Design of an ICT platform for smart grid applications in the Business-to-Business market

3TU. School for Technological Design

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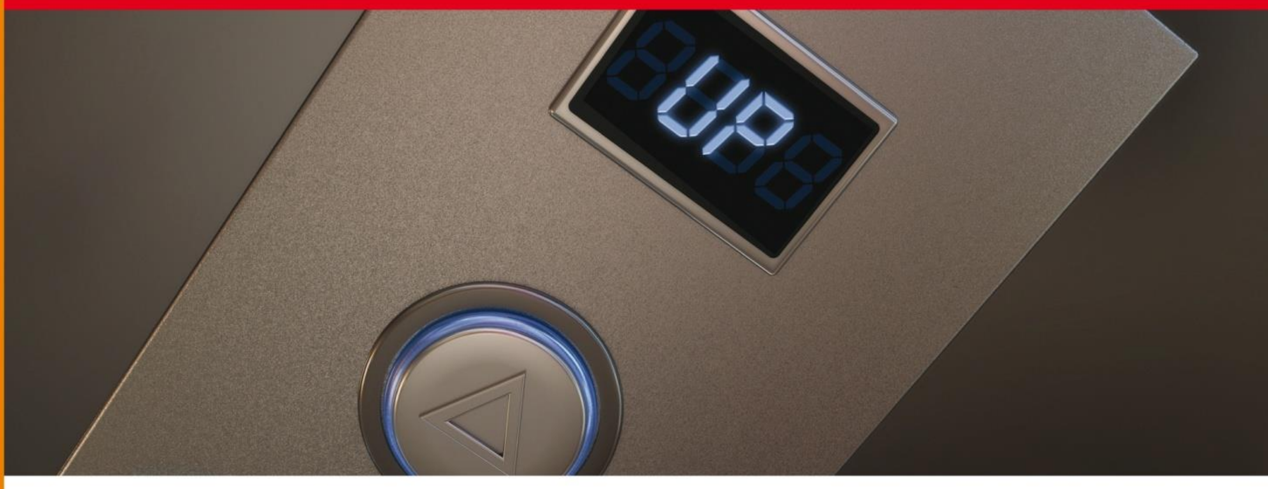
Rosa María de Guadalupe Morales González

February 2014



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3TU. School for Technological Design, Stan Ackermans Institute

PROGRAM IN SMART ENERGY BUILDINGS & CITIES

—CONFIDENTIAL—

DESIGN OF AN ICT PLATFORM FOR SMART GRID APPLICATIONS IN THE BUSINESS-TO-BUSINESS MARKET

By

Rosa María de Guadalupe Morales González

A dissertation submitted in partial fulfillment of
the requirements for the degree of
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COFELY GDF SUEZ

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Executive Summary

In the energy transition, flexibility will play a key role at all levels of the electricity value chain. Pinpointing and capturing the value of flexibility requires the addition of “intelligent” systems into the traditional power system. This modernized power system in which Information and Communications Technologies (ICT) are pervasive is also known as the Smart Grid. It should effectively accommodate large-scale and local, distributed (renewable) generation, storage systems, and consumer loads for a more efficient and reliable distribution of electricity with low losses and affordable costs [1]–[4].Within the Smart Grid concept, a new role is created for one or several entities in charge of managing and capturing the value of resource flexibility at the different parts of the power system value chain. Whoever manages to be the first-to-market can benefit from gaining and/or sharing control of the flexibility for attractive profit margins while contributing to a stable, reliable, and affordable Smart Grid for its customers.

The main purpose of the project is to assist Cofely in designing an ICT Platform for Smart (Micro)Grid applications, and developing a business strategy regarding market rollout of this system and/or its components within the Business-to-Business (BtoB) market. These goals were pursued in the framework of Modienet, a Smart Microgrid pilot spearheaded by Cofely.

Modienet ICT System Design

The main objective of the Modienet microgrid is to procure and facilitate, by means of an ICT platform, the local electricity exchanges between producers, consumers, and storage capabilities of an industrial park and its surroundings. Critical aspects of this system are: flexibility (i.e., interoperability), scalability, reliability, availability, and security, all of which the system design should take into account. Systems Engineering was chosen as the main design methodology. The iterative nature of this process allows for many revisions in the design stage, which is the stage where most projects go wrong.

The system architecture of the Modienet ICT platform is as follows: sensors and actuators placed at customer, storage, and generation premises collect data regarding the electricity consumption and production that takes place onsite. Individual generators, storage units, and customer premises have sensing devices for internal optimizations and for aggregated control functions controlled by the Modienet Energy Services Provider. The Modienet participants gain insight on their electricity consumption/production patterns via dashboard applications.

The data collected by the control system is relayed via the Modienet communications network to a data warehouse hosted in a datacenter suite. Apart from providing storage space for the Modienet data, the datacenter also supplies the computing power to standardize the incoming signals and create relations to process them into information and assets that can be used in the Modienet application for coordination and aggregation purposes, such as:

- matching supply and demand in the microgrid;
- supervisory control;
- local optimization of resources;
- portfolio management;
- billing;
- demand-response services;
- reserve-market participation; and
- emerging / future services.

Route-to-market strategy of the ICT System and/or its components

Planned implementation of the business strategy should be done in phases that should ideally consist of relatively low-cost add-ons with high expected benefits. Although the solutions would incrementally increase in complexity, they are enabled by the previous implementation in order to maximize benefits and reduce marginal costs. That is, each new solution will build on the previous one to offer, cross- and up-sell alternative uses for the product or additional services.

Implementation in increments will additionally promote customer acceptability, foster customer segment growth, and improve quality perception. The customer base consists of current customers of the Cofely Building and/or Industrial Automation business units, or new commercial and industrial customers who are looking to get better insights of their electricity consumption or who want to secure stable electricity prices for long-term contracts. When early adopters show satisfaction in the product they are using, new clients could be attracted and convinced not only to become an early majority of the first implementation, but also early adopters of the more sophisticated, subsequent implementations.

Four Smart Grid-ready ICT BtoB service packages, or bundles, are identified for capturing the value of flexibility within the Smart Grid:

- Energy Monitoring;
- Demand Response;
- Energy Services Company (ESCO) contracts; and
- Market participation in the reserve and spot exchanges.

These bundles respond to the following customer needs:

- Insight on their energy consumption;
- Lower electricity bills;
- Price stability in the advent of volatile energy retail and wholesale prices;
- Less risk in their energy situation; and
- Profit from their smart energy use.

In order to thrive in the Smart Grid market, Cofely has to take advantage of the wide range of applications and services of its internal business units, create strategic partnerships with third-party technology- and engineering services providers where there is no in-house knowledge available. Cofely should also look for opportunities for vertical integration with other GDF-Suez brands, such as GDF-Suez Energie Nederland for aggregation, market participation and portfolio management. It should also seek partnerships with public and private research institutions in order to innovate on optimization algorithms. Only this way can Cofely truly be the one-stop-shop for hardware, software and services in the Smart Grid development.

Cofely can ensure a sustainable competitive advantage in the Smart Grids market by organizing and bundling all of its in-house knowledge and activities around becoming a service operator and not just a technical installer.

Investment in ICT technologies for smart grid applications is highly advisable, since there are many business opportunities in each of the links of the ICT system value chain, especially regarding the exploitation of flexibility. With the transition towards Smart Grids, new roles for coordinating electricity flows, such as the Aggregator or the Energy Services Provider, have been created. Who should fulfill these roles within the Smart Grid is still not defined and therefore represents a great opportunity for Cofely.

Acknowledgements

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List of Acronyms

AMI	advanced metering infrastructure
BtoB	Business-to-Business
CEN	European Committee for Standardization *(Comité Européen de Normalisation)*
CENELEC	European Committee for Electrotechnical Standardization *(Comité Européen de Normalisation Électrotechnique)*
CHP	combined heat and power generation
DER	distributed energy resources
DR	Demand response
DSO	distribution system operator
ESP	Energy Services Provider
ETSI	European Telecommunications Standards Institute
EV	electric vehicle
GHG	greenhouse gas
ICT	Information and Communications Technologies
IoT	Internet of Things
IPIN	Intelligent Networks Innovation Program
IPR	Intellectual Property Rights
KPI	key performance indicator
M2M	Machine-to-Machine Communications
Modienet	Modular Intelligent Energy Networks for industrial terrains *(Modulair Intelligent Energienetwerk voor bedrijventerreinen)*
ODA	independent service provider *(Onafhankelijke diensten aanbieder)*
PV	photovoltaic energy system
RES	renewable energy sources
RTU	remote terminal unit
RVO	Netherlands Enterprise Agency *(Rijksdienst voor Ondernemend Nederland)*
SE	Systems Engineering
SGAM	Smart Grid Architecture Model
WP	Work-Package

Chapter 1
Introduction

1.1 Problem description

Concerns over fossil-fuel dependence and the need to curb greenhouse gas (GHG) emissions have steered Dutch energy policy towards the transition to renewable energy sources (RES), such as solar photovoltaic (PV), wind, and biomass. In compliance with European goals, the Netherlands have committed to increase their share of energy produced from renewable sources from 4 to 16% by 2020 [5]. In response, local governments have drafted (re)zoning and development plans in which energy neutrality —energy self-sufficiency through local RES— plays a key role in attaining their sustainability targets [6]–[8].

However, the stochastic nature of RES could negatively impact power availability, network reliability, and energy affordability in the Energy Transition. Because renewable energy systems have generation patterns that generally do not follow the load, maintaining the power system in balance becomes more complex as penetration of RES increases. Paired together with other issues like fluctuating oil prices and an aging power system infrastructure, it is expected that electricity prices could become more volatile and increase considerably in the future if this issue is not properly addressed in the coming years [9]–[11]. Improving local balancing to create demand patterns that follow electricity supply requires changes in the infrastructure and operation mode of traditional power systems and their markets.

The modernized power system, also known as the Smart Grid, employs Information and Communications Technologies (ICT) to monitor, control and optimize grid assets and the distributed energy resources (DER) connected to the network [1], [12]. Examples of DER are distributed generators, storage units, and (flexible) customer loads. ICT systems also enable the unbundling of regional distribution grids into smaller local self-supporting networks, also known as microgrids, that utilize optimally-sized and coordinated DER to provide electricity to the customers situated in the area.

In this transition, flexibility will play a key role at all levels of the electricity value chain, pictured in Fig. 1:

- flexibility of generation resources;
- flexibility of the transmission and distribution system;
- flexibility of distributed energy resources (DER);
- flexibility at the consumer level; and
- flexibility of the electricity markets [13].

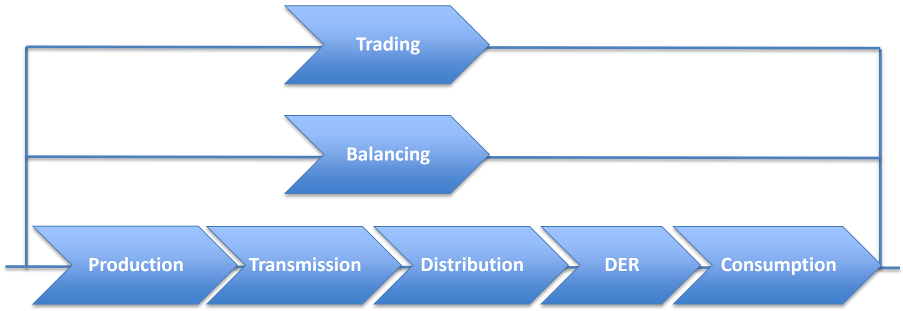

Fig. 1. The power system value chain

Being able to pinpoint and capture the value of the various sources of flexibility requires "intelligent" systems to carry out a pervasive and widespread collection, communication, analysis, and interpretation of data. The data, processed from scattered metrics to meaningful information, will play a crucial role in guiding the business and technical balancing decisions to be made in the Smart Grid. Due to the pervasiveness and importance of these intelligent systems in the future power system, ICT can be considered the great facilitator of the Smart Grid.

1.2 Opportunities

With approximately 50% of primary energy consumption occurring in industrial areas and commercial buildings [14], the renovation and construction of these types of areas are a logical starting point for implementing the microgrid concept to achieve energy-neutrality in accordance with the national and local energy policies mentioned in the previous section [15]–[17]. Despite the ongoing crisis of the building sector, energy-neutral (re)zoning projects remain prolific in the Netherlands thanks to the support of activist organizations and the government. This, in addition to the obvious ecological reasons, makes it interesting for companies to participate and invest in sustainability projects. One can assume that the order-winning criteria for open tenders on developing energy-neutral industrial and commercial areas will seek to maximize the synergies between public resources and policy, and the expertise and know-how the private sector [18].

Additionally, a new role is created within the Smart Grid concept for one or several entities in charge of managing and capturing the value of resource flexibility at the different links of the power system value chain. Whoever manages to be the first-to-market can benefit from gaining and/or sharing control of the flexibility for attractive profit margins while contributing to a stable, reliable, affordable Smart Grid for its customers.

1.3 Cofely and the Energy Transition

Cofely is the largest Business-to-Business (BtoB) technical services supplier in the Netherlands, and caters to the Industry, Utility, Infrastructure, and Building Services markets, as well as to public collectivities.

As a brand of the French multinational electric utility company GDF SUEZ, Cofely does business in more than 25 countries in 1,500 sites and has 77,000 employees worldwide, making it the leading BtoB energy-efficiency services brand in Europe.

In response to the demand for an increasingly efficient —yet affordable— use of energy, Cofely has specialized in the design, implementation, operation, and maintenance of integral and sustainable technical solutions for its customers.

These solutions are aimed at:

- improving the energy and environmental performance of buildings, industries, utilities and public infrastructure;
- integrating facility management services to ensure user comfort and optimal performance of technical installations; and
- producing, using, and distributing locally-generated renewable energy.

The core competences mentioned above make Cofely a key player in the Energy Transition and an important partner of local governments and energy policy enactors.

Cofely's expertise in industrial installations, energy services, and ICT systems can facilitate the company's market entry into private-sector or public-private Smart Grid initiatives regarding:

- the deployment of Energy Management Systems at the customers' side of the grid connection;
- the deployment of Energy Management and Asset Management Systems of Smart Microgrids; and
- the participation in pilot project initiatives in the Netherlands (e.g., those within the framework of the Intelligent Networks Innovation Program (IPIN) launched by the Netherlands Enterprise Agency (RVO, formerly known as *AgentschapNL*).

This project is focused on investigating the aforementioned points from an ICT-systems perspective.

1.4 Project formulation and scope

The main purpose of the project is to assist Cofely in designing an ICT Platform for Smart (Micro)Grid applications, and developing a business strategy regarding market rollout of this system and/or its components.

The design objectives are formulated below:

> *Define and develop a platform about the "smart part" within Smart Grids, which enables the individual parts of the value chain (production, transport, distribution and consumption) to be optimized independently and as a whole to function within the existing electricity system."*
>
> *Examine in which areas —e.g., data collection, data validation, demand response management, grid scenario handling, billing, Electronic Data Interchange (EDI), Business Process Management (BPM), Reporting, Electronic Application Integration (EAI), Forecasting— Cofely should/could distinguish itself, and with which products and/or services.*

The following sub-questions were formulated to help in fulfilling the design objectives:

- How can Cofely ensure that local existing solutions can be applied into a Smart Grid in the future?
- What technological (development) management platform should be chosen and how feasible is this platform within Cofely?
- How can Cofely benefit from the fact that the company, as part of GDF SUEZ, is represented in the whole electricity value chain?
- How can Cofely permanently distinguish itself in the market for Smart Grids?
- Make or buy?

These objectives and questions will be pursued in the framework of Modienet, a Smart Grids pilot project initiative currently under execution by a consortium spearheaded by Cofely.

1.5 Approach

This report is product of an eleven-month investigation divided into four phases: Orientation, Analysis, Design, and Documentation. A schematic of the approach is given in Appendix A.

1.5.1 Orientation phase

The Orientation phase consisted of an introduction to the Modienet pilot, its design team, and familiarization with the project objectives and breakdown. The scope and objectives of the Modienet ICT subsystem were established in a Work-Package (WP) Description that was agreed upon with the WP responsible, and the Modienet Design Team Leader *(see Appendix B for the document details).*

In the first biweekly meetings of the Modienet Design Team, two design constraints were set:

1. The preferred design methodology is Systems Engineering (SE). A description of this approach and motivation for its use in the design of the Modienet concept are given in Chapter 3.
2. The starting point for the Modienet concept design is the Smart Grid Architecture Model (SGAM) developed by the CEN-CENELEC-ETSI Smart Grid Coordination Group [19]. This framework is explained further in Chapter 4.

Based on the WP Description and the above design constraints, a breakdown of the ICT system functions was performed to outline the activities required of the ICT subsystem design team. An eight-member team —including the trainee and the WP responsible— was assembled through a series of pitch sessions intended to recruit Cofely colleagues specialized in each of the ICT system functions. A Project Initiation Document was drafted and circulated among the team members [20]. Orientation phase activities culminated with a kick-off meeting and brainstorm session with the members of the Modienet ICT subsystem team *(see Appendix for the brainstorm results)*. The role of the trainee within the design team was to explain the SE methodology to the other members and manage the iterative design process of the ICT system and each of its subsystems.

1.5.2 Analysis phase

In the analysis phase, the trainee became acquainted with the SE methodology. This was done through individual exercises, literature surveys, and brainstorms led by the team's SE experts. The learning process started at the Orientation phase and intensified during the Analysis phase. Feedback from the Design Team's SE experts related to the methodology persisted throughout the Design and Documentation phases.

One-on-one and group meetings with the Modienet ICT subsystem design team were held weekly or biweekly to discuss the principles and intricacies of applying the SE methodology in the subsystem design. These forums were also used to discuss the practicalities of implementation of the SE methodology for the design solutions of each individual subsystem: best practices, results of other team members, success stories, difficulties, and questions. The experiences of the ICT system design team were shared and discussed during the biweekly meetings of the Modienet Design Team.

A literature review considering options, understanding technical and economic challenges, and familiarization with ICT technologies was performed in parallel to the interviews conducted. Furthermore, the team members provided input for their individual designs. At the end of this phase, they submitted their individual design concepts. Interviews with other WP leaders were held in order to ensure that the different concepts would be compatible. Communication was crucial in this stage. Coordinating WP activities was also part of the job.

1.5.3 Design phase

The design phase consisted of collecting and integrating the input from the ICT subsystem design team and ensuring compatibility with the designs other design teams within Modienet. This phase also involved reading the inputs given by the ICT subsystem design team and providing feedback in terms of content and execution of the SE methodology. The Modienet Design Team biweekly meetings became a forum to discuss progress, report on content and experiences regarding the deployment of the SE methodology, discuss the validity of the chosen design solutions of each subsystem, and integrating subsystem designs into the Modienet overall system design.

1.5.4 Documentation phase

The documentation phase comprised the writing of the WP end report (from which this document is derived), making changes on the design proposal report, researching the possible business cases and going over policy and legal issues that could affect the performance or existence of the solution proposed in the Design phase. This phase also involved validating the system design based on feedback and the systems engineering verification of the requirements.

After the individual design concepts were finalized and documented, feedback was collected from the team and the Modienet Design Team Leader. The Modienet Project Leader took up the tasks of integrating the different reports into two documents: an extensive technical handbook and a management summary of the project.

1.6 Deliverables

The following will be delivered at the end of the project:

- Systems Engineering Handbook of the Modienet ICT platform design [21]. This report outlines the architecture for the ICT systems that optimize the energy exchange between DER, storage, customers, and the grid.
- An executive report containing:
    - a discussion of the SE methodology and experiences from its practical implementation in the ICT subsystem design;
    - ICT platform design summary;

    - route-to-market strategy of ICT Systems for Smart Grid Applications in the BtoB Market; and
    - conclusions and recommendations for future work.
- A final presentation, both for the University and the Modienet Design Team.

1.7 Report structure

This report is structured as follows:

- Chapter 2 introduces the Modienet pilot project, its organization and goals.
- Chapter 3 discusses the Systems Engineering design methodology and the lessons learned from applying it in the design of the ICT subsystem.
- Chapter 4 summarizes the Modienet ICT system design detailed in the SE Handbook delivered to the Modienet Design Team.
- Chapter 5 suggests a route-to-market strategy for ICT systems for Smart (Micro)Grid applications in the BtoB Market.
- Chapter 6 gives conclusions and recommendations for implementation.

Chapter 2
The Modienet Pilot

This section gives background information on the Modienet pilot project for which the ICT platform was designed.

2.1 Pilot description

Modienet (Modular Intelligent Energy Networks for industrial terrains) is a Smart Grids demonstration project whose main objective is to procure and facilitate the local electricity exchanges between producers, consumers, and storage capabilities of an energy-neutral industrial park and its surroundings. Additionally, the following sub-goals should be addressed:

- The electricity distribution grid must be flexible enough to grow as the industrial park evolves, so that the availability, accessibility and affordability of electricity are guaranteed.
- The system should couple sustainable, decentralized electricity generators to the electricity consumption of affiliated companies and storage of electrical and thermal energy, so that the electricity demand is tailored (balanced) to the local sustainable electricity supply.
- The system should foster and facilitate cooperation among Modienet stakeholders in order to create mutual economic benefits.

The aim of the pilot is to design the microgrid components for the industrial park, especially the local distribution network assets, as a modular structure. In this way, it could be possible to upscale the business park dimensions in the future without having to know the consumer profiles in advance, and without resorting to over-dimensioning production and distribution capacities.

A modular realization would also make the Modienet concept suitable for green- or brown-field situations alike. The first test-bed for this demonstration project will be the A1 industrial park in the city of Deventer. However, Modienet is intended as a versatile, repeatable Smart Microgrid concept for industrial and commercial areas regardless of their state of development. Modienet is the blueprint that will help to guide the choices for any and all Smart Grid projects in which Cofely participates in the future.

2.2 Pilot organization

The design and realization of Modienet is in charge of a consortium consisting of Cofely GDF-SUEZ, Royal Haskoning DHV, Alliander, Laborelec, and the Eindhoven University of

Technology. The pilot falls under the framework of the Intelligent Networks Innovation Program (IPIN), a series of twelve test-beds aimed at accelerating the introduction of Smart Grids in the Netherlands. IPIN, in turn, is an initiative of Netherlands Enterprise Agency (RVO, formerly known as *AgentschapNL)*, a division of the Dutch Ministry of Economic Affairs responsible for enacting policies and tendering subsidies related to sustainability and innovation [22].

The Modienet project organization is depicted in Fig. 2 below:

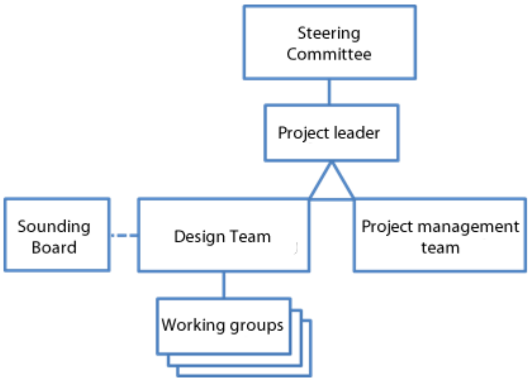

Fig. 2. Modienet project organization

A Design Team was assembled with members of the consortium, and working activities were divided into five packages, each looking into one key aspect of the Smart Grid infrastructure and how it interacts with the producers, the distribution network and the consumers located at the industrial park, as depicted in Fig. 3. The design team met on a bi-weekly basis. In the beginning of the project, the meetings were intended as a forum to learn the basics of the Systems Engineering methodology, which will be discussed in this report in Chapter 3. Subsequent meetings were used to discuss progress within the working groups' activities and any possible interfaces with the other groups.

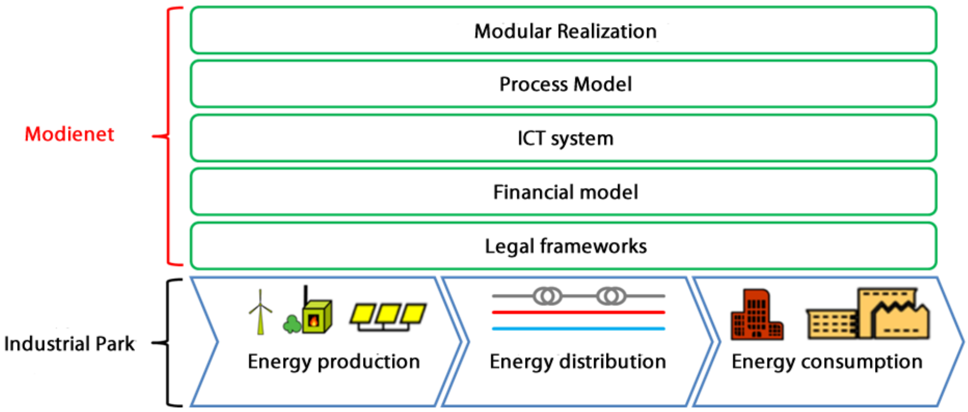

Fig. 3. Modienet themes (working groups) in the context of an industrial park

From March to August, the design sub-teams for every working group worked on developing their design concepts independently, although interviews were held outside the Design Team meetings to keep project interfaces aligned. From August to December, the individual design concepts were integrated into a comprehensive Systems Engineering handbook that will serve as a blueprint for any and all Modienet implementations. Additionally, the individual design concepts were compiled into a document for the Modienet Steering Committee to give advice on the investment and business possibilities for Modienet implementations in the near future.

Chapter 3
Systems Engineering

This chapter introduces the concept of Systems Engineering (SE), its usefulness in projects such as Modienet, and discusses the learning experiences from implementing SE in the Modienet ICT System design.

3.1 Overview

The innovative nature of Modienet not only calls for applying existing technological solutions, but also for creating a paradigm shift on how future electricity networks should operate, taking into account possible forthcoming scenarios. In addition, Modienet is a complex system that consists of a number of subsystems that encompass diverse disciplines, stakeholders, and modes of interaction. A traditional design approach cannot be used in this case given the complexity of the task, on which both technologies and the concept itself need to be innovated.

With the above in mind, Systems Engineering (SE) is chosen as the design-guiding method for the design phase of the Modienet project. It combines methodologies for project, information, design, and quality management with the purpose of understanding clients' needs in terms of functions without rushing to technical solutions; that is, experiencing the problem behind the client's question from both a technical and socio-economical perspective, and translating their wishes, demands, expectations, and priorities into a complete view of the playing field. Using this methodology to document the design process will result in an all-purpose blueprint for future implementations of the Modienet Smart Grid, suitable for industrial and commercial terrains at any development stage.

Systems Engineering helps to break down the main question into sub-questions, for an incremental, iterative design cycle that takes all stakeholders, their environments, and their interactions into account. This not only enables the development of innovative yet feasible solutions in the framework of a comprehensive, structured, transparent, and explicit method, but also aligns all stakeholders into a common, interdisciplinary vision of the end result. The iterative nature of this process allows for many revisions in the design stage, which is the stage where most projects go wrong for not understanding the problem properly or entirely. A comprehensive comparison of Systems Engineering with respect to other design methodologies is given in [23].

3.2 The Systems Engineering Methodology

The steps to be followed iteratively in the SE design process are depicted in Fig. 4.

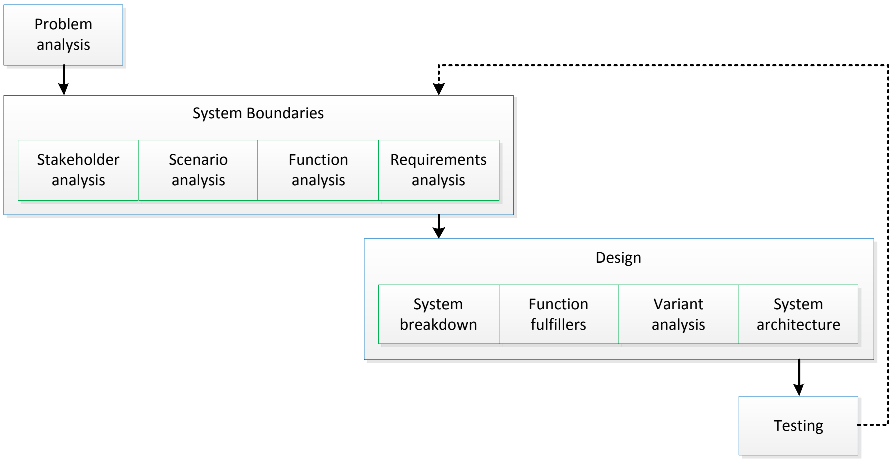

Fig. 4. Schematic of the Systems Engineering design process (Adapted from [24]**)**

An explanation of the four stages of the design process is given below:

1. Problem analysis: *What are the objectives of this (sub)system?*
2. System boundaries:
   - Stakeholder Analysis – *Which are the parties involved, directly or indirectly?*
   - Scenario analysis – *What kind of technical and socio-economic outlook can be foreseen for when this system is in its operational phase? What does it mean for the (sub)system being analyzed?*
   - Functions and Requirements Analyses – *How should the system perform in its operational phase? What are the key performance indicators (KPIs) on which the (sub)system will be assessed?*
3. Design:
   - System breakdown – *How can the (sub)system be broken down into simpler systems/tasks/topics in order to fulfill the requirements/functions established by the system boundaries?*
   - Trade-off analysis (function fulfillers and variant analysis) – *For each function/requirement that needs to be met, what options are available to solve them? What is the best solution possible (e.g., in terms of time, quality and money)?*
   - System architecture – *What will the solution look like?*
4. Testing:
   - Validation & Verification – *How appropriate is the solution in terms of fulfilling the system requirements and functions, KPIs?*
   - Communication – *What do other actors think about the appropriateness of the solution?*
   - Evaluation – *What is the next step?*

This method progresses incrementally and iteratively, as depicted in Fig. 5. That is, the next step after every successful run of the design process entails going one level deeper in detail: from the main system to its subsystems, and from their subsystems to their components. It is important to note that this method only describes the design process and activities within this process. The choice of the design instruments and tools with which to follow this process is up to the design team of each (sub)system.

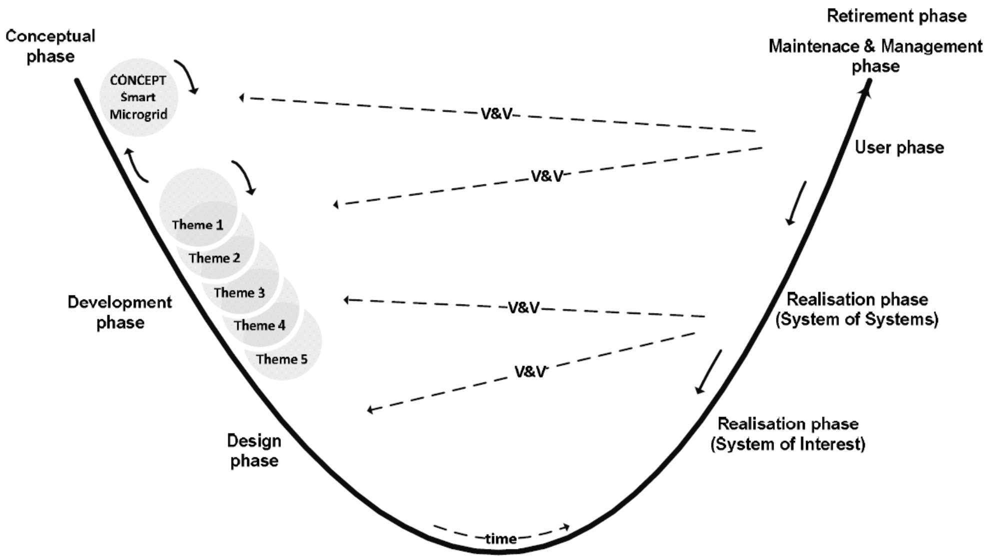

Fig. 5. The SE iterative development method for Smart Microgrids [23]

3.3 Lessons learned

Systems Engineering, though a very useful tool, proved to be a bit counter-intuitive in its implementation. The designers of the ICT System sub-team, who were initially not familiar with the methodology, found the idea of keeping the concept as generic as possible counter-intuitive. This is because usually clients provide the system requirements and functions, and, for Modienet, the designers had to determine their own. It was also difficult for them to grasp the methodology when it was discussed in general terms. Using concrete examples to clarify each step of the design process was a more effective method. Given the designers' vast experience in the field, they were quick to jump to solutions without making a conscious analysis of the process by which they got the solution. In other words, the Systems Engineering-way of thinking was already implicitly present in the design, but it was not being externalized or documented. The methodology makes the designer's thought-process and choices transparent to the client and other stakeholders involved, which facilitates communication. The experience of other working groups within the Modienet Design Team, not to mention the Modienet Steering Committee, was similar to what occurred in the ICT System sub-team. In all instances, it was easier to understand the methodology and its importance by seeing an example of how Systems Engineering was implemented in a specific system of interest.

In order to facilitate implementation of the methodology, a "Reverse" Systems Engineering method was developed within the ICT System sub-team, in which the starting point is the solution that was automatically thought up by the designer. From this concrete concept, the steps of Systems Engineering are worked out in reverse until the concept is made more general in order to extract the basic functions and requirements for the system of interest. This method proved to be very effective within the sub-team, since it provided a concrete example on which to implement the Systems Engineering methodology. It also created a sense of awareness of the complexity of the problem and the importance of documenting the entire thought process. A schematic of the "Reverse" SE approach is depicted in Fig. 6.

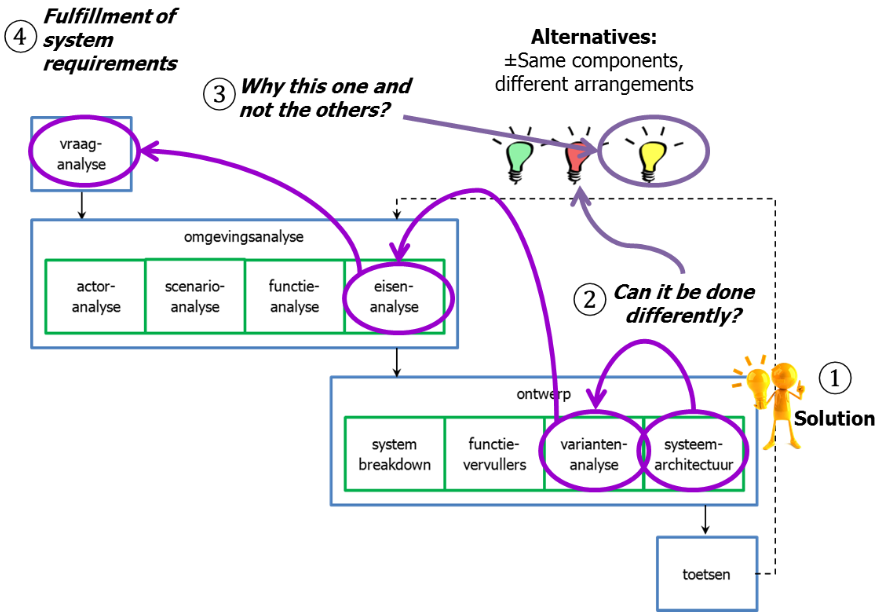

Fig. 6. The "Reverse" Systems Engineering method

Step one of this method is to deconstruct the proposed solution (system architecture) and ask: *is it possible to solve the problem differently?* Thoughtful consideration of other options is equivalent to performing the variant analysis. By analyzing why the proposed solution distinguishes itself from the other proposals, the system KPIs can be obtained. In the designer's mind, rejecting other choices comes automatically because those options do not perform as well as the solution they had in mind in terms of those KPIs—meaning they do not fulfil the requirements that are desirable and/or necessary for the system. Identifying the KPIs will yield the system requirements. By analyzing why these requirements are necessary and/or desirable in the first place, the system functions can be deducted from the requirements. A schematic of the thought process of the "Reverse" SE method is compared alongside the original methodology in Fig. 7.

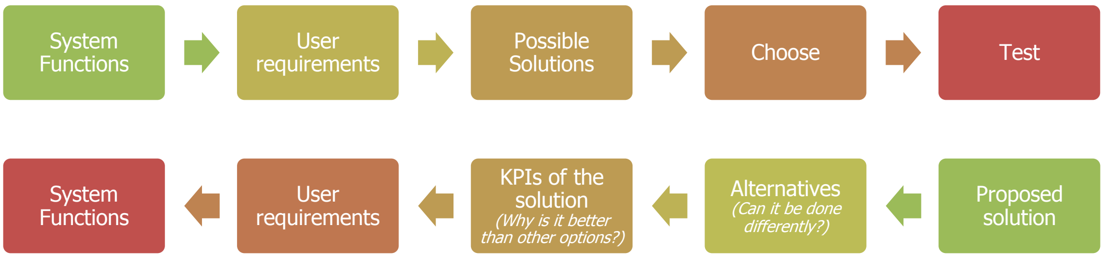

Fig. 7. Comparison of the "Reverse" SE method (bottom) with the original methodology (top)

The "Reverse" SE method was created as an ad hoc solution for coping with the fact that, due to the time constraints of the project, the design team had to learn Systems Engineering almost at the same time that they had to use SE to start designing. In future implementations where time is not such a critical constraint, it would be preferable to divide the content of the design from the SE process. The ICT System Design sub-team would have benefitted from an SE expert within Cofely who could actively advise on, manage, and guide the team's process without actually being involved in the content produced by the team. Making this happen in future Modienet implementations would be very feasible, since Cofely already counts with such experts in-house.

Chapter 4
ICT Platform Design

This chapter summarizes the design choices for the Modienet ICT System detailed in the Modienet ICT System Design Handbook [21].

4.1 ICT as the facilitator of Smart Grids

This section highlights the importance of ICT in the Smart Grids concept. Fig. 8 depicts the Smart Grid Architecture Model (SGAM), the common European framework for smart grid concepts developed by the CEN-CENELEC-ETSI Smart Grid Coordination Group [19]. This framework is used to describe Modienet and its system of systems. The motivation for this is that by using a common framework, the concept can be more easily understood by others who are familiar with this reference architecture and benchmarks can be performed against other projects working with the same reference framework.

The SGAM describes the interactions of the Smart Grid and its stakeholders in three dimensions:

- the physical Smart Grid domains, which refer to the power system management requirements in each link of the electricity value chain;
- the partitioning zones, which represent information management hierarchies; and
- the interoperability layers, which represent the Smart Grid's business objectives and processes, functions, information exchanges, data models, communication protocols, and components. All of these aspects are influenced by the physical domains of the Smart Grid and the information management hierarchies.

Fig. 8 is illustrated with examples of the ICT subsystems and components found in each of the interoperability layers of the SGAM. As can be seen from this figure, ICT is pervasive throughout all aspects of the Smart Grid.

In the Component Layer, sensing and actuating devices located behind the meters of the local distribution grid are collecting data and receiving instructions from applications that perform system functions. The advanced metering infrastructure (AMI), composed of smart meters and telemetry equipment, collects the energy consumption data and other metrics from producers, consumers, and the point of connection to the regional distribution grid.

The data collected are relayed across local- and wide-area networks in the Communication Layer to the computing resources in the Component Layer. There, they will be sifted through, processed and analyzed into useful information. This will be done by using data models stored in the Modienet software architecture located in the Information Layer. The consolidated datasets and information will be also stored in the Information Layer and made available to countless computer applications pertaining to the Function Layer as input to perform optimization algorithms, coordination efforts, demand- response management schedules, and other system functions that will help Modienet achieve its business objectives outlined by the Business Layer of the SGAM.

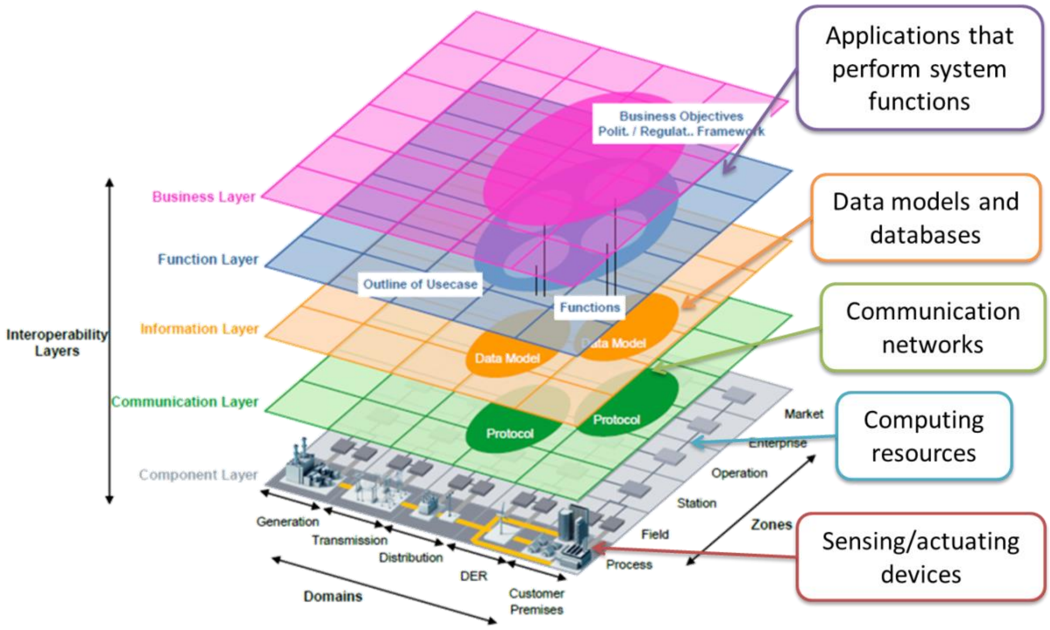

Fig. 8. ICT systems components abound in all layers of the SGAM. (Adapted from [19])

4.2 Complexity of the Modienet ICT System

Section 4.1 introduced the reference architecture in which the Modienet system as a whole is framed. This section introduces the reference architecture related to the Modienet ICT infrastructure in particular. For Modienet's ICT system design, Machine-to-Machine (M2M) communications technologies will be used in addition to the SGAM. A part of the burgeoning Internet of Things (IoT) concept, M2M aims to pervasively use devices of different varieties (e.g., sensors, actuators, robots, mobile phones, personal computers) that interact with each other [25]. By working together, these devices can reach common goals, such as expanding the footprint of end-user services, creating new systems, and generating new value [26]. Communications networks play a key role in establishing the conditions that allow a device to bi-directionally and interoperably exchange information with a software application. The device and/or the application can act as the trigger(s) for the information exchange to occur.

The SGAM framework can be interpreted as an instance of the M2M architecture for Smart Grid concepts. Fig. 9 depicts the M2M Modienet ICT System Architecture in terms of SGAM:

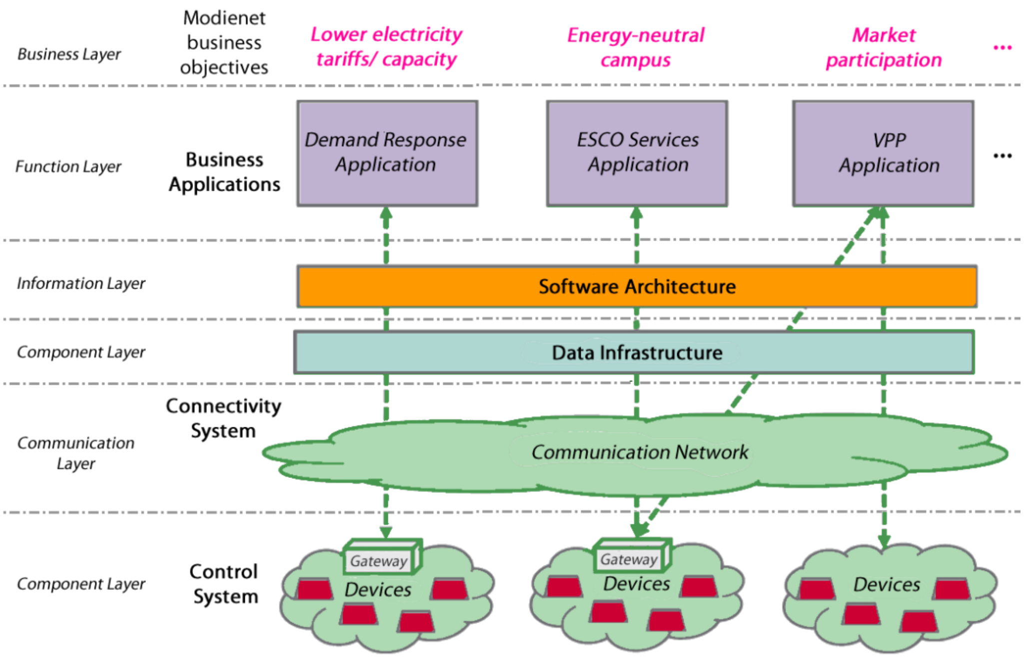

Fig. 9. The Modienet ICT System described in terms of SGAM (Adapted from [26])

In the bottom part of the diagram, all sensing and actuating devices used in the field (e.g., smart meters, valves and motors controlled by demand-response mechanisms) are part of the **Control System**. Its area of influence includes the Process and Field Zones of the SGAM Component Layer. In the SGAM Communications Layer, data collected by the Control System are transmitted across the physical media and telecommunication networks of the **Connectivity System** to the **Data Infrastructure**. The physical computing and storage resources that make up the Data Infrastructure are part of the SGAM Component Layer. This infrastructure hosts the Modienet **Software Architecture**, represented by the SGAM Information Layer. This software backbone collects the data harvested by the Control System devices and processes them into useful information. The information and processed data sets are made available to the **Business Applications** that were developed to fulfill the business objectives of the Smart Grid (e.g., demand response, provision of energy services such as local balancing, energy optimization, and aggregation of resources for market participation). In this way, business transactions with customers for basic and ancillary services within Modienet can be translated and incorporated into the ICT platform for a seamless integration of the power, information, and money flows within the microgrid.

4.3 Modienet system functions

The Modienet system functions are an output of the Process Model [27], and were derived from the objectives discussed in Section 2.1. Five main function categories are identified:

- integration functions;
- stability functions;
- operational functions;
- functions for balancing electricity exchanges in the industrial park, and
- market functions.

Fig. 10 depicts the Modienet system functions. Given the importance and pervasiveness of ICT systems, they should play an active role within Modienet in enabling the system functions.

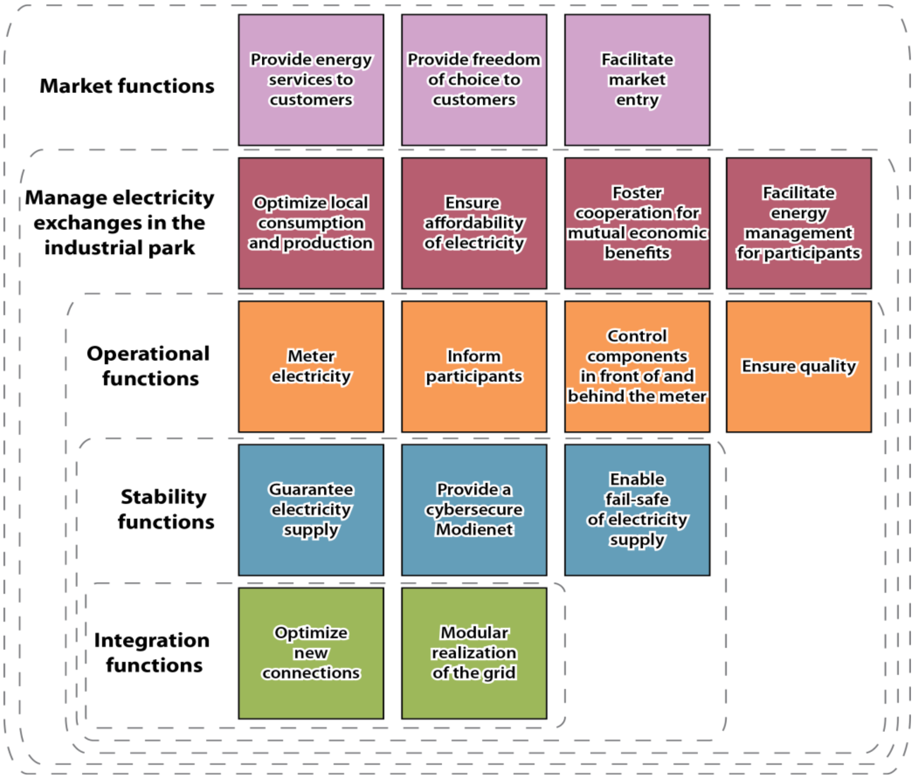

Fig. 10. Overview of the Modienet system functions

4.4 ICT System key performance indicators

The Modienet high-level system functions are translated into key performance indicators (KPIs) or pass/fail decision-making criteria for the Modienet ICT System. In order to enable the system functions mentioned in the previous section, the ICT system should form a

- flexible
- scalable
- reliable
- available
- secure

platform that ensures the integration and interoperability of the other layers of the Smart Grid architecture, whilst safekeeping the privacy of the data collected. The ICT system KPIs are depicted in Fig. 11.

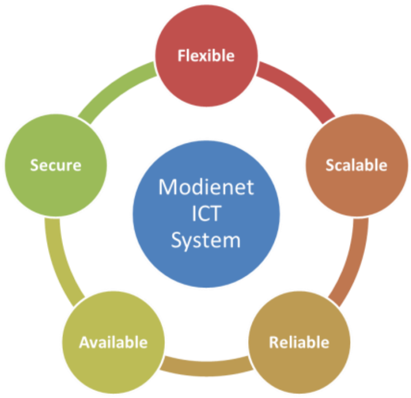

Fig. 11. ICT System KPIs

4.5 ICT Subsystem designs

The designs for each subsystem are summarized in this section. The full analysis of each subsystem can be read in [21].

4.5.1 Control System

The control system of Modienet's ICT platform comprises all instrumentation devices operating in the Modienet smart microgrid, as part of the customer, DER, and/or distribution network premises, namely:

- the main meters and controllers at the customers' and DER sites' points of connection to the electricity distribution grid; and
- all sensors and actuators placed behind the main meter at each of the customer premises and DER sites.

These can be already existing devices that are inherent to the above-mentioned stakeholders' individual processes (e.g., combined heat and power (CHP) units for industrial manufacturing processes, smart electric vehicle (EV) charging stations, and wind energy production), or be added on by the Modienet Energy Services Provider (ESP) for campus-wide applications.

4.5.1.1 System architecture

The system architecture of the Control System is depicted in Fig. 12:

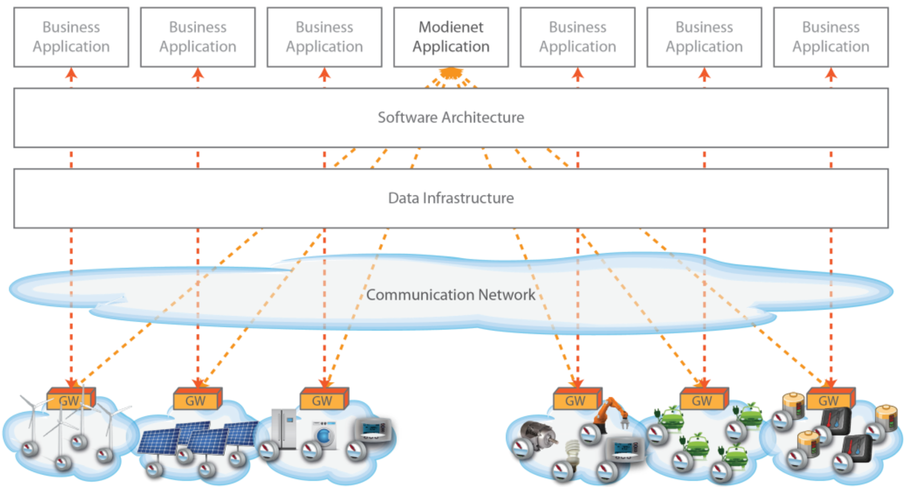

Fig. 12. Control System architecture (Adapted from [26])

Each cluster of devices at the Modienet participants' premises forms a local network, which connects to the Modienet campus network via a mediation device, such as a gateway or a remote terminal unit (RTU), denoted in Fig. 12 by "GW". This RTU converts the signals of each individual customer into a universal format. The Software Architecture will then process the data into information and store it for use by the Modienet Application for microgrid coordination efforts, such as demand response mechanisms at participants' premises. The information can also be used by other Business Applications for running local processes at customer premises.

4.5.1.2 Demand response applications

Demand response (DR) mechanisms aim to trigger changes in users' electricity consumption and/or local production patterns in reaction to price signals [28]. DR can occur in the short- or medium-term to reduce system capacity or shift energy use. As per the Modienet Process Model [27], three DR mechanisms will be set in place:

- **load scheduling**, where equipment and processes at participants' premises are programmed to run or not, according to spot pricing signals;
- **load shaping**, where equipment and processes at participants' premises are programmed to run according to the availability of flexibility in the microgrid; and
- **peak shaving**, where non-essential equipment and processes at participants' premises are programmed for curtailment to reduce the local distribution system capacity in order to optimize power system assets, and/or avoid penalties for surpassing contracted peak capacity.

The participants will be coupled to the Modienet Demand Response Application by using the participants' existing industrial or building automation systems. Each participant gets a custom-made application based on the number and type of control devices (e.g., process control units such as meters, valves, and pumps, charging controllers, pitch controls for wind turbines, and active/reactive power controls for PV inverters).

Apart from its technical simplicity and low tie-in cost, this solution can be marketed as a simple, plug-and-play connectivity box to Modienet. Because this solution requires hardwiring the customer's control systems, some customers might find that a violation of their internal privacy/security policies. It is the Control System provider's duty to set policy and security mechanisms and agreements in place in order to reassure and ensure the customer that their processes and data will remain safeguarded.

Fig. 13 depicts the chosen system architecture of the DR Control System.

4.5.1.3 Advanced Metering Infrastructure (AMI) requirements for Modienet

The Dutch Metering Code establishes the type of instrumentation required at the POC between the distribution grid and consumers, small-scale producers, and other electricity networks [29]. Solutions relating to Modienet's AMI should take into account existing privacy, security and performance regulations laid out in [30]–[33].

Large-scale consumers, prosumers, and producers

Large-scale consumers (connections larger than 3×80A) are equipped with telemetric metering devices. The telemetry device is usually a remote terminal unit (RTU) or general-purpose process control computer that collects the desired data from meters and transmitters placed at the customers' point of connection (POC) with the grid. The telemetry unit sends the data to the distribution system operator's (DSO) supervisory system via a communication network. Although the telemetry devices in all three cases are remotely accessible by the DSO, the data transmitted are read-only and communications go one way. The data collected by the telemetry unit can be extracted for use in Modienet as shown in Fig. 14.

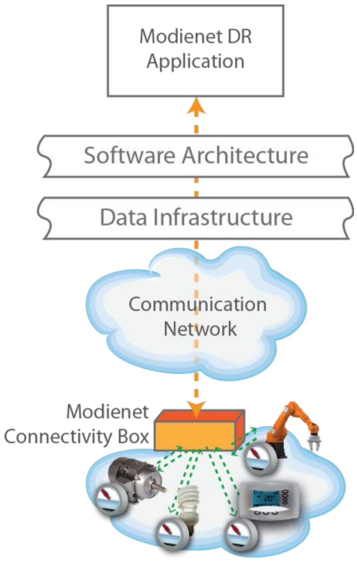

Fig. 13. System Architecture of the Demand Response Control System (Adapted from [26])

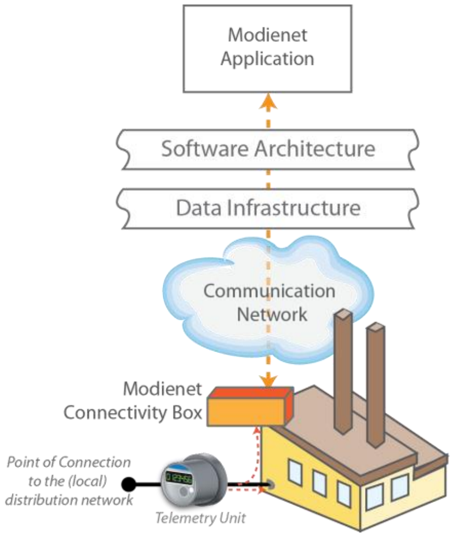

Fig. 14. Extracting telemetry data for use in the Modienet Application

Small-scale consumers

As part of a roll-out plan that started in 2012, smart meters will be installed by default by the DSO for all new connections of small-scale consumers and *prosumers* (connections of less than or equal to 3×80A) [34]. Metering data from these units can be collected for use in Modienet by placing an interfacing module at communications port P1, is reserved for read-only communication with the metering system. The read-only functionality is intended to avoid compromising the metering system or the data collected from it. Extracting meter data by setting up an interfacing module at Port P1 has the advantages of being low-cost and simple to install, operate and maintain. Data security can be ensured by setting up access control through authentication and logging. In this case, the customer only needs to authorize access to this port for use in the Modienet Application via a written agreement. The port can still be accessed by the customers themselves for their own data analytics, or they could depend on energy services provided by the Modienet Application or third-party business applications.

The other available communications port (P4) is only accessible to independent service providers (ODAs), energy suppliers, and grid companies. That means that the Modienet ESP would need to become a certified ODA or licensed metering company. Apart from the investment costs and time associated with getting the certifications, the data pulled by Port P4 from the DSO supervisory system database have a delay of one day; the smart meter pulses are buffered in a 24-hour period then transmitted at the end of this period. This is not practical in a system where decisions are taken on a near real-time basis. However, pursuing ODA certification could be interesting if the number of small-scale customers scattered throughout the different future implementations of the Modienet microgrid is large enough (typically, in the range of hundreds) to use the data for aggregation and day-ahead market participation.

4.5.2 Connectivity System

The Connectivity System refers to all physical connections, data links, and telecommunications networks between the different Control Systems found within the Modienet microgrid and the Data Infrastructure that houses the Modienet Software Architecture. The Connectivity System also plays a role within individual customer, DER, and distribution network premises by interconnecting the devices within a local area network. All data transfers between the instrumentation and the data infrastructure need to be available in a reliable and secure fashion, following the customer's quality criteria and in compliance with existing/possible future regulations. Furthermore, the implementation of a new item in the local or wide-area networks must have a low technical and financial impact on the overall connectivity system.

In Modienet a high volume of data is captured, transported and viewed by numerous different participants in the microgrid. These data need to be handled in a secure, reliable and scalable telecommunications network. There are several technologies that can be employed to provide Modienet with a connectivity system, such as IP technology, and industrial and utility bus systems. Because most of the data collected in the Modienet microgrid will be computed on ICT-based platforms, basic architecture of the telecommunications network needs to meet the requirements of common ICT systems.

Apart from the capability to establish a connection, reliability and scalability are necessary in the telecommunications network. In the modular concept, many changes must be foreseen in the network in order to make it scalable. Network architectures for this kind of applications are typically based on a client-server solution. In this type of solutions, an error in the network has a large impact on the system reliability; the network must therefore be based on proven technologies, in order to minimize this risk.

4.5.2.1 System architecture

The choices made for the connectivity strongly depend on the specifications of the Control System, the frequency and bandwidth of the data collected and their projected growth or evolution throughout the industrial park's lifetime; the choices made for the data infrastructure, the available budget, and the characteristics of the site in which the Connectivity System will be implemented (i.e., whether it's a brown- or a green field situation). Apart from technical feasibility and cost of installation, operation and maintenance, the solution has to be future-proofed for new developments in the area of the Internet of

Things (IoT), Machine-to-Machine (M2M) communications, and Business Information Systems for Smart Grid applications. In order to achieve this, it is important to have a Connectivity System provider for Modienet with the know-how, experience, and contacts with third parties in order to deliver a future-proof (i.e., flexible, scalable, reliable, available, and secure) technical solution and a transparent, competitive, and attractive service contract for the industrial park in question. Two options can be distinguished:

1) Campus telecommunications network

The campus network is a private network inside the Modienet. It consists of a redundant ring at the physical boundaries of the Modienet microgrid, as shown in Fig. 15. The system is redundant because the private ring has two Network Access Points; that is, it is connected to the public telecommunications network —depicted as a grey cloud labeled "Server Provider Network" in Fig. 15— in two places. The Network Access Point functions as a marketplace where telecommunication service providers can offer their products to clients located within the confines of the campus network. The campus network can also communicate with the Modienet Data Infrastructure, which is illustrated by the grey server racks and storage symbols in Fig. 15.

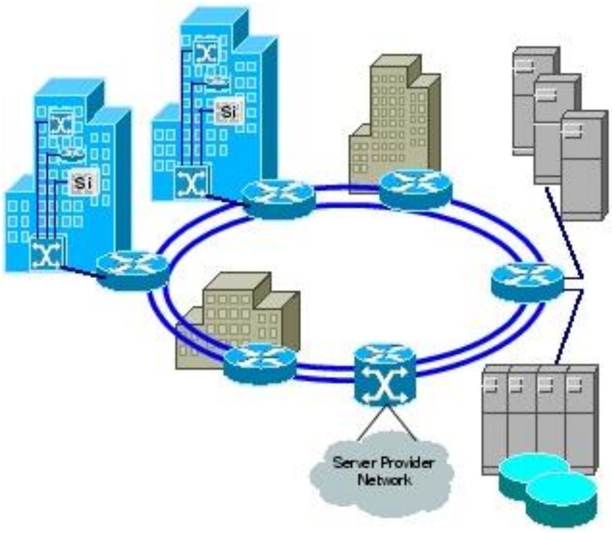

Fig. 15. Campus telecommunications ring network [35]

Three types of guided media can be distinguished through which data could be transmitted and received in the campus ring:

- copper twisted pair wiring from standard telephone lines;
- copper coaxial cable; and
- optical fiber.

Although optical fiber networks require high investment costs and are difficult to exploit, their large capacity bandwidth can help future-proof the Modienet communications network by supporting a very high number of connections per shared line. Apart from yielding fast system response times thanks to the high data rates, such a network enables more services that can be provided to the end-user; e.g., VOIP, Internet, security services.

The disadvantages can be countered if a strategic partnership can be formed between the connectivity system provider and the suppliers of the telecommunications network of the industrial park. That way, risk is shared between both parties, and investment costs can be split. Additionally, the investment costs could only be justified if the campus ring is used by all participants for other bandwidth-intensive services that require fast data rates (like VOIP, Internet, telephone, and video) apart from data transmission to and from the Modienet Application. For this reason, it would make sense to have Park Management make strongly recommend its tenants to use the Campus Network infrastructure for all their data communications needs. If Modienet participants agree to this, but chose a telecommunications service provider that does not, on account of company policy, employ third-party infrastructures (like the private fiber optics ring at hand) to deliver its services, then there would be a problem of having not two, but three or more network rings in the industrial park premises. This problem can be solved by making agreements beforehand with the telecom providers so that the risks associated with using infrastructure not owned or maintained by them to provide a service can be minimized. Another possibility would be to form a strategic partnership with the owner of the public telecommunications network to try to make the campus ring an extension of the public network, opposed to a private ring.

2) Wireless M2M communications

Wireless connectivity technologies based on cellular networks (such as UMTS, GPRS, 3G and 4G) can be easily connected to field devices on customer premises and establish a connection to the Modienet Application using multiple low-power transmitters placed in a hexagonal tile pattern that covers the physical area of the industrial park. An example of such a system is depicted in Fig. 16.

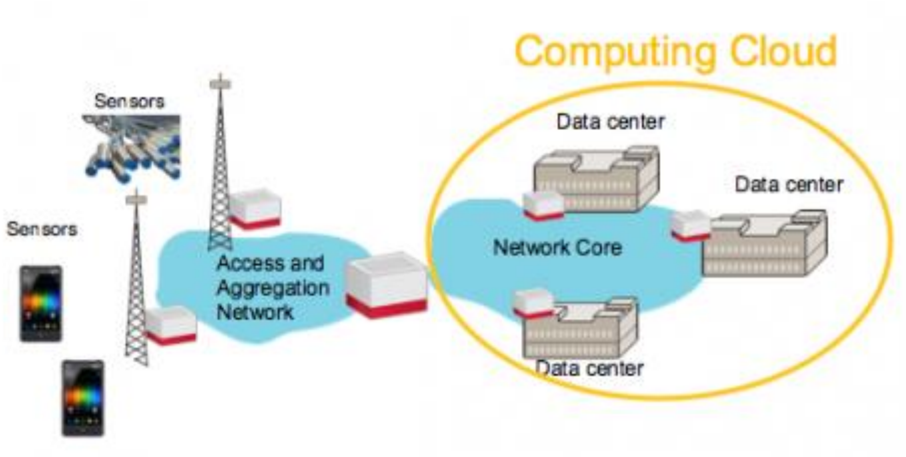

Fig. 16. Wireless M2M telecommunications network [36]

M2M wireless communications is an industry that has not yet reached maturity. This means that efforts are being made to iron out the cons and add more pros to the system characteristics with every new generation of cellular technology. Very likely, the shortcomings (e.g., service interruptions due to fading and limitations on channel availability) will be reduced as telecommunications networks are optimized for stationary or low-mobility applications (as opposed to mobile ones), and as greater bandwidths and faster data rates bring about new services that will not have to clash with the use of personal communication devices [26].

The choice must be made depending on the specific situation of the industrial park where Modienet will be implemented. Some key factors include:

- stage of maturity of commercially-available M2M communications technologies by the time Modienet is implemented;

- the possibility of dropping prices on optical fiber networks;
- strategic partnership opportunities;
- available budget;
- whether the industrial park at hand is a brown- or green field development;
- available infrastructure (planned or existing); and
- constraints related to geographical location.

4.5.3 Data Infrastructure

The Data Infrastructure is the collection of data storage, processing power and other computing resources that enable the storage and processing of the data harvested in the Modienet network. Furthermore, it hosts the coordinating algorithms necessary for Modienet's day-to-day activities.

The availability of information is becoming more and more important for environments in trade markets and 24/7 businesses. Thanks to declining costs of storage and processing power, the collection and analysis of data to drive business decisions has become increasingly pervasive over the last decade [37]. The volume of data has become so large, however, that the processing power from a single computer can no longer satisfy businesses' needs to make decisions based on analytics on a near real-time basis [37], [38]. These problems have prompted innovations in computing technologies, which substitute rigid, centralized techniques with distributed storage and analysis resources [39].

The coordination programs for balancing supply and demand, and the local optimization of energy use through flexibility will require lots of computational power and a considerable amount of storage as data keeps growing with the passage of time. It is necessary to have a data infrastructure that is flexible and scalable; reliable and widely available, yet secure, to guarantee the continuity and stability of the business decisions derived from the data analysis. Furthermore, the benefits of the data infrastructure should come at an affordable price. That is, that the cost of implementing big-data should not outweigh the economic value it creates.

4.5.3.1 System architecture

The chosen solution consists of a system in which all Modienet participants and the ESP share the available data storage, computing resources, and information services. Although this configuration is not as customizable as variant (i), data redundancy is eliminated, and customers can expect the same quality of data and high system reliability. Most importantly, Modienet participants and the ESP share in the system's financial and technical risks associated with setting up, operating and maintaining the data infrastructure. It also facilitates scaling up on storage capacity and processing power as more customers are connected to the Modienet microgrid.

Participants and the ESP have access to different Business Applications hosted in the data infrastructure, but they can only see and interact with the information models for which they have been authorized and authenticated in the Software Architecture settings. The same security and data privacy policies apply to everyone. Participants at user premises can access the Business Application through the Modienet Wide Area Network.

Shared computer resources will be achieved through semi-private cloud computing services in a pay-as-you-use business model. By signing on a large number of clients and sharing resources among this pool, they are able to offer computing as a utility service, like gas and electricity. Although it is more expensive than public clouds, customers can fully customize their system, which is a requirement for a highly specialized application like Modienet [40]. Customers can additionally rely on the expertise of datacenter service providers to set up, operate and maintain the computing resources while maintaining control of the Software Architecture characteristics. That way, customers and the Modienet ESP do not have to deter from their core competence to invest excessive time and money on setting up their own data infrastructure, without sacrificing customizability.

The system architecture for the Data Infrastructure is shown in Fig. 17. In this schematic, the clients are connected via the Connectivity System to the datacenter, where the Application Infrastructure is hosted, and where computing power and storage resources are shared among the clients. Each client's own Business Applications are built on the Application Infrastructure. Although the latter is common for every client, access is restricted to the Business Applications via stringent access controls, both physical and software-based.

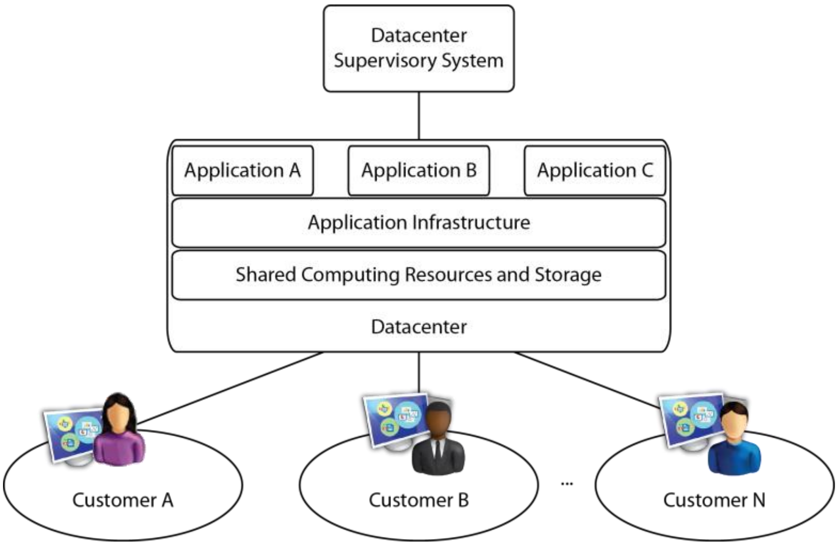

Fig. 17. System architecture for the Data Infrastructure

Industry expectations are that cloud computing (in all its variants) will become a commodity within 5 to 10 years. Eventually, the infrastructure will probably be able to migrate between datacenters in the same way as mobile phones nowadays migrate between towers and providers. In order to distinguish themselves from their competitors, Data Infrastructure providers should provide services with the following technical and socio-economic outcomes:

- maintainable without influencing the user environment;
- scalable up/down depending on the customers' wishes; and
- sustainable in terms of efficiency in power consumption and low carbon footprint.

The socio-economic outlook for this system must be:

- future-proof to address growing user requirements and increasing data volumes; and
- based on a pay-as-you-use pricing scheme that can effectively address customer needs by offering different service and availability levels.

Availability is a key requirement for the Modienet Smart Grid, and therefore it is also a crucial aspect of the datacenter environment. Service contracts made with the customer are based on a standardized tier system developed by the Uptime Institute, where each level describes the requirements for the datacenter infrastructure and availability of data. A higher level indicates greater availability and a higher price.

In addition to availability, information security and privacy are very important not only in terms of business reputation and customer satisfaction, but also in terms of legal requirements. The upcoming European General Data Protection Regulation, to be enacted in 2014 and enforced by 2016 will set policies and mechanisms in place to protect individuals and businesses against data breaches, empower them with data portability, and make transparent what the responsibilities and accountabilities of information service companies are when a service contract is signed. Datacenters could benefit from using certifications such as the ISO 27001 standard for information security and data protection to comply with this and other data protection policies and regulations.

4.5.4 Software Architecture

To manage all kind of automation aspects of Modienet, several business applications (user-apps) are needed. The kind of applications that are needed and the data that needs to be processed and provided depend on the Modienet Process Model and the requirements of each individual Modienet implementation at a specific industrial park.

The main function of the Software Architecture is to provide a standardized data model and a standardized way to get or send data to the field equipment, or assets. In addition, it should be possible for third party application developers to design and implement Modienet-based apps.

The Software Architecture consists of three layers:

- the **user-apps**, which are all applications that fulfill Modienet automation needs (e.g. energy monitors, dashboards, reporting tools, etc.);
- the **assets**, or all of the customers' energy-related sensing and actuating devices; and
- the **asset warehouse**, which is the connector, or intermediate layer, between the user-apps and the customer assets. This layer is responsible for all communication between those two parties.

When an asset warehouse is available, the amount of user-apps and customer devices could technically be unlimited because it is designed to expand dynamically. The Asset Warehouse will be the central (single) point for user-apps to obtain and transmit their data. With this approach, customers have to make agreements with one single party only (the asset warehouse owner). There must be strict, standardized procedures on how the Asset Warehouse owner deals with the data and who gets this data. The major benefit of this is that the user-app-providers do not have to talk to every single customer, and vice-versa.

The Asset Warehouse reads asset data via different open- and proprietary protocols into standardized templates. It translates and stores all data and asset interrelations into a standardized data model which is made available to the user apps in real-time. The warehouse could also cache data, so the apps can work without an active asset connection. It is possible to easily create, modify, and delete assets and customers in this configuration. The Asset Warehouse and its components are schematically depicted in Fig. 18.

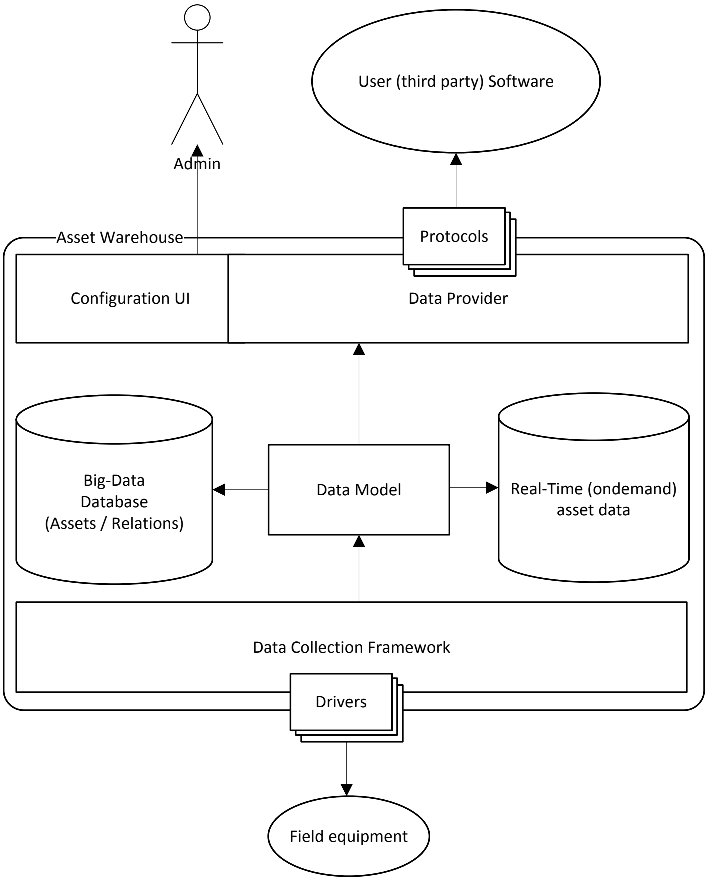

Fig. 18. System architecture of the data warehouse

The main benefits of an asset warehouse are:

- **One central data owner**. This allows all kinds of interpretations an analysis of the available data. This will help future development and evaluation of the Modienet concept.
- An Asset warehouse should **lower the effort a customer needs to invest** in setting up data communication to the Modienet domain. Independent of the amount of Modienet apps, every customer has to make an agreement with one party: the asset warehouse owner.
- The same applies to **the apps-suppliers**. They also need to invest **less effort** to implement the Modienet communication layer. Standardized 'clients' could be made available by the asset warehouse owner.
- As every piece of information is stored only once, the **data integrity** is easy to manage.

4.5.5 Business Applications

This section briefly discusses the variety of Business Applications suited for the Modienet microgrid. This includes front-end applications that are required for day-to-day operations as well as those needed for the creation of new, value-creating services for the Modienet ESP, and/or its customers and DER owners/administrators. The algorithms for the different applications required for Modienet fall out of the scope of the project. The types of applications needed for Modienet were derived from the specifications laid out in the final report of the Process Model [27] and are meant to fulfill the following functions:

- Day-to-day operations:
    - Matching supply and demand
    - Supervisory control
    - Local optimizations through:
        - Generation-side management mechanisms
            - Peak shaving
            - Generation forecasting
        - Demand response mechanisms
            - Load scheduling
            - Load shaping

    (note: the objective functions of the optimizations can be event-driven or based on price or energy efficiency)
- Customer services:
    - Portfolio management
    - Billing
    - Ancillary / future services
- Market
    - Bidding/buying flexibility
    - Reserve market participation: power delivery contracts with TenneT and/or (VPP) aggregator

Business Applications are enabled by the data models created by the Software Architecture, and are tied in with and validated by the business objectives, opportunities, and cases of the Modienet Microgrid concept.

4.6 System Architecture

The Modienet ICT Platform system architecture is schematically depicted in Fig. 19:

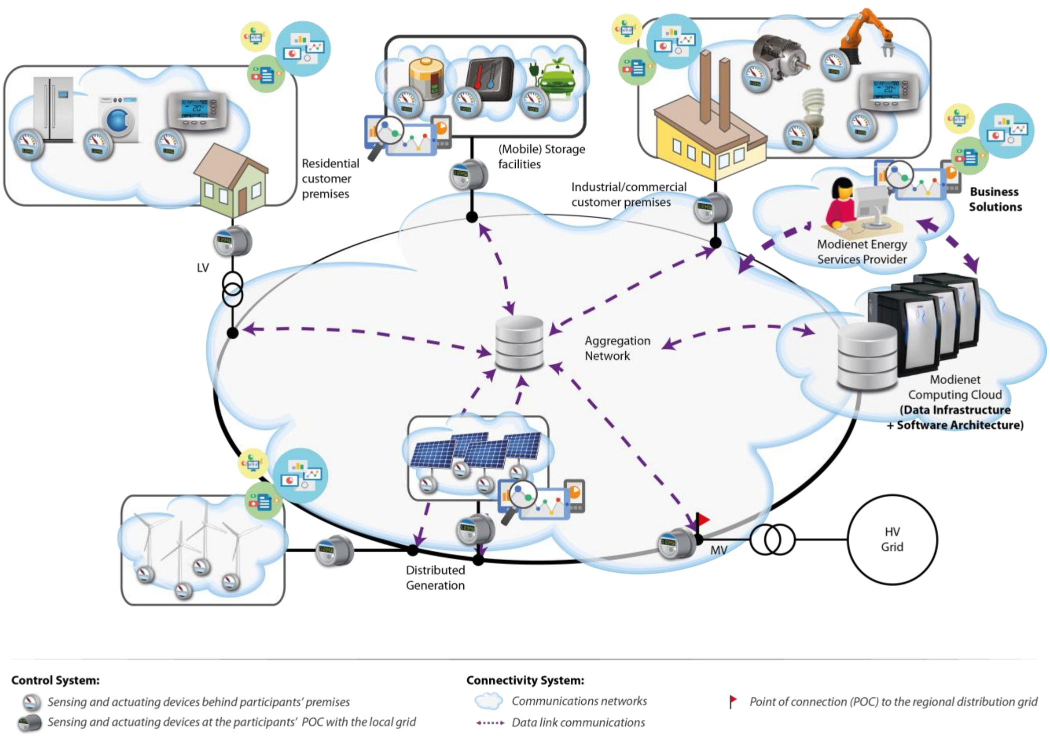

Fig. 19. The Modienet ICT platform concept (Adapted from [41])

The figure depicts a ring that symbolizes the medium voltage distribution network of the industrial terrain. This forms the basis of the Modienet microgrid. A metering device has been put in place at the POC to the main grid to measure energy and peak power. Sensors and actuators placed at customer, distributed generators, and storage facilities collect data regarding the electricity consumption and production that takes place onsite. Individual generators and storage units have devices put in place behind the meter both for internal optimizations and for aggregated control functions controlled by the Modienet ESP. Customer premises also have instrumentation behind the meter to control their internal processes and to bid their flexibility for demand-response applications. The Modienet participants can also gain insight on their electricity consumption and/or production patterns via dashboard applications.

The data collected by the control system is relayed via the Modienet communications network to a data warehouse hosted in a datacenter suite. Apart from providing storage space for the Modienet data, the datacenter also supplies the computing power to standardize the incoming signals and create relations to process them into information and assets that can be used in the Modienet Application for coordination and aggregation purposes, such as: matching supply and demand in the microgrid, supervisory control, local optimization of resources, portfolio management, billing, demand-response services, reserve market participation, and other emerging / future services.

Modienet participants should also be able to create custom applications with the data models created by the Software Architecture to gain insights on their energy consumption and production patterns, and to keep track of the flexibility they bid to the Modienet system and its financial rewards.

Chapter 5
Route-to-Market Strategy

This section outlines the route-to-market strategy for ICT Systems for Smart Grid Applications in the Business-to-Business Market. The main purpose of this chapter is to assist Cofely in developing a medium- to long-term business strategy regarding market rollout of the ICT system design and/or its components for Smart (Micro)Grid applications within the BtoB market in general, and the Modienet microgrid concept in particular.

5.1 Context

Full-fledged first commercial implementation of Cofely ICT solutions for Smart Grids should occur in approximately three years, with a planned implementation in phases. This layered implementation should ideally consist of relatively low-cost add-ons with high expected benefits. The selected business strategy, apart from facilitating the company's entry into the Smart Grids market, should guarantee Cofely's permanence as a key player as the market evolves through time. It should also take advantage of —but not necessarily limit itself to— the company's existing products and/or services, technical expertise, business know-how, reputation, and vertical integration with other brands of GDF SUEZ, to offer new attractive, empowering products and/or services to its customers.

5.2 Capturing flexibility value mechanisms

Implementation should be done incrementally, with solutions that grow in complexity, but are enabled by the previous implementation in order to maximize benefits and reduce marginal costs. Each new solution will build on the previous one to offer/up-sell alternative uses for the product or additional services.

Implementation in increments will additionally promote customer acceptability, foster customer segment growth, and improve quality perception. When early adopters show satisfaction in the product they are using, new clients could be attracted and convinced not only to become an early majority of the first implementation, but also early adopters of the more sophisticated, subsequent implementations.

Several business opportunities can be identified in each of the implementation phases, in order to capture the value of flexibility in the Smart Grid.

5.2.1 Energy monitoring

Before trying to convince the customer that flexibility is a valuable concept for them rather than a Smart Grid abstraction, it is first necessary to raise their awareness on how electricity is consumed at their premises and how much it is costing them. In the era of 24/7 economies where information is king, customers need all different kinds of data inputs in order to make business decisions, diagnose problems, and spot opportunities to increase cost efficiencies. Energy monitoring would be one of those inputs.

5.2.1.1 Value proposition

Capturing electricity consumption data, sifting it out to extract meaningful metrics that can be turned into information, and harvesting this information into knowledge adds value to the customer's decision-making process and improves their business performance.

The energy-monitoring implementation would be a service package (bundle) contracted by the customer to have a dashboard portal installed in which visual descriptions and diagnoses of the customer's electricity use are portrayed. Depending on the level of detail they want to attain, they could select whether they want to see this information refresh itself on a daily, hourly, near- or real-time basis. These dashboards can be custom-made to the client's wishes, and realization only requires tapping into their existent building or industrial automation systems, regardless of what kind of vendor installed this control system. Naturally, the procedure is simplified (in terms of technical difficulty but also in terms of customer agreements) if the customers have Cofely control systems installed at their premises. The data collected can be read directly from the control system buffers, or processed and stored in a secure Cofely data cloud for historic descriptive statistics and self-benchmarking.

Customers would pay a monthly fee, whose amount would depend on the number of data points to be collected, the complexity of the desired energy dashboards, and the contracted space in the cloud. The intention is to bundle everything into a single package, so what the customer is actually paying for is an energy monitoring kit consisting of a BtoB connectivity box (which captures the data) and visualization portal with three different service layers to choose from (e.g., bronze, silver and gold). Installation and maintenance is hassle-free for the customer. Operating the system is absolutely painless given it is a read-only system in which the user can only choose different ways of viewing and reporting the information contained in the cloud.

In other words, the customer leases the control system from Cofely, who is in charge of maintenance and servicing. The data collected is stored in our own datacenters and the customer pays for that in a pay-as-you-use scheme (in terms of storage space and computational power —Infrastructure as a Service (IaaS), and also access to the data processing software —Software as a Service (SaaS).) Bundling increases perceived value, reduces the initial investment costs, and facilitates upselling.

5.2.1.2 Customer profile

Our assumption is that customers interested in getting such a system will already have some sort of building or industrial automation system set in place at their premises, which makes prohibitive investment costs something less to worry about. But if they did not, on account of them being a new factory or consumer building, the Cofely Industrial and/or Building Automation business units could cross-sell their customers such an energy monitoring kit with the installation of the automation system as an add-on.

By gaining insight on where they are spending their electricity and the costs in which they incur, they might be persuaded to look, in a later stage, for ways in which the flexibility of their own loads can help them use their electricity more efficiently and/or pay less for what they consume. Shifting from using information as insight to foresight (as depicted in Fig. 20)

—i.e., moving from using descriptive statistics to make business decisions to receiving predictive, intelligence-based support for the decision-making process— requires investment in a more complicated system. Instead of getting a new information platform all together, they can simply upgrade their energy monitoring kit to the second implementation of Cofely's Smart Grid-ready ICT solutions.

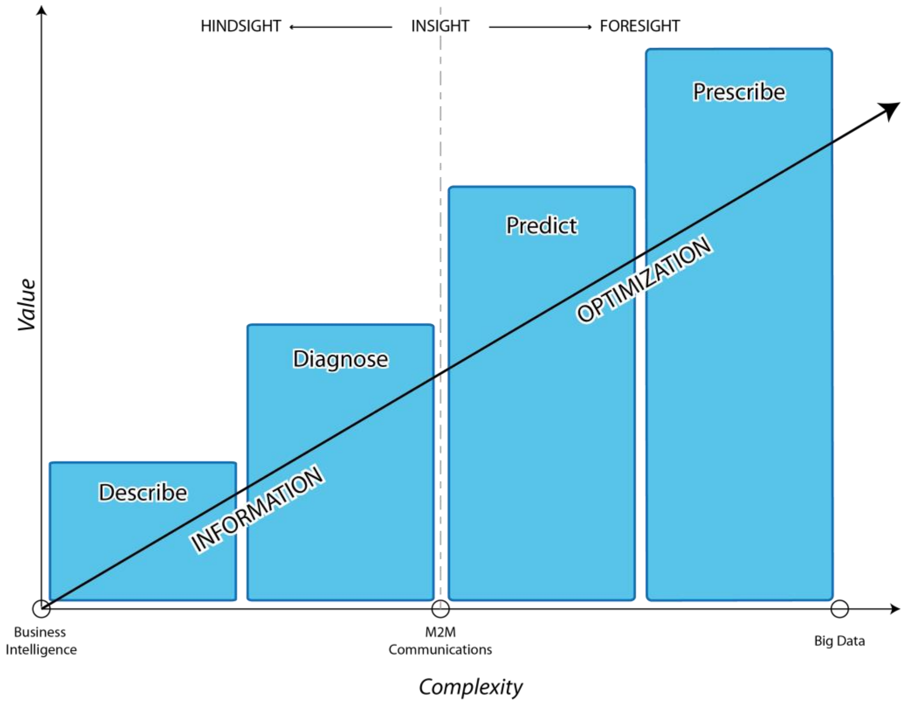

Fig. 20. Capturing the value of data (Adapted from [42]**)**

5.2.2 Demand Response

5.2.2.1 Value proposition

This upgrade consists of adding a simple demand-response program to the Energy Monitoring service bundle. This demand-response program is custom-made to the customer's specifications and installations and is meant to shift flexible loads to off-peak times to reduce overall electricity costs, as schematically depicted in Fig. 21. These savings consist of lower cost of energy (€/kWh) and reduced contracted peak capacity (€/kWp). Reduced contracted capacity also translates into cheaper connection costs for the customer, as less investment in infrastructure is required for the regional Distribution System Operator (DSO). Inventorying flexible loads is done by Cofely based on the historical data collected from the Energy Monitoring system (if available). Because of the high customizability of this service, the customer needs to be in close communication with the company at all stages of the demand-response algorithm design.

5.2.2.2 Customer base

The target market for this service bundle consists of existing Cofely clients: the Demand Response service can be cross-sold to customers of the industrial and/or building automation business units. It can also be up-sold as an add-on to customers who already have the Energy Monitoring System installed.

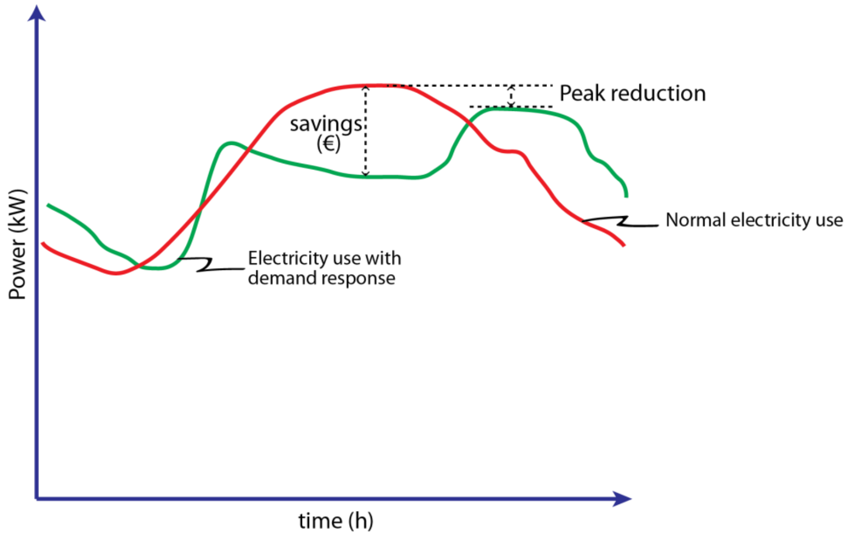

Fig. 21. Schematic representation of a peak-shifting demand-response mechanism

5.2.3 ESCO service contracts

Perhaps the customer has little or no interest in gaining control of its own flexibility to reduce its operation costs, and is more concerned with securing stable prices for its electricity supply, even if it means paying for slightly higher electricity tariffs than the actual market value. Flexibility is a highly untapped resource at the moment. If electricity prices fluctuate in the future, the value of flexibility will increase, but so will the value of having stable electricity tariffs. This is what makes the business strategy of ESCO service contracts so attractive. As a third implementation —or rather, as an alternative to the second implementation—, Cofely should offer these types of customers fixed-price, long-term electricity contracts, in which their costing becomes predictable.

5.2.3.1 Value proposition

Such a contract would enable customers to divest the non-core problem of variable energy costs, and convert it into a predictable, constant figure. To the customer, this means one less variable to consider for their financial planning, as well as less dependence on the local/global economic energy climate and possible rise and volatility of future electricity prices.

Through this service, Cofely enables the risk mitigation of its customers' energy situation, as a sort of insurance/assurance company. For clients, making a capital investment in the present will save them money on variable costs (which are, incidentally, non-core costs) in the future. It is true that Cofely would be assuming its customers' market risk, but they can mitigate it by managing the customers' available flexibility with the use of the demand-response mechanisms mentioned in the previous section. Any demand-response program that can be successfully used by Cofely to reduce electricity costs will result in profit, since what customers are buying is packaged predictable cost. Of course, Cofely would have to assume the payback time of investing on the Demand-Response system that will be installed at customer premises, but that is included in the service premiums, which compensate for Cofely assuming its clients' variable costs and risk, and investing in the creation of custom-made demand-response programs to effectively and efficiently capture the flexibility of the customer site.

In this scenario, two core competences of Cofely come together to offer a service that can distinguish itself from its competitors: Cofely's experience in ICT systems and it is track record in marketing structured agreements in the BtoB and public-private sector for managing long-term contracts with financing options.

5.2.3.2 Customer profile

The customer segment in this case can come from cross-selling to clients of Cofely's automation and/or installation/infrastructure management business units, cross-selling to the Demand Response System customers, or up-selling to clients of the Energy Monitoring System.

5.2.4 Market participation

The Smart Grid concept and the value of flexibility are not only creating new roles, but also creating and opening electricity markets for the participation of consumers. With the increased intelligence of the power system, flexibility of individual consumers can be aggregated and traded within the geographical confines of a microgrid for participation in the reserve electricity market. At a larger scale, individual microgrids can be aggregated across different geographical domains to form a virtual power plant (VPP) that can participate in the spot market by bidding its flexibility as a balance responsible party, for example.

5.2.4.1 Value proposition

Cofely, as facilitator of this market participation, can assume the newly-created role of aggregator or participate in the spot market as a balance-responsible party that manages and trades the flexibility at the spot market or directly with other energy producers.

The final iteration of the Smart Grid-ready BtoB ICT system empowers the user in that the objective function of the demand-response mechanisms evolves from reducing customer costs to actually earning profits for the customers.

5.2.4.2 Customer profile

Customers in this instance can result from up-selling the Demand-Response system, or from cross-selling the service to industrial and/or commercial zones (i.e., microgrids) managed by Cofely.

5.3 Market

5.3.1 Client Needs

The customer needs, as discussed in the previous section, can be prioritized in terms of desirability and level of urgency:

- insight on their energy consumption;
- lower electricity bills;
- price stability in the advent of volatile energy retail and wholesale prices;
- less risk in their energy situation; and
- profit from their smart energy use.

5.3.2 Client profile

As discussed in Section 5.2, the targeted customer segment is the Cofely Building/Industrial Automation customer base that already has a control system in place at their premises. Because they are existing customers, acceptability not so difficult to achieve, switching costs could be high for them if they have to investigate other vendors, and also if there is an interoperability issue with the customer's existing control system and a 3rd party vendor's system.

5.3.3 Market Size

Market size is limited to cross- and up-selling the service to Cofely's existing customer base. However, as Cofely is the largest technical services provider in the Netherlands, this is a sizeable starting point; although, granted, not all of them might want to participate. As future, more sophisticated implementations are made, it is possible that the success stories of existing clients —the early adopters— can attract external customers that can either jump on the early majority bandwagon of a product or spearhead the early adopters of a new implementation.

5.3.4 Sustainability

The previous sections discussed how Cofely can be able to break through the Smart Grid market and position itself as a leading brand in Smart Grid services and solutions. Recapping, some of Cofely's competitive advantages are:

- existing market-leading position of the technical services providers;
- industry experience and technical know-how in a plethora of fields of expertise;
- support capability as a sole provider/installer/project manager, or as a link in a consortium of technology and service providers;
- strong financial standing; and
- local and global reputation as the leading brand for technical services and energy efficiency.

Cofely has competitors that can distinguish themselves in at least one of the above-listed categories in a comparable way to how Cofely distinguishes itself in the field. It faces competition from technology providers like Schneider Electric, Siemens, NXP or Honeywell who, are transitioning from a product company to a services provider. There are also installers and contractors such as BAM and Heijmans who are making a lateral move into offering Energy Management solutions for the buildings and constructions they already build and administer.

Cofely can ensure a sustainable competitive advantage in the Smart Grids market by organizing and bundling all of its in-house knowledge and activities around becoming a service operator and not just a technical installer. The business unit in charge of rolling out the Smart Grid-ready ICT BtoB bundle has extensive knowledge and counts with the trust of its customer systems, but does not have wide experience in energy supply or customer systems. In order to thrive in the Smart Grid market, Cofely has to take advantage of the wide range of applications and services of its internal business units, create strategic partnerships with third-party technology and engineering services providers where there is no in-house knowledge, and also look for opportunities for vertical integration with other GDF SUEZ brands. Only in this way can Cofely truly be the one-stop-shop for hardware, software and services in the Smart Grid concept.

5.4 Intellectual Property Rights (IPR)

Another way to maintain first-mover advantage in the Smart Grid market is to protect the intellectual property rights of Cofely proprietary systems. This includes, but is not limited to:

- algorithms for demand-response programs and aggregation;

- Smart Grid-ready BtoB box concept and all its services;
- privacy and security best-practices and policies; and
- the Modienet Smart Microgrid concept itself.

5.5 Operational Plan

This section briefly outlines the activities that need to be done and the resources needed to carry them out in order to deploy the business strategies discussed in the previous sections.

A series of test-beds need to be deployed in the short-to-medium term in order to provide a proof of concept of the technical solutions and the validity of the business strategies outlined in this document. At the moment, Cofely has been busy for over a year with implementations of the Energy Monitoring and Demand Response BtoB bundles with customers who find themselves in the innovator or early-adopter part of the technology adoption lifecycle. Once these two services launch as mainstream products (expected date: 2014), field tests on the aggregation algorithm will start.

Another significant test bed for the Smart Microgrid concept is, naturally, the Modienet concept discussed in the previous chapters of this report. Before building phase begins on the Modienet instance that will be implemented in the A1 Industrial Park in Deventer, the steering group of the Modienet consortium needs to meet to discuss role allocations within the Smart Microgrid concept. In these meetings, discussion should be steered towards finding ways of implementing the technical solutions the Design Team came up with and the business strategies outlined in this document, in order to take advantage of flexibility; and to find opportunities to work together with other GDF SUEZ brands to exploit flexibility in the Smart Grid in a vertical way. Adequately merging business objectives with technical solutions can tilt the balance in favour of a successful proof of concept. Currently, Cofely has successfully applied for more government grants to explore other implementations of this microgrid concept in other brown-and green-field situations. Technically, it is a very appealing concept, but it has to make financial sense in order for these concepts to survive without government funding.

The actual market roll-out is not expected until three years from now. Until then, it is necessary to use the results of the innovator and early-adopter test cases in order to write a solid business plan, come up with a solid business model, and do a more thorough market research. These tasks fall out of the scope of this research.

Chapter 6 Conclusions and Recommendations

In this final chapter, conclusions and recommendations are given regarding the ICT System for the Modienet Smart Microgrid concept.

6.1 Conclusions

The main purpose of the project was to assist Cofely in designing an ICT Platform for Smart (Micro)Grid applications, and developing a business strategy regarding market rollout of this system and/or its components. The design and business strategy proposal were framed in the context of Modienet, a Smart Grids pilot project initiative spearheaded by Cofely.

The principal results and conclusions of the project are presented here.

The Systems Engineering design methodology

Systems Engineering proved to be an effective design methodology. It captured the complexity of the problem and the stakeholders involved while simplifying the design tasks by breaking down the problem into systems of systems. For the inexperienced user, the learning curve might seem steep initially, but the adage of *practice makes perfect* applies in this case: implementation becomes easier and the concepts become clearer with each iteration. Cofely also has the in-house expertise to provide support with getting familiarized with the concepts and managing the overall learning process.

The “Reverse” SE method proved to be a very useful tool to successfully apply the SE methodology while simultaneously using it as a design tool. By taking a concrete example, it was easier to retrace the steps of the designers’ internal thought processes and clarify them for the other stakeholders and the client. Systems Engineering is not only valuable as a design methodology, but above all, as a way to make the Modienet concept a replicable, repeatable blueprint for any type of industrial or commercial areas, be them green- or brown-field instances.

ICT Systems for Smart Grid applications

ICT is the great enabler of the Smart Grid because it is present in every domain and zone of the electricity power chain, as well as in every functional layer of the SGAM framework. This is also evidenced by the amount of Modienet system functionalities that are related —either directly or indirectly— to the ICT system.

By designing a flexible, scalable, reliable, available, and secure platform, the integration and interoperability of Smart Grid devices and processes can be ensured. Given the complexity of this problem, however, this was not a straightforward task, but rather required breaking down the ICT system into smaller subsystems —the Control System, the Connectivity System, the Data Infrastructure, the Software Architecture or Application Infrastructure, and the Business applications or Solutions— and working on the designs one level of abstraction at a time.

Apart from the flexibility (interoperability), scalability, reliability, availability, and security requirements for the Modienet ICT platform, cost (albeit qualitatively) plays an important role in determining the design choices of every subsystem. Onerous, upfront investments tend to deter customers from participating in novel technological endeavors such as the Smart Grid. Customer acceptance and willingness to participate cannot only be achieved through technical solutions, but rather by building trust, creating relationships, and offering values that only exist in the Smart Grid and not in the traditional power system.

Capturing the values of the Smart Grid

One of these values is flexibility: decoupling demand from supply by means of storage or a change in electricity consumption patterns. In order to exploit flexibility in the most optimal way possible, it is necessary to have a good control of how energy is being produced and consumed onsite, and how it could be used more efficiently to minimize electricity costs or peak capacity in the distribution network. Regardless of which of these two objective functions are used, they both require ICT systems to work in synergy with the other systems of the Microgrid.

Capturing the values of the Smart Grid —empowerment through information and flexibility— is a must in order to break ground and thrive in the burgeoning Smart Grids industry. It is also important to use flexibility to create sustainable business models, for Modienet in general and the Modienet ICT System in particular, in order to gain independence from available grants and subsidies for pilot projects.

Attractive opportunities in the electricity value chain

There is great potential to exploit these values with the in-house knowledge of Cofely and by having other brands of GDF-Suez, such as GDF-Suez Energie Nederland, represented along the entirety of the electricity value chain. The strategic vision at mid- and long term is to transform Cofely from a technical installer to a service operator. By bundling and organizing its in-house activities, it can become a strong competitor in the ICT services for the Smart Grids industry.

6.2 Recommendations

Based on the above considerations, in its quest to make a name for itself in the Smart Grids industry, Cofely can benefit from pioneering Smart (Micro)Grid initiatives such as Modienet and implementing the concept in numerous green- and brown-field test beds. Successful implementation of this concept requires not only technical solutions, but also transparent contracts, and security, service-level and privacy policy agreements in order to gain and retain customer satisfaction, trust, and acceptability.

Its in-house expertise in building and innovating modular technical and business solutions, and its status as the Netherlands' largest technical services provider will provide Cofely a head-start with respect to its competitors. Additionally, Cofely should take advantage of its extensive partner network to acquire solutions where there is no in-house expertise available or where the learning curve would take too long for fast implementation of in-house solutions. In order to sustain this initial competitive advantage, it should harvest its extensive customer base to create cross- and up-selling services of the Modienet BtoB Connectivity Box. These cross- and up-selling services can, in turn, ensure the sustainability of the business model, given that the implementations of these solutions are modular in nature. One product/service implementation will not block changes in the customer premises or the industrial parks; on the contrary, it prepares the ground for alternative uses of the Modienet BtoB Box and additional services.

Investment in ICT technologies for Smart Grid applications is highly advisable, since there are many business opportunities in each of the links of the ICT system value chain, especially regarding the exploitation of flexibility. With the transition towards Smart Grids, new roles for coordinating electricity flows, such as the Aggregator or the Energy Services Provider, have been created. Who should fulfill these roles within the Smart Grid is still up for grabs. Opportunities for participating in the Smart Grid as a new player are vast. They might be especially attractive if there is a chance to implement turn-key solutions across all of the subsystems that make up the ICT system as a one-package deal. This can only be achieved by cultivating in-house expertise, fostering customer relationships, and creating strategic partnerships with third-party technology and other service providers like the regional DSO, energy suppliers, regulating authorities, and telecommunications providers.

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Appendix A
Approach

A schematic of the approach followed to solve the PDEng project task is shown in Fig. 22.

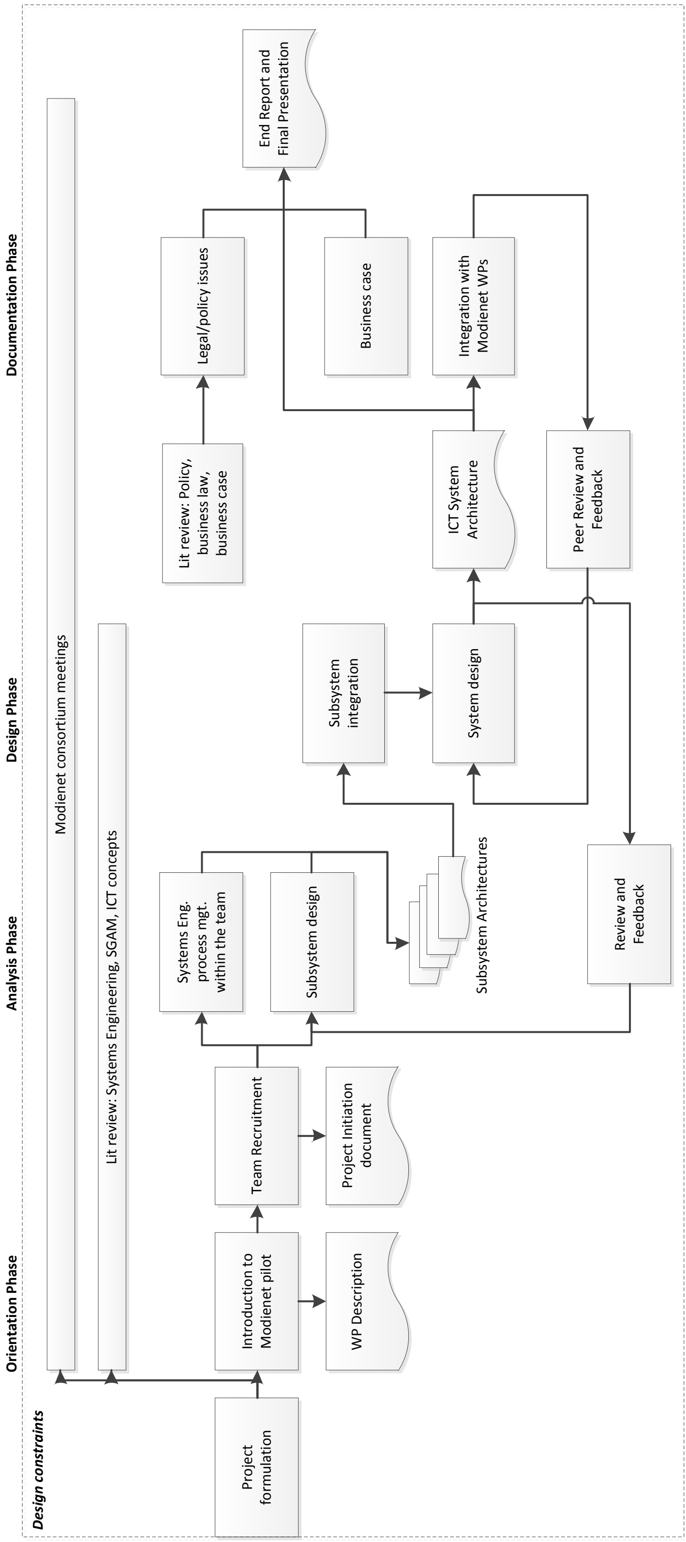

Fig. 22. Design Approach

Appendix B
Modienet ICT System
WP description

A1
BEDRIJVENPARK
DEVENTER
SMART choice.

WERKPAKKETBESCHRIJVING WP-107

Project: Modienet
Projectnummer: 16409001
Bedrijf: Cofely Zuid Nederland, Regio Zuidoost
Datum: 18-02-2013
Auteur: Rose Morales (RMO)
Versie: 0.3

Titel werkpakket	Werkpakket ID	Bovenliggende ID in WBS
Besturing	WP-107	

Doelstelling werkpakket	The information and communications layers of the Modienet smart grid should form a: - flexible, - scalable, - reliable, - available, and - secure platform that ensures the integration and interoperability of the other layers of the smart grid architecture, whilst safekeeping the privacy of the data collected.
Input van het werkpakket	- Systems engineering methodology - M2M Value Chain - Problem, stakeholder, scenario analyses - Function and requirement analysis - Other WP descriptions, contact persons - Smart Grid Architecture Model Framework (SGAM) - Background information (general literature, standards, benchmarks)
Werkzaamheden binnen het werkpakket	- Conduct applied research: Literature survey, market study, stakeholder analysis, definition of functionalities and requirements (in collaboration/communication with other WPs, stakeholders) - Extract practical business know-how - Elaborate a design concept of the ICT platform for Modienet, considering the interrelationships between the Market, Network, and System Users (consumers/producers/*prosumers*) - Iteratively validate and verify results at each step
Output van het werkpakket	- Literature survey summary - Market research summary - ICT platform concept for smart grids - Business case - Recommendations for future work
Ter acceptatie en ter toetsing aan te bieden producten	- Report on the ICT platform concept for Modienet - Implementation of BtoB box service/product for Modienet at local and aggregate levels
Relaties met andere werkpakketten	Yes, to all, but especially the one relating to Demand Response Mechanisms (WP Process Model led by Michiel van Lummig (MLU))
Verantwoordelijke functionaris Werkpakket	Roland Schneiders (RSC)
Planning	Startdatum: 19-Feb-13 | Einddatum: Beginning of July
Budget	Uren: 1728 | Geld: [redacted]
Van toepassing zijnde risico's op dit werkpakket	- Limited access to information - Sensitivity of information (IP issues) - Limitations due to regulations, policies and/or standards - Lead times, throughput
Van toepassing zijnde documenten	- Modienet PID, templates for the problem, stakeholder, and scenario analyses; other WP descriptions - SGAM (CEN-CENELEC-ETSI) - Standards (e.g., IEC), policies and regulations - Scientific literature (t.b.d.)

Appendix C
ICT System Team Kick-off Brainstorm

The purpose of the brainstorm held during the Modienet ICT System team kick-off meeting was for the participants to think about what the ICT System Objectives meant for each of their subsystems of expertise. The brainstorm formulation and its results are presented in Fig. 23.

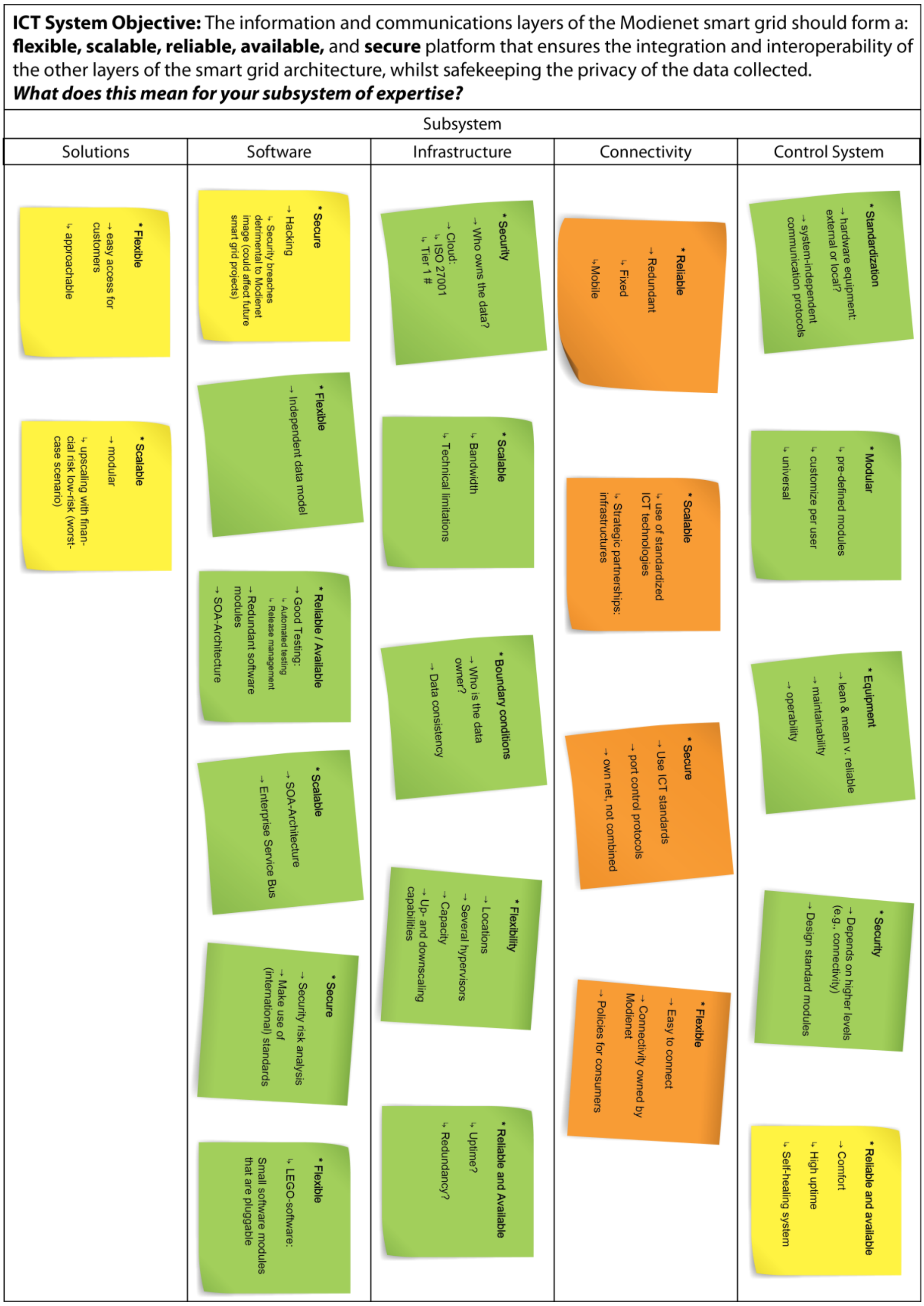

Fig. 23. Results of the Kick-off Meeting-Brainstorm

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