CHAPTER 2

Solutions, Technology & Road Map for Smart Grid Deployment in Israel

Dr Dan Weinstock

Emek Sadot

Table of Content

Table of Tables

Table of Figures

1. Executive Summary

Traditionally, the power sector has adapted and reinforced the power grid by laying more and thicker cables in the ground, building more substations and securing access to sufficient generation capacity. The consumers have been primarily "passive" with predictable and regular consumption patterns.

Electricity consumption and generation in Israel is set to change significantly in the coming years. This will include the following trends:

- Electricity customers will demand new services as they replace oil-fired burners with gas and solar energy
- Emergence of private production facilities
- Replacement of traditional petrol-powered vehicles with electric vehicles / plug-in hybrid vehicles
- Growing public demand to better utilize existing assets rather than building new ones
- The general trend toward customer information-visibility, sharing and engagement

The electricity sector should be ready to provide these services with the same high level of delivery quality as today.

Smart Grid is a new approach to meeting the needs of the new (power) world, where consumers will be able to interact with the power system for both consumption and generation through automated and intelligent control of their electrical appliances, thereby acting as resources for the power system.

Smart Grid will be manifested through series of technologies addressing the 2 main segments:

1. The grid itself - assets add network - from generation facilities to end consumers.
2. End consumers and small scale generation facilities.

Technology-wise, Smart Grid would be seen as "one system to rule them all" with 4 main sectors, which overlap and complement each other. Each sector presents different challenges and requires different solutions, as follows:

1. **The grid** – from central generation plants through transmission and distribution networks and facilities, the Smart Grid will offer higher asset utilization, fewer power outages, energy saving, reduced CAPEX (postponing reinforcement) and OPEX (better maintenance), problem prediction, enhanced power delivery quality, better renewable energy integration, improved planning and forecasting. These improvements will be implemented through a variety of technologies all based on real-time monitoring along the grid, which communicates to the Smart Grid central control system that supervises it.
2. **End consumers and small-scale generation facilities** – Smart Grid will revolutionize the way end customers interact with the power system. End customer appliances and small-scale generation facilities will be connected to the Smart Grid control center, thus offering a new landscape of services and opportunities to end customers as well as to the grid operator and demand response vendors (e.g. flexibility). End customers' Smart Grid technology will be based on a home communication network (i.e. HAN) connection to a smart meter, which relays the data upstream to the Smart Grid control center. Alternatively, dedicated in-house hardware will be installed, which may replace or supplement the smart meter.
3. **Flexibility** – enabling home power appliances and small-scale generation facilities to respond to the power system needs offers a new kind of services and products for the benefit of society. Flexibility, in this context, is defined as the ability of end customer appliances connected to the power system to change their behavior to meet the needs of the power system. Flexibility will be achieved by means of communication from end consumption or production units directly to the Smart Grid control center or through demand response aggregators.
4. **Smart Grid control center –** in the heart of Smart Grid lies the control (IT) center system, which is connected to all end units and manages all services.

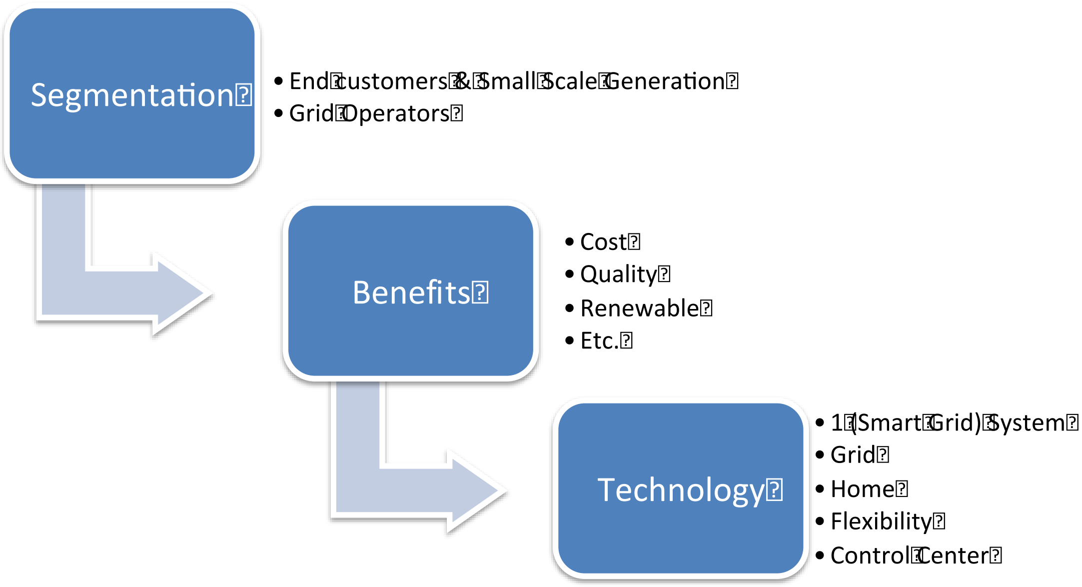


Figure 1: Segmentation, Benefits and Technology

2. Introduction

The Smart Grid Solutions, Technology & Road Map Deployment chapter discusses the landscape and alternative solutions, services, technologies and deployment aspects of the Israeli Smart Grid.

This chapter is organized as follows:

- Section 0 describes Smart Grid segmentation.
- Section 2 describes the benefits and services that Smart Grid provides to each segment.
- Section 3 describes the technologies which enable the expected Smart Grid benefits.

3. Segmentation

In order to explore the relevant Smart Grid solutions, technologies and roadmap we will start by defining the different segments to which Smart Grid applies and the benefits it will provide to each segment. To this end the energy market can be viewed as 2 distinct areas, each of which has its own characteristics such as benefits, solutions and technologies, etc.

3.1 The grid itself - assets add network - from generation facilities to end consumers.

3.2 End consumers and small scale generation facilities.

1.1 Grid Operators

The energy grid refers to the legacy assets, network and facilities, which provide the 3 key elements: generation, transmission and distribution facilities.

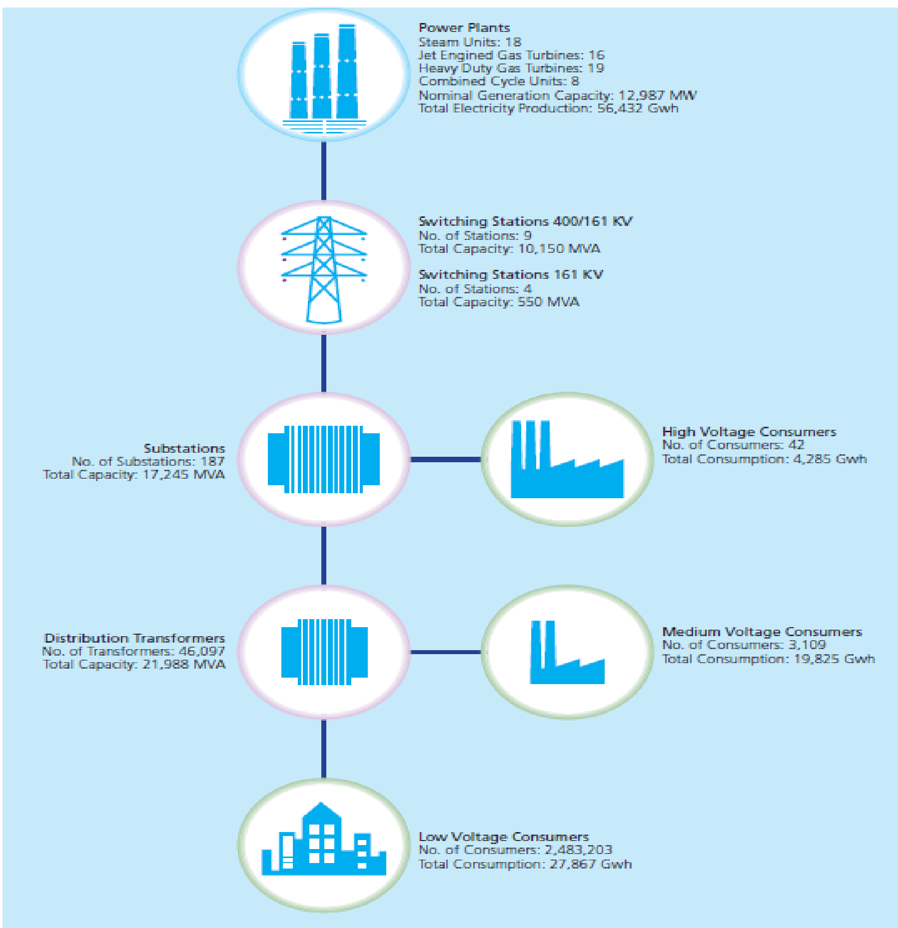


Figure 2: Generation, Transmission & Distribution Facilities (2010)

1.2 End Customers and Small Scale Production

End customers are split into 3 main categories:

1.2.1 Household/SME

About 2.5 million households/SME are present in Israel, which consume around 32.8% of the total electricity and are usually characterized by a low connection capacity (i.e. 3x25A or 1x40A for households), which indicates a relatively low individual consumption rate and volume.

1.2.2 Industry

Industrial facilities (including agricultural facilities and water pumps) consume around 67.20% of the total electricity and are usually characterized by a large connection capacity, which implies higher customer flexibility in terms of how they are able to consume electricity.

1.2.3 Small Scale Generation

Small scale generation represents various production facilities, which range from commercial PV, diesel generator to windmills, etc.

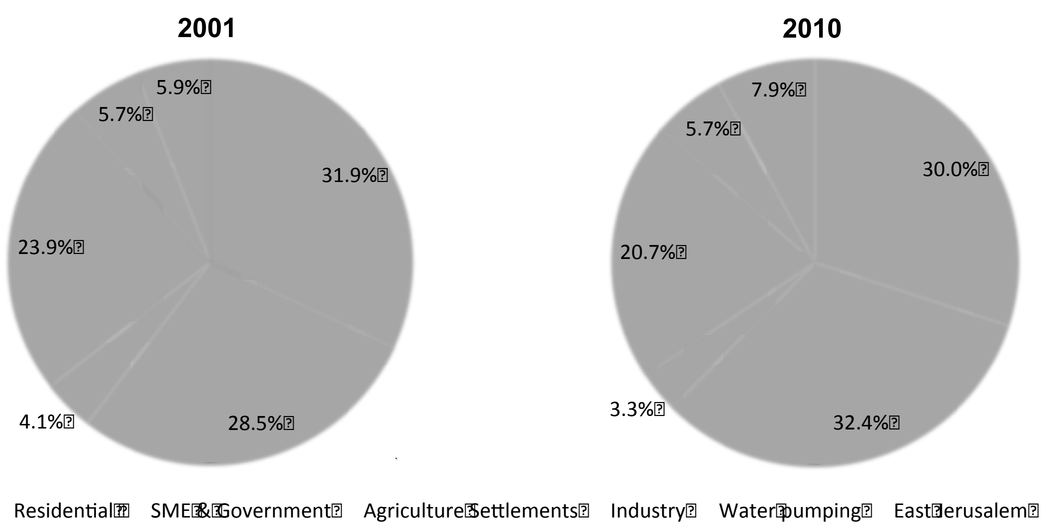


Figure 3: Total Consumption by Sectors

2 Smart Grid Benefits / Services

This section outlines Smart Grid benefits and services for the two main segments (e.g. end customers and grid) described above.

2.1 Smart Grid Beneficiaries

The table below summarizes the Smart Grid “beneficiaries” – the entities that will gain from implementing Smart Grid.

Smart Grid Beneficiaries	
Grid Operators	▪ Production Facilities ▪ Transmission System Operators ▪ Distribution System Operators
End Customers	▪ Household/SME ▪ Industry ▪ Small Scale Generation

Table 1: Smart Grid Beneficiaries

2.2 Grid Operators Smart Grid Benefits / Services

Table 2 below lists the grid operators' Smart Grid benefits and services:

	Grid Operators' Smart Grid Benefits / Services
Cost & Quality	▪ Improved system stability resulting in higher security of delivery, which will reduce duration of power outages (e.g. time of energy not supplied) ▪ Better utilization of existing grid, thus avoiding reinforcement of network, assets and production facility (avoid CAPEX) ▪ Holistic, comprehensive, end-to-end and real-time visibility of all grid assets (reduce OPEX) ▪ Elevate energy efficiency ▪ Reduce energy cost ▪ Elevate quality of energy delivery ▪ Faster remedy of faults in the power grid by identifying problems in real-time and automatically fixing ▪ Problem prediction (before it happens) ▪ Facilitate renewable energy integration into the mix

Table 2: Grid Operator Smart Grid Benefits / Services

2.3 End Customer Smart Grid Benefits / Services

Table 3 below lists the end consumers Smart Grid benefits and services:

	End Customer Smart Grid Benefits / Services
Cost Saving	▪ General energy savings and lower electricity prices for consumers who use managed / intelligent consumption units and are enrolled in a relevant demand response program. ▪ Minimize the total facility electricity cost, based on electricity price forecasts, by consumption planning of the various available units. ▪ Keep power load below a certain threshold in order to save connection fees, by managing various local consumption units according to the metered total load on the connection.
Local production unit	▪ Self-consumption is economically attractive as the customer doesn't have to pay taxes and electricity transportation costs when self-consuming.
Renewable	▪ Customers may wish to subscribe to non-emission (renewable) electricity delivery.

Personalization	▪ Being aware of own consumption, production and storage data. ▪ Personalization services and products offered by grid operators. ▪ Customer's immediate information sharing from grid operators. ▪ Customer interaction with the power system and grid operators.  Figure 4: Visibility & Personalization

Table 3: End Customer Smart Grid Benefits / Services

2.4 Flexibility Providers Smart Grid Benefits / Services

Table 4 below lists the energy suppliers or grid service aggregators (i.e. flexibility providers) Smart Grid benefits and services as reflected by the end customers and small-scale production.

Flexibility Smart Grid Benefits / Services	
Flexibility	▪ More options to create power balance in a less expensive and more efficient way ▪ Increased integration of renewable energy through flexibility offered by electric vehicles, plug-in hybrid ▪ Increases the market opportunity of secondary and tertiary reserve programs ▪ Peak Shaving (demand response) ▪ Balancing / frequency regulation ▪ Voltage control

Table 4: Flexibility Smart Grid Benefits / Services

3 Technology

The technology chapter describes technologies needed to support the Smart Grid benefits and services described above.

3.1 Introduction

The way towards an intelligent power grid can be described briefly in three phases:

1. Facilitating in the short term
2. Establishment in the medium term
3. Commercialization in the long term

Figure 5: Smart Grid Realization Phases

In order to follow these steps, a smart grid will require close coordination across the interfaces of the power system. It will therefore be necessary to establish IT systems capable of receiving and processing data about the status of the power system online, based on standard mechanisms and protocols. These IT systems should make it possible to fulfill the wishes and needs of the consumers without overloading the power system and thus reward the consumers for their flexibility.

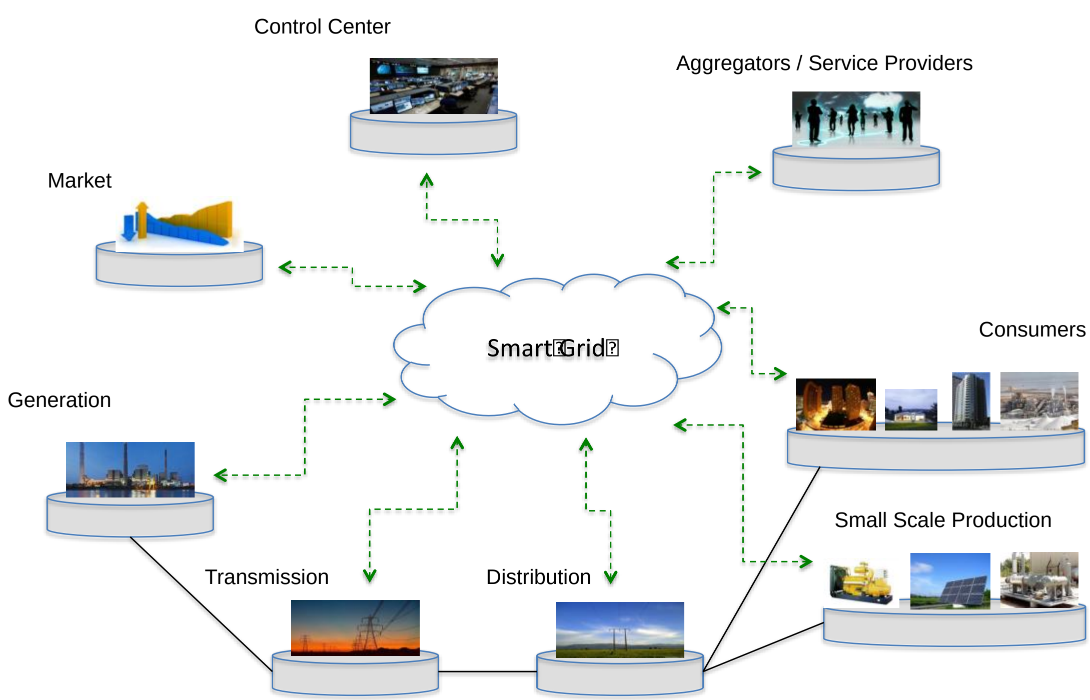
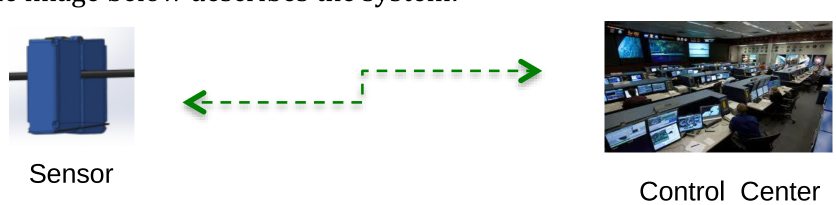


Figure 6: One System to Rule Them All

3.2 Grid Operators Smart Grid Technologies

Measuring the condition of the transmission and distribution network is a prerequisite for ensuring that the distribution network does not overload. Consequently, measuring equipment should be installed at nodes and along the line of the transmission and distribution network, particularly in those areas that are at risk of such overloading. This measuring equipment should be able to send real-time information about the condition (e.g. load) of the grid.

<table>
<tr><th colspan="2">Technology</th></tr>
<tr><td>Description</td><td>
1. Sensors - precisely measure a wide variety of electrical parameters (e.g. current values and discrepancy, frequency, etc.).
2. Control Center (CC) - a backend IT solution which collects all data from various in-the-field sensors, processes it and create outputs for the operator and grid operator system, such as:
a. Real time asset and grid status
b. Immediate alarm and fault monitoring
c. Failures prediction
The CC features components configuration, maintenance activities, fault handling, system administration and performance monitoring of the grid through a comprehensive graphic user interface.
3. Communication – a bidirectional standard communication system facilitates data transaction from the sensors to the CC and vice versa (e.g. maintenance, provisioning, SW upgrade, etc.).
The image below describes the system:


</td></tr>
<tr><td>Benefits</td><td>
Transmission & Distribution sectors benefits:
▪ Postpone / avoid upgrading the grid
▪ Reducing operational costs
▪ Reducing maintenance costs (proactive)
▪ Energy saving per given kWh sold
▪ Maximizing infrastructure utilization & performances
▪ Reduce number and duration of outages (energy not supplied)
▪ Improve electricity Quality of Service
</td></tr>
</table>

<table>
<tr>
<td>Features</td>
<td>
The technology should feature the following Smart Grid capabilities:

Alerts for:

Theft
Current cutoff
Short circuit to ground / single phase grounding short
Short circuit between phases
Current overload
Frequency deviation
Unbalanced current phases
Contamination over power line insulator-strings
Leakage detection – fault prediction
Unbalanced power consumption – recommendation for efficient usage

Reports on:

Asset utilization
Current consumption profile (at various time periods per location/route)
Environmental information (cable and ambient temperature, cable inclination and many more)

Concurrent, real time measurements of the grid:

Present current and peak current
Grid line voltage and peaks
Frequency
Temperatures (cable, ambient etc.)
Vibration, cable movements, inclination etc.
Measurements of substation and user provided power (e.g. solar systems) with information on each source

It's strongly advised that sensor installation will not require power shutdown and will exploit inductive technology (to avoid high maintenance cost).
The CC should process all the information and be able to present current status, utilization, performance, detect faults, produce warnings, predict trends of upcoming faults. In addition, real time collected measurement of the grid should be presented in different views such as tree view, tables, charts and geographic maps to allow the grid operator to analyze and watch the actual real time of the grid.
</td>
</tr>
</table>

Table 5: Transmission & Distribution Networks Smart Grid Technology

3.3 Consumers' Smart Grid Technology

Customer services and flexibility features serving the grid operators are managed by one or more electronic units on the consumer's premises - whether it's a private home, SME or industrial facility. These units control the consumption of the flexible electrical appliances in the house or facility. This control can simultaneously maximize the consumer's quality of service and ensure effective interaction with the needs of the power system as expressed through price signals, while at the same time offering flexibility back to the grid operators.

Customer Smart Grid services and flexibility require a home network, and connectivity to smart consumption and production units is mandatory. Smart metering is one technology that can meet connectivity needs. Alternatively, a dedicated demand response home solution can be installed to facilitate flexibility back to the grid operators and customer energy saving.

The advantage of a dedicated demand response home solution lies, to some extent, in a detached model of the traditional energy market structure (bypassing the DSO meter). On the other hand, it cannot offer full Smart Grid services (e.g. it lacks customer visibility into full home consumption, meter remote reading, etc.).

Whether the technology used is a smart meter or a dedicated demand response home solution, it will provide 2 main features:

1. Communication with local (downstream) consumption and production units through HAN technology and upstream with the smart grid CC.
2. Management and control.

3.3.1 Smart Meter Technology

Based on Advanced Metering Infrastructure ("AMI") – comprised of smart meters, real-time two way communications, Meter Data Management ("MDM") software, demand response technologies, and incorporating Geographical Information Systems (GIS) - utilities will be able to reliably and economically optimize the behavior of the grid all the way to the customer level on the low voltage network.

An additional application of this technology is the use of an energy forecasting algorithm model, which analyzes dynamic consumption profiles and forecasted weather to predict energy consumption and where an outage might occur.

Through the smart meter device, the Smart Grid will have functionality to plan outages in critical energy situations by incorporating intelligent capabilities distributed within the smart meters to shed the load of specific customer appliances or specific groups of customers.

Smart meter features 2 communication interfaces: downstream HAN technology toward the consumption and production units and upstream toward the smart grid CC.

2. Downstream, in building communication (HAN) – Wi-Fi, ZigBee and PLC are the 3 competing technologies, where PLC presents a unique advantage of no-coverage barriers. On top of that today's trend is to consolidate PLC and ZigBee HAN technologies (HW and SW) into a single chip.
3. Upstream, to Smart Grid CC – RF, cellular, PLC and fiber-to-the-home are the competing technologies, where no single technology rules. Each technology satisfies a different scenario:
    a. PLC and Fiber-to-the-home – density rollout, for instance country or city wide smart meter deployment, where in plc case a concentrator sits next to the block's transformer.
    b. Cellular – fragmented smart meter deployment ("here and there") where it's not economic to deploy a PLC concentrator next to the block's transformer.
    c. RF – single payable facility with multiple feeding lines and optionally multiple sub-meters (e.g. "kibbutz").

Smart meter with HAN technology will manage and control the house's smart consumption and production units. In normal operation mode it'll need to execute Smart Grid commands, on the other hand the smart meter will need to operate standalone when communication to the Smart Grid is (temporarily) down.

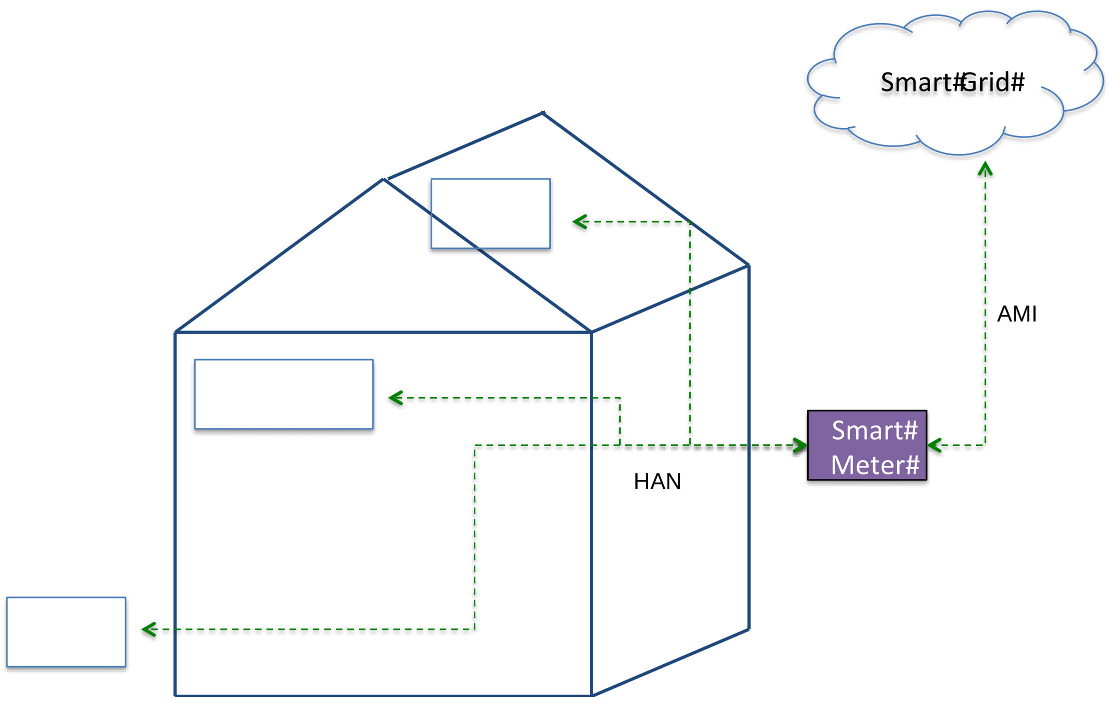


Figure 7: Smart Grid Smart Meter Technology

3.3.2 Dedicated Demand Response Home Solution

A dedicated demand response home solution is composed of:

1. Home communication concentrator, which is self installed and connected to the house's router. Alternatively a home's router technology could be modified and embedded with the required communication technology, making the dedicated communication (hardware) unit unnecessary.
2. A pluggable intermediate unit, which resides between the consumption or production unit and a normal household outlet. Alternatively the consumption or production unit could be modified and embedded with the required technology, making the dedicated intermediate (hardware) unit unnecessary.

Similarly to smart meter, the dedicated demand response home solution features 2 communication interfaces: downstream HAN technology toward the consumption and production units, and upstream toward the smart grid CC.

1. Downstream, in-building communication (HAN) – Wi-Fi and ZigBee are the 2 competing technologies, where PLC may be used if the dedicated hardware is integrated into the home's wireless router.
2. Upstream, to Smart Grid CC – Internet connectivity through customer's existing home wireless router.

The dedicated demand response home solution will manage and control the home's smart consumption and production units. In normal operation mode it'll need to execute Smart Grid commands, but on the other hand the smart meter will need to operate standalone when communication to the Smart Grid is (temporarily) down.

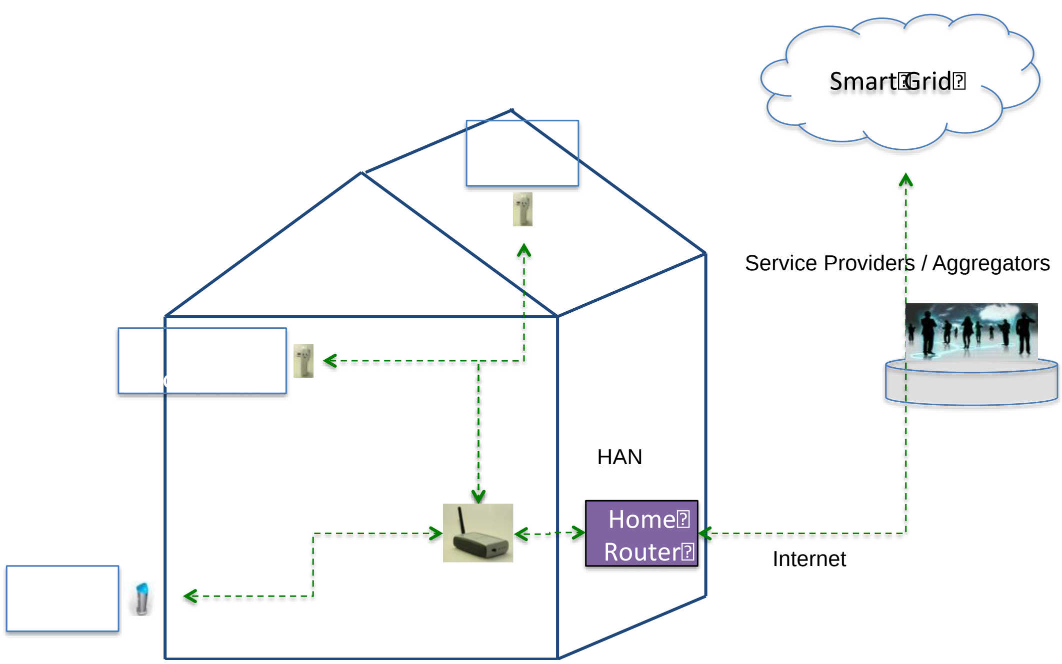


Figure 8: Dedicated Demand Response Home Solution Smart Grid Technology

3.4 Flexibility

Flexibility, in this context, is defined as the ability of end customer appliances (consumption and production) connected to the power system to change their behavior to meet the needs of the power system. For example, a household air conditioner or a privately owned photovoltaic system reduces its capacity because a power line is overloaded, or an electric car that adapts its charging patterns to balance out fluctuating solar energy levels.

With the objective in mind of avoiding upgrading the network and assets, while mainlining high quality energy delivery, the main challenges throughout the transmission network would include flexibility (i.e. balancing consumption and production and maintaining voltage stability) to ensure the stability of the entire power system. Similarly, the main challenge of the extended distribution network consists of handling increased loads due to higher electricity demand and handling increased local production capacity.

Smart Grid will facilitate activating flexibility from the end customer toward the grid operators through set of standard interfaces and protocols and a central Smart Grid IT system. The central system will supervise the process and facilitate several essential functions such as: offering, requesting, trading, dispatching and settlement. The goal is to ensure the efficient integration and exchange of information between all the various components and players involved.

To utilize the flexibility from end customer consumption and production units and on the other hand meet grid operator needs and allow introduction of new players in a seamless and transparent manner - easy market access is necessary. Therefore one of the design principles is to use international standards, which define the required information model, facilitate the process and allow everyone to participate. To that end, two international standards for Smart Grid are pivotal, each one including a number of parts and related standards.

1. IEC 61850 standard for managing distributed units
2. IEC 61970 standard, which covers a wide range of system activities in the power system, for example electricity markets. The information model in IEC 61970 is called the Common Information Model - CIM.

The two information models are being harmonized with a view to defining a combined information model for the entire power system and its associated components and processes.

Generally speaking, 2 mechanisms will incentivize and activate Smart Grid flexibility:

1. Pricing – price signals, static (i.e. TOU table) or dynamic, will incentivize customers to modify their electricity consumption, or small scale production for that matter, to align with the grid operator's needs.
2. Flexibility (pre-defined) product – a product or service which has been clearly defined and agreed in advance by all parties in the marketplace. For example reducing the load in a specified grid area can be activated as and when needed by grid companies at an agreed price.

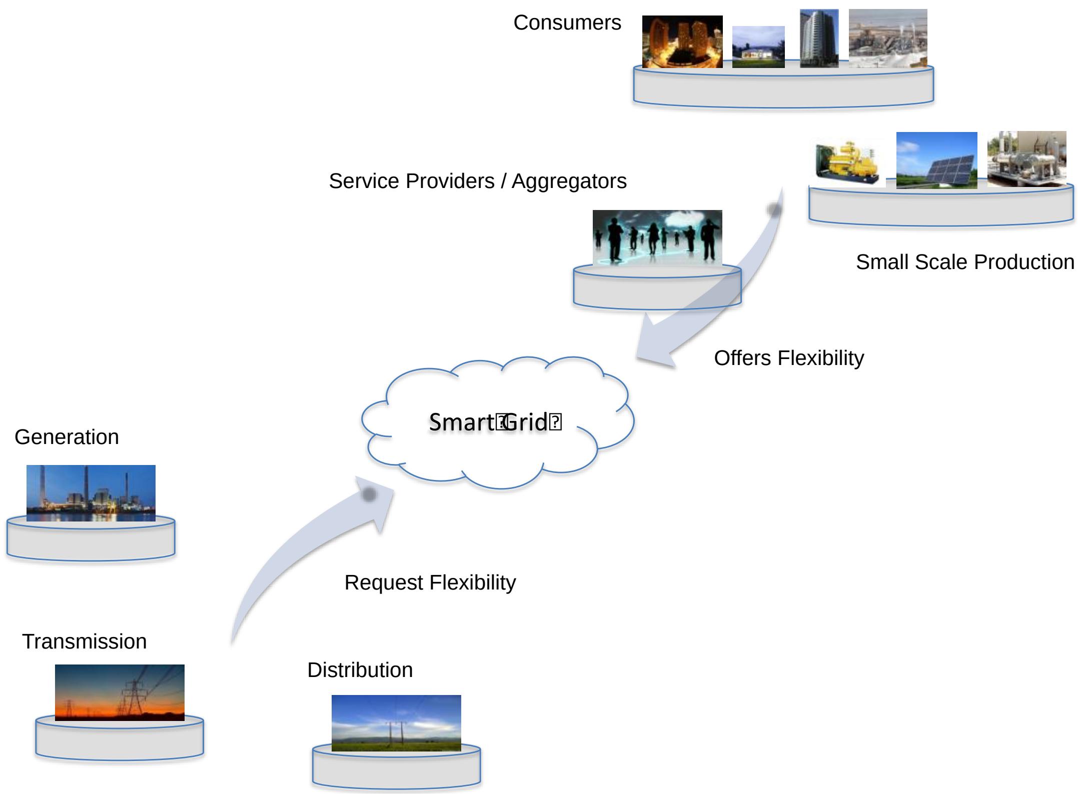


Figure 9: Smart Grid Flexibility Technology

3.5 Smart Grid Technology

Smart Grid control center technology consists of many features described in this section.

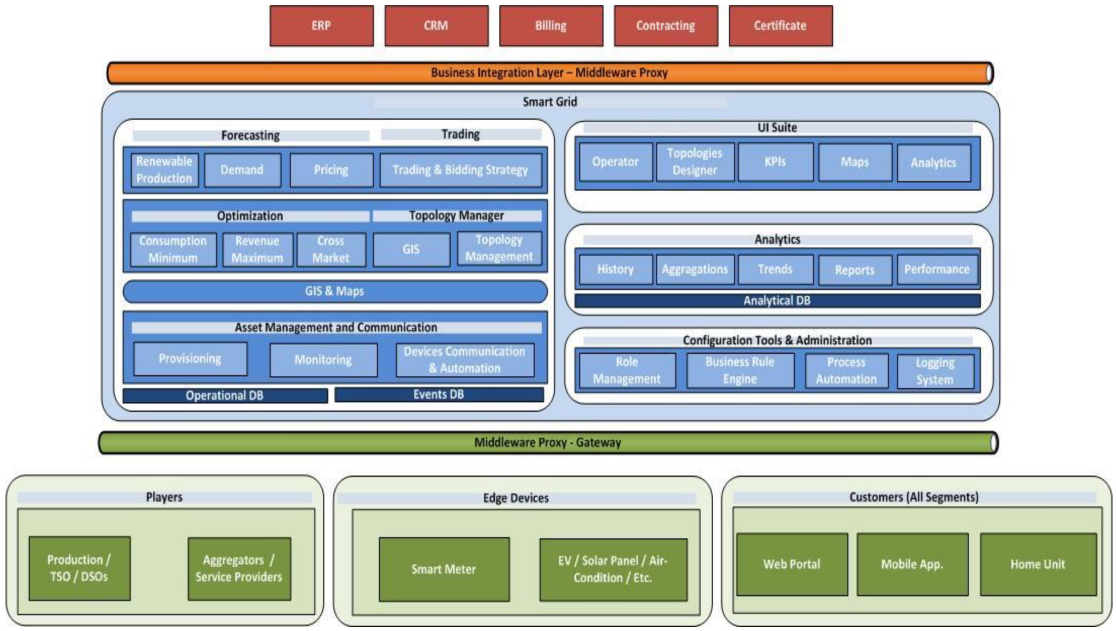


Figure 10: Smart Grid Control Center Technology

Name	Description
Optimization	
Optimization	Optimizing between grid operators' requests and end customer consumption and production units flexibility according to business rules and trading system. Forecasting is yet another technology that processes historical data, trends and current variables in order to calculate consumption, pricing, assets health and production power forecasts.
GIS and Maps	
Maps	Map layer and topology manager to present and change topologies and service status (from a single device up to country level aggregated status).
Asset Management Modules	
Asset management	Asset management capabilities responsible for registering new devices into the system, remote configuration, activation and upgrade of the devices, health status, alerting, etc.
UI Suite	
Operator UI	Primary Smart Grid operator management tool that provides 360 view of all Smart Grid assets, status and processes.
Analytics	
History	Historical data business analytic tools such as trends reports, performance, etc.
Middleware Proxy Gateway	
Middleware	Middleware layer abstract dedicated protocol and interface to various players and devices while maintaining clear and interface to the inner smart grid logic and components.
Player, Edge Devices & Costumers	
Players	Standard interfaces and protocol toward specific entities such as grid operators, aggregators, service providers and end customers.
Business applications	
Biz.	Business applications like CRM, billing, ERP, contracting, etc.

Table 6: Smart Grid Control Center Components & Technology