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BUSINESS MODELS AND MARKET PRICING MECHANISMS WITHIN VIRTUAL MICROGRIDS FOR SMART ENERGY NETWORKS

A European Market Perspective

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Master Thesis, Energy, Natural Resources and the Environment

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Declaration

This thesis is based on VIMSEN project FP7 ICT-619547 of EU Horizon 2020 initiative. VIMSEN is a multi-country, multi-stakeholder research project being undertaken in three phases and duration 2014-2017. The VIMSEN project is divided in 8 different work packages (ref. Appendix A). I worked as an intern at DNVGL, one of the project partners, during the 2nd phase of the project in 2015 on Deliverable 8.2.2 of WP 8. This document significantly draws information from different reports under the VIMSEN project mainly Deliverables 8.2.1.; 8.2.2; 2.1.1 and 2.2.2.

My contribution to the report was analysis of market models proposed and applying the concepts of business model canvas and value proposition canvas to different VIMSEN stakeholders.

I have mentioned all the sources used and that I have cited them correctly according to established academic citation rules.

Abstract

Over the past decade, a number of countries across the world have taken up steps to increase the share of renewables such as Wind and Solar PV in their generation portfolio. EU has a goal to enable the transmission and distribution of up to 35% of electricity from dispersed and concentrated renewable sources by 2020 and a completely de-carbonized electricity production by 2050. However, these "clean" sources too have a lot of critics questioning the stability and reliability of the future power system with large scale integration of renewables. This is primarily due to the intermittent and non-reliable nature of renewables. A concept of microgrid aggregator (VMGA) has been investigated in this thesis work as a step forward in an attempt that, a power market system with large scale integration of small RES prosumers is possible.

This thesis work investigates the possible market pricing models in a decentralized electricity market network by participation of aggregators who will have market power to participate in the grid. Full integration of RES prosumers in future power system is visualized. Ten different pricing models based on existing economic principles and market types have been discussed in detail. The recent trend in research is to exploit business possibilities and opportunities in ICT backed grid of the future where RES energy is a reliable and profitable business. In keeping with the trend, business model canvas and value proposition canvas for the microgrid aggregator (VMGA) has been illustrated so as to enable the managers to be better prepared while working in decentralized grid of the future.

Keywords: electricity markets, pricing models for electricity markets, business model canvas, value proposition, micro grids, microgrid aggregator, prosumer, smart grids, VIMSEN

Acknowledgements

Coming from an Indian village where I studied in kerosene lamps as a kid, to writing about possible future market and business models of decentralized electricity markets, life certainly has come a long way. I am delighted that my graduation thesis is completed and that I will soon become a master graduate from Norwegian School of Economics (NHH). This is a very memorable moment for me as an individual, student and a future professional in new energy. However, this would not have been possible with the constant support and guidance of a lot of individuals whom I am indebted to.

I would like to begin by thanking my professor and thesis supervisor, Prof. Mette Helene Bjørndal, for guiding me deep into electricity markets, a daily necessity which majorly influences our living condition. Concepts learnt during her teaching of the master course on electricity markets are the basic foundation of this academic work. She has always provided me with quick and practical solutions. I consider myself very fortunate to have worked with her and specially thank her for giving me freedom in shaping this work and showing trust in my abilities to pull off this topic.

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Finally to the lads and ladies, I have called friends; for your relentless encouragement and support - May our paths cross again, in lands where barrels are never empty, where the joys of life are plenty.

Contents

List of Abbreviations

Acronym	
AEMF	Active Energy Management Framework
AGC	Automatic Generation Control
AMI	Automatic Metering Infrastructure
ATC	Average Total Cost
Auto-DR	Automated Demand Response
BM	Business Model
BMC	Business Model Canvas
BRP	Balance Responsible Party
BS	Base Station
CAPEX	Capital Expenditure
CC	Cloud Computing
CES	Community Energy Scheme, Community Energy System
CHP	Combined Heat and Power
CPP	Critical Peak Pricing
CSP	Concentrated Solar Thermal
DAS	Data Analysis System
DDNS	Dynamic Domain Name System
DER	Distributed Energy Resource
DR	Demand Response
DRM	Demand Response Manager
DRMS	Demand Response Management System
DSM	Demand Side Management
DSO	Distribution System Operator
DSS	Decision Support System
DSU	Demand Side Unit

DUoS	Distribution Use of System
EDMS	Energy Data Management System
EE	Energy Efficiency

EMFT	Energy Modelling and Forecasting Toolkit
ENM	Energy Negotiation Module
EO	Energy Operator
ESCO	Energy Services Company
ESO	European Standardization Organization
FIT	Feed In Tariff
ETS	CO_2 Emission Trading System
FMS	Forecasting and Modeling System
GA	Geographical Area
GDRM	Global Demand Response Manager
GSN	Greek School Network
GUI	Graphical User Interface
GW	Gateway
HAN	Home Area Network
HES	Head End System
H/W	Hardware
IaaS	Infrastructure as a Service
ICT	Information and Communications Technology
IF	Interface
IoT	Internet of Things
IPP	Independent Power Producer
ISP	Imbalance Settlement Period
KPI	Key Performance Indicator

LAN	Local Area Network
LCE	Low Carbon Energy
LDRM	Local Demand Response Manager
MAM	Meter Asset Management
MC	Marginal Cost
MDM	Meter Data Management
MG	Micro-Grid
M2M	Machine-to-Machine
MNO	Mobile Network Operator
MO	Market Operator
MQTT	Message Queue Telemetry Transport
MR	Marginal Revenue
MRSO	Meter Registration System Operator
MTC	Machine Type Communication
M&V	Measurement & Verification
NAN	Neighborhood Area Network
NEW	North Western European
OPEX	Operational Expenditure
OTC	Over The Counter (energy contracts)
PaaS	Platform as a Service

PC	Power Company
PCR	Price Coupling of Regions
PTR	Peak Time Rebate
PV	Photovoltaic
PX	Power Exchange (energy wholesale market)
QoS	Quality of Service
RES	Renewable Energy Sources
RDL	Raw Data Logger
RTP	Real Time Pricing
SaaS	Software as a Service
SCC	Smart Cities Community
SDN	Software Defined Networks
SDO	Standards Development Organization
SEM	Single Electricity Market
SIM	Subscriber Identity Module (i.e. SIM card in mobile phones)
SLA	Service Level Agreement
SM	Smart Meter
SMP	System Marginal Price
SP	Smart Plug
SRMC	Short Run Marginal Cost
SSE	Server Side Events
S/W	Software
ToU	Time of Use
TP	Telecommunications Provider
TSO	Transmission System Operator

TUoS	Transmission Use of System
UC	Use Case
VA	VIMSEN Aggregator
VGW	VIMSEN GateWay
VMG	Virtual Micro-Grid
VIMSEN	Virtually Integrated Microgrids for Smart Energy Networks
VMGA	Virtual Micro-Grid Aggregator
VMGA-DSS	Virtual Micro-Grid Aggregator Decision Support System
VMO	VIMSEN Market Operator
VP	VIMSEN Prosumer
VPC	Value Proposition Canvas
VPN	Virtual Private Network (secure data connection through internet)
VPD	VIMSEN Prosumer Dashboard
VPT	VIMSEN Prosumer Terminal
WAN	Wide Area Network
WO	Weather Operator
WS	Weather Station

Chapter 1 Introduction

This chapter presents the context about the research that has been carried out in this work. Subsequently, a brief definition of the Research Problem/Questions to be answered is provided with a concluding remark on the methodology used in this research. Outline of the thesis concludes the chapter.

1.1 Context Analysis

In the modern world, electricity plays a pivotal role in our daily lives. The traditional methods of electricity generation, i.e. power plants fuelled by fossil fuels, nuclear fuels, etc. are losing their appeal due to increasing awareness of their negative environmental impacts and climate change risks. There is a growing trend in governments across the world, to set ambitious targets of renewable integration in their electricity generation; the success of which ultimately depends upon the long term view of regulatory and business environments.

Local renewable generation would not only reduce the dependence on fossil fuel but also lead to a greener and sustainable electricity generation system. Renewables such as Wind and Solar PV are a good choice for the future due to their ability to produce power (the terms “power” and “electricity mean the same and are used interchangeably in the document) in a sustainable manner. However, their market participation is difficult because power producers from RES can only contribute infinitesimally small amount of energy to the existing electricity grid which does not promise sufficient returns on investment. The minimal trading volume of hourly contracts for power at the European Energy Exchange (EEX) spot market is 0.1MW(EPEX, 2015). To participate in the control energy market a minimal nominal power of 30MW-50MW is necessary(EPEX, 2015)[1]. Such policies prevent small unit producers from RES to participate in the market due to their limited capacity. Thus, to make electricity from RES cost effective, it is important to aggregate enough demand to size by gathering multiple users into a shared system(Sherman, 2012). A way to achieve this, as proposed in a project by EU, is concept of "Microgrids and More-Microgrids"[2]. To make microgrids commercially viable, it is important to create a possibility of a Virtual Micro grid Aggregator (VMGA) by collecting the generation capacity of several microgids.

The aim of this study is to understand the VIMSEN concept, identify the new services & stakeholders, and ideate on possible market models for electricity generation of the future. This thesis will also try and evaluate the business models for multiple stakeholders who see common benefit in their shared efforts.

1.2 Problem Definition

Renewable energy sources and energy storage applications will play a complimentary role in ensuring a sustainable and reliable energy supply in a future power system. So the problem at hand is to understand what kind of market mechanisms can be applied when VMGAs have to be integrated during transition from existing centralized grid to decentralized grid of the future. In the new ICT backed power grid, there will be new stakeholders which will participate in the market. We also must understand the business models for these stakeholders.

[1] Prerequisites for day ahead market participation in different EU countries can be seen in appendix B.
[2] http://www.microgrids.eu/default.php

1.3 Research Question and Objectives

Following the definition of the problem in the previous section, the following research question is formulated:

"For a grid with a large penetration of renewable generation, what kind of market mechanisms can be used to improve the dynamic response of the system while integrating VMGAs?

The Research Objectives are as follows:

1. To identify the potential market models which can be exploited by various stakeholders within the VIMSEN framework
2. To illustrate a business model canvas and value proposition for new stakeholder, VMGA

1.4 Research Approach and Methodology

The first step involved is to understand the VIMSEN concept and objectives in detail. Before presenting ideas about new market and pricing mechanisms, an analysis of traditional market models has been presented along with country specific examples within EU. The document will provide an overview of the market operational rules and practices concerning RES electricity generation under the VIMSEN framework. Based on this analysis, new pricing models and mechanisms are proposed enabling the market participation of small distributed resources in more competitive and fair way as compared to conventional generation units. Next, concepts of business model canvas (BMC) and Value proposition canvas (VPC) have been used to illustrate business opportunities for the VIMSEN stakeholder VMGA.

1.5 Outline of Thesis

This section provides an overview about the organization of this thesis work, as enumerated below.

1. **Chapter 1** introduces the research questions involved and the objectives of this thesis work, while also providing a context analysis of the topic and the research methodology employed.
2. **Chapter 2** is a chapter in this thesis from a conceptual viewpoint. And introduces the VIMSEN concept and objectives in detail keeping in mind the power grid of the future. Furthermore, it details the assumptions and simplifications of this concept along with an illustration of VIMSEN system information and operation lifecycle.
3. **Chapter 3** is another key chapter in this thesis and deals with the existing market models applicable to traditional centralized grid market. This chapter highlights key stakeholders and gives examples of electricity markets in select European countries of Netherlands, Italy and Germany.
4. **Chapter 4** discusses the new pricing mechanisms which the VIMSEN framework might use in order to aggregate the RES units to promote dynamic assembly of multiple microgrids. This chapter also details the new stakeholders like prosumers,VMGA .
5. **Chapter 5** discusses an important take-away from this thesis work- The theories of business model canvas and value proposition canvas are applied to newly introduced VIMSEN stakeholders VMGA which could be further utilized to identify business opportunities and potential products/services.
6. **Chapter 6** discusses the results obtained from this study and is the main take-away from this thesis work. This chapter culminates by providing recommendations for future research work based on the observations from this work.

Chapter 2 VIMSEN Concept & Objectives

This chapter presents an overview of the proposed rationale supporting VIMSEN concept, which is essential for the further progress of this research. This chapter brings to the fore the objectives of this new concept and illustrates a typical VIMSEN system operation. Main assumptions and simplifications, which have been considered to simplify the process of concept development with regard to the scope of this work, have also been detailed.

2.1 Concept & Objectives[3]

The creation of virtual micro-grids (VMGs), revolutionizes the traditional framework of the centralized electricity market, by transforming this into a distributed market. Microgrids are based on smart grid technologies. Before going any further we must define smart grids and micro grids. Smart grids are seen as the efficient means in transition from current energy distribution network and are defined by Gellings as "grids which provide power systems with intelligence by means of the use of sensors, communications, computational ability and control in some form to enhance the overall functionality of existing power delivery system"(Gellings, 2009). Microgrids are "small, self-contained electricity heat and sometimes cooling distribution systems that coordinate and distribute energy supplied from multiple generation sources to a network of users in defined area and primarily use RES to generate electricity" (Sherman, 2012). Micorgrids shall be discussed in more detail in Chapter 4. Figure 2-1 presents the advantages of the decentralized rationale introduced by the VIMSEN project compared to the traditional centralized one. In the traditional model, the electricity producers sell their energy on the central market. Instead, in the proposed VIMSEN rationale, small energy producers (also called prosumers[4]) have the flexibility of either:

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[3] This introduction is based on the concept note of VIMSEN project and the reports generated in 1st Phase of the project. Please refer appendix A for more information on different work packages and project partners.

[4] For detailed explanation of prosumers, please refer chapter 4

- directly participating in the electricity market through the respective VMGA, which acts as a big power production unit or,
- re-distributing energy among each other to compensate energy production-demand differences

Towards this framework, VIMSEN aims to develop new use cases and business models to investigate the trade-off between the benefits of the association and the cost of the technologies (ICT) needed to establish this association. And, furthermore, to study the trade-off between the costs and benefits of the association and its individual prosumers on the one hand, and the wholesale market actors and grid operators on the other hand.

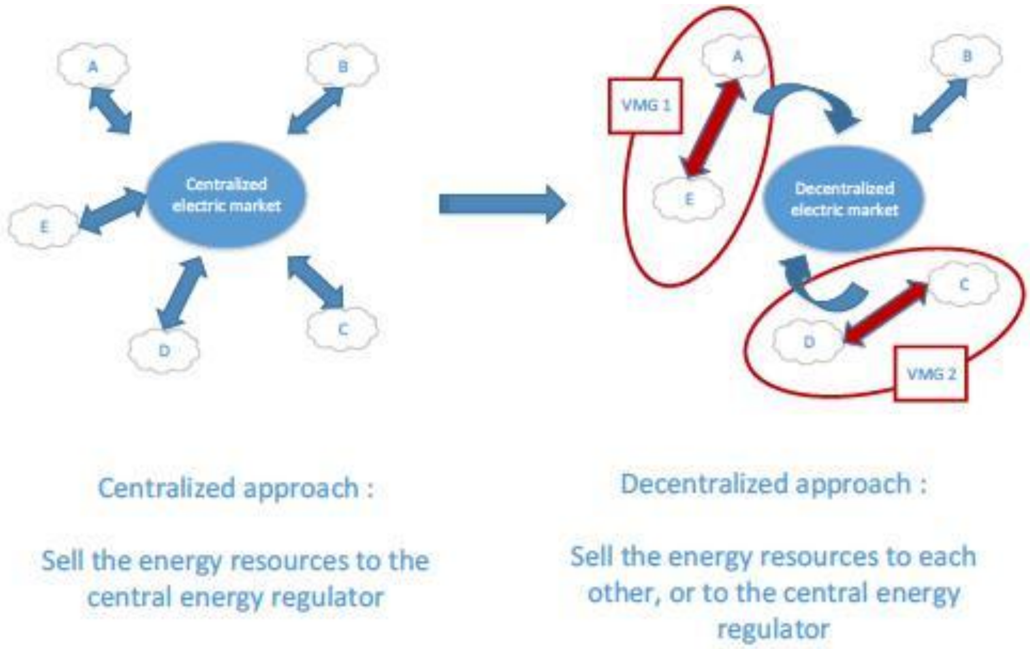

Figure 2-1: The decentralized conceptual rationale adopted by the VIMSEN project (on the right). In the traditional model, the energy producers sell their energy resources centrally (left side).

VIMSEN: The aim of this project is to research on ICT technologies that allow the creation of Virtual Micro-Grids under a highly dynamic and distributed electricity market framework. Virtual Micro-Grids are dynamic associations of multiple micro-grids operating under a common information and communication framework that allows efficient energy management and control. VMGs present many advantages that revolutionize the smart energy grid concept towards the research objectives of Horizon 2020 and beyond.

VMGAs can offer new business models for small and very small RES producers (i.e. VIMSEN Prosumers – VP), to share their surplus of generated energy to the energy market. In particular, small and very small prosumers can form virtual associations of micro-grids and through these associations they can sell the energy produced to the entire network at a better price. This way:

- All energy producers are treated equally, without using subsidy policies that actually increase electricity price.
- Incentives are given to small and very small producers to share their generated energy with the market.
- Better sale prices are achieved for small and very small producers since they interface through virtual associations as a bigger unit and harvest gains from positive energy externalities (i.e. environmental and geographical credits).
- Rapid investments of renewable energy sources are promoted from small units without relying on subsidy policies.
- There is no requirement for small energy producers to be physically connected to form the associations, as only virtual connections are formed.
- The advantageous position of large-scale production on the energy market is diminished, since almost all energy consumers can potentially be producers (i.e. VIMSEN prosumers - VPs).

For the above-mentioned visionary VIMSEN approach to be realized, a toolbox of appropriate Information and Communication Technology (ICT)-based solutions is being developed, which constitute the overall (technical) VIMSEN architecture. In Figure 2-2, a typical VIMSEN system operation and information lifecycle is illustrated.

VIMSEN "intelligence" is mainly introduced at the VIMSEN Aggregator's (VMGA) side and consists of the following software components/subsystems:-

- Energy Data Management System (EDMS), for VMG-level pattern analysis

- Forecasting and Modeling System (FMS), for VMG-level forecasting and modeling
- Decision Support System (DSS), where VMG-level decision making procedures take place about the VMG infrastructure creation and dynamic adaptation as well as interaction with the traditional market/grid operators.
- Global Demand Response System (GDRMS), where VMG-level decisions about DR load allocations are made.

Furthermore, VIMSEN "intelligence" is also applied at the prosumer's side via the VIMSEN gateway (VGW) that is able to provide:

- Communication-related functionalities, being hardware (vendor) and protocol/ technology agnostic as well as modular in terms of hardware and software, so that it can support the diversified requirements of the various VP types.
- Energy management-related functionalities, as event detection, short-term forecasting and energy disaggregation algorithms are run distributed at each VP
- Facility automation related functionalities as local demand response intelligence resides at the VP site.

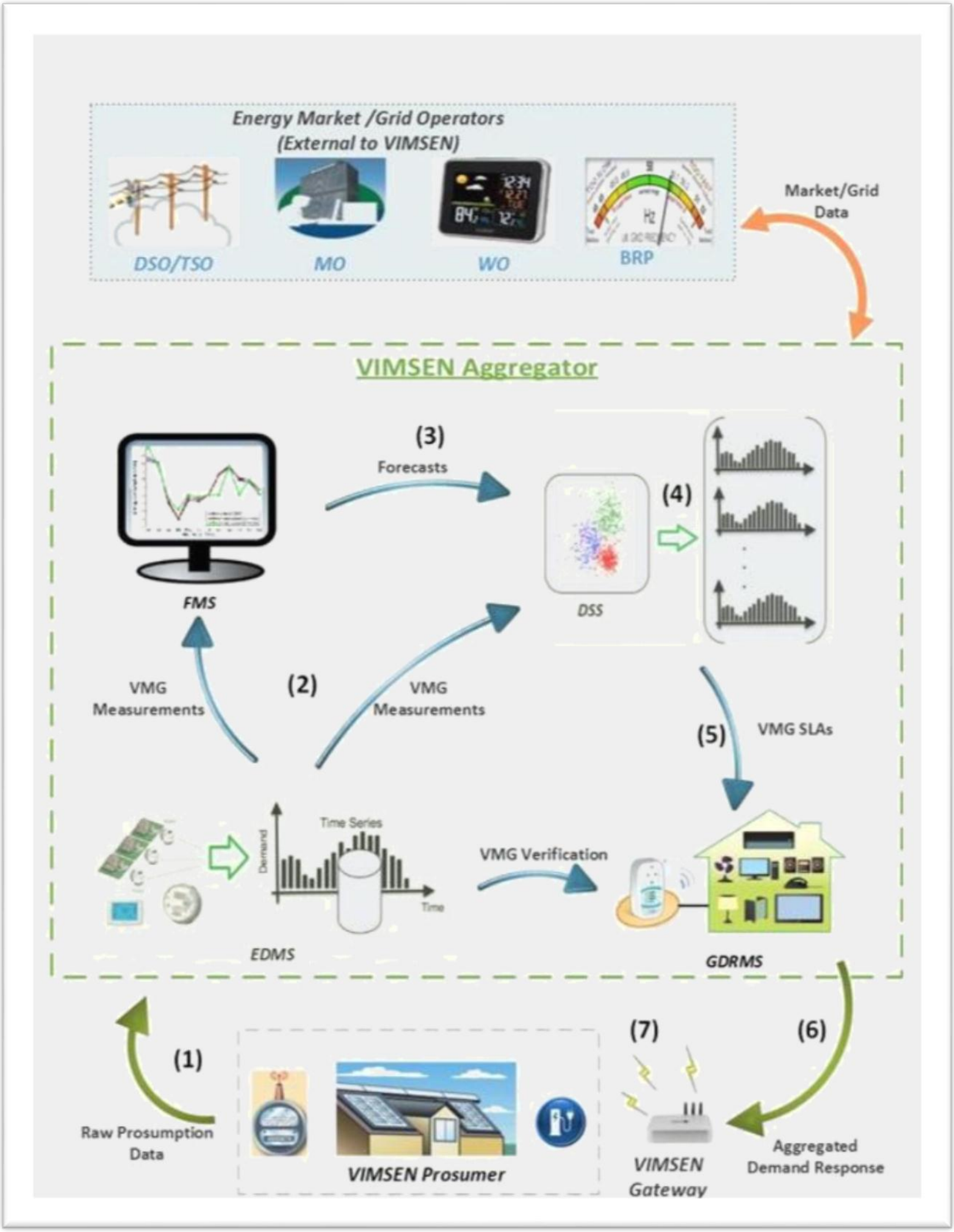

Figure 2-2: VIMSEN System Operation and Information Lifecycle

2.2 Assumptions & Simplifications

The VIMSEN project transforms the traditional centralized wholesale electricity market into a distributed one where RES energy producers and operators (in cases, prosumers) optimize their long term economic benefits by selling/buying energy not only to/from the wholesale market but also to/from each other. Certain assumptions have been made about the interaction between the VIMEN RES market and the traditional wholesale market.

In the analysis of the VIMSEN market and the VIMSEN pricing models, the following assumptions apply:

- Because of political choices (EU RES Directive), the wholesale market is obliged to trade a certain amount of RES as part of the energy mix for electricity production
- There is not enough RES energy on the traditional wholesale market. The majority of the RES must come from distributed prosumers (because of the lack of other options)
- Existing RES producers, e.g. wind parks, are assumed to be of similar size or smaller than VMGAs, or they can behave like VMGAs
- VMGAs are the main players in VIMSEN RES market. The number of VMGAs may vary from one to many. Subsequently, VMGAs can compete, or can make a cartel (depending on the rules)
- For research and investigation purposes, different VIMSEN pricing models are defined and the consequences are studied. Later on the feasibility of these different pricing models is evaluated with respect to the current and future market based on free market principles
- Bilateral trade between VMGAs is also possible within the VIMSEN market.

Furthermore, some simplifications for analysis are introduced:

- VIMSEN establishes a RES wholesale market as part of the traditional wholesale energy market
- For simplicity of the analysis, the VIMSEN market is a split part of the traditional wholesale market, with its own operator, the VIMSEN Market Operator
- The required RES share of the traditional market is defined as a RES demand from the traditional market to the VIMSEN market.
- Consequently, the VIMSEN market will issue a price bid on the traditional market. Because a split market is assumed, the VIMSEN market price for RES may be different from the energy price on the traditional market.

Chapter 3 Traditional Market Pricing Models

This chapter deals with the traditionally prevalent market models in existing electricity market. It also highlights entities which compose the current value chain of the centralized grid driven electricity market. Examples of Netherlands, Italy and Germany have been discussed to understand existing markets better.

3.1 Introduction

Electricity markets have traditionally been operated by a centralized grid producers connected to distributed consumers based on a demand oriented strategy. Such "vertically integrated utilities" are characterized by single utility which handles the entire value chain i.e, generation, transmission, distribution and delivery with a defined area. However since the 1990s, rules and regulations have been framed to limit such monopoly of the network. Legal framework of deregulation and unbundling in European electricity markets are currently governed by the *Internal Market in Electricity Directive 2009/72/EC*[5] which are governed by goal to create a fair and non-discriminatory market in general.

3.2 Definition of Major Stakeholders

Value chain of electricity markets consists of various stakeholders. Regular electricity production, distribution, and consumption value chain is illustrated in figure 3.1. Definition of all the stakeholders are as per the *Directive 2009/72/EC.*

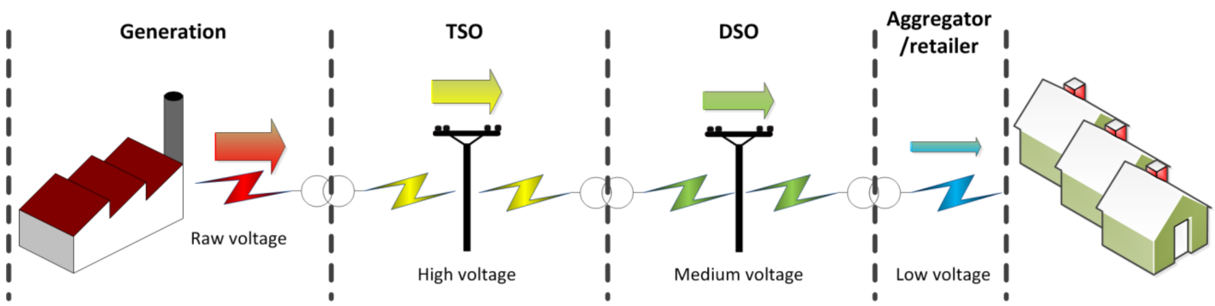

Figure 3-1: Value Chain in a traditional electricity production(Rodríguez-Molina, et.al, 2014)

[5] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0072&from=EN

Energy Regulatory Authority (ERA), is an independent national authority playing the administrative role in the electricity market. ERA can take autonomous decisions, independently from any government, political body, public or private Entity ,market interest.

To ensure this, ERA has separate annual budget allocations, with autonomy in the implementation of the allocated budget, and adequate human and financial resources to carry out its duties.

Producer, is a natural or legal person generating electricity for the purpose of sale inside the system where he is established (wholesale market).

The energy production licensing is granted by the relevant competent ERA. When a Producer is licensed, the entity can participate in Energy Wholesale Market and/or in Ancillary Services Market.

The Producers can be classified as,

- ***Conventional Producers***, whose electricity generation is based on the use of limited energy reserves, such as: Fossil fuels (i.e. hard coal, lignite, oil, natural gas, nuclear energy … etc.),
- ***Renewable Energy Sources (RES)***, whose electricity generation is based on the use of inexhaustible sources, such as: wind , sun , water (Rain, Tides, Waves) , geothermal heat, biofuel , biomass

Supplier (Retailer), is a natural or legal person purchasing electricity (from wholesale market) for the purpose of resale inside or outside the system where he is established (to retail market).

The energy supplier licensing is granted by the relevant competent ERA. When a Supplier is licensed, the entity can participate as a Consumer, buying energy, in Energy Wholesale Market and as a Supplier in Energy Retail Market for reselling the purchased energy.

Transmission System Operator (TSO), is a natural or legal entity responsible for operating, ensuring the maintenance of and, if necessary, developing the transmission 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 transmission of electricity.

Few main responsibilities of a TSO are

- To facilitate market integration and maintain its interconnections with other system with an optimal financial operations so as to maintain environment and energy efficiency.
- To ensure long-term ability of the Electricity Transmission System (ETS) by managing energy flows on the ETS taking into account exchanges with other interconnected systems.
- To provide ETS users and the operators of any other interconnected ETS with sufficient information to ensure their effective access to the System.
- To collect congestion rents and payments under the inter-transmission system operator compensation mechanism, granting and managing third-party access and giving reasoned explanations when it denies such access, these shall be monitored by the national regulatory authorities, in carrying out their tasks.

Market Operator (MO), is a natural or legal person responsible for clearing and settling wholesale transactions (bids and offers) in Energy Market. Market operator does not clear trades but often require knowledge of the trade in order to maintain generation and load balance.

Distribution System Operator (DSO), is 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.

Few main responsibilities of a DSO are:

- Ensuring the long-term ability of the Electricity Distribution System (EDS) for meeting reasonable demands for Distribution of electricity,
- Development of EDS, according to energy efficiency/demand-side management measures (DR) or Distributed Generation (DG)
- Providing all services under transparent, objective and non-discriminatory criteria between EDS users or classes of EDS Users, particularly in favor of its related undertakings.
- May require, when dispatching generating installations, to give priority to generating installations using Renewable Energy Sources (RES), or using waste or producing Combined Heat and Power (CHP).

3.3 Traditional Market Trading Models

3.3.1 Uniqueness of Electricity Markets

In the usual market, equilibrium is reached when demand equals supply. But in case of electricity, the supply of power must match the consumption of power at every point in time to maintain the overall frequency of the grid.

Electrical energy is a homogenous good that is injected into the transmission grid by all generators and is withdrawn by all end users. There is usually no way to identify the electricity generated by producer A with the power utilized by consumer B. A useful analogy is to think of the transmission grid as a large pond, with producers putting water into the pond while consumers are simultaneously taking water out(Griffin & Puller, 2005). Unlike many other goods, over supply of electricity as a good cannot be readily disposed of, and if the grid is even slightly under-supplied large areas of the market lose the ability to consume power. There is a continuous need to balance supply and consumption on electrical networks which in a way means that Adam Smith's invisible hand is hardly invisible for electricity markets(Griffin & Puller, 2005).

To understand the electricity markets better, we discuss main trading models where the electricity generators/sellers and buyers interact – wholesale market, retail market and balancing market.

3.3.2 Wholesale Electricity market

Wilson(2002), while examining the architecture of power markets, points out that wholesale markets remain an interesting point of research given that they remain incomplete under a deregulated market for three key structural reasons:

- They cannot be perfectly monitored
- Energy storage is difficult and expensive
- At a retail level, variable pricing is not matched with flexible spot pricing

However, a traditional electricity market consists of a centralized wholesale market, through which power companies and suppliers trade electricity. Most transactions in a wholesale market occur through Power Exchanges (PXs). Electricity generators sell their electricity to the suppliers/buyers at the marginal cost of producing each unit (€/MWh) through bidding governed by a code pf practice. A common wholesale electricity market in a European country is shown in figure 3-2, as described in Ruska & Similä (2011).

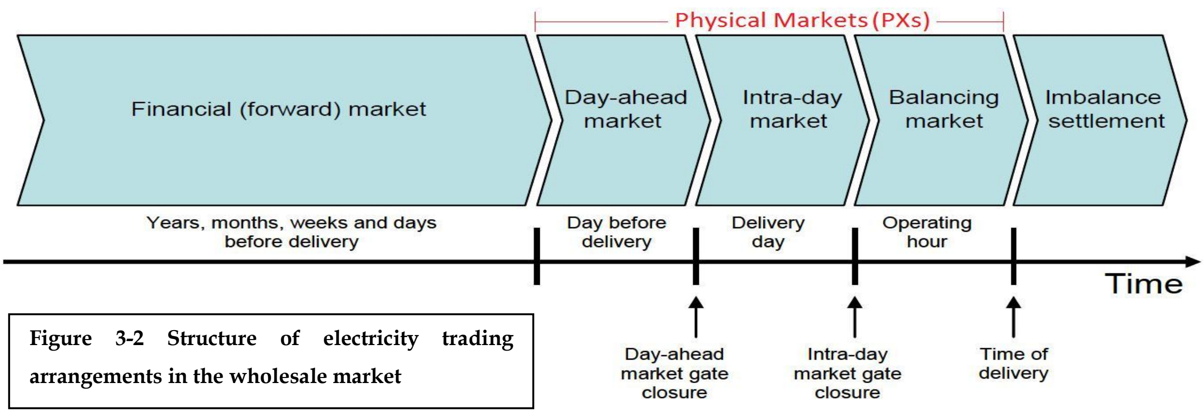

Figure 3-2 Structure of electricity trading arrangements in the wholesale market

Day Ahead Market

Day ahead market is a market that operates through a two sided auction and is the main area of trading power. Here, contracts are made between seller and buyer for the delivery of power the following day, the price is set and the trade is agreed[6].

Operational Features of a Day Ahead Market

- At the start of each day Producers/Importers make offers with specific amounts of power production, price (€/MWh) and hourly block of power delivery for the next day (i.e. at 08.00-09.00 of 01/01/2016 they bid for 08.00-09.00 of 02/01/2016).
- After all of the Producers/Importers have made their offers (bids), they cannot take them back.
- Following the same procedure suppliers, exporters and maybe some large Customers make their bids.
- All the offers/bids have to be handed in/submitted until a specified deadline (e.g. 12 o'clock noon the day before delivery).
- Offers (Bids) are ranked in ascending (descending) price order.
- After the execution of a linear minimization procedure, the Market Operator in cooperation with Transmission System Operator (TSO) compute the System Marginal
- Price (SMP) of each day ahead in hourly blocks (or half hourly or quarterly, depending on the country).

Intra Day Market

The intraday market or intraday trade is the trade that takes place during the day of operation when the power exchanges (day-ahead market) are closed[7]. According

[6] http://www.nordpoolspot.com/How-does-it-work/Day-ahead-market-Elspot-/
[7] http://www.energinet.dk/EN/El/Engrosmarked/Viden-om-engrosmarkedet/Sider/Intraday-marked.aspx

to Nordpool, This is a continuous market, and trading takes place every day around the clock until one hour before delivery (timing of closure may vary as per country regulations). Prices are set based on a first-come, first-served principle, where best prices come first – highest buy price and lowest sell price. The intraday market is becoming increasingly important as more RES enters the grid. RES are unpredictable by nature, and imbalances between day-ahead contracts and produced volume often need to be offset. This type of market can be a key enabler to increase the share of renewable energy in the energy mix.[8]

Balancing Market

Balancing power is defined as "The electric power required to counterbalance short-term differences between generation and consumption of electricity in a grid." (Müsgens et al., 2014, p. 2). Balancing Market is a one-sided auctioning market operated by TSOs to maintain a real-time balance between power production and demand when the market cannot facilitate the required level of balance between electricity generation and consumption on its own.

Power Producers (Conventional or RES) called Balance Responsible Parties (BRPs) , which have a license from the TSO(s), are required to maintain generation and consumption balance of the grid over a given timeframe (the Imbalance Settlement Period (ISP) is generally 15 minutes in most Europe).

3.3.3 Retail Electricity Market

Retail market operates when supplier after buying electricity from the wholesale market sells directly to the final consumer after paying a fee to TSO and DSO for its delivery to commercial and residential customers. Presently, electricity supply is fully deregulated in most of EU and customers can chose their own suppliers who compete amongst themselves on pricing.

[8] http://www.nordpoolspot.com/How-does-it-work/Intraday-market/

3.4 Electricity markets in Selected European countries

Although EU electricity markets are based on common regulations, there is still scope for differentiation in trading based on

- Variations in electricity grid structure and grid design, level of competition and concentration in the market, and
- Variations in procedures such as bidding, pricing, settlement, congestion management, transmission pricing in respective wholesale markets

These variations can be basis of designing customized innovative business models for smart energy networks of Europe. Here, three different countries are being detailed for reasons particular to the project. Netherlands is where a major VIMSEN partner DNV GL (KEMA) is based. As per project details, Italy will have a real life testing site for the project. Germany has been chosen because it is the leading EU country in integrating RES in its electricity market.

3.4.1 Netherlands

Regulatory Authority

The independent energy regulator in The Netherlands is the Authority of Consumers and Markets (ACM)[9]. The Energy department of the ACM deals with energy regulations.

Transmission System Operator

The Dutch TSO is TenneT[10]. TenneT is the first international TSO of the world: it is also one of the four TSOs in Germany. In The Netherlands, TenneT runs the balancing and ancillary services markets as the single buyer.

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[9] www.acm.nl
[10] http://www.tennet.eu/nl/home.html

Distribution System Operator

In The Netherlands there are four large DSOs: Alliander[11], Enexis, Stedin and Delta[12]. There are a few smaller ones. The four larger DSOs have both electricity and gas networks. Some smaller ones have either electricity or gas.

The transmission and distribution fees in The Netherlands are presently a fixed monthly fee that only depends on the nominal power capacity of the grid connection. This means that it is independent of the amount of energy bought, as is the case in most European countries. The fixed capacity fee was introduced a few years ago. The benefits for the DSOs is that their income is stable, although many private consumers buy less electricity because of own PV production.

Meter Registration System Operator

In The Netherlands, there are 15 acknowledged parties having Electricity Metering Responsibility according to the Electricity Measuring Code. The metering parties are acknowledged by TenneT. All Dutch DSOs have a department or an associated company that is an Electricity Metering Responsible party.

Electricity Market Operator

APX Power NL[13] is the Dutch energy spot market. It is part of APX Group that also operates platforms in the United Kingdom (APX Power UK) and Belgium (Belpex).

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[11] http://www.alliander.com/en/alliander/index.htm
[12] www.delta.nl
[13] http://www.apxgroup.com/trading-clearing/apx-power-nl/

3.4.2 Italy

Regulatory Authority

The Italian Regulatory Authority for Electricity Gas and Water (AEEG)[14] is the independent body, which regulates, controls and monitors the electricity and gas markets in Italy.

Transmission System Operator

Terna S.p.A.[15] - Rete Elettrica Nazionale is the Italian electricity transmission system operator. With 63,500 kilometers (39,500 mi) of power lines, Terna is the first independent electricity transmission grid operator in Europe and the sixth the in world based on the size of its electrical grid.

Distribution System Operator

One dominant DSO, ENEL Distribuzione, covers more than 80% of the market. The rest is shared by medium and small DSOs, of largely domestic private ownership or municipally owned.

Electricity Market Operator and the Electricity Market

GME, Gestore dei Mercati Energetici, is the company organizing and economically managing the Electricity Market in Italy, under principles of neutrality, transparency, objectivity and competition between or among producers, as well as of economically anaging an adequate availability of reserve capacity. It is owned by the GSE, Gestore dei Servizi Energetici.

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[14] http://www.autorita.energia.it/it/inglese/index.htm

[15] http://www.terna.it/

The Electricity Market, commonly called **Italian Power Exchange (IPEX)**, enables producers, consumers and wholesale customers to enter into hourly electricity purchase and sale contracts. Market Participants connect to an online electronic platform and enter into on-line contracts under secure-access procedures based on digital certificates.

3.4.3 Germany

Regulatory Authority

The Federal Network Agency (German: Bundesnetzagentur, BNetzA[16]) is the German regulatory office for electricity, gas, telecommunications, post and railway markets. It is a federal government agency of the German Federal Ministry of Economics and Technology and headquartered in Bonn.

The Energy Act assigned the task of regulating Germany's electricity and gas markets to the Bundesnetzagentur. The purpose of regulation is to establish fair and effective competition in the supply of electricity and gas. Therefore, the responsibilities of the Bundesnetzagentur include ensuring non-discriminatory third-party access to networks and policing the use-of-system charges levied by market players.

Electricity Market Operator

EPEX SPOT operates the spot market (Day-ahead and Intra-day) for Germany, France, Austria and Switzerland. EPEX SPOT is operated by EPEX SPOT SE, which is a European company (a Societas Europaea or SE). EPEX SPOT SE is incorporated in France but the rules that are applicable to it are defined at European level. The foundation of a Societas Europaea (SE) allows companies

[16] http://www.bundesnetzagentur.de/EN/Home/home_node.html

incorporated in different member states to merge or form a holding company or joint subsidiary, while avoiding the legal and practical constraints arising from the existence of different legal systems.

Distribution System Operator

There are approximately 850 municipal energy distributors (*Stadtwerke*) in Germany, according to the VKU, the association representing the interests of the local authorities (www.vku.de/energie.html). E.ON, EnBW, RWE and Vattenfall – the big four power generation companies in Germany.

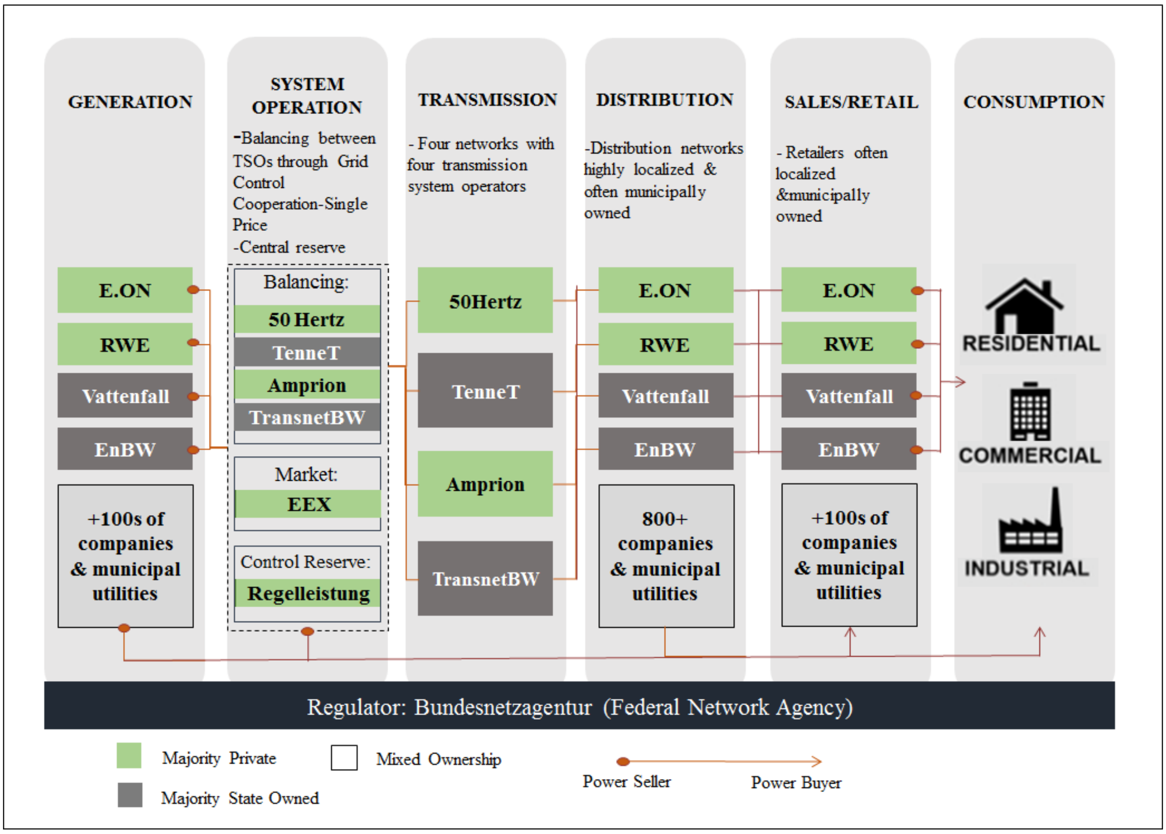

Figure 3-3: Value Chain in electricity production in Germany (Robinson,C., Davies, A., Hounsell, 2014)

3.5 Discussion

As the awareness of emissions and its induced impacts on the environment like global warming, smog, etc. are increasing, a shift to sustainable sources of energy has been taking place with increased penetration of RES into electricity generation. This trend is expected to carry forward in the future as the impacts of global warming become more tangible worldwide ("Climate Change-Threats and Impacts,”). Most countries in Europe have signed to comply with Kyoto Protocol through *the Renewable Energy Directive 2009/28/EC*[17]. Based on this they have set overall targets for share of RES in energy consumption by 2020 (for table, please refer appendix- C). The long term goal is to have de carbonized electricity production by 2050 in pan European network.

Although RES have zero fuel costs and have shown reduced investment costs in recent years, their cost of electricity generation is still substantially high. The traditional operational and regulatory framework does not facilitate small RES electricity producers to participate in the market. Even if the regulations change, small RES producers will be in danger of being “lost” in current system because of their small size and low reliability levels because of being weather dependent.

IEA report (2008) suggests it is essential to offer sufficient investment security and a reasonable return on investment (ROI) to attract investment in RES. Several support mechanisms and incentives have been implemented to increase and encourage RES to achieve proposed targets. Common ones are tax credits, subsidies & loans, green certificates (GC) and feed in tariffs (FITs). We will look into developments in FITs in greater detail in the following section because FITs are the most widely used concept to promote larger share of RES in electricity generation.

FIT scheme provides RES owners with long term price certainty at which they can sell the renewable electricity produced to the grid(Couture & Gagnon, 2010). These prices are generally market independent and have long duration purchase agreements of 15-20 years. It reduces uncertainty for investors and ensures certain cash flows. Though this policy has significant success and seen widespread implementation, (Germany has been pioneer in this scheme so far), a large RES share would result in market imbalance, reduce the competitiveness of RES and result in increased energy prices for the end customers. As electricity price affects

[17] http://www.buildup.eu/publications/31450

all areas of economy, increase in prices will increase overall cost. Hence, FIT scheme cannot be continued infinitely for a future grid with high RES penetration. To overcome these challenges, VIMSEN concept is being introduced which expands the current centralized electricity market into a distributed market framework. Small RES producers will be able to participate in the grid through a new stakeholder VIMSEN aggregator (VMGA).

Chapter 4 VIMSEN Market Pricing Mechanisms

This chapter starts with discussing the influence of RES on electricity generation. It further discusses the new stakeholders in the VIMSEN market. Based on the transformed distributed electricity market, potential pricing mechanisms in VIMSEN framework shall be analyzed.

4.1 Introduction

Large share of RES in electricity generation has economic and environmental benefits. RES generate energy close to the point of consumption which greatly reduces transmission losses during transportation of energy and saves investment costs in improving distribution network over long distances. Environmental benefits of RES are in the form of lower emissions per unit energy produced.

Scaling up of RES energy producers is the vision of VIMSEN premise, by introducing new pricing models and mechanisms that promote dynamic assembly of multiple microgrids. VIMSEN market analysis chances upon the opportunities arising out of Demand Response (DR) concept and is based on the assumption that EU regulations will force market operators to buy electricity from RES producers to meet reduced emission targets.

4.2 Major VIMSEN market stakeholders

In order to have a better market analysis, it is important to understand the major VIMSEN market shareholders. In current context, we shall discuss in detail prosumers, microgrids and Virtual microgrid aggregator (VMGA).

4.2.1 Prosumer

With the emergence of advanced, smarter technology, consumers can now make more informed choices about energy usage and become energy producers and consumers themselves – known as “prosumers” -resulting in a two way directional flow of power.[18] Prosumers have the choice to manage their energy consumption costs by using RES for onsite energy production. This flexibility helps balancing the grid by using Demand Response and Demand Management mechanisms. Prosumers have the potential to dramatically change the relationship between utilities and their end customers who are now able to monetize their generation capability and flexibility.

Example of prosumers are: (a) individuals (e.g., PV owners in urban or rural areas), (b) Small/Medium/Large Enterprises (owning PVs, wind-mills, etc.), (c) municipalities (e.g., having PVs on lamp-posts), etc.

4.2.2 Microgrids

Microgrids are small, self-contained electricity, heat, and sometimes cooling distribution systems that coordinate and distribute energy supplied from multiple generation sources to a network of users in a spatially defined area (Sherman, 2012). Based on their configurations, and function there can be multiple types of microgrids. However figure 4-1 shows the main components of a microgrid.

[18] http://reneweconomy.com.au/new-paradigm-utilities-rise-prosumer-26384/

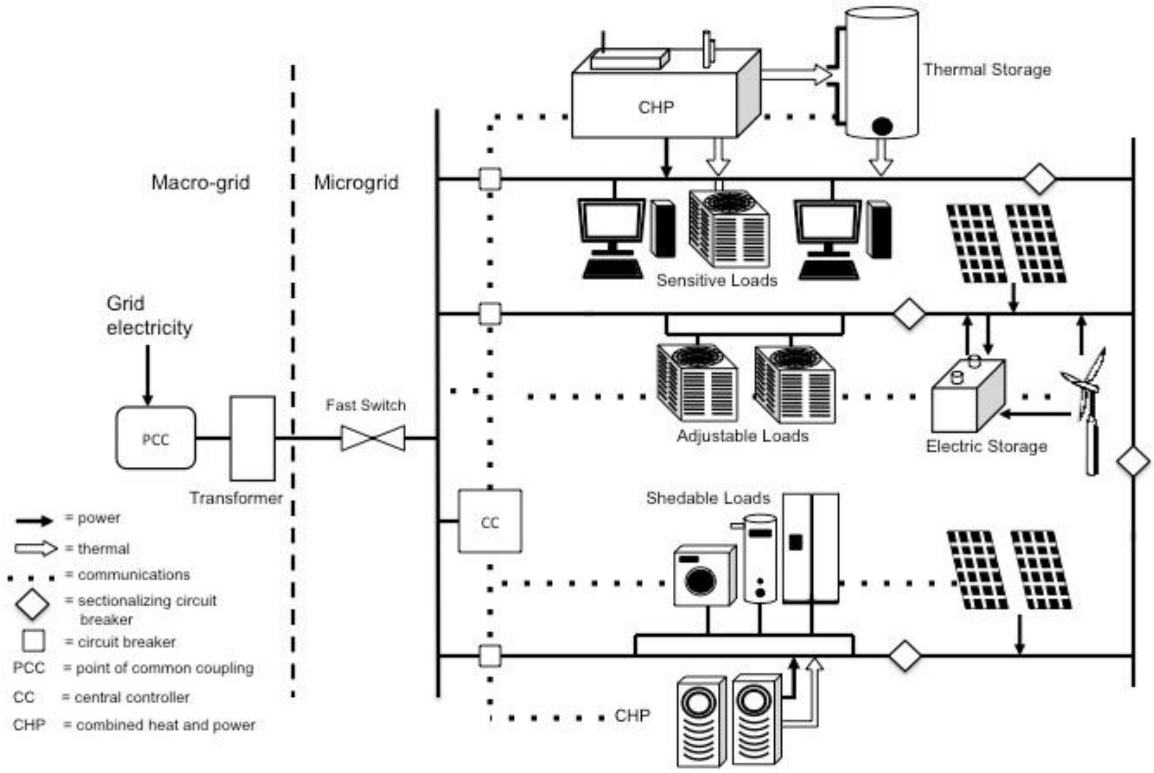

Figure 4-1: Schematic Illustration of a Microgrid (Source: Hammer & Hyams, "Smart energy for cities" in *Metropolitan Sustainability Understanding*)

In this document, we will consider microgrids as electricity producers from RES with focus on production, distribution and quality. A microgrid can also be an aggregation of very small RES producers or a trivial case of microgrid can be a VISEN Prosumer (VP) defined above. Each MG choses the VMGA to participate in the bidding market.

4.2.3 Virtual Microgrid Aggregator (VMGA)

An aggregator is a company who acts as an intermediary between electricity end-users and RES owners and the power system participants who wish to serve these end-users or exploit the services provided by these RES(Ikäheimo, et. al, 2010). Aggregation is an act of grouping distinct agents in a power system (i.e. consumers, producers, prosumers, or any mix thereof) to act as a single entity when engaging in power system markets (both wholesale and retail) or selling services to the system operator(s)(Burger, et.al , 2016).

In context of this project, VMGA is an entity which may act as an energy administrator of an association of VIMSEN prosumers (VPs), to satisfy the association's own energy needs and/or as their representative in order to sell the surplus energy to the Energy Market. As defined in VIMSEN project document, main responsibilities of VMGA are described below[19].

VMGAs' main responsibilities are:

- To perform day-ahead forecasting of production/consumption of its VPs and to efficiently manage the energy resources produced by the VPs, aiming at covering the association's own needs first.

- In case of energy surplus, to maximize the profit for its own VPs, by: Monitoring the energy market demand and negotiating with the Energy Market.

-In the negotiations, the VMGA should take into account the green and geographic positive externalities that the production of its members (RES producers) bring to the overall market, instead of letting the other market players benefit from these externalities for free, for their own sake.

- Taking proactive actions to ensure the active fulfillment of activities(optimal formation of VMGs, Demand-Response with its own VPs, etc.)

- (Re)negotiating with other VMGA or Market Operators (if needed)

4.2.3 VIMSEN Ecosystem[20]

Now that the main stakeholders in a VIMSEN perspective have been described, it is important to identify their inter-relationships and responsibilities for successful market operation.

Initial goal of VMGA is fulfillment of their own needs, based on day-ahead forecasts and Demand-Response with its own VPs. Each VP is associated with a specific VMGA. The VMGA is responsible for the negotiations on behalf of its own VPs- with other VMGAs and/or PC/MO (technically, through a VIMSEN portal), in order to sell the surplus energy (aggregate energy from prosumers) to

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[19] http://ict-vimsen.eu/images/Open_Data/public%20deliverables_pdf/vimsen_d2.1.2_final_30072015.pdf

[20] http://ict-vimsen.eu/images/Open_Data/public%20deliverables_pdf/vimsen_d2.1.2_final_30072015.pdf

the energy market, while maximizing the profit. Each VMGA may sell energy to more than one PSs. - One PS may buy (renewable energy) from more than one VMGAs, in order to cover its daily/hourly needs (per geographical area (GA).

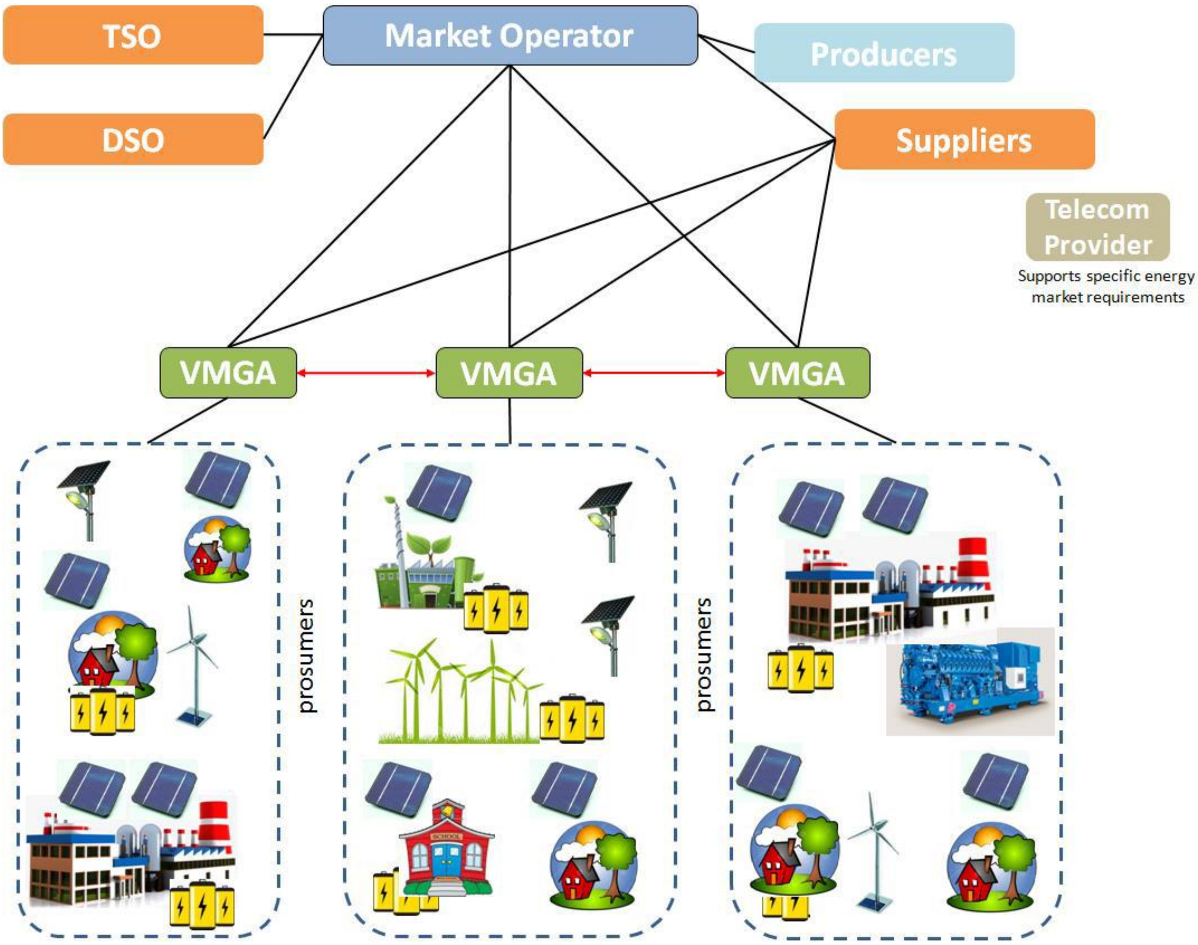

Figure 4-2: VIMSEN Ecosystem - VIMSEN Actors Relationships (Source: VIMSEN2-1-1)

4.3 VIMSEN Market Models

4.3.1 VIMSEN Wholesale Market Model

The VIMSEN market behaves similarly to the traditional wholesale electricity market with similar constraints. That is, instantaneous overall production (energy sold) and consumption (energy bought) of electricity should be in balance (i.e. equal). Thus, the necessary instant consumption of the generated (renewable) electricity leads to building a market having as a goal the effective forecast of the generation and demand in the next time window. Of course, as in the traditional electricity market, an important mechanism for the economic sustainability of a market is the acceptance of the cheapest offers. VIMSEN's market structure consists of an energy pool that aggregates the supply bids of the VMGs. Then, the VIMSEN market operator, using a matching algorithm (i.e. a suitable market model), calculates both the VMG formations and the bids that satisfy the requested RES demand that comes from the traditional market.

As explained before, for simplicity of the analysis it is assumed that the VIMSEN market is a split part of the traditional wholesale market. The VMO receives a demand from the traditional market, which equals the required RES share (EU 2020 targets) of the traditional market. Consequently, the VMO will issue a price bid to the traditional MO.

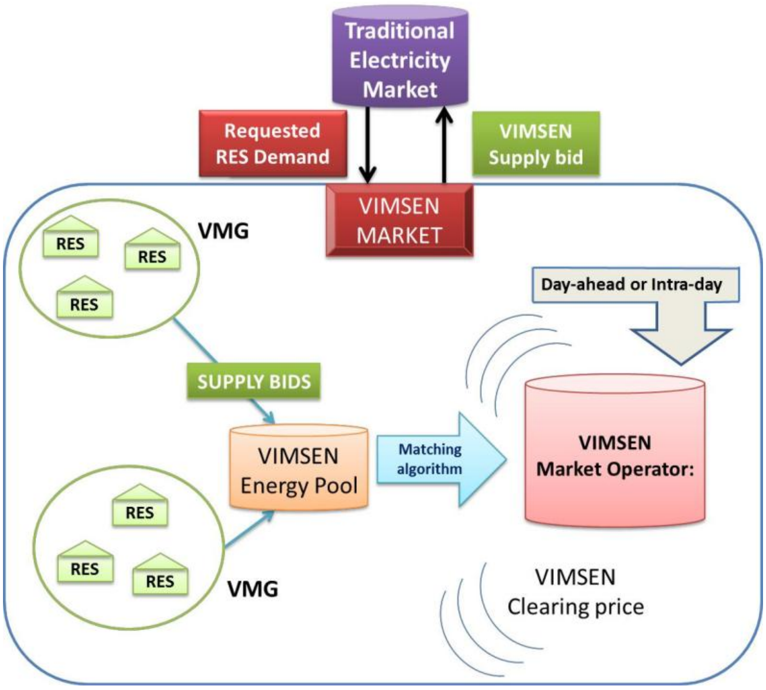

Figure 4-3 VIMSEN market model

The traditional clearing process is the standard uniform auction, where through a matching algorithm the clearing price is set at the point where the overall aggregated demand meets the overall aggregated supply. That is, the traditional market process selects the bids to minimize the unit price. Consequently, the VMO must create such an offer to the traditional market, that the remaining (i.e. non-VIMSEN) MGs cannot satisfy the same RES demand at a cheaper price.

4.3.2 VIMSEN Demand Response

Demand Response (DR) mechanism is a service of significant prominence in the grid of the future with sizable RES share. DR is a collection of policies that has as a target flattening energy consumption during different times of the day, aiming especially to lower energy demand at peak hours. Since these are the most critical working times for a power station, incentives are offered to the end users that will reduce their electricity consumption during those particular moments. End users will get economic compensation for equipping devices to work as load controllers (since any piece of equipment consuming electricity will be regarded as a load) (Rodríguez-Molina et al., 2014).

Similarly to traditional DR, VIMSEN DR can be defined as the active deviation of consumption from the normal consumption pattern in response to changes of electricity prices (or other triggers) over time. DR in general can be classified in three main categories:

(i) demand curtailment (i.e. reduction), (ii) load shifting (postponement in time) and (iii) increase of onsite generation, as illustrated in Figure 4.4 However, also the opposite DR actions may be required, e.g. in case of a surplus of RES power generation: (i) demand increase, (ii) load shifting (bring forward in time) and (iii) onsite generation curtailment.

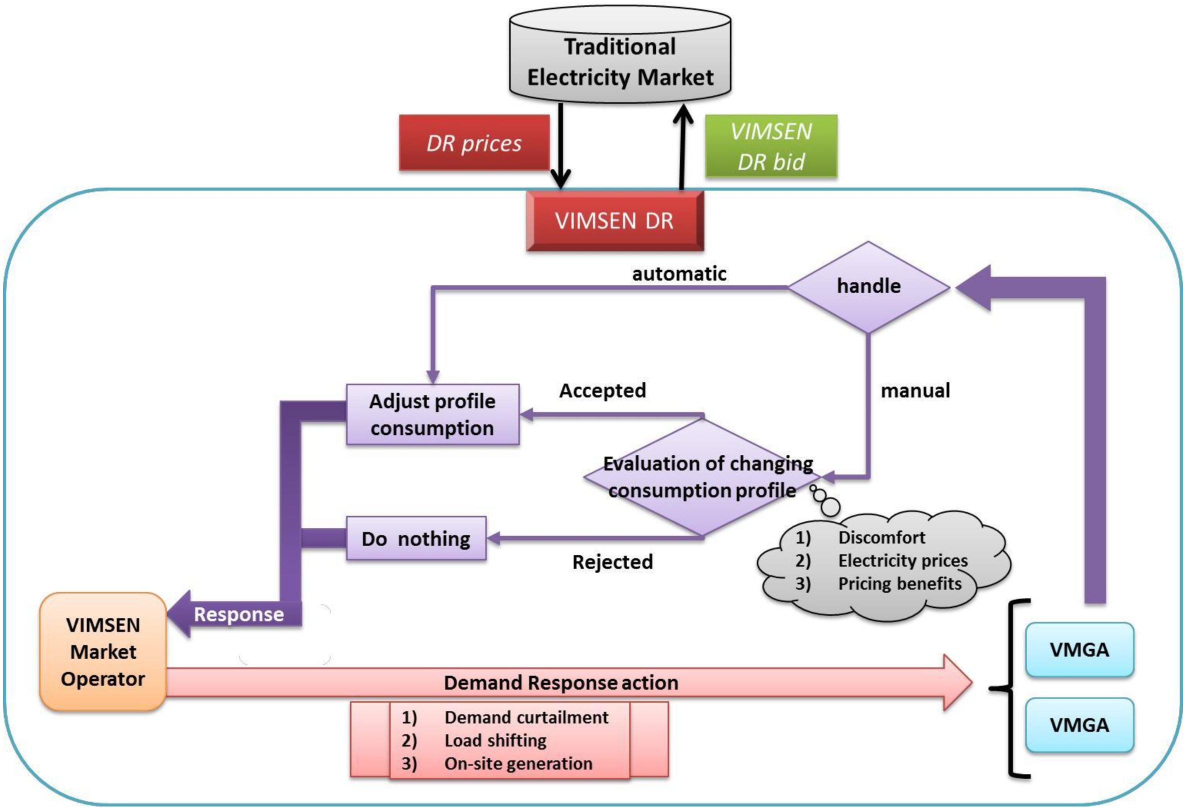

Figure 4-4 VIMSEN Demand Response

The VMO constantly monitors the traditional market for DR opportunities. When this occurs, he informs the VMGAs about this opportunity. Then, all VMGAs respond to this and inform the VMO about their actions. Then, the VMO informs the traditional MO about the actions it will perform. In general, DR can be either automated or enforced remotely by an aggregator, or manually operated by the end-consumers. VIMSEN will focus on automated DR, but also will look at manually operated DR.

As described above, the VMO will first *internally* trade/negotiate the RES or DR units, before he bids them to the traditional market. In the next section the potential pricing policies that the VMO could adopt are described.

4.4 VIMSEN Pricing Models and Mechanisms

In the following sub-sections, initial VIMSEN pricing models and mechanisms[21] are described that can be envisioned for the VIMSEN electricity market.

4.4.1 General Cost Model of VMG

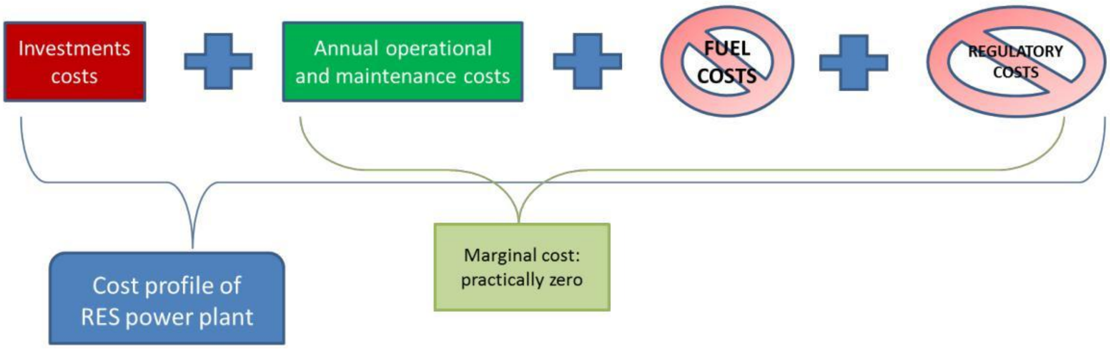

Figure 4-5 General cost profile of a RES generator

In the VIMSEN market, a VMGA is an association of microgrids consisting of RES. A RES will have very high investment costs, relatively low operational and maintenance (O&M) costs and no fuel or regulatory costs. Thus, its marginal cost is lower in comparison to conventional generators. In all market models the marginal cost of producers is the main component that determines the final price as well as the quantity of supply of each competitor. However, due to extremely high startup costs for RES, an average cost or "Levelized Cost Of Electricity" (LCOE) should be used for RES markets in place of marginal costs.

An average cost is defined as the fixed costs plus variable costs divided by total production and can be calculated either in short run or in long run. Similar to the average cost is the LCOE, which is the average cost during RES lifetime accounting

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[21] These pricing models were conceptualized during 1st phase of VIMSEN project and have been further analyzed in 2nd phase for deliverable 8.2.2 that I worked on.

for the discount rate. The Discount rate is a financial factor that represents the future value of money in current money. LCOE is a better cost calculation because it allows more accurate comparisons between different technologies producers (Moro, Duart, 2013):

$$lcoe = \frac{total\ CAPEX\ during\ lifetime + \ total\ OPEX\ during}{lifetime\ total\ estimationof\ energy\ produced\ during\ lifetime}$$

4.4.2 Open Market VIMSEN Model

Within an open market model, each MG is self-sustainable and competes against the other MGs to achieve a satisfactory share in supplying the electricity market. More specifically, in this model, many MGs have an insignificant share of the market and are too small to influence the market price or create a change in market supply. Since all market actors are seeking profits, each MG tries to bid for the highest achievable price for their entire production (left side of Fig. 4.6).

Unfortunately, other MGs have similar reasoning, resulting in overabundance of RES units (blue arrow in Figure) and finally to a low RES electricity price (right side of Fig. 4.6). As explained before, the clearing price is defined where aggregated supply meets requested demand, therefore, each MG must rethink rationally and make a lower bid (by lowering supply) to survive and achieve a supply share in the electricity market. Finally, the price of the generated energy units will be close to their marginal cost, since bidding lower than the cost of generating a unit is not an option. In this case, the VIMSEN market price will be equal to the average cost resulting in near-zero profits and also MGs will not be able to be credited for the environmental externalities mentioned above, since no compensation for these exist in the traditional wholesale market. On the other hand, buyers benefit from this model, due to the extremely low RES electricity price. However, in the long term, new investments in RES will be held back due to the small revenue streams, thus neglecting the goal of high RES integration.

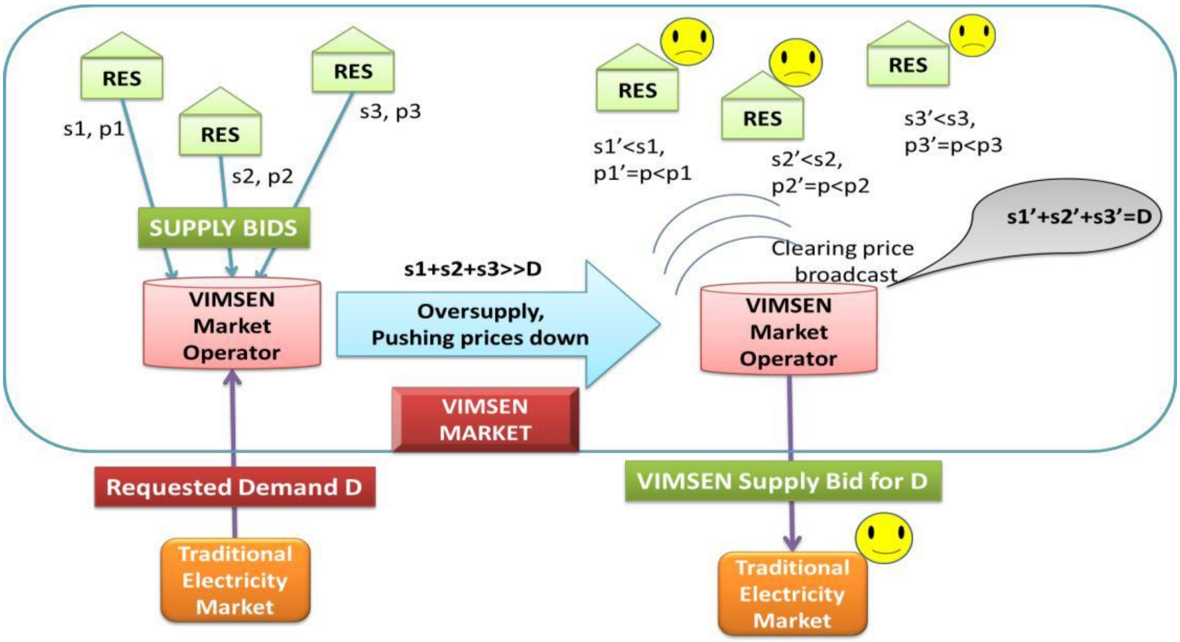


Figure 4-6 VIMSEN Open Market Model (existing situation)

The part on the left shows the bids; the blue arrow in the middle shows the next step in case of oversupply; the part on the right shows the end situation with low prices. The two orange blocks are the same entity: there is only one electricity market. Also the two pink blocks are the same entity, i.e. the VMO.

4.4.3 VIMSEN Monopoly Market Model: Creation of One Dominant Cluster of MGs

The idea for the monopoly is that all RES microgrids are clustered to one VMGA, a concept of aggregator that provides internal bilateral agreements between the MGs to control the whole RES energy market. This is not an impossible scenario, mainly due to the fact that market operator satisfies thresholding barriers for a RES to enter the market. This implies that we need to include aggregation and clustering mechanisms so that bigger renewable energy associations are reached. If there is no regulation about the size of the aggregation, big RES producers (e.g. large wind farms) may choose to participate in the formed cluster, dramatically increasing its market power. It is possible, therefore, for the aggregator to control the whole market and therefore to increase the microgrids' profits against the benefits of the traditional wholesale market actors.

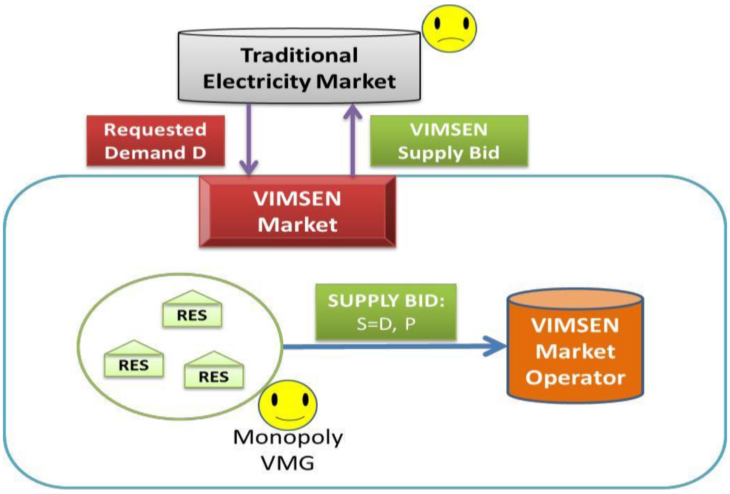


Figure 4-7 VIMSEN monopoly model

The monopolist faces the entire market demand and can influence the market price (since it's the only RES producer) and thus is assumed to be the price-maker. Like a competitive microgrid, the monopolist is assumed to strive to generate profits as large as possible. However, unlike a competitive microgrid, a rational monopolist understands that it can only sell what the clients (i.e. the traditional market actors) are willing to buy, and, since being the only RES producer in the market, can set both the price and the production volume. This power of monopoly in determining the price (and supply volume) makes the existence of an independent regulator more than essential, who is able to monitor the market and manage the disadvantages of the other actors. In case the demand is flexible, the VMGA monopolist will supply the quantity that maximizes its profits. In this case the clients, as compared to the open market, can experience a substantial quantity loss.

In general, the union of MGs in one monopolistic organization can be partly justified since the benefits coming from generation of RES form a positive externality to other actors (e.g. fossil-based producers) of the market as explained above. More specifically, currently regulators force the power company to pay for a steep penalty in case of violation of the CO_2 emissions. Thus, the use of RES units is more desirable for power companies and society in general. In case of the VIMSEN open market this quality of service would be impossible for RES MGs to exploit as an additional source of profits due to competition.

4.4.4 VIMSEN Duopoly Market Model: Creation of Few Dominant Clusters of MGs

In the VIMSEN monopoly, the firm's profit maximization strategy might result in a small quantity produced compared to a perfect competition. This difference means that the prosumer's surplus passes on the monopoly, resulting in welfare losses.

Oligopoly is a case where the number of market players is between the perfect competition and the monopoly and this can reduce the welfare losses. In this scheme the MGs are clustered in a few VMGAs that determine their quantities and the VIMSEN market price. If the oligopolies preserve a competitive behaviour we speak of a quasi-competitive model; in the simplest case the RES market consists of two VMGs – a duopoly.

A useful tool to find the market equilibrium in this case is the Cournot equilibrium (Fig.4.8). In this model each firm acts as a price-taker and its output decision is formed assuming that the other VMG's output is fixed and is not affected by its actions. The two outputs are then the reaction function since it provides the best output of each firm dependent on the other's output. At the point where the two reactions intersect this is the Cournot equilibrium.

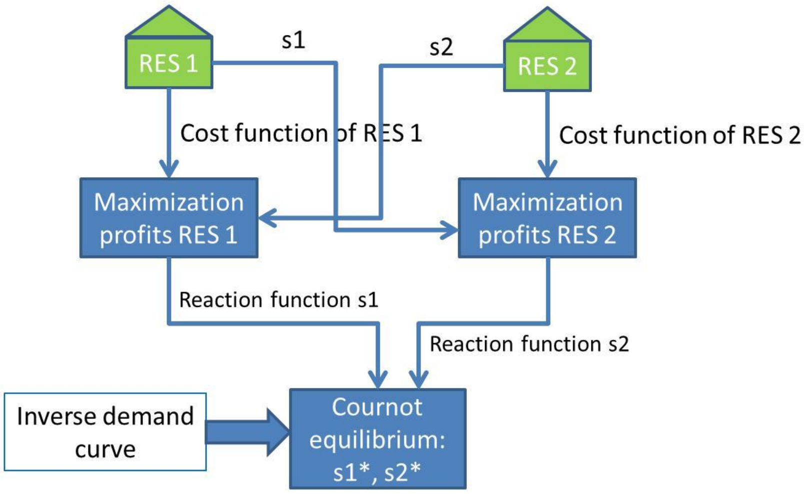


Figure 4-8 Cournot equilibrium algorithm in case of a duopoly

A problem with the Cournot equilibrium is that each VMG must know the other's cost function and also an inverse demand curve needs to be known. That is how the market price is affected in terms of the total supply.

4.4.5 VIMSEN OPEC Model: Defining Higher Prices than the Open Market Model

Inspired by the oil market, it is observed that the dominant players of the market are combined into a single group (cartel) to achieve higher profits. The higher revenues are achieved by adopting a common strategy that determines the supply volume and the price. In scope of this project, OPEC can be seen as an authority that monitors its members' behavior and compliance. However, to be able to build this cartel, a high share of the total supply needs to be possessed by its members, which means that many MGs need to participate in the OPEC model. An ideal cartel can act as a monopolist operating the RES plants to maximize its profits (the multi-plant monopoly cartel). Under this assumption the high-cost MGs may not produce at all, provided that predefined profit share agreements exist and are obeyed. A market-sharing cartel is a way in which each member's profits come from the common decision about each plant's production level. The "fair" share among OPEC members is a big issue that needs to be examined and solved for the OPEC to survive. The biggest threat in OPEC's cohesion is the temptation of the extremely high profits if one cheats on the agreed supply. If a dominant player with an overwhelming market share exits, the stability of the OPEC is not threatened, provided that dominant player satisfies its objectives. Assuming that there is no leader in the cartel, the monolithic cartel can be used. In this approach, the OPEC is described as a monopolistic firm, without competition among RES, and as a result it determines the price considering that the other players of the market act like a competitive firm. The non-OPEC players act as price-taker competitors and will increase their production with the price set by OPEC.

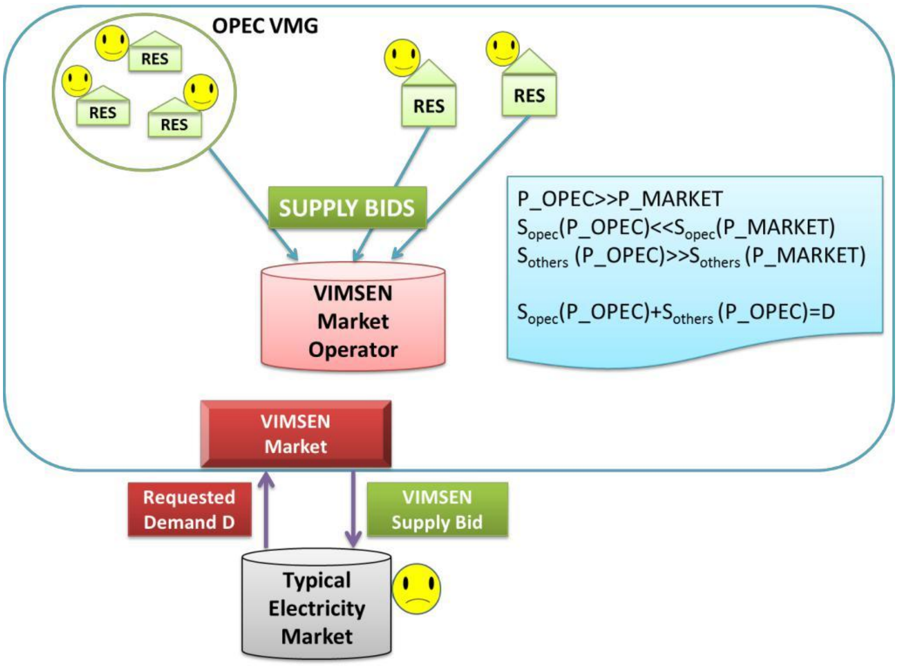


Figure 4-9 VIMSEN OPEC model

The larger the OPEC VMG grows, the lesser the competition is and, thus, the higher the prices are. Similar to the monopoly case, a market-fair regulator that is independent from the OPEC needs to exist. The level of the OPEC's size might be the regulator's responsibility.

4.4.6 Max-Benefit Cluster VIMSEN Model

In this model, similar to OPEC, some of the RES producers are organized in a cluster (VMGA) and together act as an individual entity. The VMG gets involved into the open market assuming that it has the price function of the most expensive MG. In this way, every member of the VMG will receive a share of this high price, provided that the VMG will achieve a winning bid. Like the OPEC model, two options for the share of profits exist. Either high-cost plants may not produce at all and share profits, or they take a fair share of the VMG's total supply. Similarly to OPEC, the "fair" share remains to be determined. Due to less competition, less pressure on prices will exist during the negotiation period with the buyers. In this model, contrary to the OPEC model, no restrictions exist about how many VMGs will be created or how many MGs will form a VMG. However, in rural areas or areas isolated from the grid, this model is expected to be more stable due to a small number of competitors and the lack of alternative VMGs and, thus, the threat of a MG deviating from the VMG will be practically zero.

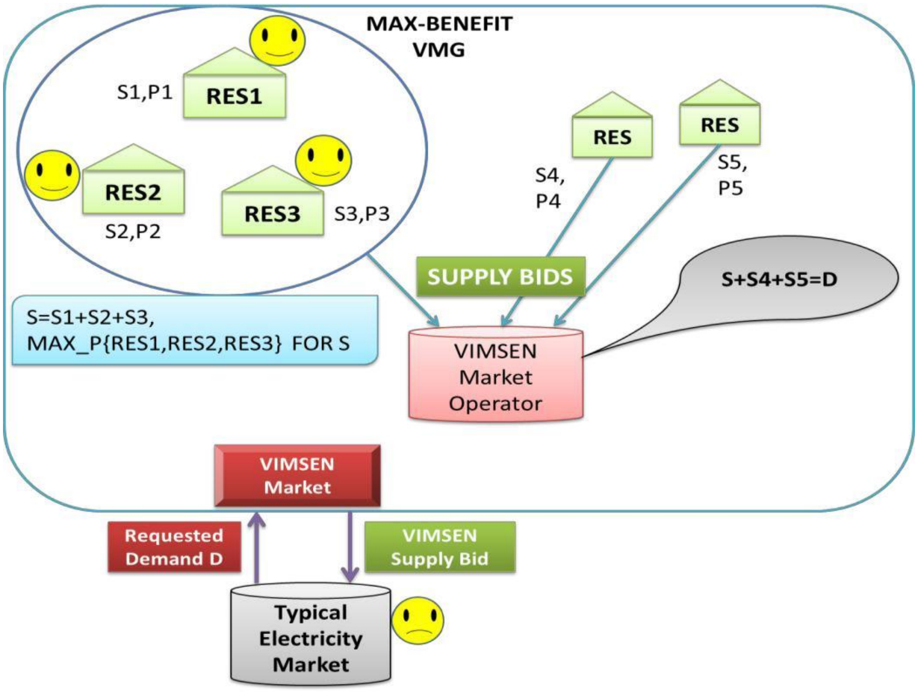


Figure 4-10 Max-Benefit VIMSEN model

4.4.7 Fair Cluster VIMSEN Model

"*Fair Cluster*" is more appropriate for competitive environments. The idea is to cluster the whole set of the RES market into VMGAs. The VMGAs can be formed by differentiating the prices achieved by each cluster for the requested demand. In this case, the VMGAs are optimized to contain the least number of MGs so that each VMG is able to satisfy the requested demand and simultaneously achieve the highest profits among its contained MGs. The minimization of the cluster is achieved by ensuring that the MGs that are left outside the cluster cannot form a VMG that gives the requested demand at lower price. Two policies can then be followed. In the first one, only the cheapest VMG is chosen to ensure the higher profits for the MGs composing it. This policy, however, deters the other players from participating in the market, allowing in the long term only the cheapest to exist. In the second policy, the RES market is clustered in many VMGs and they are sorted by price. Then, it is suggested that all VMGs in the market should benefit and that they should be awarded a portion of the final supply to the market, depending on their bidding price. In this manner no RES MG will starve and prices will be kept at considerable levels.

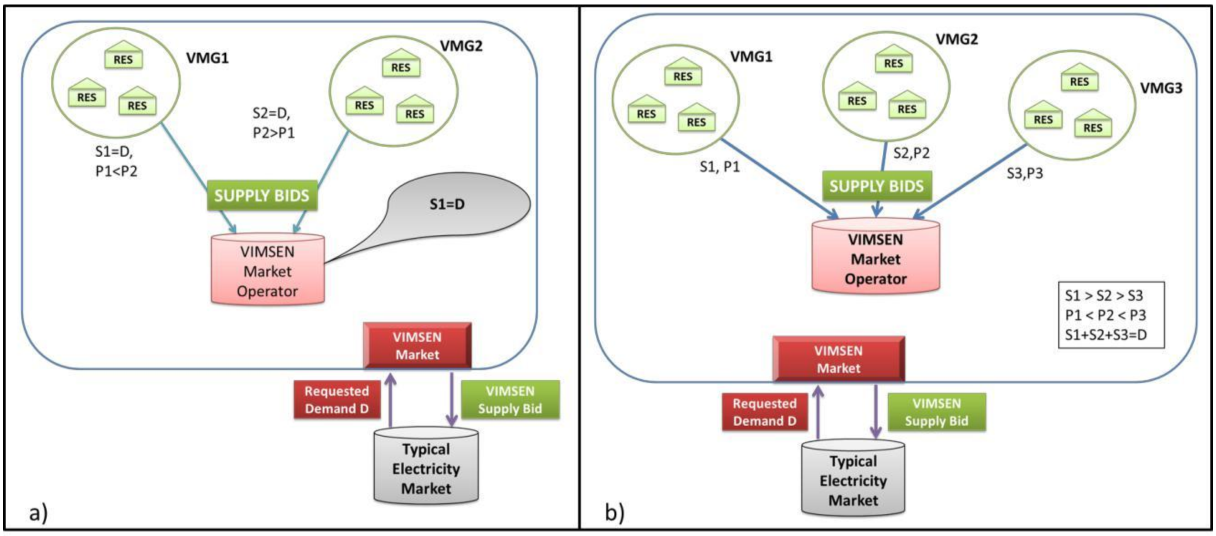


Figure 4-11 Max benefit model and Fair cluster model

a) max-benefit: VMG1 is the cheapest cluster and the only winner in the market (P1<P2). b) fair clustering policy: VMGs are create in price order (P1<P2<P3), supply is finally allocated to all VMGs depending on price (S1>S2>S3).

4.4.8 Almost Uniform Cluster VIMSEN Model

In this model, the clusters are organized to make the prices of all VMGs (almost) equal, like in an oligopoly. Consequently, the market is composed of equally sized VMGAs achieving approximately the same price and volume share and operating in an oligopoly, following their own strategies.

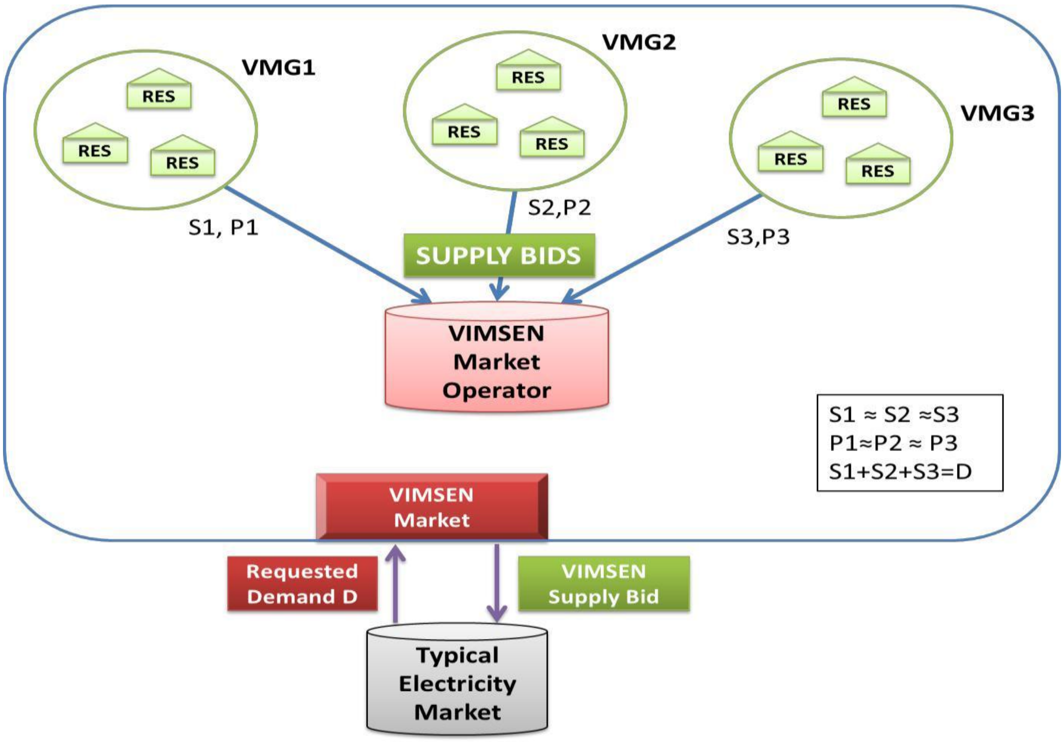


Figure 4-12 Almost uniform clustering policy: VMGAs are created with a similar market power

4.4.9 VIMSEN Location Based Pricing Mechanisms

As already explained, RES production (especially dispersed or distributed RES) is usually close to the consumers, and thus avoids grid transmission losses and big investments needed for distribution network. If the RES energy is sold in the traditional energy market (at "normal" market prices), these positive externalities benefit the other market players (e.g. the grid operators and fossil-based producers) and the RES producers would get nothing extra for it. Taking these externalities into account would help RES producers achieve a higher share in the market. In this view, a merit representing the transmission costs and depending on the distance to the targeted area could be added to the "normal" price of the power plants. Thus, the closer the RES supplier is to the target area, the higher the share he could gain, since his price will be more competitive in contrast to the case where the transmission costs are not accounted for. In this market model one cluster is derived by unifying all MGs in the neighborhood. This concept is best deployed in areas where the main grid is at a great distance, therefore justifying the term location-based pricing. In this model all parties in the market benefit, because the local RES producers provide a relatively cheap solution for the transmission & distribution system.

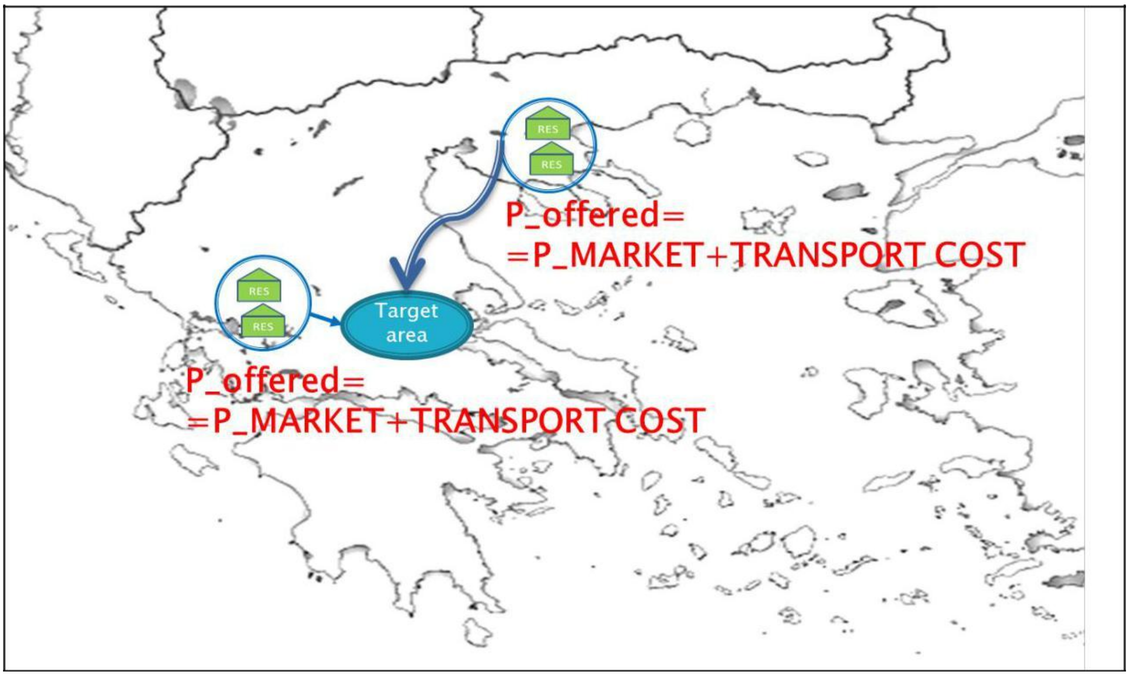


Figure 4-13 VIMSEN Location based model: local RES is favored before distant production

4.4.10 VIMSEN Islanding Pricing Model

In island mode (Fig. 4.14) the MGs are interconnected but not connected to the main grid or the wholesale market. In this mode, the local RES producers (i.e.

prosumers) are operating on the local retail market and have capacity to cover the requested demand on the island(s). In this mode, the MGs provide a great externality to the DSO by relieving it from investing in expanding the grid and the accompanying maintenance efforts, while other power producers are also relieved from the obligation to transfer energy from far locations. Due to the smaller grid, the MGs are more active in the delivery and the satisfaction of the demand, making them more important for the smooth operation of the energy system. Therefore, in island mode, similar to location-based mode, it is expected that one cluster is to be formed (probably in a close geographical context) and that pricing the externalities mentioned and/or the business coalition models described in the previous sections can be justifiably considered.

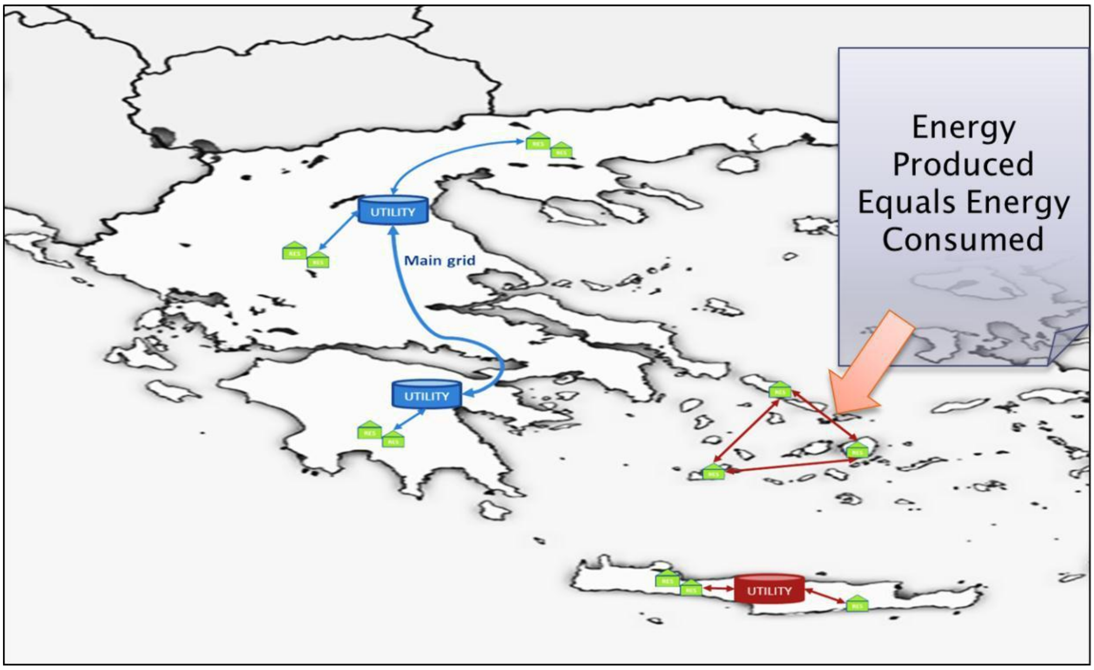


Figure 4-14 Island mode pricing model

4.4.11 VIMSEN Clustering based on Production Profiles

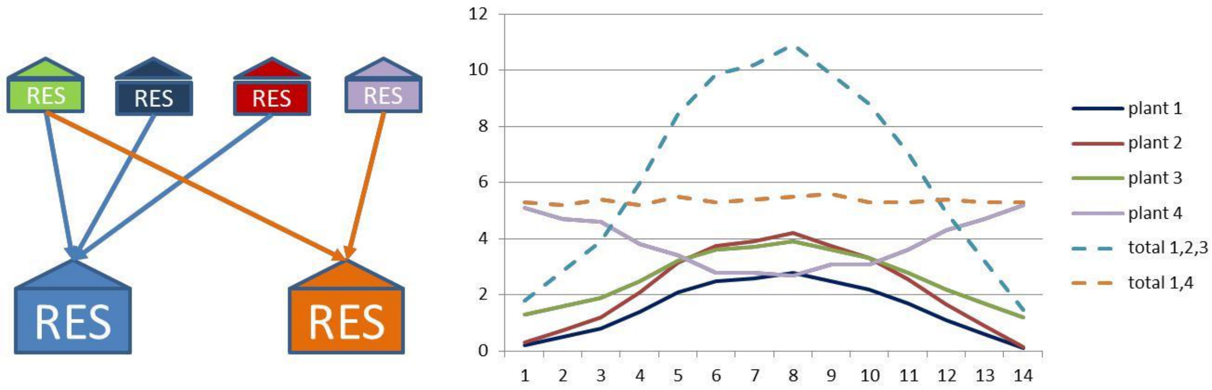


Figure 4-15 VIMSEN clustering based on production profiles: the blue house contains three positively correlated profiles (curve 'total 1,2,3' in the graph on the right), the orange house contains two negatively correlated profiles ('total 1,4')

The idea of this model is that the MGs' production profiles can play an important role in the determination of the price depending on the clustering that is chosen. For example, MGs that have the same production profile (positively correlated) have probably common incentives and are competitors. By unifying them some competition is eliminated aiding the MGs achieve higher profits. In another example negatively correlated MGs (in production profiles) could be clustered to achieve a constant supply in the market, thus combatting intermittency issues and obtaining a reliability license. In this case MGs generally benefit along with the rest of the actors, without any of the market players being at an advantageous position.

4.5 Discussion

We see that aggregation and introduction of VMGA expands DER benefits and has the ability to support the overall electricity market. It is in line with recent research which has shown that with increased DER penetration, DER cannot anymore operate under the "fit and forget" principle, but requires some level of DER aggregation and control(Djapic P., et.al, 2007). VMGA as a novel market stakeholder tries to combine existing characteristics with new ICT based approach in the above pricing models.

Pricing models above borrow from different economic and market principles such as open market, monopoly/duopoly, OPEC model, cluster based approach and pricing based on location or production profile. Table 4-1 summarizes benefits from the proposed pricing models from the viewpoint of different stakeholders.

Pricing Model	Producer (VP, VMGA)	Buyer(DSO, VP, Utilities
Open Market	Low profits	Low cost
Monopoly	High profits	High cost
Duopoly	High profits	High cost
OPEC Model	High profits	High cost
Max Benefit	Moderate benefits	Moderate cost
Fair Cluster	Low profits	Low cost
Uniform Cluster	Moderate profits	Moderate cost
Location Based	Moderate profits	Low costs(externalities)
Island Mode	Moderate profits	Low costs(externalities)
Production Profile based	Moderate profits	Moderate costs(externalities)

Table 4-1 Benefits from pricing models

The General observation from the table is that higher the level of cooperation amongst MGs while forming VMGA, better are the chances of profits based on market power.

Further examining the pricing models one by one,

In an open market model, it is like a perfectly competitive market where each MG is on its own and competes with others. Investments in RES will be deterred because there will be no incentive for RES producers. TSOs and DSOs can continue to buy qualitatively cheap (e.g. fossil-based) energy leading to low prices. If the VMGA's interest is with the MGs, its profits will also be minimal. Similar to open market model is max benefit model where VMGAs have incentive to form low priced VMGs in a price sensitive market. Fair-Clustering is another model that preserves competition through its clustering formation and can be implemented either to benefit the cheaper MGs only (and, therefore, the buyers) or to benefit all RES producers of the VIMSEN market or even to create some form of oligopoly.

Monopoly can easily arise in areas where transmission costs are high. For Monopoly to be successful all MGs in a specified area need to be unified into a single cluster and exploit inflexible amount of demand. On the other hand, if there is no inflexible demand, the monopoly can modify its production levels to maximize profits. Overall energy cost in the market will increase while MGs and VMGAs will earn higher revenues. An immediate problem with monopoly is that in order to maintain constrained supply, RES production will not be fully exploited. Duopoly lies somewhere in between monopoly and perfect competition resulting in intermediate levels of MGs profit and market/consumer cost. In this option, two VMGAs are created that have equal market power to operate freely.

The OPEC model for an electricity market set up borrows heavily based on existing oil market. High profits for all MGs and VMGAs are assumed as prices from OPEC are relatively high due to cartel formation. The main problem of this model is that it's fundamentally unstable due to extravagant profits should an MG deviate from OPEC's instructions. Also, OPEC model for existing oil market operates because there is no viable alternative. OPEC pricing model in electricity with RES producers seems farfetched in current situation where share of RES is very low.

Location-based and island mode models will be feasible in cases where TSOs and DSOs will find difficulties in distribution and transmission of energy, such as in remote islands. Buyers from VMGAs are assumed to be satisfied in this case as their respective energy demands are met reliably. In the island mode the VIMSEN market is itself a retail market and provides alternative to the wholesale market which cannot reach islands.

The production profile model clusters the MGs based on the type of RES used to generate electricity. If the RES type is similar, competition is eliminated by providing a homogeneous market. If the RES type is complementary, DSO's reliability and market predictability is improved.

An overview of the proposed VIMSEN pricing models was presented and analyzed. It would be easy to say that only pricing models based on free market principles will be taken forward for real case scenario and others be discarded. However, we have previously seen that in cased of energy, cartels like OPEC or producer clusters have operated. So, These pricing models need to be extensively tested in the market to find out which ones are applicable and incorporated in today's electricity market & regulatory frameworks, while others will require further investigation in ongoing research to test its feasibility.

The expected outcome of VIMSEN[22] is to offer a RES pricing model toolkit, which will provide insights towards the creation of an online marketplace, which is able to support RES trading among local RES producers and consumers, thus paving the way for a more dynamic and decentralized electricity market.

[22] VIMSEN project document

Chapter 5 Business Model Canvas for Entities in VIMSEN

This chapter presents an overview of Business Model Canvas and Value proposition canvas. This concepts will be used to illustrate and discuss possible business model canvas of VMGA with different customers in the new energy market.

5.1 Introduction

In order to better understand the business possibilities in a decentralized energy market, it was decided to apply the concepts of business model canvas (BMC) to VMGA because this easy to apply methodology has been extensively tested in practical scenarios in structured manner. Also, it has been implemented in the field of smart grids as an analytical tool (He, et.al, 2011; Okkonen & Suhonen, 2010). BMC for Prosumers in a smart grid set up for a DER electricity market has been elaborately researched and explained in Molina, et.al (2014). To come up with BMC and VPC for VIMSEN stakeholders, a workshop was organized in DNV GL for brainstorming (Refer to Appendix-D) with the objective that the illustration of BMC for VMGA will make it handy for managers to design, implement, operate, change and control their own businesses.

5.2 Business Model Canvas

There is not an established definition of business model in scientific literature, yet different researchers have diverse interpretation of the subject. Magretta (2002) simplifies it by saying it to be a "story that explains how enterprises work". Here, we shall use the definition of business model from Osterwalder et al. (2005) where the paper defines it as " a conceptual tool containing a set of objects, concepts and their relationships with the objective to express the business logic of a specific firm".

In popular book Business Model Generation(BMG) (2010), Osterwalder adds that "a business model describes the rationale of how an organization creates, delivers and captures value". In short, business models tell you how a business works, what kind of value business creates and how business connects with customers.

Designing business models has always been a complex task. Communicating the story becomes easier if it can be told visually. Hence, Business Model Canvas (BMC) was conceptualized to design a business model and explain it visually. Osterwalder & Pigneur (2010) designed a canvas on which every business model can be based. BMC has nine business model building blocks which makes it a handy tool. The combination and consensus between these building blocks leads to a unique business model. It is to be noted that individual building blocks do not give the complete "picture". It is the dynamic interaction between different blocks which ultimately contributes to a successful business model. In the figure below, BMC is shown.

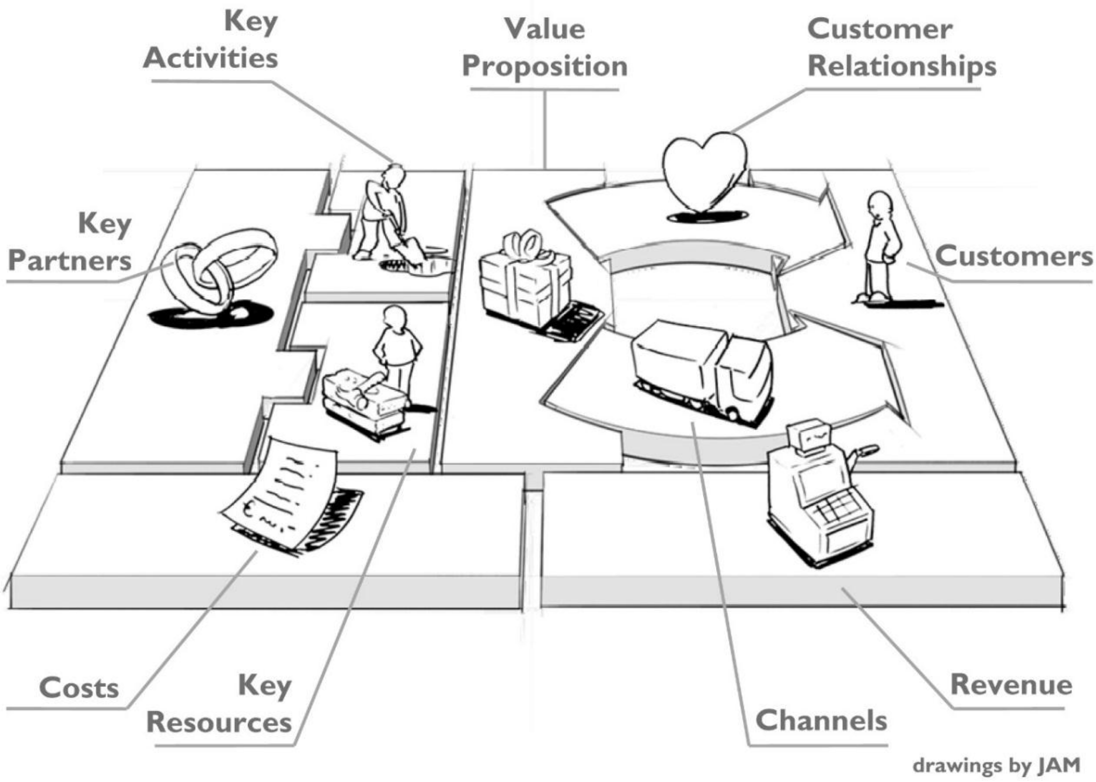


Figure 5-1 Nine Blocks of Business Model Canvas

For better understanding, all the building blocks will be described in detail, the way it has been described in the book BMG.

Customer Segment

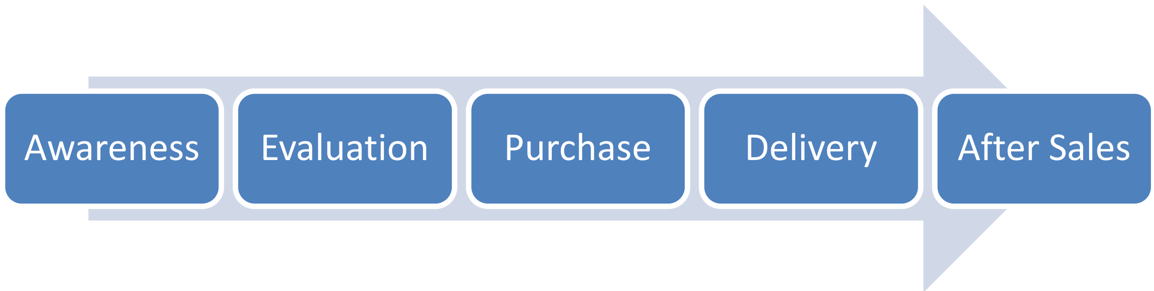
Customer segment is defined as "… different groups of people or organizations an enterprise aims to reach and serve"(Osterwalder & Pigneur, 2010). It is of utmost importance to have customers at the heart of any business model. An enterprise must know the customers' needs and the ways it can generate profits by satisfying those needs. There can be one or many, small or big, similar or different customer segments. These can be formed on the basis of types of relationships, different distribution channels, or paying ability. An enterprise should know which customers to cater to. Once the customers are identified, a business model can be designed to satisfy the specific customer needs.

Value Proposition

Value proposition is at the center of the canvas and is the key to satisfying the customer needs. This is defined as "… the bundle of products and services that create value for a specific customer segment"(Osterwalder & Pigneur, 2010). Some value proposition can be similar to existing market offers delivered in a new way. Others may be truly innovative or disruptive in nature. In all cases, value proposition must satisfy the customer needs if the enterprise has to survive for long. Values may be qualitative or quantitative. Few examples of value proposition could be customization, accessibility, design, price reduction, and cost reduction.

Channels

Channels are the medium used by the enterprise to interact with the customers. This block describes how company communicates with and reaches its customer segments to deliver a value proposition (Osterwalder & Pigneur, 2010). Channels can be either direct, indirect or mix of both. They can be either owned channels or partner channels. The enterprise has to find the right balance between different types of channels to maximize profits by effectively meeting customer needs. As described in the book, channels have five distinct phases as depicted below.



Customer Relationships

Customer relationships has the most influence on overall customer experience with the enterprise. This describes the connection between the customers and the enterprise which ultimately leads to acquiring new customers and customer retention. This block describes the types of relationships a company establishes with specific customer segments (Osterwalder & Pigneur, 2010). If there are different customer segments, an enterprise should have clarification on the type of relationship it wants with each one of them.

Key Resources

In the book BMC, Key resources is described as "the most important assets required to make a business model work" (Osterwalder & Pigneur, 2010). Based on the type of business model, enterprises will need different resources. Resources are required to build and maintain relationships, to reach markets and, to deliver and capture value. Key resources can be one, many or all of the following: physical, intellectual, human, financial (Osterwalder & Pigneur, 2010). They can be either owned or rented or acquired from or shared with key partners.

Key Partnerships

Enterprises do not have all the resources for all activities in a business model by itself. Hence, the need to form partnerships. This block describes the network of suppliers and partners that make the business model work (Osterwalder & Pigneur, 2010). Three main motivations for creating partnerships are reducing risk and uncertainty, economy of scale and acquiring resources. A well-defined business model shall create value for the enterprise, and partners such as buyers and suppliers.

Key activities

A business model will require a number of key activities which is described as "the most important things a company must do to make its business models work (Osterwalder & Pigneur, 2010). The key activity of an enterprise will depend on the type of business it is in. It can be either production like manufacturing firms or problem solving for services or providing a platform for network activities. In VIMSEN case, key activities will be different depending on whether the enterprise is a prosumer, DSO, Telecom operator or any other stakeholder.

Revenue Streams

Successful answer to the question "what is a customer willing to pay?" is crucial for an enterprise. Revenue stream is "cash an enterprise generates from each customer segment"(Osterwalder & Pigneur, 2010). Revenues minus the costs create earnings for an enterprise. Any given business model can have two types of revenue streams. One which can be onetime payment based on transactions. Other can be recurring revenues based on ongoing payments for a subscription or licensing. Pricing can be either fixed or dynamic.

Cost Structure

In the book BMC " the cost structure describes all costs incurred to operate a business model" (Osterwalder & Pigneur, 2010). The blocks key resources, key activities, and customer channels do not necessarily generate revenue on their own and incur costs. Cost structure depends on the business model and can be either cost driven or value driven. Costs generally are fixed costs, variable costs, costs incurred during economies of scale or economies of scope or both.

The nine building blocks and different aspects of BMC have now been described. BMC gives us a fair idea of what should be considered while designing a business model. Yet, there is no "one size fits all". Application of BMC is dependent on individual business environment of the enterprise and the sector in which it operates. Nine building blocks and the dynamic interaction between them is an important step towards making a story that business model is supposed to be. Figure5-2 below shows the empty canvas with all nine blocks which has to be included in a business model.

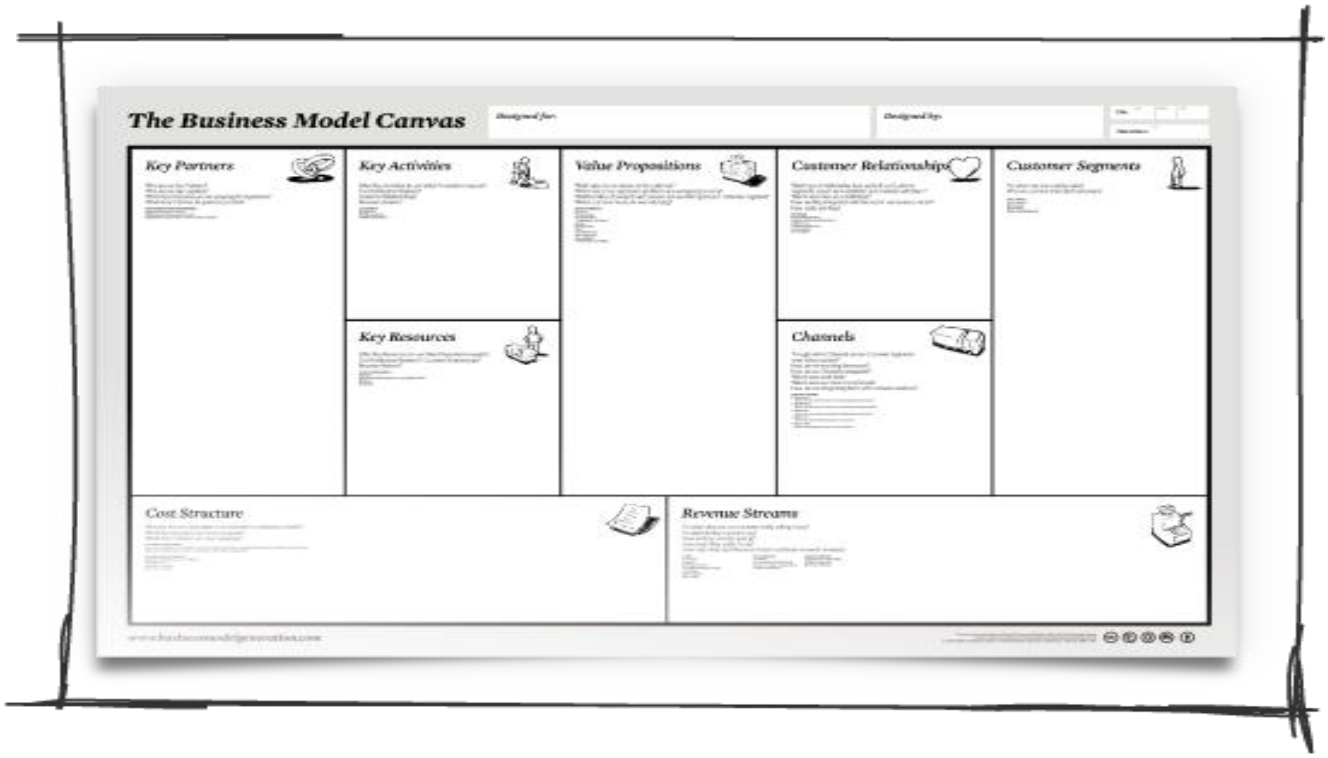


Figure 5-2 Representation of Business Model Canvas

5.2.1 Why Business Model and Business Model Canvas Matter?

We now have understood the concept of business model and BMC. All business models are variations on the generic value chain underlying all businesses (Magretta, 2002). Yet, it matters because,

" …business modeling is the managerial equivalent of a scientific study- you start with a hypothesis, which you then test in action and revise when necessary (Magretta, 2002).

For a business model to be successful, the story has to make sense and it should be backed by relevant assumptions and numbers. This concept allows structured ways of evaluating markets, partners and customers which ultimately helps design a business. BMC as a planning tool shows how different blocks of a business model fit together to make it work in a dynamic business environment. We have chosen this framework because it has been extensively tested in energy management and implemented as an analytical tool for smart grid technology studies (In Rodríguez-Molina, et. al, 2014; Shrimali, et.al, 2011; Kley, et.al, 2011).

The business model canvas framework has total nine building blocks. These can be further consolidated into four dimensions of a business model: relationships, value, capabilities and financial aspects (Zott, Amit, & Massa, 2010). The dynamic interaction between these four dimensions help us understand the business environment. In the table 5-1 below the four dimensions are linked with the building blocks of BMC.

Dimensions	**Business Model Blocks**
Relationships	Customer Segment, Customer Relationship, Key Partners, Channels
Capabilities	Key Resources, Key Activities
Financial aspects	Cost Structure, Revenue Streams
Value	Value Proposition

Table 5-1 Dimensions of Business Model Canvas

5.3 Business Model Canvas for VMGA

As discussed in earlier section VMGA is a virtual association of RES micro grids. We are discussing the BMC from the perspective of VMGA. The nine blocks of BMC shall be discussed under the consolidated four dimensions of business model as shown in table 5-1.

Relationships

In the new electricity business model, VMGA will be a key market participant and active agent which shall directly interact with the market. In the new business model, the roles shall differ from the regular electricity market. As is the growing trend in smart grid scenarios, even in the cases of micro grid two way communication will be the way of interaction with the energy providers. Besides the usage of existing power infrastructure, using ICT platforms will be new channel for VMGA while interacting with new suppliers such as prosumers. The ICT platforms can be in the form of green power community and smart home system using VIMSEN gateway based internet platform or apps. Automated integration shall be the preferred channel for stakeholders in the new value chain who will also be the customers.

For a sustainable local energy system, VMGA has to treat to all the different stakeholders in the new value chain as customers. The customers for VMGA shall be prosumers, DSO, wholesale energy market, ICT operator, BRP and other VMGAs. The customers for VMGA will also be the partners who shall ensure regular supply of electricity to the end user.

Each partner will have a specific role to play in the business model. Prosumers will produce RES power and provide assets for DR. DSOs will broadcast requests for DR depending upon predictions/information they have about congestion in the energy market. Wholesale energy market is responsible for the overall market by setting clearing prices and deciding volumes of RES and conventional electricity. Other VMGAs will first trade amongst themselves. Next, they will trade on the RES market to form one RES bid to join the traditional market for electricity. A key partner for VMGA shall be the regulatory bodies which will formulate the new laws for smooth functioning of the energy market in the changing conditions.

Relationships with VMGA is based on an assumption that there is one wholesale energy market in a given country. We also assume that VMGA provides balancing services by flexible generation and/or DR to one BRP. Most relationships are built upon automated client interface with different customers. VMGA will have one to one relationship with a prosumer or a group of prosumers depending upon how much surplus energy is provided by them to be sold into the market. With the BRP, VMGA may negotiate about volume and price before BRP bids on the market. VMGA will work together with other MGs and VMGAs to co-create a VIMSEN market community which will aim for the best collective RES price possible to to be traded on the traditional wholesale energy market. The usual route of key account management is another way to maintain relationships with the Prosumers or micro grids. The VMG pool of prosumers may be a community of green force and energy saving with additional services. (out of VIMSEN scope.)

Capabilities

Capabilities of VMGA shall be vital as a dynamic electricity market with new features takes shape. To the match the expectations of end customers, key activities of VMGA must be ably supported by key resources. Key activities for VMGA shall be RE production and transmission along with ability to have energy storage facilities. VMGA must run its decision support system (DSS) for optimal negotiations, energy bids and DR actions by using automated monitoring, control and communication. VMGAs will have more personal relationship with prosumers who shall be part of VMG communities through web platforms, newsletters or other similar sharing platforms. By establishing VMG communities for customer engagements, VMGAs together shall form a network which will ensure low internal energy costs and high external RES prices. Other key activity which will be different from the conventional electricity supply shall be to ensure two way communication. These key activities shall require the resources of AMI, RES infrastructure, Distributed generation and network systems, energy storage devices, and a reliable ICT gateway for two way communication. As most of activities will be automated, requirement of human resources will be low. To participate in the wholesale energy market, the trading system of VMGA must be at par with the latest available technology. This will also be motivation for prosumer who shall be guaranteed best possible settlement prices for their surplus energy.

Financial aspects

For VMGA to function well, managing of cost and revenues shall be essential. With multitude of functions that VMGA has to take care off, there shall be significant costs involved. Along with the expected fixed costs of infrastructure there shall be costs involved in ICT, operation and maintenance, costs of shared facility with partners. Some of the ICT related costs include hardware, software, subscription to external data, and telecom charges. Commercial activities of sales and marketing shall also incur costs. A major cost for VMGA will be the cost incurred to procure surplus energy from the prosumers.

For VMGAs to be profitable in the long run, it must tap revenues from prosumers and other stakeholders. It will charge prosumers for two services – one, for giving them market access to sell extra energy produced; two, by selling the energy to other prosumers who are willing to buy. VMGA can charge a membership fee from the prosumer to be part of the team. VMGA will charge DSOs for providing demand response services in real time. Similarly, VMGA can charge wholesale energy market for providing RES and extra services related to the existing consumers who are now prosumers. As VMGA will be the nearest to prosumers and shall have access to large amount of information, it can cooperate with ICT provider to sell information as a product to all parties involved. Data has the potential to be a novelty product besides the usual energy related services. Real time market will have dynamic pricing in the form of negotiations, bids and settlement prices. Fixed pricing of services provided by VMGA will depend upon product feature, customer segment and volume. Once the business model is operational for testing phase, we have to find out where can the VMGAs earn the most – RES trading amongst themselves, RES trading on the wholesale market, DR for congestion management for the DSO, DR for balancing services for BRP or by selling the vast amount of data generated.

Value

The evolving market change in the electricity market and resulting complexity due to prosumers and VMGA should result in substantial value created. The biggest value of VMGA is that by being an aggregator, it gives market access to prosumer who shall not only be encouraged toward self-sustainability but also produce more to sell. By using DR, prosumer shall can also have extra income with possible energy savings. The spread of RES for energy generation shall make more options available for energy management specially electricity consumption. Due to actions of VMGA, DR shall be effectively monitored and will lead to better load management; thus minimizing the risk of grid overload for DSOs. VMGA will provide assets to BRPs for balancing power to TSOs. By forming communities with other VMGs, VMGA will trade surplus power by incurring low inter VMGA energy prices and high RES sale prices on the wholesale market. Proliferation of electricity generation using RES which shall be beneficial for all stakeholders involved and will definitely result in positive impact on the environment and judicious use of abundant natural resources such as sun and wind. This will be an enabler for the wholesale energy market in Europe to reach the required RES percentage as defined by EU 2020 targets.

The 9 blocks of BM have been described in detail for each customer type individually in the following BMCs. Five business cases have been illustrated with different customer segments namely – prosumers, DSO, wholesale energy market, BRP and other VMGAs. These BMCs are conceptual illustrations and need further research and validation in a dynamic and functional market scenario.

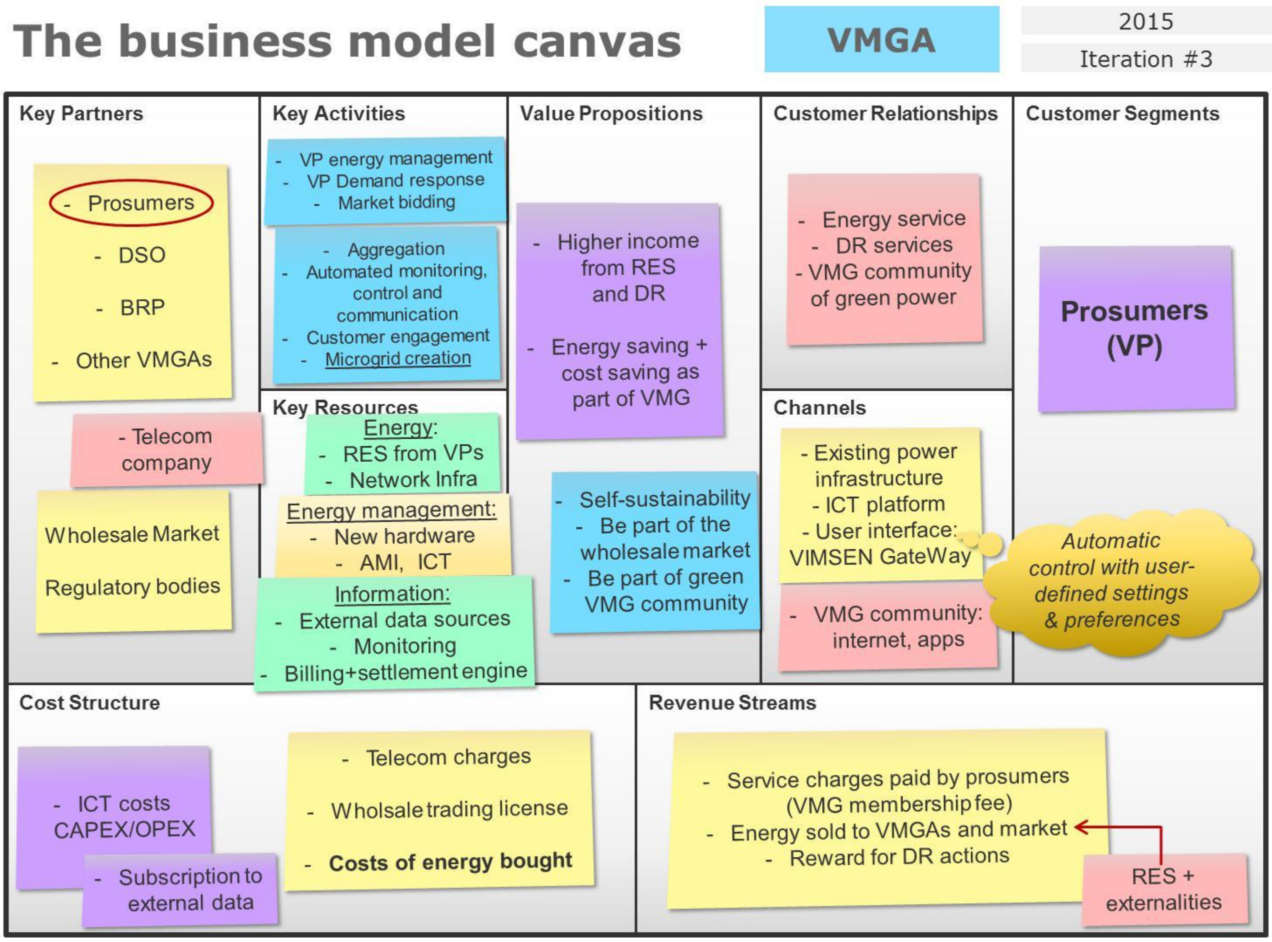


Figure 5-3 Business model canvas describing business model of VMGA services to prosumers

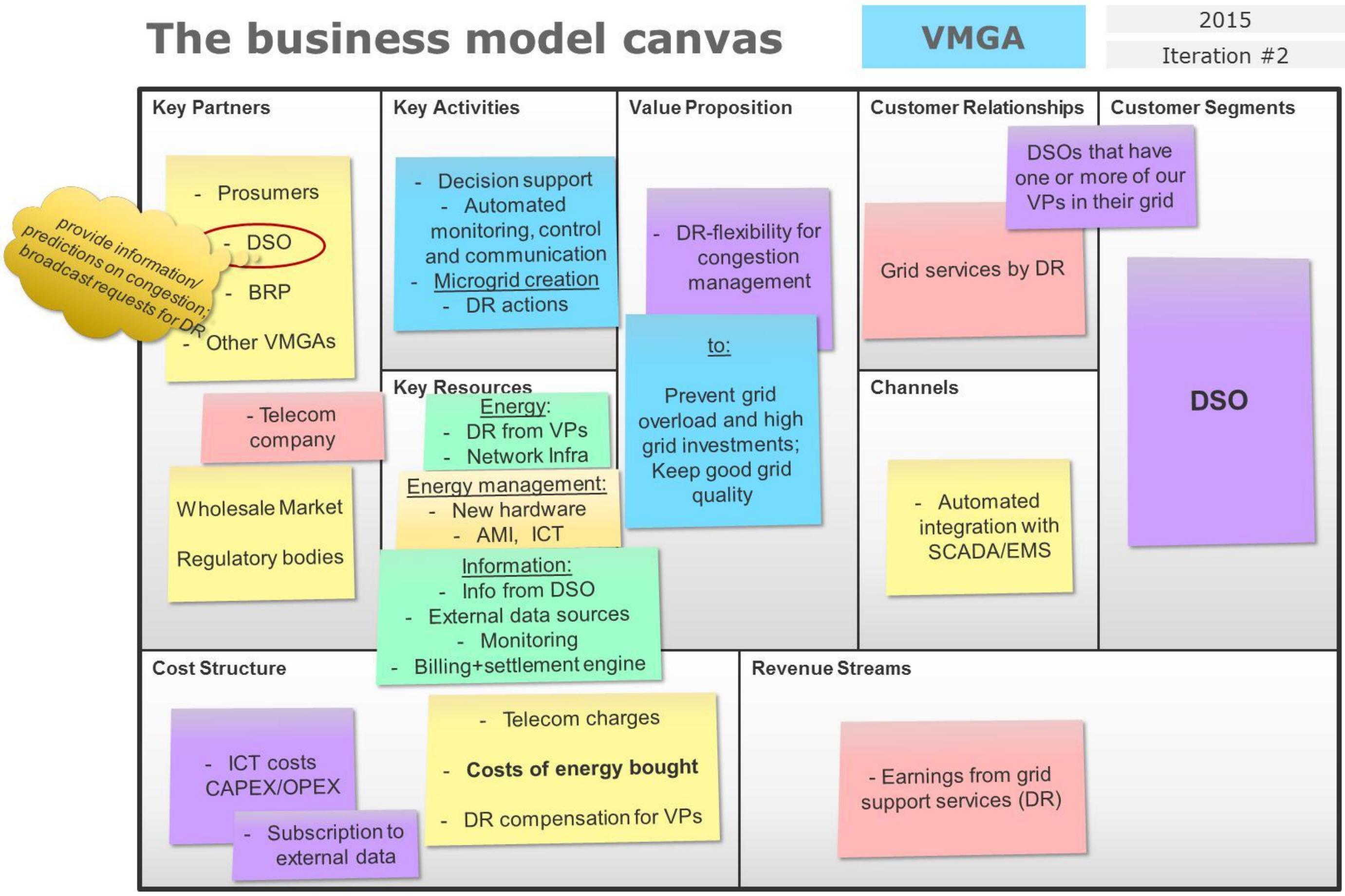


Figure 5-4 Business model canvas describing business model of VMGA services to DSOs

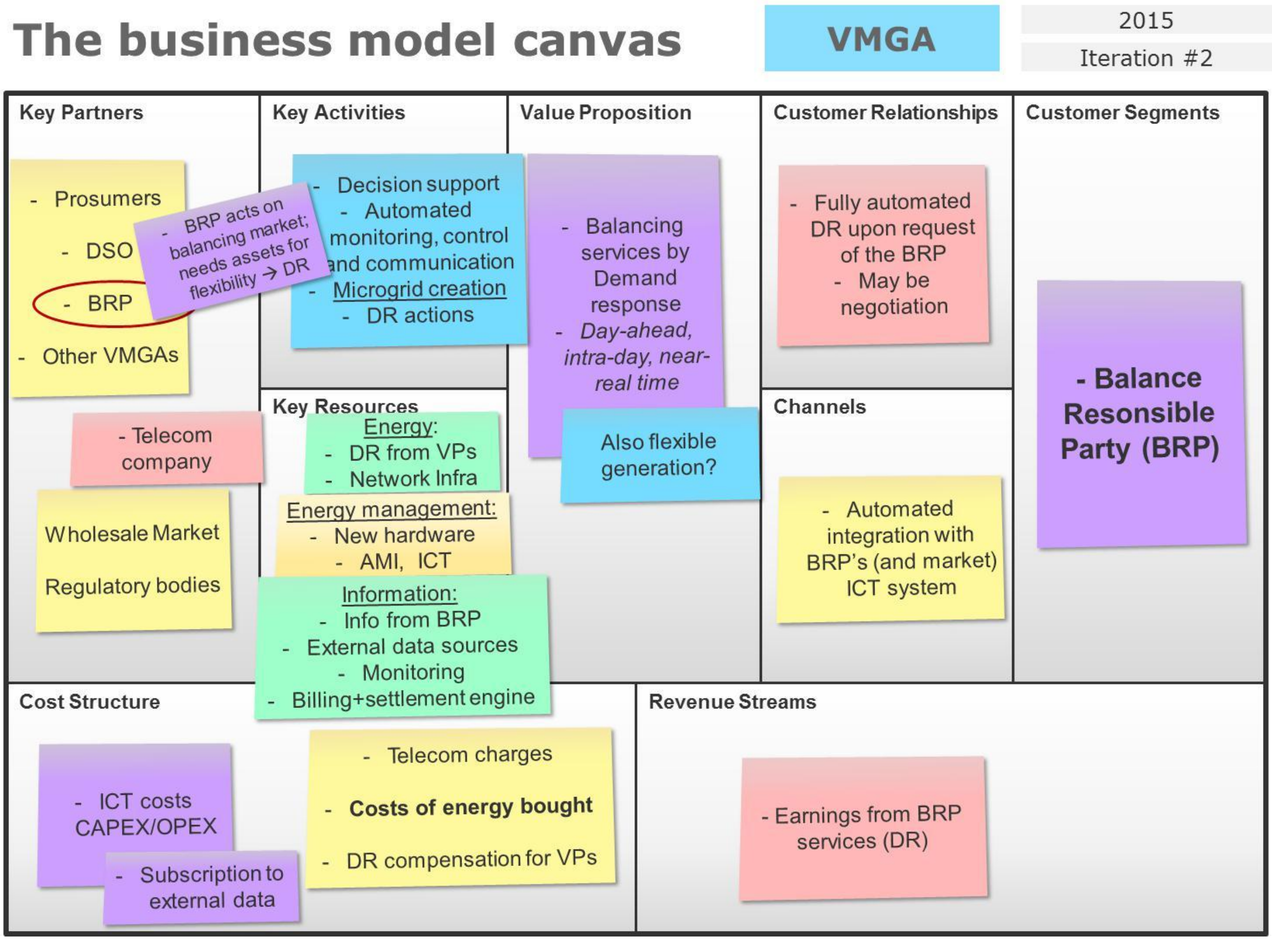


Figure 5-5 Business model canvas describing business model of VMGA services to BRPs

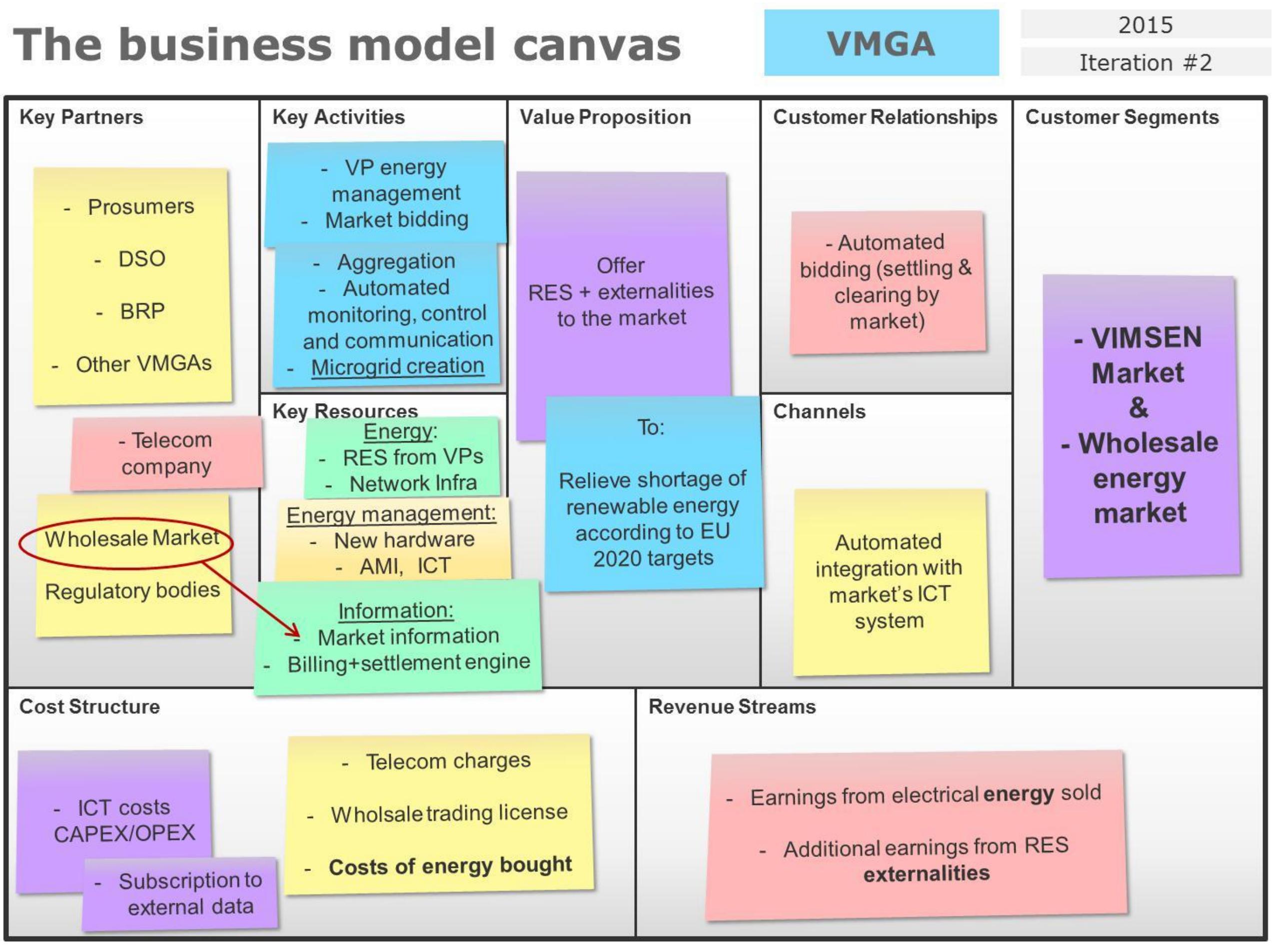


Figure 5-6 Business model canvas describing business model of VMGA services to energy market

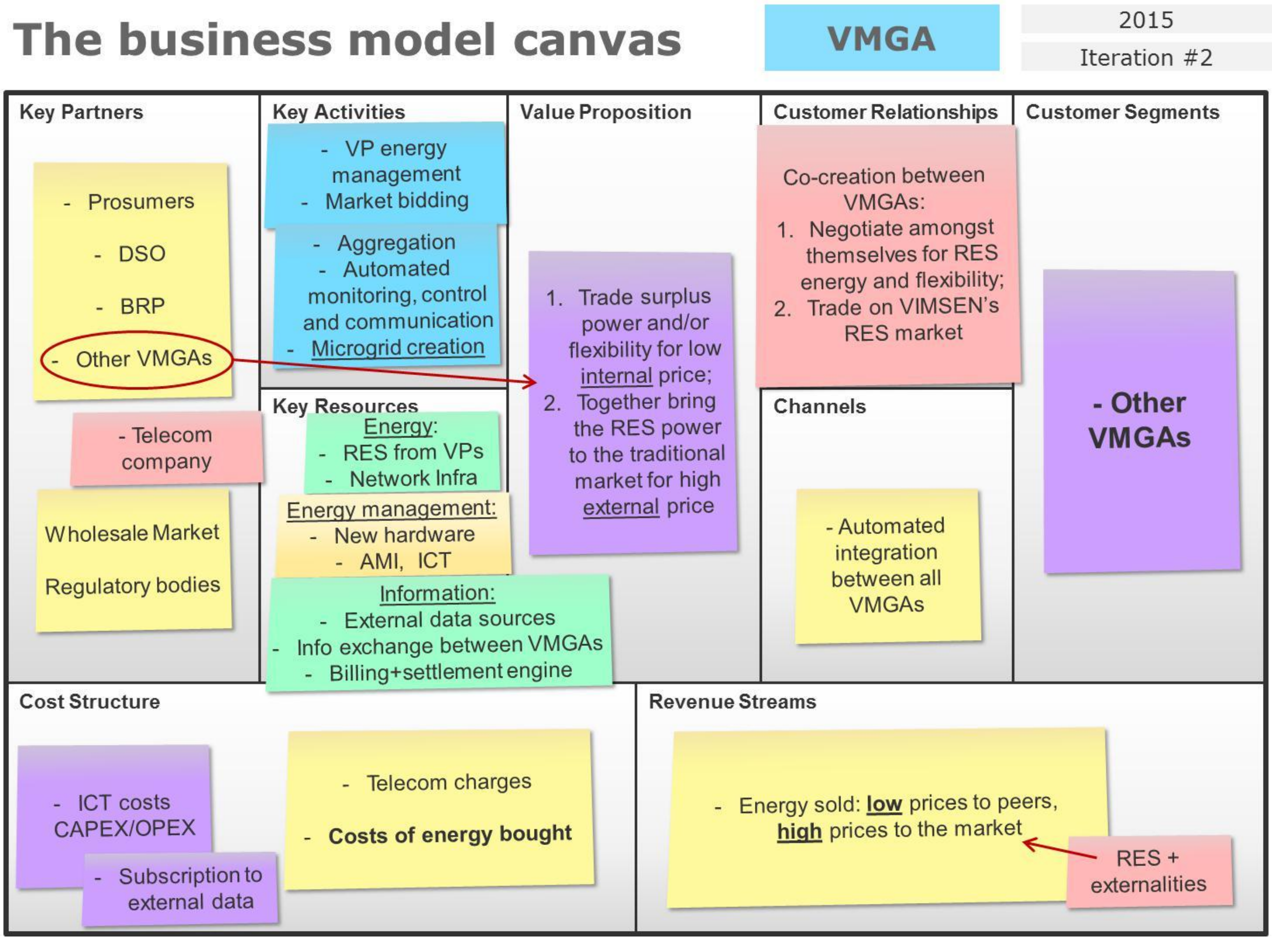


Figure 5-7 Business model canvas describing business model of VMGA services to other VMGAs

5.4 Value Proposition Canvas

"*Value is determined by the net satisfaction derived from a transaction* (Fill, 2011 p.188)"

In the BMC discussed above, when we combine the micro grids, VMGA and TSOs/DSOs, there is a dynamic electricity market where the stakeholders are looking for value beyond the conventional products and roles. Clearly, value of a product or a service could easily mean different things to different stakeholders in the business model. Yet, a common theme in the new business model is on two way energy related information exchange. Also, a stable service along with specific value proposition and offers between different stakeholders is foreseen. Taking into account the new business relations and offerings, a value proposition canvas for different stakeholders needs to be drawn.

From the BMC already discussed, blocks value proposition and customer segment should go hand in hand and are considered to be the heartbeat of the business. The Value Proposition Canvas (VPC) functions like a plug-in to the BMC and zooms into the value proposition and customer segment to describe the interactions between customers and product more explicitly and in more detail. This keeps things simple by giving us the big picture at the business model level (Osterwalder, 2012).

The VPC gives us a "product/market fit" by connecting the value map to customer profile. It has total 6 blocks with 3 each for value map and customer segment.

Value Map	**Customer Segment**
Products and Services	Customer Jobs
Gain Creators	Customer Pains
Pain relievers	Customer Gains

Customer Segment

In VPC, *customer jobs* aims to describe what the customers are trying to accomplish in terms of their needs or problems to solve. This is done to have a definite definition of customer segment and tries to answer one or all of the following questions as suggested in Osterwalder (2012).

- What functional jobs are you helping the customer get done?
- What basic needs are you helping your customer satisfy?
- What social/emotional jobs are you helping your customer get done?
- Whether the customer in the business model is a buyer, co-creator or transferrer of products and services offered?

The next *customer pains* describes the undesired costs, risks and situations that customer could experience before, during or after getting the job done. It explains the current pain points of the customer and identifies the cost, time and effort they encounter in using a product or service. The questions below try to estimate the intensity it represents for a customer segment.

- What are the main difficulties and challenges your customer encounters?
- How are current solutions underperforming for your customer?
- What risks or negative consequences does your customer encounter?
- What does your customer find too costly?
- What common mistakes or barriers are keeping your customer from adopting solutions?

The third segment *customer gains* is about identifying the benefits for customer segment in terms of functional utility, social gains, new products and services and cost savings. The gains must be relevant to specific customer segment. The relevance of customer gains can be estimated by answering the questions below.

- What are customers looking for or dreaming about?

- What would make customer's life easier and likelihood of adopting a solution?
- What outcomes does customer expect and what would go beyond expectations?
- What savings are customers looking for?

Value Map

The value in a business model is built around the *products and services* which are offered to satisfy the needs of the customers. It is important to analyze whether the products and services offered are crucial or trivial for the customer. The offers can be tangible, intangible, virtual/digital or financial.

Gain creators in the value map directly answers the questions *customer gains* are looking to answer. These show the way how the products and services in the business model are relevant for the customer segment. *Pain relievers* describe ways in which customer pains are alleviated in the business model.

An illustration of Value Proposition canvas is shown in figure 5-8.

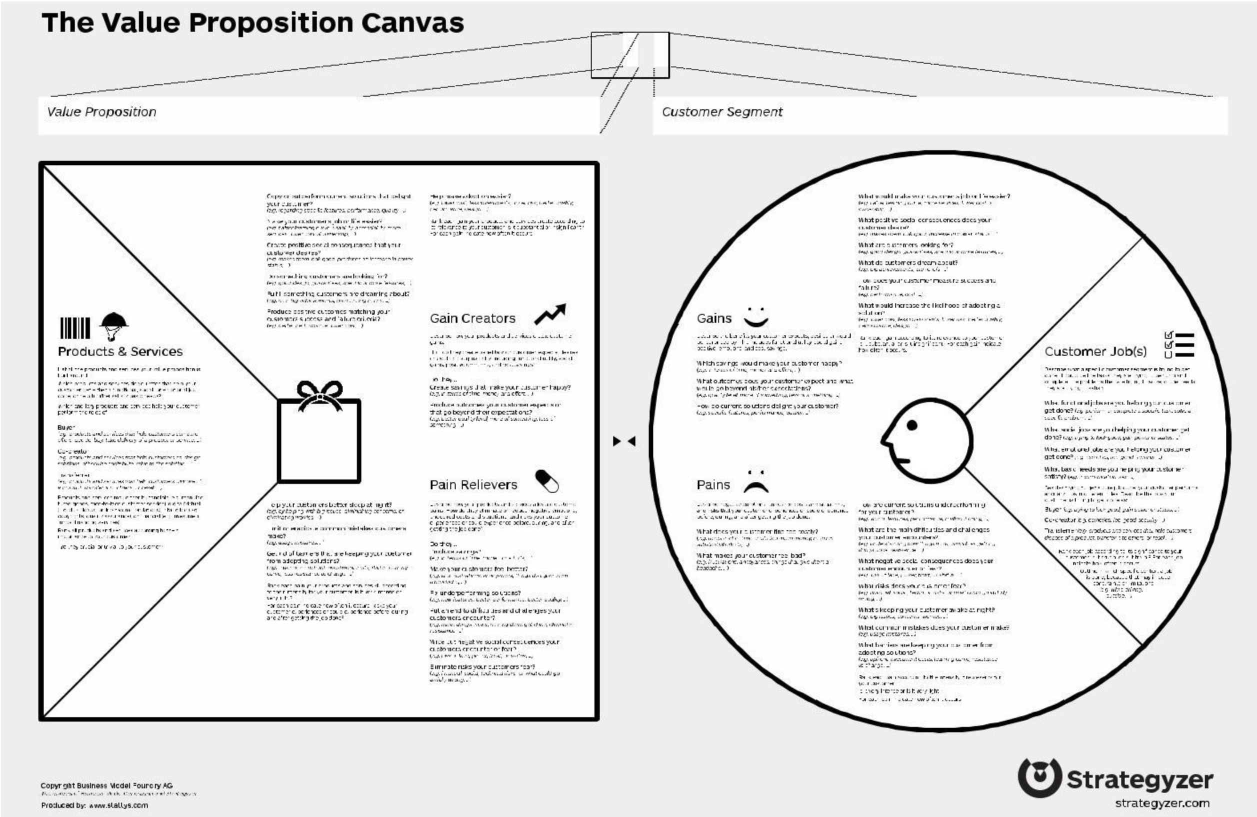


Figure 5-8 The Value Proposition Canvas (www.Strategyzer.com)

5.5 Value Proposition Canvas for VMGA

Customer Segment

In the proposed business model, VMGA is one of the key stakeholders with different customers such as prosumers, DSO, wholesale energy market and BRP. The basic need VMGA must satisfy is to provide green electricity at a fair price and generate revenue by using RES. VMGA along with its customers act as co-creators of energy to be supplied to the larger grid. Using DR actions, VMGA has to assist in congestion management for the DSOs. For the Prosumers who will be the most important customers for VMGA, the task for VMGA is to ensure market access for the energy supplied by prosumers.

VMGA by aggregating the energy from prosumers tackles lots of customer pains in the electricity value chain. Prosumers who individually produce only small amounts of energy do not have a chance to trade in the wholesale market. The EU is encouraging prosumers towards self-generation of electricity but if too many prosumers join the main grid without any control, there are chances of overloading the grid. Also a significant pain for customers of VMGA is that there are lots of unknowns and uncertainties in the changing electricity market value chain.

There are overall customer gains by actions of VMGA in the electricity markets. The biggest gain from VMGA is that it facilitates continuous supply of environment friendly green energy through the existing grid system. By being the aggregator, it provides opportunities for prosumers to generate surplus even if it is in small quantity. VMGA uses ICT to enhance two way communication and automation between different stakeholders in new business model.

Value Map

VMGA ensure that jobs get done by providing relevant products and services for its customers who are new actors in dynamic electricity market. A key task of VMGA is automated grouping of surplus power from the prosumers and sell for the highest price possible in the main grid. By effectively managing DR, it generates extra income with possible energy savings along with load management and differential pricing. By being at center of new business model, VMGA acts as ICT platform for two way communication exchange and provides the necessary micro grid infrastructure to connect prosumers with the main grid. As RES are often weather dependent, providing energy storage facilities is a key task for VMGA for un-interrupted energy supply to establishments.

VMGA provides the products and services required in the new electricity market value chain. It enables immense gains by becoming a co-creator along with the prosumers, of renewable electricity energy which can be integrated into the wholesale energy market.

Summary of the value propositions for customers of VMGA is shown below in the table.

Customer Type	Value proposition
Prosumer	Arrange profitable access to the market
DSO/TSO	Provide congestion relief
BRP	Provide balancing services
Wholesale energy market	Provide RES to meet regulatory targets
Other VMGAs	Share cheap energy, combine to sell RES at higher prices

5.6 Discussion

Illustrations of BMC and VPC for VMGA has shown that integration of VMGA into electricity markets significantly enables the decentralized electricity market and has the potential to provide substantial benefits to all stakeholders involved in the all levels of the value chain. Possible revenue models which came up during BMC for VMGAs are flexible electricity tariff pricing based on offtime/peak usage hours. Value of VMGA is twofold- one, it eases market participation for prosumers; two, prosumers have to pay lower electricity price in such a localized market place. VMGAs facilitate system flexibility for the DSO and the wholesale electricity market by providing choices of energy source. Local transmission is a way forward to reduce transportation costs.

In a rapidly evolving electricity market which is getting used to concepts of smart grids, smart metering, demand response and demand management, aggregators like VMGA could be seen as "one too many" and face challenges on different fronts.

How prepared is the market – when it comes to new energy markets, mostly it stops at smart metering and ancillary activities. All stakeholders involved might not be prepared for one more change in what has traditionally been a slow changing business model. VMGA integration is based on advanced ICT based services and interactions between multiple stakeholders. ICT services for electricity markets need to be better merged for efficient operations.

Fear of Unknown- Centralized grid based **e**lectricity markets have not seen much change in a long time. Sudden disruption in the market may lead to hostile receptions from existing stakeholders who are well established. Clear regulatory guidelines and framework for RES integrated market operation needs to be put in place for smooth and continuous supply of electricity.

In this section, framework of BMC and VPC has been shown only for VMGA. Similar exercise were done for other stakeholders in the VIMSEN network like ICT/communication provider, municipality or regions keen on RES integration, DSO/TSOs, building management companies and others for deeper scenario analysis of the opportunities which may arise in the grid of the future.

Chapter 6 Conclusions and Scope of Further Research

This chapter summarizes this work. Recommendations for further research shall be made at the end.

6.1 Conclusion

This academic work based on ongoing VIMSEN project has investigated the integration of VMGA into the decentralized electricity market of the future which will have large penetration of RES in electricity generation. For small RES prosumers to seamlessly integrate in the grid with market power, VMGA has been shown as a key enabler in the value chain. Conclusions that can be drawn from this work are the following

- Subsidy policies such as FITs need to be substituted by the newer market & pricing models to encourage participation of RES prosumers and VMGAs.

- Concepts developed in this document show VMGAs are scalable and their integration in the electricity market will reduce transmission and distribution losses by encouraging local consumption. These benefits will pass on to other stakeholders such as DSOs, TSOs, and BRPs. With increased share of RES in electricity generation, consumption of clean energy is increased.

- VMGA has the potential to integrate in market in different ways. Different pricing models have been put forward to show that electricity generation with large RES share is possible. For this to happen, existing stakeholders must be prepared for the transformation.

- Integration of VMGA is highly dependent on ICT based services. Electricity grids which have functioned the same way for more than 50 years now will certainly have improved decision making by using two way communication and analysis of big data.

- By illustrating BMC and VPC for VMGA, it has been shown that VMGA generates new business opportunities in the value chain. Integrating VMGAs into electricity markets have both economic and environmental benefits which cannot be ignored.

- Concept of aggregator in the smart grid based electricity market is comparatively new. Tried and tested methods of BMC and VPC have been applied from scratch to show market based interactions between different stakeholders with varying demands and expectations from the evolving market.

- Clear guidelines and regulatory framework are required at both macro and micro levels of the value chain in order to promote investments in shaping the decentralized electricity market. This will be an important step towards enhanced participation and doing away with "fear of unknown".

6.2 Further Scope of Research

With global awareness to combat climate change on the rise, electricity markets will have to move towards larger share of RES in their power generation mix. For this to materialize, different business models with current stakeholders and new ones must continue to take place in the future. Market & pricing models studied in this work should be replicated and evaluated beyond VMGAs for other stakeholders in the value chain.

This has been a conceptual analysis. Conceptual framework of this work must be tested with algorithms, data analysis and simulation amongst different stakeholders to derive at cost benefit analysis of the solutions proposed.

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Appendix

Appendix A

This thesis is based on VIMSEN project FP7 ICT-619547 of EU Horizon 2020 initiative. VIMSEN is a multi-country, multi-stakeholder research project being undertaken in three phases and duration 2014-2017. The VIMSEN project is divided in 8 different work packages and has stakeholders from different EU countries.

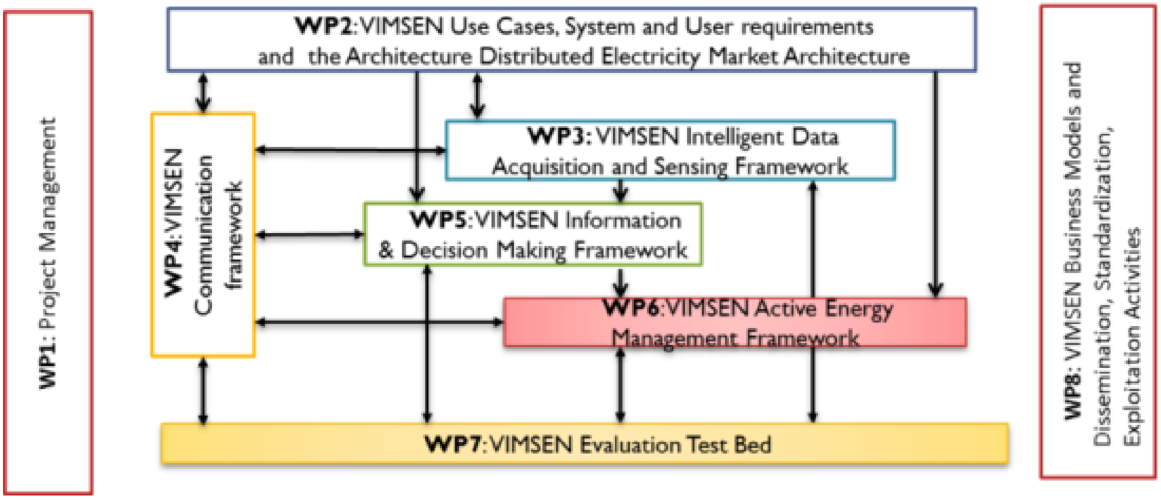


Fig A-1 Different work packages in VIMSEN project

Table A-1: Different partners in VIMSEN project

Type	Name	Country
Network Partner	Cosmote Kinites Tilepikoinonies AE (COS)	Greece
Power Utility	Public Power Corporation S.A. (PPC)	Greece
SMEs	INTELEN	Cyprus
	Wattics	Ireland
	TELINT Consultancy	United Kingdom
Municipality	Sedini	Italy
Energy Company	DNV GL (KEMA)	Netherlands
Academic Partner	Computer Technology Institute and Press, CTI	Greece

Appendix B

Table B-1 Prerequisites per EU member for participation in the day ahead electricity market
Source Renewable Energy Resources, 2nd Edition. John Twidell and Tony Weir. 2006.

EU Member Country	Market Operator	Minmum contract volumes for participation in the day-ahead electricity market.
Belgium	BELPEX	The minimum contract volume is 0.1 MWh (for 1H block).
Poland	POLPX	The minimum contract volume is 0.1 MWh (for 1H block).
Hungary, Czech Republic and Slovakia	PXE / OTE /OKTE	The minimum contract volume is 1 MWh (for 1H block).
Northern Europe (Denmark, Estonia, Finland, Latvia, Lithuania, Norway, Sweden)	NORD POOL SPOT*	Trading is based on three different types of orders: single hourly orders, block orders and flexible hourly orders. The members can use any one or a combination of all three order types to meet their requirements. The minimum contract volume is 1 MWh (for each order).
Germany/Austria/France/ Switzerland	EPEX SPOT	Day-ahead auction with delivery on, 1. The German/Austrian TSO zones has minimum contract volume of 0.1 MW for 1H blocks (individual hours) and 0.1 MW for 12H blocks 2. The French TSO zone has minimum contract volume of 0.1 MW 3. The Swiss TSO zone has minimum contract volume of 0.1 MW for 1H blocks (individual hours) and 0.1 MW for 12H blocks /block of several hours/user defined blocks
Ireland & NI	SEMO	All Generators with Maximum Capacity > 10MW must sell all their output through the SEM.
Greece	LAGIE	The generation unit's capacity must be declared in MW and the number must be integer. Thus, the minimum declared capacity is 1MW (for 1H block).
United Kingdom	ELEXON, APX Power UK	The minimum contract volume is 0.1 MWh (for 1H block).
Spain/Portugal	Omie	The production units with installed powers of more than 1 MW may furnish bids for any schedule periods (in hours)
Italy	GME	The minimum contract volume is 1 MW (for 1H block).
Netherlands	APX Power NL	The minimum contract volume is 0.1 MWh (for 1H block).
Romania	OPCOM	The minimum contract volume is 1 MW (for 1H block).
Slovenia and Serbia	South Pool	The minimum contract volume is 1 MW (for 1H block).

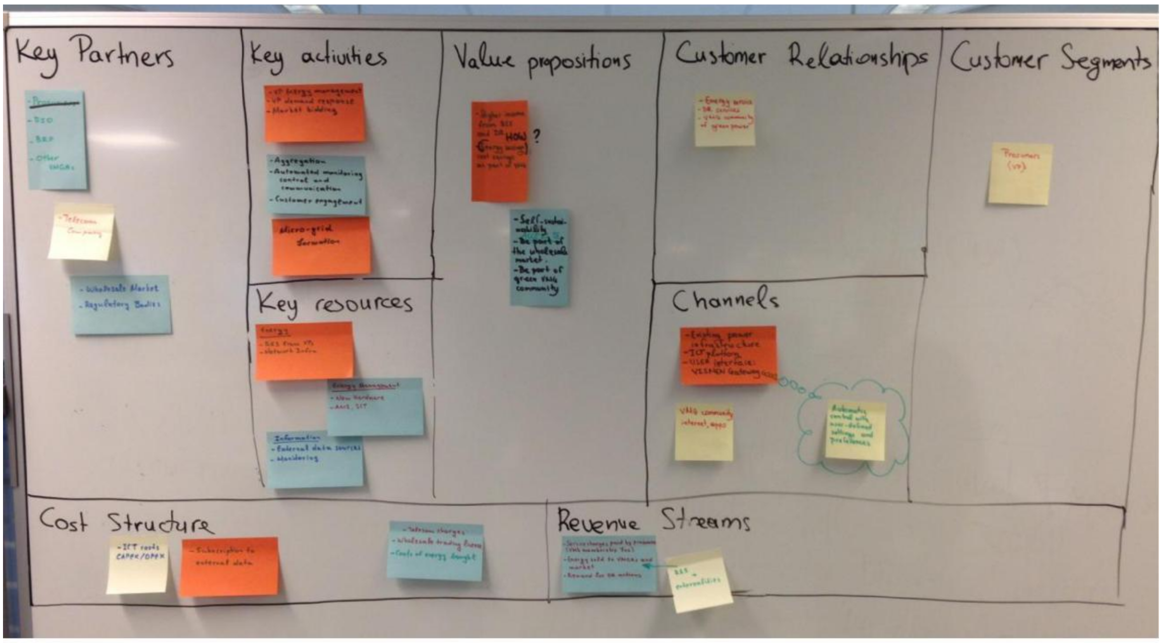
Appendix C

Table C-1 EU overall targets for the share of energy from RES. Source: Directive 2009/28/EC.
S = Share of energy from RES in gross final consumption

European Union Member Country	S%(2005)	S%(2020)
BELGIUM	2.2	13
BULGARIA	9.4	16
CZECH REPUBLIC	6.1	13
DENMARK	17	30
GERMANY	5.8	18
ESTONIA	18	25
IRELAND	3.1	16
GREECE	6.9	18
SPAIN	8.7	20
FRANCE	10.3	23
ITALY	5.2	17
CYPRUS	2.9	13
LATVIA	32.6	40
LITHUANIA	15	23
LUXEMBOURG	0.9	11
HUNGARY	4.3	13
MALTA	0	10
NETHERLANDS	2.4	14
AUSTRIA	23.3	34
POLAND	7.2	15
PORTUGAL	20.5	31
ROMANIA	17.8	24
SLOVENIA	16	25
SLOVAK REPUBLIC	6.7	14
FINLAND	28.5	38
SWEDEN	39.8	49
UNITED KINGDOM	1.3	15

Appendix D

Ideation workshop for BMC and VPC with regards to VMGA was held at DNV GL (KEMA) campus in Arnhem, The Netherlands. The results from the workshop have been included in the report. Pictures below are for illustrative purposes.


Key Partners
Key activities
Value propositions
Customer Relationships
Customer Segments
Key resources
Channels
Cost Structure
Revenue Streams


Key activities
Key resources