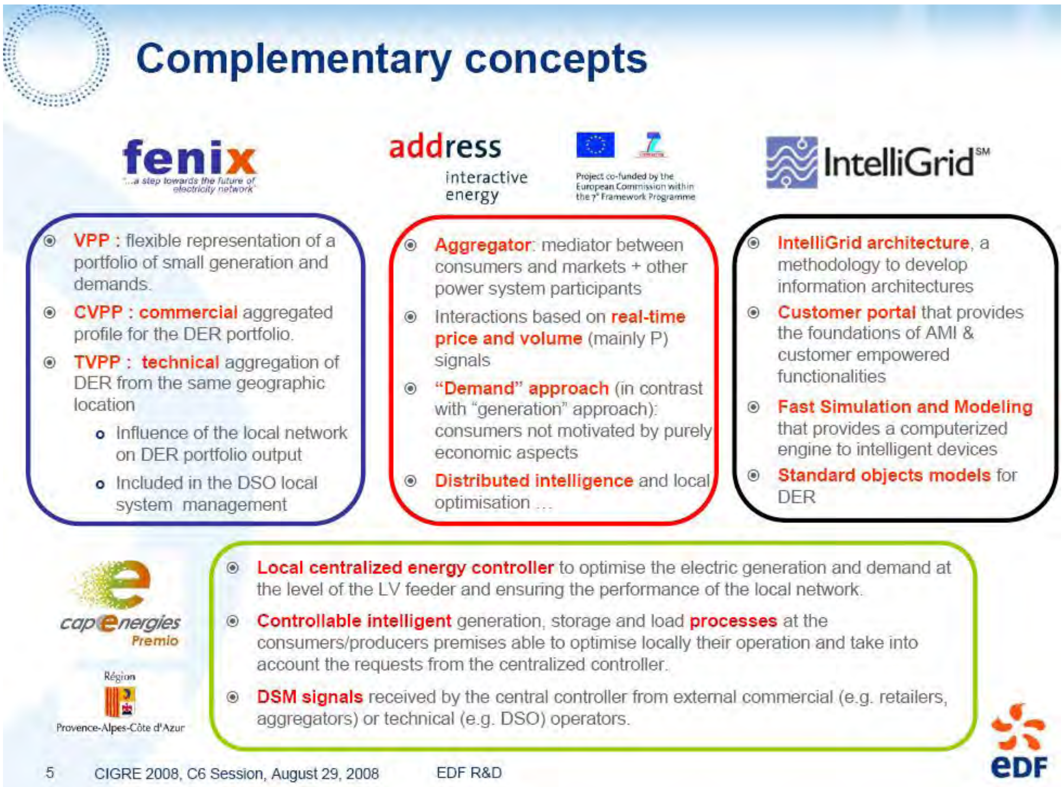

Figure 5. Comparison of the concepts of the Figure 4.

2 IEA DSM Task XVII

2.1 IEA and DER

IEA is dealing with energy questions in several ways. One of them is to start Implementing Agreements (IA) to study specific topics. IEA has several Implementing Agreements dealing with distributed generation (DG) (such as wind, photovoltaic, chp), energy storage and demand side management (DSM). Some of the aspects related to the DER are currently or have been studied in the Wind Implementing Agreement (dealing with the power system operations with a large share of wind and small hydro) or in a new IA that deals with network aspects (ENARD). In this IA, IEA DSM Agreement, several tasks (especially tasks VIII, XI, XIII and XV) work with load shapes where distributed generation is included as a resource for demand response (See Annex). However, the question of how to handle the integration of various distributed energy resources (DER) is not actually studied in other Tasks or Agreements, since IEA ENARD Annex II focuses on the network issues of DER integration.

This IEA DSM task (XVII) is focusing on the aspects of this integration. This work aims at studying and assessing the level of advancement of the different aspects we have identified as being relevant to this integration

2.2 Objectives

The main objective of this Task is to study how to achieve a better integration of flexible demand (Demand Response, Demand Side Management) with Distributed Generation, energy storages and Smart Grids. This would lead to an increase of the value of Demand Response, Demand Side Management and Distributed Generation and a decrease of problems caused by variable distributed generation (mainly based on renewable energy sources) in the physical electricity systems and at the electricity market. The Task deals with integration aspects both at local (distribution network and customer) level and at transmission system level where large wind farms are connected.

Thus the integration means in this context:

- how to optimally integrate and combine Demand Response and Energy Efficiency technologies with Distributed Generation, Storage and Smart Grids technologies, at different network levels (low, medium and high voltage)
- and how to combine the above mentioned technologies to ideally support the electricity networks and electricity market

The Task will provide the integration based solutions and examples on successful best practices to the problems defined above to the different stakeholders.

2.3 Approach

The first step in the Task is to carry out a scope study collecting information from the existing IEA Agreements, participating countries and other sources (research programs, field experience, information collected through Cigre working groups, etc), analyzing the information on the basis of the above mentioned objectives and synthesizing the information to define the more detailed needs for the further work.

On the basis of the collected information a systematic analysis is carried out to produce the state of the art to the integrated approach of the utilization of Demand Response and Energy Efficiency in combination with other DER aspects and barriers related to it and to define the detailed further work.

This kind of approach presumes the co-operation between different Implementing Agreements related to DG, storages, DSM and networks. Experts are needed from each area. Especially information exchange and coordination with Wind and ENARD is organized.

In July 2008, a workshop with the stakeholders was arranged to get feedback and inputs from outside to the conclusion and the definition for the future work. The workshop material can be found from http://ieadsm.org/ViewTask.aspx?ID=16&Task=17&Sort=0

This work has been divided into chapters related to the aspects we considered as relevant for the integration of more various distributed energy resources. Main topics are

– DER and electricity supply
– Flexibility in electricity demand
– Communications and IT
– Integration analytics and
– Regulation, policy and business models

Inside each main topic the most relevant items have been discussed. We also collected information on the tools and methods to be used in the assessment of integration and pilots, field tests and case studies. These are shortly summarized in the report and more detailed information is given in the separate Annex report (Vol. 2).

We have also come to an agreement during our work that we would not focus extensively on regulations and policies. They determine the structure of the market as well as the business models which can be implemented in each country. It is assumed that as technologies evolve and ways to capture benefits will appear, be proven or become more available, business models will appear or evolve likewise in the available markets. Some examples on business models, however, are given.

Moreover, the market structures are very different in the participating countries. Our work aims at identifying integration performance and development in very different market structures and we wish our recommendations not to depend too much on them.

Country experts also produced the description of the DER integration situation in their respective countries. These country reports are included in the Vol. 2 report (Annexes).

3 DER and electricity supply

This chapter discusses the electricity systems which include distributed energy resources like demand-side management, generation and storages. Flexible loads and demand response are, however, discussed more in the chapter 4. DG and storage technologies are described shortly in this chapter and the operational questions of the systems are discussed.

3.1 Background: effects of variable output generation on electricity supply

3.1.1 Variability and uncertainty

A central station-dominated utility system has two principal sources of variability – changes in load, and supply contingencies (such as the loss of a transmission line or generation unit). If you add a high amount of renewable generation such as wind or solar to such a system, the system operator faces a third source of variability and unpredictability, but can operate the system by dispatching to net load – load net of renewable generation – and forecast net load. When that system takes on additional complexity with growing levels of distributed energy resources, there are more uncertainties and variability to consider.

Distributed generation is usually operated at the owner's discretion, not the utility's will; energy efficiency is often initiated by the end user, not only the utility's programs and encouragement; customers' demand response decisions are affected by a variety of motivations beyond what the grid operator wants and needs; and as customers decide to install more distributed renewable generation, it changes the topology of the distribution grid as well as the load patterns perceived on the utility side of the meter. The resulting grid is significantly more complex and uncertain and requires a more complex, interactive means of operation and coordination.

3.1.2 Two kinds of utility systems

This study posits an electric power system that incorporates a variety of central station renewable and traditional generation technologies (including fossil and nuclear), as well as a breadth of distributed energy resources (including combined heat and power, small renewables, energy storage, energy efficiency, and demand response).

Traditional utility systems have central station generation with power flows and controls flowing one-way down from the generation and transmission system to the user. In contrast, a system that contains a high penetration of distributed energy resources will need a different model of communications and controls – an extensive, wide-spread set of monitoring, two-way communications, distributed controls, and analytics.

While the centralized power system is organized so that supply resources are operated to follow demands under all circumstances, in a distributed system customer demands interact with and respond to supply conditions and capabilities.

While the centralized power system is operated by a single dispatch entity that commands and operates all assets in an optimized fashion according to a consistent set of values, in a system with high levels of distributed energy resources, there will be a variety of assets operated by many different owners and operators acting to serve their own interests rather than to optimize the electric system.

Therefore, such systems will have to be operated with high-speed monitoring, sophisticated analytics, and information and incentives (particularly price) disseminated on two-way communications systems, will be needed to enable assets to respond in a coordinated rather than command fashion.

3.1.3 Greater flexibility

The key to the integration of these higher levels of variability and uncertainty are to increase the system operational flexibility and diversity, fuel and technology diversity, with more sophisticated analytics, faster response times and reaction capabilities. Improving grid flexibility requires more dispatchable power plants with wide operating ranges and fast ramp rates, but also much greater use of power electronics, energy storage, automation, and managing customer loads and demand-side resources to balance supply side resources.

3.2 Distributed generation and renewable energy sources

Distributed generation (DG) involves a large number of generation technologies: small turbines with a steam cycle, small turbines with an organic Rankine cycle (ORC), gas turbines, micro turbines, diesel- or gas-fuelled reciprocating engines, Stirling engines, fuel cells (high and low temperature), photovoltaic systems, wind turbines and small hydro turbines. There are also different ways to characterize distributed generation.. Depending on the context, it may be fuel-based or non-fuel-based, renewable-based (fuel or non-fuel) or non-renewable, controllable or uncontrollable (variable output). Also size or network connection (isolated, low-voltage, medium-voltage, high-voltage) may be used as defining aspects. All the above aspects are important in assessing the usability of distributed generation in distributed energy systems. Investment and operational costs, reliability, service life, level of technology development etc. are also important factors.

For example, different types of turbines, reciprocating engines and fuel cells all require fuel, which means that the operator of such units needs to purchase and transport the fuel. Therefore, the fuel purchase has to be taken into account in the production cost of the energy. Photovoltaic, wind power, hydro and a part of the CHP production are dependent on the meteorological situation and industrial CHP depends on the production processes. Therefore the risks due to the lack of predictability of the generation will have to be taken into account for investment decision-making.

Some of the technologies are still emerging and have high investment costs, e.g. fuel cells, while others are already widely deployed. It should be noticed that although many DG technologies use fossil fuels, most of them can also be run using renewables such as biofuels. However, nowadays small-scale DG is mainly used as a local means for one consumer to reduce his consumption or as an emergency generator. Very little, and often nothing at all, is done to use DG in order to achieve other goals such as participating to renewable balancing or to network management.

Some technologies like wind, solar and hydro power use renewable rather than fossil fuels, and so are unaffected by fluctuations in the oil and gas market. The down side is that in most cases they need to be located at particular places, which may be far away from the network or on a weak network, thus increasing connection costs. Non-controllability also brings in additional costs to cover the risks due to the fluctuation in generation.

Table 2 indicates the present installed capacity for DG and RES in participating countries. This study sets a 20 MW limit in size for a unit to be considered as being distributed generation.

Country	**Wind** (MW)	**Solar** (MW)	**CHP** (MW)	**µCHP** (MW)	**Small hydro** (MW)	**Others** (MW)	**Estimated Total DG** (MW)
Finland	122	marginal	294	N/A	270 *(<10 MW)*	< 20	800
Italy	1500	120	3242 *(<25 MW)*	N/A	4138	672*	9700
Netherlands	1560	53	8500	N/A	marginal		10200
Spain *(<25 MW)*	3705	413	4214	0.788	1702	538**	10600
USA	1078	810	***	minimal	minimal		2000
Austria	1032	36	402	****	1559 (<20 MW)	1	5000
Korea	178	36	3455	148	60 (<5 MW)	81	4000

Notes
* : In Italy, others are biogas (347 MW) and heat & enthalpy recovery (325 MW)
**: In Spain, others are biomass, biogas and municipal solid waste fired units
***: In USA, total capacity almost 50 000 MW, most over 20 MW units
****: In Austria, total µCHP generation 6165 MWh, 1172 MW of small hydro capacity <10MW

Table 2. Installed capacity (in MW) for DG and renewables

3.3 Energy storages

Energy can be stored at different phases of energy chains: as a primary energy (fuels, hydro) or after conversion into secondary energy (heat, electricity, compressed air, mechanical or chemical energy). The usage of energy storage as part of the distributed energy systems offers several benefits for managing the fluctuations in energy use or generation. The investments into peak and reserve type capacity as well as in energy transfer and distribution networks will decrease and the utilization rate of existing capacities will increase, depending on the type and location of storage.

Heat storage can be utilized in connection with CHP either in large units or at the customer site, where it can be seen as a part of demand response like in electric heating or cooling. Energy storages related to electricity use and generation are based on different types of technologies with different characteristics and applications.

The applications of electricity storages can be defined on the basis of different parameters like storing or discharging time and capacity of storages. Very short-term applications (less than one second) are related to power quality, reliability and security of power systems and can be defined as high-power applications. The applications from minutes to hours can relate to the support of distributed energy generation or load variations but also to needs for uninterruptible power supply or energy management needs of consumers or power suppliers. Depending on applications in power systems, the capacities of storages can vary from less than 1 kW to 1 GW. This kind of application is related to high-energy needs.

High-power electricity storage technologies, such as capacitors, flywheels, superconducting magnetic energy storage (SMES) etc. are applicable for fast-response voltage and power quality management, whereas high-energy electricity storage technologies such as pumped hydro, compressed air energy storage (CAES), flow batteries, etc. are used in daily cycles for economic gain. High-power applications are storage technologies that can supply a large power, but only for a time up to a few seconds or minutes, typically to maintain the voltage level during the start of the emergency generators (bridging power).

High-energy applications can not supply such a large amount of power, but can sustain it for a much longer period of time. These are used more to shift some electricity production. On the basis of the power ratings of storages, pumped hydro, CAES and SMES are large with capacities from tens of MWs up to hundreds MWs compared to capacitors, different types of batteries and fly wheels, which range from 10 MW down to several kWs.

Figure 6. describes the discharge time of different storages. The applicability of different types of storage also depends on the efficiency, lifetime (in operating cycles) and investment costs. Especially in the applications of DR these characteristics are important.

If the capital costs are taken into account, pumped hydropower and CAES are the cheapest ones per charge/discharge cycle. But they need to be installed at a specific site. For the batteries, it can be noticed that the biggest units are built from the best-known technologies (i.e. lead-acid and Ni-Cd). Flywheels seem to be suitable for power quality systems or for short maintenance of the power. Flow batteries, because the tanks are isolated one from the other, have a slow discharge rate and can be used in energy management. They also offer the advantage of lower replacement cost, since only the tanks have to be refilled. In the other batteries, the whole system has to be replaced. Electrochemical capacitors show good qualities and can be designed for different types of operation, but they are limited in their possible power output.

Concerning our interests for this work, storage technologies are especially useful. The efficiency and maneuverability of local energy management can be greatly improved by using storage devices or by exploiting the storage capacities that consumers have on-site. Integrating storage units to a local management system can take the costs down as well as making new possibilities available.

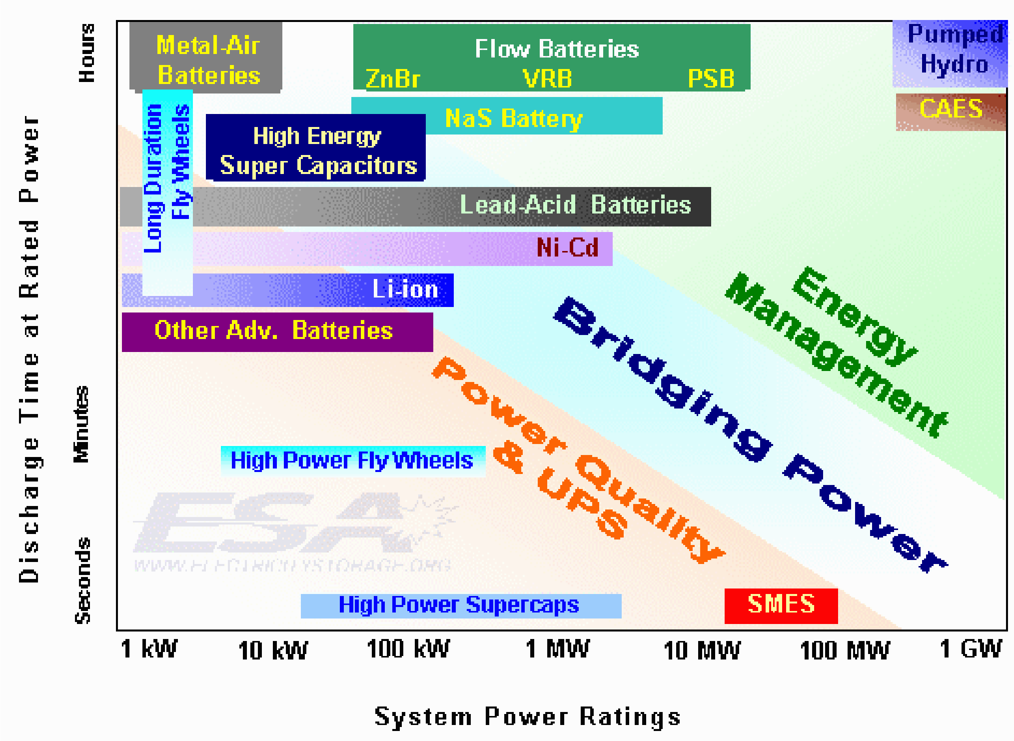

Figure 6. Discharge time at rated power of different types of energy storages. The figure also shows the applications of storages (source: Energy Storage Association)

The Table 3 indicates the storage technologies used in a large scale in the participating countries. We can see that at the supply level, the most used ones are pumped hydro in countries where sufficient difference of height are available and large-scale heat storage. The heat storage at consumer's level is represented in this table although it concerns more demand response and should be found in that chapter (Chapter 4).

	Pumped hydro	**Heat storage (large scale)**	**Heat storage (consumer's level)**
Austria	6.5 GW / 11.2 TWh		Yes
Finland	No	About 17 GWh and 900 MW_h (non-coincident)	Yes
Italy	7.6 GW/5 TWh (2007)	N/A	rare
Korea	3.9 GW	699Gcal/h	649 MW (ice storage)
Netherlands	No	Yes	Not really
Spain	2.7 GW	No	No
USA	Yes	Yes	Yes

Table 3. Energy storage capacities

3.4 Economic dispatch

One of the goals when integrating various Distributed Energy Resources (DER), and a condition without the concept can not work, is that every actor receives enough payment or compensation to make it profitable. In the traditional and centralized approach, the focus is on the optimizing the operation of the system as a whole with centralized generation and transmission, often neglecting the potential of distributed resources.

When more distributed resources are to be integrated, the revenues must also become distributed and we can somehow talk of distributed optimization. We should however keep in mind that due to the large number of actors with sometimes contradictory interests, even if we could determine a global economical optimized operation, the actual operation is more likely done to suit some other goals.

Distributed market based optimization does not work well if there is not enough variety in the units to be optimized. Thus a centralized approach is probably often better for the internal optimization of a local system consisting only of a few DER-units.

Optimization of the operation of CHP units needs to include storage and use of heat, in addition to electricity and heat production, electricity market and own electricity use. Also the constraints imposed by the power distribution and heat distribution networks need to be taken into account.

The actual control and operation of DER units depends on the optimization strategy, business models applied, physical and ICT infrastructure etc. Later some examples are given.

The actual trading and optimized operation of a DER portfolio or virtual power plant in competitive and unbundled market conditions is complicated, as can be seen from the next figure. A large number of factors have to be taken into account: different types of contracts and short-term deals, variations in market prices of electricity and fuels, balancing conditions and suppliers of imbalances (open suppliers), uncertainties related to the consumption and production of electricity and heat, measurements etc.

All these factors affect the optimization of the operation of DER units and on trading of energy, and their interconnections are presented as an example in Figure 7. [9].

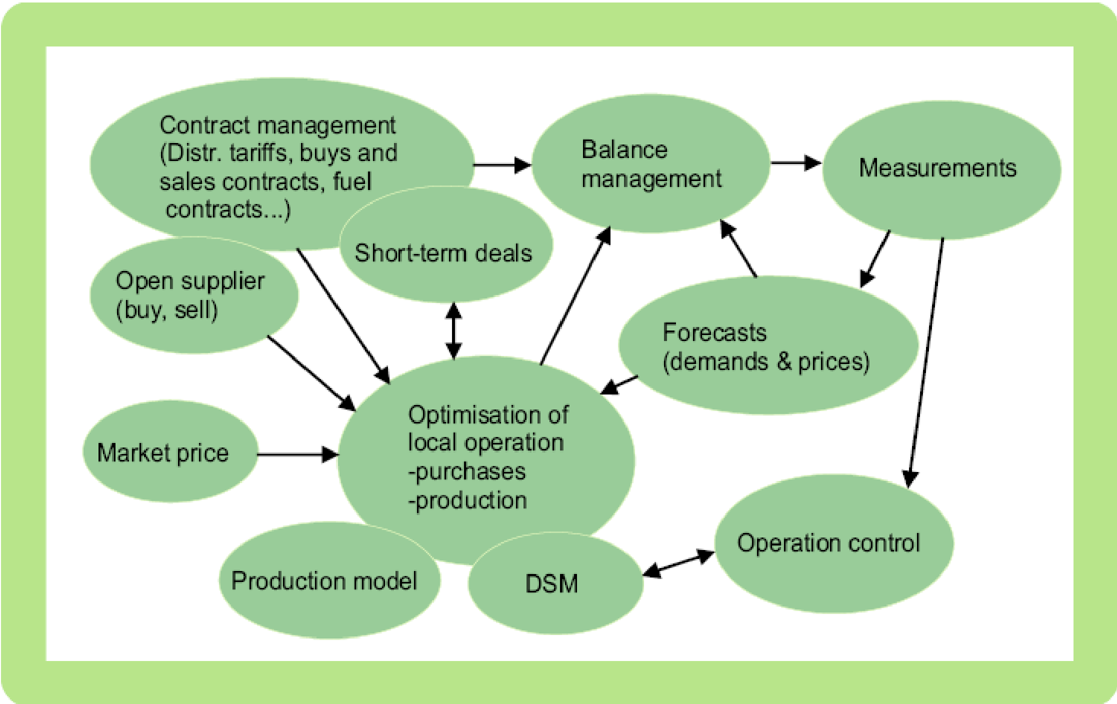

Figure 7. Structure of operation of DER has several interconnections.

Although demand response can be bid into a competitive wholesale market, it complicates economic dispatch further because dispatch typically optimizes supply-side resources against a specific demand forecast for the dispatch period. If demand-side resources such as DR are bid in and accepted in the dispatch, this forces a reexamination of the supply-side resources against a DR-modified demand forecast.

3.5 Real-time grid operation

Communications, monitoring, measurement, analysis and information technology links are central to the effectiveness of real-time grid operations, especially with respect to the smart grid and the integration of diverse resources into power system operations.

3.5.1 Power quality management

Power quality pertains to the voltage level, the frequency and the harmonics of the base frequency in the grid. Frequency control, now, is often based on precisely controllable large hydro-plants. The Voltage level may drop due to certain load types or increase due to small generators in low levels of the grid or by reactive power shortages. Reactive power currently is delivered mainly on the MV-grid level by capacitor banks. In the future grids with a large proportion of DG-RES, inverters may take over parts of this delivery of reactive power.

The traditional view on the contribution of DG to Power Quality is, that it has two-way interactions with the power quality: on one hand many distributed energy resources are often rather sensitive to power quality disturbances, because excessive dimensioning is rather expensive and the specification may not have taken into account this potential problem. On the other hand different forms of distributed power production may disturb the power quality of the public power supply network. In addition to normal healthy states, also possible faults both in network and in customer installations create needs to detect and manage the power quality.

Thus, the effect of introducing DG-RES in the grid may be positive or negative, depending on whether ICT compensates intelligently for PQ-loss or even aids in increasing Power Quality. Also automated DR can be used to manage and maintain voltage on feeders; can be used to manage frequency by feathering on and off loads, and for responsive reserve to replace lost generation.

Power quality measurements are often needed at or near distributed power production, especially if the level of power produced is high compared to the source impedance of the network. In general, power quality and its measurements are usually more important inside the premises of the customer of the power distribution company than in the public power distribution network. Thus the customer, either local generator or user of electricity needs power quality measurement results.

Measurements of voltage level, voltage interruptions, and voltage dips are most often needed preferably permanently. Keeping the voltage levels within standards may require limiting temporarily the operation of distributed power production. It may also set constraints on the operation of the power distribution network. Tuning the response of protection systems of DG to voltage dips and short interruptions becomes more critical in networks where voltage dips are frequent for example due to network protection based on auto-reclosure sequences. Some types of distributed power production, especially fixed speed wind power plants, have such fluctuations in their output power that cause visually disturbing flicker of incandescent lighting. Measurements of flicker severity indices may be needed in such sites. Variable speed technology is much less likely to produce flicker but produces harmonics and possibly also some interharmonics. Distributed power production has often also reactive power compensation that may create a resonance that amplifies harmonics and interharmonics. Faults, blown fuses, erroneous grounding or unbalanced loads in customer installations or network components may cause power quality problems, such as severe asymmetry or DC-component that need to be detected rather quickly in order to avoid further damage or tripping protection of DG. If DER is used as a separate island, also the fundamental frequency needs to be measured for monitoring and control purposes.

The short-circuiting behavior of high DG-RES grids deserves extra attention, because currents flow differently as compared to a completely hierarchical grid. This also holds for black-starting strategies.

As seen above, DERs increase the needs for voltage quality monitoring. However, an adequate overall view of the voltage quality can be obtained by permanent measurements at some critical points in the power distribution network. There is no need to install specific power quality monitoring instruments to a large number of small DER units. On the other hand communication infrastructure is necessary for aggregating or coordinated scheduling – e.g. Virtual Power Plants. Monitoring of the generation is often desired even at small DERs.

3.5.2 Protection

There may be measurement needs related to monitoring the operation of power distribution protection and DER protection. These are mainly measurements of power quality quantities that the protection uses for tripping such as the fundamental frequency, voltage levels, voltage asymmetry and voltage dips. Measurements directly used to critical protection typically require fast response (roughly speaking 10 milliseconds from detection to tripping), high reliability and independence from other systems. Due to these requirements long distance data communication is avoided. Thus a general-purpose measurement system does not provide measurements for protection equipment and systems. However, DER increases the need for coordinating, tuning and monitoring the operation of protection equipment dispersed over the power distribution network. Some measurement data for this purpose may come from or via other systems. It is also becoming more and more common, that protection equipment and systems provide their measurements to other systems thus reducing the need to install parallel measurements.

With an increased share of DER in the network, and especially of DG units, some network operators require that the protection equipments are not too sensitive. For example in Spain (and Germany for all DGs connected to MV networks from 2009 on), wind turbines must be able to ride through a defined voltage dip before access to the network will be granted (so-called fault ride-through capability). The reason behind this requirement is that if at time of a voltage dip, all the wind turbines disconnect from the network due to their protection equipment, the situation on the network may worsen.

3.5.3 Distribution automation

Power distribution automation needs measurements for load forecast and for real-time monitoring of the network state and power flows. These include measurements of active and reactive power, currents and voltage levels. With this information the network state can be estimated, predicted and controlled more accurately. Power distribution automation typically does not have enough measurements from the customer connection points, because the costs of extending the distribution automation system that far are relatively high. The same measurements are often available in or can with minor costs be added to other automation and measurement systems and transferred from there to the distribution automation system. In recent years, utilities are undertaking extensive advanced meter installations with the intention that the communications system installed to support the advanced meters will be used as the communications platform for distribution and transmission system automation.

Modern network state estimation tools are able to use these measurements to improve the accuracy of the state estimation and the estimation models. In this kind of use rather long measurement delays and some missing measurements can be tolerated. However, situations needing rather fast reaction may occur, which requires the possibility to send alarms. It is also useful to give some power quality information to power distribution automation so that it can be taken into account when operating the network. Power distribution automation may sometimes need temperature measurements of distribution transformers, for example, in order to know how much they can be loaded. Automation of the distribution of other energy forms, such as natural gas and district heat, may also need information from the DER connection point. Possible solutions in high-DG RES grids for quick fault location are fault passage indicators. In high G-RES grids a more granular approach is necessary to find and resolve faults.

The communication needs between DER and power distribution automation systems depend on the size and penetration of DER. Standard IEEE 1547-2003 states that each DR (distributed resource) unit or aggregate of 250 kVA or more at a single PCC shall have provisions for monitoring its connection status, real power output, reactive power output, and voltage at the point of DER connection. The standard EN 50438, which deals with microcogeneration units (less than 16A per phase with some national exceptions, 16A per phase is a little over 10 kVA in three phase connection), does not require any communication between microcogeneration and power distribution automation. The new German interconnection guideline for DGs (e.g. inverters of PV-systems) connected to MV networks requires, beside fault-ride-through (behavior under fault conditions) the capability of the active and reactive power control, and generation management. It could be expected, that these guidelines will extend to the distribution network connected DGs in the near future.

The IEC 61850 standard deals with Communication structures in Substation Automation. Part 7-420 (currently in state “for voting”) deals with Communications systems for distributed energy resources (DER) – the information model, information exchange and services for control of DER. (See Annex 1)

4 Flexibility in the electricity demand

This chapter discusses on the utilization of flexibility as a distributed resource. It describes shortly the demand-side resources and automatic and price-based demand response.

4.1 Demand-side resources

The availability of the demand response resources (and to a lesser degree, energy efficiency) means that consumers may have some flexibility in how and when they use electricity. This means that given both the ability to easily manage their electricity use and information about its value, they can be willing to change that usage. Some part of their consumption can be shifted in time or simply suppressed. Typical flexible loads include different types of industrial processes, e.g. groundwood plants and mechanical pulping plants, electrolysis, arc furnaces, rolling mill, grinding plants, extruders, gas compressors, etc. In the commercial and residential sectors flexible loads can include space heating, water heating, cooling, ventilation, lighting, etc.

Theoretically almost all electricity consumption is flexible if the electricity price is high enough. In that sense the potential for demand response is huge. In practice the potential depends on several factors, like information or warning in advance of actual demand response, duration and timing of demand response, technical processes and ICT, metering and automation solutions at end-users, and economic benefits and pricing/contracts. The availability of enabling technologies such as in-premise automation facilitates customers' responsiveness to price signals and other demand response triggers.

In practice, different types of potentials can be defined. **Technical potential** is the amount of load reduction that would be realized if all eligible customers adopt DR measure(s) without regard to economic or market barriers. **Economic potential** is the amount of technical potential that would be realized from DR measures that meet specified economic criteria like pay-back time of investments or anticipated revenue from DR. **Market** or **achievable potential** is the amount of load reduction that could realistically be achieved by an actual DR program over a certain period of time.

4.2 Automated demand response devices

Often, it is easier and thus preferable for the consumer to be able to make its demand response automated. Devices exists that can control some loads automatically ̃[10,]. Most often, that type of devices receives a signal such as an alarm or a price signal and control loads accordingly. In most cases, consumers accept that type of device only if there is a possibility to override the automated control and to adapt or change the control strategies. More will be said about these signals and the way loads can be remotely operated in the communications and IT chapter.

4.3 Pricing granularity or smart rates

We have chosen the term of price granularity to express at what frequency consumers see the price of their electricity vary in time. The first element regarding the granularity is that it is closely related to the metering capability at the consumer's premises. If the consumers are submitted to for example night and day tariff (ToU-tariffs), their meter must be able to distinguish between the energy consumed in each different rate periods. Otherwise, the consumption is calculated based on a scenario and doesn't take into account any effort taken to respond to the prices. Shorter, more detailed pricing periods – e.g., real-time pricing or various peak pricing rates (e.g., critical peak periods) require advanced interval meters to record customers' period-specific energy use and charge them accordingly. Therefore more flexibility is needed in pricing, or for example power line communication (PLC) is used to switch the loads on and off.

In most of the participating countries, large consumers have hourly (or half-hourly) meters and tariffs. But when it comes to smaller consumers, the spread of hourly meters is a lot smaller, or even non-existing. It is quite common, however, that small consumers have night and day tariff or tariffs that vary from day to day.

The main obstacle to introduce more price granularity at consumer's level is the costs of installing and monitoring the meters. Our opinion is that it can become profitable in near future as the prices of fuel go up, the price volatility increases due to a larger share of renewables and as low voltage systems become more integrated and new sources of revenues are developed.

4.4 Customer response and production

In all the participating countries, demand response is present to some extent. The most common DR scheme is the time of use tariff (ToU) or the real-time pricing. These are schemes where consumers see different electricity price according to the time of the day. In ToU tariffs, the price vary only between a few values (typically day or night for example) while in real-time pricing, the price is linked to the spot market trade. Moreover, interruptibility contracts for industrial customers, considered within indirect load control initiatives, have been widely deployed for power balancing in most countries, at least in Europe and USA.

The best known type of DR that is commonly used in the participating countries is the load shedding, in order to help the transmission system operator in case of critical situations, such as avoiding a blackout (congestion management) or restarting the system after one. This type of DR is not included in the table in order to be able to make the difference with the direct load control programs where some consumer's appliances (often air-conditioning or water heating devices) are controlled directly by the energy retailer.

In addition to these programs, in some countries consumers that are large enough or an aggregation of consumers can act directly on power exchanges or on other service markets such as ancillary or regulating power services. There is however a reluctance of the balance responsible party, often the TSO, to accept the participation of small consumers.

Type of DR	Country	Note
Time of use	Finland	Retail and network ToU, usually for customers over 10 to 15MWh per year
	Italy	Night&Day tariffs for residential customers
	Spain	Compulsory above 50kW, otherwise optional
	Austria	
	Netherlands	
	USA	
	Korea	Industrial and commercial consumers
Real-time pricing	Finland	Some suppliers are offering this form of pricing for small customers if customer has an hourly meter [11]
	Italy	For large and medium consumers
	Spain	For large consumers
	Netherlands	For large consumers
	USA	Exists and is viewed to increase
Curtailment and direct load control programs *	Italy	Interruptible load deals with VHV grid large customers (by 7% of country peak load)
	USA	Most of the DR programs are of this type
	Austria	
* : Does not include emergency curtailment programs that exist in all the participating countries		

Table 4. Existing DR options in the participating countries

5 Communications and IT

This chapter describes the communication, monitoring, metering, automation and intelligence questions related to the DER integration.

5.1 Communication networks

Total costs for installation of specific communication network and infrastructure will increase non-linearly and converge when a certain density and penetration of ICT is reached. Initially, the costs per network node at a certain voltage level are highest. Replication in ICT generally leads to fast decrease of component cost.. The efficiency savings for the customers will be linearly increasing with the numbers of participants. Most communications networks enabling smart grid and DER integration are installed with advanced metering infrastructure. Once that communications network is installed, transmission automation and distribution automation can use that system. Also, advanced meters enable distributed intelligence and time of use rates and active demand response.

Public communication networks exist and are operational. Most of the pilots conducted nowadays utilize public TCP/IP networks, such as the public or private Internet in order to transmit information. Some other technologies, such as radio or cell phone communications are also possible in areas where the Internet access is not possible or too expensive to install, although a convergence of Internet technology currently is taking place in which the communication medium is transparent.

5.2 High-speed digital monitoring

In order to have a flexible and adaptable system, it is necessary to have a great deal of high-speed digital monitoring. The technologies and techniques for generation monitoring already exist and are used for large-scale generation and also for some DG units.

The transmission networks are also monitored in real-time with, among others, information about the energy flows and about the power quality at the system's nodes.

At the distribution level, the monitoring is limited by the deployment of smart meters or exists only partly in new or refurbished substations.

5.3 Smart meters deployment

There is no single definition of smart metering, however all smart-meter systems comprise an electronic box and a communications link. At its most basic, a smart meter measures electronically how much energy is used in a certain time-interval, and can communicate this information to the utility. This information can be shared with end-use devices to let the customer see how much energy they are using and how much it is costing them [12]

Definitions of smart metering are discussed in more details for ex. in [13]. Smart metering may have the following features:

- Automatic processing, transfer, management and utilization of metering data

- Automatic management of meters

- 2-way data communication with meters allowing control functions by a service provider

- Provides meaningful and timely consumption information to the relevant actors and their systems, including the energy consumer

- Supports services that improve the energy efficiency of the energy consumption and the energy system (generation, transmission, distribution and especially end-use)

The deployment of smart meters is still in an early phase in many countries. But many initiatives and plans have been launched recently to accelerate the deployment, and some countries like Italy already have almost 100 % penetration of smart meters. Driven by directives on energy efficiency in the EU, it seems that during next few years the deployment of smart meters will be forced in several European countries.

In most countries there are no adequate requirements for functionality of smart meters. The lack of common requirements increases costs of smart metering systems and makes it expensive to develop, maintain and implement market applications and services that are based on smart meter data. Some examples of common minimum requirements for smart meter functionality can be found [14, 15].

The frequency or duration of meter intervals depends upon the electricity provider’s tariff and rate designs. The requirements for billing metering stem from the tariffs applied. In principle, it is not necessary for the metering system to know the tariff applied. It is enough that the meter meters both the consumption and production of active and possibly reactive power separately (so called four quadrant metering) with the time resolution required for the tariff. In the Nordic countries this time resolution is 1 hour, in some other countries it is 15 or 30 minutes. Consumption and customer-initiated generation usually have different tariffs. Meter data can be stored in the meter for days or weeks before it is transferred to the utility’s meter data management system. The data must be reliable and accurate. Lost or erroneous data may cause significant costs, but transactional communication mechanism can avoid this.

Apart from solid ‘back-office’ applications receiving the metering data, detection of meter faults, erroneous installation and tampering is useful. Compensations for long voltage interruptions are also quite often included in the billing. Compensations for some power quality defects are also tentatively considered. Thus registering of voltage interruptions and perhaps even some basic power quality characteristics may be required for the billing meters of the future.

Data communication with the meter shall be such that the accuracy of the measurement data produced by the meter is not reduced due to data communication. The accuracy requirements of static billing meters are defined in IEC 61036 standards. It is reasonable to require that the hourly or 15 minute values required by the tariff maintain the original accuracy. In other words the data communication may not be the biggest source of measurement error. Typical source of such unacceptable inaccuracy is too large pulse size of pulse metering, because in some countries such recommendations for billing metering pulse size are commonly applied that do not meet this criterion.

5.4 Interoperability

Technical regulations, together with market regulations, can have a major impact on the development of distributed generation systems. Those technical protocols reflect emerging interoperability across elements of the electricity system, which affects how easily devices can connect and information can flow across the system. For DER resources to succeed and contribute most effectively to the grid, they will need both standardized physical interconnections to the networks and standardized information exchange. Interoperability can hasten DER integration; the lack of interoperability can slow or obstruct installation of DG and effective interactions between devices, device-go-grid, and back-office integration by the grid operator.

A large number of international standards have been developed or are under development for the connections of different types of DG. These are, however, voluntary unless a specific organization or legislation requires adopting these standards. Hence, worldwide there are a large number of additional national or regional standards, requirements, guidelines, recommendation or instructions for the interconnection of DG.

Regarding the connection of DG to an electrical network, different working groups elaborate on the development or maintenance of standardized documents. European countries significantly participate in the International Electrotechnical Commission (IEC) and in European Committee for Electrotechnical Standardization (CENELEC). Parallel to these and partly in co-operation the standardization work in the Institute of Electrical and Electronics Engineers (IEEE) is going on.

These working groups were concentrating initially on one type of DG, taking into account also the connection aspects to the electricity network. However the basic principles for interconnection are common and do not always depend on the type of DG. Therefore, a more recent approach comes up, where connection of a DG is treated irrespective of the type of ‘primary’ energy.

Annex 1 gives the summary on the most relevant standardization work.

Data communications architecture and application object models for DER are described in draft standard proposals such as UCA-DER and IEC 61400-25. These are based on IEC 61850 standards and their scope and point of view are around power distribution automation. In the UCA-DER and IEC 61400-25 draft standard proposals, electricity market interface, DER and load management issues are not included and the possible separation of distribution and trade businesses is not taken into account. While these and other IEC 61850 based standards deal with automation issues the Common Information Model (CIM) for power system energy management is defined in the standards IEC 61970-301:2003 (Energy Management System Application Programming Interfaces EMS-API) and IEC 61970-302:2004. The objective of CIM is to support the integration of between EMS systems, or between an EMS and generation and distribution management systems.

Very little work has been done to promote interoperability for demand response devices relative to the electric system; to date, most interoperability for DR has focused on in-premise automation, communications and information technology.

5.5 Functional Automation/Monitoring

Building automation and other electricity end-use automation often include energy management that controls and monitors end user's loads. Time resolution of about 1 minute is typically needed and long delays are unacceptable, when the measurements are used in control loops or observed online. Often the systems are monitored from a remote control centre. Alarms from abnormal load behavior are useful.

About the monitoring, for individual loads and appliances, it is needed for

- development and updating of load models and forecasts
- verification of control response
- some load control strategies.

Time resolution of 1 to 10 minutes is usually adequate for modeling and verification purposes. Modeling and verification tolerate delays of several days, but faster response makes these tasks more efficient.

When using some type of load control strategies, particular end user’s loads or appliances may require individual monitoring capabilities. Such load control strategies are usually developed for residential customers and imply that the proper infrastructure is deployed within end user’s facilities in order to transmit the information from individual appliances to the control centre. If we want to have a significant amount of controlled load, many residential customers have to be monitored and the cost of real time monitoring of many individual residential appliances is high. Even if one-minute time resolution is very desirable, delays of 5 or 10 minutes could be acceptable, if very fast response is not compulsory.

Due to the high communication costs of minute level data at large number of residential customers other methods are usually applied to define demand response of small customers like feeder based measurements and statistical analysis.

5.6 Intelligence/Smart behavior

5.6.1 Load modeling

Often the purpose of load modeling is to create and update models for hourly load curves. Even then it is essential to understand the behavior of loads and better time resolution is needed for that. Also verification of load control responses requires time resolution of one or some minutes. Otherwise the responses cannot be accurately distinguished from other load variations. Often both active and reactive powers need to be registered.

Load models are also developed for the prediction of the response to controllable loads. Then time resolution of some minutes is typically needed. Loads to be modeled may also include DG.

5.6.2 Automation of distributed energy resources (DER)

The requirements of DER-automation depend very much on the type of DER in question and on the way DER is operated: mainly customer-operated or utility/aggregator operated. Control, management, and state and condition monitoring are typical DER-automation functions. There are needs to send alarms on exceptional situations to control centers. Maintenance checks of far-located DER-processes and equipment need to be as automatic as possible. The same applies also for the possible fuel supply chain of DG. Significant costs are saved, if problems can be solved based on remote expert advice instead of requiring the expert to travel long distances. Also energy trading needs advance information on DG failures and maintenance stops. Remotely readable measurements are needed for such purposes. At some DER installations there may not be any such DER-automation system that could transfer measurements to a remote control centre. Thus the electricity measurement system may need to transfer also some other measurements. Some examples on the DER automation exist like [16].

Metering systems may transfer DER-management commands, time variable tariffs and weather forecast data for use in optimization of DER operation. Local trading system may also interact with energy markets by exchanging offers and contracts, but probably these functions are outside the scope of metering systems.

5.7 User/primary process feedback

In several studies it has been shown that customer behavior can be affected by the feedback and information. In IEA DSM Task XI three main mechanisms were identified by which smaller customers can be motivated to change behavior, save energy and be rewarded for making the changes [17]:

- **End Use Monitoring and Feedback (EUMF):** customers are presented with a breakdown of their individual end uses of electricity, its costs and environmental impacts and are motivated to make general energy savings

- **Time of Use (TOU):** electricity customers are presented with different prices for electricity at different times and respond by shifting demand from high to low cost price periods. A variation of this motivating mechanism is Dynamic TOU pricing where customers can change their use of electricity with reasonably short notice times (typically 24 hours notice) in response to notified price changes.

- **Demand Side Bidding (DSB):** customers participate in energy trading, by contracting specific demand changes in response to requests by System Operators or Suppliers (for ex. an offer to deliver a specific change in energy use when the spot market price hits a specific level). Dynamic TOU pricing is a valuable motivator for delivering DSB, which can deliver energy saving as a result of reduced system losses and reserve generation capacity and overall increases in operational efficiency.

Customers also respond strongly to reliability events, enrolling to deliver a contracted response when called to do so by the grid operator. These measures can include direct load control, instantaneous interruptible load, and similar programs.

More detailed discussion on the effect of the feedback and the related technologies is given in the report [18]. Recently new technologies are coming into market where the feedback from the meters can be obtained at customer displays either directly from the meters or indirectly from the service providers.

5.8 Intelligent agents and distributed controllers

The integration of a DER portfolio can be done following the concept of the Virtual Power Plant (VPP). Although the size can vary, the concepts found are very similar. We can however make the distinction between two types of integrated DER portfolio. The first one is purely commercial and aims at aggregating units in order to mitigate risks and to be able to act on the different power or capacity markets. The other one is the smart grid concept and includes technical aspects such as local network management.

From the technologies point of view, both VPP systems have elements in common. They are often organized with a central unit gathering information from smaller dispatched units and sending them orders according to the market or network situation. As it has been discussed already, the collection of metered data as well as the orders can have different forms and be realized with different time scales.

The information sent from the dispatched units can include:

- consumption / production of one or several resources
- amount of available flexible power and its price bidding
- confirmation that an order has been realized as required
- situation on the network

And the information from the central unit to the dispatched ones can be:

- direct orders or requests (such as time schedules)
- remote control signals
- prognosis data
- price signals

Sending price signals seems to be the most convenient way to control dispatched units. The local units can then transform these price signals into direct control or into an alert to the consumer.

The Figure 8. represents the architecture most commonly found in current VPP projects. Not all projects have all these interactions with the different actors. Also, a single local unit can operate several different local resources or some smaller local units without those units located in the same physical area.

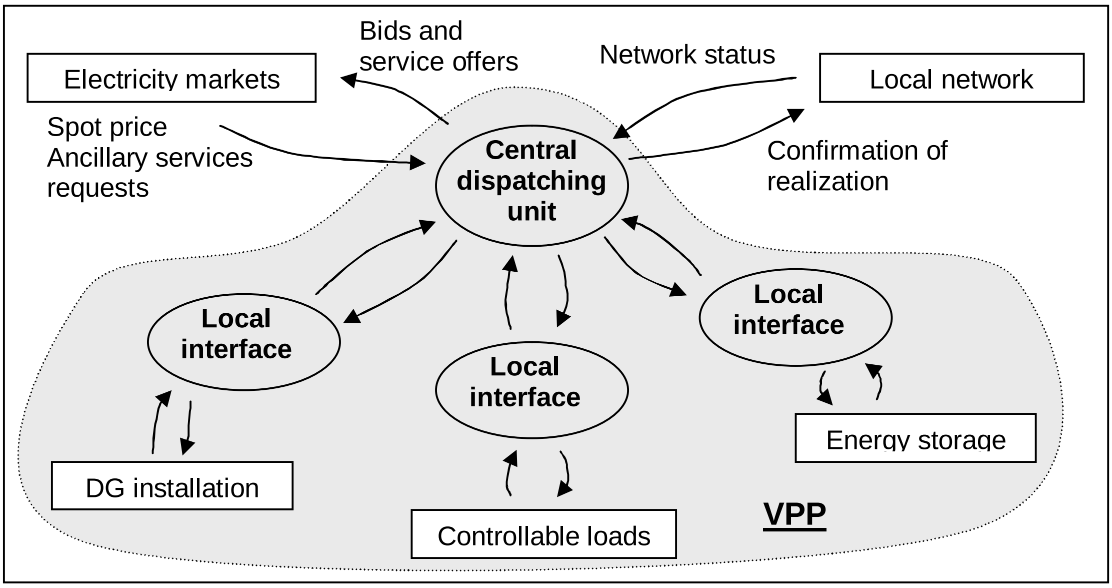

Figure 8. Architecture of a Virtual Power Plant such as some projects reviewed in chapter 8.

One example on the general communications system architecture for the DER management is illustrated in Figure 9. (Source: EU-DEEP project [5]). Here are as an example some characteristics of the local interfaces, of the central unit and a general description of its ICT infrastructure.

5.8.1 Local interface or local DER Controller

The Local DER Controller is the Logical Device according to the IEC 61850 acting as "Server", which provides data, responds to commands and manages the seamless operation of the DER device. It can be a simple electronic controller linked to a single device, a more capable Intelligent Electronic Controller (IED) providing additional functionalities, or a local server which manages multiple devices.

The presence of a Local DER Controller becomes compulsory, in accordance with IEEE 1547.3, in case of a DER unit with 250 kVA or more rating or a DER installation at a single PCC with an aggregate rating of 250 kVA or more. In such occasions, the Local DER Controller provides for monitoring of information related to connection status, real power output, reactive power output and voltage at the point of connection.

5.8.2 DER/EMS management system

The DER Management System monitors, controls, and maintains the local Electric Power System (EPS), supporting switching operations of DER devices and local loads. This DER Management System may be a system that handles the scheduling and running of DER devices only or it could be a part of a Building Automation System (BAS).

A more complex configuration involves the use of a remote DER Management System that handles multiple DER installations, providing different levels of monitoring, control, statistics-gathering and maintenance support. In all configurations, the DER Management System acts as an UCA-DER client.

5.8.3 ICT infrastructure

In this diagram the oval entities represent the various stakeholders, who are involved in DER system transactions (one stakeholder can assume more than one role). All these stakeholders will interact with the Local DER Controller and among them via a public TCP/IP network, such as the Internet.

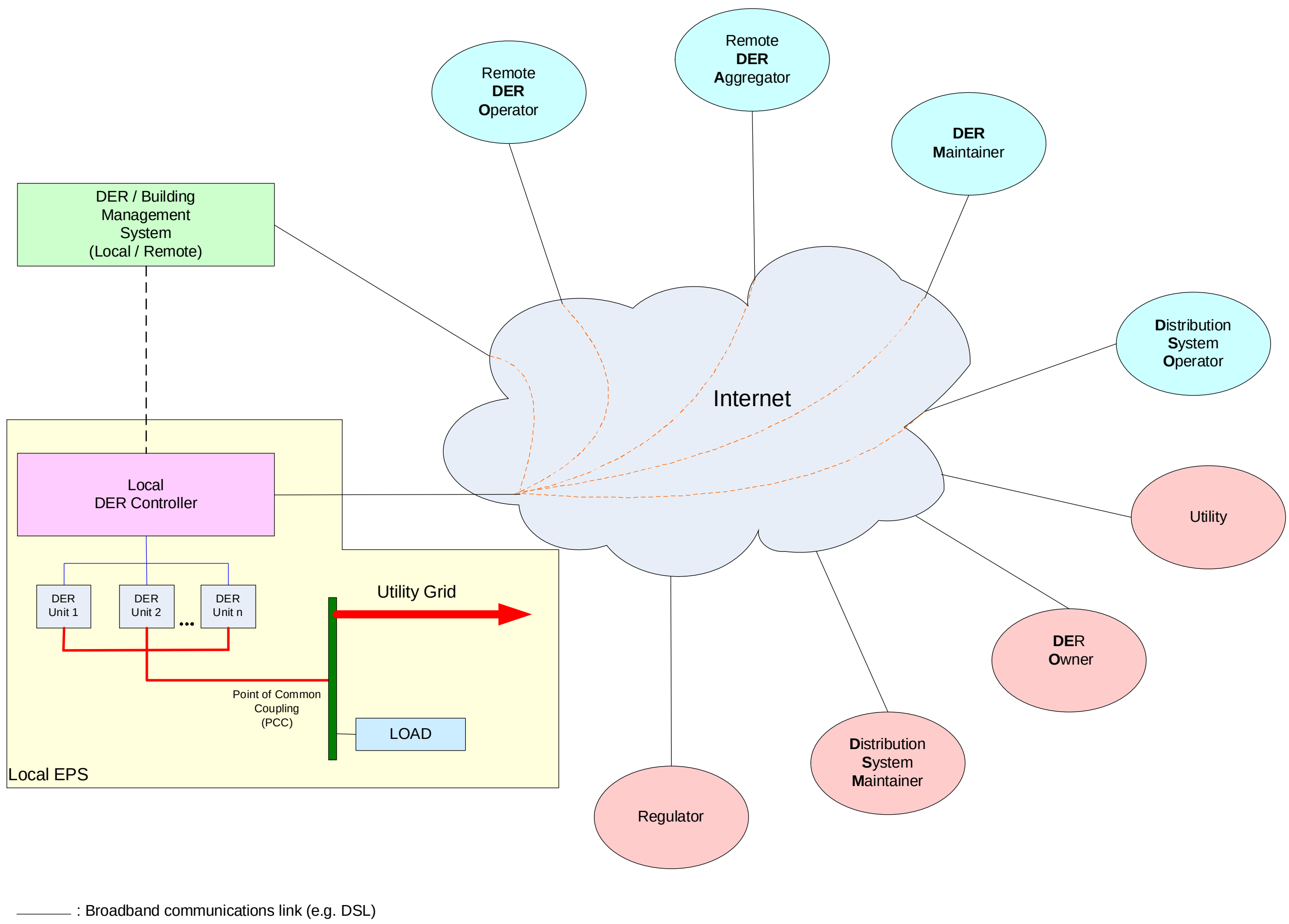

Figure 9. Example on the Communications System Architecture for DER

Internet is the undisputable choice for a public TCP/IP network, as it is the biggest virtual network in the world and is accessible to everybody independently of its platform. The main advantages of the Internet are:

– Interoperability, as it is based on the standard TCP/IP protocol suite.

– Availability of cheap hardware and software devices with TCP/IP functionality incorporated.

However, using the internet can expand network vulnerability to cyber security, creating security and redundancy challenges that become important for maintaining reliable grid operations.

TCP/IP uses several protocols, which provide very scalable routing properties and can select reliable or unreliable communication, depending on the needs of the applications. If timely transmission is required, UDP (User Datagram Protocol) is often selected for use, but also other transport layer protocols can be developed for special purposes. Power system communication protocol standards use special communication protocols (IEC 61850 GOOSE and GSSE protocols) for time and safety critical communication.

In order to satisfy the requirement for wideband communications, the high speed Internet access Digital Subscriber Line technology (DSL) is proposed with speeds, which depending on the application needs, can vary from 128 kbps up to several Mbps. . DSL technologies use sophisticated modulation schemes to pack data onto copper wires and offer high speed communication. The local site may have several DER units and automation systems in the same site and they are connected via a switch to a DSL router. The site has also functionalities for the DSL modem, VPN and firewall. The most important VPN technologies are probably IPsec/IKE and MPLS. This way, secured tunnels can be provided between parties (Local site, DER Aggregation, DER unit and electricity market), the basis for security in Internet is achieved by VPN technology, but other technologies and methods of defense are necessary in addition.

Within the Local DER Controller, the UCA-DER architecture is adopted, as it ensures interoperability and compatibility with the TCP/IP standard. The Local DER Controller acts as an UCA-DER server and every user, who wants to communicate with it, acts as an UCA-DER client.

For communication exchanges between any two stakeholders, the proposed architecture is Web Services, as it constitutes the standard technology today for Business-to-Business applications and guarantees interoperability.

For DER System control functions, in particular, there are some instances such as protection mechanisms, whereby there is a demand for fast response times (e.g. 10ms from detection of the problem to tripping, the transfer of trip and breaker status is very fast, maximum end-to-end transfer time is typically specified between 3-10 msec, according to IEC 61850). This type of action requires high reliability and predictability that the Internet cannot guarantee. As a result such functions should be decided and executed locally by the Local DER Controller. However, for many remote automation applications the requirements are significantly less strict and the performance of the Internet is satisfactory.

6 Integration analytics

This chapter is mainly describing the tools and methods available for the analyzing the effects of integration to the energy systems. It is mainly based on the survey done by VTT and is not in any sense comprehensive, but more or less illustrative. A comprehensive survey would require a larger group of experts, who have first-hand experience of using many tools.

6.1 Analytical tools and analysis methods for the assessing the effects of integration

6.1.1 General description of the tools

With DR, DG, storage and smart grid technologies we may be able to solve problems such as network congestion, high transmission losses and supply variation from variable generation, including wind power, run-of-river hydro power and CHP. It is difficult to know by manual inspection how to implement them in a way so that we achieve a good cost/benefit ratio. Analysis tools can help in making the right kind of investments at the right time. After the investment has been made, different tools can help in operating the resources in a way that the owner's and (hopefully) the system's benefits are maximized. They can also show the physical effects of DER penetration on the network. Certain tools can also be used for finding the right kind of incentives to promote investments, taking into account their externalities and system security. Without these tools, we do not yet understand the technical ramifications and consequences of such integration, nor can we estimate the benefits from enacting policies to push integration faster.

The tools that we have considered are mainly high-level software tools, which, while not absolutely necessary, can support decisions concerning energy policy and investments and operation of DER. Some of the tools can also be connected into a larger automated system including also hardware components such as meters. There are few tools which have been built specifically for the analysis of integration of demand response with distributed generation, storage, or smart grid technologies. However, many tools allow the addition of a demand response and a distributed generation and/or a storage component. When network effects such as congestion and losses are not considered, demand response can be considered as one form of DG. Certain forms of DR and DG also inherently contain energy storage.

6.1.2 Classification of tools

We divided the tools according to their purpose into following classes:

- resource planning and policy analysis tools,
- energy flow and market integration tools,
- power system analysis tools,
- customer level simulation tools,
- operation optimization tools
- forecasting tools

Integration of DSM, DG, RES and storages: Integration analytics

Resource planning and policy analysis tools perform macro-scale analysis, which does not only include technical but also economic variables. They can calculate the economic effects of introduction of DR, DG, and (some tools) storage, into the power system. These tools work with time scales up to several decades, and normally do not go beyond one hour time resolution. They can calculate things such as

- Power demand (and duration curve) development trends,
- costs of maintaining the current power generation system and expanding the system with different alternatives,
- analysis of alternative future scenarios in terms of cost, emissions and security,
- effects of taxes, subsidies and emission limits.

The drawback of these tools is that they can easily lull an inexperienced user into a false sense of security. Often the tools require projections of fuel prices, industry trends, consumption patterns, etc. into distant future. These are inherently difficult to predict. One should perform quite an extensive sensitivity analysis to get an understanding of the performance of different policies or investment plans under future uncertainty. In addition, one should remember that even with perfect forecasts of relevant parameters the models can make errors because of their imperfect description of reality.

Energy flow and market integration tools can calculate the coincident load in certain area, or its probability distribution. They may be able to simulate supply, too, for example by performing system-level economic dispatch optimization. This way they may be able to produce price forecasts and transmission bottleneck forecasts.

Power system analysis tools do the detailed physical simulation of power (or fluid) network. They can be used for planning, design, control and optimization of power systems and their performance. This becomes more and more important when penetration rate of distributed generation increases. There are new potential grid problems that might arise. Low-loaded lines and cables tend to become capacitive, which might lead to over-voltages and instability of power plants. These problems can be identified with network simulation. Components such as power lines, relays, appliances, transformers and generators can be included in the simulation. The tools can be for example used when deciding the location of a DG unit, although other factors, such as fuel supply, which are out of the scope of these tools, also have to be taken into account. Different simulation tools are available for gas networks. They are relevant because CHP units often use natural gas as fuel.

Customer-level simulation tools are simulation tools for single building or a group of buildings, or an industrial facility. They calculate heat and power consumption at customer sites and possibilities for consumption control. Heat consumption is relevant because the customer may have electric heating or consume heat produced by a CHP unit. Some of them can forecast demand response and the subsequent payback peak, when consumption is larger than normal.

Operation optimization tools suggest the optimal way to operate DR, DG and storages on the electricity market. The reason for needing these tools is that usage constraints. For example, we may not ask DR from a customer more than two hours per day, therefore we must consider the opportunity cost of not being able to use it at some other time during the same day. There are also uncertainties in the price that is received from power generated / load reduced which is obtained as the result of call (dispatch command), as well as the magnitude of the load reduction itself.

We further divided the tools into "operational" class which is suitable for actual real-time operation and "assessment" class, which is more suitable for investment planning. They calculate a longer period, such as one or two years, with different values of relevant parameters. To do this quickly, their model must be simpler. On the other hand, Aggregators or DG or DR use real-time DER optimization tools to manage their aggregated DER. The tools which we listed work from the point of an individual generator. Note that the system-wide optimization is a different problem.

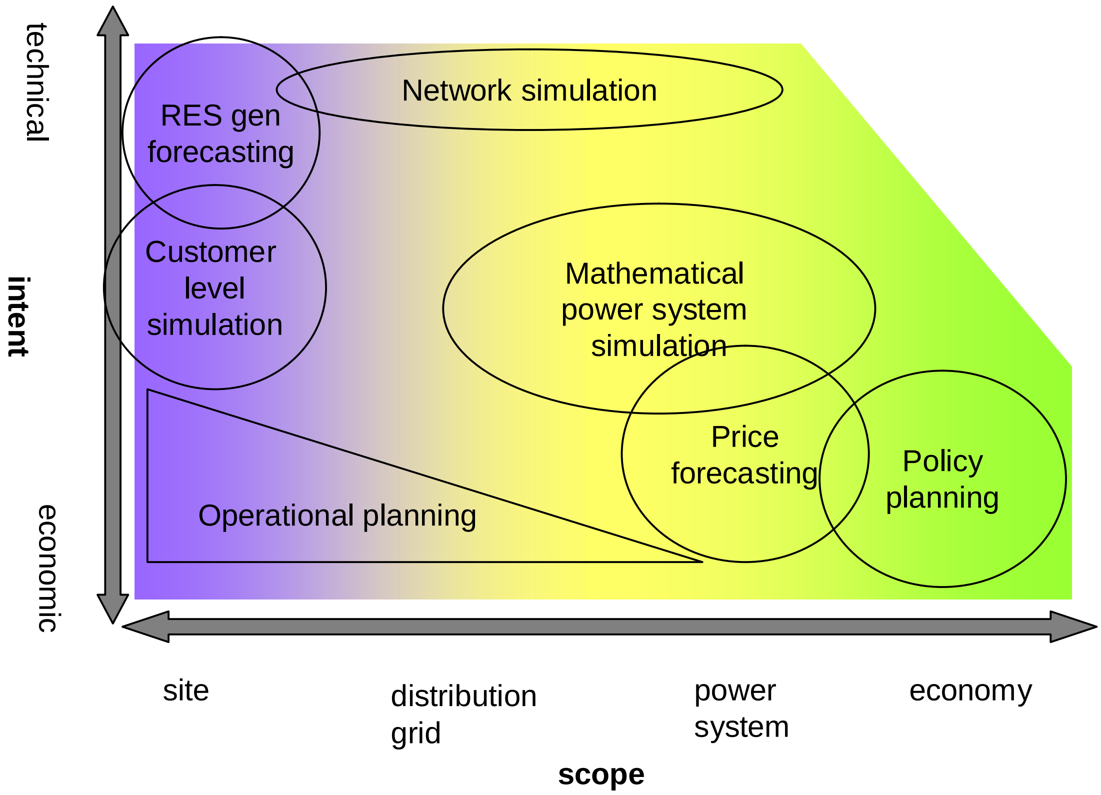

Figure 10. Tool categories presented in a scope-intent matrix.

Forecasting tools are important in optimizing the operation of DR, DG and energy storages. Activation time of DER is often one hour or more. At this time several important variables such as imbalance charges, and wind power production, are still undetermined. Moreover, because of production constraints, dispatching DG or calling DR at one time will cause that it cannot be used at some later time, at which it could be needed more. Having good forecasts can then help us scheduling production at the best possible way.

In other words, the tools can be used to forecast prices and variable generation such as heat demand driven CHP, run-of-river hydro power and wind power. Forecasts can of course be extended further ahead to help also investment planning. These are commonly socioeconomic forecasts about prices and technology development. In our opinion one should be cautious with such forecasts. It is common to underestimate the confidence intervals of forecasts. Indeed, e.g. power price can easily jump to a new level because of a change in price of tradable emission permits.

6.1.3 Readiness level and weaknesses of the tools

We have undertaken the attempt to define the readiness level of activities and technologies in the electricity sector. That is to say, we try to identify the activities and technologies which still need research and those that are already widely available. We defined four levels or readiness:

- early (in R&D level),
- young (pilots and field tests exist),
- existing (available commercially, from at least one vendor, early adopters are involved),
- mature (widespread commercial).

“Mature” does not imply the tools can no longer be developed further but rather that it is working and well available. Table 5 below lists our assessment of the readiness of the different tool categories.

tool category	readiness
resource planning and policy analysis tools	mature
energy flow and market integration tools	mature
power system analysis tools	mature
customer-level simulation tools	existing
operation optimization tools	mature
forecasting tools	existing

Table 5. Readiness level of the tool categories.

A significant weakness is the difficulty of communication -- i.e., lack of interoperability – the common, easy technical interface and informational semantics and formats -- between different tools. For example it may be necessary to feed output from a forecasting tool or customer-level simulation tool as input into an operation optimization tool, or output from a operation optimization tool as input into a network analysis tool. For this to work the tools should "speak the same language" (be able to read the other tool's output, i.e., be interoperable) and "be on the same wavelength" (use the same assumptions). For example, a forecasting tool may produce price forecasts without any confidence intervals, which cannot be accepted by the operation optimization tool.

6.2 Good, real data

As we have discussed in the communications and IT chapter, we can see that little data on real consumption are available for small consumers. Most of the time, their behavior is assumed to follow a pre-determined load profile. The development of projects aiming at introducing demand response into small consumers’ behavior as well as the deployment of smarter meters are currently making real data more available. In some cases there is also lack of statistical system-level data such as system (imbalance) prices.

7 Regulation, policy and business opportunities

This chapter discusses on the costs and benefits of DER integration, policy instruments applied in different countries and business opportunities in the framework of different regulation and policy.

7.1 Understanding relative costs and benefits

Distributed energy business has the character that there are many actors which all have their own goals [19]. These actors can include customers, on whose premises DG or DR equipment are installed, the energy supplier, the company who installs and controls the operation of DG and DR (if this is different from energy supplier), distribution network operator, transmission system operator, gas network operator, government and the whole society. Moreover, the interactions between different parties are not simple value chains but value constellations in which enterprises are collaborating in networks. The introduction of changes into this system can have a negative or positive effect on the well-being of different actors. Negative effects to some actor can jeopardize or delay the follow-through of the changes.

Example of such negative effect can be found in smart metering. They may not be profitable to the DSO (who installs them) only. However, they can include extended services such as load control and can thus be exploited by demand response aggregators. A suitable price for the metering and control services should then be found so that DSO as monopoly can make normal profit. In principle, if the business can bring net benefits to the whole society, it is possible to find income transfers which would make all parties better off. These can take the form of payments between companies or between taxpayers and companies, such as subsidies.

There are tools for understanding the transactions between different actors in networked economy especially in the case of DG and DR. One such tool is the "Busmod" (business modeling) or "e^3-value" methodology [20, 21]. It graphically shows the financial connections between different actors and can also calculate profits for all relevant actors in simple cases. It does not, however, calculate the complicated decisions needed in e.g. operating DG units; prices and quantities for transactions can only be calculated in a simple way. By explicitly modeling a DER business case using a shared and well-defined terminology, it is also a good tool for helping to increase understanding between different parties. This tool has been better introduced in Annex 2: Busmod methodology.

7.1.1 Costs and benefits of different actors related to the integration of DER

Large number of actors in the electricity market can derive benefits from the use of DR in the connection of DG, RES and energy storages. ***Policy-makers or regulators*** can increase system security, improve economic efficiency through reduced market prices and protect the environment. ***Market operators'*** benefits are related to the decrease in the market power of big players and thus increased credibility of the market, and to the development new products for the market.

*A **system operator or transmission system operator (TSO)*** can use DR for system balancing (regulating power market in many cases), for handling disturbances in generation and in the transmission system (auxiliary services), for preventing blackouts and restoration from blackouts, for handling bottlenecks in transmission and for better use of existing generation and transmission capacity. A **distribution network operator (DSO)** is able to handle network bottlenecks during the peak load period and to better utilise network capacity. In addition, demand response helps to prevent blackouts and restore from blackouts, to decrease the problems caused by distributed generation (especially variable generation: wind, solar, CHP), to increase the quality of supply (voltage etc) and finally, to meet the requirements of regulators and energy policy.

Traders, suppliers and retailers can use DR for risk management and hedging in the electricity market, in developing new products and services for customers, and in developing new businesses (like acting as aggregators between customers and electricity market).

Customers get their own economic benefits. They enjoy the lowering of electricity price. They can also better react to tariffs, prices or other incentives and they get economic benefits from trading loads. All in all, demand response improves system reliability and the environment.

For **manufacturers** the benefits are related to development of new ICT, metering and automation products for the needs of demand response.

The demand response market can also stimulate ***the development of new business opportunities for new actors such as aggregators and metering service provides***. This field is still under development. As can be seen, the benefits of demand response are divided among a large number of actors, but this is also a barrier in an unbundled and competitive market: it is difficult to develop business cases where enough of the benefits accrue to one or more actors in a way that allows a win-win-win situation, even though the benefits for society as a whole are obvious. Costs and benefits of demand response are described for ex. in [22].

As a general rule, the costs and benefits of an increased DER penetration are starting to be known for DG units and large consumers, but there is a lack of knowledge when it comes to information about smaller consumers. Some pilots and projects are being conducted, but their results are not yet available.

7.2 Incentives and subsidies

DG/RES is not yet usually economic to consumers or investors compared to the large scale electricity production although their benefits are seen on long term and for the whole society. Therefore different types of support schemes are developed to improve the market access of DG/RES.

Typical incentives are:

- different types of feed-in tariffs (fixed, variable, price premium),
- priority access,
- quota systems,
- investment support,

- tax reductions, and
- R&D support.

Support mechanisms for DG do not only differ between the countries, but may also differ for the different DG technologies. The mostly used support mechanism in Europe is the feed-in tariff – either as a fixed tariff or as a time dependent tariff [23].

Feed-in tariffs have been very effective in promoting DG in many countries. However, with an increasing share of DG in the national supply system the feed-in system is not efficient. Electricity is generated according to the tariff levels and not according to the actual demand for power. Therefore, some countries have replaced their feed-in systems with more market-based systems, e.g. price premiums, where the support follows the demand for power. An example is Denmark that has a large share of DG CHP. Until 2005, the DG CHP plants received a fixed feed-in tariff with three time dependent steps. This created problems with excess production in some hours. From January 2005 the tariff structure changed to a price premium, i.e. the support follows the supply through the spot market prices, which gives incentives to adjust the supply when there is excess production or excess demand.

The Table 6 shows the available incentives used in the participating countries to this IEA task. In the USA, the situation varies very much from utility to utility. In some states, there are goals and incentives, in some others not.

	Country	**Note**
Investment support	Finland	30% (40% for wind power)
	Korea	30% ~ 80% (depend on the types)
Tax reduction	Finland	Certain generation forms do not pay electricity tax
	Korea	10 % of investment in renewable energy can be deducted from corporate income tax
Feed-in tariffs	Italy	CIP6 scheme with frozen eligibility; all-inclusive scheme for devices less than 1MW
	Spain	Optional if under 50MW
	Austria	
	Korea	
Fixed premium	Italy	PV solar
	Netherlands	
	Spain	Optional if under 50MW
Green certificates	Italy	Quotas up to 6.8% (2012) of fossil generation & imports
Quota	Austria	For balancing areas

Table 6. Renewable energy incentives

Similarly, it can be seen that demand response needs also some incentives to customers to offer DR services. ***Incentive-based demand response*** [24] refers to programs proposed by utilities, load serving entities, or a regional grid operator. These programs give customers load reduction incentives that are separate from, or additional to, their retail electricity rate, which may be fixed (based on average costs) or time-varying. The load reductions are needed and requested either when the grid operator thinks reliability conditions are compromised or when prices are too high (reliability or economy based DR). Most demand response programs specify a method for establishing customers' baseline energy consumption level. Hence, observers can measure and verify the magnitude of their load response. Some demand response programs penalize customers that enroll but fail to respond or fulfill their contractual commitments when events are declared. Typical incentive-based demand responses are:

- **Direct load control:** a program by which the program operator remotely shuts down or cycles a customer's electrical equipment (e.g. air conditioner, water heater, space heating) on short notice. Direct load control programs are primarily offered to residential or small commercial customers.

- **Interruptible/curtailable (I/C) service:** curtailment options integrated into retail tariffs that provide a rate discount or bill credit for agreeing to reduce load during system contingencies. Penalties may be assessed for failure to curtail. Interruptible programs have traditionally been offered only to the largest industrial (or commercial) customers.

- **Demand Bidding/Buyback Programs:** customers offer bids to curtail based on wholesale electricity market prices or an equivalent. Mainly offered to large customers (e.g., one megawatt [MW] and over).

- **Emergency Demand Response Programs:** programs that provide incentive payments to customers for load reductions during periods when reserve shortfalls arise.

- **Capacity Market Programs:** customers offer load curtailments as system capacity to replace conventional generation or delivery resources. Customers typically receive day-of notice of events. Incentives usually consist of up-front reservation payments, and face penalties for failure to curtail when called upon to do so.

- **Ancillary Services Market Programs:** customers bid load curtailments in ISO/RTO markets as operating reserves. If their bids are accepted, they are paid the market price for committing to be on standby. If their load curtailments are needed, they are called by the ISO/RTO, and may be paid the spot market energy price.

7.3 DER business opportunities

7.3.1 Market based DER

In the market based solution getting DER into market the market design gives framework to stakeholders to develop solutions or react to market conditions. Typical examples **for DG/RES** are market price based feed-in tariffs and green certificates and **for energy efficiency** white certificates.

Correspondingly ***price-based demand response*** refers to changes in usage by customers in response to changes in the prices they pay:

- **Time-of-use (TOU):** a rate with different unit prices for usage during different blocks of time, usually defined for a 24 hour day. TOU rates reflect the average cost of generating and delivering power during those time periods.

- **Real-time pricing (RTP):** a rate in which the price for electricity typically fluctuates hourly reflecting changes in the wholesale price of electricity. Customers are typically notified of RTP prices on a day-ahead or hour-ahead basis.

- **Critical Peak Pricing (CPP):** CPP rates are a hybrid of the TOU and RTP design. The basic rate structure is TOU. However, provision is made for replacing the normal peak price with a much higher CPP event price under specified trigger conditions (e.g., when system reliability is compromised or supply prices are very high).

If the price differentials between hours or time periods are significant, customers can respond to the price structure with significant changes in energy use, reducing their electricity bills if they adjust the timing of their electricity usage to take advantage of lower-priced periods and/or avoid consuming when prices are higher. Customers' load use modifications are entirely voluntary.

Market based solutions also give solid background to develop new business opportunities for ex. to aggregators.

7.3.2 Examples of business models

By "business model" here we mean a description of the partners, main transactions, sources of value, and incentives of a business. A business model also includes at least a simple estimation of profitability of the business. Business model does not concern itself with how to deal with competition (this is more a topic for business strategy).

In the EU-DEEP research project (European distributed energy partnership) DR as well as DG and storages are employed at small and medium-sized customers [5]. Three business models have been selected for development in view of valuing the benefits of DER in the system and of optimising this value (see): DER is installed locally where they have the most relevance, but are operated globally to optimise their value. They will rely on the aggregation of DR and DG as key sources of value creation. The business models differ in terms of actors (customers and the aggregator) as well as DER technology.

Business model	Aggregator	Customers	DER technology
1	electricity supplier	medium commercial and industrial	flexible demand, wind
2	electricity and gas supplier	small residential	CHP
3	energy service company (ESCO)	medium commercial	CHP and flexible demand

Table 7. EU-DEEP business models.

In the first business model, the idea consists in an electricity supplier using flexible demand from medium-sized industrial and commercial customers to balance wind power generation and integrate both in electricity markets. The business model contains several sources of value. They involve aggregating small load reductions, and selling them to the spot market when spot price of electricity is high, to reduce imbalance (originating for example from wind power generation) when they can be seen to provide power at a cheaper price than would be the imbalance price for power deficit, or (for certain types of flexible loads) to increase load when better price can be obtained by selling power surplus to flexible customer than would be the imbalance price for power surplus, and selling them to the balancing mechanism to help TSO keep system balance, and providing ancillary services such as short-term operating reserve.

The aggregator in this case is the supplier itself. The regulatory requirement for the business model to be feasible is that the load reductions are summed into the supplier's imbalance account (in UK there are two balance accounts, consumption and generation, and load reductions as well as wind power generation are summed in the former).

In the second business model an electricity and gas supplier aggregates flexible micro-CHP units owned by residential customers. The flexibility (ability to quickly react to the need of power) is realized through a decoupling of heat and electricity generation using heat storage capacities inherent in the buildings. A single micro-CHP unit cannot participate in electricity markets on its own, because its size is normally much lower than the required capacity to participate in the market. Moreover, the schedule of micro-CHP's should be optimized to get better price for the electricity. To reduce such overhead costs, aggregation is necessary. This business model has been most thoroughly analyzed in Germany but also in four other European countries. The problem in Germany at the moment is the feed-in tariff for micro-CHP which does not give incentive to run it when it is most needed for system balance.

The customer can benefit by reducing his energy supply costs. The source of the saving is that the aggregator shares his benefits, which he gets from customer flexibility, with the customer. Another source of saving is the higher energy efficiency of CHP compared to separate production of heat and electricity, as well as possible government subsidies.

The third business model involves an Energy Service Company (ESCO), which installs CHP units at commercial customers such as hospitals and universities. The customers can exploit the heat (or cold if absorption chiller is included) and ESCO can exploit the electricity in the same way as in business model 1, although this of course depends on the regulations of the country in question. It is also possible to use the DG units to relieve distribution network congestion. In order to increase CHP flexibility, the ESCO can install a boiler and a heat storage tank for each customer (in addition to the CHP unit). In this model ESCO, which acts as aggregator, owns the CHP unit.

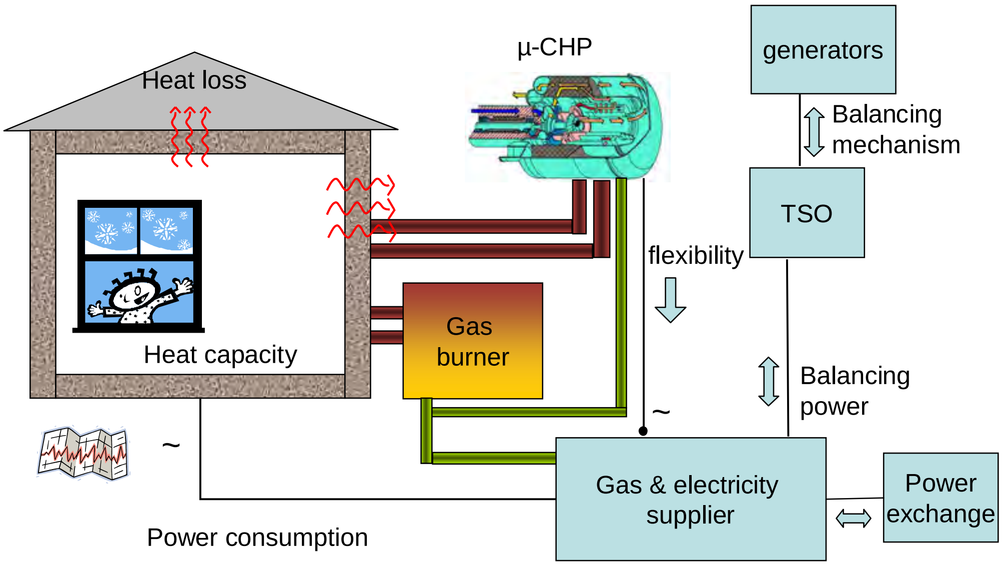

Figure 11. Customer and aggregator (supplier) in the second EU-Deep business model. The power ouput of customer's micro-CHP unit and heat output of his gas burner can be adjusted according to gas and electricity prices (and possibly the supplier's imbalance).

The profitability of these business models in the current regulatory situation is not yet known. One of the goals of the EU-Deep project is to assess the profitability in different countries and under different market rules. There are quite a lot of uncertainties which make the assessment more difficult. These include:

- development of fuel and electricity prices,
- development of equipment prices (e.g. micro-CHP and controllers),
- development of regulations and subsidies,
- customer's willingness to accept demand response, and
- competition.

A company can of course limit itself to selecting and analyzing potential DER sites and doing the installation, leaving the actual control to another party. In this case there is no regulatory barrier that the consumption or production of individual sites should be summed into the aggregating company's power balance. The business works, if they are summed into their supplier's power balance, and the supplier and the aggregating company are in long-term principal / subcontractor relationship. Naturally, the customers should have a long-term supply contract with the supplier.

The Figure 12. below shows how Enernoc in USA conducts business by demand response program design and implementation, customer recruitment, site enablement (installation), event dispatch (calls) and response verification. The actual decision about when to perform calls is made by the principal, which can be electricity supplier or network operator if DR is used for network management.

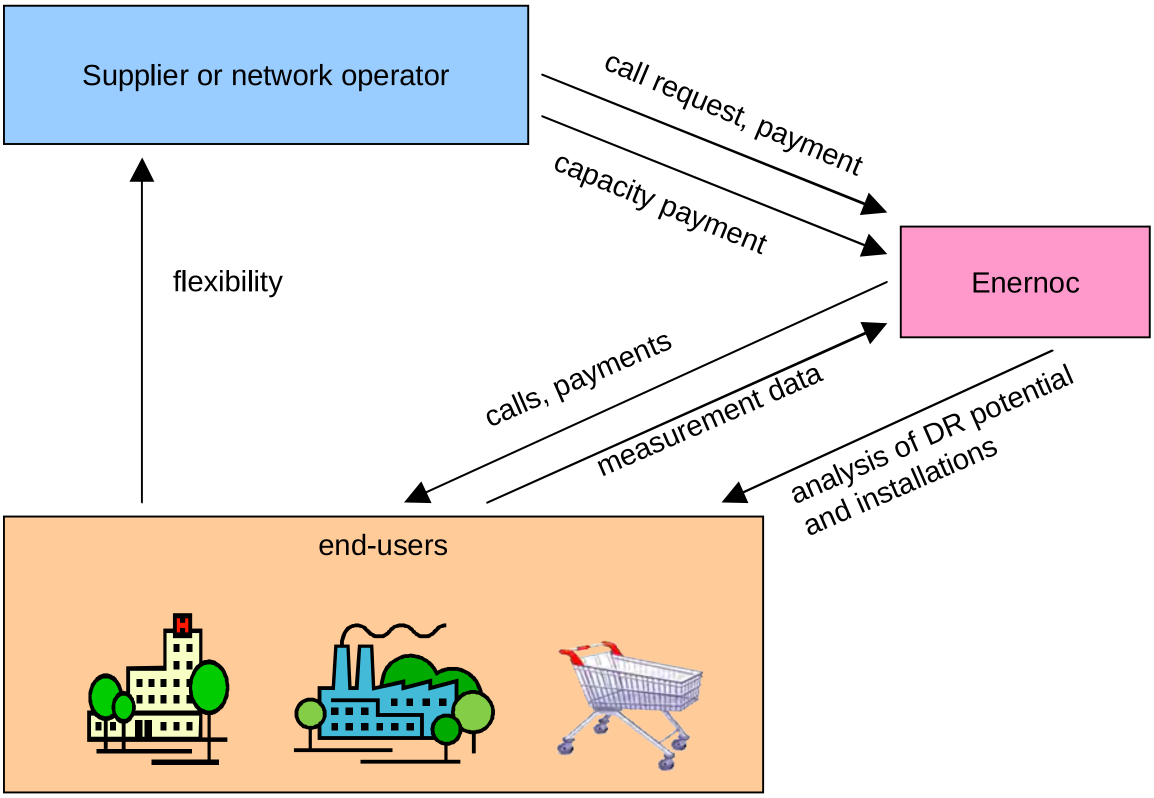

Figure 12. Company Enernoc finds and installs DR and operates the DR when directed by the grid operator.

8 Market in participating countries

This chapter is mainly derived from the analysis of the country reports provided by the task's country experts and the answer they provided to a questionnaire regarding the situation in their market. For more detailed information about any of the participating countries, you can consult the country reports in the Annex Report (Vol 2).

8.1 Electric Industry: market structure and market actors.

8.1.1 Market structure

The market structure and the market actors are very different in the countries we consider. The first element is to know if the market has been liberalized or if it is regulated. A liberalized market sets the prices and transactions according to the offer and demand concepts. A regulated market is one where the price is set by a regulating actor. Out of some states in the USA, the only participating country having a regulated market is South Korea (see Table 8).

The case of the USA, as it will be the case throughout this chapter, is difficult to categorize. The USA electricity market is different according to the transmission area or to the State.

8.1.2 Market actors

In the countries where the market has been liberalized (see Table 8), the transmission, distribution and reliability management are separated from the generation and retail services. Often, the transmission system operator is in charge of the reliability management and the balancing services.

The distribution networks are owned and operated by local distribution network operators. There are from several to hundreds of them in each country. We'll note though that in the Netherlands, the distribution networks are on the way of being re-regulated and joined to the transmission network operator.

In South Korea, a single government owned entity, KEPCO, is in charge of the, transmission, distribution and retail of electricity. The production is open to different participants (six subsidiaries companies of KEPCO and several, smaller, independent producers), but they have to place their offer according to their production costs. These costs are checked by an independent commission.

In the USA, the situation varies again from state to state and from region to region. We can find vertically organized structures as well as competitive markets. The generation can be utility, state or federally owned, or it can be owned by cooperatives or again independent non-utility generators.

	Countries	Power pool
Liberalized / Competitive market	Finland	Nordpool
	Italy[1]	IPEX
	Netherlands	APX
	Austria	EXAA
	Spain[1]	Omel
	Some US states	
Regulated market	Korea	KPX[2]
	Some US states	

[1]: LV customers can still choose to have a regulated tariff.
[2]: KPX operates the cost-based power pool and now prepares a bilateral bidding pool.

Table 8. Participating countries sorted by their type of market.

8.2 Electricity market transactions.

All the participating countries have currently a day-ahead, intra-day and balancing market, with the exception that balancing market is not yet opened in Korea

Regarding DER, they most often can not have a direct access to these markets. Each market has its rules with a minimum tradable power or capacity and DER units are usually too small to participate. This is why they need aggregation. A large enough set of DER can become able to act directly in the markets. That type of aggregation is already used mainly to aggregate DG units, but there are also a few examples, for example in the USA, where DR is also aggregated.

8.3 Bilateral and self-supply for DER

Many DG operators, utilities and electric supply companies have the option of creating and using DG, storage or DR to improve operations or manage supply portfolio through self-supply or bilateral deals, rather than waiting for the DG or DER provider to sell into the bulk power market. For self-supply, a utility can install DG, storage or DR onto its own transmission and distribution system or put DG onto customer premises to improve T or D reliability , defer new capital expansion, manage congestion, or use direct load curtailment for emergency reliability controls. Bulk electric supply wholesalers can contract with large loads or aggregators to secure DR or load management to the client as a peak resource and price-hedging scheme.

9 Experiences from the pilot case studies

During this IEA task, we have collected information about case studies, experiments and research projects conducted in the participating countries and some in other countries. We have sorted them into different categories. Although there is usually not much information publicly available, they still give a pretty good idea of how far the research and tests have been conducted so far. In the Annex Report (Vol. 2) the list of the projects can be found along with the references to find more information about them. A more detailed description of the pilot case studies can be found in the secure web-site of IEA DSM which is available to participating countries.

9.1 Autonomous grids, microgrids.

The first type of pilot cases submitted, and with probably the deepest integration of DG, DR/DSM and energy storage is the concept of the autonomous grid or microgrid (see Chapter 5.8).

The Table 9 lists the submitted microgrid projects with their level of advancement. We'll note that in cases where islanded operation is an objective, there is a need for a sufficient storage capacity.

Name	Country	Advancement	Islanded operation	Notes
Microgrids	Europe	Field test	Yes	
DINAR – Pool-BEMI	Germany	Research	No	
Qurrent	Netherlands	Research	?	
Dispower	Germany / Spain	Field test	Yes	Battery storage
Microrred	Spain	Research	Yes	Battery storage

Table 9. Autonomous grid pilots

9.2 Balancing DG units

This type of pilot projects involves the use of DR/DSM in order to balance the production of DG units. The projects mentioned in the preceding section already do that, but in this case, the operation is simpler. It doesn't try to manage all types of units, but only to compensate the variations of DG units by using DR (even though the demand response is itself sometimes obtained by using local energy storage, such as cold storage in the Night wind project).

Table 10 lists the pilot projects submitted with their level of advancement and their main characteristics. The last four projects in the table are not exactly used to balance the DG output, but more to show that a set of measures including renewable production and energy efficiency can provide a sustainable option for the future.

Name	Country	Advancement	Balanced DG	DR
Night wind	Netherlands	Demonstration	Wind	Cold storage
Smart-A	Germany	Demonstration	Renewable and cogeneration	Domestic load shifting
EEG – Integration of wind energy	Austria	Research	Wind	All
Green VPP	Austria	Research	Renewable	All
VPP and DSM	Austria	Research	Wind	Heating, cooling, washing, drying and dish washing
Viselio	Italy	Research	Solar	Heat storage and biomass plant
Renewable buffering on minor islands	Italy	Research	Renewable	Hydrogen storage or desalinated water production
EU-Deep – Task force 1	Europe	Demonstration	Wind	All and local generators
Solar cities	Australia	Field tests	PV	Energy efficiency
Acciona solar building	Spain	Exists	PV	Energy efficiency in one building
Antondegi	Spain	Exists	Solar, Wind, biomass	Energy efficiency
Sarriguren	Spain	Exists	Solar, Wind, biomass	Energy efficiency

Table 10. Pilots aiming at balancing the DG output

9.3 Aggregation of units and virtual power plant

These types of pilots have the goal to aggregate or to coordinate several DG units. The DG units being located at the consumers' sites, it is therefore a way to use local DG to offer DSM services.

The last projects don't include only DG units, but also load and storage units.

Table 11 lists the submitted projects that correspond to the aggregation of several DG units or the development of virtual power plants.

For the three types of projects already mentioned, it is necessary that the market allows the aggregation of the different types of units, and especially the aggregation of producing and consuming actors into a single account. This may be an issue for example in Spain where the consumption and production accounts must be separated (though CHP generation can be included in the consumption account).

Name	Country	Advancement	Type of units	Goal
Electrotek	USA	Field test	Controllable DG	Act on the market
Real Energy	USA	Exists	Controllable DG	Optimise enterprise's DG operations
NRE	Korea	Field test	All DG	Collect production data
Local energy resources	Finland	Research	Controllable DG	Aggregate small units
Multipower	Finland	Research		Develop a DG testing environment
Cogeneration systems	Korea	Existing	CHP	Use of local DG units to avoid peak prices
EU-Deep – Task force 3	Europe	Demonstration	CHP	Increase of CHP flexibility through DR
Weiland proef	Netherlands	Demonstration	µCHP	Observe the electrical behaviour of an aggregated set of µCHP
Clustered operation of µCHP cluster	Netherlands	Field test	µCHP	Use of dispersed local µCHP to offer power flexibility
Use of fuel cells	Korea	Field test	Fuel cells	Assessment of fuel cells operation
Crisp	Netherlands	Field test	All distributed resources	Aggregate different types of units.
Fenix VPP	Netherlands / Spain	Field test	All distributed resources	VPP operation
IRON	Austria	Research	All distributed resources	Market and infrastructure models for distributed resources aggregation

Table 11. Pilots aiming at aggregating several units

9.4 Traditional DR/DSM

There are in the participating countries some traditional DR or DSM schemes such as time of use or real time tariffs or peak pricing (see Table 8, chapter 8.1). They all have as a consequence to encourage demand response and thus, to push to consumers to use local energy storage or local generation units to offer it.

In Austria and Spain, projects of smart metering have been launched. They aim at replacing the old meters by new versions that would allow bidirectional communication for load curves or tariffs. They would also allow the monitoring of power quality at the end user's site or the utility or retailer to have direct control options on the loads.

9.5 Delay network investments

Some projects have been started by some distribution companies in order to delay network investments. The distribution company chooses between the investment in a new substation or a new line and the investment in promulgating energy efficiency or installing direct load control systems. A number of US utilities have used DG , EE and LM to defer new T&D capital investment, including PG&E, Commonwealth Edison and Consolidated Edison.

A project in Finland delays network investment by direct control of electric heating while the Castle Hill project in Australia intended to increase energy efficiency to reduce the peak load and hence the need for other, more expensive, investments.

The winter peak project in Ireland is a bit different. It aims to reduce the peak demand at a national level so that investments in security of supply can be reduced.

9.6 Conclusions from the case studies

It is difficult to make general conclusions from the case studies since they all involve a different level of resource integration. We can however pinpoint some elements.

Most of the case studies are still in research, pilot or field test level and only very few were actual business cases.

The technologies to integrate different resources with different characteristics exist. However, in the cases where hundreds or thousands of small units are taken into consideration, metering and communication technologies are too expensive to install and maintain.

Some algorithms involving the optimization of an aggregated portfolio exist also for some of the projects, but they are not directly available to the public.

As we already mentioned, it is necessary that the market rules allow the integration of units of different natures, especially the aggregation of production with consumption.

10 Vision of successful integration and conclusions

As a conclusion of this analysis it can be said that the increased penetration of DG as well as the technology and market developments result in

– new roles of the different stakeholders meaning new business environment and possibilities; on the other hand new tools are also needed in this new business area,

– metering and ICT technologies are developing rapidly,

– the above development will result in new products, services and pricing policies which can activate the more deep participation of final consumers in the market

Successful integration means that different technologies in supply and demand side as well as in ICT are developed to the level where their integration is feasible both technically and economically and that regulation, policy and market give the successful framework for the integration.

Table 12 gives the summary on the situation of integration on the basis of the above chapters and expert group opinions. For each item, we have agreed on a status among the following:

- Early: R&D
- Young: Pilots / Field tests
- Existing: Available, at least one vendor; early adopters involved
- Mature: Widespread commercial

Electricity supply	Fossil fuel based technologies ▪ fuel cells ▪ micro chp ▪ conventional chp	Young Existing Mature
	Renewables ▪ Wind ▪ pv ▪ small hydro ▪ waves, tidal ▪ biomass	Mature Existing/Mature Mature Young/Mature Young/Mature
	Renewable production forecasting	Young/Existing
	Electrical energy storage ▪ energy management ▪ bridging power ▪ power quality	Young/Mature Existing/Mature Early/Existing
	Economic dispatch, SCUC software	Mature
	Resource planning techniques, tools	Mature
	Real-time grid operation tools	Mature
Electricity demand	Many DSM techniques	Mature
	Automated DR devices	Young

	Pricing granularity (smart rates) ▪ Small customers ▪ Large customers	 Early Existing
	Consumer response and production	Early
Communication, control and monitoring	Communication networks	Mature
	High-speed digital monitoring ▪ Generation ▪ Transmission (EU) ▪ Transmission (USA) ▪ Distribution	 Mature Mature Young Early
	Smart meters deployment	Young/Existing
	Cyber-security	Young/Existing
	Interoperability	Existing
	Functional Automation/Monitoring ▪ for large assets ▪ for DER	 Mature Young
	Intelligence/Smart behaviour	Young
	User/primary process feedback	Young/Existing
	Intelligent agents and distributed controllers	Young
	Communication semantic and content	Young/Existing
Integration analytics	Modelling electricity system impacts	Young/Existing
	Understanding relative costs and benefits	Existing
	Controlling and coordinating parts	Young
	Good, real data	Early / Young
Regulation, policy and business	How to capture benefits	
	Incentives and subsidies	
	How to pay for everything	
	Taxation	
	Aggregator business	Young/Existing

Table 12. Summary of the status of integration.

On the basis of the analysis, it was noted that there are some needs for the future work inside this Task XVII to be defined. Especially topics which are at the level of young/existing give possibilities to mutual development and sharing experiences.

The following list of the interesting topics was produced by the expert group when new ideas were discussed:

– Future needs for better metering and better data across the system (prices etc). The slow spread of advanced meters that allow customers to participate in ToU rates and sophisticated demand response offerings is an obstacle as well as the lack of widespread dynamic rates and price signals to reveal to customers the value of electricity across time and place

Integration of DSM, DG, RES and storages: Vision of successful integration and conclusions

- How much does the early status of high-speed monitoring especially at distribution level hold back the system's evolution? Where are the best benefits?
- More detailed analysis of the Integration analytics and ICT to see how much they delay the integration of DER?
- Power quality questions related to DER, positive and negative effects of DER to the power quality, improvement of power quality management
- Isolated systems: islanded systems in rural areas and on islands, islanded operation of network connected systems (microgrids and larger islanded subsystems)
- Quantitative effects of DER penetration into existing power systems, for.ex electric vehicles, heat pumps; understanding costs and benefits of different stakeholders
- Increasing of predictability of generation and demand (forecasting also consumer response)
- Market design aspects: analysis of the effects in different countries, interoperability between countries and regions
- Potential surveys of DER
- Legal frameworks to DER
- Comparison of best practices and recommendations on national level
- Guidelines for the interoperability
- Rate design and applications of incentive schemes for installing DER
- Aggregator business analysis, comparison and development
- Customer behavior and response to price-responsive demand response options.

The topics with the red color were the most supported within expert group meeting in Seoul. It was decided that the topic related to the assessment of the effect of DER penetration to the costs and benefits of different stakeholders and the whole system will be further elaborated by the Operating Agent.

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Annex 1: Standards on integration DSM, DG, RES, ES

An overview of the most relevant standardization work for the synthesis report is given in the following tables:

Standard(s)	Title	Stage
IEEE 1547 (Part 1 – 6)	IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems	Published (Draft)
EN50438	Requirements for the connection of micro-(co)generators in parallel with public low-voltage distribution networks	Draft
IEC 61850	Basic communication structure for substation and feeder equipment	Published
IEC 61850-7-420	Communications systems for Distributed Energy Resources (DER) - Logical nodes	Draft

Table 1: Interconnection and Communication (not limited to one type of generation)

Standard(s)	Title	Stage
IEC-EN 61427	Secondary cells and batteries for solar photovoltaic energy systems – General requirements and method of test	Published Under revision
IEC-EN 61724	Photovoltaic system performance monitoring. Guidelines for measurement, data exchange and analysis	Published Under revision
IEC-EN 61727	Photovoltaic (PV) systems. Characteristics of the utility interface	Published
IEEE 928	IEEE Recommended Criteria for terrestrial photovoltaic power systems	Published
IEEE 929	IEEE Recommended Practice for Utility Interface of Residential and Intermediate Photovoltaic (PV) Systems	Published

Table 2: Photovoltaic Systems

Standard(s)	Title	Stage
EN 61400 (Part 1 – 25)	Wind turbine generator systems -	Published / Drafts
IEC WT 01	IEC System for Conformity Testing and Certification of Wind Turbines Rules and procedures	Published

Table 3: Wind Turbines

Standard(s)	Title	Stage
IEEE 502	IEEE Guide for Protection, Interlocking, and Control of Fossil-Fueled Unit-Connected Steam Stations	Published
UL 2200	STANDARD FOR SAFETY Stationary Engine Generator Assemblies	Published
prEN 50438	Requirements for the connection of micro-cogenerators in parallel with public low-voltage distribution networks	Draft

Table 4: (Micro)cogeneration

Standard(s)	Title	Stage
IEC-62282 (Part 1 – 6)	Fuel cell technologies	Published

Table 5: Fuel cells

Standard(s)	Title	Stage
IEC 61850-7-410	Hydroelectric Power Plants - Communication for monitoring and control.	Published
IEC-EN 61116	Electromechanical equipment guide for small hydroelectric installations	Published

Table 6: Small Hydroelectric Power Plants

Standard(s)	Title	Stage
IEC/PAS 62111	Specifications for the use of renewable energies in rural decentralised electrification	Published
IEC/TS 62257	Recommendations for small renewable energy and hybrid systems for rural electrification	Published Work in Progress
IEEE P1561	Guide for Optimizing the Performance and Life of Lead	Published

	Acid Batteries in remote Hybrid Energy Systems	

Table 7: Hybrid Systems

Standard(s)	Title	Stage
IEC 60146	Semiconductor convertors	Published
IEC 62103	Electronic equipment for use in power installations	Published
UL 1741	Inverters, Converters, and Controllers for Use in Independent Power Systems	Published

Table 8: Converters

Standard(s)	Title	Stage
IEC-EN 60086	Primary cells and batteries	Published Under revision
EN 50272	Safety requirements for secondary batteries and battery installations	Published Work in progress
IEEE 485	IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications	Published

Table 9: Batteries

Standard(s)	Title	Stage
EN 50160	Voltage characteristics of electricity supplied by distribution systems	Published
IEC 61000 (-2,-3,-4)	EMC	Published
IEEE 519	IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems	Published
IEEE 1159	IEEE Recommended Practices for monitoring electric power quality	Published
IEEE 1250	IEEE Guide for service to equipment sensitive to momentary voltage disturbances	Published
IEEE 1346	IEEE Recommended Practices for evaluating electric power system compatibility with electronic process equipment	Published
IEEE P1409	IEEE Guide for the application of power electronics for power quality improvement on distribution systems rated 1 kV through 38 kV	Draft

IEEE 1453	IEEE Recommended Practice for measurement and limits of voltage flicker on AC power systems	Published
IEEE P1564	IEEE Recommended Practice for the establishment of voltage sag indices	Draft

Table 10: Power Quality

Standard(s)	Title	Stage
IEC-EN 60870-5-102	Telecontrol equipment and systems – Part 5: transmission protocols – section 102: companion standards for the transmission of integrated totals in electric power systems	Published
IEC-EN 62056	Electricity metering – Data exchange for meter reading, tariff and local control	Published
IEC-EN 61334-4	Distribution automation using distribution line carrier systems – Part 4: Data communication protocols	Published

Table 11: Metering

	IEEE 1547	IEC 61727 FDIS Ed2.0	pr EN50438
Under voltage	R	R	R
Over voltage	R	R	R
Under frequency	R	R	R
Over frequency	R	R	R
Loss of mains	R	R	IR
Reconnection after utility recovery	R	R	R

Table 12: Interface protection – response to abnormal conditions (R: Required, IR: If Required by national regulation)

Websites of international organizations related to the standardization:

www.cenelec.org	CENELEC: European Committee for Electrotechnical Standardization
www.eurelectric.org	EURELECTRIC: Union of the Electricity Industry
www.cigre.org	CIGRÉ: International Council on Large Electric Systems
www.cired.be	CIRED
www.iec.ch	IEC: International Electrotechnical Commission
www.ansi.org	ANSI: American National Standards Institute
www.ieee.org	IEEE: Institute of Electrical and Electronics Engineers, Inc.
www.ul.com	UL: Underwriters Laboratories, Inc.

Annex 2: Busmod methodology

The BUSMOD methodology uses, on the one hand, well established business modelling methodologies for networked enterprises such as e[3]value, and on the other hand, traditional economic investment assessment techniques such as calculation of Net Present Value (NPV) and Internal Rate of Return (IRR). These two approaches are then used for. ex. in the realm of Distributed Generation, by utilising a specialised terminology and a correct way of working.

The graphical description of the process of building a business case for ex. for DG is illustrated in Figure 13. Business case building includes a number of sequentially executed steps. The result of each step is an input for the following step, and the outcome of the whole process is a business model including a graphical representation and corresponding financial profitability sheets, which facilitate sensitivity analysis of the business case.

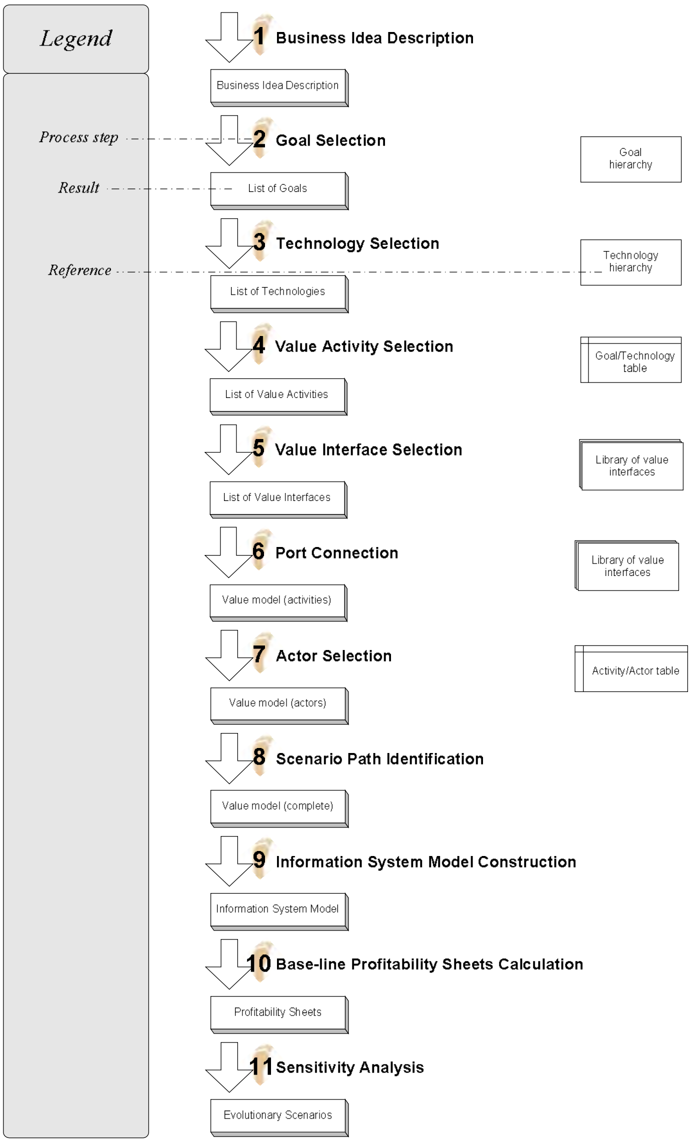

Figure 13. Diagram of the process steps

Integration of DSM, DG, RES and storages: Annex 2: Busmod methodology

The Busmod/e^3-value model defines transactions between parties, which normally include a good (such as power or heat) and payment. Departments can be defined inside each party. It also defines dependencies between transactions, which are called scenario paths. Scenario paths start when an actor has a need which has to be met and the starting point is a start stimulus. For example consumer demand may be the start stimulus, and it can be fulfilled by performing transactions with one or more suppliers. The downside is that the graphs can become quite difficult to interpret.

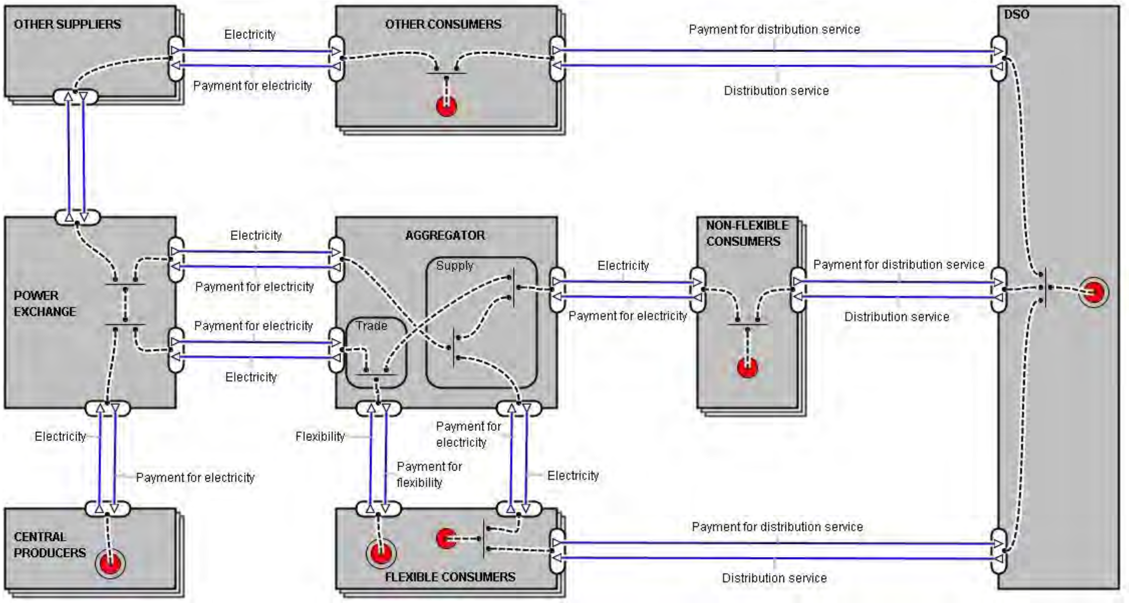

Figure 14. Example of DR business in the Busmod format. The aggregator supplies flexible and non-flexible consumers with electricity. To that end, electricity is bought at the power exchange or, in the case of non-flexible consumers, it can also be bought from flexible consumers. In addition, the aggregator buys flexibility from flexible consumers to sell it to the power exchange (this depends on the market rules).

Figure 14. **Error! Reference source not found.**shows an example of the Busmod/ e^3-value graphical model, where an aggregator enables and controls demand response at customer sites. DR (which is here called flexibility) is used either to supply aggregator's own portfolio or to sell electricity to the power exchange.

For more info, visit Busmod project's website:
http://www.e3value.com/projects/ourprojects/busmod/

Annex 3: Overview of IEA

Overview of the International Energy Agency (IEA) and the IEA Demand-Side Management Programme

The International Energy Agency

The International Energy Agency (IEA), established in 1974, is an intergovernmental body committed to advancing security of energy supply, economic growth, and environmental sustainability. The policy goals of the IEA include:

- diversity, efficiency, and flexibility within the energy sector,
- the ability to respond promptly and flexibly to energy emergencies,
- environmentally-sustainable provision and use of energy
- development and use of more environmentally-acceptable energy sources,
- improved energy -efficiency,
- research, development and market deployment of new and improved energy technologies, and
- undistorted energy prices
- free and open trade
- co-operation among all energy market participants.

To achieve those goals, the IEA carries out a comprehensive program of energy cooperation and serves as an energy forum for its 26 member counties.

Based in Paris, the IEA is an autonomous entity linked with the Organization for Economic Cooperation and Development (OECD). The main decision-making body is the Governing Board, composed of senior energy officials from each Member Country. A Secretariat, with a staff of energy experts drawn from Member countries and headed by an Executive Director, supports the work of the Governing Board and subordinate bodies.

As part of its program, the IEA provides a framework for more than 40 international collaborative energy research, development and demonstration projects, known as Implementing Agreements, of which the DSM Programme is one. These operate under the IEA's Energy Technology Collaboration Programme which is guided by the Committee on Energy Research and Technology (CERT). In addition, five Working Parties (in Energy Efficiency, End Use, Fossil Fuels, Renewable Energy and Fusion Power) monitor the various collaborative energy agreements, identify new areas for cooperation and advise the CERT on policy matters.

IEA Demand Side Management Programme

The Demand-Side Management (DSM) Programme, which was initiated in 1993, deals with a variety of strategies to reduce energy demand. The following 19 member countries and the European Commission have been working to identify and promote opportunities for DSM:

Australia	Japan
Austria	Korea
Belgium	The Netherlands
Canada	Norway
Denmark	New Zealand
Finland	Spain
France	Sweden
Greece	United States
India	United Kingdom
Italy	

Integration of DSM, DG, RES and storages: Annex 3: Overview of IEA

Programme Vision: In order to create more reliable and more sustainable energy systems and markets, demand side measures should be the first considered and actively incorporated into energy policies and business strategies.

Programme Mission: To deliver to our stakeholders useful information and effective guidance for crafting and implementing DSM policies and measures, as well as technologies and applications that facilitate energy system operations or needed market transformations.

The Programme's work is organized into two clusters:
- The load shape cluster, and
- The load level cluster.

The 'load shape" cluster includes Tasks that seek to impact the shape of the load curve over very short (minutes-hours-day) to longer (days-week-season) time periods. The "load level" cluster includes Tasks that seek to shift the load curve to lower demand levels or shift loads from one energy system to another.

A total of 18 projects or "Tasks" have been initiated since the beginning of the DSM Programme. The overall program is monitored by an Executive Committee consisting of representatives from each contracting party to the Implementing Agreement. The leadership and management of the individual Tasks are the responsibility of Operating Agents. These Tasks and their respective Operating Agents are:

Task 1 International Database on Demand-Side Management & Evaluation Guidebook on the Impact of DSM and EE for Kyoto's GHG Targets - *Completed*
Harry Vreuls, NOVEM, the Netherlands

Task 2 Communications Technologies for Demand-Side Management - *Completed*
Richard Formby, EA Technology, United Kingdom

Task 3 Cooperative Procurement of Innovative Technologies for Demand-Side Management – *Completed*
Dr. Hans Westling, Promandat AB, Sweden

Task 4 Development of Improved Methods for Integrating Demand-Side Management into Resource Planning - *Completed*
Grayson Heffner, EPRI, United States

Task 5 Techniques for Implementation of Demand-Side Management Technology in the Marketplace - *Completed*
Juan Comas, FECSA, Spain

Task 6 DSM and Energy Efficiency in Changing Electricity Business Environments – *Completed*
David Crossley, Energy Futures, Australia Pty. Ltd., Australia

Task 7 International Collaboration on Market Transformation - *Completed*
Verney Ryan, BRE, United Kingdom

Task 8 Demand-Side Bidding in a Competitive Electricity Market - *Completed*
Linda Hull, EA Technology Ltd, United Kingdom

Task 9 The Role of Municipalities in a Liberalised System - *Completed*
Martin Cahn, Energie Cites, France

Task 10 Performance Contracting - *Completed*
Dr. Hans Westling, Promandat AB, Sweden

Task 11 Time of Use Pricing and Energy Use for Demand Management Delivery- *Completed*
Richard Formby, EA Technology Ltd, United Kingdom

Task 12 Energy Standards
To be determined

Task 13 Demand Response Resources - *Completed*
Ross Malme, RETX, United States

Task 14 White Certificates – *Completed*
Antonio Capozza, CESI, Italy

Task 15 Network-Driven DSM
David Crossley, Energy Futures Australia Pty. Ltd, Australia

Task 16 Competitive Energy Services
Jan W. Bleyl, Graz Energy Agency, Austria
Seppo Silvonen/Pertti Koski, Motiva, Finland

Task 17 Integration of Demand Side Management, Distributed Generation, Renewable Energy Sources and Energy Storages
Seppo Kärkkäinen, VTT, Finland

Task 18 Demand Side Management and Climate Change
David Crossley, Energy Futures Australia Pty. Ltd, Australia

Task 19 Micro Demand Response and Energy Saving
Barry Watson, EA Technology Ltd, United Kingdom

Task 20 Branding of Energy Efficiency
Balawant Joshi, ABPS Infrastructure Private Limited, India

Task 21 Standardisation of Energy Savings Calculations
Harry Vreuls, SenterNovem, Netherlands

For additional Information contact the DSM Executive Secretary, Anne Bengtson, Box 47096, 100 74 Stockholm, Sweden. Phone: +46 8 510 50830, Fax: +46 8 510 50830. E-mail: anne.bengtson@telia.com

Also, visit the IEA DSM website: http://www.ieadsm.org