Small or medium-scale focused research project (STREP)

Energy Demand Aware Open Services for Smart Grid Intelligent Automation

SmartHG

EU FP7 Project #317761

Deliverable D7.3.1

Third Year Dissemination Activity and Exploitation Plan

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Consortium

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SEAS – NVE	SEAS	Denmark
Kalundborg Municipality	KAL	Denmark
Minskenergo	MINSKENG	Belarus
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Target Outcome	**d**) Home energy controlling hubs that will collect real-time or near real-time data on energy consumption data from smart household appliances and enable intelligent automation.

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Contents

Executive Summary

Objectives The role of WP7 in the SmartHG is to carry out dissemination and exploitation activities.

Retrospect The main achievements of WP7 during SmartHG second year were the following. As for the dissemination activities (Task T7.2), project results were disseminated through 5 talks at international scientific events, 5 talks at international events, 8 scientific papers acknowledging EU support. Furthermore, networking activities with other projects have been carried out. Finally, all dissemination tools developed in the first year (project web-site, leaflet, etc) have been improved and brought to a mature level. As for the exploitation activities (Task T7.4), our second year exploitation plan identified SmartHG services to be exploited along with their potential customers. This, in turn, defined an exploitation plan for each SmartHG partner as well as for the consortium as a whole.

Present Achievements During our third year, SmartHG results were disseminated (Task T7.2) through 5 talks at international scientific events and 12 scientific papers acknowledging EU support, networking activities with other projects have been carried out and all dissemination tools developed in the previous years (e.g., project web-site and leaflet) have been further improved. In our planned dissemination event in Kalundborg (Denmark), the project consortium has broadly disseminated SmartHG concepts and results to several stakeholders, as energy distributors, retailers, residential users, as well as to scientists, industry representatives, politicians, students and press.

A final SmartHG exploitation plan has been defined (Task T7.4). Our plan envisions the exploitation of the integrated SmartHG Platform as a whole as well as of the single services to both electricity retailers (in the short term) and DSOs (in the medium term). A plan to turn the SmartHG Platform into a profitable commercial product has been defined and a possible structure of the company which will bring the SmartHG Platform to the market has been envisioned, also addressing potential IP issues among project partners.

Impact Dissemination activities carried out during the third year have demonstrated the potential of the approach as well as the methods and tools developed within SmartHG to many relevant stakeholders (DSOs, electricity retailers, scientists, press and residential users). The final SmartHG exploitation plan and profitability analysis has defined a solid road map to bring the project technology to the market in the next years.

Chapter 1

Retrospect

In this section we briefly recall the main achievements (and the main shortcomings identified) in the second year version of the SmartHG dissemination and exploitation activities, which was described in Deliverable D7.2.1.

The main dissemination activities (Task T7.2) in the second year have been the following: SmartHG has been presented at 5 scientific events, project partners gave talks in 5 conferences, published 8 scientific papers acknowledging research financial support from the European Union, further 7 scientific papers related to the project topics and 2 on-line contributions. Dissemination tools produced in the second year were the first version of the project leaflet and two sets of slides showing an overview of the project. Furthermore, several networking activities with other projects were carried out.

The second year iteration of the exploitation plan (Task T7.4) identified SmartHG services to be exploited along with their potential customers. This, in turn, defined an exploitation plan for each SmartHG partner as well as for the consortium as a whole. Our second year exploitation plan has focussed on a medium term exploitation scenario, leaving the definition of short term exploitation paths as future work.

Chapter 2

Introduction

WP7 focusses on dissemination activities (Task T7.2) and SmartHG exploitation plan (Task T7.4). Tasks T7.1 (Dissemination Plan) and T7.3 (Market Analysis) were concluded during SmartHG first year.

Dissemination and exploitation activities are essential to provide appropriate distribution of knowledge, networking within the scientific, industrial and social communities and, finally, to identify and explore markets for the project results. Dissemination and exploitation activities are the focus of WP7 in the SmartHG project, and are described in this deliverable, which reports about the work carried out in Tasks T7.2 (dissemination activities and tools) and T7.4 (exploitation of SmartHG services).

During the third year, several dissemination activities have been successfully carried out: SmartHG partners presented the project as a whole at 5 scientific events, gave talks related to SmartHG at 8 conferences, workshops, or symposia, and published 12 scientific papers acknowledging EU support. Networking activities with other projects have also been carried out.

SmartHG consortium organised, as its main dissemination event, the "Kalundborg – Smart Energy 2015" workshop in Kalundborg, Denmark, on May 2015.

Dissemination tools released so far include: (a) the SmartHG project website [1], which contains a revised Technical Section showing information about SmartHG Platform, test-beds, and technical, economic and environmental evaluation of the Platform on our three test-beds; (b) the project newsletter [2]; (c) SmartHG accounts on social networks (Facebook [3], Twitter [4] and LinkedIn [5, 6]); and (d) dissemination artefacts (poster, leaflets, sets of presentation slides, templates for all kinds of project documents).

2.1 Outline

The rest of this document is organised as follows:

Chapter 3 describes our third year Dissemination Activities. Chapter 4 presents the third iteration of our Exploitation Plan. Table 2.1 shows a mapping between WP7 tasks and sections of this deliverable.

Task	Task Name	Sections
T7.2	Dissemination Activity	Chapter 3
T7.4	Exploitation Plan	Chapter 4

Table 2.1: Mapping between WP7 tasks and sections of this deliverable.

Chapter 3

Dissemination Activity

This section is devoted to summarise our dissemination activity in the third reporting period. It collects all scientific publications about SmartHG related topics produced by the project partners in the period. Moreover, the SmartHG project itself as a whole has been presented in 5 events. Project leaflets (see Section 3.2.2) have been distributed in other events attended by SmartHG partners. A complete list of SmartHG dissemination activities and publications (including also those of the first and second year) are shown in the final report.

3.1 Project Website

The SmartHG project website is hosted at http://smarthg.di.uniroma1.it/ and it is reachable also via the new registered domain http://smarthg.eu. Home page of the SmartHG website is shown in Figure 3.1. In the third year, SmartHG website has been completely redesigned to provide our visitors (energy distributors, retailers, residential users or simple onlookers) with an easier way to learn about SmartHG aims, services, and benefits.

Besides an improvement in the integration with social media (Facebook, Twitter, and Linkedin), the site home page contains an animation showing the idea behind SmartHG services. This introductory movie tells a story to the general audience, showing the differences in energy usage and costs between a residential district without SmartHG technology and a district equipped with our technology. We believe that this story will attract more visitors and convince them that it is worth investigating on the whole website and on project results.

Among the new features and improvements in the general section, the website contains also a revised and easy-to-use Technical Section (see Figure 3.2), which gives information about SmartHG Platform, test-beds, and technical, economic and environmental evaluation of the Platform on SmartHG test beds. Information about test bed data analytics (which now also contains data from our Minsk test bed) are supplied in different languages: English, Russian and Danish.

More than that, the new website shows an attractive showcase exposing all information on the hardware (e.g., sensors and gateways) deployed in SmartHG test beds, information on the Panoramic Power dashboard, some screenshots of the (anonymised) electrical consumption of the monitored homes (taken from Panoramic Power dashboard) and the data on Plug-in Electric Vehicle (PEV) usage gathered from Test-an-EV project and used in SmartHG. Security and privacy issues have been duly taken into account in selecting the project data that can be made public through the project website.

Figure 3.1: Home page of SmartHG Website.

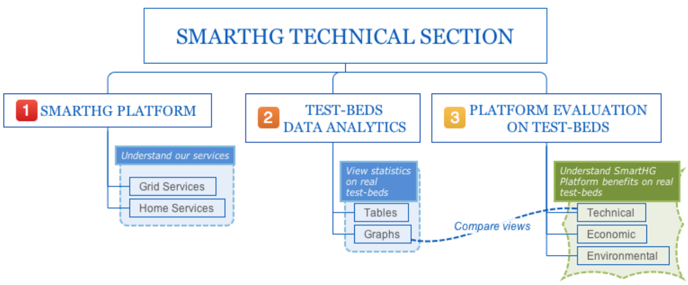


Figure 3.2: Overview of the Technical Section in the SmartHG website.

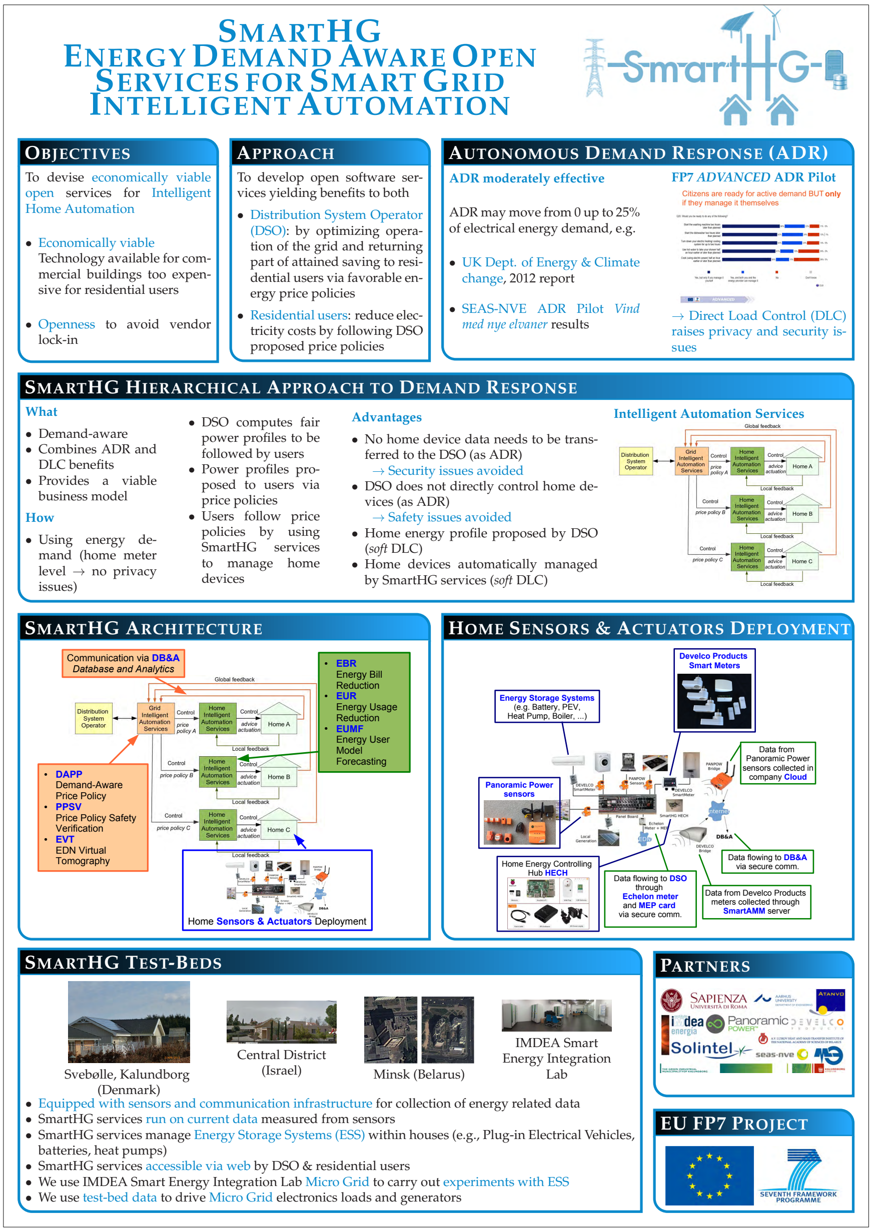


Figure 3.3: SmartHG project poster #1.

3.2 Dissemination Artefacts

Dissemination artefacts are useful tools to further support dissemination of project results. In this section, we describe SmartHG project dissemination artefacts realised or updated during the third year of the project. All SmartHG dissemination artefacts are available on the Downloads page of project website: http://smarthg.di.uniroma1.it/downloads.

3.2.1 Poster

Poster #1 (see Figure 3.3) has been created and shown at the events in which SmartHG has been presented by consortium partners (see Section 3.6.3).

Figure 3.4: SmartHG project leaflet #2.

3.2.2 Leaflets

Leaflets #2 and #3 have been created with updated information about SmartHG and a renovated design, to be handed out during the different events attended by partners. Leaflet #3 is available both in English and Danish as it has been distributed during the "Kalundborg – Smart Energy 2015" workshop organised by SmartHG (see Section 3.4). Leaflets #2 and #3 are shown in Figures 3.4 and 3.5.

3.2.3 Presentation Slides

A new set of slides describing SmartHG has been prepared and shown at the events where SmartHG has been presented (see Section 3.6.3).

Figure 3.5: SmartHG project leaflet #3 (English version).

3.3 Communication Channels Toward the Public

In this section, we describe SmartHG communication channels towards the public, divided by channel category.

3.3.1 Mailing List and Newsletter

SmartHG Newsletters #9, #10 and #11 have been published and delivered to the project mailing list, which contains email addresses of several coordinators of projects related to SmartHG topics. The newsletters contain information about project website contents and SmartHG news and upcoming events. The newsletters are available on the Newsletter page of the project website: http://smarthg.di.uniroma1.it/news-letter.

3.3.2 Social Networks

SmartHG is active on social networks with a Facebook [3] page, a Twitter [4] account and a LinkedIn account [5] and group [6].

Facebook page

SmartHG Facebook page is active and available at https://www.facebook.com/SmartHGproject. Visiting the page, Facebook users can find updates and photos about project activities and they can comment and share them.

At the end of the project, the SmartHG Facebook page had 240 *likes*.

Twitter account

SmartHG Twitter account is active and available at https://twitter.com/SmartHGProject. It displays the project logo and information and news about the project activities. It is also used to follow other Twitter accounts related to SmartHG topics, in order to be constantly updated about their activities. Several tags have been added to SmartHG tweets (as for example *#smartgrid*, *#energy*, *#smartcities*, *#demandside*) in order to be easily found by other Twitter users interested in the main topics covered by the project.

At the end of the project, the SmartHG Twitter account had 380 *followers*.

LinkedIn account and group

During the third year, although not planned beforehand, SmartHG activated a LinkedIn account [5] and a LinkedIn group [6], in order to be connected to potentially interested people and companies active on LinkedIn and further share results, benefits and impact of the SmartHG technology.

At the end of the project, the SmartHG LinkedIn account had 55 *connections* and the SmartHG LinkedIn account had 40 *members*.

3.4 Kalundborg – Smart Energy 2015 workshop

Kalundborg Municipality is the first city council in Denmark to have adopted an official act to transform the entire municipality into a smart city. This act also commits the administration to support this transformation accordingly. Moreover, Kalundborg

Municipality has signed an agreement, together with other Danish municipalities, called *Covenant of Mayors*. This agreement commits Kalundborg to provide in the short-term a sustainable energy action plan in order to make Kalundborg become a Climate Municipality, by going beyond the EU 2020 objectives in terms of CO2 reduction, adapting the city structure accordingly, and mobilising the population. The plan also foresees the deployment of renewable energy generators within a municipal spatial planning context, including buildings, car fleet, other vehicles for transportation, and other public utilities.

Due to the importance of these municipal plans for the goals of the projects, and in order to support and foster collaboration with the Covenant of Mayors, SmartHG consortium organised an international workshop in Kalundborg (5–6 May 2015) titled "Kalundborg – Smart Energy 2015".

During the workshop, SmartHG consortium broadly disseminated concepts and results of the project to several stakeholders of the electricity market as electricity distributors, retailers and residential users, to scientists and industry representatives involved in the field as well as to politicians, students and press.

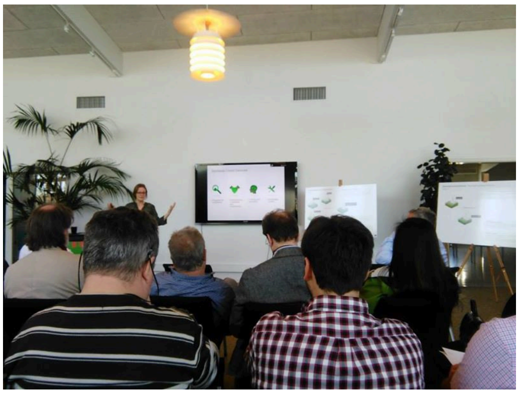
We organised such an event in Month 32, in conjunction with the second review meeting held in Copenhagen. Several guided tours have taken place during the event to show the different activities carried out in Kalundborg aimed at higher energy efficiency.

An event open to the public has taken place at Kalundborg Hallerne. A bus tour was also organised to show the Svebølle SmartHG test-bed (described in Deliverable D6.3.1 – Third Year Demonstration) to workshop participants. A poster and a leaflet (the latter in both English and Danish) have been produced to be presented and distributed at the workshop and at the public event (see Sections 3.2.1 and 3.2.2). Figure 3.6 shows a workshop presentation, the SmartHG poster presented at the public event, workshop participants, and the visit to the test-bed.

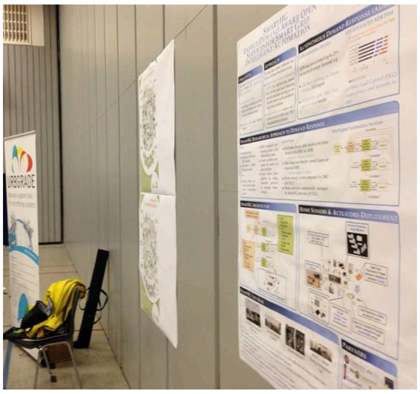
The workshop was divided in two tracks: *Integration of Utilities* and *Smart Utility in a Smarter World*. The following presentations took place:

- Cooperation for sustainable development for utility, industries and citizens (by Jesper Lange, Vice President, Business Development at SEAS)
- Smart municipality = Smart Utility (by Hans Martin Fris Møller, CTO at Kalundborg Utility)
- The Citizen and the new, smart technology (by Nicolaj Sonne, Journalist and host of Gear TV)
- Citizen in the smart future (by Martin Brynskov, Associate professor at Aarhus University)
- Smart Utility development in an European perspective (by Lance Boxall, European Commission, Project Officer)
- Cross-cutting Development (by Henrik Kærgaard, Director at Niras)
- SmartHG Project (by Enrico Tronci, SmartHG coordinator)
- URB GRADE Project (by Trine Plambech, Alexandra Institute)

The event participants were a mix of international Smart Grid experts, Danish university professionals, Danish utility experts from various utilities and organisations, and

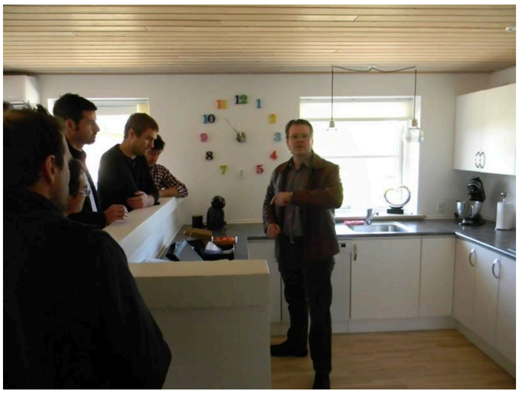


(a) A workshop presentation



(b) SmartHG poster show-case

(c) Public event participants



(d) Visit to the test bed in Svebølle

Figure 3.6: "Kalundborg – Smart Energy 2015 workshop"

municipality employees from Kalundborg and other municipalities in the region (planners, decision makers, development employees).

The workshop enabled us to show relevant results of the SmartHG project and to take advantage of and include also other achievements made within the framework of the Smart City Kalundborg and of the Covenant of Mayors initiatives. This enabled discussion of project results and will foster further collaborations with workshop participants. The networking activities undertaken during the workshop are listed in Section 3.5

3.5 Networking and Cooperation

Networking and cooperation activities undertaken during the SmartHG third year are reported in Table 3.1.

Actors	Event	Topic
Club Español de la Energía (Spain) Iberdola (Spain) Gas Natural Fenosa (Spain)	Demand Aware Services for Smartgrids workshop, September 2015, Madrid, Spain	Discussed regulatory frameworks for electricity distribution as well as Distribution System Operator (DSO) needs as for peak shaving capabilities. Discussed how to use Smartmeter data in future optimising, maintaining and operating DSO grid.
INDRA (Spain)	Demand Aware Services for Smartgrids workshop, September 2015, Madrid, Spain	Discussed integration with DSO software through Common Information Model (CIM) standard as defined by IEC 61970-301 and IEC 61968 along with its XML format for network model exchanges as defined by IEC 61970-501 and IEC 61970-452.
GE Energy Management (Spain)	Demand Aware Services for Smartgrids workshop, September 2015, Madrid, Spain	Discussed SCADA systems for Smart Grids. Discussed how to implement Smarthome systems in future operation of DSO Low Voltage (LV) grid.
ENERGRID (Italy)	Demand Aware Services for Smartgrids workshop, September 2015, Madrid, Spain	Discussed exploitation of SmartHG technology focusing on electricity retailers.
EU FP7 SEMIAH project EU FP7 CONTREX project EU FP7 VIMSEN project	System Design for the Smart Grid special section of 18th Euromicro Conference on Digital Systems Design, August 2015, Madeira, Portogual	Discussed about Smart Grids and future trends and opportunities for demand response technologies.
Aarhus University (Denmark)	PhD event 2015, August 2015, Aarhus, Denmark	Discussed about the dissemination part of SmartHG for general public.
Power electronics research group (Italy)	Scientific meeting, September 2015, University of Salerno, Italy	Discussed interaction between Maximum Power Point Tracking (MPPT) systems for photovoltaic panels and energy storage.
EU FP7 URB-Grade project	Kalundborg - Smart Energy 2015 workshop, May 2015, Kalundborg, Denmark	Discussed use of SmartHG Home services to support residential home energy efficiency.
Kalundborg Utility (Denmark)	Kalundborg - Smart Energy 2015 workshop, May 2015, Kalundborg, Denmark	Discussed extension of SmartHG approach to distributed utility management.
Alexandra Institute (Denmark)	Kalundborg - Smart Energy 2015 workshop, May 2015, Kalundborg, Denmark	Discussed consumer behavior and social issues in demand response systems.
Niras (Denmark)	Kalundborg - Smart Energy 2015 workshop, May 2015, Kalundborg, Denmark	Discussed future needs and business opportunity for demand response systems.
DTU RISØ, Technical University of Denmark (Denmark)	iPower Conference: From Research to Innovation, May 2015, Aarhus, Denmark	Discussed how to control distributed renewable resources in the LV and Medium Voltage (MV) grid.

Table 3.1: SmartHG third period networking and cooperation activities.

3.6 Participations and Publications

During the third year, SmartHG partners have given talks in 8 international events (conferences, workshops, symposia), published 12 scientific papers acknowledging European Union financial support, plus 1 on-line contribution.

The following sections list SmartHG third year participations and publications. A complete list of SmartHG participations and publications (including also those of the first and second year) are shown in the final report.

3.6.1 Conferences

Below we list the conferences and workshops in which publications acknowledging SmartHG financial support have been presented during the third year.

1. Sixth International Symposium on Games, Automata, Logics and Formal Verification [7] (GandALF 2015) in Genova, Italy (September 2015).
2. 22nd RCRA International Workshop [8] (RCRA 2015), co-located with the 14th Conference of the Italian Association for Artificial Intelligence [9] (AI*IA 2015) in Ferrara, Italy (September 2015).
3. 18th Euromicro Conference on Digital Systems Design [10] (DSD 2015) in Funchal, Madeira, Portugal (August 2015).
4. IEEE PES General Meeting [11] (PES 2015) in Denver, CO, United States (July 2015).
5. IEEE PES Europe Conference [12] (PowerTech) in Eindhoven, Netherlands (June 2015).
6. Fourth International Conference on Smart Systems, Devices and Technologies [13] (SMART 2015) in Brussels, Belgium (June 2015).
7. 2015 IEEE International Conference on Communications [14] (ICC 2015) in London, UK (June 2015).
8. 23rd Euromicro International Conference on Parallel, Distributed and Network-based Processing [15] (PDP 2015), Special Session on Formal Approaches to Parallel and Distributed Systems (4PAD) in Turku, Finland (March 2015).

3.6.2 International Journals

Below we list the international journals in which publications explicitly acknowledging SmartHG financial support have been published during the third year.

1. IEEE Transactions on Smart Grid [16] (July 2015).

3.6.3 Events

Below we list the events in which SmartHG has been presented during the third year.

1. Demand Aware Services for Smartgrids workshop in Madrid, Spain (September 2015).
2. 17th International Workshop on Computer Science and Information Technologies [17] (CSIT 2015) in Rome, Italy (September 2015).
3. Power electronics research group meeting at the Department of Computer Science and Electrical Engineering and Applied Mathematics at Salerno University [18], Italy (September 2015).
4. Kalundborg – Smart Energy 2015 workshop (see Section 3.4) in Kalundborg, Denmark (May 2015).
5. Technological Brokerage Event in Energy and Enviroment [19] (GENERA 2015) in Madrid, Spain (February 2015).

Also a visit to SmartHG test-bed deployed at IMDEA Smart Energy Integration Lab (SEIL) (described in Deliverable D6.3.1 – Third Year Demonstration) and a demo of SmartHG Services has taken place during the Demand Aware Services for Smartgrids workshop held at IMDEA Energy Institute.

Furthermore, in July 2015 SmartHG has appeared on Madri+d [20], a news portal promoting science, R&D and innovation. The text is in Spanish and some general description about the project goals and aims are provided.

3.6.4 Publications

This section shows the publications produced by the SmartHG project consortium during the third year, which acknowledge the financial support from the European Union.

1. V. Alimguzhin, F. Mari, I. Melatti, E. Tronci, E. Ebeid, S. A. Mikkelsen, R. H. Jacobsen, J. K. Gruber, B. Hayes, F. Huerta et al. "A Glimpse of SmartHG Project Test-bed and Communication Infrastructure." *In Digital System Design (DSD), 2015 Euromicro Conference on*, 225–232., 2015.
2. E. Ebeid, S. Griful, S. Mikkelsen, and R. Jacobsen. "A Methodology to Evaluate Demand Response Communication Protocols for the Smart Grid." *In IEEE International Conference on Communications* (ICC), UK, 2015.
3. B. P. Hayes, and M. Prodanovic. "A comparison of MV distribution system state estimation methods using field data." *In IEEE PES General Meeting*, Denver, CO, United States, 2015.
4. B. P. Hayes, J. K. Gruber, and M. Prodanovic. "A closed-loop state estimation tool for MV network monitoring and operation." *IEEE Transactions on Smart Grid, no. 99*, 2015.
5. B. P. Hayes, J. K. Gruber, and M. Prodanovic. "Short-term load forecasting at the local level using smart meter data." *In IEEE PES Europe Conference* (PowerTech), Eindhoven, Netherlands, 2015.

6. R. H. Jacobsen, S. A. Mikkelsen, and N. H. Rasmussen. “Towards the Use of Pairing-Based Cryptography for Resource-Constrained Home Area Networks.” *In Digital System Design (DSD), 2015 Euromicro Conference on*, 233–240., 2015.

7. E. Kidmose, E. Ebeid, and R. Jacobsen. “A Framework for Predicting User Behavior from the Main Smart Meter Data.” *In IARIA Fourth International Conference on Smart Systems, Devices and Technologies* (SMART), Switzerland, 2015.

8. T. Mancini. “Now or Never: negotiating efficiently with unknown counterparts.” *In proceedings of the 22nd RCRA International Workshop* CEUR 2015 (Co-located with the 14th Conference of the Italian Association for Artificial Intelligence (AI*IA 2015)), Ferrara, Italy, 2015.

9. T. Mancini, F. Mari, A. Massini, I. Melatti, and E. Tronci. “SyLVaaS: System Level Formal Verification as a Service.” *In Proceedings of the 23rd Euromicro International Conference on Parallel, Distributed and Network-based Processing* (PDP 2015) *special session on Formal Approaches to Parallel and Distributed Systems* (4PAD), 2015.

10. T. Mancini, F. Mari, A. Massini, I. Melatti, and E. Tronci. “Simulator Semantics for System Level Formal Verification.” *In Proceedings Sixth International Symposium on Games, Automata, Logics and Formal Verification* (GandALF 2015), 2015.

11. T. Mancini, F. Mari, I. Melatti, I. Salvo, E. Tronci, J. K. Gruber, B. Hayes, M. Prodanovic, and L. Elmegaard. “User Flexibility Aware Price Policy Synthesis for Smart Grids.” *In Digital System Design (DSD), 2015 Euromicro Conference on*, 478–485., 2015.

12. S. A. Mikkelsen, and R. H. Jacobsen. “Consumer-Centric and Service-Oriented Architecture for the Envisioned Energy Internet.” *In Digital System Design (DSD), 2015 Euromicro Conference on*, 301–305., 2015.

Chapter 4

Exploitation Plan

4.1 Introduction

This chapter outlines our exploitation plan for the services in the SmartHG platform. To this end we proceed as follows.

In Section 4.2 we estimate the Technology Readiness Level (TRL) for the SmartHG platform. This enables us to identify the technological steps needed to bring the SmartHG platform to the market. In Section 4.3 we summarise SmartHG exploitation opportunities identified by our evaluation activity. In Section 4.4, resting on the considerations in Sections 4.2 and 4.3, we identify exploitation strategies and customers for the SmartHG platform. In Section 4.5 we outline a SmartHG exploitation plan focussing on *Electricity Retailers* as customers. In Section 4.6 we outline a SmartHG exploitation plan focussing on Distribution System Operators (DSOs) as customers. Finally, in Section 4.7 we envision a structure for the company which will bring the SmartHG Platform to the market and address Intellectual Property (IP) issues.

4.2 SmartHG Platform Technology Readiness Level (TRL)

The present section has the goal of assessing SmartHG Platform TRL according to the definition given by the European Commission (see Table 4.1). This is an essential step for the definition of an exploitation plan that is feasible from an economic as well as from a technological point of view.

The *SmartHG Platform* developed within the SmartHG project consists of a set of *integrated software services* aiming at reducing electricity costs for residential users by managing their electrical energy demand in order to pursue the following, possibly conflicting, objectives:

- Reduce Electric Distribution Network (EDN) management costs, thereby providing a benefit for Distribution System Operators (DSOs)
- Reduce electrical energy costs, thereby providing a benefit for *Electricity Retailers*
- Reduce CO_2 emissions, thereby providing a benefit for the whole society.

The SmartHG platform consists of two main subsystems: the *SmartHG Grid Services* and the *SmartHG Home Services*. Grid Services focus on supporting DSOs in devising

TRL	Description
1	Basic principles observed
2	Technology concept formulated
3	Experimental proof of concept
4	Technology validated in lab
5	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
6	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
7	System prototype demonstration in operational environment
8	System complete and qualified
9	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Table 4.1: European Commission TRL.

individualised *demand aware* time dependent power bounds (*power profiles*) for residential users in order to reduce EDN management costs. Home Services focus on efficient managing of home energy storage devices (such as batteries and Plug-in Electric Vehicles), in order to support residential users in following the power profiles computed by the SmartHG Grid Services as well as *Electricity Retailers* in reducing electrical energy costs and CO2 emissions.

Both Grid and Home services, in turn, consist of many subsystems. Accordingly, the TRL for the SmartHG platform is at most the minimum among the TRL of such subsystems.

Figure 4.1 shows the dependencies among SmartHG subsystems. The arrows in the graph denote the *subsystem* relationship. Thus, the arrows outgoing from a node identify the subsystems of (the system associated to) that node.

Basically, at the beginning of the project, the TRL for the SmartHG platform was 2 (by regarding SmartHG proposal as the *formulation of the technology concept* requested by TRL 2). At the end of the project, SmartHG platform TRL is about 6.

Such an assessment stems from the following considerations. First, the SmartHG platform is a set of *software services* running on commercial (and thus with TRL 9) hardware and software. Second, a *relevant environment* (as required by TRL 6) for software is defined by the host machine(s) on which the software is running as well as from the data the software will be elaborating.

In our setting, all SmartHG services have been implemented and demonstrated on a relevant environment. In fact, all SmartHG software services run on their target hardware (namely a cluster of Linux servers for SmartHG Grid Services and a Raspberry PI for SmartHG Home Services) and have been evaluated on real world data gathered from our test beds. On such a basis, we evaluate to 6 the TRL currently attained by SmartHG software services.

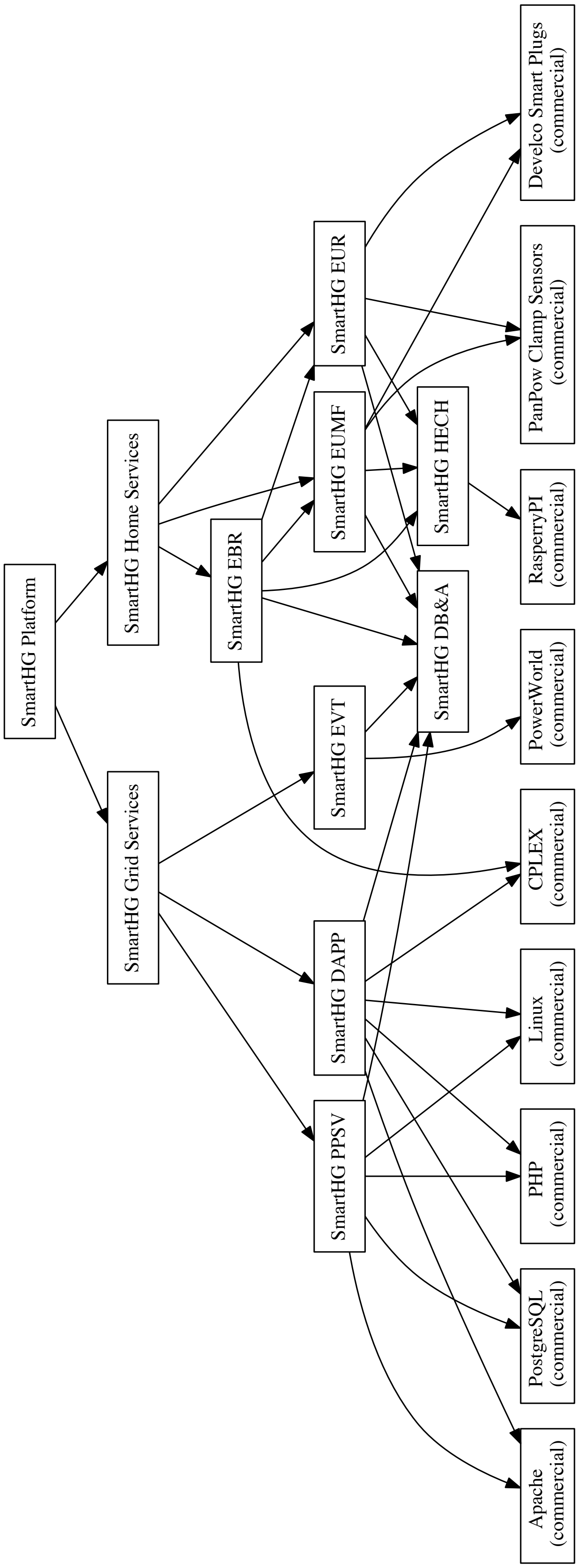


Figure 4.1: SmartHG Platform subsystems.

4.3 Exploitation Opportunities Identified from SmartHG Evaluation

In this section we summarise SmartHG exploitation opportunities identified by our evaluation activity. This information will help us in defining a strategy to transform SmartHG technological achievements into economic and social benefits.

Section 4.3.1 outlines the costs incurred when adopting SmartHG technology. Any exploitation plan should generate enough revenues to cover such costs.

Section 4.3.2 outlines Transmission and Distribution (T&D) investment deferral enabled by the SmartHG Platform. By comparing such figures with those in Section 4.3.1, we can identify a SmartHG exploitation plan seeing Distribution System Operators (DSOs) as the main customers for the SmartHG platform.

Section 4.3.3 outlines savings in electricity costs enabled by the SmartHG platform. By comparing such figures with those in Section 4.3.1, we can identify a SmartHG exploitation plan seeing *Electricity Retailers* as the main customers for the SmartHG platform. Of course a holding owning both a DSO *and* an Electricity Retailer may be able to harvest both types of economic benefits (T&D investment deferral *and* electricity cost saving).

Section 4.3.4 outlines savings in CO2 emissions enabled by the SmartHG Platform. Such savings can be achieved either when a DSO uses the SmartHG Platform to optimise Electric Distribution Network (EDN) management or when an electricity retailer uses the SmartHG Platform to minimise electricity costs. Savings in CO2 emissions is a benefit for the whole society. By using CO2 certificates, such savings can also become a further economic benefit for SmartHG customers (DSOs or Electricity Retailers).

Of course we do not expect residential users to take the lead in installing any device in their homes. Instead we envision that electricity retailers will install the needed equipment (sensors, computational devices and, above all, batteries) at user premises with a kind of leasing contract with the residential user. By sharing SmartHG economic benefits with residential users, SmartHG customers will cover the cost of SmartHG infrastructure, get economic benefits and provide, as well, economic benefits to residential users.

4.3.1 SmartHG Deployment Costs

We will describe our exploitation plan for the SmartHG platform using, as a running example, some of our evaluation results about scenarios from Kalundborg test bed. In this section, we summarise the main relevant data from such an evaluation activity.

To the electricity consumption data of each of our users in Kalundborg we add hourly consumption data from the Plug-in Electric Vehicles (PEVs) recorded in the project Test-an-EV https://www.clever.dk/test-en-elbil.

Here we focus on the following two of the 5 home energy storage configurations discussed in Section 4.2.3.3 of D5.3.1:

- The *BU configuration*, where each home is equipped with a battery and the home PEV is not controlled by SmartHG services.
- The *BD configuration*, where each home is equipped with a battery and the home PEV charge and discharge are both controlled by SmartHG services. In other words, the PEV (when present at home) is used as an energy storage device.

Name	**Description**	**Value BU Conf.**	**Value BD Conf.**
Storage Annual Cost	Average (among all participating users) amortised (over 10 years) battery cost per MWh of annual electricity consumption.	9.60 EUR/MWh	9.60 EUR/MWh
Net energy cost saving	Average (among all participating users) of the ratio between the energy cost saving deducting battery cost and the annual electricity consumption.	3.72 EUR/MWh	10.90 EUR/MWh
Gross energy cost saving	Average (among all participating users) of the ratio between the energy cost saving without deducting battery cost and the annual electricity consumption.	13.32 EUR/MWh	20.38 EUR/MWh
CO2 saving per MWh	Average (among all participating users) of the ratio between the reduction in CO2 emissions (in Kg) and the annual electricity consumption.	29.22 kg/MWh	47.42 kg/MWh
Percentage reduction CO2	Average (among all participating users) of the ratio between reduction in CO2 emissions (in Kg) and CO2 emissions (in Kg) without using SmartHG.	8.48%	14.44%

Table 4.2: Glimpse of data from Kalundborg test bed evaluation.

Table 4.2 summarises the relevant data from our third year evaluation for the above scenarios.

Figure 4.2 shows, as a function of the annual household electricity consumption, the average SmartHG deployment costs. Namely, the x-axis shows the annual household consumption (in MWh) whereas the y-axis shows the annual cost of SmartHG deployment assuming an amortisation time of 10 years. For example, considering a household with an annual electricity consumption of 5 MWh, from Figure 4.2 we see (y-axis) that on average we need a battery whose cost is about 48 EUR per year.

In our analysis we will use reference electricity costs for residential users shown in Table 4.3. Such costs are slightly below current electricity costs in Denmark and slightly above current costs in Italy. However they provide meaningful electricity costs (for residential users) for most European countries.

4.3.2 SmartHG Enabled Electricity Distribution Cost Savings

The SmartHG platform enables DSOs to optimise management of the EDN by exploiting SmartHG infrastructure deployed at residential homes. Such an infrastructure is used to shift electricity demand (*peak shaving*), thereby reducing wearing of EDN components (mainly transformers). Of course, the saving (due to T&D investment deferral) actually achieved depends on how much the EDN is actually stressed. For example, if electricity demand peaks are well below the nominal power of substation transformers, peak shaving

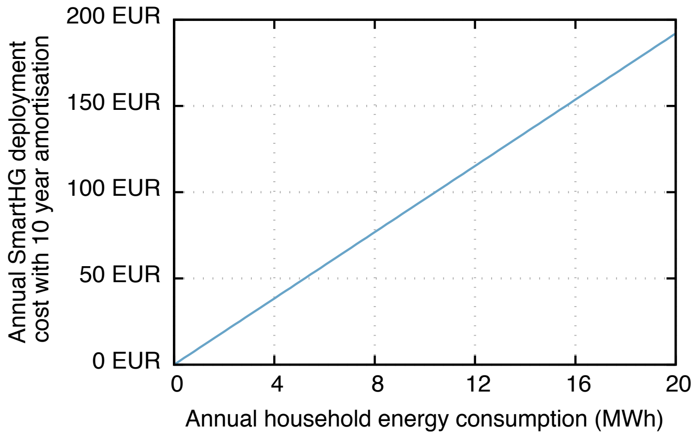


Figure 4.2: SmartHG average deployment costs (y-axis) as a function of household annual electricity consumption (x-axis).

Component	**Price**
Transmission	0.02 EUR/kWh
Distribution	0.12 EUR/kWh
Energy	0.11 EUR/kWh
Total	0.25 EUR/kWh

Table 4.3: Electricity prices (tax included) used in our analysis.

brings no real benefit. On the other hand, if electricity demand peaks make substation transformers work for a long time well above their maximum power rate, then peak shaving will bring a benefit.

Thus, the actual saving provided by peak shaving depends on the EDN operating conditions. For our purposes this can be modelled by saying that peak shaving will enable saving of a certain percentage of the electricity distribution cost (as given in Table 4.3) charged to a residential customer.

Figure 4.3 shows the saving due to peak shaving enabled by SmartHG for many plausible scenarios. On the x-axis we have the annual electricity consumption (in MWh) of a household, whereas on the y-axis we have the saving due peak shaving enabled by SmartHG platform as a fraction p of the distribution cost (for different values of p). For comparison, Figure 4.3 also shows the annual SmartHG deployment costs (from Section 4.3.1). Of course SmartHG technology is helpful to DSOs as long as the saving it provides is above its deployment cost. From Figure 4.3 we see that this happens as soon as p is about 0.1. That is, as soon as peak shaving may lead to a 10% reduction on the electricity distribution cost, SmartHG approach becomes viable.

4.3.3 SmartHG Enabled Electrical Energy Cost Savings

The SmartHG platform enables saving on the energy costs by leveraging on price differences during the day (*arbitrage*) as well as by saving on CO2 emissions and turning such a saving into money by trading it (see, e.g., *Nord Pool Spot* (http://www.nordpoolspot.

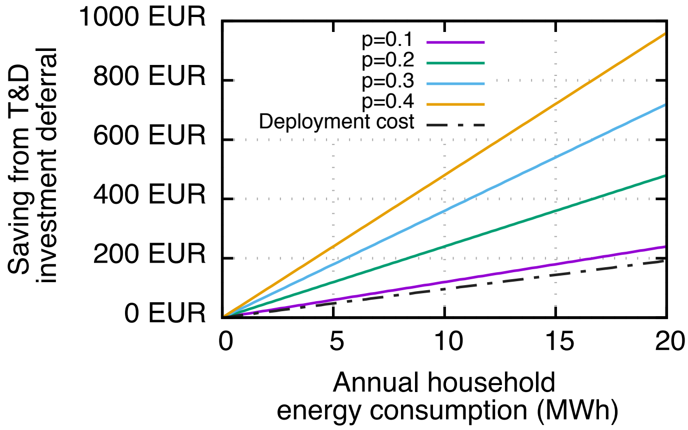


Figure 4.3: SmartHG enabled savings stemming from peak shaving.

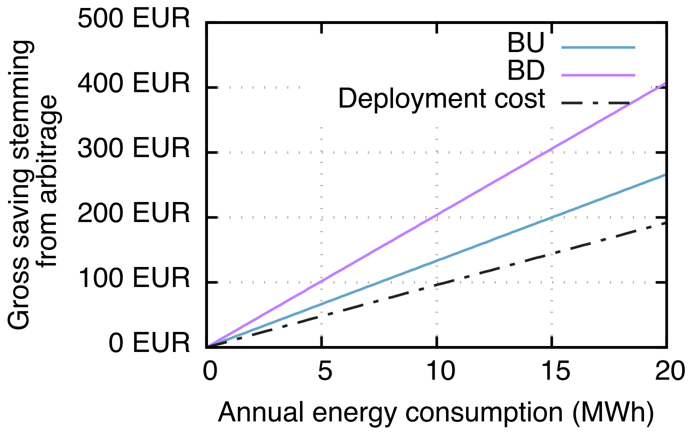


Figure 4.4: SmartHG enabled gross energy cost saving.

com).

Our evaluation activity has computed the saving on energy cost that we can achieve in the different home storage configurations we have considered. Such results form the basis for our exploitation plan towards electricity retailers.

For the BU and BD configurations of Section 4.3.1, Figure 4.4 summarises energy cost saving opportunities offered by SmartHG Home Services. Namely, on the x-axis we have the annual electricity consumption (in MWh) for a household, whereas on the y-axis we have the gross (i.e., ignoring battery cost) energy cost saving (tax included) achievable by using the SmartHG platform.

We note that by using batteries and the control strategies in the SmartHG platform we can also increase the amount of self-consumption for residential homes equipped with PhotoVoltaic (PV) panels. Typically this takes self-consumption from 30% (without batteries) to 60% (with batteries). Even with a small size PV installation producing about 3.3 MWh per year, this means taking self consumption from about 1 MWh per year to about 2 MWh per year. When there are no incentives (the case more and more common in Europe) this yields a money saving of almost 250 EUR per year (the cost of 1 MWh in our setting) for each household equipped with PV panels.

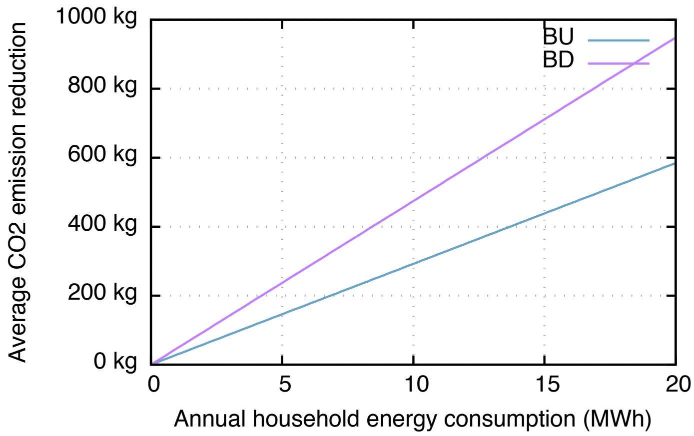


Figure 4.5: SmartHG enabled reduction in CO2 emissions.

4.3.4 SmartHG Enabled CO2 Emission Savings

The SmartHG platform enables saving on CO2 emissions by leveraging on the fact that the amount of CO2 emissions needed to produce a MWh of electrical energy changes during the day, and such figures are known beforehand.

For our reference configurations (BU and BD, as described in Section 4.3.1), reduction of CO2 emissions due to SmartHG technology are shown in Table 4.2.

Furthermore, we should consider that CO2 emissions can be traded (for example, using the data from the *Nord Pool Spot*, http://www.nordpoolspot.com). The energy saving data in Table 4.2 account for such a trading opportunity.

Of course, reducing EDN operation cost (Section 4.3.2), electricity cost (Section 4.3.3), and CO2 emissions are conflicting goals. The SmartHG platform enables stakeholders to decide the best trade-off among such conflicting objectives.

Since CO2 emission reduction enabled by SmartHG does not cover the cost of SmartHG infrastructure, we foresee that EDN operation and electricity cost reductions will be the driving forces for SmartHG adoption. CO2 emission reduction will come as an extra benefit for the society as a whole.

In Section 4.5 of D5.3.1 we have assessed that the average SmartHG enabled CO2 emission reductions in our Kalundborg test bed vary from 29.22 kg/MWh (8.48%) for the BU configuration to 47.42 kg/MWh (14.44%) for the BD configuration.

Figure 4.5 summarises the above considerations for both BU and BD configurations. More specifically: on the x-axis we have the annual electricity consumption (in MWh) for a household; on the left y-axis we have the average reduction of CO2 emissions achievable by using the SmartHG platform, whereas on the right y-axis we have the (average) money value for such a CO2 emissions reduction.

4.4 Exploitation Strategy

In this section we identify the technological and economic issues to be addressed in order to bring the SmartHG platform to the market. Resting on such considerations, in Section 4.5 we outline SmartHG energy oriented exploitation plan that sees electrical energy retailers as main customers, whereas in Section 4.6 we outline SmartHG grid oriented exploitation plan that sees Distribution System Operators (DSOs) as main customers.

4.4.1 Technological Issues

From Section 4.2 we note that the SmartHG research project took the SmartHG platform from the technology concept outlined in the project proposal (TRL 2) to a technology demonstrated in a relevant environment, that is about TRL 6. While this clearly shows the technological feasibility of SmartHG technology, a TRL of 9 is needed to put the product on the market. Thus, our exploitation plan should envisage an effective way to take SmartHG technology from the current TRL 6 to the needed TRL 9. The best way to attain such a result appears to be through a research project such as an H2020 project or a privately funded project. National project are also a possibility, although it might be hard to accommodate SmartHG international consortium within a purely national framework. A mix of the above is, of course, also a possibility. Accordingly, our exploitation plan will outline the issues to be addressed to take SmartHG technology from TRL 6 to TRL 9.

4.4.2 Economic Issues

Section 4.3.2 suggests an exploitation plan for the SmartHG platform focussing on optimising Electric Distribution Network (EDN) management. Of course, the SmartHG customers for such a *grid focussed* exploitation plan are mainly DSOs.

Section 4.3.3 suggests an exploitation plan for the SmartHG platform focusing on minimising electrical energy costs. Of course, the SmartHG customers for such an *energy focussed* exploitation plan are mainly electrical energy retailers.

We discussed the above opportunities with many DSOs and retailers. In the following we summarise the outcome of such discussions.

While all DSOs agree that at some point in the future the distribution network will be stressed to the point that the saving from the SmartHG technology will be interesting, it is not obvious that this is indeed the case now, also taking into account the reduction in electricity consumption triggered by the economic crisis. Accordingly, we regard the grid focussed exploitation plan as a *medium term* exploitation opportunity.

Presently, the electrical energy retail market is quite competitive, with retailers working hard to attract customers by offering competitive electricity prices as well as energy services. The point is that, while residential users may easily switch from one retailer to another, this is not the case for their DSO. Accordingly, no matter the retailer selected by a residential user, the DSO will typically stay the same. Retailers are thus quite interested in technologies that may allow them to attract new customers. In such a setting, the cost saving enabled by the SmartHG Home Services appears of course quite interesting to retailers, also considering the fact that selling locally generated electricity (e.g., from PhotoVoltaic) to the grid is not incentivised anymore in many European countries. Accordingly, we regard the energy focussed exploitation plan as a *short term* exploitation opportunity, since the market appears ready for it.

4.4.3 Regulatory Issues

To identify a concrete exploitation plan it is necessary to consider the current regulatory framework in Europe as well as its possible future evolution.

Such issues have been discussed with the DSOs in our consortium as well as with the Italian Authority for Electricity, Gas and Water (AEEGSI) during the Workshop on *Demand-Side Innovation* for Smart Grids (http://www.demandsideinnovation.eu) organised on October 16, 2015 in Milan by CapGemini on behalf of the DG Internal Market, Industry, Entrepreneurship and SMEs of the European Commission.

The above discussions have pointed out the following points.

First, in most European countries, regulation asks that residential users have no direct business contact with the DSO. Accordingly, we plan to offer SmartHG services as a sort of *ancillary services*. Deployment and management of the home devices could then be done through an electricity retailer, that would in this way be able to offer a discount on electricity prices to residential user, thereby providing a benefit for the users and for the retailer itself.

Second, the upcoming second generation of smart meters (e.g., their deployment in Italy will start in 2016) allows remote access from electricity retailers in order to set up their own *Time of Usage* tariffs. Furthermore, interfacing with third-party devices using open common standards (see, e.g., *Industry Alliance Energy@Home*, http://www.energy-home.it/SitePages/Home.aspx) is foreseen.

Third, the above mentioned second generation of smart meters will allow DSOs to read data every 15 minutes, thereby enabling an electricity distribution tariff dependent on the average power within a given time slot (e.g., one hour or 15 minutes if need be).

The above features considerably ease deployment of SmartHG Home Services and confirm that the focus on data and computation services of SmartHG is well aligned with emerging market trends.

4.5 SmartHG Exploitation Plan Towards Retailers

In this section we outline our exploitation plan towards electricity retailers. In particular, in Section 4.5.1 we discuss our plans to bring SmartHG to the electricity retailer market and in Section 4.5.2 we show how we plan to turn the SmartHG Home Services into a commercial product.

4.5.1 Bringing SmartHG to Electricity Retailer Market

In this section we outline SmartHG exploitation schema for Home Services. This is done by estimating SmartHG customer benefits (Section 4.5.1.1) as well as profitability for the technology provider (Section 4.5.1.2).

4.5.1.1 SmartHG Home Services Exploitation Schema

The goal of this section is to identify a specific exploitation plan for the SmartHG Home Services by taking into account the current regulatory framework in Europe as well as its possible future evolution as discussed in Section 4.4.3.

We foresee the exploitation plan summarised in Figure 4.6 and described below. Of course how the savings enabled by SmartHG Home Services are shared among residential users, the electricity retailer and the Information and Communications Technology (ICT) company providing the SmartHG Home Services depends on many considerations. Here we only provide an example in order to show feasibility of the proposed approach.

We illustrate our exploitation schema focusing on scenarios BU and BD in Section 4.3.1.

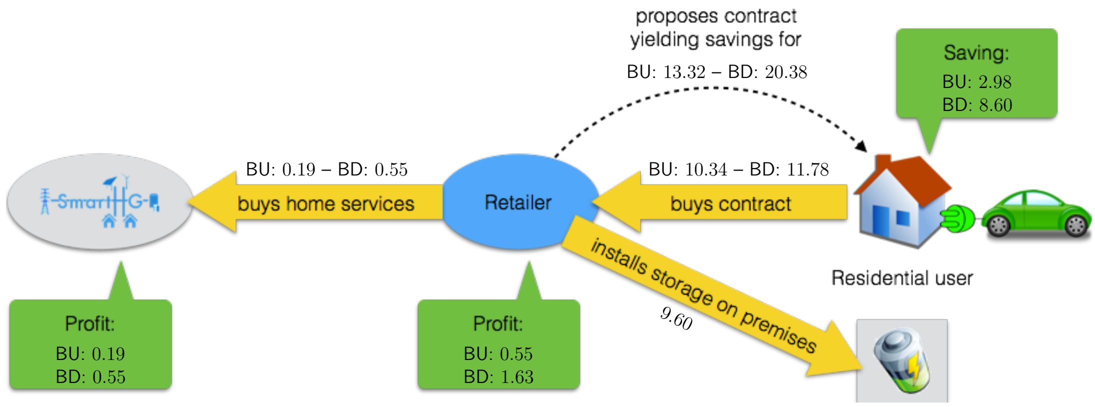


Figure 4.6: SmartHG Home Services Exploitation Schema (EUR/MWh).

4.5.1.1.1 Retailer and Residential User First of all, the retailer offers to residential users an electricity tariff consisting of a service fee along with a discount on the current (energy component) electricity price (about 110 EUR/MWh, tax included, see Table 4.3). In exchange of the service fee, the electricity retailer installs at the user premises all the needed SmartHG devices, namely: sensors, Raspberry PI running SmartHG software and the required energy storage systems. Using SmartHG Home Services, the retailer will manage such home devices in order to get lower energy prices enabling the discount on the energy tariff mentioned above.

In our example we assume (see Table 4.2 and Figure 4.6) the following.

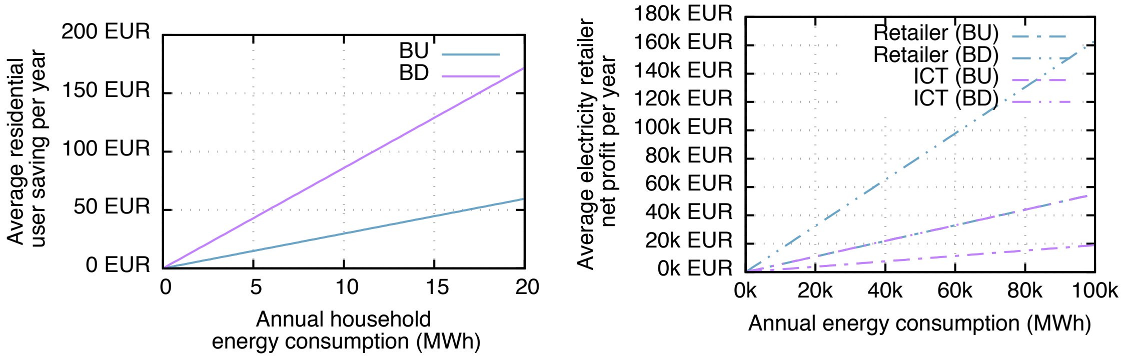
- The retailer service fee (per MWh) is the sum of: the energy storage cost and 20% of the expected net energy cost saving.
- The discount on energy cost (per MWh) is the gross energy cost saving.

This approach on one side allows the retailer to pay for the devices installed at home premises while obtaining some gain and, on the other side, provides to residential users a money saving of about 80% of the net energy cost saving. Note that, to harvest such a saving, residential users do not need to worry about time dependent tariffs, since, by paying a device management fee, they receive a discounted flat tariff.

4.5.1.1.2 Retailer and ICT Provider The retailer uses its income from the residential user to pay for the energy storage devices installed at the user premises *and* to pay for the services (management of home devices) received from the ICT company providing the SmartHG Home services. In our example, 5% of the net energy cost saving is used to pay for SmartHG Home services, thus leaving to the retailer a net profit of 15% of the net energy cost saving.

Taking into account that the average annual consumption for residential users in our Kalundborg test bed is about 7.78 MWh per year, from Table 4.2 we have that on average residential users save from 23.19 EUR/year (BU configuration) to 66.93 EUR/year (BD configuration).

As for the electricity retailer and the ICT provider, from Table 4.2 it follows that, with a business volume of about 100 000 MWh/year (about 12 850 users in our scenario):



(a) Energy cost saving for residential user.

(b) Profits for retailer and SmartHG provider.

Figure 4.7: SmartHG enabled savings and profits.

- The electricity retailer would have an annual profit from 55 000 EUR/year (BU configuration) to 163 000 EUR/year (BD configuration);
- The ICT provider would have an annual profit from 19 000 EUR/year (BU configuration) to 55 000 EUR/year (BD configuration).

Figure 4.7a shows the average energy cost saving per year for residential users whereas Figure 4.7b shows the average net profit per year for electricity retailers and ICT companies providing SmartHG Home Services.

4.5.1.2 Profitability

The analysis in Section 4.5.1.1 shows the benefits provided by SmartHG Home Services to customers (electricity retailers) and users (residential homes). However, in order to bring SmartHG technology to the market, we also need to make sure that such an activity is profitable for the *ICT provider*, that is the enterprise providing SmartHG Home Services to electricity retailers.

All software implementing the SmartHG Home Service runs at user premises and the hardware cost is paid by the fee the retailer charges to residential users. Thus, with such an approach, there is no cost for the ICT provider if not that of maintaining a web infrastructure to automate communication with retailers (for example, to upgrade firmware, etc.)

There is however a cost, incurred when a new user joins, for running the SmartHG Home Service that estimates capacity and power rate for the user batteries on the basis of the previous user consumption pattern.

Resting on the analysis presented in the Appendix to the second year deliverable D7.2.1 we can compute such a cost assuming that a cloud based infrastructure is used to provide such a configuration service (much as for SmartHG Grid Services).

Computation on a Infrastructure as a Service (IaaS) provider (such as Amazon or Google) costs on average 0.55 EUR/CPU-hour. Since running SmartHG Home Services to compute the optimal configuration of the energy storage system takes just a few seconds, we can easily overestimate such a cost assuming for it a value of 0.001 EUR/MWh. For example, the average Kalundborg residential user has an annual consumption of about

8 MWh. This means that configuring SmartHG Home Services costs on average about 0.008 EUR (currently that buys us about 52 seconds of computation time on Google, more than enough for our purposes).

From Figure 4.6 we see that in any scenario the ICT provider receives a payment from the retailer well above 0.001 EUR/MWh. This guarantees profitability for the ICT provider.

A more extended profitability analysis from the point of view of ICT providers is presented in the Appendix to the second year deliverable on *Dissemination and Exploitation* (D7.2.1).

4.5.2 Turning SmartHG Home Services into a Commercial Product

SmartHG energy oriented exploitation plan focuses on using SmartHG Home Services to reduce, for each household, the cost of electrical energy by storing energy when its price is low and by using stored energy when the energy price is high (*arbitrage*).

The economic advantages of such an approach have been described in Section 4.5.1. However, to bring forward such advantages, we need to take the Technology Readiness Level (TRL) of SmartHG Home services from the present value (about 6, see Section 4.2) to the value of 9, needed to put the technology on the market. Accordingly, in the following we outline the obstacles we face, the steps we plan to overcome them, and potentially interested enterprises we have contacted, besides those in the SmartHG consortium, to support such actions.

TRL 7 requires us to demonstrate SmartHG Home services in an operational environment. In our setting an operational environment consists of many residential homes equipped with the hardware and software needed to support SmartHG Home Services.

To install SmartHG Home Services in residential homes we need to install in *each* home in the test bed: a battery system, an inverter (if not already present), battery sensors as well as SmartHG software (namely, Energy Bill Reduction (EBR), Energy Usage Modelling and Forecasting (EUMF), Energy Usage Reduction (EUR)) controlling charging/discharging of the battery accordingly to SmartHG policy.

We note that, while SmartHG sensors have been already deployed at homes, this is not the case for the actuation hardware and its controlling software. In fact, to save on hardware money, during the SmartHG project we have interfaced our SmartHG Home Services with the batteries and inverters at IMDEA Micro grid, where we have also tested SmartHG Home Services using measurements gathered from our test beds in Kalundborg and Central District.

However, a typical operational environment will consist of inverters and batteries (possibly of different brands) in each home. Accordingly, we need to extend SmartHG interface software so that it can interface not just with IMDEA Micro grid inverter, but also with some widely used inverter (battery charge/discharge is typically controlled through the inverter, thus interfacing with inverters is basically all we need). Accounting for at least two inverter brands in our operational environment is important in order to test *vendor neutrality* of the overall SmartHG Platform.

In the following we outline our plan to address the above issues.

4.5.2.1 Battery Systems

There are many companies offering lead-acid batteries serving our purposes, with Trojan (www.trojanbattery.com), the one we used in our cost estimation, being one of the largest.

However the interest in home energy storage is booming (somehow witnessing market readiness for SmartHG technology) and many companies have announced quite competitive home battery systems suitable for our purposes. Here are interesting examples.

Tesla PowerWall (www.teslamotors.com/powerwall) is a 7 kWh capacity and 2 kW power rate Lithium battery with an inverter vendor neutral interface. This fits nicely our high-demand homes.

Enphase AC Battery (enphase.com/en-us/products-and-services/ac-battery) is a 1.2 kWh capacity and 0.5 kW power rate Lithium battery with an integrated microinverter. This nicely fits our moderate-demand homes.

Recently (June 2015) Mercedes-Benz has announced an interesting home battery system (www.theverge.com/2015/6/9/8752791/mercedes-benz-daimler-home-battery) consisting of modules with a capacity of 2.5 kWh each.

Accordingly, an operational environment for SmartHG should contain an adequate mix of market leading products, such as those mentioned above.

4.5.2.2 Inverter Systems

We have identified three enterprises offering inverters, sensors and open interfaces suitable for our purposes: SolarEdge, SMA and Victron.

SolarEdge has specific integration plans with the PowerWall system (see, e.g., http://www.solaredge.com/groups/products/storedge). This may considerably ease integration issues.

SMA offers a charger/inverter for which sensors and interfaces are available: Sunny Island (http://www.sma.de/en/products/battery-inverters/sunny-island-60h-80h.html). This can considerably ease integration with the SmartHG services controlling the battery charge/discharge.

Although Victron (http://www.victronenergy.com/inverters-chargers), whose main focus so far has been on the industrial (marine) market, is offering a quite open and modular system that also nicely matches our goals.

We have already investigated the possibility of interfacing external software (SmartHG software in our case) with SolarEdge, Victron or SMA equipment.

SolarEdge (see, e.g., http://www.solaredge.com/files/pdfs/sunspec-implementation-technical-note.pdf), Victron (see, e.g., http://www.victronenergy.com/upload/documents/Whitepaper-Data-communication-with-Victron-Energy-products_EN.pdf) SMA (see, e.g., http://www.sma.de/en/products/monitoring-control/modbus-protocol-interface.html#Overview-109910) as well as many other inverters can all interface to external systems using (a variant of) the ModBus protocol (http://www.modbus.org/tech.php).

We think that a demonstration in an operational environment should involve around 200 houses. Assuming a cost of about 5000 EUR (including installation) per home, we should consider about 1 000 000 EUR for the demonstration costs in our project to bring SmartHG to the market.

4.5.2.3 Interfacing

To complete the SmartHG services, we basically need to develop interfaces towards the inverter systems we decide to support. In order to verify *vendor neutrality* of the pursued approach, we should have at least two brands in our foreseen operational environment. We have identified commercial products, (e.g., those from MOXA http://www.moxa.com) that can support such an integration step.

Development of interface software can be done with the same approach we used to interface to DEVELCO Smart Plugs that have sensors as well as actuators. Accordingly, we anticipate that this work can be easily done within the SmartHG consortium. Of course, at least initially, we will focus on inverters used in the foreseen test bed in order to avoid wasting too much time in building interfaces that will not be used in the test bed.

TRL 8 requires us to complete our system and qualify it. A complete system has been basically built with the activities planned to reach TRL 7. Here we focus on qualification. In our setting, this entails evaluating the SmartHG Platform on more than just one operational environment and finally testing the software in order to attain a given degree of reliability.

4.5.2.4 Operational Environments

In order to enable evaluation of the SmartHG Platform in a variety of operational environments, we discussed our project with many electricity retailers (most of them part of a holding owning also a Distribution System Operator (DSO)) as well as energy management companies as described in the following.

First, of course, we discussed our plans with SEAS-NVE (http://www.seas-nve.dk) and MinskEnergo (http://www.minskenergo.by) since they are part of SmartHG consortium.

Second, during the SmartGridComm 2014 conference (November 2014) in Venice, we discussed our plans with IBM Zurich (http://www.zurich.ibm.com) and E.ON (http://www.eon.com), who presented preliminary results of an internal project of theirs, pursuing the same approach of SmartHG: exploit demand-awareness to optimise management of home devices (storage heaters in their case).

Third, during FP7 project *Advanced* workshops in Madrid (September 2014) and Rome (November 2014) we discussed our plans with ENEL (http://www.enel.it), EDP (http://www.edp.pt) as well as with energy market analysis company VaasaETT (http://www.vaasaett.com) and energy management and aggregator Entelios (http://entelios.com).

Fourth, during the Smart Grid workshop organised by IMDEA (September 2015) we discussed our plans with: the electricity retailer Energrid (http://www.energrid.it).

4.5.2.5 Testing SmartHG Home Software

System qualification requires a careful testing of the system. The SmartHG software managing home batteries is not a safety critical system, since batteries are protected from overcharging by the Battery Management System (BMS). However, a malfunctioning of the SmartHG home software may decrease the revenues expected from it. Accordingly, it has to be regarded as a *mission critical* system, that is, one whose malfunctioning may entail loss of money.

Furthermore, we should keep in mind that the SmartHG home services are to be considered *autonomous systems*, since they have to behave correctly even when the Internet connection is lost (otherwise we may have the situation where a loss of Internet connection may result in a home blackout).

To carry out such a testing activity we have already contacted an enterprise specialised in testing software for autonomous systems (e.g., for space, defence and automotive): NEXT (www.next.it).

TRL 9 requires us to prove our system in its operational environment. In our context, after the activities planned to reach TRL 8, this basically means running for 6 months or more the SmartHG Home Services in the operational environments identified above and evaluate the data gathered from a technical as well as economic point of view.

4.6 SmartHG Exploitation Plan Towards Distribution System Operators (DSOs)

In this section we outline our exploitation plan towards DSOs In particular, in Section 4.6.1 we discuss our plans to bring SmartHG to the DSO market and in Section 4.6.2 we show how we plan to turn the SmartHG Grid Services into a commercial product.

4.6.1 Bringing SmartHG to DSO Market

In this section we outline SmartHG exploitation schema for Grid Services. This is done by showing customer benefits (Section 4.6.1.1) and profitability for the technology provider (Section 4.6.1.2).

4.6.1.1 SmartHG Grid Services Exploitation Schema

The considerations in Section 4.4.3 suggest us, for SmartHG Grid Services, the exploitation plan summarised in Figure 4.8 and described below.

4.6.1.1.1 DSO First of all, the DSO offers a tariff (to which users may subscribe) that has a discount on electricity distribution *if* the user average power in any time slot meets DSO given time dependent power limits (*power profile*). Such a tariff depends on how important is for the DSO that most users follow the suggested power profile. This is modelled by the value of the p parameter discussed in Section 4.3.2 and defining the discount the DSO offers to users willing to subscribe to this time dependent tariff with respect to the standard *flat* tariff.

For example, in Italy the standard residential electricity contract has a maximum power of 3.3 kW. Higher power contracts are available, but at higher distribution costs. The above schema extends such a context to time dependent power limits. Indeed we note that second generation smart meters allow DSOs to read data every 15 minutes, thereby enabling an electricity distribution tariff dependent on the average power within a given time slot (e.g., one hour or 15 minutes if need be).

In Figure 4.8 we assume $p = 0.2$, hence that DSO decides to provide a 20% discount to residential users following the proposed power profiles. With the electricity distribution cost in our scenario being about 120 EUR/MWh tax included (see Table 4.3 in Section 4.3.1), this means a discount of 24.00 EUR/MWh.

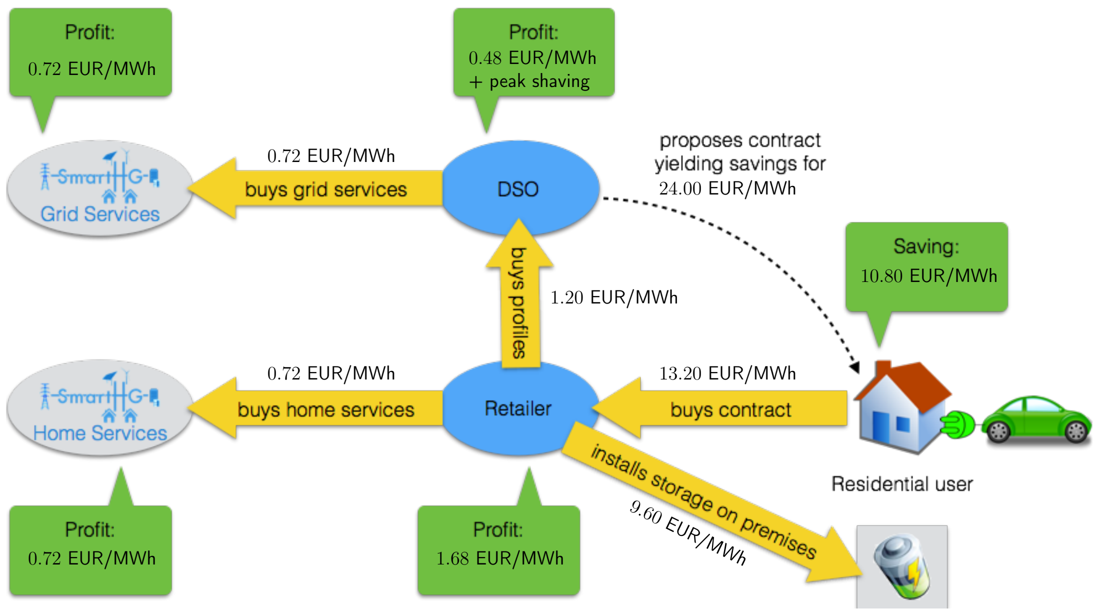


Figure 4.8: SmartHG Grid Services Exploitation Schema.

In turn, the DSO will pay SmartHG Grid Services for computing power profiles for all participating residential users. In our example we assume that such a service is paid 3% of the discount provided by the DSO to residential users (i.e., 0.72 EUR/MWh).

4.6.1.1.2 Electricity Retailer An electricity retailer can offer to a residential user an *ancillary* service helping him to follow the power profile proposed by the above mentioned DSO special tariff.

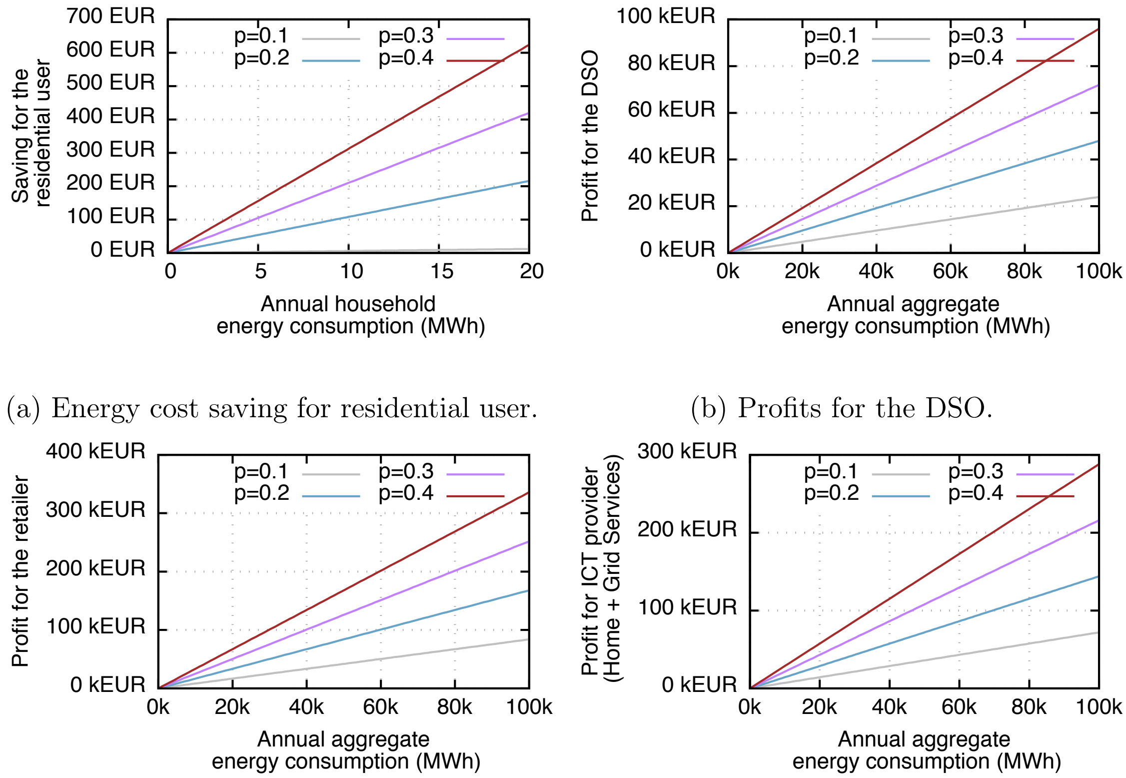
To this end the retailer will install at the user premises all the needed SmartHG devices, namely: sensors, Raspberry PI running SmartHG software and the required energy storage systems.

To pay for such an hardware infrastructure as well as for the management service provided, the retailer will charge to residential users a service fee (per MWh). Of course, how the savings enabled by SmartHG Grid Services are shared among residential users, the electricity retailer, the DSO and the Information and Communications Technology (ICT) company providing the SmartHG Grid Services depends on many considerations. Here we only provide an example to show feasibility of the proposed approach.

In our example in Figure 4.8 we assume that the retailer service fee (totalling 13.20 EUR/MWh) is the sum of: the home battery cost (amortised over 10 years) divided by the user expected annual consumption (9.60 EUR/MWh); 15% of the discount provided by the DSO to the residential user (i.e., 3.60 EUR/MWh).

The above schema leaves the residential user with 85%of the discount provided by the DSO decreased by the battery cost, which means 10.80 EUR/MWh. Note that such a saving comes to residential users without having to worry about time dependent tariffs.

The electricity retailer, in turn, will use the collected fee to pay for: the energy storage devices installed at the user premises (9.60 EUR/MWh); the services received from SmartHG Home Services (say 3% of the discount provided by the DSO, i.e., 0.72 EUR/MWh); the services received from the DSO (say 5%of the discount provided by the DSO, i.e., 1.20 EUR/MWh).



(a) Energy cost saving for residential user.

(b) Profits for the DSO.

(c) Profits for the retailer.

(d) Profits for the ICT provider.

Figure 4.9: SmartHG enabled savings and profits.

This leaves the retailer with a net profit of 7% of the discount provided by the DSO to residential users, i.e., 1.68 EUR/MWh.

4.6.1.1.3 ICT Provider Beyond the amount that the retailer will pay to SmartHG Home Services (in our example of Figure 4.8 this is 3% of the discount provided by the DSO, i.e., 0.72 EUR/MWh), the DSO will pay SmartHG Grid Services for computing power profiles for all participating residential users. In our example we assume that such a service is paid 3% of the discount provided by the DSO to residential users. This leaves to the DSO a net profit of 2% of the discount offered to the residential user (i.e., 0.48 EUR/MWh), *beyond* the savings stemming from peak shaving.

Figure 4.9 summarises benefits provided by SmartHG services to residential users, DSO, electricity retailer and ICT companies providing SmartHG services, for different values of p (we remind that numbers in Figure 4.8 refer to the scenario $p = 0.2$).

We note that residential users have the highest share per MWh. This stems from the fact that a single residential user will multiply its gain per MWh only by its annual consumption whereas electricity retailers, DSOs and ICT providers will serve (and thus get paid for) many more MWh.

The average annual consumption for residential users in Kalundborg test bed is about 7.78 MWh. This yields for residential users an average annual saving of about 84.05 EUR.

Furthermore, each 100 000 MWh (i.e., about 12 850 users) served yields (each year):

- a profit for the retailer of 168 000 EUR
- a profit for the SmartHG Home Services of 72 000 EUR
- a profit for the SmartHG Grid Services of 72 000 EUR
- a profit for the DSO of 48 000 EUR, *beyond* savings stemming from peak shaving.

We note that, as for electricity distribution, 12 850 households has to be considered a modest number of residential users in our context. So the above computation shows that we do not need a huge number of residential users to make the above described business opportunity attractive for ICT enterprises providing the SmartHG technology.

4.6.1.2 Profitability

Section 4.6.1.1 shows the advantages for the SmartHG customer (DSOs and retailers). However, in order to make this plan come true, we need to make sure that there is indeed a profit also for the ICT company that will take the SmartHG Platform to the market and not just for SmartHG customers. This is addressed in the following, details are in the Appendix of the second year deliverable on Dissemination and Exploitation (D7.2.1).

Shortly, running SmartHG Grid Services on a cloud based infrastructure takes less than 1 minute and this has to be done once a day for each substation. One hour of computation on a cloud based infrastructure (IaaS), such as the one offered by Google, will cost about 0.55 EUR/cpu-hour. Since our substation annual aggregated demand is about 1447 MWh, we have that the computation cost for providing the SmartHG Grid Services is about ($0.55 \cdot 365 \cdot \frac{1}{60} \cdot \frac{1}{1447} =$) 0.002 EUR/MWh, which is perfectly compatible with the exploitation schema described in Section 4.6.1.1.

4.6.2 Turning SmartHG Grid Services into a Commercial Product

SmartHG DSO oriented exploitation plan focusses on exploiting SmartHG Grid Services to optimise Electric Distribution Network (EDN) management. This is done by using a hierarchical approach where: (a) the higher network levels (e.g., substations) provide constraints to be met; (b) the SmartHG Grid Services compute, from such constraints, power profiles for the lower network levels (e.g., households); (c) SmartHG Home Services are used to steer power demand on the lower network levels (namely, residential homes) so that the given power profile constraints are met.

Accordingly, although we are focusing here on exploitation of SmartHG Grid Services, we need anyway to have the SmartHG Home Services in place to implement demand side management (accordingly to goals set by SmartHG Grid Services).

SmartHG Grid Services are used to compute power profiles for the lower levels in the network hierarchy (e.g., households) on the basis of the network topology and higher network level (e.g., substations) constraints, whereas SmartHG Home Services are used to drive lower network levels.

An exploitation plan for SmartHG Home Services has been presented in Section 4.5, where also deployment of SmartHG Home Services has been discussed. Such a deployment can take place *before* or *together* with that of the SmartHG Grid Services. Accordingly, in this section we focus on SmartHG Grid Services assuming availability of SmartHG Home Services.

The economic benefits that a DSO can harvest from SmartHG Grid Services have been discussed in Section 4.6.1.1. However, much as for SmartHG Home Services, to bring forward such advantages we need to take SmartHG Grid Services Technology Readiness Level (TRL) from the present value of 6 (Section 4.2) to the value of 9 needed to put the technology on the market. Accordingly, in the following we outline the obstacles we need to face to reach such a goal as well as the actions we plan to overcome them along with potentially interested enterprises we have contacted, besides those in the SmartHG consortium, to support such actions.

4.6.2.1 Interfacing with the DSOs

TRL 7 requires us to demonstrate SmartHG Grid Services in an operational environment. In the following we discuss the steps needed to attain TRL 7 from the current implementation of SmartHG Grid Services.

The starting point for the computations in the SmartHG Grid Services is the EDN topology. This is an input to the SmartHG Grid Services.

Ideally, such information could be exchanged with DSOs using the Common Information Model (CIM) standard as defined by IEC 61970-301 and IEC 61968 along with its XML format for network model exchanges as defined by IEC 61970-501 and 61970-452.

Although many DSOs are currently in the process of adopting network management software based on CIM standard (in order to have an open interface towards other systems) it is not the case that all DSOs currently run CIM based network management software.

SmartHG approach will be that of offering a CIM based interface to DSOs and then work together with them to interface towards proprietary formats as needed. Thus, in order to experiment with several operational scenarios, we will need to involve in our exploitation activities several DSOs along with enterprises working on electricity distribution management software.

4.6.2.2 Adding Operational Environments

In order to enable evaluation of the SmartHG Platform on many operational environments, we discussed our project with the following DSOs.

First, of course, we discussed our plans with SEAS-NVE (http://www.seas-nve.dk) and MinskEnergo (http://www.minskenergo.by) since they are part of SmartHG consortium.

Second, during the SmartGridComm 2014 conference (November 2014) in Venice, Italy, we discussed our plans with Elektro Gorenjska (http://www.elektro-gorenjska.si) a Slovenian DSO.

Third, during FP7 project *Advanced* workshops in Madrid (September 2014) and Rome (November 2014) we discussed our plans with ENEL Distribution (http://eneldistribuzione.enel.it), ERDF (http://www.erdf.fr), RWE (http://www.rwe.com) EDP (http://www.edp.pt).

Fourth, during the Smart Grid workshop organised by IMDEA (September 2015) we discussed our plans with: IBERDROLA (http://www.iberdrola.es) and Gas Natural Fenosa (http://www.gasnaturalfenosa.com).

4.6.2.3 Electricity Distribution Management Software

In order to evaluate the SmartHG Platform interface with the electricity distribution management software installed at DSO premises, we are discussing our plans with enterprises working on such a software, namely: PSI (http://www.psi.de/, producing the software currently installed at SEAS), INDRA (http://www.indracompany.com), Schneider-Electric http://www.schneider-electric.us) ALSTOM (http://www.alstom.com) General Electric (http://www.gedigitalenergy.com).

Both INDRA and General Electric participated in the Smart Grid Workshop in Madrid organised by IMDEA in September 2015.

4.6.2.4 Qualifying SmartHG Grid Services

TRL 8 requires us to complete our system and qualify it. In the following we outline the steps we foresee to reach such a goal.

First, we need to have interfaces towards measurements from the field so that SmartHG Grid Services can always have an updated picture of the network status. To this end, during the SmartGridComm 2014 conference (November 2014) we discussed our plans with an enterprise in the field, namely SIRTI (http://www.sirti.it).

Second, we note that most of the SmartHG software services will run in the cloud. Accordingly, in order to complete the SmartHG Platform, its services should be deployed in the cloud. In order to support such a goal we discussed our plan with Haugstad & Terkelsen (http://haugstad-terkelsen.com), an enterprise actively working towards developing cloud based software services and acquainted with SmartHG approach since one of its co-founders was previously in the SmartHG consortium.

Third, system qualification requires a careful testing of the system. We note that the SmartHG software affects the operation of the electrical grid. Thus, a software malfunctioning may entail a loss of money (safety is not much of an issue in our context since substations and batteries have protections of their own). For the above reason our SmartHG Grid Services have to be regarded as a *mission critical* system. Accordingly, in order to carry out testing of the SmartHG software accordingly to mission critical software standards, we have discussed our plans with NEXT (www.next.it), an enterprise specialised in testing of mission critical software with whom UNIROMA1 has a long-standing relationship stemming from aerospace related project activities.

TRL 9 requires us to prove our system in its operational environment.

In our context, this just could mean running for 6 months or more the complete system and evaluate the gathered data from a technical as well as economic point of view.

4.7 SmartHG Company Structure and Intellectual Property (IP) Issues

At the end of the activities outlined in the previous sections, we need to actually bring the SmartHG technology to the market.

IP from SmartHG is regulated by the SmartHG consortium agreement. On such a basis, we can define partner roles and shares for the enterprise(s) that will bring the SmartHG services to the market. To that end, two approaches are possible:

- Monolithic: by creating a single company where all partners are represented and whose objective is that of exploiting SmartHG technology.
- Distributed: by creating many *vertical* companies focused on offering a subset of the SmartHG services to the market and then by creating a *horizontal* company, focused on *integration*, that will offer the whole SmartHG Platform, that is the integrated SmartHG services, to the market.

Of course the monolithic approach is at a first sight easier to pursue. However it can find indeed many obstacles on its way as discussed below.

First, each of the services developed within the SmartHG project can be exploited also in a stand-alone fashion. In such a context, the partners involved in exploiting a service in a stand-alone fashion may wish to start a dedicated company to increase visibility and to pursue specific market strategies that may differ from those aiming at exploiting the integrated SmartHG Platform as a whole. For example, along those lines, Aarhus University is in the process of creating a start-up based on the device (Home Energy Controlling Hub) they developed within the SmartHG project whereas SOLINTEL has already opened a company in Hongkong China (CNES International) focusing on smart grid and energy efficiency.

Second, if some of the partners responsible for a given SmartHG service decide to stop working on that service, their presence inside a company focusing on exploiting the integrated SmartHG Platform may cause problems.

Accordingly, we envision pursuing the distributed approach described above where each group of services is brought to the market by the group of partners mainly involved in the development of those services. The SmartHG Platform (as a set of integrated services) is instead offered by a company mainly focusing on integrating services offered by other companies (not necessarily restricting to those from SmartHG).

Such a distributed approach easily allows commercialisation of stand-alone SmartHG services and offers some robustness with respect to future market evolutions. In fact, if some of the *vertical* companies mentioned above stops working, for example because some of the partners have lost interest in developing their services, then the *horizontal* (integrator) company can just look for another company offering those services or develop them as needed. We note in fact that all SmartHG deliverables are public and that indeed most SmartHG technology has already been subject of publications. Furthermore, all SmartHG services have an open (RESTful) interface that allows replacing a service implementation without having to modify anything else. Indeed, this kind of *fault tolerance* is one of the main reasons behind our open protocol approach.

Summing up, the company structure that at this time appears more reasonable in order to exploit SmartHG technology is a *distributed* one, where each group of partners wishing to bring their services to the market will do so with a specific company, whereas an *integration* company will focus on offering the whole SmartHG Platform, that is the integrated SmartHG services, to the market. Such an *integration* company could be an existing Energy Service Company (ESCO) interested in pursuing such an activity as well as a novel ESCO company created for this purpose. We note that we already have ESCO companies in our consortium, namely PANPOW, DEVELCO, SOLINTEL and ATANVO, who of course have experience on such a market step.

Chapter 5

Conclusions

According to the dissemination plan developed in the first year, SmartHG dissemination activities devised many different ways to reach the target audience. The consortium was able to concretise the dissemination plan with a strategy agreed by all partners. Besides a responsive website with a revised Technical Section, SmartHG communication tools include: event list, newsletter, mailing lists, social network accounts and more classical approaches such as participation at conferences and publications in international peer-reviewed papers in conferences or journals.

This year dissemination activities, besides improving the project website and project artefacts and continuing to disseminate project results at international conferences and publications, also focussed on the organisation of the main SmartHG dissemination event: the workshop held in Kalundborg (Denmark) in May 2015. The workshop has brought together researchers, public and private stakeholders and industries, and has been a great opportunity to disseminate and discuss project results and envision further developments and cross-fertilisations with the Covenant of Mayors community in Denmark, as well as with the Smart Grid community at large.

The final exploitation plan described in this document has focussed on both a short-term and a mid-term scenario. In the short-term scenario, we have shown the profitability for electricity retailers in using SmartHG Home Services in order to save on the electrical energy cost (*arbitrage*), also rewarding residential users. In the mid-term scenario, we have shown the profitability for Distribution System Operators (DSOs) in using SmartHG Grid and Home Services in order to perform *peak-shaving* of the aggregate electrical demand.

We validated our envisaged exploitation plans by identifying quantitative exploitation scenarios and estimating revenues.

Chapter 6

List of Acronyms

BMS Battery Management System 30

CIM Common Information Model 35

DSO Distribution System Operator 38

EBR Energy Bill Reduction 28

EDN Electric Distribution Network 34

ESCO Energy Service Company 37

EUMF Energy Usage Modelling and Forecasting 28

EUR Energy Usage Reduction 28

HECH Home Energy Controlling Hub

IaaS Infrastructure as a Service 27

ICT Information and Communications Technology 32

IP Intellectual Property 36

LV Low Voltage 12

MPPT Maximum Power Point Tracking 12

MV Medium Voltage 12

PEV Plug-in Electric Vehicle 19

PV PhotoVoltaic 22

RESTful REpresentational State Transfer

SEIL Smart Energy Integration Lab 14

T&D Transmission and Distribution 19

TRL Technology Readiness Level 35

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