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Abstract:

In this document, a qualitative and quantitative analysis of the data collected within WP6 “Tests and Demonstration” will be performed. All data gathered are aggregated, analysed according to the methodology described in detail in D7.1 “Evaluation plan”, and consolidated results are extracted. Based on these results and on the overall objectives defined by the project, final conclusions are drawn over the efficiency of the system and its overall impact, mainly in terms of energy savings and reduction of emissions. Furthermore, CBA and CEA are performed analysing the costs and benefits for the involved stakeholders. Finally, technical robustness of NOBEL prototypes is evaluated, and how technical requirements and thresholds are met.

Keywords:

Final results, energy reduction, energy efficiency, brokerage energy market, CBA, CEA analysis, system efficiency

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Executive Summary

The current deliverable, entitled D7.3: “Evaluation and Assessment”, has been prepared in the context of WP7: “Evaluation and Assessment” of NOBEL FP7 funded project. The main objective of this WP was to gather, consolidate and analyse all information deriving from pilot tests of NOBEL project in Alginet and finally conclude over the efficiency of the integrated system of prototypes, developed within the project, mainly in terms of environmental impact.

Firstly, the deliverable shortly presents the process of data collection during pilots, already included in D6.1 “Local integration activities and Data gathered for Evaluation” and reports in detail the emerging consolidated results. In following the analysis of these data is provided. The evaluation process followed the evaluation plan described in detail in D7.1 “Evaluation plan”. Data gathered from the pilots were aggregated, analysed and conclusions over the efficiency of the system are finally drawn. A series of tools were developed for the collection of measurements of NOBEL pilots, namely logging files, questionnaires, technical diaries, etc., which were further processed to lead to the results provided in this Deliverable. Within NOBEL, technical validation, user applications and impacts assessment were conducted. CBA and CEA analysis were also performed and in combination with pilot results, an insight in the expected impacts of NOBEL in energy efficiency and optimization is provided in this document. In addition, simulations were performed in order to evaluate impacts that were not determined through pilot testing and to investigate the scalability of the system.

In short, NOBEL managed to achieve an **overall energy consumption reduction of 17%** for standard prosumers and 40% for the senior prosumer participant (Public lighting system). In addition, considering that the simulated RES loads were real and conducted in the grid through NOBEL the overall emissions would be 20% reduced. These impacts led also to remarkable economic benefit for NOBEL system users.

During the project, NOBEL end-user applications were finalized and updated according to emerging user needs as identified for the whole duration of the pilots. For this reason, the usability and friendliness of the system was very high as extracted from the post-pilot questionnaires results and an online user survey.

From the CEA and CBA analysis, it is proved that NOBEL system will be a worth-to-implement, beneficial for all actors involved, investment that leads to incontrovertible environmental and monetary benefits.

1 Introduction

1.1 Scope of the document

The current document constitutes the overall evaluation of the NOBEL EU project, including the pilot testing results as well as other types of assessment performed, such as lab simulations. Through this document the analysis of the pilot data is performed in order to extract final results and determine the overall impact of the project. The document is focused mainly on energy impacts and on the level of achievement of the main objectives of the project, in terms of energy efficiency and sustainability. In addition, technical robustness of the prototypes integrated system and user acceptance issues are also evaluated. Based on the pilot results a socioeconomic analysis is performed. Costs and benefits are defined for all involved groups of users and consolidated results are reported. The final impacts will be determined through comparisons with baseline or thresholds defined in D7.1"Evaluation plan", taking into account also user requirements.

This Deliverable is highly connected with D6.1 "Local Integration activities and Data gathered for Evaluation" where the data obtained during pilots are included and are the main input for the current document.

1.2 Structure of the Document

The current document is organised in 8 chapters. The current chapter 1 includes an introduction, presenting the scope of the document. Chapter 2 firstly includes the outcomes of the user applications pilot system assessment. A short description of each phase of pilot testing is provided and the respective results are presented. In addition, it provides data for the pre-pilot situation, defining a reference case to be used as baseline for the impact assessment. The same chapter evaluates the marketplace through simulation scenarios that tested two main market models. In Chapter 3 the impact assessment process is performed per impact assessment category, including the required data, the methodology of their analysis and final impacts. In Chapter 4, CBA and CEA are performed for the involved group of users according to the methodology described in D7.1. In addition, a SWOT analysis is performed and finally, intangible benefits and costs estimation are provided. Then, Chapter 5 includes the results of the technical assessment, providing reports by the developers as well as qualitative, subjective conclusions over the robustness, deriving from the questionnaires assessment. Chapter 6 provides overall conclusions over the project, level of the objectives fulfilment and future implementation perspectives.

2 Pilot assessment

2.1 End-user applications and pilot participants

Pilot tests in Alginet took place in order to evaluate the 3 basic end-user applications developed within the project:

- **NOEM** (Neighbourhood Oriented Energy Monitoring and control system) is a web based application that enables the electricity network operators to have an overview about the consumptions of all grid users and manage in a more efficient way the energy distribution within grid.
- **BAF** (Brokerage Agent Front-End) is an application used as a visualization tool for a prosumer. The BAF application is used in order to achieve a more efficient energy management and its function is based on data from smart meters. Using BAF the prosumer have the option to buy or sell energy for his benefit according price, have an overview about his consumption/production or even have a prediction for this.
- **NOPL** (Neighbourhood Oriented Public Lighting Monitoring and Control System) is a service used by operators of the Public Lighting system, and enables the monitoring of electricity needs for Public Lighting and finally a more efficient energy management. Within NOBEL sensor are also installed in order to adjust public lighting according to external conditions (traffic, weather, natural light).

The above mentioned applications are respectively addressed to different user categories which were the following:

- **Local Distribution System Operators (local DSO).** A local DSO provides the last mile for the final users, as well as the adaption of the electricity from the high voltage used by global DSO and TSOs. Within NOBEL one DSO participated to the project (Alginet Cooperative), testing **NOEM** application.
- **STandard Prosumer (STP).** A STP is a basic domestic end-user that not only consumes electricity, but also may produce it; he has the ability to buy or sell in the market the needed or excess of electricity available – i.e. electricity in the network that belongs to a particular end user but that is not being used. During Alginet pilots, standard prosumers tested **BAF** application.
- **SEnior Prosumer (SEP).** A SEP is a STP that in addition requires internal energy management processes, as a public lighting system, a heavy industry, a sports centre, etc. (Industrial, Commercial and Public Infrastructure). Within NOBEL, the senior prosumer was the public lighting operator, testing **NOPL** application through segments of public lights.

2.2 First round of pilots

The first phase of NOBEL pilot tests took place in Alginet of Spain during the period 1/02/2012 – 30/04/2012 and involved gradually 100 standard prosumers that tested the first integrated version of BAF, the Alginet Cooperative testing NOEM and a segment of lights in “Reyes Catolicos” avenue testing first version of NOPL. The prediction service was not provided in its finalized version though, and the automatic agent of BAF was not yet introduced, until the second round. The results of the first round were critical and provided feedback for enhancements of the system to be applied in the second phase, especially in terms of technical problems encountered during the first phase and user interface issues. In the following sections, the process of the first round evaluation is presented, providing preliminary results of the project. These results will be compared with the second phase, where advanced and enhanced versions of the prototypes were implemented.

2.2.1 Data collection methodology

Stemming from the detailed evaluation plan and the assessment indicators as defined in D7.1, the consolidation of the collected data was performed, in order to evaluate the system performance during the first phase of pilot testing in Alginet.

The first step was the collection of pre-pilot questionnaires, aiming to investigate the pre-system energy behaviour and energy management approach by all involved groups of users. The questionnaires were available online in Google docs in English and in Spanish and all involved users had to fill them in. Different types of questionnaires were provided, addressed to different stakeholders (standard prosumers, senior prosumer (lighting system operator) and DSOs). There were focused on current energy behaviour of the users and included scaled, multiple and free questions, clustered per group of user. In addition, post-pilot questionnaires were distributed to the users including user acceptance issues and questions related to energy management and behaviour change.

In order to investigate Alginet grid end-users' profile, consumers' data were requested by the DSO (Cooperative of Alginet). The individual user electricity contracts were obtained, including information about the type of contract (with time discrimination or with flat tariffs) and contract maximum power. There were also updates during pilots in case users were modifying their contract. This information was necessary in order to determine economic impacts.

In order to evaluate energy impacts a detailed database was provided by the DSO, including the consumption per 15 min, for every user in Alginet for the period 2011-2012. The smartmeter indications are cumulative as the smartmeters never reset and constantly log information. Thus, initial necessary calculations were performed in order to extract the actual net energy consumed for each time slot. The database was then filtered per User ID, in order to dissociate the non-participants. In addition, only the period of first trial was analysed. The initial analysis of this database was the aggregation of the data in 4 intervals within day, as defined in the Evaluation plan. This aggregation enables easier analysis and also more provides more granular information. These data were aggregated daily and monthly, in order to extract total and per interval results and conclusions. The production was simulated according a pre-defined capacity for each user, in order to enable the trading game. The production level is not influenced by the system as NOBEL is contributing only in the optimized management of production and not its increase. However, production data were considered in order to evaluate emissions and economic impact.

Based on the contracts and the activity within the marketplace, energy indicators were also translated to monetary values in order to investigate economic impacts.

Direct access to the billing documents of the users was not possible, as they are personal data protected by the DSO. On the other hand, all transactions were performed in Nobelitos and had to be converted to Euros in order to have a common baseline for the impacts assessment (1 Nobelito = 1 Euro cent, as define in D7.1). Costs and revenues calculation was based both in contract information and on marketplace usage data.

User acceptance is a critical factor for the fulfilment of NOBEL objectives, as the energy efficiency enhancement required a high level of social acceptance and active participation of all users in the energy market. The only end-application that was related to this indicator was BAF, as NOEM and NOPL were only used by one single actor, namely Alginet Cooperative and Alginet Municipality. Thus, BAF application traffic was determined, extracting some generic data from log files.

2.2.2 Indicators measured

The targeted indicators were mainly focus on energy usage and aim to provide as clear and detailed information.

The specific indicators measured are the following:

- **Energy consumed monthly (kWh)** and for the **whole duration of the pilots** by each user. Average values of daily consumption and average consumption of specific intervals within day, are presented. Another indicator calculated is **electricity/person (kWh/capita).** This indicator provides estimation about the kWh that an average person is responsible for consuming.
- **Total Emissions (kg** CO_2**).** The emissions are expressed indirectly based on the average energy mix, the overall consumption and on the emissions expected from these specific quotas of different energy sources.
- The same **energy consumption indicators** will assessed individually also for the smartmeter that corresponds to the **NOPL** management area, i.e. public road in Alginet, in order to evaluate NOPL impact.
- **Total clean energy produced (kWh)** within the Alginet smartgrid by the prosumers. This indicator was expressed for the whole of the participants as more detailed analysis has no sense as the production is simulated. However, this information is necessary in order to estimate the economic benefit from the marketplace.
- In relation to monetary indicators the **overall costs for energy (€)** were measured.
- Based on the simulated electricity produced, the **revenue from production selling (€)** was also determined in case this production was real, only for informative purpose. This income was determined by the total production by PVs within pilots. It is assumed that a part is self-consumed and another is sold in the market.
- For user acceptance evaluation, the indicators measured were the **average duration of visits, the visitors per day, the overall visits, and visits per day/user.**

2.2.3 Results summary

2.2.3.1 Consumption data

Standard Prosumers Energy Consumption – BAF application

The most critical objective of the project has been the overall reduction in energy consumption and the enhancement of the overall efficiency of the local energy grid. In a first analysis, the overall consumption of the pilot participants is a sufficient indicator to have a general overview of the impact of the project. Thus, as a first step the overall consumption during the first phase pilot interval is calculated. In addition, the total consumption for each month was calculated. We have to remark that February was not complete, as the data from 1st to 17th February were not valid due to some occasional technical problems on Alginet network, thus a deduction was performed in order to extract some informational data about the changes in the consumption through months.

As mentioned before, the energy consumption data were aggregated for four intervals within day for each day of the pilots' period as defined in D7.1. The average daily consumption as well as the average consumption for each interval was estimated. In the following Table 1 the results of the energy consumption data analysis for the first round of pilots are presented. In general we can observe higher overall values than typical household consumption, due to big scale consumers (e.g. offices or SMEs participating in pilots) included in the averages. For this reason, separate results are also presented for the household and for these bigger scale users. This clustering is performed according to the consumption and the big scale standard prosumers are considered those with total consumption for the 3 months period higher than 5000 kWh. In Table 1 we can observe that

March has an increased consumption in relation to February and April. Furthermore, the peak hours are in Interval 3 and 4. Analysing these results it is shown that the peak in the domestic sector is clearly in Interval 4. In order to calculate the indicators per capita, information from the pre-pilot questionnaires is extracted about the total number of persons per house. As the questionnaires of the first phase were anonymous (they do not include Smartmeter ID or name), this analysis cannot be per user but the average persons per building will be used. The average number of inhabitants per residence (smartmeter number) is 3 persons. Considering these values, indicators are also associated with population. For the latter indicators the average values were extracted only from domestic users as the pre pilot questionnaires were filled in by them and also the persons/ building is very high for the large scale users, thus we cannot assume the average in this case.

Energy usage results for the first phase of pilot tests (1 February- 30 April 2012)			
Indicator	**Total**	**Household standard prosumers**	**Bigger scale standard prosumers**
Total Energy consumption (kWh) (17/2-30/4)	227008,5	80214,3	146794,3
February Total Consumption (kWh) (Deducted)	77022,2	30604,6	46417,6
March Total Consumption (kWh)	78959,4	26804,2	52155,24
April Total Consumption (kWh)	71026,9	22805,5	48221,45
Average daily consumption (kWh)	39,39	23,98	133,05
Average consumption Interval 1 (00:00 – 6:00)	6,0	8,7	17,5
Average consumption Interval 2 (6:00 – 10:00)	8,2	4,9	31,2
Average consumption Interval 3 (10:00 – 17:00)	12,9	8,40	50,1
Average consumption Interval 4 (17:00 – 00:00)	12,5	7,99	37,2
Daily Consumption per capita (250 persons assumed) KWh/ person/day	3,56		
Average Monthly consumption per capita KWh/ person/month	106,95		

Table 1: Energy usage results for the first round of pilots for standard prosumers

Senior Prosumers Energy Consumption (Public lighting system segments) – NOPL application

The selected segment of lights in “Reyes Catolicos” avenue in Alginet that was used to assess NOPL had an individual smartmeter (number 501001747) and will be separately evaluated. The location of this segment is illustrated in Figure 1.

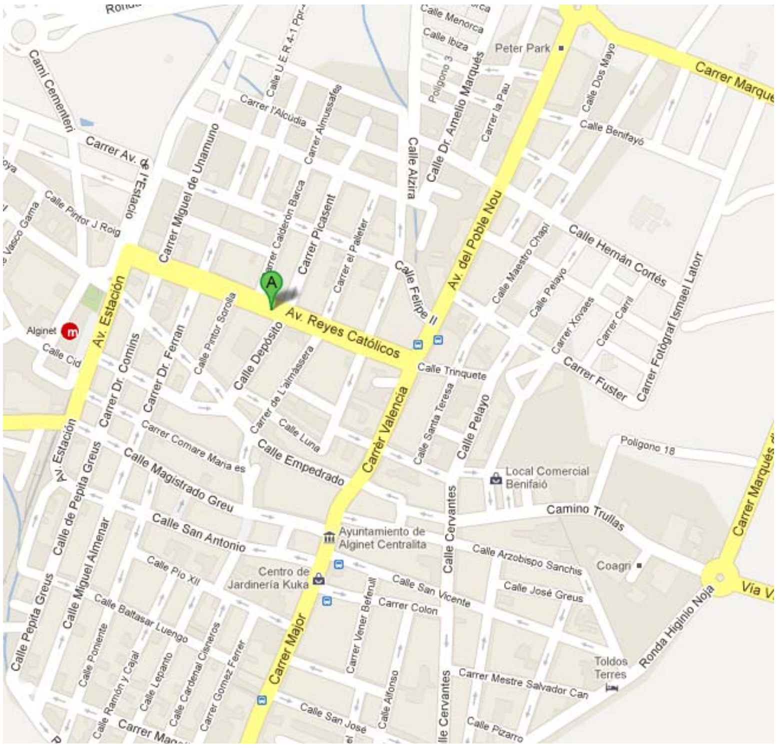


Figure 1: Avenida Reyes Catolicos in Alginet

In Table 2 below, energy consumption results for Alginet lights are presented. As expected the Intervals 1 and 4 are almost equal whereas the rest of the day the consumption is almost zero as there is day light.

Pilot public lights consumption data	
Total pilots consumption (kWh)	6562,81
Total February consumption (deducted) (kWh)	2610
Total March consumption (kWh)	2894,63
Total April Consumption (kWh)	2498,18
Average Daily Consumption (kWh)	88,88
Average Consumption Interval 1 (kWh)	43,06
Average Consumption Interval 2 (kWh)	0,45
Average Consumption Interval 3 (kWh)	0,27
Average Consumption Interval 4 (kWh)	45,06

Table 2: Energy usage results for the first round of pilots for senior prosumers (lighting system)

2.2.3.2 Production data

Standard Prosumers Energy production – BAF application

In the context of NOBEL project the production was simulated based on weather data as it was not possible to include real prosumers in the pilots, as there are very few in Alginet. The production curves for the users had very few fluctuations between them, as a limited number of different capacities were considered. Thus, production had a very specific range of values depending on the capacity and on weather conditions. However, the overall production was calculated in order to have some indicative values about the production in case this was real. In addition, for the first days of the pilots (from 17-29 February) there were no production data as we decide to include this production simulated data gradually so this analysis will take place only for March and April. For February we can assume that the production is 5% lower than in March, thus 8500 kWh. The average and the total production for these months are presented in the following figures (Figure 2 and

Figure 3).

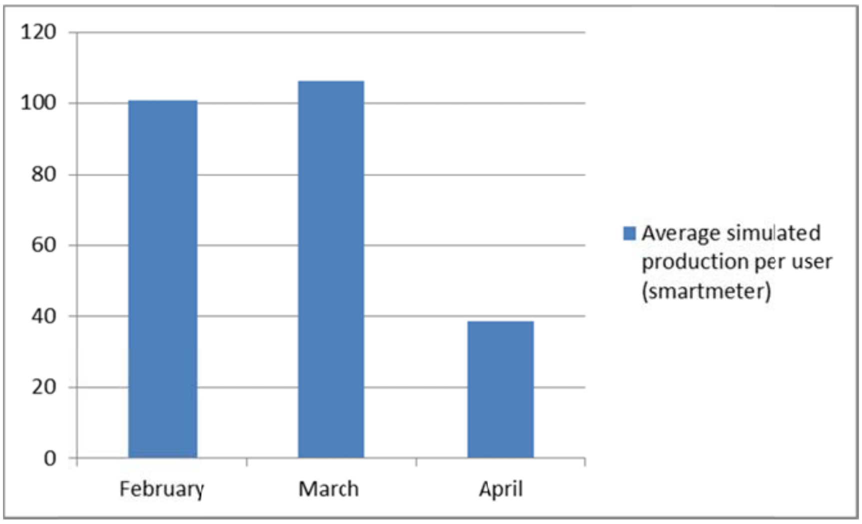


Figure 2: Average simulated production per smartmeter in KWh for the first phase of pilots

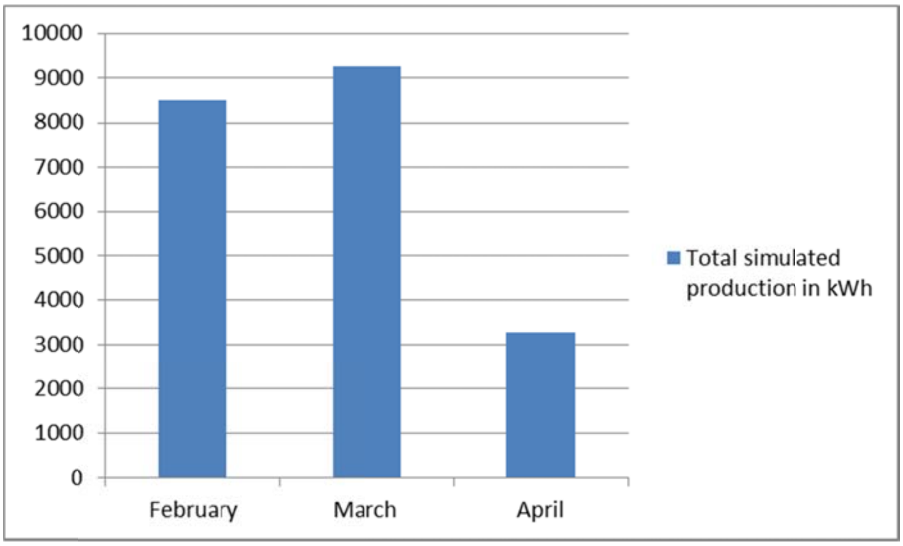


Figure 3: Total simulated production in KWh of all the first phase of pilot participants

2.2.3.3 Costs for consumption

Standard Prosumers costs for consumption – BAF application

This analysis is going to follow a blended approach as the pilot participants had two ways of interaction in order to buy energy; the local DSO and the marketplace. It is assumed that the prosumers consume part of their production; when it is higher than the consumption, then, sell the rest in the marketplace, and when the production is lower than their consumption buy energy from the DSO or from the marketplace if the price is beneficial for them. As described in the next section very few transactions took place in this phase, so it is assumed that the total consumption was bought by the DSO.

The exact billing data for the users could be obtained directly by Alginet. However, this approach was not possible as the exact billing data were protected by personal data protection laws. Thus, the amount paid for energy was determined indirectly through the kWh tariffs and the amount of energy consumed in kWh. To realize this analysis information about the type of contacts of the pilot participants were obtained by Alginet. The Utility offers different types of contracts for the users. The contracts are clustered to those without time discrimination and those with, and there are also different contracts for domestic and large scale consumers. The following **Table 3** presents the tariffs for each type of contract.

Alginet contract types and tariffs				
Type of contract	With time discrimination	Without time discrimination	Time Period	Tariff (€/kWh)
2.0A		√	Non applicable	0.137305
2.0DHA	√		2P1 peak (12:00 to 22:00 in winter and 13:00 to 23:00 in summer)	0.173701
			2P3 non-peak (22:00 to 12:00 in winter and 23:00 to 13:00 in summer)	0.060780
2.1DHA	√		2P1	0.158671
	√		2P2	0.088776
3.0A	√		3P1 (18:00 to 22:00 in winter and 9:00 to 13:00)	0.157587
			3P2 (8:00 to 18:00 and 22:00 to 24:00 in winter and 8:00-9:00 and 13:00 to 24:00 in summer)	0.119660
			3P3 (00:00 to 8:00 both winter and summer)	0.091146
3.1 A	√		3P1	0.128720
			3P2	0.114230
			3P3	0.097615

Table 3: Pilot participants contracts information

In addition, the consumption data as described in 2.2.3.1 was calculated. Thus, the costs for energy were easily estimated. However, as one of the assumptions is that users are PV owners, the self-consumption should be considered. In general in some European countries e.g. Greece, the concurrent island mode and conduction to the grid is not possible by PVs, due to national legislation. So, the users sell the whole production to the grid and there is no option to consume a part of it. However, within the NOBEL pilot scenarios the prosumers cover first their energy needs by RES and then sell the rest. They are still dependent in the DSO as there are no storage mechanisms and there are intervals where production is lower than consumption. Within this analysis we assume that 35% of the production is used in order to cover own needs. This percentage is selected based on the results of the second pilot phase (see section 2.3.3.3)

Summarizing, the users' total consumption was 227008,5 kWh. The total production is 21024,4 kWh. Thus, the production used for covering user needs is 21024,4*0.35 = 7358,54 kWh. Based on this, the consumption that is actually billed is total consumption-free energy from production = 227008,5 - 7358,54 = 219649,96 kWh. Considering the average price of 0,12 € from Table 3 we can say that the users would pay 219649,96 *0,12= 26357,99 €, during the first pilot phase, for covering their consumption needs.

Of course, this I just an assumption as the users continued to have their standard contacts and paid the whole amount of their consumption to the DSO. However, this analysis is necessary as we should evaluate a scenario where the users will have actual production and this will have real impact on their billing system.

Senior Prosumers costs for consumption – NOPL application

The light segment in Alginet avenue testing NOPL has a separate contract with tariff of 0,124 €/kWh. Considering the overall consumption of 6562,81 kWh, total costs for consumption of this segment was 6562,81 kWh *0,124 €/kWh = 813,80 €.

2.2.3.4 Revenues from production

Standard Prosumers revenues for production – BAF application

As described before, the prosumers can select to sell part of their production in the marketplace or sell it directly to the DSO with a standard price. If these users had actual PV installations, the revenue from selling this production would arise from the standard tariff for roof PVs in Spain. However, these prices are still very high in Europe due to the incentives provided in domestic users to install PVs (see Figure 4). This policy is damaging for the DSOs, as in many countries (e.g. Greece) they find it difficult to cater to their financial commitments, considering also the economic crisis striking Europe.

Country	System Type	Size [kWp]	Month / Year	FiT Start ... End	Unit	Remark
Spain	Ground Mount		2011 Jan - Dec	0.176	€ / kWh	All systems registered under RD 661 (systems installed since year 2007) will only receive FIT incentives for a total of 1,250 hours per year
	Rooftop	< 20		0.323		
		> 20		0.233		

Figure 4: Spain PV tariffs during the period January-December 2011

Taking into account this situation, stakeholders plan to reduce dramatically the feed-in tariffs and thus minimize the revenues for the prosumers. In such a model the NOBEL system is much more meaningful and beneficial as the marketplace provides to the prosumers a mean to trade their energy according the supply/demand rules and not to the standard reduced tariff offered by the energy suppliers. This price is considered to be 10 cents/kWh in our case, so usually the prosumers select to sell it through the marketplace, which is more beneficial for them. However, during the first phase of pilot testing very few matched transactions were performed so the revenues by the marketplace for the prosumers are not mentioned in this stage. Thus, it is considered that the excess production was sold to the DSO in a flat tariff of 10 cents/kWh. The Consortium dealt with the limited transactions problem by the introduction of the semi-automatic agents in the second phase of trials.

Considering again the assumption that 35% of the production is self-used, the production to be sold is: Total production – Self-used production = 21524,4 - 7533,54 = 13990,86 kWh. Thus, the total revenue was 13990,86 *0,10 = 1399,86 €.

Remark: *as in this phase the market impact is not evaluated, the revenues will be the same as in the reference case as described in 2.4.3.1.4. The reference case is a baseline scenario in order to compare the NOBEL impacts.*

2.2.3.5 CO_2 emissions

Standard Prosumers CO2 emissions – BAF application

Based on the total consumption we can calculate the respective CO_2 emissions for the first phase period. The CO_2 emission monitoring was not provided in BAF in the first phase, thus the emissions could be only estimated in directly through the consumption. An average energy mix for the energy distributed in Alginet was considered, obtained by the "Red Eléctrica de España" web site which is the TSO for the Alginet region. The specific mix of the energy distributed in Alginet local grid could not be determined so the following average percentages (Figure 5) were used wherever were necessary.

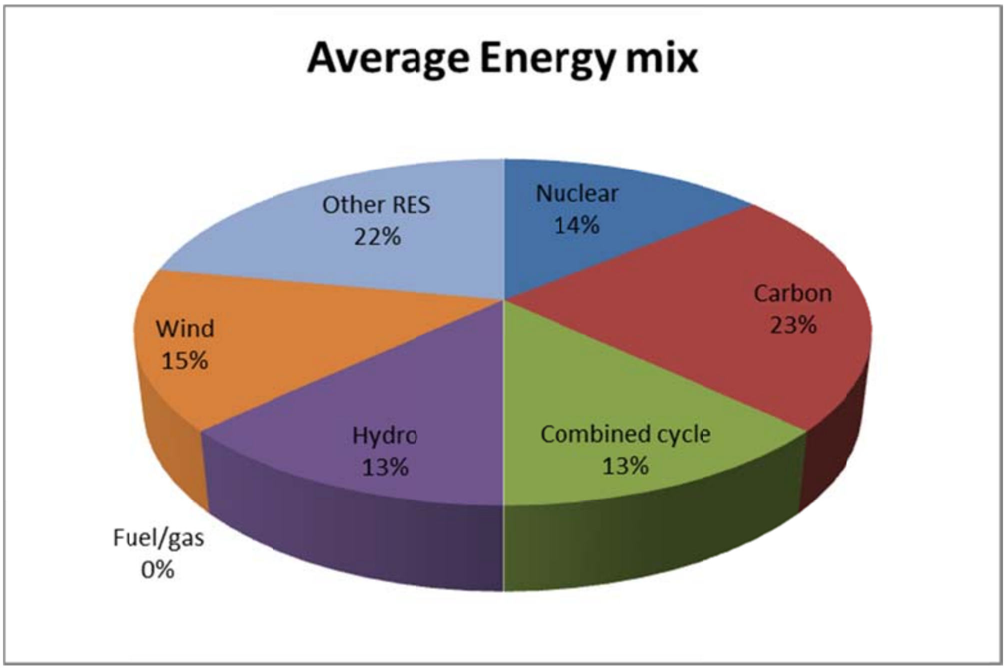


Figure 5: Average Energy mix in Spain

In addition, the indicative values for $kgCO_2/kWh$ released by each source of energy production are the following:

- Nuclear: 0,60 $kgCO_2$ /kWh

- Carbon: 0,95 $kgCO_2$ /kWh
- Combined cycle: 0,37 $KgCO_2$ /kWh
- Hydro: 0,00 $KgCO_2$ /kWh
- Fuel/gas: 0,70 $KgCO_2$ /kWh
- Wind: 0,00 $KgCO_2$ /kWh
- Other renewable sources (RES): 0,00 KgCO2 /kWh

Based on the energy mix and the above mentioned values we can easily calculate the emissions for each kWh distributed in Alginet grid.

Total $kgCO_2$ /kWh distributed in grid: 0,351 $KgCO_2$ /kWh (based in the energy mix quotas).

Based on these values we can estimate the emissions using the following formula:

CO_2 (kg) = 0,351 $KgCO_2$ /kWh * Total consumption (kWh) = 0,351 * 227008,5 = 79679,9 kg CO_2

Remark: *If the production and the marketplace transactions were real, the emissions would be less due to high clean energy usage.*

In this case, the production conducted in the grid has to be considered in the energy mix. In addition, part of the consumption is clean energy as described in the previous sections. As described before the consumption the derive from the energy mix is 219649,96 kWh (considering the self-used production). In case the production was real, an additional amount of 13990,86 kWh will be also added to the energy mix, to the “other RES” category.

Thus, the new energy mix will be as illustrated in **Figure 6**:

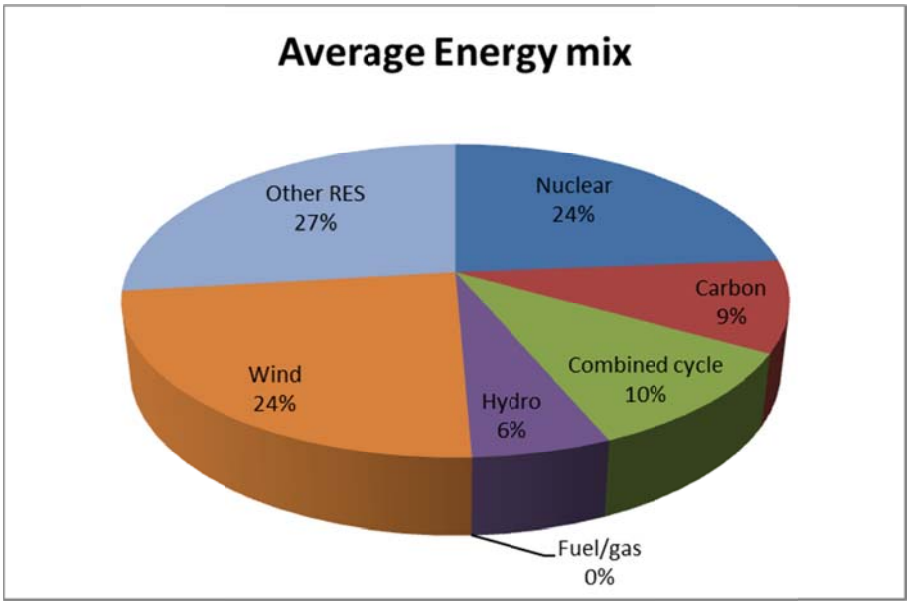


Figure 6: Average Energy mix for pilot users if the production was real

Based on the average emissions per type of energy the **$kgCO_2$ /kWh** is now: 0,329 $KgCO_2$ /kWh.

Summarizing the CO_2 (kg) = 0,329 $KgCO_2$ /kWh * Total consumption from energy mix (kWh) = 0,329 * 219649,96 = 72264,83 kg CO_2 .

As expected the emissions would be lower if these prosumers generated actual production.

Senior Prosumers CO2 emissions – NOPL application

Assuming the same energy mix for the lights segment consumption the respective emissions are: CO_2 (kg) = 0,269 KgCO_2 /kWh * Total consumption from energy mix (kWh) = 0,329 * 6562,81= 2159,16 kg CO_2 .

2.2.3.6 End-users application usage statistics

Standard Prosumers usage statistics – BAF application

One of the main prerequisites for the achievement of the NOBEL system objectives is the wide participation of the users, especially for the marketplace as the benefit for the users is directly dependent on the number of participants, considering the demand-supply rules. For this reason, statistical data for BAF usage were obtained for the Web application.

The first indicator measured was the duration of individual visits for the whole first round interval. The average duration of individual visits was 5.19 min for the first round of trials. Visits had a very wide range of duration and it seems that some specific users remained logged in for a significantly bigger time slot, while other just logged in for a few minutes or even seconds. Thus, we can assume for these users that they did not have performed any transactions.

The average visits per day were 6, without taking into account the multiple visits per day from single users. After considering this factor the average unique visits per day were 4. Analysing the average visits per month we cannot detect significant differences between them. However, in order to perform a comparison of the total amount of visits per month, the comparison between March and April is only possible, as the pilot testing period started at 17 of February. During March visits were 15% more than in April as the following chart shows, due to Easter holiday break (Figure 7).

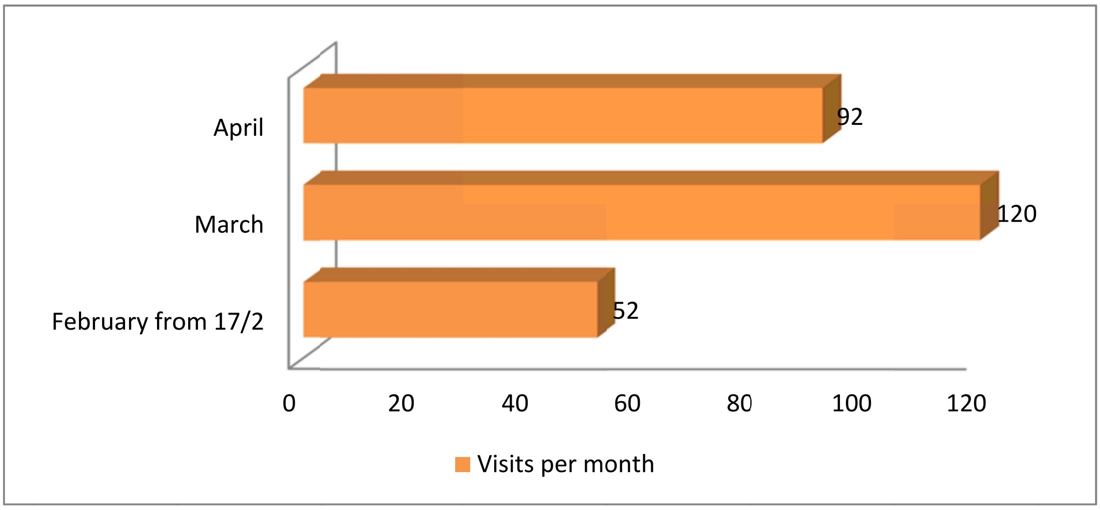


Figure 7: Visits per month for the first round of pilots

2.2.3.7 Questionnaires

Qualitative data over the system efficiency and acceptance were obtained by the post-pilot questionnaires. This mean of evaluation referred to both first and second round of trials, as they were filled in at the end of the project. Thus, separate results for the two phases are not provided and the overall conclusions from questionnaires will be presented and analysed in the second phase results, in section 2.3.3.7.

2.3 Second round of pilots

The second phase of the pilot testing officially started on 1st of July 2012. However due to the fact that the users were on summer break, the project consortium get an extension for the project by the EU, in order to achieve a more valid assessment. Thus, the evaluation considered the period 01/09/2012 – 30/11/2012. The pilot tests involved gradually 146 users that tested the final integrated version of the end-user application services, including marketplace service. On the other hand, about 5.000 users had access to the whole system except marketplace. Stemming from the results of the first phase technical problems as well as user motivation problems, were confronted. During this second round of trials, users were motivated to participate more actively in the marketplace game by offering an award to the winner, by providing energy saving tips and notifications as well as more weekly challenges. Many improvements and inputs were performed in all 3 applications, enhancing the interface and services, taking into account also users feedback.

In addition, the main difference in comparison to the first phase was the introduction of the semi-automatic agent that performed transactions automatically within the marketplace following a predefined profile. However, the user could still make manual orders and even cancel automatized transactions. This input was foreseen to increase the effectiveness of the system as in the first phase very few matched transactions were performed. 44 of the 146 users participated in the marketplace through active agents. Due to technical problems in the smartmeters, 83 users were finally assessed and 29 of them had active agents. As not all the participants had activated automatic agents, a comparison was performed between the users that used the agents and those who did not. The agents are not expected to have impact on the total consumption but to shift loads between peak and non-peak times.

2.3.1 Data collection methodology

The data collection methodology followed was the same as in the first phase and described in section 2.2.1 and the same indicators were calculated. A main difference was that the intervals within the day were in this case just two, for peak and non-peak hours. This approach was finally chosen as more convenient in order to evaluate the impacts.

In addition, the impact of the automatic agent was studied, so the group of users with active agents was analysed separately. Finally, the same usage statistics identified for BAF Web application were now also analysed for the Android version. The usage statistics for other applications had no sense as the user was only one per application (Alginet and Lighting operator).

2.3.2 Indicators measured

As described in the precious section the indicators evaluated are the same as for the first phase and mentioned in section 2.2.2.

2.3.3 Results

2.3.3.1 Consumption data

The consumption data of the second phase participants were analyzed in the same way as described in section 2.2.3.1. The same database was obtained from Alginet and random values were also cross-checked with BAF log files, in order to validate the quality of the data collected. The results of the second phase of testing in terms of energy consumption are presented in the following tables (**Table 4 and** Table 9).

Standard Prosumers Energy Consumption – BAF application

Energy usage results for the second phase of pilot tests (1 September- 30 November 2012)			
Indicator	**Total**	**Domestic users**	**Bigger scale users**
Total Energy consumption (kWh) (17/2-30/4)	231269	80964	150305
September Total Consumption (kWh)	78619	25734	52885
October Total Consumption (kWh)	72819	23960	48859
November Total Consumption (kWh)	79831	31270	48561
Average daily consumption (kWh)	30,84	12,96	127,12
Average consumption for Peak Hours	25,00	6,97	72,49
Average consumption for Non Peak hours	12,24	6,09	54,63
Daily Consumption per capita (250 persons assumed)	4,05 KWh/ person/day		
Monthly consumption per capita	121,5 KWh/ person/month		

Table 4: Energy usage results for the second phase of pilot tests for standard prosumers

Senior Prosumers Energy Consumption (Public lighting system) – NOPL application

In the second phase of tests in Alginet two types of lights were used in order to assess NOPL. The same avenue was used as in the first phase (with installed sensors) as well as two led lights triggered by magnetic loops. A description of the testing infrastructure is provided in the following sections, as well as overall energy usage results for these two cases.

Points of light triggered by magnetic loops

One of the energy saving strategies tested in Alginet has consisted in making the luminosity level of certain parts of the town that hold an important traffic flow dependent on the actual presence of vehicles on the road. The objective of this strategy is to achieve energy savings by reducing the luminosity level of the lamps to a level adequate to the pedestrians when the traffic flow on the road is lower, while increasing the luminosity level in the presence of vehicles, in order to ensure the security of both pedestrians and drivers.

The idea of this strategy is to save as much energy as possible without reducing the security and comfort of the pedestrians and the drivers.

The Segment Controller is able to communicate with a magnetic loop (usually employed to retrieve traffic measurements) in order to check when a vehicle is driving through the controlled road. This information is used in the lighting control loop to perform changes on the luminosity of the lamps.

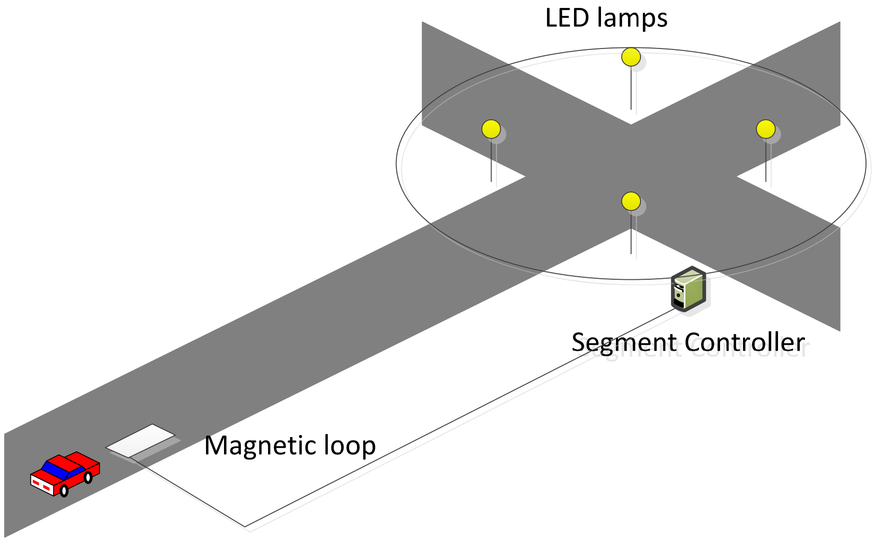


Figure 8: Segment controller - Magnetic loop integration

This kind of strategy is only feasible with the use of LED lamps, due to their ability to modify instantaneously their luminosity level without degrading the lamps.

In order to test this strategy, two LED lamps controlled by one Segment Controller have been installed in one of the main streets in Alginet (Calle Mayor / Plaza Constitución). The Segment Controller was configured to manage the LED Lamps with the following behaviour:

- LED lamps are switched on during sunset
- LED lamps are switched off during sunrise
- Nominal luminosity level of LED Lamps is set to 20% (which provides good visibility for pedestrians)
- LED lamps are set to a luminosity of 100% when a vehicle is detected in the magnetic loop. This level is maintained for 1 minute
- The detection of new vehicles reset this timer (LED lamps keep a luminosity of 100% after 1 minute since the last vehicle has been detected)

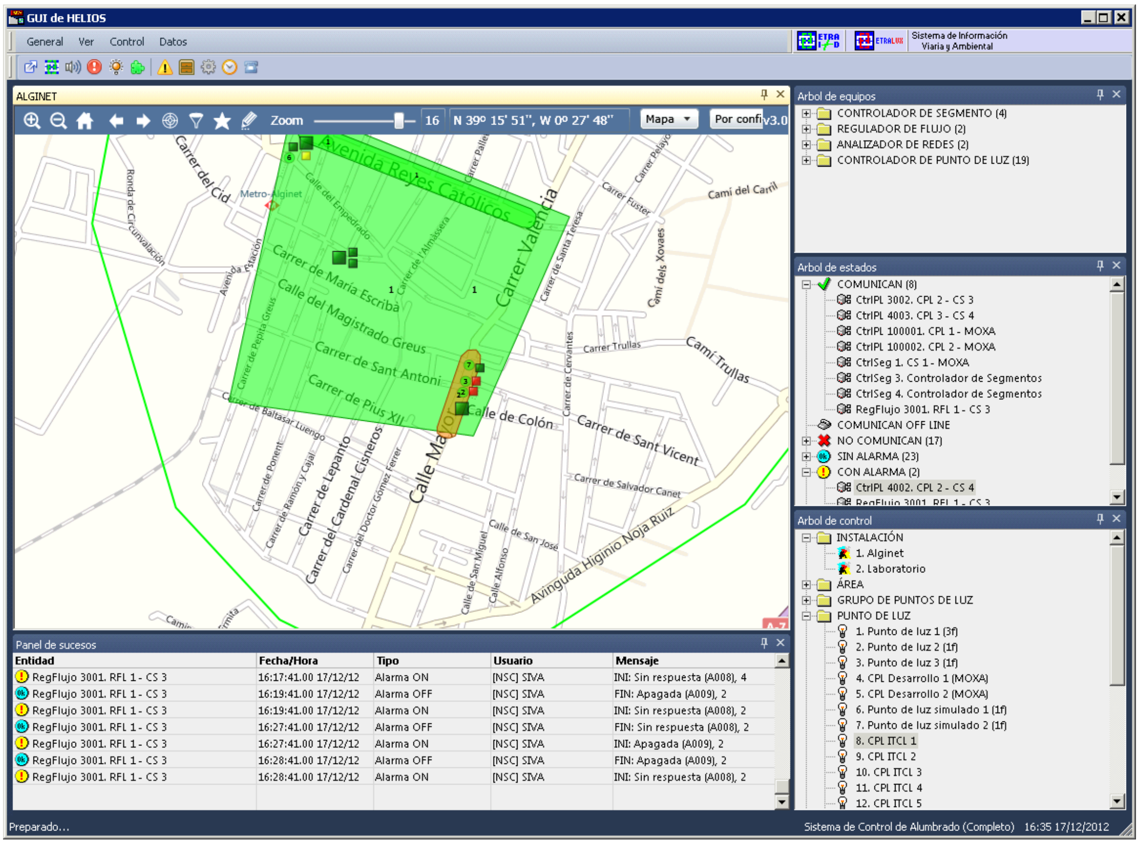


Figure 9: NOPL showing location (in center) of this particular use case in Alginet

Analysis and evaluation of the data retrieved by NOPL has shown different patterns for nights during the week and nights in the weekend.

Monday-Friday

The following graphic for the night of 11 to 12/12/2012 (Tuesday to Wednesday) shows the usual pattern for a night in weekdays.

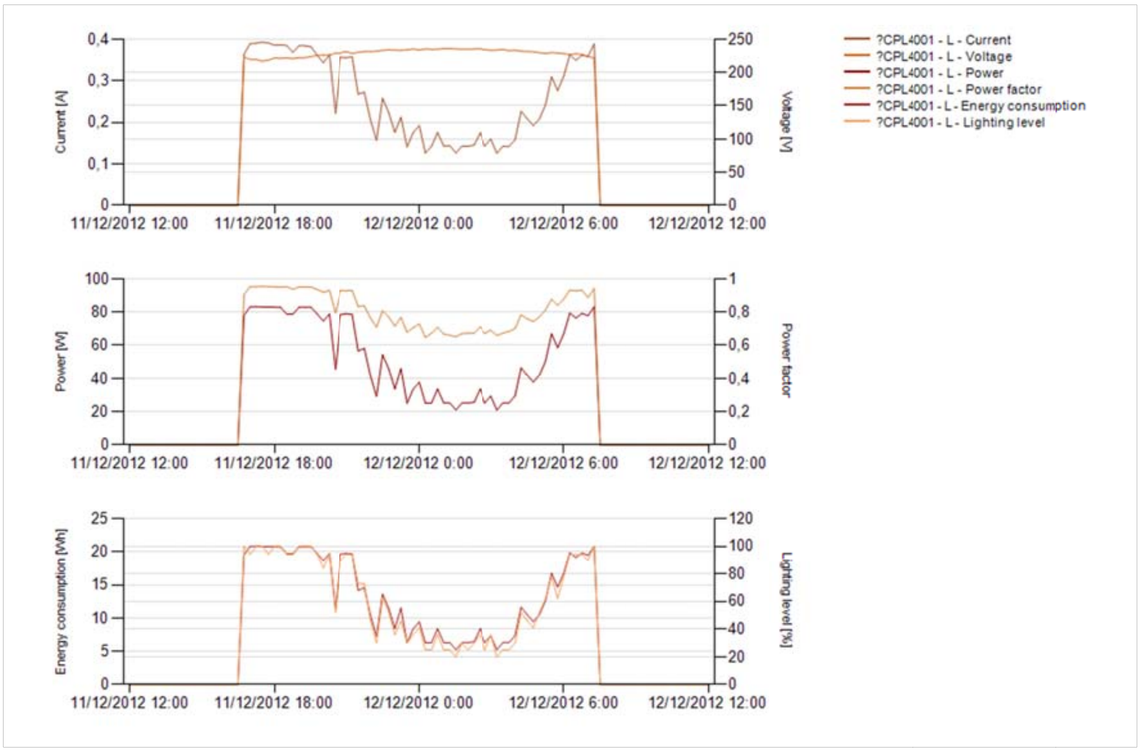


Figure 10: Magnetic loop-based regulation during the week

It can be observed that the lighting level is higher around sunset and sunrise, when there is more traffic. In this context, great saving is achieved during the early morning hours, when the road traffic is much lower, and therefore not so much luminosity is needed on street.

The following information about energy savings can be extracted from the example:

Lighting hours	14:30
Energy consumption with saving strategy	796.83 Wh
Energy consumption without saving strategy (estimated*)	1201,76 Wh
Energy saving rate**	33.69%

Table 5: Energy savings for specific lighting hours on Monday-Friday

* consumption estimation is based on a consumption of 82.88 Wh / hour / lamp, as measured on the NOPL

** energy saving rate calculated as (E1 – E2) / E1, where E1=Energy consumption without NOBEL saving strategy and E2=Energy consumption with NOBEL saving strategy Weekend

The following graphic for the night of 08 to 09/12/2012 (Saturday to Sunday) shows the usual pattern during the weekend:

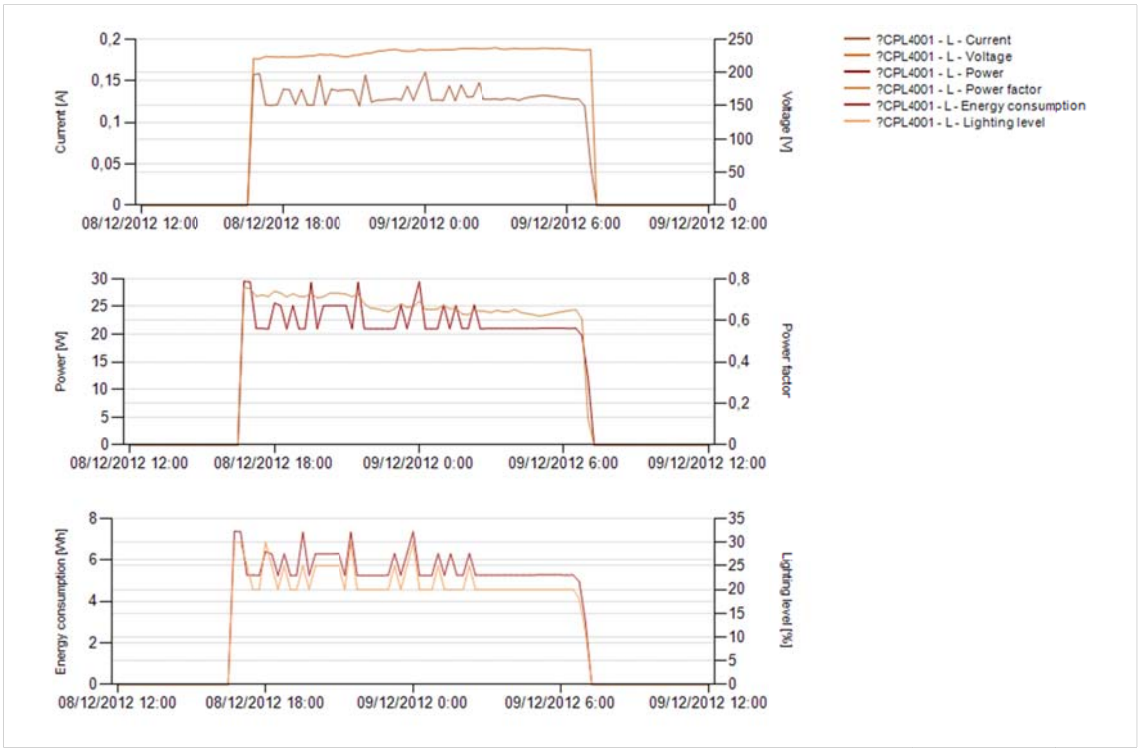


Figure 11: Magnetic loop-based regulation during the weekend

Since the road of the pilot tests is pedestrian zone during the weekends, the lighting level stays around 20% (with small variations, due to the punctual circulation of metallic masses over the magnetic loop) for the whole night.

Lighting hours	14:15
Energy consumption with saving strategy	326.62 Wh
Energy consumption without saving strategy (estimated*)	1181.04 Wh
Energy saving rate**	72.34%

Table 6: Energy savings for specific lighting hours on weekends

* consumption estimation is based on a consumption of 82.88 Wh / hour / lamp, as measured on the NOPL

** energy saving rate calculated as (E1 – E2) / E1, where E1=Energy consumption without NOBEL saving strategy and E2=Energy consumption with NOBEL saving strategy

<u>Summary</u>

The energy saving strategy based on regulating lighting levels based on vehicle presence has been demonstrated in the pilot site of Alginet, by installing two LED lamps controlled with a Segment Controller in one of its streets. Different degrees of saving rates have been achieved during the week days and the weekends, due to the different usages the municipality gives to the road under test.

During the week, where road traffic is present in the street, traffic intensity on this street presents a curve with higher values around sunrise and sunset, and lower values in early morning hours. Therefore, the applied strategy is able to reduce consumption mainly on these early morning hours. Lighting levels are kept high in the presence of traffic, for the sake of pedestrians and drivers security. An energy saving rate of approximately 34% has been met.

During the weekends, this street is converted into a pedestrian area, and there is not traffic of vehicles. Therefore, the applied strategy is able to reduce consumption almost to the maximum over the whole week. Lighting levels are kept around 20%. An energy saving rate of approximately 72% has been met.

Light sensors strategies

The reason of including light sensors in the system is to demonstrate the capability to adapt energy consumption to ambient sensors, adding another parameter to discriminate better between energy saving and luminosity comfort and safety.

The light sensors used during the trials in Alginet are commercial usage assigned to detect unique luminosity level to control the lighting level of a lamp. Applied to the system, each sensor is configured with different activation level. The system treats them as digital inputs, thus, it is built a multilevel light sensor.

A process in the Segment Controller is responsible to check periodically the light sensor status. Light sensors are attached to a CPL via database configuration and whenever a change happens, the attached equipment is notified.

In Alginet's installation, a light sensor array is used to adapt dimming level to ambient luminosity, and also to move forward or delay power on/off of the Flux Regulator, but only in the range of +/- 45 minutes from calendar de/activation. Thus, there is a limit to avoid a power consumption excess if a detection fault occurs.

E.g. the calendar sets lights activation at 21:30. If light sensors detect a luminosity low level between [20:45 – 21:30] (because of a rainy cloudy day), then they will trigger the flux regulator to switch on to minimum dimming level the lights. At 21:30 it will be set up to calendar dimming level. In the case light sensors detect low luminosity (sunny day) after calendar activation (e.g. at 21:40), then the flux regulator will not switch on until 21:40.

In the first case, it will not save energy but will offer a better service with comfort and safety effects on the final user. Second case is energy saving oriented not losing neither comfort nor safety.

The following table shows activation and deactivation times of the three light sensors in a sunny day compared to the current installation calendar (switch on at sunset and switch off at 16 minutes to sunrise).

Date	Sensor 1	Sensor 2	Sensor 3	Sunset/Sunrise-16
06/06/2012	21:57:08	21:59:22	21:59:48	21:26
07/06/2012	06:27:48	06:08:33	06:06:48	06:18
07/06/2012	21:56:33	21:58:42	21:58:44	21:27
08/06/2012	06:23:00	06:08:17	06:06:59	06:18
08/06/2012	21:54:43	21:56:22	21:59:43	21:27
09/06/2012	06:22:57	06:08:49	06:03:59	06:18
09/06/2012	21:55:51	21:57:11	22:00:22	21:28
10/06/2012	06:24:17	06:08:16	06:03:07	06:18
10/06/2012	21:58:35	21:59:41	22:02:18	21:28
11/06/2012	06:20:50	06:08:38	06:02:58	06:18
11/06/2012	22:00:17	22:01:33	22:04:15	21:29
12/06/2012	06:21:28	06:07:22	06:02:36	06:18

12/06/2012	22:00:10	22:01:22	22:03:58	21:29
13/06/2012	06:21:23	06:07:29	06:02:38	06:18

Table 7: Activation and deactivation times of the three light sensors

The graphical representation below remarks switching instants and it can be figured out when energy could be saved.

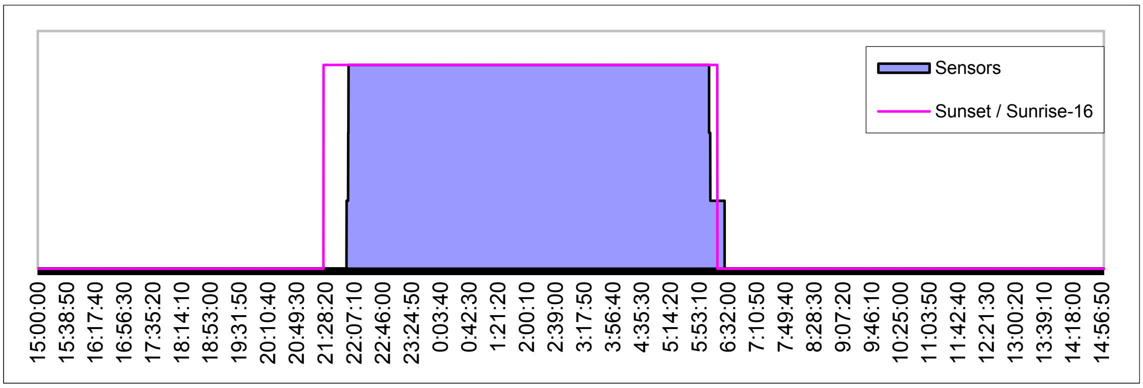


Figure 12: Switching instants

As shown on the graphics, activation could be delayed approximately 30 minutes without losing luminosity comfort, reducing consequently power consumption.

The switch-off instant is nearer to light sensor detection when a negative offset is set up.

Considering only the switch-on case to estimate how much energy could be saved when using a sensor adaptive system, the table below shows the time span considered from sunset to first sensor detection for each day, obtaining an average time span of 30 minutes:

Date	Time span (hh:mm)
06/06/2012	0:31
07/06/2012	0:29
08/06/2012	0:27
09/06/2012	0:27
10/06/2012	0:30
11/06/2012	0:31
12/06/2012	0:31

Table 8: Sensor time spans

Then, it is estimated that all the lights could be turned off during 30 minutes every day, assuring comfort and safety.

Assuming that the power of a light is 150 W (average value of Alginet town public lighting installation), it is assumed that the energy saved every day by one light in Alginet would be 75 W.

Calendar-based lighting control

Most of the lamps installed in the Public Lighting System in Alginet are Sodium-vapour lamps. This kind of lamps has a slow response-time, and fast changes are known to reduce their useful life. These conditions have a direct effect on the design of the energy-saving strategy; since the luminosity of the lamps accepts slow response times, it cannot be dependent of spontaneous events (as it happens in the magnetic loops strategy); in addition, once a certain luminosity level is set, it must be hold for a relatively long time period, since fast changes reduce the useful life of the lamps.

Taking these considerations into account, a calendar-based energy-saving strategy has been tested in the test pilot in Alginet. In addition to the already explained constraints, the design of the strategy has taken into account the following reflections:

- The pedestrian flow in the town is higher around sunset and sunrise and lower in early morning hours.
- A luminosity of 60% is the minimum luminosity level identified that ensures good visibility, comfort and safety in the streets.
- The difference between a luminosity of 100% and 80% is almost no noticeable on the streets.

The calendar-based energy-saving strategy is based on modifying the luminosity of the lamps through three different steps all along the night, trying to save energy while minimizing the impact perceived by the population of the town:

- From sunset minus 16 minutes * to 22:00: luminosity level of 80%
- From 22:00 to 05:00: luminosity level of 65%
- From 05:00 to sunrise minus 16 minutes*: luminosity level of 75%

* sunset and sunrise minus 16 minutes is the time when all Alginet lights are turned on and off; this energy-saving strategy keep these values.

Figure 13: Calendar-based regulation on a real device in Alginet

This strategy has been tested in one of the avenues of Alginet (Avenida Reyes Católicos). In addition, a simulation has been performed, in which the whole town is simulated with both the new strategy (which would be applied if NOPL controlled all the lamps in the town) and the usual strategy in Alginet (level remains at 100% the whole night). In the next section it will be compared the simulating the use of the new strategy in the whole village and with the current strategy used in Alginet.

Second phase overall consumption results

The second phase included the same segment of lights in AV. REYES CATOLICOS in Alginet with installed sensors but also two points of led lights using magnetic loops in PLAZA CONSTITUCION. The additional points of light had also a different smartmeter and their consumption is assessed separately. As these led lamps are part of a segment, the values in the following table are overall for the segment but we can still evaluate the energy reduction.

Pilot public lights consumption data			
		PLAZA CONSTITUCION	AVENIDA REYES CATOLICOS
Total consumption (kWh)		12496	8522
Total September consumption (kWh)	00:00 - 08:00	3139	2004
	8:01 - 23:59	860	646
Total October consumption (kWh)	00:00 - 08:00	3033	1908
	8:01 - 23:59	1060	761
Total November Consumption (kWh)	00:00 - 08:00	3179	2206
	8:01 - 23:59	1225	997

Table 9: Energy usage results for the first round of NOBEL pilot tests for senior prosumers (lighting system)

2.3.3.2 Production data

Standard prosumers production data – BAF application

Simulated production data are also provided for this phase to be used for costs evaluation. The total simulated production of the standard prosumers for the second phase period is 37875,5 KWh, and the average production per smartmeter is 473,44 kWh for these three months.

2.3.3.3 Costs for consumption

Standard Prosumers costs for consumption – BAF application

The calculation of costs will be performed as described in 2.1.3.4. However in this case the marketplace was used more efficiently. This change is mainly due to the introduction of the semi-automatic agents. This was also confirmed by the fact that users with active agents made much more transactions than the users that made them in a manual way.

Thus, the blended approach described previously is now followed. The total consumption is considered to derive by two sources. One part is covered by the PV production (when the production is higher than consumption) and the rest is bought either by the local DSO or the marketplace (when the production is lower than consumption). The first part is free while the second is billed either by the standard contracts of the users with the DSO, or with the marketplace matched bid price.

Users placed orders for the whole of the excess production in each timeslot, but not all of these orders were matched and finally executed. In case a sell order was not matched the energy was sold in the lowest market price (0,10 €). Considering the total quantity of sell orders in the market self-used production is easily estimated, applying the following formula:

Self-used production = Total production – production supplied in the market (finally matched or not) = 37875,5 - 24572,57 =13302,93kWh.

Thus, the percentage of the total production that is self-used is 13302,93/37875,5 *100 = 35%. This amount was also used for the first phase where the self-used production could not be calculated. Considering this amount, which is free for the user, we can easily calculate the amount of consumption actually paid, bought either in the marketplace or by the DSO.

Consumption paid = Total consumption – Self-used production = 231269 - 13302,93= 217966,07 KWh.

In addition, the total amount of energy and cost of consumption bought in the market is known by the transactions log files and is 1585,38 € for buying 10356,12 kWh in total.

Thus, the rest of the consumption paid is billed by the DSO contract:

Total consumption paid though contract = Total consumption paid – Total consumption bought in the market = 217966,07 - 10356,12 = 207609,95 kWh. This amount is billed with the average contract price 0,12 €. Thus, the total cost paid to the DSO is 207609,95 *0,12 = 24913,2 €.

Summarizing the total amount paid for energy by the standard prosumers was:

Total cost of energy bought in the marketplace + Total cost of energy bought from the DSO = 1585,38 € + 24913,2 € = 26498,58 €.

The following table summarizes the above calculations.

Total Production (kWh)	3787,5
Total Production supplied in the market (matched or not) (kWh)	24572,57
Self-used production (kWh)	37875,5 - 24572,57 =13302,93 → 35% of the total production
Total consumption (kWh)	231269
Consumption paid (DSO and marketplace) (kWh)	231269 - 13302,93= 217966,07
Consumption bought through the market (kWh)	10356,12
Cost of consumption bought through the market (€)	1585,38
Consumption paid through contract (kWh)	217966,07 – 10356,12 = 207609,95
Average contract tariff (€)	0,12
Costs of Consumption paid through contract (€)	207609,95 *0,12 = 24913,2
Total costs (€)	1585,38 € + 24913,2 € = **26498,58 (€)**

Table 10: Standard Prosumers costs for consumption

Senior Prosumers costs for consumption – NOPL application

The two lighting segments (Reyes Catolicos avenue and Constitucion square) had contracts with standard tariffs. The average contact tariff for the sensors segment is 0,124 €/kWh and for the led lamps segment is 0,117 €/kWh. Considering the consumption for each case the costs are presented in the following table.

Segment of lights	Total Consumption for the second pilot phase (kWh)	Average tariff (€/kWh)	Total costs (€)
Reyes Catolicos	8522	0,124	1060,5
Plaza Constitucion	12496	0,117	1462

Table 11: Senior Prosumers total costs for energy – second phase

2.3.3.4 Revenues from production

Standard Prosumers revenues for production – BAF application

Following the same approach, the total production is either self-used or sold (to the market or DSO). The production that is sold is 65% of the total production (as 35% is self-used).

The production that leads to revenues is thus:

Total production*0,65 = 37875,58*0,65= 24619,13 kWh.

The total amount earned by the users from selling production in the market from matched transactions was 1283,1 € for selling 8374,321kWh. Thus, the rest of the production to be sold was not matched and it was sold in the lowest market price as mentioned before. This amount is:

Production not matched (sold in the lowest price) = Total production to be sold - Total production sold by matched bids = 24619,13 - 8374,321 = 16244,81 kWh. The revenue from this amount was 16244,81 *lowest price = 16244,81*0,10 = 1624,48 €.

Summarizing, the total revenues were: revenues from matched orders + revenues from non-matched orders = 1283,1 +1624,5 = 2907,6 €.

The following table summarizes the above calculations.

Total Production (kWh)	3787,5
Total Production supplied in the market (matched or not) (kWh)	37875,58*0,65= 24619,13
Production sold through the market (kWh)	8374,321
Revenue from production sold through the market (€)	1283,1
Production not matched (sold in the lowest price) (kWh)	24619,13 - 8374,321 = 16244,81
Lowest market price (€)	0,10
Revenues from not matched production (€)	16244,81*0,10 = 1624,48
Total revenues (€)	1283,1 +1624,5 = **2907,6 €.**

Table 12: Standard Prosumers revenues for production

2.3.3.5 CO_2 emissions

Standard Prosumers emissions – BAF application

During the second phase of pilot tests in Alginet, BAF integrated also a monitoring service of the CO_2 emissions for each user. This function was also included in NOEM, where aggregated values for the total emissions in the local grid are presented. The following screen shot, shows the total emissions for the second period of trials for all Alginet users. However, the "overview" service provides overall values for the whole local grid. Thus, this amount is much higher than the emissions from the pilot participants. For this reason, the emissions calculation followed the same approach as described in section 2.2.3.5, taking into consideration the change in the energy mix due to clean energy production.

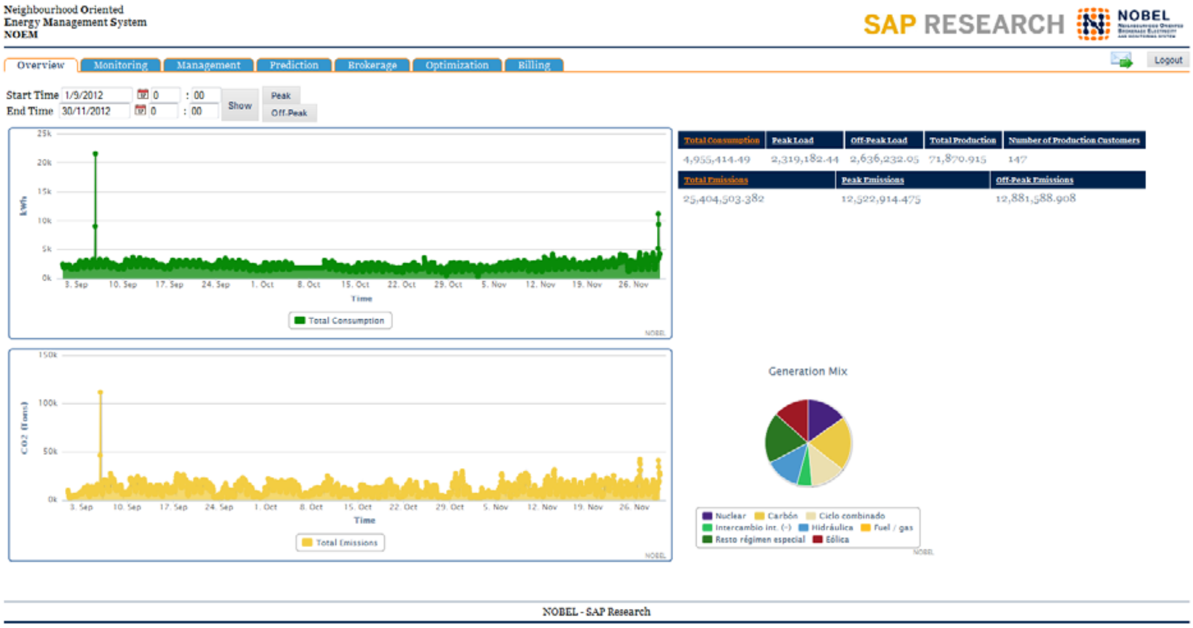


Figure 14: Second phase overall emissions

Considering the overall production conducted in grid we calculate the new energy mix (as described in section 2.2.3.5.

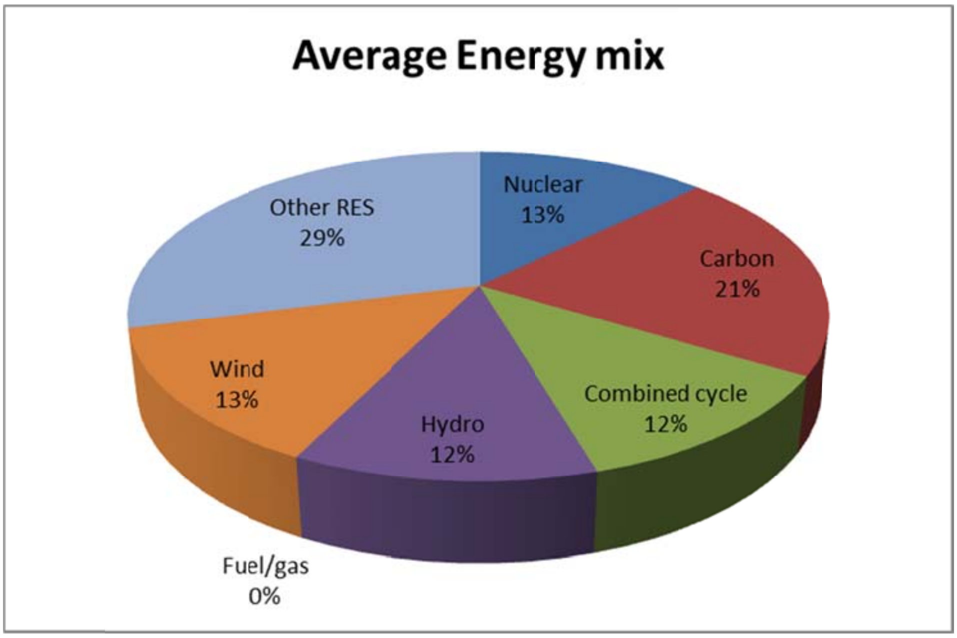


Figure 15: Second phase Average Energy mix

Based on the average emissions per type of energy, the **$kgCO_2$ /kWh** is now: 0,319 $KgCO_2$ /kWh.

Summarizing the CO_2 (kg) = 0,319 $KgCO_2$ /kWh * Total consumption from energy mix (kWh) = 0,319 * 207609,95 = 66227,57 kg CO_2 .

Senior Prosumers emissions – NOPL application

Using the same **$kgCO_2$ /kWh** = 0,319 kg/CO2 and considering the overall consumption for each segment of lights the respective emissions are presented in the following table:

Light Segment	Overall consumption (kWh)	Overall emissions (kg CO2)
Reyes Catolicos	8522	2718,5
Plaza Constitucion	12496	3986,2

Table 13: Second phase senior prosumers emissions

2.3.3.6 End user application usage statistics

Standard Prosumers usage statistics – BAF application

In the context of second pilot phase, users had the option to use either the web application through their PC or the Android application, in case they use smartphones. In the following sections, data related to both forms of application usage is provided.

2.3.3.6.1 Android application

During the second phase of trials the Android version of BAF application was released and available for the users of Alginet. The application could be downloaded for free from the Android market by everyone but only the pilot participants could log in using their web application credentials. 53 users downloaded the Android version.

2.3.3.6.2 Web application

In the following Table 14, the Web application usage statistics are presented. As is shown in the table the total logins were remarkably increased in relation to the first phase for the whole duration of the pilot trials. The average duration of each visit is also provided as well as the average visits per day. In addition, the average unique visitors per day are provided where the multiple logins by a single user in the same day are not considered. We can conclude that the number of logins is directly connected to the overall energy reduction as on October the reduction percentage was the highest.

September 2012 logins	147
October 2012 logins	218
November 2012 logins	110
Total logins	475
Average duration per login (min)	7,8
Average logins per day	6
Unique visitors per day	4

Table 14: BAF Web application usage statistics

2.3.3.7 Questionnaires

2.3.3.7.1 Standard prosumers

General

Standard prosumers filled the end-user post-pilot questionnaire (included in D7.1) through google docs. The questionnaire was related to the overall impact of the system from both phases of pilot testing. In following, the summarized answers are provided.

The usefulness and user satisfaction rating consolidated answers are presented in **Figure 16.**

useful |_|X|_|_|_| useless
pleasant |_|X|_|_|_| unpleasant
good |_|X|_|_|_| bad
nice |_|X|_|_|_| annoying
effective |_|X|_|_|_| superfluous
likeable |_|_|_|_|_| irritating
assisting |_|X|_|_|_| worthless
desirable |X|_|_|_|_| undesirable

Figure 16: Usefulness and User satisfaction rating for BAF

Users also commented that they liked the fact that they can control consumption and decide when to unplug home appliances.

As main advantages of the system, users mentioned the graphical monitoring of their consumption and the potential reduction of their bills.

As main disadvantages of the system, users said that the prediction was sometimes inaccurate; the consumption presented is sometimes different from real-consumption (according their estimations) and the systems crashed often enough. A pilot participant said that he/she would like an improved Android version, and a more simply visualized auction game. A user also mentioned that he/she found it difficult to have an overview of the transactions made.

Finally, the majority of pilot participants mentioned (77%) that NOBEL system has not any personal data protection related risk as it is simply informative.

Energy usage

In following users mentioned that they actually changed their routine in order to achieve energy saving and efficiency. The following table presents the actions that the user made to achieve this.

		Yes	No
	I replace broken bulbs by energy saving lights	90%	10%
	I turn out the light when leaving the room	98%	2%
	I switch off the TV directly at the apparatus	49%	51%
	I switch off the display of the computer when I pause for more than 10 minutes	76%	24%
	I own electric appliances with energy efficiency class A (or better)	76%	24%
	After charging my mobile phone I don't leave the connector in the power outlet	85%	15%

Table 15 Energy saving actions by pilot participants

40% of the users mentioned that managed to achieve remarkable energy reduction through NOBEL. The rest said that they observed a reduction but not as enough as wished. In addition, most of them said that they did not noticed remarkable revenues from selling production within the marketplace game. As commented before, this is due to low production capacities and also limited matched transactions. Users also found it sometimes difficult or time-consuming to perform transactions.

BAF Interface

Users answered questions targeted to the BAF interface. Half of the users said that the BAF interface was user friendly enough and 47% found appealing the user interface. 66% of the users found it easy enough to find the required information on the screen. They found the graphs appealing as some of them found the auction process complicated. 44% of the users mentioned that the BAF response was matching their orders on a satisfying level. However, the majority of them said that the prediction service did not match the actual loads on a very high level. 66% of the pilot participants found the refresh intervals often enough and 78% mentioned that the BAF sessions required either normal time or they were even not at all time consuming.

In relation to the system failures, users said that the system did not crashed very often. Finally, 78% of the users did not wished for any additional feature that is currently missing from BAF interface. The rest of the users mentioned that that they wished to have an overview of the real billing information (however this is not related to the application but on the fact that the pilot scenario was just a game) and also VAT and other taxes to be included in the final bill.

SUS scale results

SUS scale is a specially formed questionnaire to be completed after the trial of a system. This scale should be completed after the use without any explanation or discussion with the researcher. In the following figure the answers for the SUS scale are presented:

System Usability Scale Questionnaire					
SUS questions	1- "Strongly Disagree"	2	3	4	5- "Strongly agree"
1. I think I would like to use this system frequently.				X	
2. I found the system unnecessarily complex.		X			
3. I thought the system was easy to use.				X	
4. I think that I would need the support of a technical person to be able to use this system.				X	
5. I found the various functions in this system were well integrated.		X			
6. I thought there was too much inconsistency in this system.				X	
7. I would imagine that most people would learn to use this system very quickly.				X	
8. I found the system very cumbersome to use.		X			
9. I felt very confident using the system.				X	
10. I need to learn a lot of things before I could get going with this system.		X			

Table 16: SUS scale results – Standard prosumers (BAF application)

Commenting on SUS scale results, we can say that the users found the application easy to use, not requiring any specialized knowledge.

2.3.3.7.2 Public lighting system operator

General

The lighting operator in Alginet answered the post-pilot questionnaire, that included questions related to usefulness and user satisfaction through NOPL usage. The NOPL users were in general satisfied from the application as shown in **Figure 17.**

useful |x|_|_|_|_| useless

pleasant |_|x|_|_|_| unpleasant

good |_|x|_|_|_| bad

nice |_|x|_|_|_| annoying

effective |_|x|_|_|_| superfluous

likeable |_|x|_|_|_| irritating

assisting |x|_|_|_|_| worthless

desirable |_|x|_|_|_| undesirable

Figure 17: Usefulness and User satisfaction rating for NOPL

The lighting system operator mentioned that NOPL contributed to the reduction of consumption for the involved segments of light and that does not involve any security related risk.

NOPL Interface issues

The NOPL user mentioned that the interface was very friendly and appealing. The required information was easy to be located on screen, while the NOPL maps were accurate and easy to read. As individual functions are concerned, the user was satisfied by the function of the tree of entities, however was not fully satisfied by the messaging area.

The information refresh intervals were often enough. However, they thought the process to assess data during a NOPL session was time consuming. In addition, the system crashed many times (about 40% of the total attempts). Finally, the user said that there no desired additional information that is currently missing from NOPL screen.

SUS scale

System Usability Scale Questionnaire					
SUS questions	1- “Strongly Disagree”	2	3	4	5- “Strongly agree”
1. I think I would like to use this system frequently.				■	
2. I found the system unnecessarily complex.	■				
3. I thought the system was easy to use.				■	
4. I think that I would need the support of a technical person to be able to use this system.				■	
5. I found the various functions in this system were well integrated.			■		
6. I thought there was too much inconsistency in this system.	■				
7. I would imagine that most people would learn to use this system very quickly.			■		
8. I found the system very cumbersome to use.	■				
9. I felt very confident using the system.				■	
10. I need to learn a lot of things before I could get going with this system.		■			

Table 17: SUS scale results - Public lighting operator (NOPL application)

Based on these answers we can conclude that NOPL users found the system easy to use and that does not require any specific technical knowledge. However, they would appreciate assistance from a technician.

2.3.3.7.3 DSO Alginet

The local DSO of Alginet answered a post-pilot questionnaire related to NOEM usage.

The general usefulness rating is provided in **Figure 18:**

useful	|X|_|_|_|_|	useless
pleasant	|_|X|_|_|_|	unpleasant
good	|X|_|_|_|_|	bad
nice	|X|_|_|_|_|	annoying
effective	|_|X|_|_|_|	superfluous
likeable	|_|X|_|_|_|	irritating
assisting	|X|_|_|_|_|	worthless
desirable	|X|_|_|_|_|	undesirable

Figure 18: Usefulness and User satisfaction rating for NOEM

NOEM user mentioned that they actually controlled the distributed energy in the grid using the monitoring and predictions services. The DSO said that achieves 98% prediction accuracy using NOEM. In addition, the NOEM users said that NOBEL system is not related to any security or personal data protection related risk. They also suggested improving prediction as well as providing aggregated information for selected intervals. Alginet DSO was in general very satisfied by NOEM usage highlighting that the information refresh intervals were very convenient and useful, the required information was easily located on screen and the whole process was quick enough. However, they mentioned that the system crashed often enough (40% of total attempts).

2.4 Analysis of the pre-pilot situation

2.4.1 Overall approach

In order to evaluate the impact of NOBEL system in terms of energy usage, economic and social benefit, a baseline case was required to be defined. In order to make an accurate comparison, historical data was obtained for the pilot testing participants. The reference case defined was slightly different from the actual existed situation in Spain especially for the marketplace evaluation. The evaluation of economic impacts cannot be directly compared with the existed market model as this model is based on static billing policies and does not include dynamic energy trading services. Thus, any assumption made in order to conclude on more realistic impacts assessment will be analysed in detail in this section.

As the number of users differs per pilot phase, each phase will be compared to a different reference case, considering a different sample of users, as the users are compares to their own historical behaviour.

2.4.2 Data collection

An average case should be defined, in order to identify any energy consumption reduction due to the NOBEL system. Each user's consumption should be compared to an average value of overall and per indicator consumption. Normally, average values of consumption for the last years in Alginet and their average should be considered. However, the amount of this data is vast and cannot be handled in the context of the project. Thus, it was decided, to take as a reference case 2011, as it was a year with similar weather and economic conditions. Ambient conditions may slightly differ from year to year but it was considered it is safer to compare with the same user's historical data than take statistical data for the local grid of Alginet. A database was analysed in the same way described in section 2.1.1 and the respective consumption for 2011 was calculated per user. The total consumption for the respective periods (same months with the two pilot phases), the monthly consumption, the average daily consumption, the average consumption for the peak and not peak hours were calculated.

2.4.3 Results

Stemming from the data collected as described in the previous section two baseline cases are formed in order to evaluate the impact for the two pilot phases. These two cases are presented below.

2.4.3.1 First Phase reference case

2.4.3.1.1 Consumption data

During the first phase the consumption analysis was performed for the intervals as described in 2.2.1. These intervals were selected in order to achieve a more granular analysis of the peaks' fluctuations. The following table outlines the pre-pilot profile of Alginet users for the Interval 17 February- 30 April 2011. These values will be compared with the results from the first phase of trials and the impacts will be presented in section 3.

Standard prosumers energy consumption – BAF application

Indicator	Total	Household standard prosumers	Bigger scale standard prosumers
Total Energy consumption (kWh) (17/2-30/4)	235963,5	89169,6	146793,9
February Total Consumption (kWh) (Deducted)	80284,32	33867,1	46417,22
March Total Consumption (kWh)	82154,08	29998,8	52155,24
April Total Consumption (kWh)	73525,12	25303,7	48221,45
Average daily consumption (kWh)	40,7	30,1	110,2
Average consumption Interval 1 (00:00 – 6:00)	6,5	4,6	15,1
Average consumption Interval 2 (6:00 – 10:00)	8,1	5,9	27,6
Average consumption Interval 3 (10:00 – 17:00)	12,5	9,4	38,9
Average consumption Interval 4 (17:00 – 00:00)	12,9	9,8	28,6
Daily Consumption per capita (250 persons assumed)	10,5 KWh/ person/day		
Average Monthly consumption per capita	315 KWh/ person/month		

Table 18: Energy consumption data for 17 February- 30 April 2011 for standard prosumers

Senior Prosumers Energy Consumption (Public lighting system)

The pre-pilot consumption for the segment of lights of the avenue in Alginet is presented in **Table 19**.

Pilot public lights consumption data	
Total consumption (kWh)	10830,00
Total February consumption (deducted) (kWh)	4218
Total March consumption (kWh)	4772,00
Total April Consumption (kWh)	4167,00
Average Daily Consumption (kWh)	148,36
Average Consumption Interval 1 (kWh)	72,00
Average Consumption Interval 2 (kWh)	2,20
Average Consumption Interval 3 (kWh)	0,26
Average Consumption Interval 4 (kWh)	73,90

Table 19: Energy usage results for 17 February- 30 April 2011 for the lighting system (senior prosumer)

2.4.3.1.2 Production data

Standard prosumers energy production – BAF application

As described previously, the overall production will be assumed to be the same as simulated for pilots. So the data are the same as provided in section 2.2.3.2. Based on data of the second phase, we assumed that 35% of the production was used by the users for their own energy needs so we can say that they pay only for the rest of the energy bought by the DSO. The overall production considered for the standard prosumers is 21024,22 kWh.

2.4.3.1.3 Costs for consumption

Standard prosumers costs for consumption – BAF application

In this reference case, there is no marketplace so all the consumption is billed though standard contracts. However, we assume that only a percentage of the consumption is billed by the standard contracts and the rest of it is free as it is generated by self-owned PVs (an assumption that production is real has to be made). Thus, the total consumption as provided in 2.2.3.1 was 202817, 75. So, the amount of money that would be paid by the users for energy by Alginet was:

Total consumption – 0,35*Total production = 235963,5 - 21524,22*0,35 =228430 KWh. The average price of 0,12 €/kWh was used as an average of the tariffs of the user contracts. Thus the overall amount paid for consumption is 228430 *0,12 = 27411,6 €.

Senior Prosumers Energy Consumption (Public lighting system) – NOPL

As mentioned before, the light segment in Alginet avenue testing NOPL has a separate contract with tariff of 0,124 €/kWh. Considering the overall consumption of 10830 kWh, total costs for consumption of this segment was 10830 kWh *0,124 €/kWh = 1342,92 €.

2.4.3.1.4 Revenues from production

Standard prosumers revenues from production – BAF application

As only standard prosumers were considered to have production the following results refer to this group of users. As described before, it is assumed that a 35% of the consumption derives from PVs. The overall production considered is 21524,22 kWh as described in 2.1.3, for the whole reference period. Thus, the production that covers energy needs is 21524,22*0,35= 7533,5 kWh. So, the production sold to the DSO (there is no marketplace in the baseline case) is 21524,22 – 7533,5 = 13990,7 kWh, so considering the 0,10 €/kWh, we can conclude that the total revenues of the users from PV energy selling was 13990,7*0,10= 1399,07€. The 0,10 €/kWh price is considered due to reasons analysed in 2.1.3.5.

2.4.3.1.5 CO_2 emissions

Standard Prosumers emissions – BAF application

As mentioned before the marketplace transactions are not considered for the first phase evaluation, as there were limited. Thus, potential reduction of CO2 emissions is only due to the energy consumption reduction. Based on the previous sections the overall energy consumption is 235963,5 kWh and the self-used production is 7533,5. Based on the average energy mix as provided in section 2.2.3.5, the new energy mix taking into account the production sold in the grid is shown is the following Figure.

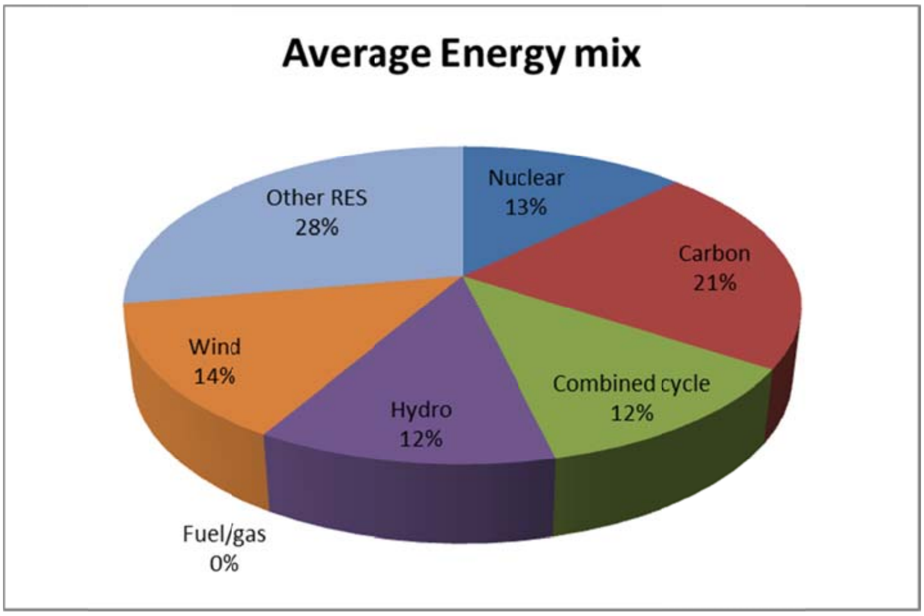


Figure 19: First phase reference case average energy mix

Based on the average emissions per type of energy the **$kgCO_2$ /kWh** is now: 0,325 $KgCO_2$ /kWh.

Summarizing the CO_2 (kg) = 0,325 $KgCO_2$ /kWh * Total consumption from energy mix (kWh) = 0,325 * 228430 = 74239,75 kg CO_2.

Senior Prosumers emissions – NOPL application

Considering the overall consumption of the segment of sensor-equipped lamps for the first phase reference case, the overall emissions for senior prosumers would be 10830 kWh* 0,325 $KgCO_2$ /kWh = 3519,75 Kg CO2.

2.4.3.2 Second phase reference case

2.4.3.2.1 Consumption data

The same analysis is performed also for the second phase.

Standard prosumers energy consumption – BAF application

Indicator	Total	Household standard prosumers	Bigger scale standard prosumers
Total Energy consumption (kWh) (1/9-30/11)	277076,2	120557,6	156518,67
September Total Consumption (kWh)	78619	37057	53738,5
October Total Consumption (kWh)	86220,75	37512,7	48708,2
November Total Consumption (kWh)	100059	45987	54072
Average daily consumption (kWh)	37,04	18,68	135,94
Average consumption Peak Hours (kWh)	25,80	10,42	55,03
Average consumption Non-Peak Hours (kWh)	12,80	8,02	54,63
Daily Consumption per capita (210 persons assumed)	6,3 KWh/ person/day		
Average Monthly consumption per capita	189 KWh/ person/month		

Table 20: Energy consumption data for 1 September- 30 November 2011 for standard prosumers

Senior Prosumers Energy Consumption (Public lighting system) – NOPL application

The pre-pilot consumption for the segments of lights is presented in Table 21.

Pilot public lights consumption data			
		PLAZA CONSTITUCION	AVENIDA REYES CATOLICOS
Total consumption (kWh)		14897	14928
Total September consumption (kWh)	00:00 - 08:00	3550	3393
	8:01 - 23:59	1033	1079
Total October consumption (kWh)	00:00 - 08:00	3521	3418
	8:01 - 23:59	1263	1309
Total November Consumption (kWh)	00:00 - 08:00	3945	4129
	8:01 - 23:59	1585	1600

Table 21: Energy usage results for 1 September- 30 November 2011 for the lighting system (senior prosumer)

2.4.3.2.2 Production data

Standard prosumers energy production – BAF application

As described previously, the overall production will be assumed to be the same as simulated for pilots. So the data are the same as provided in section 2.3.3.2. The overall production considered is 37875,5 kWh as described in 2.3.3.2.

2.4.3.2.3 Costs for consumption

Standard Prosumers Costs for Consumption (Public lighting system) – BAF application

As in the previous reference case, there is no marketplace so all the consumption is billed though standard contracts. Again, we assume that only a percentage of the consumption is billed by the standard contracts and the rest of it is free as it is generated by self-owned PVs. Thus, the total consumption as provided in 2.4.3.2.1 was 277076,2 kWh. So, the amount of money that would be paid by the users for energy by Alginet was:

Total consumption – 0,35*Total production = 277076,2 - 37875,5*0,35 = 263819 kWh. The average price of 0,12 €/kWh was used as an average of the tariffs of the user contracts. 31658 Euros

Senior Prosumers Costs for Consumption (Public lighting system) – NOPL application

The two lighting segments (Reyes Catolicos avenue and Constitucion square) had contracts with standard tariffs. The average contact tariff for the sensors segment is 0,124 €/kWh and for the led lamps segment is 0,117 €/kWh. Considering the consumption for each case the costs are presented in the following table.

Segment of lights	Total Consumption for the second pilot phase (kWh)	Average tariff (€/kWh)	Total costs (€)
Reyes Catolicos	14928	0,124	1851,07
Plaza Constitucion	14897	0,117	1742,95

Table 22: Senior prosumers costs for consumption

2.4.3.2.4 Revenues from production

Standard prosumers revenues from production – BAF application

As described before, it is assumed that a 35% of the consumption derives from PVs. The overall production considered is 37875,5 kWh as described in 2.1.3, for the whole reference period. Thus, the production that covers energy needs is 37875,5*0,35= 13256,4 kWh. So, the production sold to the DSO is 37875,5– 13256,4 = 24619,1 kWh so considering the 0,10 €/kWh, we can conclude that the total revenues of the users from PV energy selling was 24619,1 *0,10= 2461,9 €. The 0,10 €/kWh price is considered due to reasons analysed in 2.1.3.5.

2.4.3.2.5 CO_2 emissions

Standard Prosumers emissions – BAF application

A performed for the previous cases a new average mix is calculated according the production and the emissions per kWh are provided. Thus based on the consumption from the energy mix, total emissions are extracted.

Based on the average emissions per type of energy the **kgCO_2 /kWh** is now: 0,303 KgCO_2 /kWh.

Summarizing the CO_2 (kg) = 0,303 KgCO_2 /kWh * Total consumption from energy mix (kWh) = 0,303 * 263819 = 79937,16 kg CO_2 .

Senior Prosumers emissions – NOPL application

Using the same **kgCO_2 /kWh** = 0,303 kg/CO2 and considering the overall consumption for each segment of lights the respective emissions are presented in the following table:

Light Segment	Overall consumption (kWh)	Overall emissions (kg CO2)
Reyes Catolicos	14928	4523,18
Plaza Constitucion	14897	4513,80

Table 23: Second phase senior prosumers emissions

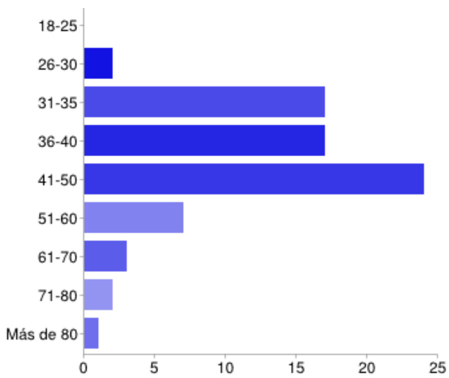
2.4.3.2.6 Pre-pilot questionnaires

Pre-pilot questionnaires were addressed to standard prosumers in order to study the current energy behaviour of the Alginet grid users. The results are presents below.

Demographics

The Pre-pilot questionnaires aimed to investigate the profile of the pilot participants in terms of energy behaviour and level of satisfaction with the current energy management model. The questionnaires included multiple choice, scaled and free questions and were available on-line to all users through Google docs. The users were motivated to fill in the questionnaires during the whole period of trial but not all of the participants finally filled them in.

77 users in total filled in the pre-pilot questionnaires. Their ages range is shown in the following Figure where the horizontal axis numbers are translated in percentages of users.



Axis Indication	Users percentage
0	0%
1	1%
2	3%
3	4%
7	9%
17	22%
24	32%

Figure 20: Age range of the pilot participants

The majority of the users had completed high education as 76% of the participants had degrees higher than secondary high-school education. 76% of the households had total income lower than 30.000 € (Figure).

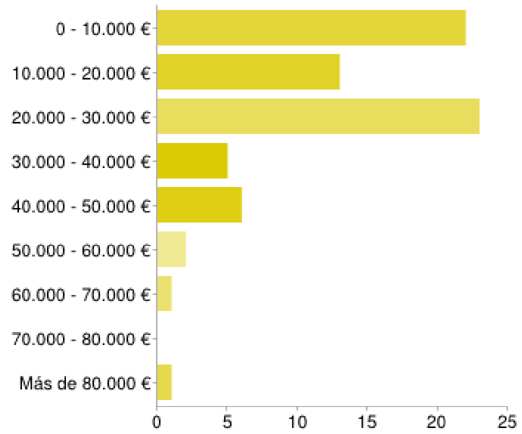


Figure 21: Average income of the pilot participants

67% of the residences were individual building while the rest were part of apartment blocks with 3-4 inhabitants in most of them.

Energy behaviour and satisfaction level

The majority of the residences were equipped with all typical electric appliances (TV, Washing machine, Dishwasher, Refrigerator, Television, Hairdryer, Vacuum cleaner, Electric stove, Water heater, Air condition units). None of the residences had photovoltaic systems installed and seem to be completely energy dependent on the local DSO as only one had alternative energy generator (oil boiler).

The participants were in general not satisfied from the costs monthly paid for energy as 61% of them consider this amount high or even unaffordable. The majority of the participants mentioned that had no special knowledge of the energy market and its actual function. 100% of the users said they would like to have a better overview of their consumption, preferably through laptop or some of them with their mobile phone.

Attitude towards energy reduction and environmental issues

Most participants (75%) mentioned that they are concerned enough about the future in energy management and about environmental issues related to energy usage. In addition, all of the participants declared that they are willing to use innovative technologies in order to reduce their energy consumption but also to contribute to environmental friendly actions. 90% of the users said that they would be willing to share anonymous/aggregated information within a local level in exchange with cheaper energy. However 53% of the users mentioned that they would not accept to pay slightly more expensive energy in order to consume higher share of RES that will contribute to minimize negative environmental impacts. This can be explained considering the economic crisis striking Europe and especially Spain. However, 67% of them would sell to their neighbours non used energy, e.g. for photovoltaic panels in order to have economic benefits. 77% of the users mentioned that they would be positive to let a third party to manage their energy transactions in the same way an investor advisor would manage their investments. Finally, 96% of the users mentioned that they would share private consumption data with their DSO in order to have cheaper and of better quality energy services.

2.5 Simulations

2.5.1 Marketplace Simulation evaluation

The market and brokering functionalities in IEM have been implemented in such a way, as to be able to realise also simulations of different stakeholder behaviours as these are expressed via their respective agent strategies. In this section, the NOBEL market is evaluated by using the modified Zero Intelligence Plus (ZIP) [2] agent. The evaluation is carried out through simulation scenarios based on real demand measurements and supply profiles that are calculated from localized weather and solar irradiation data. The trading outcomes under the different evaluation scenarios are analysed to determine the economic and resource usage impact of the market.

2.5.1.1 Simulation Scenarios

The proposed market model is evaluated in the context of the following evaluation scenarios:

- **Scenario 1 – "Status Quo":** This corresponds to a migration approach towards fully liberalized energy market trading that considers existing schemes such as feed-in tariffs. The difference between retailer supplied electricity costs and feed-in tariffs is enough to create an area of opportunity in which participants will be motivated to trade in the market. The retailer contracts held by the participants will dictate their limit prices for the purchase of electricity, and the feed-in tariffs will dictate the limit prices for the sale of electricity. Supply that is not sold in the market is fed in to the grid at the feed-in tariff price.
- **Scenario 2 – "Free Market":** The feed-in tariff scheme is phased out. The limit prices for the sale of electricity are now governed by the production costs of the supplied electricity. Any production capacity that is not sold in the market, or through bi-lateral contracts, is either not produced, not injected in the grid, or injected in the grid without any monetary benefit (e.g. by government mandate). Therefore, in this scenario, participants might sell their energy below cost, to minimize losses. The underlying assumption is that retailer contract costs will be greater than the production costs of the DERs.

More advanced evaluation scenarios can also be envisioned, such as scenarios in which retailer contracts become more complex (e.g. take-or-pay, prepaid), forcing another degree of complexity on the traders, or in which the retailers themselves become market participants. These are, however, not the focus of this work.

2.5.1.2 Evaluation Methodology

A discrete agent-based simulation environment is used to simulate the functioning of the market and the traders. In any simulation scenario, there is one market agent, which is in charge of opening and closing the trading timeslots, and a configurable number of trading agents. At the end of each step, once the trading agents have run, the market agent closes the most recent timeslot, and opens a new timeslot in a rolling-window fashion. Each trading agent is run 1000 times per time step, in a random order. The amount of demand, supply, demand bid, supply offered, supply bought, supply sold, and retailer contract price for every agent in each time period is recorded, in addition to all bids, offers, and transactions in the market.

The agents are defined by three components: their demand profile, their supply profile, and their strategy. The demand profile used for the agents is taken from real measurements taken from the participants in the NOBEL project trial. The measurements are interpolated over 15minute intervals and converted to Wh, as this is the unit of trade in the market. A database with demand profile of over 1000 real NOBEL trial participants, between

01−Feb−2012 and 28−Mar−2012, is used, with the demand profiles being assigned randomly to each trading agent.

In this evaluation, only solar photovoltaic generation is considered. The supply profile, in Wh, of a given installation i, for a particular 15 minute interval, t, is given by:

$$E_i(t) = \frac{\alpha_i \bar{G}(t)\epsilon_i \omega(t)}{4}$$

Where αi is the area (m2) of the installation, G is the global irradiation in a fixed plane (W/m2), $\varepsilon_i \in [0, 1]$ is the efficiency of the installation, ω(t) is a dimensionless scaling factor in function of the weather conditions at time t (e.g. clear sky is 1, thunder storms is 0). The irradiation data is taken from the daily irradiation utility offered by JRC's Photovoltaic Geographical Information System (http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php). The weather factor is calculated from weather data collected from the web-services offered by Wunderground (www.wunderground.com). Both irradiation and weather data were collected for the city of Alginet, in Spain, where the NOBEL trials are taking place.

The strategy employed in this evaluation is the modified Zero Intelligence Plus agent previously described. For simplicity, in this investigation the difference between the demand and supply of the agent, for a particular timeslot, will define if the agent is a buyer or a seller on that timeslot. That is, if the difference is positive, the agent will attempt to buy the difference from the market. Alternatively, if the difference is negative, the agent will attempt to sell the difference on the market. At each iteration, the agent will first calculate its profit margin based on the modified ZIP behavior. Once the profit margin is determined, the agent's price is calculated. It will then remove its current quote from the market, if one exists, and quote its full remaining quantity on the market at the calculated price. As an agent buys, or sells, electricity in the market its remaining quantity is updated. Once an agent has no more energy to buy or sell, it no longer participates in the market. For simplicity, the agents only trade on the nearest open timeslot, and forecasting errors are not considered.

An agent is also assigned a retailer contract that defines its price of electricity outside the market. When an agent is buying, its limit price will be defined by its retailer contract price for the particular timeslot. It is assumed that the agent would be willing to pay the same price as their contract price, in order to buy from the market. The limit price for sellers is defined by the assumed feed-in tariff, for evaluation scenario 1, and the assumed production costs, for evaluation scenario 2.

2.5.1.3 Results

The executed simulation scenarios are defined by two key parameters: the number of agents (100, 500, and 1000), and the probability that an agent will have a PV installation (10%, 50%, and 100%). All agents are assigned the same flat- tariff contract of 14 cents/kWh. The feed-in tariff is a constant 5 c/kWh, in the context of evaluation scenario 1. The same value is used as the assumed production costs when considering the evaluation scenario 2. The PV installations are all identical, with a 25m^2 area and an efficiency of 0.15. The market parameters are as follows: a maximum price of 20 cents/kWh, a minimum price of 0 cents/kWh, 96 concurrent timeslots, and 1 hour between the current time and the closest open timeslot.

In this evaluation, supply and demand prediction errors are not considered, and the distribution system costs are assumed to be the same for all participants and are not considered in the calculations.

2.5.1.3.1 Economic and Efficiency Measures

In Table 24, the economic impact of trading in the market given evaluation scenarios 1 and 2 is shown. The economic impact is assessed by two key measures: the percentage of increase in revenue due to supplying the grid with electricity through the market, ξ1 and ξ2, for evaluation scenarios 1 and 2 respectively, and the percentage of decrease in costs incurred through the retailer contract, v. Thus,

$$\xi_1 = 1 - \sum_i \sum_j \frac{(s_{i,j} - d_{i,j} - s_{s_{i,j}})c_{fit} + s_{s_{i,j}} c_{s_{i,j}}}{(s_{i,j} - d_{i,j})c_{fit}}$$

$$\xi_2 = 1 - \sum_i \sum_j \frac{(s_{s_{i,j}} c_{s_{i,j}})}{(s_{i,j} - d_{i,j})c_{fit}}$$

$$\nu = \sum_i \sum_j \frac{(d_{i,j} - s_{i,j} - d_{b_{i,j}})c_{r_{i,j}} + d_{b_{i,j}} c_{b_{i,j}}}{(d_{i,j} - s_{i,j})c_{r_{i,j}}} - 1$$

Where $s_{i,j}$ is the supply, $d_{i,j}$ is the demand, $s_{si,j}$ is the supply sold to the market, $c_{si,j}$ is the weighted average of the sale transaction prices, $c_{ri,j}$ is the retailer contract price, $d_{bi,j}$ is the demand bought from the market, $c_{bi,j}$ is the weighted average of the purchase transactions, of agent i on timeslot j, and c_{fit} is the standard feed-in tariff that is the same for all agents. Additionally, ξ1 and xi2 only take into account instances where $s_{i,j} > d_{i,j}$, and v only takes into account instances where $d_{i,j} > s_{i,j}$.

Essentially, ξ1 is calculated as the increase in revenue percentage when com- paring the supply revenues with the market (FIT revenues from what was not sold in the market added to market revenues) and what revenues would have been without the market (solely FIT revenues), ξ2 is the percentage of revenue increase when comparing the revenues solely from the market and revenues generated solely from the FIT scheme (i.e. no market). Finally, v is the percentage cost decrease when comparing electricity costs with the market (market costs added to the retailer contract costs for what was not bought from the market) and what the costs would have been without the market.

Economic Impact				
#Participants	**%PV**	**ξ_1 (%)**	**ξ_2 (%)**	**ν (%)**
1000	10	136.05	136.05	0.82
1000	50	59.62	39.66	8.04
1000	100	12.48	-57.93	9.41
500	10	138.21	138.21	0.72
500	50	57.42	33.62	7.37
500	100	13.80	-53.17	9.70
100	10	126.39	126.39	1.12

100	50	36.44	-7.71	10.17
100	100	10.26	-59.51	11.60

Table 24 Economic Impact of the market

As can be seen, qualitatively, all the simulation scenarios, from now on referred to as just scenarios, behave in the same way. For any number of market participants, as the probability of a participant having a PV increases, the con- tract costs decrease, as do the supply revenues. This is a sensible outcome, since the more supply there is in the market, the lower prices will be due to competition, thus decreasing the profit margin of sellers and reducing the contract costs of the buyers.

Quantitatively, the scenarios with 1000 and 500 participants behave virtually in the same way. The scenarios with 500 participants show slightly higher values for ξ_1 and ξ_2, slightly lower values for v when compared to the 1000 participant scenarios. This is due to a small difference in the average supply levels between these scenarios. On average, there is slightly more supply available to the market in the 1000 participant scenarios, which led to this discrepancy. More interestingly, the 100 participant scenarios seem to behave differently, with much lower ξ_1 and ξ_2 measures, and higher v values across the board. This is attributed to the smaller number of active traders on the market. With 100 participants, there are not enough interactions in the market for the agents to make a good price determination.

The retailer contract costs reduction is much smaller than the revenue increase experienced by the sellers. This is due to the fact that trading is only occurring during sunlight hours, which means that participants are being supplied by their retailer in all other hours. This indicates that other types of generation technologies that complement widespread usage of PVs and, for instance, are not that much dependent on time or weather conditions, should be included in the market. Additionally, battery storage could further improve the situation for both buyers and sellers by enabling the trading of electricity out of sunlight hours.

In order to assess the resource efficiency of the scenarios, three measures are taken: the amount of capacity traded on the market in relation to the total available capacity, ζ, the maximum theoretically tradable capacity in relation to the total available capacity ζ_{max}, and the average ratio of traded capacity and maximum tradable capacity per timeslot, ε.

$$\zeta = 1 - \frac{\sum_j m_{s_j} - m_{v_j}}{\sum_j m_{s_j}}$$

$$\zeta_{max} = \frac{\sum_j min(m_{s_j}, m_{d_j})}{\sum_j m_{s_j}}$$

$$\epsilon = \frac{\sum_j^N \frac{m_{v_j}}{min(m_{s_j}, m_{d_j})}}{N}$$

Where, m_{sj} is the volume traded on the market, and m_{dj} is the total demand available for the market, for timeslot j respectively.

As can se seen in table 2, all cases show a high usage of the available resources, as indicated by ε. In cases where the probability of a household having a PV was 100%, there was high degree of excess supply that could not be sold in the market, simply because there was not enough demand to meet it. This indicates that other mechanisms, such as inter-market trading or storage technologies, are required to increase resource efficiency under these conditions.

Resource Efficiency				
#Participants	%PV	ξ_1 (%)	ξ_2 (%)	ν (%)
1000	10	100.00	100.00	100.00
1000	50	80.00	80.11	99.94
1000	100	29.60	29.79	99.28
500	10	100.00	100.00	100.00
500	50	76.20	76.29	99.92
500	100	33.04	33.43	98.66
100	10	100.00	100.00	100.00
100	50	55.85	56.28	99.41
100	100	30.23	33.43	90.75

Table 25: Resource Efficiency with market trading

2.5.1.3.2 Average Trading Behavior

The average trading behaviour is defined in terms of the average price statistics over the timeslots that occur at the same time every day during the simulation. For instance, the average price behaviour for the first timeslot of a day, the timeslot between 00:00 and 00:15, is constructed from the average prices of all timeslots that occurred in that period. Figure 22 shows how the average prices at each timeslot behaved in each of the scenarios involving 1000 participants in relation to the average total supply/demand ratio experienced on the timeslot.

As can be seen in all figures, the average prices follow the level of supply in the market. When there is more supply, prices are lowered, and when there is less supply, prices are increased. A key difference between all the scenarios, however, is the increasing level of sag in the price curves as the level of supply in the scenarios is increased. When supply is restricted, the 10% case, prices are much higher and the difference between maximum and minimum prices is smaller. However, the level of supply increases, the prices lower, and the gap between maximum and minimum increases. Thus, they are following the rules of supply and demand.

The price curves also indicate that the agents are not making as much profit as they could. Whenever the supply/demand ratio is less than one, there is more demand than supply on the market. Therefore, market prices should have a stronger tendency towards the limit prices of the buyers, which in this case is 14 cents/kWh. When there is more supply than demand, however, average prices should have a stronger tendency towards the limit prices of the sellers, which in this case is 5 cents/kWh. While these tendencies are present in the figures, they are not as strong as expected, as the limit prices are not being reached other than in very extreme, high and low, values of supply/demand.

One limitation of the trading strategy that might contribute to this effect is that it does not monitor the quantities offered in the market. The heuristics of this strategy are governed only by the prices of the quotes, relying on the relative number of buyers, or sellers, to indicate the level of supply and demand in timeslot. By also taking into account the quantities, an agent can better understand its position in the market, leading it to higher profits.

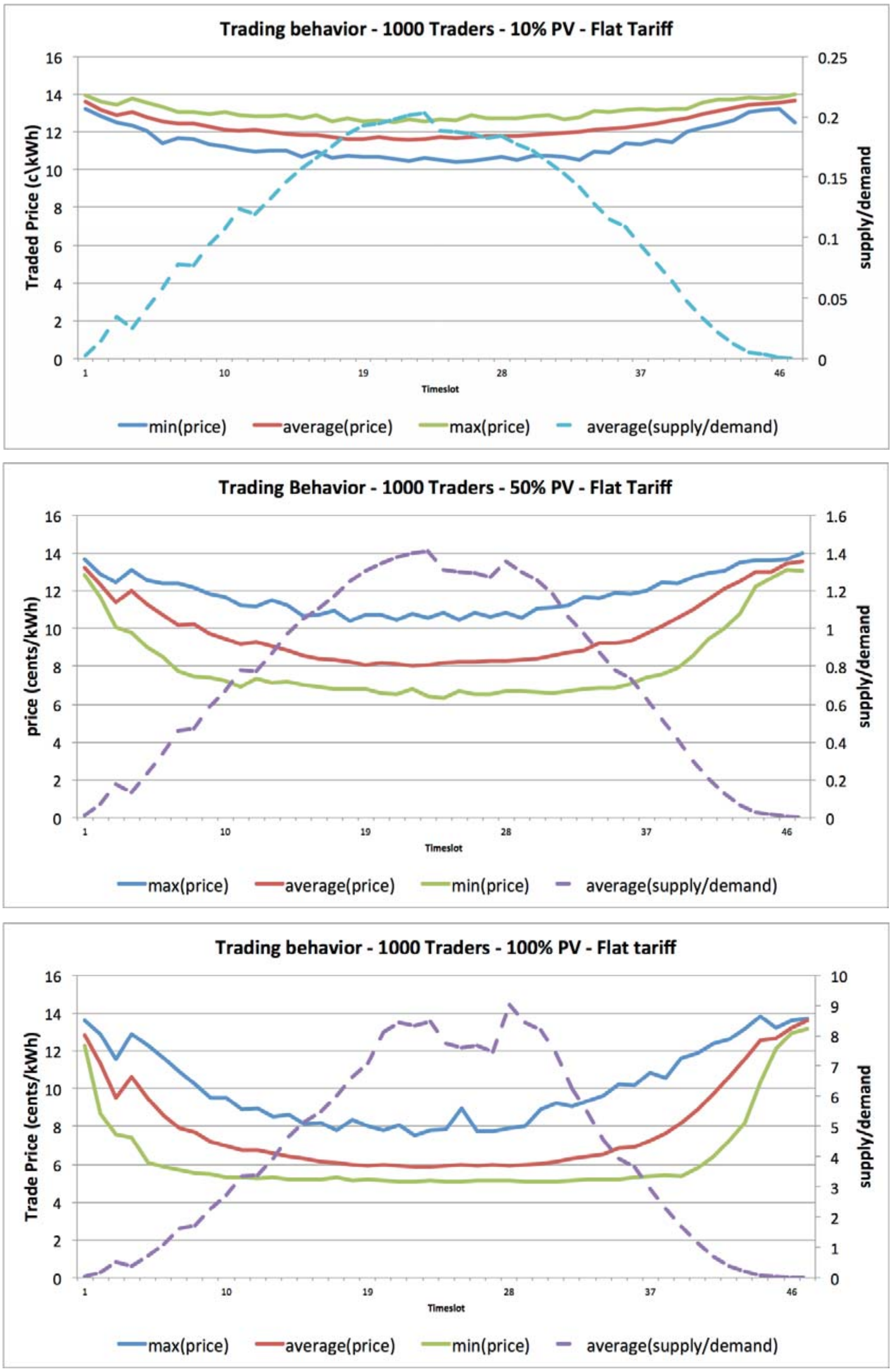


Figure 22: Average trading behaviour per timeslot for 1000 traders with 10%/50%/100% probability of PV and with fixed tariff contracts

2.5.1.3.3 Conclusions

In this investigation, the outcomes of the trades of simple trading agents on a local energy market under realistic demand, supply, and pricing conditions have been simulated and evaluated. The trading strategy adopted by the agents is simple and was based on the Zero-Intelligence plus agent. It was shown that even with a simple trading strategy, a high level of resource usage could be obtained, typically around 99% for larger quantities of agents. A small number of agents did not provide enough market interactions for price determination process. Even so, the resource usage was around 90% in the worst case. Furthermore, the agents had an increase in supply revenue through the market even without the existence of a feed-in tariff, with the exception of the cases where there was a large amount of surplus production. Additionally, a reduction in the retailer contract costs of the agents was seen, which generally followed the level of supply in the market.

One major assumption throughout the presented work is that the agents can predict their supply and demand positions with perfect accuracy. Future work will concentrate on the effects of prediction errors on the outcomes of the market. Additionally, the simulation scenarios analysed assumed a single type of participant (households) with a single type of generation technology (PV). This limited trading to sunlight hours, which limited the overall retailer contract cost reduction experienced by the agents. As such, more robust simulation scenarios that include other types of participants (e.g. factories, businesses, groups of participants), other generation technologies (e.g. wind, and µCHP) and storage technologies (e.g. electric-vehicles and battery storage) are required. Further- more, more sophisticated trading agents are required to better capitalize on the market. Here, agents only traded in the immediate timeslot, while the remaining timeslots were ignored. It is worthwhile to investigate if trading on a longer horizon can further improve the trading, and overall, outcomes, and whether this could lead to better demand response.

2.5.2 Simulation of NOBEL strategies in Alginet

A comparative study for the night of 18-19/12/2012, based on the simulation of the whole town of Alginet, has been performed. This simulation provides feasible values related to energy, power and luminosity levels. Output corresponding to other parameters (intensity, voltage, power factor) should not be taken into account.

This simulation consists in a NOPL system controlling two different sets of simulated lamps. The nominal power of those elements has been extracted from the report provided by Local authorities of Alginet, which contains real information about the structure and elements of the public lighting system of the town.

In order to make the simulation, it is necessary to highlight that that Alginet public lighting network is composed by:

- 17electrical panels
- 1.667 points of lights
- 245 KW of Nominal power

Each set of lamps corresponds with all lamps in Alginet, but two different strategies are simulated (one on each):

1. The energy-saving strategy described in section 0 *Calendar-based lighting control*.

This simulation provides a feasible approximation of what would be the situation of Alginet if Segment Controllers were deployed in the whole lighting network and NOPL strategies would control all the lamps in the town.

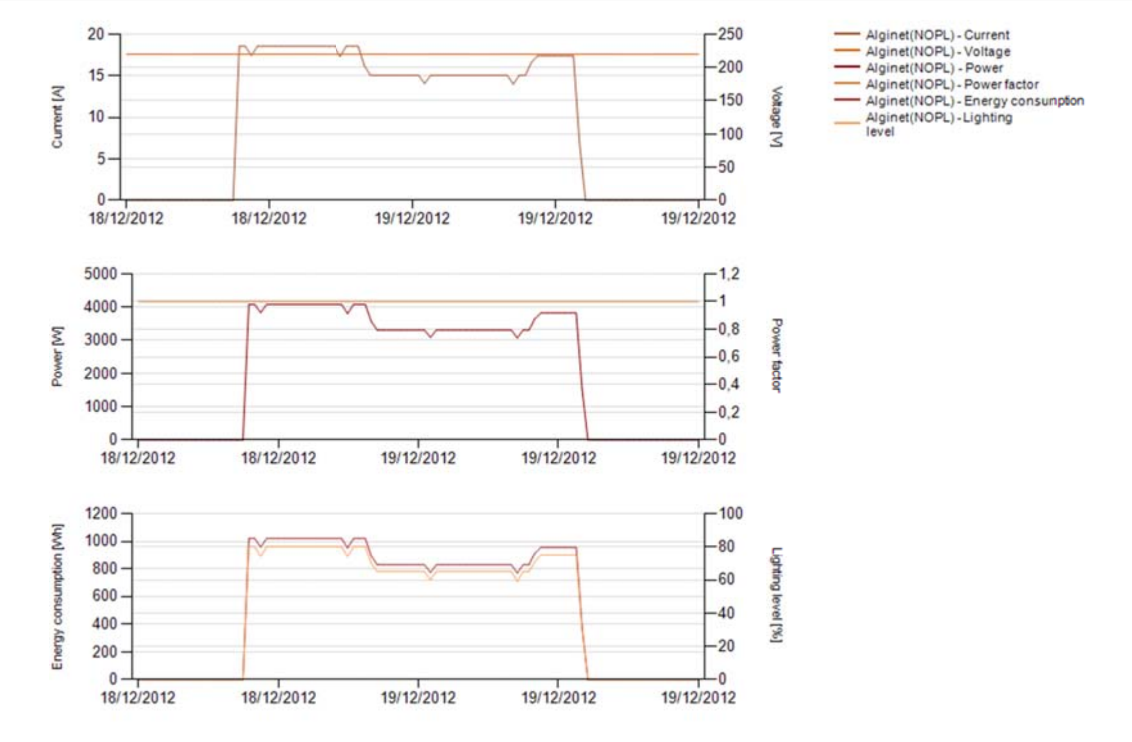


Figure 23 Calendar-based regulation in Alginet - Simulation

2. No energy-saving strategy (all lamps are turned on at 100% during the whole night)

This situation will serve as baseline in Alginet town for comparison

Figure 24 No regulation in Alginet - Simulation

The results are summarized in the following table:

Lighting hours	14:15
Energy consumption with NOBEL saving strategy	52434,36 Wh
Energy consumption without NOBEL saving strategy	72925,69 Wh
Energy saving rate*	28,10%

Table 26 Simulation results

* energy saving rate calculated as (E1 – E2) / E1, where E1=Energy consumption without saving strategy and E2=Energy consumption with saving strategy

This energy-saving strategy shows that almost up to 30% of the energy consumption of the lighting system in Alginet could be reduced with no impact on the pedestrians' safety and comfort by using the regulation capabilities offered by the combination of NOPL and the segment controllers.

2.6 User Survey

2.6.1 Overview

The smart grid and its promises have sparked worldwide research and demonstration projects, some of which focus on how to empower its users with better tools to monitor, understand, and manage their energy behaviour. It is often seen, however, that the providers of the tools may be driven by a technology push, and hence make assumptions that may fall a short of users' expectations. The lack of understanding on the real-world needs of the users as well as the impact of new technologies and tools may lead to the underestimation or the abandonment of innovative approaches. The issues of how the future smart city residential prosumer will benefit from the future smart grid services and what trade-offs s/he will be willing to make are hot topics.

The survey was comprised of 25 questions, of which 19 were yes-or-no questions, 4 were scale questions, 1 was multiple selection, and 1 was a written-response question. The survey was accessible to the public through the NOBEL project's website in both English and Spanish for a period of about 2 months. The questions were targeted at end prosumers of electricity in the residential sector, while no assumptions were made for their background. Aside from demographical questions, such as age, gender, and own assessment on the level of understanding of the subject, the questions were designed to better understand how end consumers felt about hot issues such as privacy, willingness to change their behaviour, the kind of additional information they thought they needed, and the types of energy products and services that they would be willing to engage with in the long run. The results of this survey have already been released to the public [5].

2.6.2 Willingness to Change

One of the main pillars upon which the smart grid promise is built assumes that the prosumers are willing to adjust their behaviour based on new timely information they have access to. Although this is a multifaceted problem, it is important to understand if the prosumers want to adjust their behaviour, under what conditions, and in what way. As smart grids envision highly distributed generation, the increased participation of the demand side to stabilize the grid is a highly relevant area of research, as it will greatly impact the way end-users interact with the grid. Understanding the willingness of end-users to transition into this new paradigm of thinking and acting in the smart grid, whether it be responding to price signals, actively trading energy resources, or simply paying a little more to consume more ``green" energy, is of paramount importance.

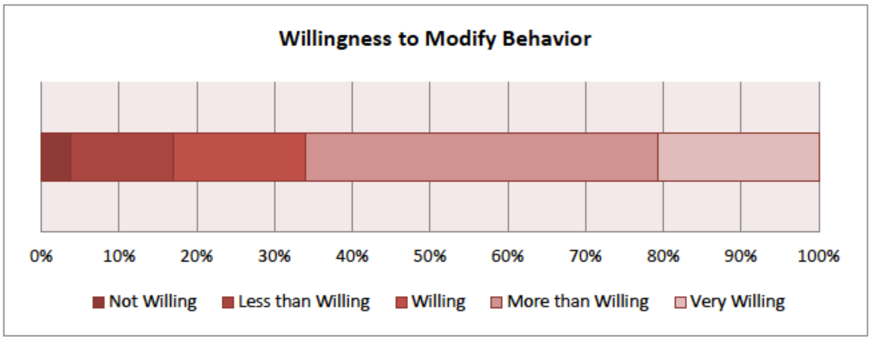


Figure 25: The willingness of participants to modify their consumption behaviour based on external signals such as price.

As the nature of the generation and distribution of electricity changes, end-users will have to take a more active role in managing their usage to manage costs and diminish their impact on the environment. Part of the survey questions were pertaining the willingness of the end-consumers to change and adapt their consumption behaviour, to engage with each other to reduce costs, and to provide usage information to their retailer in order to reduce costs. As depicted in **Figure 25**, depending on the information they acquire, the overwhelming majority of people are willing to modify their own behaviour.

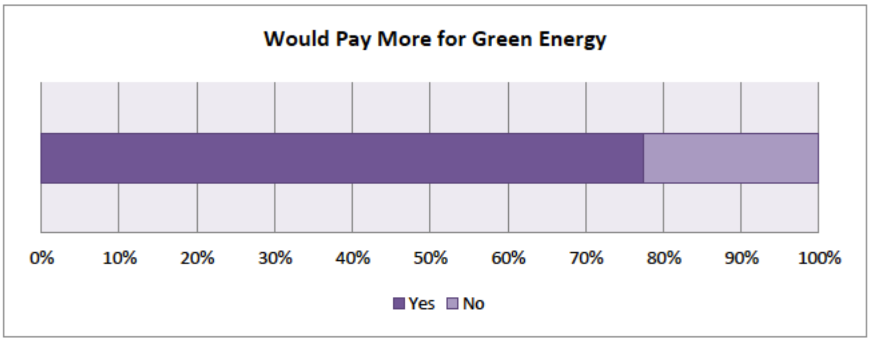


Figure 26: The percentage of participants that would pay more for green energy

These are some of the key aspects of the smart grid, where people are expected to adjust their behaviour in order to assist reducing energy at peak times, as well as maximize the use of intermittent renewable energy, such as wind of solar photovoltaic. Additionally, the majority of participants would be willing to pay slightly more to reduce environmental impact by using green energy (**Figure 26**). Therefore, in principle the prosumer has an interest in modifying their behaviour; however, to what extent, and by what means, needs to be further investigated.

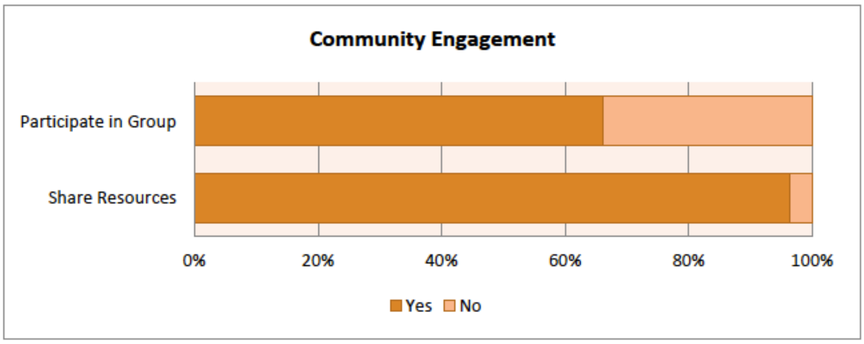


Figure 27: The percentage of participants that would like to engage with their community to form groups and share resources.

An interesting aspect in the envisioned smart grid is based on the willingness of ``prosumers'' to share resources (for example, unused ones) or trade them on an electricity market. The major goal here is the understanding of prosumers' energy behaviour both as individuals as well as part of groups (defined by social, economic, geographic, etc., criteria). The aforementioned objective may be greatly assisted by having better prediction and real-time analytics on the provided and vast smart-grid information. As shown in Figure 27, there is overwhelming support for sharing unused resources, especially if some monetary benefit can be obtained. Additionally, about 2/3 of the prosumers seem positive towards participating in shared-interest groups. This is especially interesting in the cases where service providers may act on behalf of a larger group of users (such as prosumer Virtual Power Plant [13]) and perform actions such as bidding into energy markets or actively managing their participants' energy devices according to bilateral service contracts.

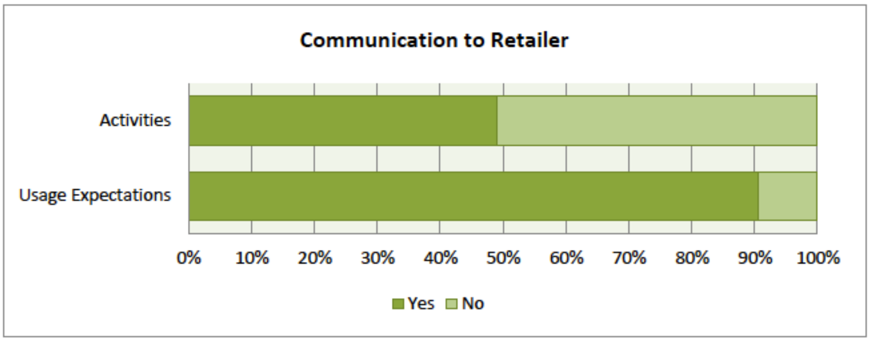


Figure 28: The percentage of participants that would communicate their activities and their usage expectations to their retailer.

As the smart grid is expected to be information-centric, one has to look at the broader picture and not only the technical information that may be acquired by the infrastructure. The increasing trend towards bilateral communication between retailers and their customers means new interaction patterns can emerge, and new approaches in handling dynamic changing situations as required in Demand Side Management and Demand Response can emerge. For instance, customers may reduce their energy costs by providing extra information about themselves, which in turn might help their retailers better assess situations and reduce costs incurred for example by forecasting errors.

The survey results as depicted in Figure 28 reveal that the majority of participants are willing to provide information about their energy-usage expectations to third parties. However, only about half of them are willing to classify in detail their behaviour pattern, for example being on vacation. This seems to suggest that new tools need to be offered to prosumers that allow them to model and understand their energy usage patterns so that they may convey their usage expectations to retailers without revealing detailed, privacy-infringing aspects. Hence, the right balance between privacy and rich user-information provision that the smart grid promises is based upon needs to be striven towards to, and supported by, the necessary tools.

2.6.3 Energy Monitoring and Understanding

The main argument for the massive roll-out of smart meters has been strongly coupled with the provision of fine-grained information (mostly metering but also other technical aspects) that would enable both retailers and residential end-users to attain a finer insight into their energy consumption and production. This motivation has tangible roots and fits perfectly with the consumer expectations and needs, as depicted in Figure 29, where over 90% of prosumers (i) wish a better information-rich overview of electricity consumption, and (ii) would like to have a better understanding on the impact of individual devices on their energy bill and behaviour. This is a strong case for analytics on the fine-grained energy information that may be generated by the smart grid, and may assist in better understanding of energy impact on the user side. However, this also implies that, apart from the detailed monitoring, the need to be able to either actively enable intelligent devices to communicate their energy behaviour (long-term) or passively deduct it (mid-term), as well as correlation of user-specific context (such as daily tasks) to a workflow of events and the associated energy consumption.

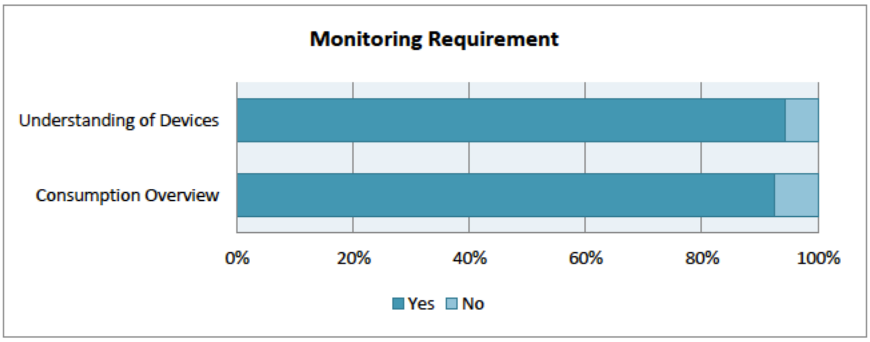


Figure 29: The percentage of participants that would like a better overview of their consumption, or a better understanding of how each device contributes to their usage.

Understanding the need for information that the end-users should be presented with is fundamental in empowering them. To be able to bridge the gap between the information generated on the technical side with a way that can be assessed by the individual user may be subject to several aspects, such as regional, social, economic, etc. From discussions and collected input via the survey, there seems to be a need on a detailed view of the energy consumption by day, and by year, and access to real-time or time-of-use (TOU) pricing. Furthermore, the need for information about the generation mix, weather information, and consumption forecasting was also prevalent, although less so. Some raised the issue of more visibility on how their energy behaviour may impact or comply with larger efforts, such as at local or regional levels, for better energy management and sustainability. Also interestingly enough, over 70% of survey participants showed an interest in comparing their personal behaviour with other energy consumers (such as neighbours or similar households).

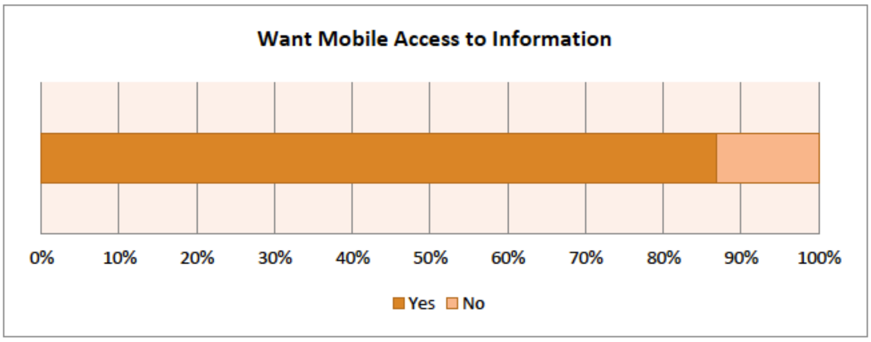


Figure 30: The percentage of participants that would like to access their consumption information from a mobile device.

These findings pose a clear message towards the need to not see the users as individual stand-alone entities but put them in the broader context of a smart neighbourhood and a smart city as well as couple them to ongoing regional and national efforts towards better energy management and sustainability efforts. The latter also implies better visibility of energy policies and their implementation, and could be proven to be a powerful tool for decision makers as well as informed energy-aware citizens of the future.

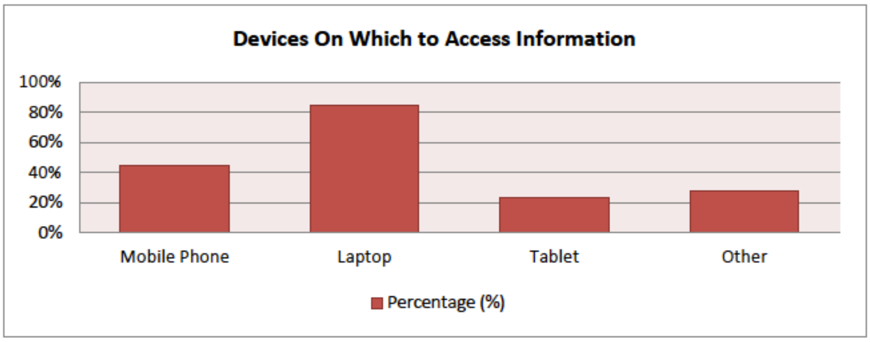


Figure 31 Participant preferred devices (multiple selection).

Having detailed information is key, but the question that arises is how can this be communicated. We have seen the rise of several ideas: monitoring via dedicated in-house appliances, up to anytime, anywhere approaches via mobile phones, etc. The findings of this survey concur as depicted in Figure 30, that the overwhelming majority of users would be interested in monitoring their personal energy consumption from a mobile device, with the highest-rated devices being laptops and mobile phones, followed by tablets and potentially other dedicated ones Figure 31. To our view, this is a clear message that the prime target for providing information to the end-user should not be dedicated (and potentially costly) new devices, but rather re-use existing user devices such as smart phones and laptops, at least in the short and mid term. We can also only estimate that tablets and other devices may rate so low, as users are either not very familiar with them (laptops and smartphones are commodities nowadays), while cost may also be a significant roadblock, especially when it comes down to a dedicated device. For the mid and longer term, other approaches might also be applicable, again by reusing existing infrastructure, for example via smart TVs.

2.6.4 Automated Control

Although information-rich real-time monitoring of energy aspects is a key promise of smart grid, in order to be effective this needs to be strongly coupled with real-time control and management of the infrastructure. This will make possible large-scale energy-management approaches such as peak-shaving, as now situations can be monitored and reacted upon in much more sophisticated ways. There are several promising scenarios here, for instance independent service providers would be able to remotely control household devices to curb usage in peaks times. This idea may not be new, as it is already implemented in commercial and industrial sectors, but applying it at large-scale residential areas and infrastructure that could not be monitored and controlled in real-time is new ground. EnerNOC (www.enernoc.com) is a good example of a company offering DR in the commercial and industrial sphere. It bids the energy flexibility of their customers in the energy market; in some cases, its customers can generate more revenue by shutting down machinery to curb energy usage, than by continuing production.

In a more long-term scenario, the devices themselves (or in-house management systems) have access to information, such as prices, and can adapt their behaviour according to the goals of the participant [13], while still maintaining operational and health and safety guidelines. For instance, a smart refrigerator could adapt its cooling cycle to reduce costs, while not adversely affecting the lifetime of the food it contains.

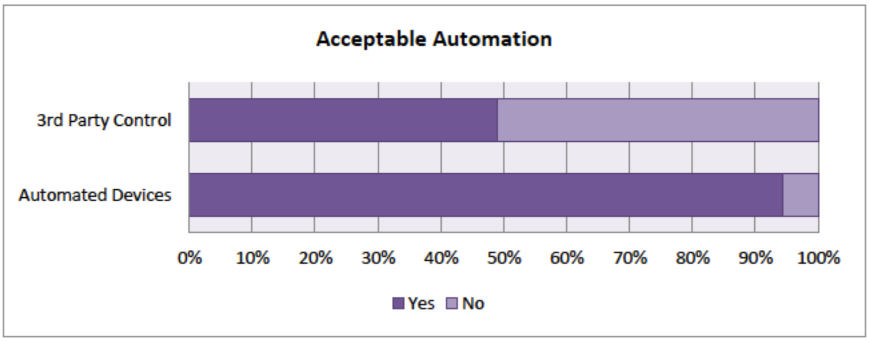


Figure 32: The percentage of participants that would like automates devices and would accept 3rd party management of devices.

Figure 32 depicts that the survey participants are willing to allow automatic management of devices as far as this does not affect any loss of comfort. This open the door for optimisation approaches between usage-patterns and device operation (which may lead to increased energy efficiency), effectively moving away from ``one-size-fits-all'' design and operational assumptions of appliances towards user-specific adaptations. However, the findings point out that people are more willing to allow their own devices to automate their energy consumption (based on external signals, such as price), than to allow external parties to manage their behaviour. This puts forward a clear message that the user wants to be in control of his/her own infrastructure but would happily engage to automatic control approaches that do not negatively impact the accommodated lifestyle.

Interestingly, in a follow-up question ``If you could trade any excess photovoltaic production in a small market, would you be willing to allow another party to manage that task for you in the same way a managed fund might manage your investments?", 81% of participants said yes. This seems to indicate a disparity in the willingness to allow third parties control between consumption and production devices. It also suggests that neighbourhood level energy aggregators may be a viable business model for managing local energy requirements in the future. However, this reaction might also be result of inexperience with energy-producing devices and their tight integration with in-house consumption, something that has been fortified with the existing feed-in tariffs in several countries that led to users considering the energy-generation sources as a third-party infrastructure that is just co-located to their premises and hence fail to make the connection between the energy produced by such systems and their own consumption.

2.6.5 Value-Added Services

As well as providing end-users with an in-depth view of their energy consumption, fine grained metering data together with artificial intelligence and data-mining algorithms can provide end-users with novel added-value services. Such services are expected to play a pivotal role in retailer offerings, as they might serve as key differentiators between competing stakeholders. Examples of these services could be: enabling end-users to compare their consumption with that of similar households in the region, allowing the retailer to provide their customers with suggestions on how to improve their behaviour, as well as bill shock services (which notify the customer early enough that s/he is on track for a larger than usual bill), or vacation services, which allow the customer to be informed of any unexpected energy usage in the house during a period of absence, such as when travelling. Although innovative creative thinking might come up with new ideas, in order for them to materialize one would have to heavily rely on monitoring, assessment, and management of the infrastructure, its stakeholders, and the information it holds.

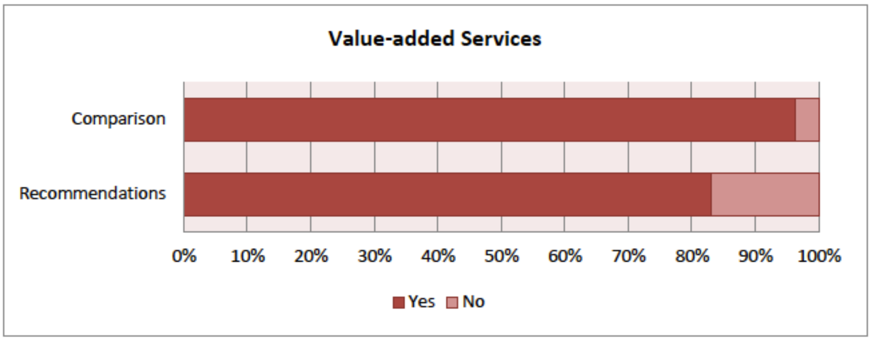


Figure 33: The percentage of participants that would like value added services such as comparison and recommendation.

As can be seen in **Figure 33**, there is a high level of interest in value-added services such as recommendation and comparison services. In order to catalyse this process, it would be important to outfit consumers with tools that give them access to their consumption data, as well as the ability to manage it, which implies sharing it via user-controlled policy access. With such enabling approaches, innovative on-line services could be created that leverage this data to create value for the customer and the service provider, much in the same way several providers operate today, for instance Facebook and Google in the social media domain.

2.6.6 Privacy

Privacy is a key area in the emerging smart grid that needs to be properly addressed in order not to pose as a roadblock. Experience so far both on telecommunications and Internet services has shown that value can be created for the users who may be willingly (or simply unaware of the compromises they get to) sacrifice part of their privacy in order to enjoy such services. Similarly, here the privacy concerns versus the services offered will be a battlefield, and approaches that offer a user-controllable balance between functionality and (private) information provided are sought.

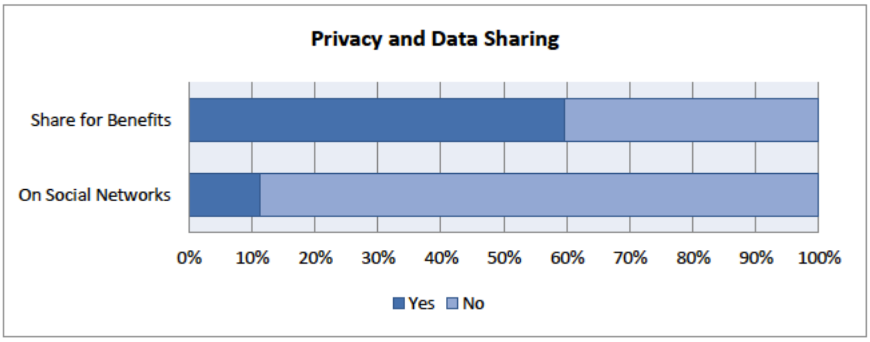


Figure 34: The percentage of participants that would like share their usage information on social networking sites or for additional benefits.

As depicted in **Figure 34**, the finding is that users may share information and partly trade their privacy if this is done in a controllable visible way, such as sharing data with the energy provider. However, over 90% said that this should be done under privacy preserving measures (e.g. anonymization, etc.). This is in line also with the interest in sharing information on social networking sites, for which most of the users do not see the benefit of simply sharing their energy consumption at the moment, probably due to absence of real value-added applications in these. However, this lack of interest dropped to about 50% if additional benefits were given, such as better pricing or access to additional value-added services. Concluding, the finding is that while privacy is paramount, it is still negotiable; however, it is still unclear how much privacy would the participant be willing to sacrifice, and for what level of benefits.

2.6.7 Towards Prosumer Energy Services and the NOBEL Energy Platform

The analysis has provided some key messages for the stakeholders actively involved in realising the smart grid. The need to go beyond the fundamentals, which is, smart metering and couple the smart grid with an advanced energy service infrastructure, is eminent. This should not be a standalone one for the sake of the smart grid, but amalgamated with the existing Internet so that existing Internet applications and services can further evolve by taking into account energy information, while the traditional grid processes may also benefit from prosumer interactions at other levels. The latter holds especially true for the three directions dealing with (i) monitoring, (ii) assessment/analytics, and (iii) control, where significant work needs to be invested.

In a more detailed fashion some of the findings in the survey point out towards the following:

- Finding 1: there is a need for better and more fine-grained access to data acquired by monitoring, even down to per device level
- Finding 2: although there is a need to preserve privacy, there is also the necessity of sharing information and trading part of it in order to enjoy value-added services
- Finding 3: users are willing to share their energy resources with the local community, in an effort to reduce their own energy costs \
- Finding 4: users would allow third parties to manage and trade their energy resources (solar photovoltaic panels, etc.)
- Finding 5: think favourably of the idea of smart and self-managed devices, but are unfavourable to third-party direct control of their consumption devices

An interesting issue is how one should approach these findings, especially from the view of developing new applications and functionalities for the emerging smart grid. The traditional approach in the energy domain is to create monolithic applications, since usually the whole value chain, that is, the data acquisition, analysis, and partially control, were in the hands of the same stakeholder. However, with the liberalisation of the energy market as well as the vision of the smart grid, there are now multiple stakeholders competing in multiple layers. Therefore, integration and interaction based on the traditional models would be not only anachronistic but impossible in the future. The quest then is towards finding commonalities, such as at the functional level, that may be realised by open platforms and services and may provide various views on the acquired data and enable further composition of them to more sophisticated ones. Hence, there is an eminent need for the so called common energy services (as e.g. provided by the IEM) and data models that can be used as a basis for future developments.

In order to satisfy finding 1, services and infrastructure need to be in place to collect the meter readings, assess them in a specific context, and make the information accessible in a variety of forms, such as real-time consumption and historical consumption aggregated by day, week, etc. for different time frames. Additionally, they should be offered in a way that a large variety of devices and applications can consume them. In this way, not only will the customers be able to access their information through the web and mobile-phone applications, but new devices can be created that leverage this information to help customers manage their energy usage.

Given the participants privacy concerns (finding 2), data should be regulated and only accessible by user-allowed stakeholders. However, in order to make more value-added services available, it would be interesting for customers to be able to share their information with third-party service providers (aggregators) in a policy-controlled manner. There are technologies, such as OAuth (http://oauth.net), which can serve as a basis for this type of functionality. While this point is still contentious, because it might go against the interests of the retailer in some situations (such as competitors using the customer data to provide better rates), it can help to accelerate innovation in this area. A significant amount of work will need to be invested in providing not only the right fine-grained access to specific data, but also providing sophisticated capabilities on top, such as anonymization of data, degree of detail to be shared, and even recall of access to data provided to third parties. These, however, call for further significant research and real-world assessment until functional approaches are found and tried-out.

As electricity gets more expensive and technologies improve, the amount of internal generation, at the household level, is likely to rise. This will create new challenges for distribution-grid managers, as the power flow will originate from several points in the distribution grid. This is a big shift from the traditional model where power flowed in one direction. The good news is, at least, that the participants in this survey are willing to share their resources for a cost benefit (findings 3,4). Providing a convincing case to the users, especially tackling the aspects of intelligent device control (self o external) and usefulness of having it as part of a broader DR action, is a key area that needs to be addressed. This also indicates that new business models and services are required to enable this type of behaviour.

There is already some existing effort in these directions, and as an example we shortly mention the impact on our current work within the NOBEL project that targets to create a secure, robust, and interoperable platform of Internet energy services (such as the IEM). The energy services are complemented with mash-up applications targeting grid operators as well as prosumers. Services covering basic functionalities identified in the survey are developed; for instance, metering data collection and monitoring, asset, and user management and billing, as well as added-value services, such user-specific consumption and production prediction. Additionally, to allow consumers to interact and share their energy resources, a local energy-market model was developed and implemented [9]. Services were also developed to allow the customers to trade their energy on the market, as well as for grid operators to manage it. All services are implemented using the REST

(REpresentational State Transfer) methodology, which allows them to communicate with any IP-enabled device. This aspect is especially important since it allows the platform to be leveraged from a variety of devices, not only desktops or laptops.

Based on this view, one can better understand the motivation of designing and implementing a common energy services platform such as the IEM. Additionally via the integration with end-user applications, we can tackle several whitespots identified.

3 Impact assessment

3.1.1 Overall Approach

This section aims to evaluate the impact of NOBEL system. In order to conclude on impacts a comparison with a reference case is required. Stemming from sections 2.2, 2.3 and 2.4, changes on energy consumption, emissions, costs and revenues can be estimated, concluding on the overall NOBEL impacts assessment.

3.1.2 Indicators measured

The indicators to be used for the impact assessment of NOBEL project were provided in detail in D7.1. ”Evaluation plan”. The initial evaluation plan was modified and enriched with simulations, considering different energy market models. Thus, some of the indicators were determined through real data deriving from pilot testing and some of them it was considered as “safer” to be determined through simulations in order to simulate as close as possible the behaviour of the market under parameters that were not influencing pilots that will be critical in a more “real” implementation of the trading game.

3.1.2.1 Pilot testing impact assessment indicators

The indicators to be evaluated for the impact assessment based on the data provided by the pilot testing are the following:

- **Energy Savings (percentage),** i.e., reduction of energy consumption. This indicator will be determined for the total of the users, for domestic users and for the public lighting testing area in relation to 2011 respective time intervals that are considered as the reference case in the context of the project. The reason for the selection of this interval is described in previous section.
- **Energy Stabilization,** i.e. observe if the energy peaks are moved and the load is normalized.
- **CO_2 reduction (percentage).** CO_2 emissions are not measurable in local level as change in the local grid users’ behaviour cannot be detected. The reference point as well as the post-NOBEL values for the emissions was calculated through average production
- **Reduction of expenses for energy (percentage).** This indicator will determine the financial benefit for all the users and in particular for the public lighting operator and it is based on the consumption and the standard user contracts. This is the actual amount paid by the users before and during pilots. The difference is due to the reduction of consumption. If the market was real, this amount would be less as the average tariff within the market will be lower. This reduction is calculated based on the average price of the kWh for the transactions performed within the game.
- **Socioeconomic indicators** as environmental awareness, change of attitude, etc., that are going to be extracted by the end users’ questionnaires.

3.2 Energy Impact

In this section, impacts related to energy usage and management will be investigated. This analysis will consider the pilot results analysis of the previous sections and compare them with a baseline scenario in order to conclude over the efficiency of the integrated system.

3.2.1 Comparison of User application system results with the baseline case

In this section the energy usage data extracted from the pilot tests will be compared to the baseline case as defined in section 2.4.3.1. As the two phases of testing took place during different weather conditions the comparisons will be performed per phase and not for aggregated values.

3.2.1.1 First phase energy impacts

Standard prosumers consumption- BAF application

The following table presents the comparisons of the first phase with the reference case as defined in section 2.4.3.1. Total consumption has been reduced by **3,79**%. A shifting of the consumption from Interval 1 and 4 to Interval 2 and 3 can be observed.

Indicator	First Pilot phase	Baseline case	Difference (%)
Total consumption (KWh)	227008,8	235963,5	-3,79
Total consumption on February (KWh)	77022,2	80284,32	-4,06
Total consumption on March (KWh)	78959,4	82154,08	-3,89
Total consumption on April (KWh)	71026,9	73525,12	-3,39
Average daily consumption (KWh)	39,39	40,7	-3,22
Average consumption Interval 1 (KWh)	6	6,5	-7,70
Average consumption Interval 2 (KWh)	8,2	8,1	1,23
Average consumption Interval 3 (KWh)	12,9	12,5	3,20
Average consumption Interval 4 (KWh)	12,5	12,9	-3,10

Table 27: First pilot phase energy impact on standard prosumers consumption

Senior prosumer consumption (lighting system)- NOPL application

The following table presents the energy impact of NOPL for the lighting segment in AVENIDA REYES CATOLICOS. A remarkable energy consumption reduction of **39,40%** is observed in relation to the reference case as provided in section 2.4.3.1.1

Indicator	First Pilot phase	Baseline case	Difference (%)
Total consumption (kWh)	6562,81	10830	-39,40
Total February consumption (deducted) (kWh)	2610	4218	-38,12
Total March consumption (kWh)	2894,63	4772	-39,34

Indicator	First Pilot phase	Baseline case	Difference (%)
Total April Consumption (kWh)	2498,18	4167	-40,05
Average Daily Consumption (kWh)	88,88	148,36	-40,09
Average Consumption Interval 1 (kWh)	43,06	72	-40,19
Average Consumption Interval 2 (kWh)	0,45	2,2	-79,55
Average Consumption Interval 3 (kWh)	0,27	0,26	3,8
Average Consumption Interval 4 (kWh)	45,06	73,9	-39,03

Table 28: First pilot phase energy impact on public lighting consumption

3.2.1.2 Second phase energy impact

Standard prosumers consumption – BAF application

The same comparisons are performed for the second phase of pilot testing in Alginet. In this case the reduction is much higher (16,53%). In addition, a percentage of the peak hours consumption is shifted to the non-peak interval. The baseline case is provided in section 2.4.3.2.1.

Indicator	Second Pilot phase	Baseline case	Difference (%)
Total consumption (kWh)	277076,22	231269	-16,53
Total September consumption (kWh)	78619	90796	-13,41
Total October consumption (kWh)	86220,75	72819	-15,54
Total November consumption (kWh)	100059	79831	-20,22
Average daily consumption (kWh)	37,04	30,84	-16,74
Average consumption Peak Hours (kWh)	25,80	25,00	-3,10
Average consumption Non-Peak Hours (kWh)	12,10	12,24	1,16

Table 29: Second pilot phase energy impact on standard prosumers consumption

Senior prosumer consumption (lighting system) – NOPL application

As mentioned before, NOPL evaluation was performed for the second phase by controlling two smartmeters, on segment of lights in the AV. REYES CATOLICOS avenue, where sensors where installed and two led lamps in PLAZA CONSTITUCION with inductor loops. The impacts of NOPL for these two cases are presented in the following Tables, in comparison with the baseline case as described in 2.4.3.2.1

Indicator	Second Pilot phase	Baseline case	Difference (%)
Total consumption (kWh)	8522	14928	-42,91
Total September consumption (kWh)	2650	4472	-40,74
Total October consumption (kWh)	2669	4727	-43,54
Total November consumption (kWh)	3203	5729	-44,09

Table 30: Second phase energy impact on AV. REYES CATOLICOS lamps consumption

Indicator	Second Pilot phase	Baseline case	Difference (%)
Total consumption (kWh)	12496	14897	-16,12
Total September consumption (kWh)	3999	4583	-12,74
Total October consumption (kWh)	4093	4784	-14,44
Total November consumption (kWh)	4404	5530	-20,36

Table 31: Second phase energy impact on PLAZA CONSTITUTION lamps consumption

As expected the AV. REYES CATOLICOS lamps saved 43% energy, while the led lamps 16%. Sensors achieve more dynamic energy management as they take into account any change in the traffic in the area.

In order to evaluate future implementation of NOPL, it is convenient to know the saving per point of light, considering also the hardware equipment. Thus, the following table provides the saving per point of light.

Type of equipment	Total energy saved in the pilots (kWh)	Interval (months)	Units of light	Saving per point of light per month (kWh/point of light/ per month)
Sensors	6402	3	106	20,13
Led Lamps	12,28	3	2	2,05

Table 32: Saving per point of light/per month for different types of equipment

Considering a road with lights of the same type as in Alginet and assuming that an average road had lights with sensors installed every 20 m, the saving per km (thus 100 lights, 50 on each side) are 100 lights*20,13 kWh/point of light/ per month =2012 kWh/month/km.

3.3 Economic Impact

3.3.1 First Phase

Standard prosumers economic impact – BAF application

As described before, during the first pilot phase the manual transactions in the market place were very few. Thus, the economic impacts identified for this phase of testing has to do only with the reduction of consumption and thus on money paid to cover energy needs. In addition, the revenues from production are considered to be the same as only the marketplace can have impact on this indicator. Thus, the economic comparisons of the first phase and the reference case (sections 2.4.3.1.3 and 2.4.3.1.4) are presented in the following table.

Indicator	First Phase of pilots	Reference Case	Impact
Costs for consumption (€)	26357,99	27411,6	Reduction of 3,8%
Revenues from production (€)	1399,9	1399,9	There is no impact

Table 33: First Phase Economic impact for standard prosumers

Senior prosumers economic impact – NOPL application

The remarkable energy consumption reduction due to NOPL, led also to economic benefits for the public lighting system operator. The following table presents the economic impact for the Reyes Catolicos avenue.

Indicator	First Phase of pilots	Reference Case	Impact
Costs for consumption (€)	813,80	1342,92	Reduction of 39%

Table 34: First Phase Economic impact for senior prosumers

3.3.2 Second Phase

Standard prosumers economic impact – BAF application

During the second phase of pilot testing in Alginet, the marketplace was used more efficiently, with the semi-automatic agents ensuring high user participation. The economic results are compared with the respective reference case as described in previous sections. The impact results are provided separately for all market participants and for only those who have active agents.

3.3.2.1 All Market participants

Indicator	Second Phase of pilots	Reference Case	Impact
Costs for consumption (€)	26498,58	31658	**16% Reduction**
Revenues from production (€)	2907,6	2461,9	**18% Increase**

Table 35: Economic impacts for standard prosumers

We can conclude that the users both have benefits from costs reduction and revenues increase. The reduction of costs is of course due to two reasons; overall consumption reduction and more beneficial trading through the marketplace.

3.3.2.2 Participants with active agents

Indicator	Second Phase of pilots	Reference Case	Impact
Costs for consumption (€)	12977,07	12718,84	**2,03% Increase**
Revenues from production (€)	1436,00	1126,37	**27,53% Increase**

Table 36: Economic impact for active agents

These are the impacts in total costs and revenues. From the analysis per user we conclude that the average increase on costs per user is 0,5% and the increase of revenues is 19,3%.

Remark: *These amounts are not the actual amount that the users paid, but the amount they would pay if the marketplace was not a game but their actual billing mean. However, the users actually reduced their expenses due to better monitoring and reduction of the overall consumption.*

3.3.2.3 Senior prosumers

The public lighting segments participating in the pilots did not participated in the market. Thus, the economic benefit is only due to the consumption reduction. The lighting system has a contract with standard tariff and thus the economic impact is presented in the following table. The average contact tariff for the sensors segment is 0,124 €/kWh and for the led lamps segment is 0,117 €/kWh.

Indicator	Segment of lights	Total Energy Saving (kWh)	Contract tariff (€)	Impact (€)
Costs for consumption (€), Consumption* contract price	**AV. REYES CATOLICOS**	6406	0,124	**794,4 Savings** **42,7% Reduction**
	PLAZA CONSTITUTION	2401	0,117	**280,92 Savings** **16,12% Reduction**

Table 37: Economic impact for senior prosumers (lighting system)

3.4 Social Impact

3.4.1 Emissions

3.4.1.1 Standard prosumers – BAF impact on emissions

The reduction of CO_2 emissions is categorized in social impacts, as it has direct impact on consumers' quality of life and health. The following table presents, the potential reduction of emissions in case the simulated production was real and was conducted in the grid in an optimum way, through NOBEL system.

Phase of testing	Pilot emissions (kg CO_2)	Reference case emissions (kg CO_2)	Impact (%)
First phase	72264,83	74239,75	2,66% Reduction
Second phase	66227,57	79937,16	17,15% Reduction

Table 38: Economic impact for senior prosumers (lighting system)

We can observe that the reduction in the second case is much higher. This amount is partially due to the higher energy consumption reduction during the second round of pilots.

3.4.1.2 Senior prosumers – NOPL impact on emissions

Following the same approach, the impact of NOPL in emissions is presented in the following table.

Phase of testing	Pilot emissions (kg CO_2)	Reference case emissions (kg CO_2)	Impact (%)
First phase – Reyes Catolicos avenue	2159,16	3519,75	38,6% Reduction
Second phase – Reyes Catolicos avenue	2718,5	5423,18	49,87% Reduction
Second phase – Constitucion square	3986,2	4513,80	11,7% Reduction

Table 39: Economic impact for senior prosumers (lighting system)

3.4.2 Attitude towards sustainability, new business cases and innovative ICT solutions

As shown from the post-pilot questionnaires, NOBEL motivated the pilot participants, to gradually change their behaviour, proceed to energy efficiency increase measures, reduce their consumption and raise their awareness for environmental issues. As shown through the user survey, 18% of the users are willing to change behaviour and adopt a more environmental friendly approach. In addition, NOBEL aimed to change the standard static billing model by introducing to the users an innovative way of interaction with the grid and by preparing the ground for emerging in European level business models that require high social acceptance for their implementation. An indicator for this change is that 78% of the users mentioned that they would pay more in order to use higher quotas of clean energy.

3.5 Overall Impact Analysis

NOBEL pilots were successfully completed in Alginet pilot site involving different types of potential NOBEL applications users. The analysis of the data consolidated results proved that the system managed to achieve the NOBEL Consortium initial objectives in a very satisfactory level.

The overall energy consumption reduction due to the full system (agents activated) was 17% for the standard prosumers participating in the fully integrated NOBEL system using active brokerage agents. In addition, a reduction of 3% on consumption on peak-hours was observed, that leads to a more stable grid and in a bigger scale would also reduce energy imports during peak hours in expensive prices. In specific, for NOPL application a 43% reduction of consumption was observed for the sensor-equipped lights and 16% for the magnetic loop-equipped lights. The reduction of energy consumption led also to respective CO_2 emissions reduction.

This reduction led also to economic benefit for the users. BAF users managed to reduce 16% the costs for energy, increasing in the same time 18% their revenues from selling clean energy, while NOPL user managed to reduce expenses 43%.

The users seemed to like the whole system in terms of user interface and also services provided. The pilot participants were motivated and willing to change behaviour and adopt innovative technologies and systems in order to protect the environment but also reduce their expenses.

4 CBA and CEA Analysis

The scope of the current section is to provide a structured model for the cost and the profit of the different NOBEL modules, either as units, or an integrated system for use in the current energy market. The costs and the estimations are always in reference with the situation in the competitive market and according to the views of the consortium experts that provided valuable aid towards the realization of the calculations of cost and profit.

It was assumed that a governmental or an energy actor will implement the integrated system and thus the analysis will be performed from this scope. The outcome of this analysis should be taken into account from NOBEL partners, in order to exploit their modules in the most appropriate way, whereas it will also constitute the basis for the issue of the exploitation plans of the Consortium in Deliverable D8.3.

4.1 CBA Analysis

4.1.1 Overall Approach

CBA is an analysis aiming to identify all costs and benefits that derive from a specific system for different actors. This kind of analysis aims to investigate if a system is viable in terms of qualitative and quantitative criteria. The costs and benefits can be not only monetary but also non tangible. Within NOBEL project various stakeholders are involved and an attempt to evaluate the economic perspectives for the implementation of such a system is performed. However, the Consortium faced several difficulties performing this task, especially for the estimation of the cost and benefits for the DSO, as the system was of small scale including simulated factors and the benefits for the DSO were not measurable in most cases.

The CBA is performed per exploitable NOBEL prototype (NOEM, NOPL, and BAF) and from two viewpoints. The first one is from the perspective of the developer of the application, namely SAP for NOEM, ETRA for NOPL and CERTH for BAF. This analysis estimates the costs for commercialise their products and the foreseen benefits from their exploitation. This input derived from the answers of the distributed to all partners CBA questionnaires (Annex 10 of D7.1), the aim of which has been the collection of relevant financial estimations regarding NOBEL products and has a limited time horizon (up to 5 years).The second type of analysis includes the costs and benefits of key stakeholders, DSO (NOEM), Public lighting system operator (NOPL) and prosumers (BAF) when using the each application.

In some cases, costs and benefits cannot be monetized and are just analysed in a qualitative way. However, wherever it is possible, the following indices are calculating assessing the value of the investment for each actor:

- **Net Present Value (NPV):** This is defined as the sum of the discounted flows (discounted inflows minus discounted outflows for each one of the years of the evaluation period). The evaluation period for the financial evaluation is selected to be 5 years.
- **Internal Rate of Return (IRR):** This is defined as the rate of discount for which the sum of the discounted annual cash inflows and outflows within the evaluation period will become equal, therefore representing in some respects a financial return on capital.
- **Pay Back Period:** This is considered as the most comprehensive criterion as it defines the time period in which the monetary expressed benefits of NOBEL

products will outweigh their costs (investment and operational costs).

The analytic CBA process was described in D7.1 “Evaluation Plan”.

4.1.2 BAF and NOEM applications

The CBA for the developers and the respective users of NOEM and BAF application could not follow the typical CBA approach applied for NOPL in the next section. These applications are not standalone like NOPL and are both connected and based on IEM. The developers of NOEM (SAP) and BAF (CERTH) were not able to provide accurate estimation for the CBA analysis as they could not estimate the real costs and benefits from a wider future implementation. Their cost is manifold and in order to commercialize them they would have to adhere to industry standards. BAF and NOEM are considered as an integrated system as they are both needed in order to achieve the benefits deriving from NOBEL system. A product-realization would involve a large number of developers, e.g. 200 with very specific reimplementation, interacting with real systems, etc. It is thus decided not to perform the CBA (calculating standard indices) for the end-user applications.

However, a rough estimation of the development costs was attempted, through COCOMO model. The Constructive Cost Model (COCOMO) is an algorithmic software cost estimation model developed by Barry W. Boehm. The model uses a basic regression formula with parameters that are derived from historical project data and current project characteristics.

The following analysis was performed inserting different modules, considering the total physical source lines of code as well as estimated required personnel effort.

“IEM”.

SLOC	Directory	SLOC-by-Language (Sorted)
20385	IEM	java=19817,xml=530,sh=27,jsp=11
9321	Market Sim	java=8767,xml=554
3014	Market Core	java=2982,xml=32
2246	NobelUtils	java=2167,xml=79
1068	ProductionSimulation	java=808,xml=260
910	Market - Entity	java=898,xml=12
808	Market - Kernel	java=796,xml=12
608	TimeSeries	java=597,xml=11
457	EnergyLoadSampler	java=364,xml=81,jsp=12
388	GenerationMix	java=243,xml=145
234	Market Core Client	java=217,xml=17
108	Market Configuration	java=96,xml=12
85	Market Verification	java=73,xml=12
65	GoogleProtoBuf	xml=65
21	Market Time	java=16,xml=5

Totals grouped by language (dominant language first):

java: 37841 (95.27%)

xml: 1827 (4.60%)

sh: 27 (0.07%)

jsp: 23 (0.06%)

Total Physical Source Lines of Code (SLOC) = 39,718

Development Effort Estimate, Person-Years (Person-Months) = 9.55 (114.59)

(Basic COCOMO model, Person-Months = 2.4 * (KSLOC**1.05))

Schedule Estimate, Years (Months) = 1.26 (15.15)

(Basic COCOMO model, Months = 2.5 * (person-months**0.38))

Estimated Average Number of Developers (Effort/Schedule) = 7.56

Total Estimated Cost to Develop = $ 1,289,966

(average salary = $56,286/year, overhead = 2.40).

This is an estimation of the initial development costs of an IEM and end user applications system. This is just indicative and the cost-benefit analysis for the developers is not one of the main objectives of the evaluation. A detailed study should be performed from the developers before a wide implementation of the integrated system.

On the other hand an estimation of costs and benefits for the users of these applications (DSO, prosumers) is more meaningful, as the utmost objective of the project is the enhancement of energy management in terms of energy efficiency but also of monetary values.

4.1.2.1 DSO

In case of a real NOBEL implementation, the DSO would have to undertake an initial investment cost in order to obtain a license. As described before this amount cannot be determined accurately. The annual costs for the DSO include software maintenance, service and updates annual costs. The exact monetized value of the costs for the DSO depends on the defined software price but also on the DSO infrastructure and the grid profile. As NOBEL brokerage system was just a game, pilot results could not extract conclusions on the effect of the integrated system on the DSO. Thus, as specific estimations could not be provided by Alginet on this stage, a rough analysis of the costs and benefits is performed. The costs and benefits for the DSO derive both from NOEM usage and BAF usage by their customers.

The main functionality of NOEM is monitoring, offering to the DSO an overview of the grid. The application enables the user to select specific individual or groups of consumers, time slots and dates in order to have efficient monitoring of the grid. This service leads to the reduction of operational costs due to fewer truck rolls, and less demand on call center operations, engineering, and outage response resources. More benefits are anticipated due more efficient management of billing (avoidance of meter reading labor costs). The real-time monitoring of the grid leads to the early handling of outages and thus electricity sales are interrupted less frequently and for shorter durations. Outages are anticipated to cause high costs for the DSO. For example, for a grid with 4,800 residential consumers with total load of 12,000 kW the average interruption costs, normalized by the annual peak demand (kW) and a four hour outage have been estimated as 1.5 €/kW [14]. This is especially important for grids with high average electricity interruption times (more than 4 hours/year, e.g. Greece). In addition, reduction of shortages in the balancing area is also beneficial for the Power utilities. That is, by avoiding shortages in the balancing area, costs of balancing power are reduced. The reduction of balancing costs by similar systems is estimated to be up to 63% [14]. The reduction of shortages also lead to qualitative benefit, as higher customer satisfaction ratings and improved relations with the regulator, the community, etc. are accomplished. Moreover, reduction in injuries and deaths of employees due to reduction in time spent in hazardous situations and the availability of more intelligent systems that support worker safety is accomplished. The prediction service also leads to essential benefits for the DSO. The distributed electricity follows the predicted load and thus energy waste is avoided, avoiding also power generation costs. In addition, the reduction of overall energy consumption due to BAF leads to the deferral of future capital investments (e.g. transmission lines extensions, etc.). The utilization of local clean energy loads leads to the reduction of energy imported in very high prices usually during peak hours. Spain for example is highly dependent on imported energy, close to 75% [15] and would have benefits from reducing this dependency by using local RES or shifting peak loads.

4.1.2.2 Standard prosumers

As mentioned in D7.1 and was also highlighted in the context of NOBEL 2nd review meeting, NOBEL system aims to overall societal benefits, mainly related to environmental aspects. Thus, EU and NOBEL partners envisaged that the implementation costs of such a system could burden either a governmental body or the Power Utility. Thus, additional costs for the consumer are not anticipated. NOBEL services will be free for the final user, also contributing in this way, to the user acceptance and participation. For that reason, the typical CBA analysis has no sense in this case as only benefits are involved for the final grid user. However, the foreseen benefits for the end-user are very high and a cost of even 20 Euros would be very low in relation to the anticipated reduction of costs. The benefits for the final users were provided in section 3.3. These costs derive from the pilot results and cannot be directly projected to wider implementations. The market function is directly related to the number of participants, their loads, their PV capacities, etc. For this reason, wider implementation simulation scenarios were tested in order to evaluate economic impact of the marketplace, as described in section 2.5. Taking into account the selected business models as defined in D7.3 and the simulation results as shown in Table 24 we can conclude on the following:

Deployment Scenario 1 (Business Case 1): “Mandatory deployment of NOBEL services for all end users”

Assuming a region of 1000 users, all participating in the marketplace, we select the first row of Table 24 with 100% of the users participating and only 10% of them to be PV owners. We can see that there is significant increase of revenue (136%) for both implementation scenarios (Scenario 1 “Status Quo” and Scenario 2 “Free market”). In addition, a decrease of 0,82% for energy costs is also foreseen.

Deployment Scenario 2 (Business Case 2): “Mandatory deployment for prosumers”

In such a model we will select the case where only prosumers participate in the market, which is the 10% of the grid users. Thus, we select the case where 100 users are participating and all of them are PV owners. In this case we can see that only Scenario 1 “Status Quo” leads to the increase of benefits for the involved users (10,26%), while the decrease of costs is 11,60%. Thus, Scenario 1 is considered to be more beneficial for Business model 2.

Deployment Scenario 3 (Business Case 3): “Optional deployment for all end-users”

Considering an optional deployment of the system, we can select the case where half of the grid users participate in the market and 10% of them are PV owners. This scenario seems to be the more beneficial in terms of revenues increase (138%) and had very slight difference from Deployment Scenario 1, in terms of costs reduction (0,72%). The mixed participation of prosumers and simple consumers seem to be the more efficient implementation approach as the demand and supply rules require both actors to enable the trading process. The difference from Scenario 1 may be due to many unmatched transactions because of the big number of users.

Stemming from this remark, we can say that the number of the users participating should be big enough to enable a good price determination but be limited to these levels in order to be managed more efficiently.

4.1.3 NOPL

The NOPL (Neighbourhood Oriented Public Lighting Monitoring and Control System) was developed in order to enable the lighting system operator to achieve optimum management of segments of lights and thus reduce energy consumption. NOPL wider implementation leads to costs and benefits for two types of actors, namely the user and the developer. Thus, CBA is performed for these two types of actors.

4.1.3.1 CBA for Public lighting system operator

The reduction of energy consumption leads to remarkable economic benefits for the operator, as proved through the pilot tests results. Through this CBA, the scalability of the pilot tests is investigated assuming a scenario of a wider implementation of NOPL. NOPL is a standalone application and can also exist without IEM. In the context of this analysis, it is considered that NOPL is used as a standalone application in combination with hardware equipment for lights-NOPL interaction. As the public lighting system operator is usually a public body (municipality), we assume that the operator undertakes the costs for this system.

The specific scenario tested for the CBA will consider the implementation of NOPL system in the whole Alginet area. In specific, each segment of points of lights is controlled by a central box. In total there are 17 boxes in Alginet, and 1667 points of light. Within this analysis, we will assume that 1000 lights are equipped with sensors and only 20 of them are also equipped with magnetic loops. This assumption is made because sensors contribute to higher energy saving and loops would be better to be installed in areas where there are very few cars or people passing. It is not considered that all lights are equipped as the hardware equipment cost is very high.

The decomposition of all costs and benefits from such an implementation is performed in the following sections:

4.1.3.1.1 Initial Investment

The first step of the analysis is to define the initial investment required in order to use the system. The lighting operator will have to undertake costs to obtain the NOPL license which is charged in a flat cost and it is not dependent on the number of lights, and thus it is estimated as 2000 €. In addition, modifications are needed to be performed, integrating hardware equipment in the segments. In specific, the required equipment are sensors or loops per point of light and also a pole gear tray, a junction box and a segment controller per box. Thus, the total sensors are 1000; the loops 20 and the sets required per box are 17.

Type of cost	Number of units	Cost per Unit (€)	Total cost (€)
Software			
NOPL license cost	1	2000	2000
Hardware equipment			

Segment boxes modification cost	17	3156	53652
Sensors	100	1000	10000
Magnetic Loops installation	20	300	6000
Total (€)			71652

Table 40: Initial investment costs

4.1.3.1.2 Operational costs

Operational costs are costs that burden the user for operating NOPL during the 5-year period. Operational costs include the hardware maintenance costs and the software updating and maintenance costs. The maintenance costs are considered to be 2000 € for the whole duration of the CBA scope (5 years), beginning with 200 per year, increasing every year. NOPL software updating and maintenance is estimated as 10% of the license costs per year. An assumption is made that in year 1 we assume there are no maintenance costs.

Type of cost	Period	Number of units	Cost per Unit (€)	Total cost (€)
Software				
NOPL maintenance cost	Year 1	-	-	-
	Year 2	1	200	200
	Year 3	1	200	200
	Year 4	1	200	200
	Year 5	1	200	200
	Total			1000
Hardware equipment				
Hardware equipment maintenance	Year 1	-	-	-
	Year 2	1	200	200
	Year 3	1	300	300
	Year 4	1	400	400
	Year 5	1	600	600
	Total			1500
Total				2500
Total with overhead costs (20%)				3000

Table 41: Operational Costs

4.1.3.1.3 Benefits

The main benefit foreseen for the NOPL users (municipality, etc.) is the reduction of costs paid for energy as a result of the remarkable energy usage reduction. Pilot results showed that the two points of light with magnetic loops save 2,05 kWh/per light/per month and the avenue with sensors save 20,13 kWh/per light/per month. In addition, as NOPL will lead to an automatized monitoring of the lighting system a reduction of personnel costs is also anticipated, equal to 17.500 €/per year, if we consider an average salary of 35.000€/per year.

Based on the contracts of each smartmeter, corresponding to the respective segment, we can calculate the annual benefit for each type of light. The average contact tariff for the sensors segment is 0,124 €/kWh and for the led lamps segment is 0,117 €/kWh. The annual benefits are shown in Table 42.

Type of benefit	Period	Number of units	Benefit per Unit (€)	Total Benefit (€)
Reduction of energy consumption cost from sensors	Year 1	1000	29,954	29954
	Year 2	1000	29,954	29954
	Year 3	1000	29,954	29954
	Year 4	1000	29,954	29954
	Year 5	1000	29,954	29954
	Total			149767,2
Reduction of energy consumption cost from magnetic loops	Year 1	20	2,87	57,65
	Year 2	20	2,87	57,65
	Year 3	20	2,87	57,65
	Year 4	20	2,87	57,65
	Year 5	20	2,87	57,65
	Total			287,82
Reduction of personnel cost	Year 1	1	17500	17500
	Year 2	1	17500	17500
	Year 3	1	17500	17500
	Year 4	1	17500	17500
	Year 5	1	17500	17500
	Total			87500
Total benefit (€)	237557,82			

Table 42: Total benefits due to NOPL usage

4.1.3.1.4 Net Present Value (NPV)

Net Present Value of a product is defined as the difference between the present values of its future cash inflows and outflows. This means that all annual cash flows should be discounted to the start time at a predetermined discount rate. The calculation of the NPV is given by the formula:

$$NPV = \sum_{1}^{n} \frac{B_i}{(1+r)^i} - initial\_investment$$

where:

Bi= Benefits in year i.

r=discount rate.

n=the number of years (5 years the evaluation period in our case).

Based on the previous sections we can insert the inflows and outflows for each year in this formula. As mentioned before, the analysis is performed in a 5-year horizon, thus n = 5.

In order to use the NPV criterion, a discount rate has to be set. This is very important for the evaluation of the products since it can affect the final outcome. Discount rate is the rate at which future values are discounted to the present. Usually it is considered roughly equal to the opportunity cost of the capital. All costs and benefits occurring in different years should be discounted at a base-year possibly by using a uniform discount rate. For example, 1€ invested at 5% yearly rate, will become 1+5%= 1,05 after one year; (1.05)x (1.05) = 1.1025 after two years; (1.05)x(1.05)x(1.05) = 1.157625 after three years, etc. The economic present value of 1 € that will be spent or gained two years later is 1/1.1025 = 0.907029; three years later is 1/1.157625= 0.863838. This is the inverse operation of the above.

At the European level societal discount rates of 4% and 5.5% have been suggested [16]. However, if the discount rate is to provide a fair reflection of the relative risk of the projects, then a higher discount rate should be applied for smart grid investments that have higher risk than conventional investments.

In the context of CBA survey, the discount rate was considered to be 6%, in order to make safer and more preservative estimations for the profits of the developers.

After the finalisation of the estimations of all the parameters, the NPV should be positive for the product to be financially justifiable. The highest the NPV is, the more profitable a product is considered.

Applying these assumptions and formula, the NPV of the investment for each year and the total NPV after 5 years from the initial investment are presented in the following

Year	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Total
NPV (€)	-71.652,00	44.822,31	41.858,00	39.387,93	37.063,37	34.786,10	**126.265,71**

Table 43: NPV values for 5 year time horizon (Lighting operator case)

the NPV is estimated to be 126.265,71 € for the five year period. As one can see, the NPV is positive and very high, which means that the product is acceptable within the predefined 5 years horizon and under the defined assumptions.

4.1.3.1.5 IRR

The Internal Rate of Return is the discount rate at which a stream of cost and benefits has a net present value of zero. It can be calculated if we consider the formula of NPV with same inputs equal to zero, substituting the discount rate with the IRR.

$$\sum_{1}^{n}\frac{B_i}{(1+IRR)^i}-initial\_investment=0$$

If IRR>r then the product is financially justifiable.

If IRR<r then the product is not financially justifiable.

If IRR=r then the conclusion is neutral, neither positive, nor negative.

However, a very low or even negative financial rate of return does not mean that the product is not in line with the objectives of the project. CBA may yield a positive socio-economic appraisal of such a product.

In this case IRR is equal to 50% is much higher than the predefined 6% discount rate. This implies that the product is financially justifiable.

4.1.3.1.6 Pay-back period

The Pay Back Period is the number of years it takes for the cumulative value of benefits to exceed the cumulative costs of a product.

Net benefit for each year (cumulative benefits – cumulative costs) are calculated and as illustrated in **Figure 35,** the pay-back period is approximately 14 months from the initial investment.

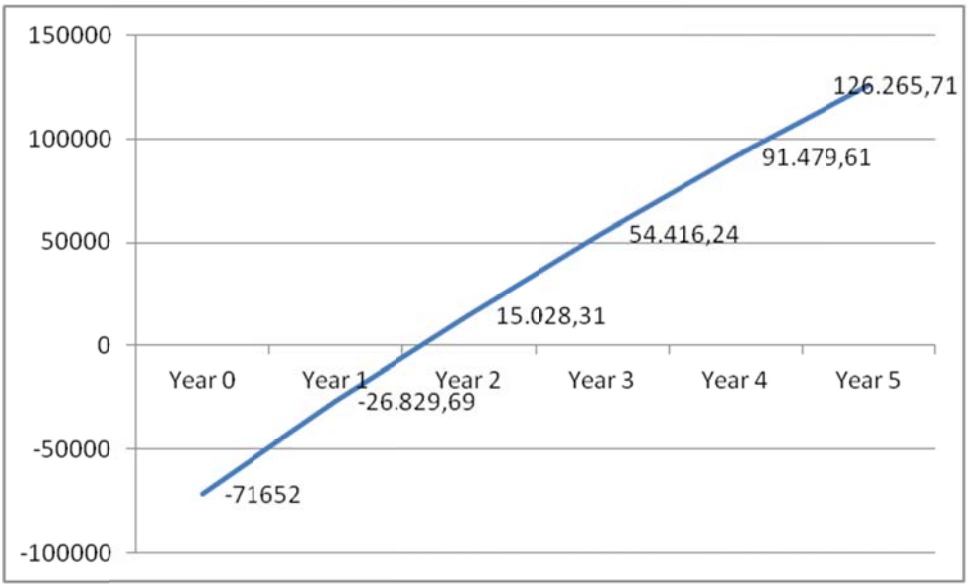


Figure 35: Payback Period for the NOPL user

4.1.3.2 CBA for NOPL developer (ETRA)

NOPL developer (ETRA) plans to commercialize the product in a European level and make marketing efforts to disseminate NOPL to European districts or cities. Thus, the same analysis, considering the costs and benefits from the NOPL developer's point of view, is performed. The developers provided estimations for costs and benefits foreseen, filling in the CBA questionnaire of ANNEX 10 of D7.1.

4.1.3.2.1 Initial Investment

In case NOPL developers (ETRA) aim to commercialize their product, they will undertake certain initial investment costs. Development costs are estimated based on the effort put within the project development activities and are 35.000 €. As the prototype is not ready for bigger scale use, an additional commercialization cost of 5000 € is required.

Type of cost	Number of units	Cost per Unit	Total cost
NOPL start-up developing cost	1	35000	35000
Adaptation cost	1	5000	5000

Table 44: Developer initial investment costs

4.1.3.2.2 Operational costs

The developer and seller of NOPL (ETRA) will undertake operational costs in order to provide the product. These costs include marketing costs which are costs incurred to influence the buying behaviour of individual customers and maintenance costs which include any costs (salaries, etc.) needed to maintain or update the product.

Type of cost	Period	Number of units	Cost per Unit (€)	Total cost (€)
Marketing costs	Year 1	1	2.500	2.500
	Year 2	1	1.500	1.500
	Year 3	1	500	500
	Year 4	1	500	500
	Year 5	1	500	500
	Total			5500
Maintenance costs	Year 1	1	-	-
	Year 2	1	2000	2000
	Year 3	1	2000	2000
	Year 4	1	2000	2000
	Year 5	1	2000	2000
	Total			10000

Table 45: Operational costs

4.1.3.2.3 Benefits

It is obvious that economic benefits are foreseen for NOPL developer. The most essential benefit is the revenue from selling it in a specific price. This price was defined by ETRA at 2.200 € including annual updates and technical support. NOPL is an interoperable application that can be used as stand-alone and thus the targeted market is Pan-European.

The potential customers could be mainly municipalities but also any other body that operates lighting systems. The expected units per price were defined as 20 for the first year, rising gradually. The following table illustrates the benefits per year. This number of units is completely justified, considering the evident high benefit for the lighting system operator. Stemming from the pilot testing results, NOPL efficient marketing will be easier to achieve.

Type of benefit	Period	Excpected number of units sold	Benefit per Unit (€)	Total Benefit (€)
Sell NOPL including maintenance and service	Year 1	20	2200	44000
	Year 2	30	2200	55000
	Year 3	30	2200	66000
	Year 4	35	2200	66000
	Year 5	40	2200	88000
	Total			319000

Table 46: Benefits for the NOPL developer

4.1.3.2.4 NPV calculation

Applying the assumptions and formulas as described in section 4.1.3.1.4, the NPV of the investment for each year and the total NPV after 5 years from the initial investment are presented in the following Table 47.

Year	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Total
NPV (€)	-40.000,00	36.415,09	55.001,78	52.896,01	58.614,93	63.516,94	226.444,76

Table 47: NPV values for 5 year time horizon (Lighting operator case)

the NPV is estimated to be 226.444,76 € for the five year period. As one can see, the NPV is positive and very high, which means that the product is acceptable within the predefined 5 years horizon and under the defined assumptions.

4.1.3.2.5 IRR calculation

IRR can be calculated according the formula provided in previous section and it is equal with 110%. Thus, the investment is justifiable.

4.1.3.2.6 Pay-back period

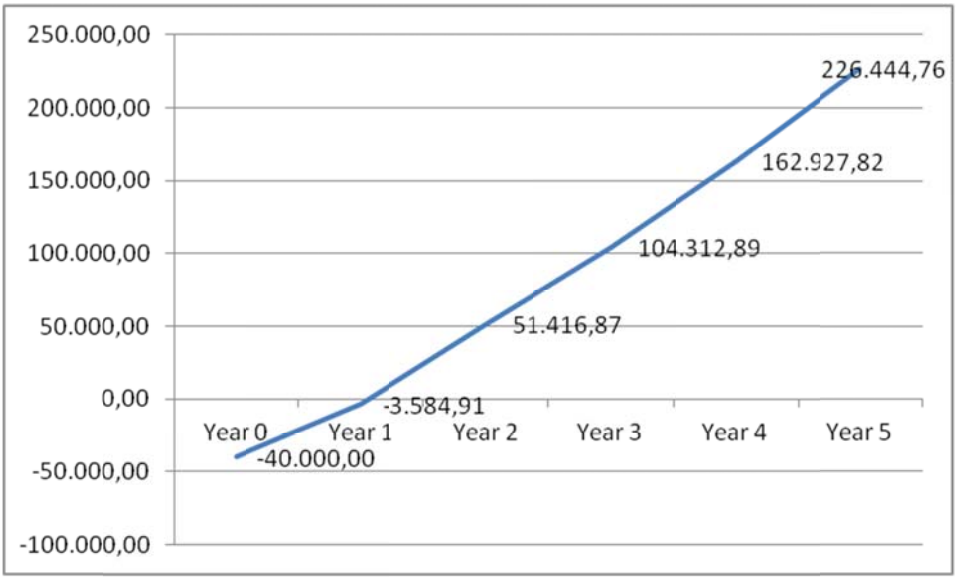


Figure 36: Pay Back Period for NOPL developer

Following the same approach, we can see that the pay-back period for the NOPL developer is 7 months after the initial investment.

4.2 CEA Analysis

4.2.1 Introduction

Cost effectiveness analysis is a qualitative analysis that evaluates costs and outcomes (effects) without monetizing the indicators that are being assessed. The CEA process defines business oriented criteria influencing final impacts and rates them. The detailed CEA methodology was already thoroughly described in D7.1 in Annex 1. However this methodology was adapted according to the project specificities and all necessary modifications were performed.

4.2.2 Evaluation Criteria, Deployment Scenarios & Hierarchical Decision Tree

The first thing to be defined for the socio-economic assessment according to the methodology described in D7.1 is the hierarchical decision tree as well as the linkages between the several levels of the hierarchy. The first step for this is to identify the interacting items, which in our case is the deployment scenarios (as alternatives), and the criteria/impacts (objectives), upon which each of these scenarios has been rated by the decision makers. The focus in this case is the assessment (in qualitative terms) of the socio-economic impacts of the NOBEL system across its three different deployment scenarios.

The deployment scenarios, also aforementioned and described, which serve as the "alternatives" and thus the basis of our analysis are the following:

- **Deployment Scenario 1 (Business Case 1):** "Mandatory deployment of NOBEL services for all end users"
- **Deployment Scenario 2 (Business Case 2):** "Mandatory deployment for prosumers"
- **Deployment Scenario 3 (Business Case 3):** "Optional deployment for all end-users"

The criteria, upon which, these scenarios/business cases have been rated are as follows:

1. Reduction of Energy Consumption for all actors involved
2. Energy Efficiency
3. Reduction of CO_2 emissions
4. Renewable Energy Sources penetration in the current energy model
5. Reduction of Financial Expenses for Energy for all actors involved
6. Costs for deployment
7. Reduction of Financial Expenses for Energy for domestic users
8. Maintenance and training costs

On the basis of the above definition of the evaluation criteria and the alternatives (deployment scenarios), the hierarchical decision tree, which constitutes the basis of the multicriteria analysis, is easy to be constructed (Figure 37).

The upper level of the hierarchical decision tree is the focus of the analysis, namely the NOBEL socioeconomic impacts. In the right lower level, the main clusters of the impacts are discerned, namely the societal and the economic/monetary impacts. The third level of the hierarchy consists of the expected impacts, as identified by the NOBEL Consortium (the analysis objectives/criteria) and their clustering as "societal" or "economic" is evident through the relevant links. The last level of the hierarchy consists of the deployment scenarios (or alternatives of the analysis), which are linked to all criteria. All three deployment scenarios are correlated with all evaluation criteria.

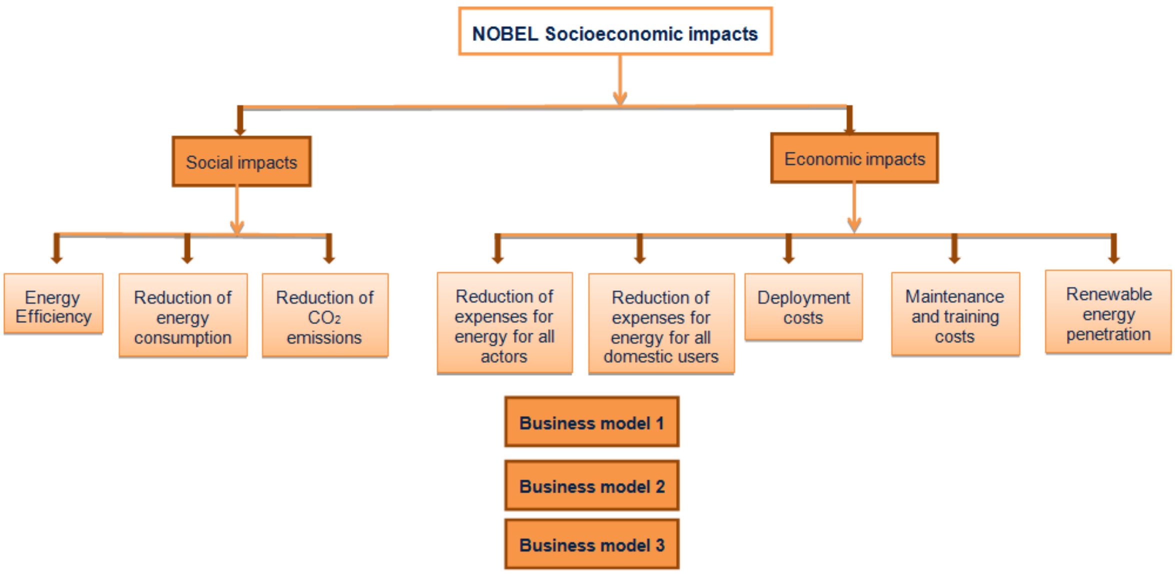


Figure 37: NOBEL Hierarchical Decision Tree

4.2.3 Multicriteria Analysis results & Conclusions

The methodology followed is the one described in D7.1, with the necessary adaptations in order to serve the scope of the specific analysis.

The analysis started with the pairwise comparison of the aforementioned evaluation criteria. This comparison was performed through a relevant table, especially constructed for this reason, which is shown below.

Criteria	Reduction of Energy Consumption for all	Energy Efficiency	Reduction of CO_2 emissions	Renewable Energy Sources penetration	Reduction of Financial Expense	Costs for deployment	Reduction of Financial Expense	Maintenance and training costs

	actors involved			n in the current energy model	s for Energy for all actors involved		s for Energy for domestic consumers	
Reduction of Energy Consumption for all actors involved								
Energy Efficiency								
Reduction of CO_2 emissions								
Renewable Energy Sources penetration in the current energy model								
Reduction of Financial Expenses for Energy for all actors involved								
Costs for deployment								
Reduction of Financial Expenses for Energy for domestic users								
Maintenance and training costs								

Figure 38: Template for pairwise comparisons of evaluation criteria.

The pairwise comparisons were performed by 3 clusters of stakeholders, namely energy market experts, developers and consumers. 4 participants for each cluster filled in the above template. Their pairwise rating leaded to 12 completed templates like the above. The corresponding values were averaged, leading to one template at the end, which was normalised, leading to the final ranking of the evaluation criteria, as depicted in **Figure 39.** Thus, this figure depicts the ranking or, in other words, the importance of each criterion in relation to the other.

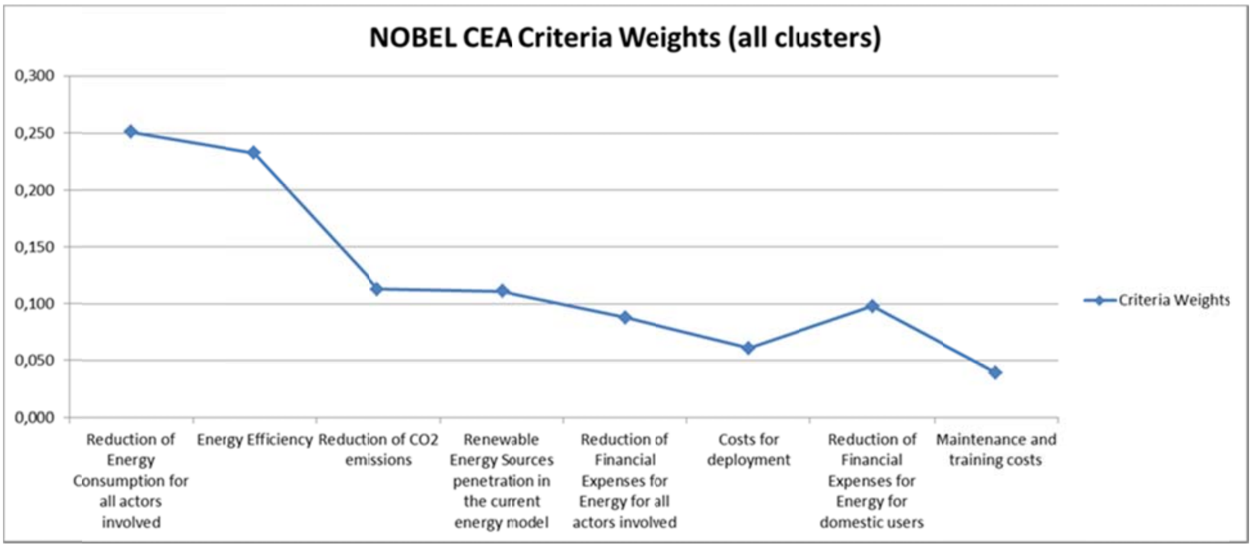


Figure 39: NOBEL CEA Criteria Weights (all clusters)

As illustrated in the above figure, the most important criterion for all clusters is the Reduction of Energy Consumption and the Increase of energy efficiency. However, the clean energy penetration is not considered as very important. It is remarkable that despite the economic recession the energy related criteria are assessed as more important and environmental issues are of top priority.

The criteria ranking has also been performed per cluster and is illustrated in **Figure 40, Figure 41 and Figure 42.**

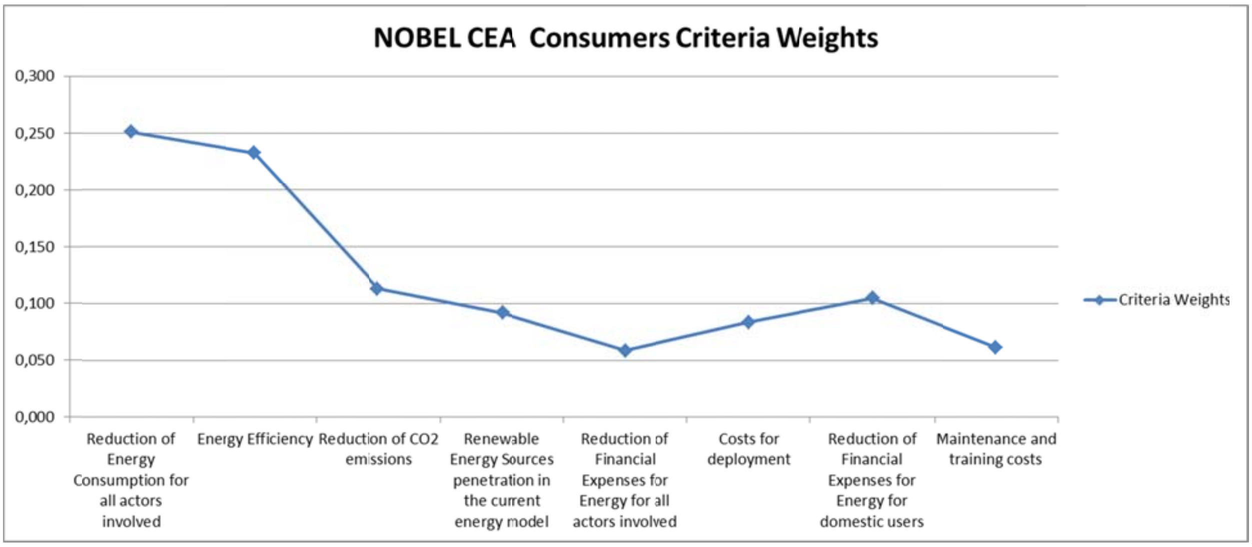


Figure 40: NOBEL CEA Criteria Weights (consumers)

The consumers ranking is very similar to the average one. As expected, simple consumers give higher importance to the reduction of their own expenses for energy, in relation to the overall weighting.

The following figure illustrates the criteria weighting as ranked by Experts on the Energy field.

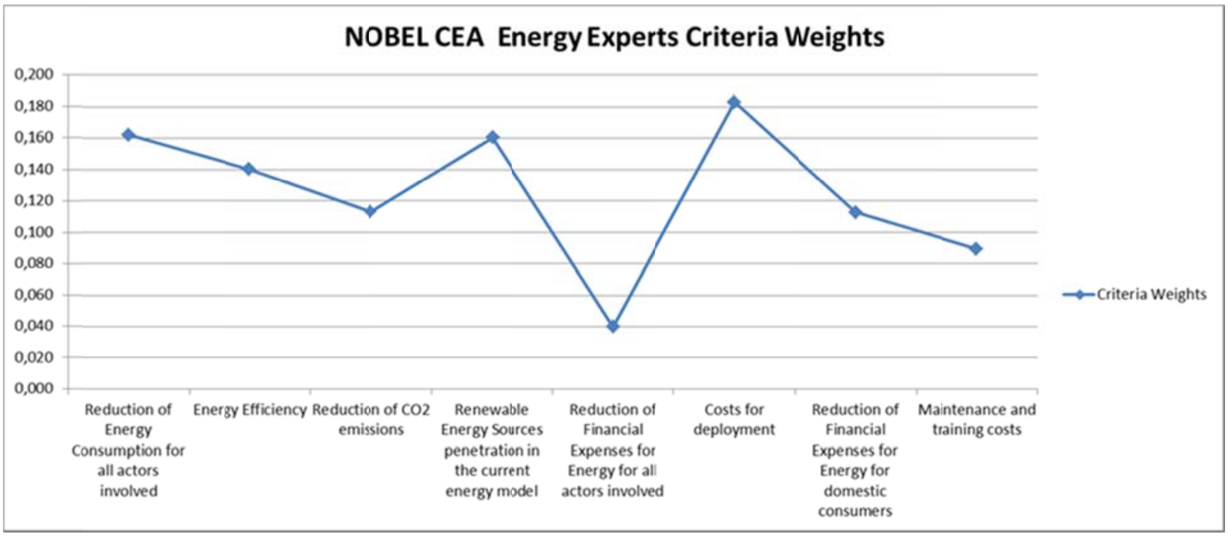


Figure 41: NOBEL CEA Criteria Weights (Energy Experts)

It is normal that energy experts consider as more important criteria related to the overall change of the energy market, including high RES penetration. In addition, they find the costs for deployment as the most essential to be considered. This cluster is aware of possible economic constraints involved in the implementation of such a system, and thus places this criterion first. They also place the consumer benefit in a higher place than the overall benefit of all actors.

The following figure illustrates the criteria weighting as ranked by ICT developers.

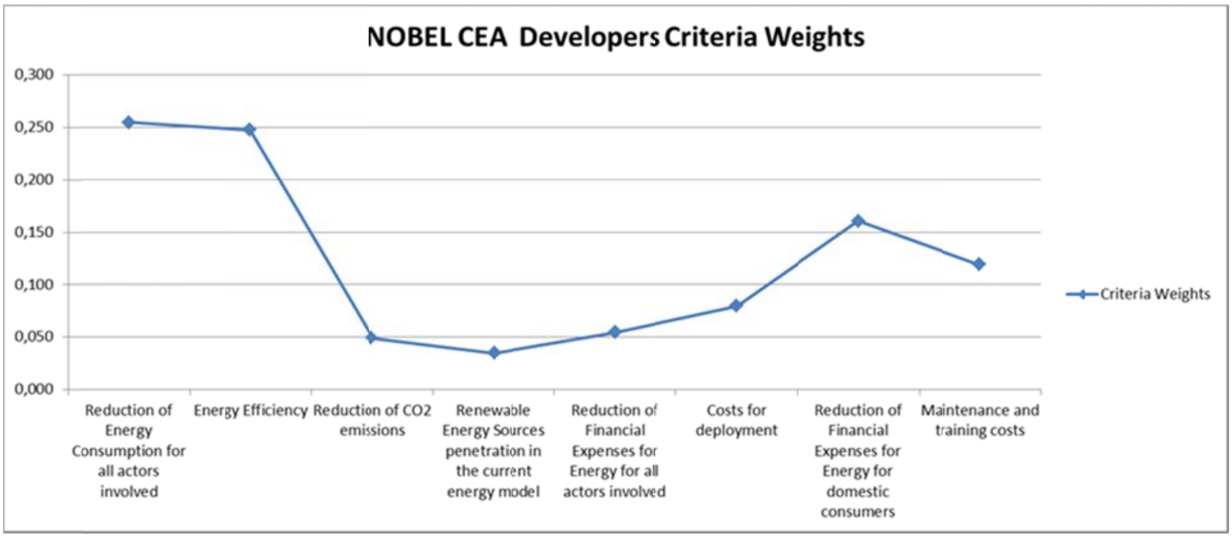


Figure 42: NOBEL CEA Criteria Weights (Developers)

Developers places also the energy efficiency related criteria on top. They also consider as essential the reduction of costs for domestic users. Finally, they place the maintenance and training costs criterion on a high position.

After the realisation of the pairwise comparisons of the evaluation criteria, the same experts were asked to identify what would be the impact of each deployment scenario in specific on each of the different dimensions, reflected by each evaluation criterion. The deployment scenarios were analysed to the experts and after that, pairwise comparisons, similar to the above, were held, but in this case, taking into account the specific conditions implied by each deployment scenario (see following example figure).

Reduction of Energy Consumption for all actors involved	Business model 1	Business model 2	Business model 3
Business model 1			
Business model 2			
Business model 3			

Figure 43: Example template used for pairwise comparisons of deployment scenario per evaluation criterion

Once again, the pairwise comparisons by the CEA participants were averaged leading to three templates (one for each deployment scenario) that were normalised and led to the combinational Figure 44 The figure below demonstrates the level up to which each of the deployment scenarios is expected to influence each criterion, etc., always according to the CEA survey participants. From this figure we can conclude that the business model 3 is not efficient as the wide participation is one of the success elements of the system. However, it involves lower deployment costs according to the survey participants. As expected, business model 3 seems to be more efficient than model 2 in terms of costs for domestic users, as the model 2 involves more prosumers and less consumers. On the other hand, business model 2 is expected to have stronger impact than model 1, as incentives for prosumers are involved in model 2.

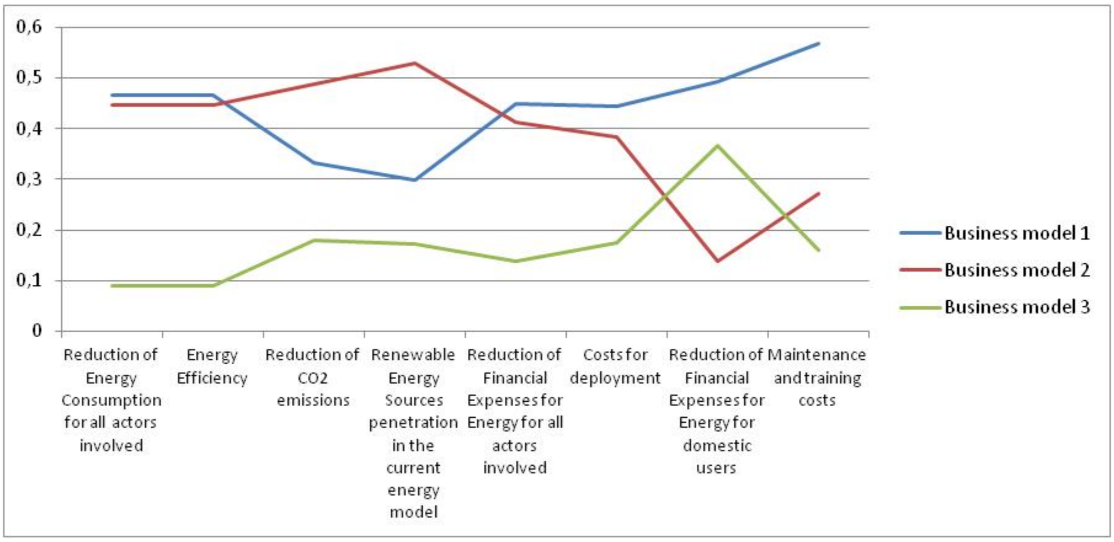


Figure 44: CEA criteria comparisons per Business model

4.3 SWOT Analysis

4.3.1 Methodology

SWOT Analysis is a strategic planning method used to evaluate the Strengths, Weaknesses, Opportunities, and Threats involved in a project or in a business venture. It involves the specification of the objective of the business venture or project and the identification of the internal and external factors that are favourable and unfavourable towards the achievement of that objective.

- Strengths: attributes of the organization that are helpful for the achievement of the objective.
- Weaknesses: attributes of the organization that are harmful for the achievement the objective.
- Opportunities: external conditions that are helpful for the achievement of the objective.
- Threats: external conditions, which could do damage to the business's performance.

Figure 45: Illustrative diagram of SWOT analysis.

If, on the other hand, the objective seems attainable, the SWOTs are used as inputs to the creative generation of possible strategies, by asking and answering each of the following four questions, many times:

- How can we Use each Strength?
- How can we Improve each Weakness?
- How can we Exploit each Opportunity?
- How can we Mitigate each Threat?

Internal and external factors

The aim of any SWOT analysis is to identify the key internal and external factors that are important for the achievement of the objective. These come from within the company's unique value chain. SWOT analysis groups key pieces of information into two main categories:

- Internal factors – The strengths and weaknesses internal to the organization.
- External factors – The opportunities and threats presented by the external environment to the organization.

The internal factors may be viewed as strengths or weaknesses depending upon their impact on the organization's objectives. What may represent strengths with respect to one objective may be weaknesses for another objective. The factors may include all of the 4P's[1]; as well as personnel, finance, manufacturing capabilities, and so on. The external factors may include macroeconomic matters, technological change, legislation, and socio-cultural changes, as well as changes in the marketplace or competitive position. The results are often presented in the form of a matrix.

SWOT internal issues are sorted into the programme planning categories of:

1. Product (what are we selling?)
2. Process (how are we selling it?)
3. Customer (to whom are we selling it?)
4. Distribution (how does it reach them?)
5. Finance (what are the prices, costs and investments?)
6. Administration (and how do we manage all this?)

By sorting the SWOT issues into the 6 planning categories one can obtain a system which presents a practical way of assimilating the internal and external information about the

[1] ***Product*** - A tangible object or an intangible service that is mass produced or manufactured on a large scale with a specific volume of units. Intangible products are often service based like the tourism industry & the hotel industry. Typical examples of a mass produced tangible object are the motor car and the disposable razor. A less obvious but ubiquitous mass produced service is a computer operating system.

Price – The price is the amount a customer pays for the product. It is determined by a number of factors including market share, competition, material costs, product identity and the customer's perceived value of the product. The business may increase or decrease the price of product if other stores have the same product.

Place – Place represents the location where a product can be purchased. It is often referred to as the distribution channel. It can include any physical store as well as virtual stores on the Internet.

Promotion – Promotion represents all of the communications that a marketer may use in the marketplace. Promotion has four distinct elements - advertising, public relations, word of mouth and point of sale. A certain amount of crossover occurs when promotion uses the four principal elements together, which is common in film promotion. Advertising covers any communication that is paid for, from television and cinema commercials, radio and Internet adverts through print media and billboards. One of the most notable means of promotion today is the Promotional Product, as in useful items distributed to targeted audiences with no obligation attached. This category has grown each year for the past decade while most other forms have suffered. It is the only form of advertising that targets all five senses and has the recipient thanking the giver. Public relations are where the communication is not directly paid for and includes press releases, sponsorship deals, exhibitions, conferences, seminars or trade fairs and events. Word of mouth is any apparently informal communication about the product by ordinary individuals, satisfied customers or people specifically engaged to create word of mouth momentum.

business unit, delineating short and long term priorities, and allowing an easy way to build the management team which can achieve the objectives of profit growth.

In specific for NOBEL the following factors were identified and analysed.

4.3.2 Strengths

- Real time monitoring

One of the major innovations of the project was the real time information and monitoring in very frequent time slots of 15 min (first phase of the pilots) or 30 min (second phase of the pilots). This feature motivates the consumer to proceed to actions to reduce consumption as well as make decisions in a timely manner. In addition, the real time monitoring enables the network operators to reorganize energy distribution and to avoid unexpected peaks of load.

- IPv6-based communication

Within NOBEL, IPv6 communication between the different embedded devices was simulated. This innovation enables communication based on a common standard. By using an IPv6-compliant protocol stack, the sensor network can be easily integrated into IPv6 networks and leverage existing tools, protocols, knowledge and networking infrastructure. Furthermore, for embedded devices that communicate wirelessly, the power consumption of the radio has been a major and therefore standardization work within the 6LowPan group has reduced the header overhead of IPv6, thereby reducing part of the power consumption.

- Semi-automatic brokerage agent

In the context of NOBEL, a semi-automatic agent was introduced, that enables the end users to configure a brokerage profile. The agent automatically performs transactions according rules manually inserted by the user. The agent has remarkable positive impact to the user acceptance and thus to the overall objectives of the system, as it is much more convenient for the prosumer to define time slots and price limits and not be obligated to have constant monitoring of the consumption/ production.

- Benefits for all groups of users

As described in previous sections, NOBEL impacts included benefits for all involved clusters of users in many aspects, energy, economic, social. All involved stakeholders benefit in terms of energy reduction, financial benefits and achievement of long-term goals set by the EU having positive impacts to the whole society.

- Vast potential for added value services

NOBEL integrated system can be easily extended in many aspects. The prosumers categories may anticipate more dimensions than the one considered within the project, i.e. photovoltaic owner. The monitoring system can be connected to a wide range of clean energy sources and prosumers including EV owners, wind turbines, etc. The cooperative principles embedded in the system architecture would allow more advanced services and communication potentials, e.g. more accurate prediction or communication between smartmeters.

4.3.3 Weaknesses

- Simulated prosumers

The main weakness of the project was the lack of real prosumers as all of them were simulated. Although, the simulated production derived from real weather data and radiation curves and different capacities were assumed for the users, the real conditions of the market could not be absolutely resembled. The users in NOBEL case could only benefit from the optimized energy management and not from production selling in the network, as this profit was not real but it was virtual money. The actual financial benefit from production would motivate the users to participate in a more active manner in the market and contribute to the optimum management approach aimed by the system.

- Need for medium to large scale deployment

As it is evident from the pilot results and CBA analysis results the more end-users subscribe in the system the more beneficial the system proves in terms of energy saving and financial benefit for the DSO. The beneficial impacts of the system cannot be observed in a small grid as it is required a holistic, preferably regional or national approach.

4.3.4 Opportunities

- High energy and societal risk

Climate change has become a significant problem for governments, power utilities, car manufacturers and consumers. All energy involved stakeholders proceed to actions in order to increase the share of the Renewable Energy Sources (RES) and reduce CO_2 emissions. In specific, Europe share common goals towards energy efficiency and sustainability, setting targets for 2020, including the reduction of primary energy consumption by 20% and the penetration of RES by 20% in the future energy mix. The societal risk related with energy is evident and constitutes the main rational for research and deployment of NOBEL like systems.

4.3.5 Threats

- User Acceptance

Most users are not always willing to adopt new, innovative technologies and services that would change their daily routine and thinking. The concept of continuous energy monitoring and performance of daily transactions instead of the current static billing model may not be easily accepted. Before a wider system commercialization, a deeper investigation on the User Interface aspects as well as on the provided services and incentives should be realised to assure intuitiveness and user acceptance.

- Economic recession

Economic recession will reduce the available social and private funds for all types of investments and services. However, the system as concluded in the CBA analysis will reduce the costs for energy in the long term and energy waste so this threat could also stand as an opportunity for NOBEL.

- Competition

Several projects, mainly European, have taken place in the area of smart-grids and energy efficiency targeted power electronics, as this field seems to be one of the most essential for the EU these years. Similar systems have been developed, thus good consolidation and synergies will lead to a coordinated effort to achieve NOBEL high level objectives.

5 Technical assessment results

According to the NOBEL vision (depicted in Figure 46), the future energy monitoring and management system is in close cooperation with enterprise systems. Enterprise services integrate information coming from highly distributed smart metering points in near real-time, process it, and take appropriate decisions. This gives rise to a new generation of mash-up applications that depend on "real-world" services, which constantly hold actualized data as they are generated. The enterprise system is comprised of several Internet-accessible services [17], which, in turn, can be used to create mash-up applications. Additionally, following a software-as-a-service (SaaS) model, we expect the rise of new applications (as well as feature enhancement) by simply rapidly combining cross-enterprise services to deliver customized functionality. Example services include: energy monitoring, billing, asset management, information services, marketplace etc.

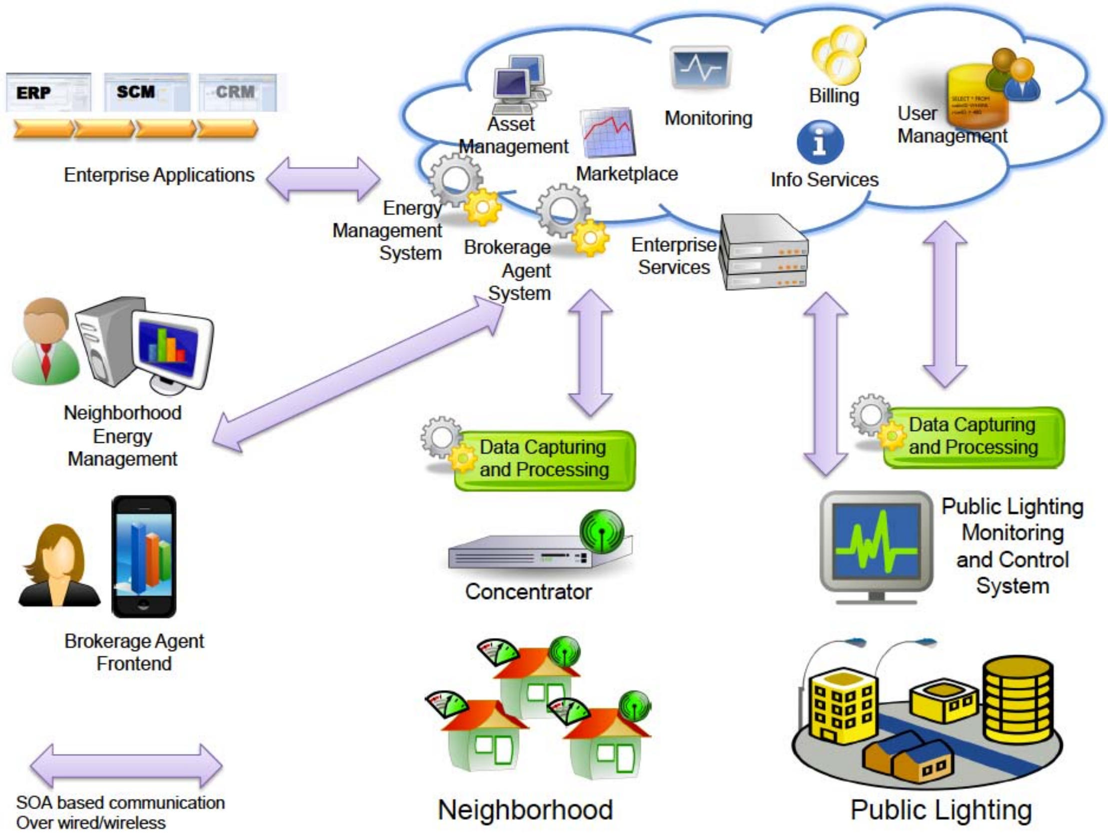


Figure 46 NOBEL high level view of the energy service enabled neighbourhoods

The NOBEL communication architecture has several layers i.e. the device layer, the middleware and the enterprise services and applications. The approach we follow is in line with the general approach for integrating networked embedded devices with enterprise systems. Embedded devices (in our case smart meters, concentrators etc.) are composed from hardware and software components that enable their low level programmability. On the top layer we have various (enterprise) services (in our case IEM) and applications that can form mash-ups. Between the two, there is a middleware layer partially at infrastructure level and partially at device level (in our case the DCP).

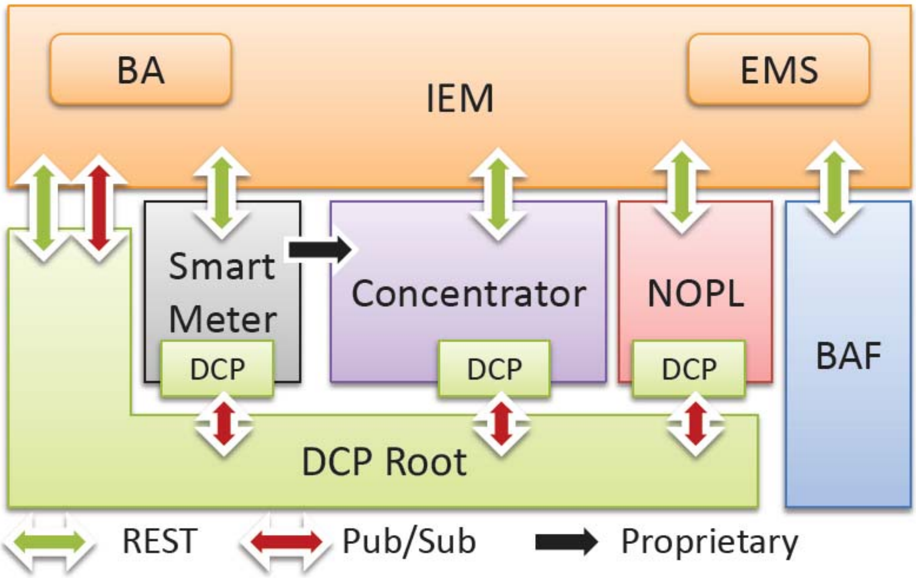


Figure 47 Interactions among the various components of NOBEL

Figure 47 depicts the communication envisioned at the begin of the project, among the different components in the NOBEL architecture. The functionality of devices such as meters, concentrators, smart phones, etc. is available via REST and/or the DCP/IPC. The whole system is based on service-based interactions via REST. A detailed assessment of the various components as they have evolved during the project will be presented in the next sections, including:

- IPC assessment
- DCP assessment
- IEM assessment
- NOEM assessment
- BAF Assessment
- NOPL assessment

5.1 IPC assessment

IPC has been used in the project as the underlying software for the end-to-end IPv6 scenarios. Since it needed to be tightly integrated with the DCP middleware, several of the tests relevant to IPC has been conducted as integrated IPC-DCP tests, presented further below in its own subsection.

5.1.1 Methodology of testing

IPC has been tested in lab settings, using both a mini-testbed with five hardware platforms, and in a timing accurate emulated mode where networks of larger size can be evaluated.

The relevant timing information have been retrieved either through emulation output logs, or directly from network statistics tools.

It should be noted, as described in previous design documents, that the size of a single IPC network is not representative for the workload of the higher level IEM services. The higher level services are designed to handle data streams coming from multiple IPC subnets.

5.1.2 Indicators measured and comparison to objectives

The factors measured for the IPC only tests are the networking round trip delays, the time for new devices to join the network, and compliance with state-of-the-art radio duty cycling protocols.

5.1.2.1 Speed of communication

For IPC only the network round trip delays are measured through network pinging of nodes with different distance from the sink/gateway.

The connection to the sink/gateway induces a close to constant delay of 30ms. Typical delay figures for one to three hops are as shown in the figure below.

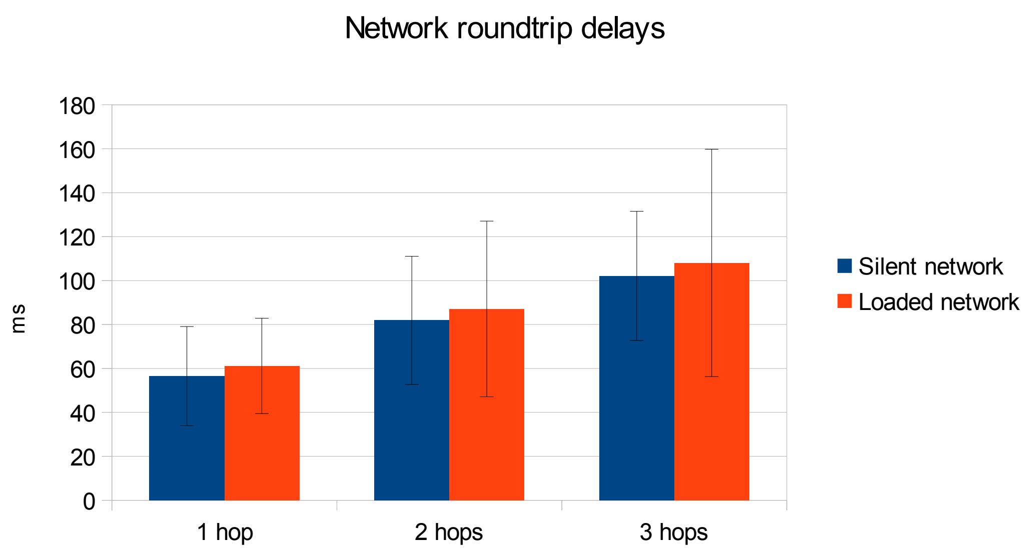


Figure 48: Network roundtrip delays

For a mostly silent network with just routing messages, the (unreliable) ping packet losses are 0% for all but the three-hop case, where it is around 1%, in a network with simulated parallel ongoing DCP metering traffic, the message losses ranges from 2%, for the one-hop case, up to 15% for the three-hop case.

5.1.2.2 Power consumption of the device

Evaluation of the power consumption is to ensure that the measurements taken to save energy are offset by the least possible amount by increased appliance consumption. For the lab tests, we have shown that the needed smart meter control can be done using low power devices, which need less than 0.2W to operate. Even this number can be furthered reduced, using state-of-the-art radio duty cycling to minimize the energy costly radio-on time. With radio duty cycling the energy usage for the test platform can be as low as 22mW, close to the consumption of the mcu itself.

For a production ready smart meter with more sensors and a bigger antenna, the resulting consumption with all sub units active would be higher, in the magnitude of a few watts, making the benefit of duty cycling more obvious.[2]

2

5.1.2.3 Interoperability and compatibility

A key benefit of using the standardized RPL routing protocol is the self-configuring capabilities. These capabilities are largely dependent on several network configuration parameters, which present a common trade-off between reactivity and messaging overhead.

For the join-scenario, when a new device is added to an existing network, the joining node will send routing queries to neighbouring nodes within reach, which will disseminate routing info about the new device upwards in the network. This can be done rapidly, with limited overhead. With a randomized base delay of around 20 seconds for start-up, a new device will be reachable in between 20 seconds and a few minutes depending on the number of hops from the network sink, and the amount of other ongoing traffic in the system.

Also the settings for the network to recover and redirect routing around a failed node are investigated. To reduce the amount of overhead messages, a rather long maximum routing information message time-out is beneficial, in the magnitude of a few minutes. When there are detected disturbances in the network, a timer reset will ensure more frequent control messages to be sent until the network topology has stabilized.

5.1.3 Comparison to original requirements and conclusion

For completeness also the list of comparison with the original requirements is included, even though this has previously been reported in the WP2 deliverables.

ID:	IPC_001
Description:	Devices must be uniquely identified
Addressed:	For the lab evaluations all devices are using unique Ipv6 addresses

ID:	IPC_002
Description:	Device Management should be possible via open Interfaces
Addressed:	Addressed where applicable to communicate with existing Smart Meters and Segment Controllers using FTP and a well specified DCP API.

ID:	IPC_003
Description:	IP End-to-End connectivity from IEM to device should be possible
Addressed:	Realized through the usage of Ipv6 and, using today's internet, tunneling

ID:	IPC_004
Description:	IPC should support IP connectivity for heterogeneous devices (e.g. via GW functions)

http://healthvermont.gov/pubs/ph_assessments/radio_frequency_radiation_and_health_smart_meters.pdf, retrieved 2012-11-30, and http://www.nachhaltigwirtschaften.at/nw_pdf/1216_smart_metering_infrastructures_scoping_study.pdf, retrieved 2012-11-30].

Addressed:	For the lab evaluations all devices are using unique Ipv6 addresses

ID:	IPC_005
Description:	IPC should support bidirectional communication
Addressed:	IPC supports both (bidirectional) UDP and TCP/HTTP communication

ID:	IPC_006
Description:	IPC must enable IPv6 usage and take advantage of its capabilities
Addressed:	Realized through self-configuring naming/discovery and routing

ID:	IPC_007
Description:	IPC may synchronize the time of the meters actively
Addressed:	For the lab trials, this is addressed through DCP functionality for resetting the clock on making new subscriptions.

ID:	IPC_008
Description:	Communications in Alginet between the Control Centre and the concentrator should make use of IP over Wimax
Addressed:	Fulfilled by using FTP over a TCP/IP/Wimax network to communicate with the concentrators.

ID:	IPC_009
Description:	Communications in Alginet between the concentrator and the smart meter should make use of REE protocol based on IEC 870-5-102 protocol
Addressed:	Fulfilled by the hardware deployed in Alginet.

ID:	IPC_010
Description:	Hardware to be use in Alginet for the smart meter should be based on the PLC-800 from circutor
Addressed:	Fulfilled by the hardware deployed in Alginet.

ID:	IPC_014

Description:	Communications for the PLS, between the lamps and the segment controller should be based on commercial solutions
Addressed:	Since every different lamp controller uses a different (and custom) communication protocol, the segment controller provides the NOPL with a generic communication layer; the segment controller is the device in charge of translating the commands of the generic communication layer into specific device-specific commands. Communication between NOPL and Segment Controllers is based on DCP. Communication between Segment Controllers and PoLs is based on mechanisms that are specific for each PoL controller model.

ID:	IPC_015
Description:	HW to individually control the lamps should be based on commercial solutions
Addressed:	Communication with different commercial solutions has been developed in the Segment Controllers, namely: • PHILIPS / ECHELON LLC7040 • SERVITEC Flux Regulator • CIRCUTOR CVM_NET Power Analyzer • MODBUS-based PLC solutions • ITCL PoL Controllers

ID:	IPC_016
Description:	HW for the segment controller should be based on an industrial PC running Linux
Addressed:	The segment controller application has been tested in two different industrial PC platforms: • PC-104 • MOXA IA260

ID:	IPC_017
Description:	Communications for the PLS, between the Control centre and the segment controller should be based on IP
Addressed:	Communications are based on DCP in combination with DCP-REST-TUNNEL, both working over a IP connection (3G connection)

ID:	IPC_018
Description:	IPC should allow wireless communication between radio enabled smart meters, using the 802.15.4 standard.
Addressed:	Fulfilled thorough IPC being Contiki-OS based, with support for a variety of 802.15.4 compliant radios.

ID:	IPC_019
Description:	Used wireless communications must use a minimum of energy
Addressed:	Lab trials have been performed using the ContikiMac radio duty cycling scheme, ensuring state-of-the-art in radio energy performance.

ID:	IPC_020
Description:	IPC should provide a lightweight and easy to use API and a non-specific forwarding mechanism to be used by DCP services
Addressed:	IPC is supporting both UDP and TCP.

ID:	IPC_021
Description:	IPC should provide automatic discovery capabilities.
Addressed:	Inherent from IPv6 usage.

ID:	IPC_023
Description:	Supported topologies in the smart meter networks are star-shaped, three-shaped and mesh-based
Addressed:	Inherent from the usage of RPL routing protocol. (For stable networks, the traffic patterns will mainly be star- or three-shaped.)

ID:	IPC_024
Description:	IPC should provide a collection protocol to forward data over multiple hops to a designated destination.
Addressed:	Realized using UDP over the RPL networks.

ID:	IPC_025
Description:	IPC should provide a dissemination protocol.
Addressed:	IPC through Contiki offers a low level UDP based dissemination service (described in D2.1).

ID:	IPC_027
Description:	ICP should provide a seamless connection on the networking layer between a smart meter mesh network and the intranet of the IEM.
Addressed:	Realized through IPv6 and tunneling.

ID:	IPC_028
Description:	IPC should provide a 1-to-1 routing protocol.

Addressed:	IPC supports both (bidirectional) UDP and TCP/HTTP communication

ID:	IPC_029
Description:	The IPC should be able to run on system based on energy efficient microcontrollers in the range of 8-25MHz with 4-96KB of RAM and 64KB-8MB of flash memory
Addressed:	The lab hardware trials are performed on the Wismote platform, using 18MHz, 16kb of RAM and 256KB of flash.

ID:	IPC_030-3
Description:	IPC should provide: UDP/TCP/ the address of a suitable parent to reach the root of the RPL DAG/the address of the RPL DAG root.
Addressed:	Provided through the Contiki-os, including the RPL routing protocol implementation and it's API:s.

ID:	IPC_034-5
Description:	IPC should provide a mapping function for an IPv6 address to the link-local short address of the link layer. / IPC running at a DAG root should provide a mapping function for each link-local short address to a full IPv6 address.
Addressed:	Enabled though giving access to the RPL routing tables.

ID:	IPC_036
Description:	IPC should allow querying the maximum application payload for single link-layer message.
Addressed:	Available as a low level service, described in D2.1.

ID:	IPC_037-8
Description:	IPC should inform the DCP layer when joining/leaving a RPL DAG.
Addressed:	IPC provides join/leave callback handles that applications can chose to react on, described in D2.1.

ID:	IPC_039
Description:	IPC should provide reliable communication.
Addressed:	IPC supports TCP.

ID:	IPC_040
Description:	Provide a method to enable optimization based on KPIs set by IEM

Addressed:	Because of the tight integration with DCP, the meaningful optimization scenarious are achieved when the availabe low level routing configuration parameters (in IPC) are tuned together with the subscription pattern (in DCP) that determines the total network utilization. This is further described in the IPC-DCP assessment section.

The Contiki-OS based IPC has through the evaluation shown itself as a useful substrate on which to build further smart meter specific middleware and applications.

5.2 DCP assessment

5.2.1 Methodology of testing

The DCP middleware has been tested both in the trials integrated with other components and individually in lab experiments. Complementing the results from other sections in this document and the performance analysis in a LAN environment detailed in D3.3.2, the following section is dedicated to the analysis in an emulated WAN environment. The setup is as follows:

- 10 two year old medium-performance desktop PCs
- Physical network connection by a Gigabit Ethernet Switch
- The Linux network emulation tool `tc` is used to shape the traffic providing a WAN oriented delay
  - o The delay is set to use a normal distribution within 20ms around a median of 100ms in each direction
  - o The expected ping times are, therefore, around 200ms as found in long distance WAN connections
- 9 hosts are used for publishing data
- Each host runs 10 dcp-roots each representing a concentrator
- Each dcp-root is responsible for 10000 sources of information representing smart meters
- Each source of information provides two channels as used in the trials: meter readings (i.e., consumed/produced energy, ...) and power information (i.e., voltage, ...)
- 1 host is used as the subscriber representing the IEM
- The subscription rate is 10 seconds

The experiments consisted of the following tests:

- Default: subscriptions to both readings and power information with the same subscription rate. This base line corresponds to the use in the trial.
- DetailedSum: Combines aggregation with individual readings. One subscription requests the sum of produced energy and the sum of consumed energy every 10 seconds. A second subscription requests the individual information for each meter every 100 seconds.
- Power: subscription to power information. Used as base value for the following filtering tests
- Filt10: subscription to power information with a value based filtering condition that allows 10% of messages to pass.
- Filt50: subscription to power information with a value based filtering condition that allows 50% of messages to pass.

5.2.2 Indicators measured and comparison to objectives

The following indicators have been used for analysis:

- The ping times from the subscriber host to each publisher host
    - This is measure by running the standard ping command line tool every second to record one roundtrip
- The delay for the notifications
    - This is calculated by taking the timestamp of the notification and the timestamp on the subscriber
- The total network traffic of the subscriber host. Note, this also contains traffic generated by the system and by the control tools and thus overestimates the traffic generated by the tests.
    - This value records the `/proc/net/dev` file every second to calculate the total outgoing and incoming traffic on the physical network device
- Notification losses
    - There have been no notification losses in any of the tests

Complete network communication

First, we show the total generated traffic on the subscription PC. Obviously, the vast majority of the traffic will be incoming – the notifications from the publisher hosts. The outgoing traffic results from the use of the HTTP protocol, which requires text responses.

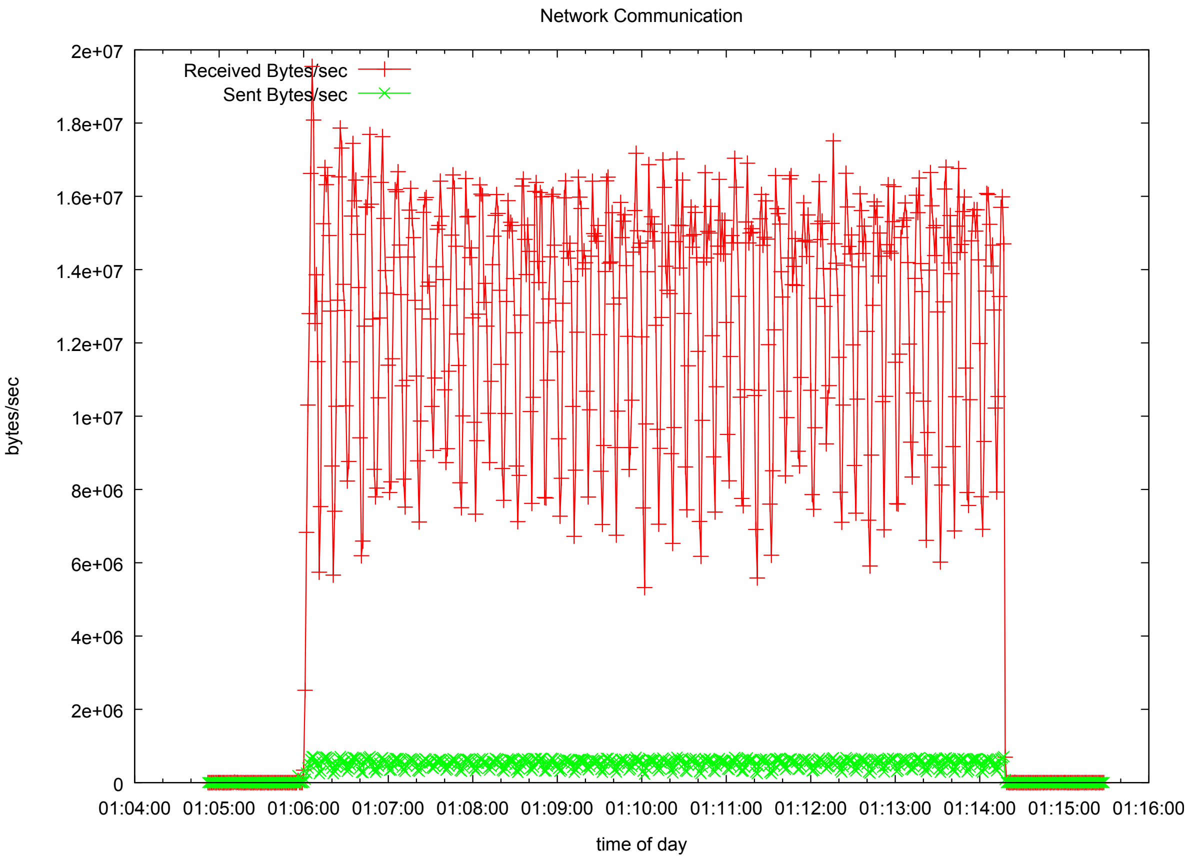


Figure 49: Complete network communication for default test

In the first plot, we show the traffic generated by the default test. As expected, this generates the highest load of all the tests. The graph shows a maximum bandwidth use of around 20 MB/sec. This translates to less than 1.8 MBit/sec per dcp-root – a value well within the range of both wired and wireless (3G) Internet connectivity.

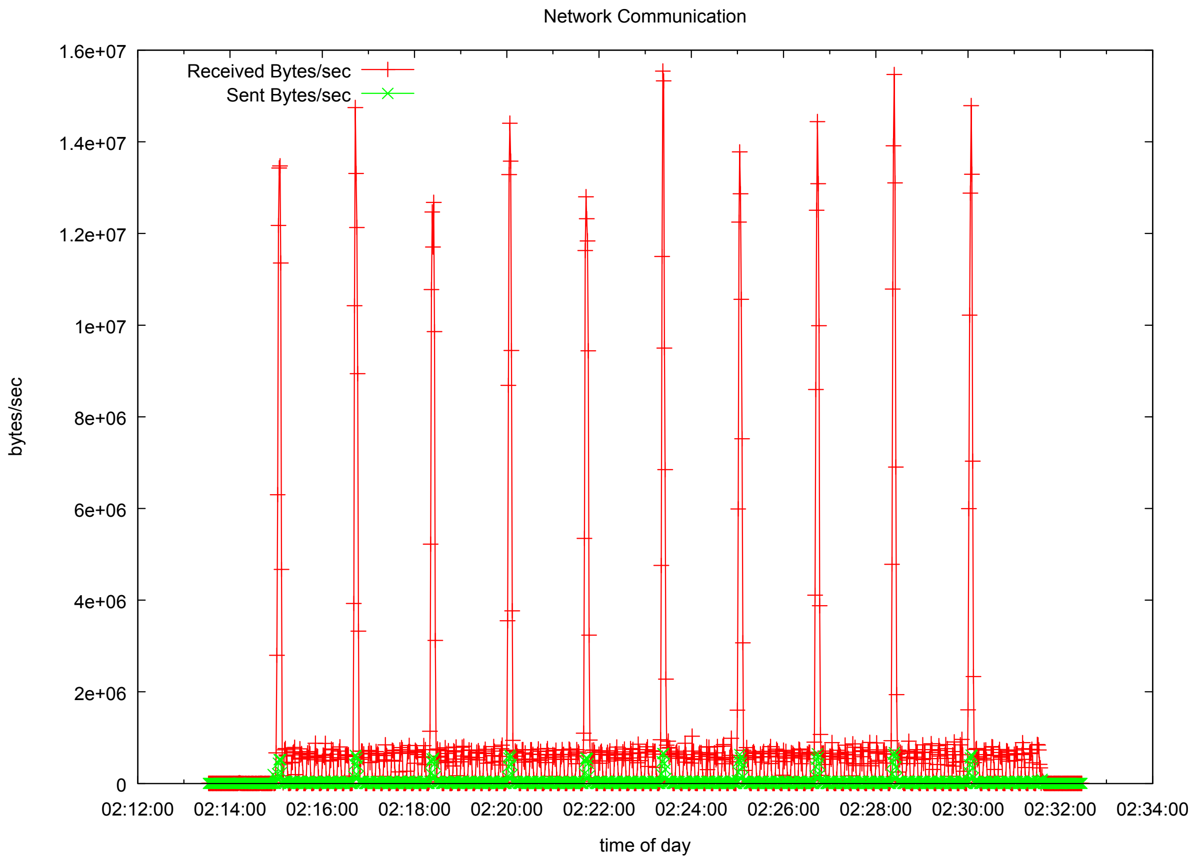


Figure 50: Complete network communication for DetailedSum test

The second plot shows the results for the *DetailedSum* test. On the one hand, this shows the much lower load generated by the aggregated results, which is collected with the same rate as the information in the previous plot. On the other hand, we see the spikes generated by the detailed (one reading per node) information, which again highlight the savings generated by the use of aggregation. It is noteworthy, that even the aggregated results generate a notable load, since they do not only contain the actually aggregated value, but also the list of node IDs that are part of this value, as per the requirement of the IEM.

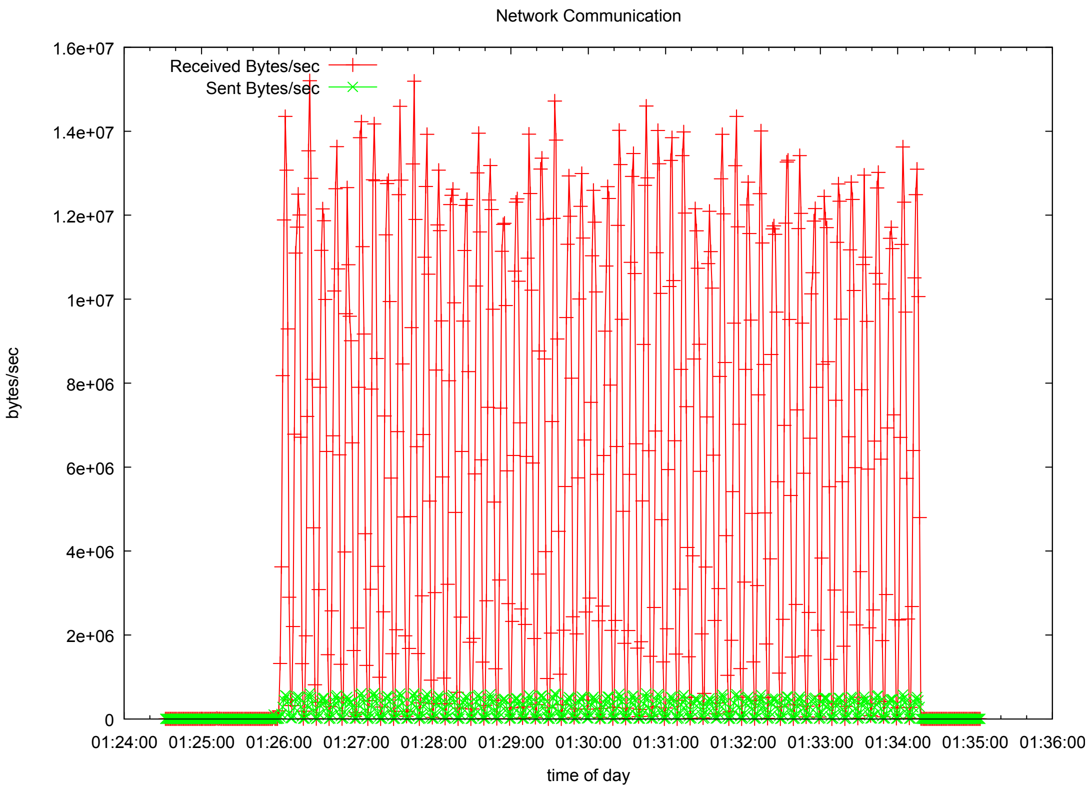


Figure 51: Complete network communication for power test

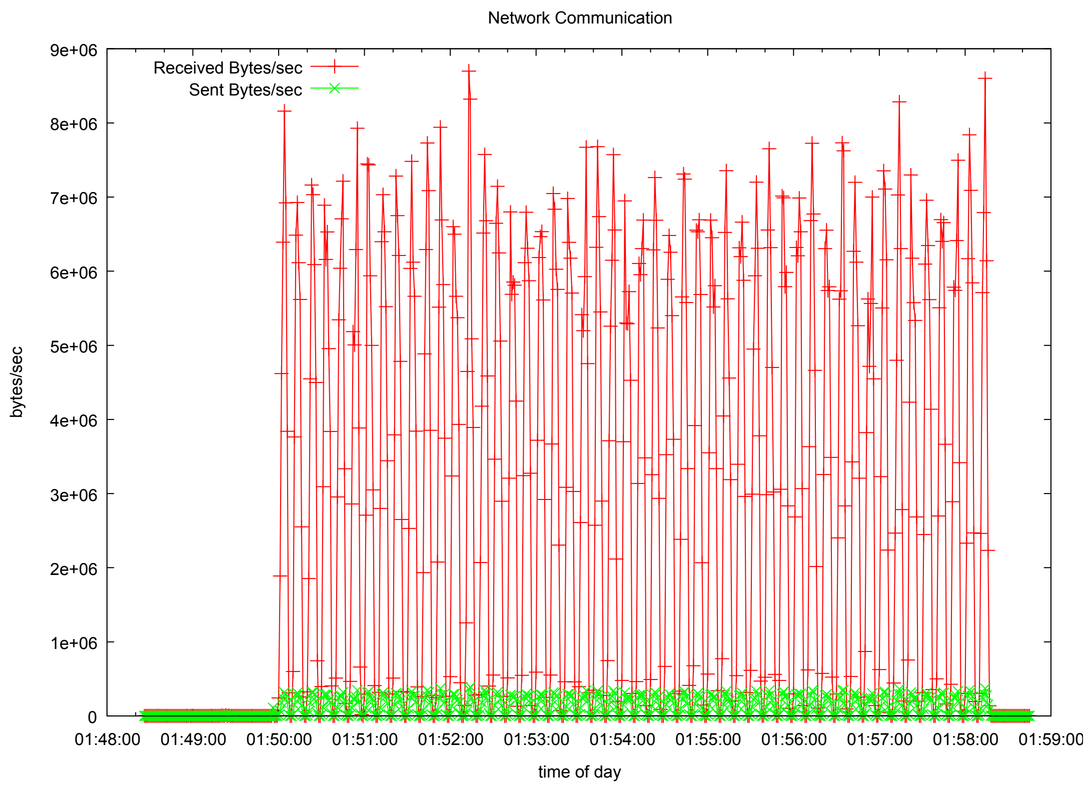


Figure 52: Complete network communication for filt50 test

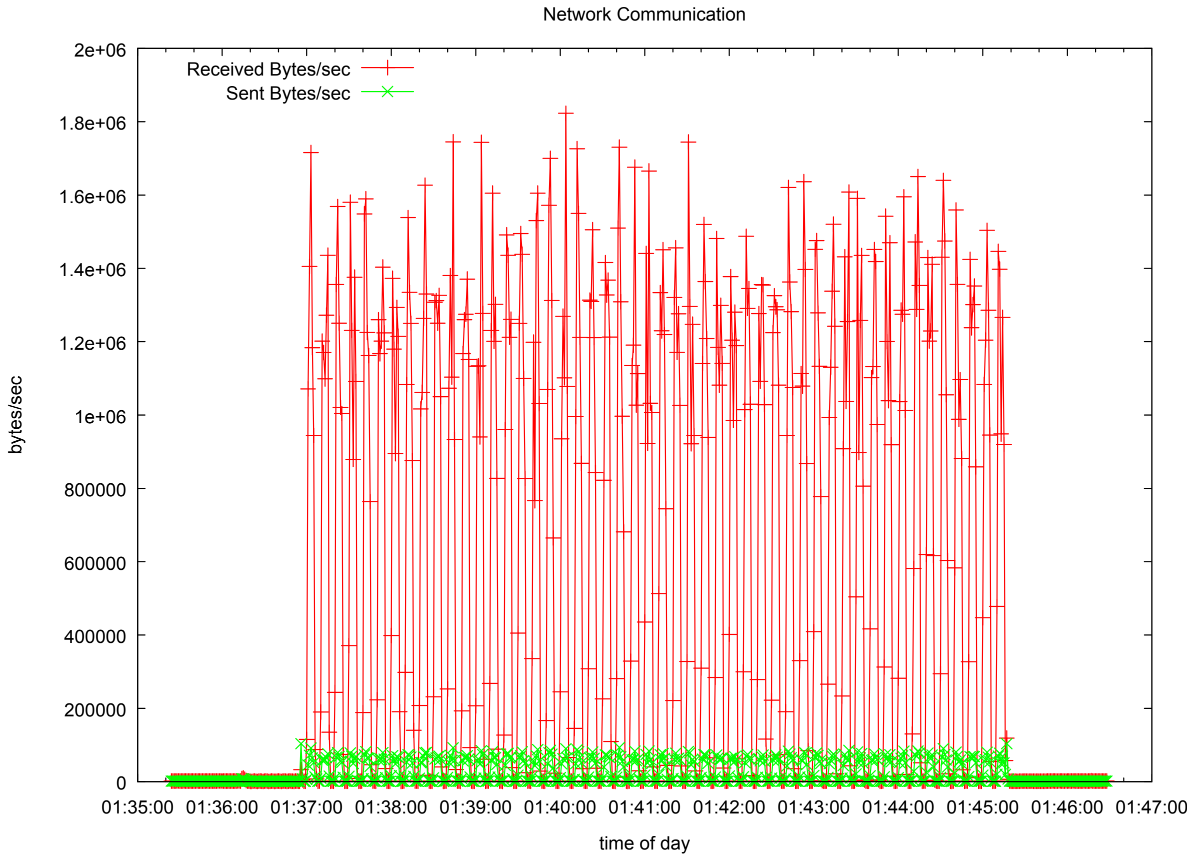


Figure 53: Complete network communication for filt10 test

The last three plots show the load generated by the *power* test, the *filt50* test and the *filt10* test respectively. The results are as expected, as the *filt50* test and the *filt10* test use filter conditions that let pass 50% and 10% of the notifications respectively. The generated load mirrors this filtering directly and highlights the potential of filter conditions for increasing efficiency considerably.

Ping Tests

We only show two plots for the ping measurements: the plot for the *default* test and for the *filt10* test, representing the maximum and minimum generated loads. The ping plots from all tests look very similar: the ping times are around 200msec and they show clearly when the test starts and ends. Since the 200msec stem already from the emulation settings, the impact from the load generated by experiments seems to not impact the ping times significantly.

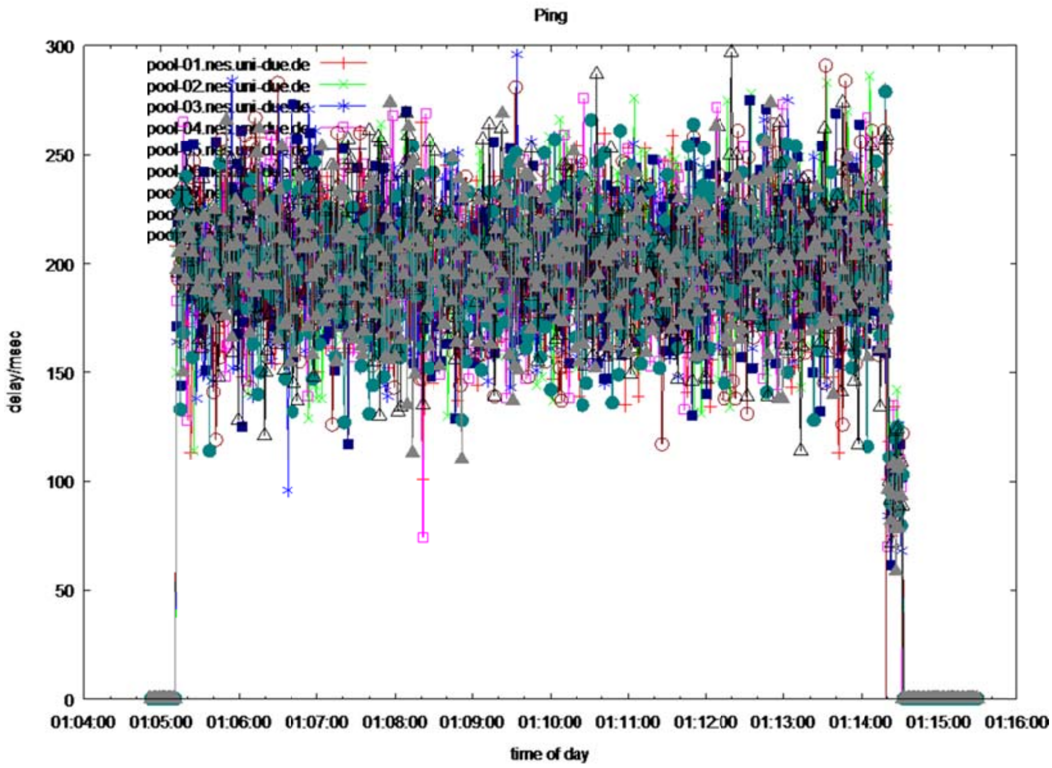


Figure 54: Ping times for default test

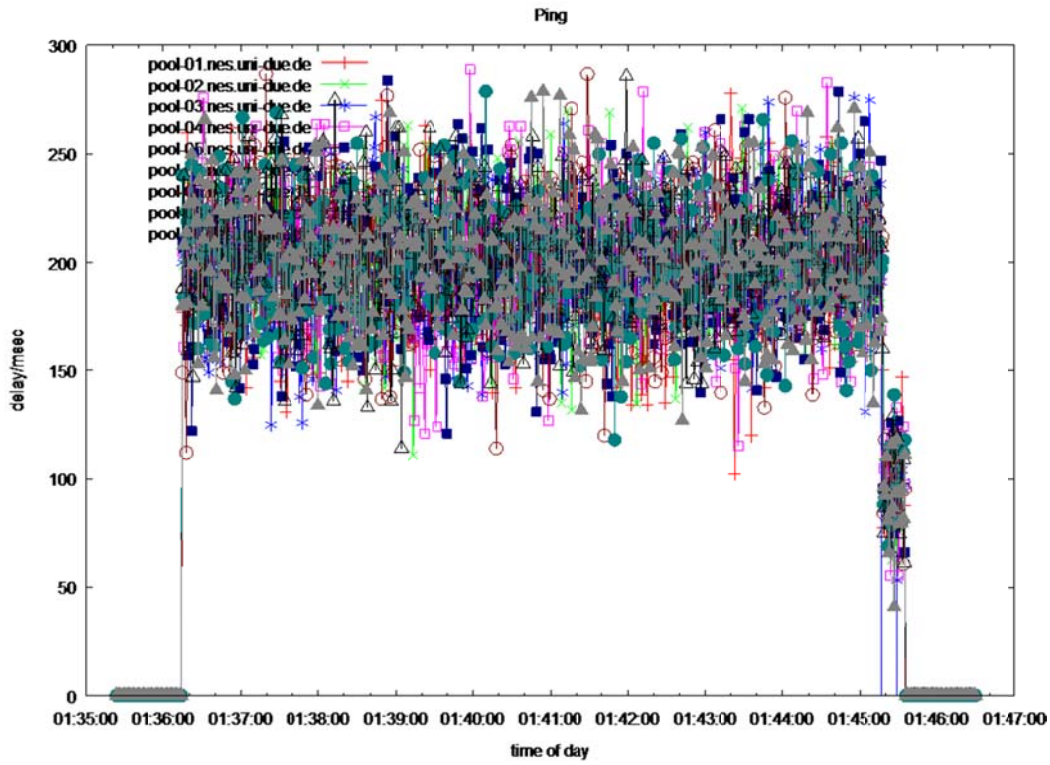


Figure 55: Ping times for filt10 test

Notification Delays

The following plots depict the notification delays. Each plot contains a histogram of the delays and a cumulative percentage indicating which ratio of notifications has been delivered with a delay smaller or equal to a given value.

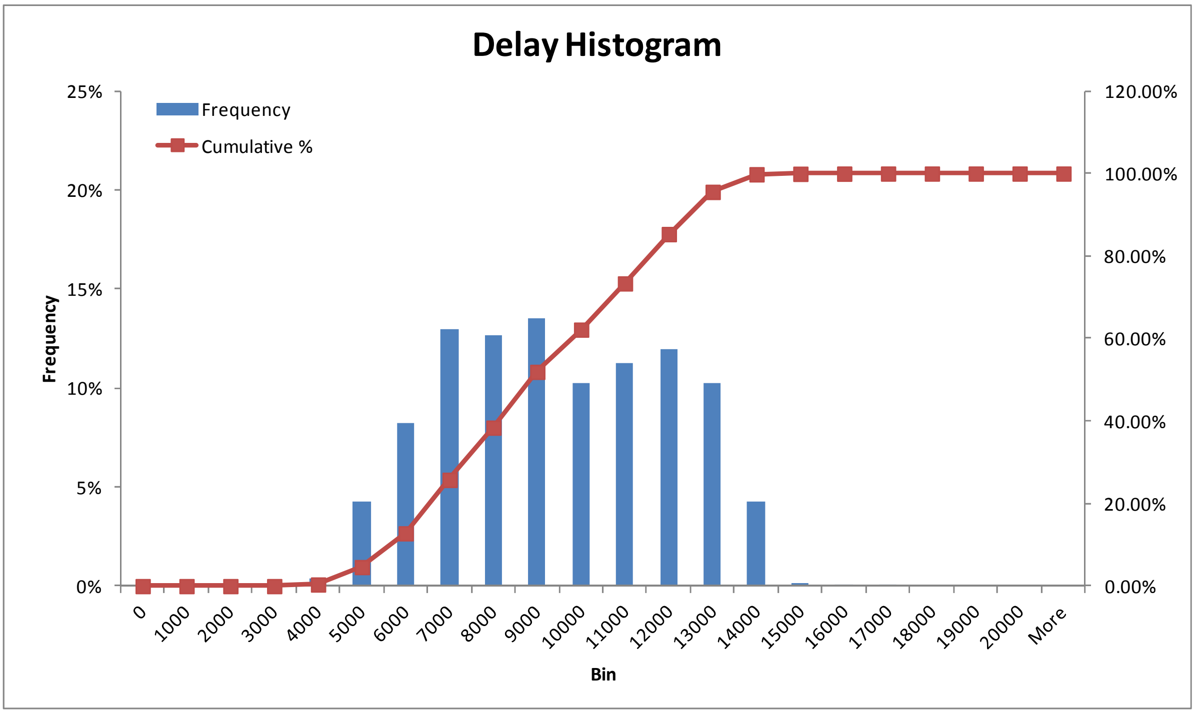


Figure 56: Notification delays for default test

The first plot shows the notification for the delay test. Since the publications are inserted with a uniformly distributed jitter between 0 and 5 seconds, the theoretically expected lower bound is at 2500msec. Tests in a LAN environment without the artificial delay showed average delays to be between 2500msec and 3000msec. Therefore, the plot shows that the artificial delay modelled after a WAN environment results in comparatively higher delay on the application level. However, with the average being around 9s and 80% of notification delivered in 12 seconds or less and a maximum measured delay of 14s, the result – despite of large number of information sources and the very high subscription rate – are well below any constraints of the use cases.

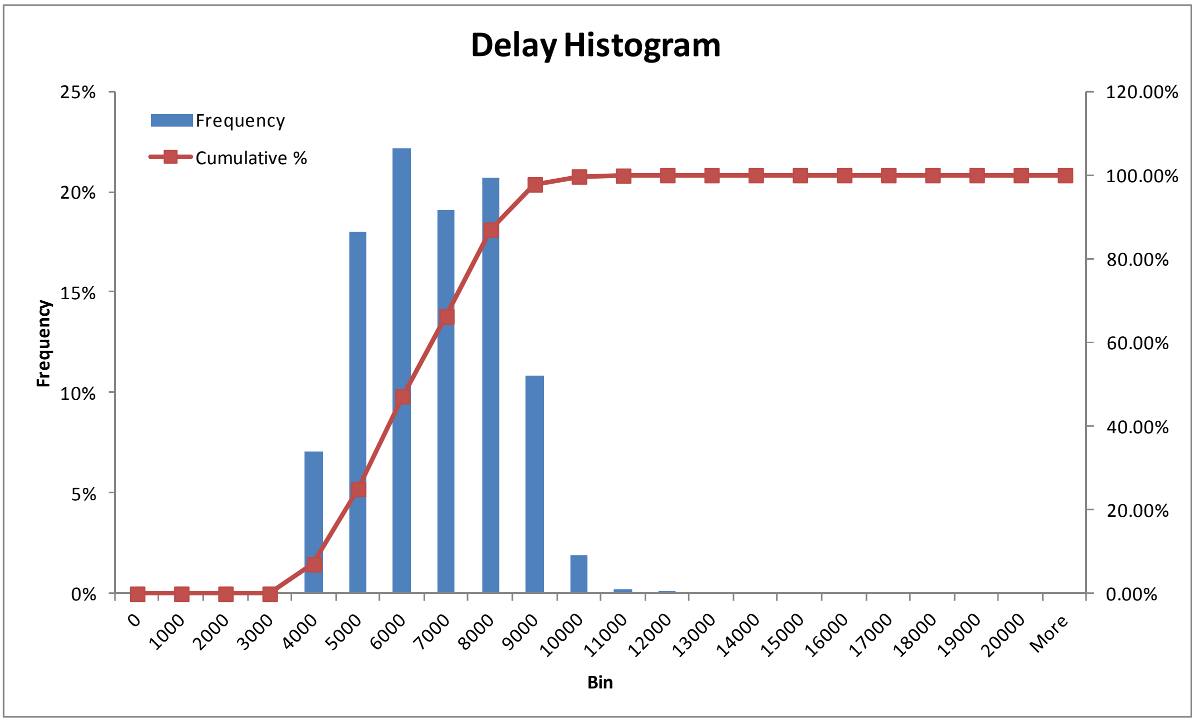


Figure 57: Notification delays for DetailedSum test: individual data

The second plot shows clearly the advantage of aggregation. Although this plots shows the delay for the individual date (every 100 seconds) in the *DetailedSum* test, the overall significantly lower loads has a positive impact on the delays with 80% of notifications delivered within 9s.

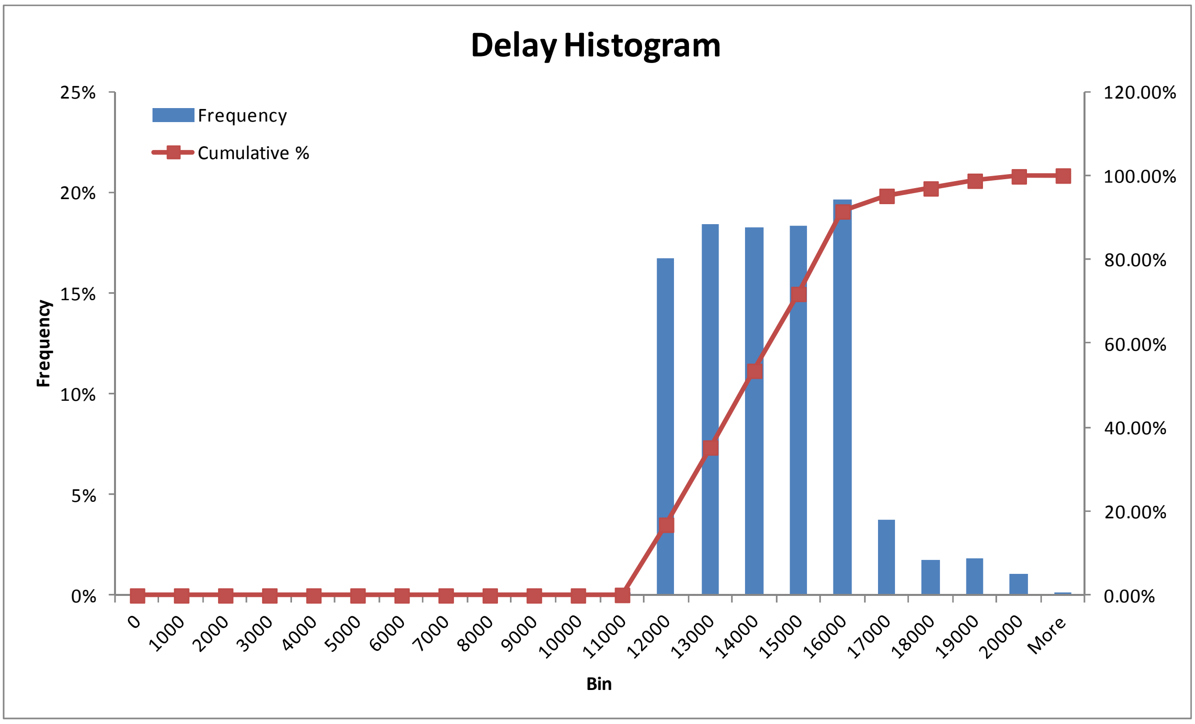


Figure 58: Notification delays for DetailedSum test: aggregated data

The delays for the aggregated data are much higher as expected. This stems not primarily from the delays imposed by the network communication, but by the specification of the application specific aggregation timeout – the maximum time the aggregation engine waits for individual results. For this experiment, this value is set to 10s. Therefore, the actual networking delays are on average just 4 seconds due to the much lower bandwidth requirements for aggregated data.

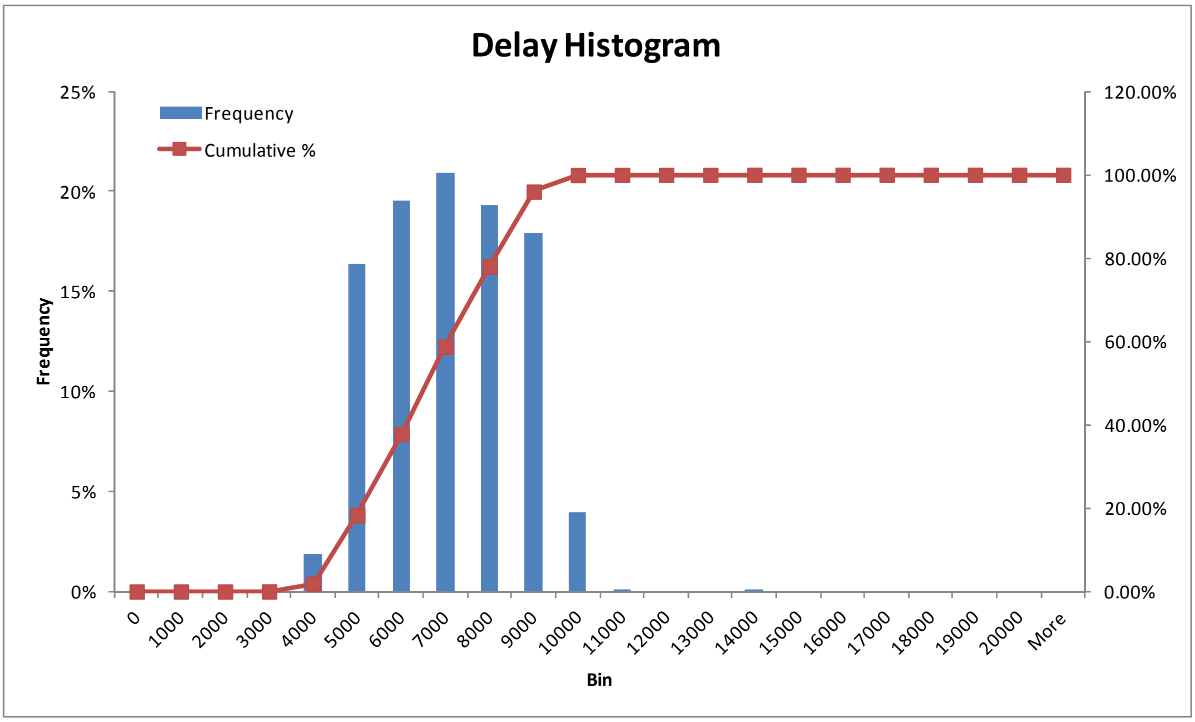


Figure 59: Notification delays for power test

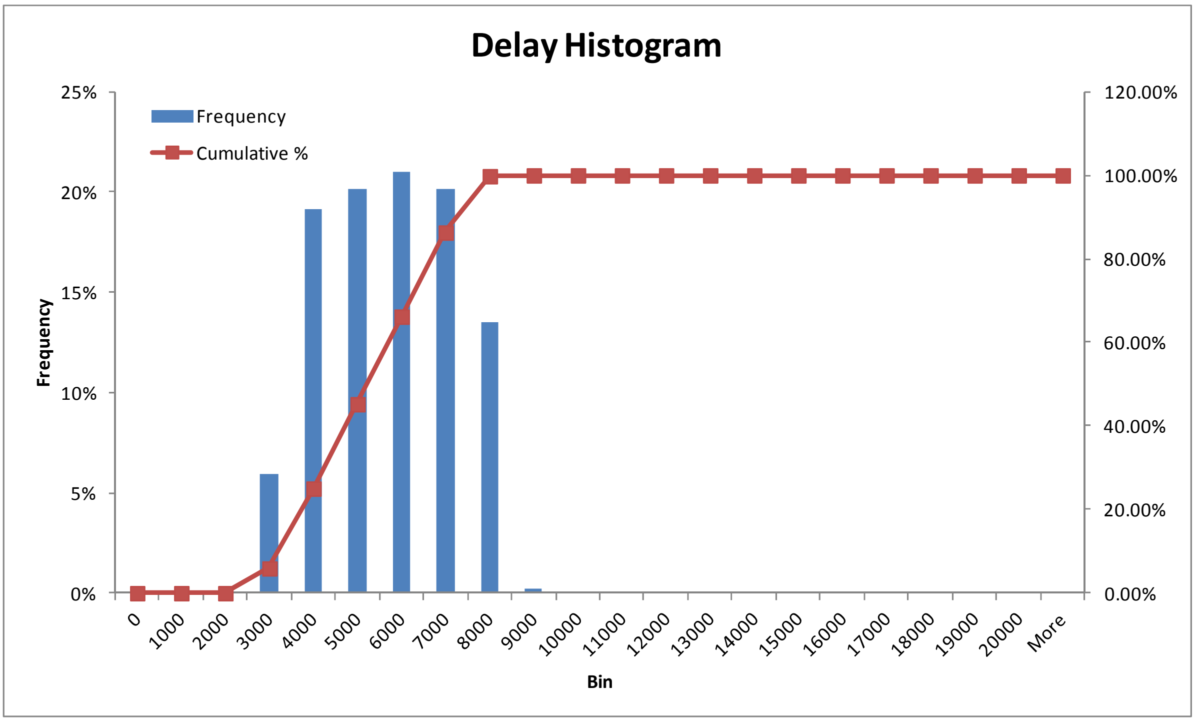


Figure 60: Notification delays for filt50 test

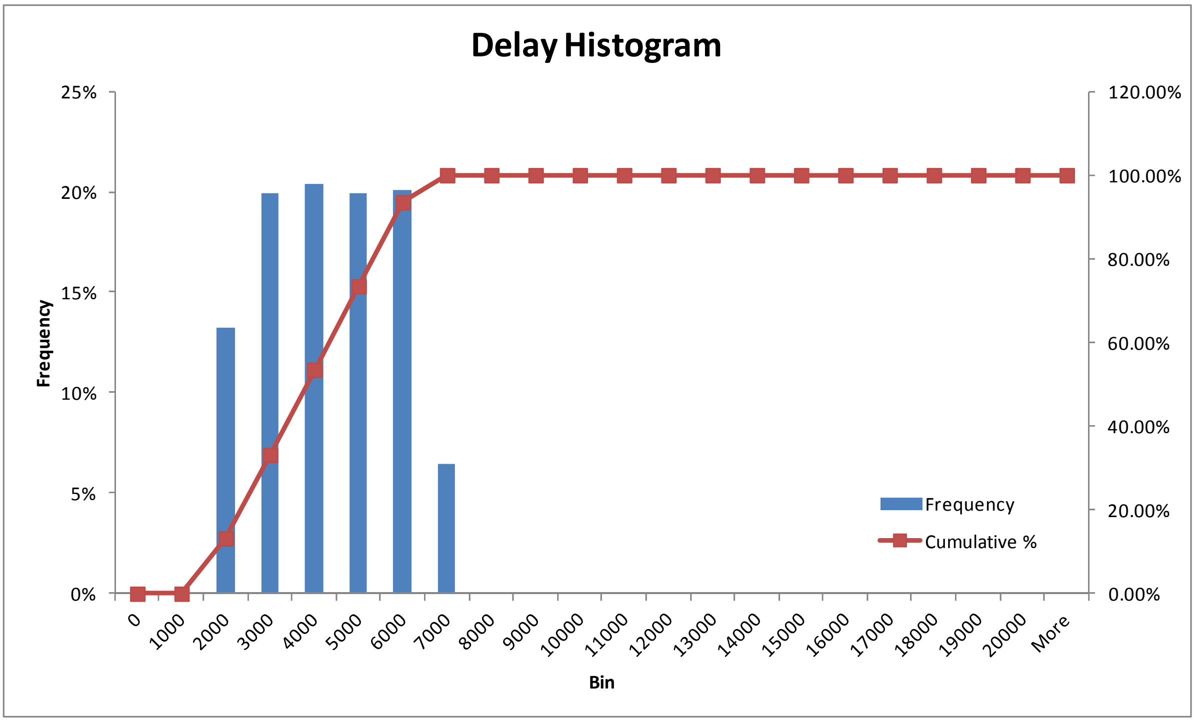


Figure 61: Notification delays for filt10 test

The last three plots show again the results of the *power* test, the *filt50* test and the *filt10* test respectively. While the trend is clear and as expected – lower loads resulting from more stringent filter conditions result in lower delays – the improvement is not in the same order of magnitude as the reduction in bandwidth requirement. However, taking into account the on average 2.5s delay resulting from the jitter, an average value of 4s for the *filt10* test can be considered an almost 50% improvement over the 7s of the *power* test.

Requirements Coverage Analysis

The following table lists the requirements gathered in D1.1 and the status of their implementation. As can be seen, almost all requirements have been fulfilled or covered in cooperation with the applications. Only the low priority requirements compression and sanity checks are not fulfilled directly. However, the use of an efficient binary serialization format offsets the potential of compression techniques to a large extent. For sanity checks, semantic information is required and further analysis of the interaction between application and middleware have led to a design where this very generic task if left to the application. The middleware has passed all performance requirements and surpassed almost all of them in lab tests by one or more orders of magnitude.

ID	Prio	Description	Status	Comments
033	High	DCP should allow the creation and use of application-defined filters for data.	✓	C.f. D3.1, Filtering on node-information currently not implemented and replaced with support for grouping by device IDs to better suit the common use cases by the applications
034	High	DCP filtering should include value based comparison operators and logical combinations.	✓	C.f. D3.1
035	High	DCP should allow aggregation of data.	✓	C.f. D3.1

ID	Prio	Description	Status	Comments
036	High	DCP aggregation should include common aggregation operators.	✓	C.f. D3.1
037	High	DCP should provide a generic publish/subscribe communication mechanism.	✓	C.f. D3.2
038	High	DCP should allow data-oriented access to the metering infrastructure.	✓	Integration Tests successful
044	High	DCP should provide a data definition language powerful enough to allow describing the required energy data types.	✓	C.f. D3.1, several channels are defined
006	High	DCP must provide its functionality and communicate in an open, independent, SOA-based (REST/WS) way, preferably standard compliant.	✓	DCP-Root + dcp-rest library
021	High	The DCP needs to have its first instance at the concentrator for the use case in Alginet.	✓	Tested in coop with ETRA
024	High	The DCP needs to have its first instance at the segment controller for the PLS.	✓	ETRA development
028	High	The DCP should be able to run over window for the PLS control system: control centre, main application	✓	DCP tested on Win, Linux, Mac
003	High	DCP should allow access to the data provided by the metering infrastructure installed at Alginet.	✓	Tested in coop with ETRA
008	High	DCP must cache metering measurements locally	✓	Support by dcp-rest-gateway;
012	High	DCP should support meter reading on-demand	✓	Generic dcp library allows querying of publication data via REST transparently for the publisher application
039	High	DCP should provide its API as a library accessible from C++.	✓	Library is implemented in C++
046	High	The Communications between the SC (PLM) and the NOPL will be granted through Web services/rest (DCP)	✓	C.f. D2.2.2
015	High	DCP must collect and convey metering measurements in a high performance way	✓	C.f. evaluation
002	High	The NOPL should use DCP to collect information.	✓	C.f. D2.2.2
005	Med	DCP should provide readings with the highest granularity provided by the meters.	✓	DCP imposes no limitations
022	Med	The DCP needs to support 1000 sources of information from the smart meter to the concentrators.	✓	Shown both in trial and in lab experiments (there 10000)
045	Med	DCP should provide a data definition language that supports efficient serialization.	✓	C.f. D3.1; positive experience
048	Med	Creation of customized computation on streams for IEM	✓	Aggregation and filtering on messages
009	Med	DCP should timestamp the data	✓	
016	Med	DCP should support bidirectional communication	✓	
027	Med	The DCP should be able to run over Linux for all the elements below the PLS control: Segment controller	✓	DCP tested on Win, Linux, Mac
011	Med	(Dynamic) Discovery and/or registration of (new) devices	✓	Automatic discovery within multicast domain; dcp-rest-tunnel connects dcp networks over the internet
017	Med	Metering data could be provided in an event-based way.	✓	Publish/Subscribe System
020	Med	The DCP needs to provide the information gathered through a REST interface	✓	DCP-Root + generic library for retrieving single publications from a device
025	Med	The DCP needs to support 100 sources of information for the segment controller.	✓	Trial successful (few devices); lab tests with up to 10000
026	Med	The DCP needs to support 100 sources of information for the PLS control system.	✓	Lab tests have used up to 10000

ID	Prio	Description	Status	Comments
029	Med	The DCP should be able to forward the information/events used by the BA	✓	
030	Med	The DCP should be able to forward the information/events used by the IEM	✓	
031	Med	The DCP should be able to forward the information/events used by the PLS	✓	
032	Med	The DCS for the PLS should include an event filter	✓	C.f. D3.1
040	Med	DCP should provide essential functionality for smart meters on extremely resource constrained devices.	✓	Nano-dcp + nano-protobuf
041	Med	DCP should provide essential smart meter functionality when running on the Contiki operating system	✓	Nano-dcp + nano-protobuf
007	Med	DCP functionality interaction via SOA (e.g. REST)	✓	Dcp-Root and dcp-rest library
019	Med	DCP should be scalable for large scale deployments	✓	Lab tests with WAN emulation successful
018	Med	Provide some very basic security features	✓	Uses standard and established libraries for TLS
023	Med	The DCP needs to support 50 sources of information from the concentrators to the IEM	✓	
042	Med	DCP should provide an easy-to-use data definition language to specify the data types used for capturing energy state.	✓	C.f. D3.1
013	Low	DCP may support compression techniques to minimize communication overhead with IEM	×	Not implemented; however, due to use of compact binary data serialization format, less important compared to heavyweight solutions like XML or JSON
043	Low	DCP should provide a data definition language based on existing standards if possible.	✓	C.f. D3.1; is also used for communication within the IEM and among the IEM, EMS and BAF
010	Low	Sanity checks on data could be made	×	Functionality not supported by DCP but could be implemented in the applications with their semantic knowledge

5.2.2.1 Conclusions

There are three main conclusions:

- Almost all requirements have been directly addressed.
- The middleware has performed reliably in the long-term trial and its flexibility has been show in the use for the PLMS, the IEM and together with the IPC in low-power embedded environments
- The lab experiments show the scalability of the middleware. While even with the network emulation, the setting is still more optimal than a WAN environment, the middleware was able to handle the equivalent of 90 concentrators transmitting information for 900000 simulated smart meters with a subscription rate of 10s, i.e. four orders of magnitude more information than required by the trials.

5.3 IEM assessment

5.3.1 Requirements Assessment

All of the original requirements set have been fully addressed.

ID:	IEM_001
Description:	IEM must provide its functionality and communicate in an open, independent, SOA-based (REST/WS) way, preferably standard compliant.
Addressed:	All services are based on REST approach and according to the HTTP specifications.

ID:	IEM_002
Description:	IEM should enable explicit contact from other components e.g. for alarms
Addressed:	Any IEM service may be contacted from any other component, as long as user invoking the services is authorized.

ID:	IEM_003
Description:	IEM must accept metering measurements in a high performance way
Addressed:	Usage of Google Protocol Buffers in combination with REST allows for high performance parsing of the exchanged messages via lightweight web service implementation.

ID:	IEM_004
Description:	The IEM should keep track of any historic data
Addressed:	The IEM platform provides access to all historic data acquired via the services.

ID:	IEM_005
Description:	The BA should enable the programming of biddings and offers with a time window of one month
Addressed:	In IEM brokerage services, a BA can manage market orders within a time window preconfigured for the market behaviour i.e. time before opening trading slot. For more details, please refer to the deliverable D4.3 [11].

ID:	IEM_006
Description:	The BA should support the submission and update of bidding with a granularity of 15 minutes
Addressed:	The IEM brokerage mechanism allows configuration of any required granularity.

ID:	IEM_007
Description:	The BA should support the set of alarms
Addressed:	The IEM brokerage mechanism allows listening on the market for many different notifications e.g. trading occurrence etc.

ID:	IEM_008
Description:	The BA should provide a secure mechanism to manage the biddings and offers.
Addressed:	All IEM services are running on top of HTTPS which is combined with an authentication and authorization framework .

ID:	IEM_009
Description:	The BA should accept the offers and biddings of identified users.
Addressed:	Every BA is running on behalf of its owner (prosumer) while only authorized users can use the specific IEM services.

ID:	IEM_010
Description:	The BAs should accept the modifications coming from a super-user/administrator.
Addressed:	Administrator is fully capable of managing brokerage activities of any BA(s) i.e. market order cancelation, BA start/stop, etc. For more details, please refer to the deliverable D4.3 [11].

ID:	IEM_011
Description:	The electricity monitoring service should provide alarms on the performance of the smart grid.
Addressed :	Any event in the grid can be registered through Eventing Services of the IEM. Via offered services even smart meters may create events to inform operators. For more details, please refer to the deliverable D4.3 [11].

ID:	IEM_012
Description:	The electricity monitoring should consider the information coming from the smart meter, concentrators and the PLS system (or any other SEP)
Addressed:	The PLS system may act as any prosumer in the IEM e.g. report consumption, acquire energy via bidding on the market etc. Additionally the Energy Optimisation service may accommodate bilateral negotiation scenarios.

ID:	IEM_013
Description:	The electricity prediction service should make use of the information available at the monitoring service and brokerage service.

Addressed:	Prediction services on IEM use metering data available from the monitoring service. The agent strategy may consider additional intelligent logic from the brokering outcome.

ID:	IEM_014
Description:	The prediction service should provide different time windows of prediction.
Priority:	The IEM prediction services offer any time window of prediction (including different granularity) as long as prerequisites of the prediction algorithm are satisfied. For more details, please refer to the deliverable D4.3 [11].

ID:	IEM_015
Description:	The Electricity pricing service should make use of the information available at the smart meters to manage the billing.
Addressed:	Billing services make use of the information collected from smart meters and contracted tariffs. For more details on contract and tariff creation, please refer to the deliverable D4.3 [11].

ID:	IEM_016
Description:	The Electricity pricing service should provide for customized pricing policies
Addressed:	The Billing services offer full dynamicity on tariff assignment to contracts being assigned to customers. For more details on contract and tariff creation, please refer to the deliverable D4.3 [11].

ID:	IEM_017
Description:	The Electricity pricing service should be aware of the different tariffs assigned to each user
Addressed:	Since any contract created via Billing services is composed out of one or multiple tariffs, different pricing is applied by assigning different contract to customers.

ID:	IEM_018
Description:	The IEM needs to provide the information related to Consumption, Production, Prediction, Biddings, Alarms, Contracts and Historic Data to the BAF through a web service interface.
Addressed:	All info is provided in IEM. For details, please refer to the deliverable D4.3 [11].

ID:	IEM_019
Description:	Information provided by the prosumer through BAF should be stored.
Addressed:	BAF is just a GUI for the IEM services. Changes to the services are

	stored where applicable e.g. any prosumer may adjust his energy prediction (calculated by a forecast algorithm) through custom prediction services of IEM. For custom prediction details, please refer to the deliverable D4.3 [11].

ID:	IEM_020
Description:	The IEM should identify clearly each user so the different services (BA, info, pricing) offer exclusively the information relevant to the user.
Addressed:	Authentication and Authorization are embedded in the IEM.

ID:	IEM_021
Description:	The IEM will provide the PLM with suggestions to reduce consumptions to face critical situations
Addressed:	IEM optimization services allow any standard prosumer (STP) or senior prosumer (SEP) to offer their energy flexibility. For details on optimization service, please refer to the deliverable D4.3 [11].

ID:	IEM_022
Description:	Management for multiple users and their profiles
Addressed:	Management services on IEM allow user profile management. For more details, please refer to the deliverable D4.3 [11].

ID:	IEM_023
Description:	Will support NOBEL-wide common language file for internationalized messages
Addressed :	The IEM has been designed and implemented in order to flexibly support any language. An important facet for use in different countries is the externalization of text that is displayed by the program. By externalizing strings, the text can be translated for different countries and languages without rebuilding the IEM services.

ID:	IEM_024
Description:	15 minutes time interval for IEM brokerage functions
Addressed :	The NOBEL market allows configuration of any required granularity (for the NOBEL trial it was set to 15 minutes).

5.3.2 Design Assessment

During the process of creating multiple mash-up applications for a variety of stakeholders (residential end-users, utility etc.), valuable lessons, both technical as well as other related to design and social aspects, were acquired. To validate the concept and the implementation of the IEM services, a web application was created composed solely from a mash-up of the IEM services. An example of the GUI is the NOEM tool that is depicted in

Figure 62, while similar applications that take advantage of the same services are also built for mobile devices e.g. BAF.

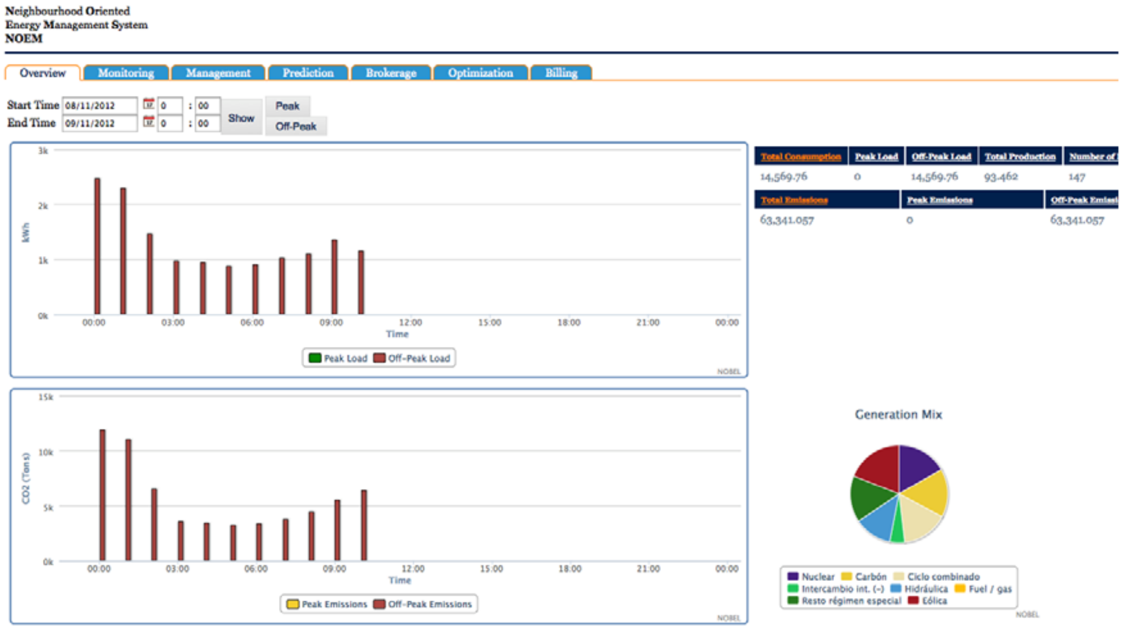


Figure 62 - A view of the NOEM tool (mash-up of REST services provided by IEM)

It would have been painful to create in the same timeframe and with the same functionality a monolithic application as it is traditional to do so in the energy domain. Without access to the energy data via open interfaces, the implementation overhead would be too costly to be realized, especially taking into account the multitude of end-user devices that were targeted. Hence the need for a layered approach, where the data acquired is processed and offered via open and long-lived interfaces is an absolute must. The provision of necessary functionalities over Internet services enables the creation of apps that can run anytime, anywhere, and interact with user's data as well as additional services in the "cloud". As such it is crucial that basic energy services are defined and standardised in order to enable a common approach on harnessing the energy data and empower the next generation of energy applications.

If the sophisticated logic had to be separately developed for each application then it would probably lead to repetition of logic and functionality with a result of more fat clients (end-user applications). However, in this case, things were easier since a platform that offered basic common energy services to all users was developed. The common requirements for end-user applications were identified early and built into the platform. Currently, the initial basic set of services is being maintained, while the platform is extended with additional sophisticated functions. It is expected that in the future such issues will be negotiated by the application developers and the platform providers in order to ensure shared benefits.

Using technologies that would enable several other aspects e.g. lightweightness, high performance, backward and forward compatibility etc. were considered. All services are Internet based and use the HTTP as a complete application protocol, which also defines the semantics for the service behaviour (as followed by RESTful approaches). Additionally, to the REST style (with PUT/GET/DELETE/POST methods) the Google Protocol Buffers (extremely efficient binary format) for enhanced performance was used, since significant amounts of data had to traverse the network from the platform to the applications. Bulk data transfer was also used, instead of many smaller messages, to make the application more network friendly and decrease network round-trips.

Services may fail at any point of time (both on the client and server side), even when processing a request. Typical such incidents that occurred during the trials were examples where the network connection failed (disrupted communication link, time-outs), or even a case of server overload. It is therefore important to implement both at client and server strategies in order to detect and handle such failures.

Sometimes the server processing took extensive time (due to the nature of the request or server overload) and in the meantime the client either timed-out or was blocked. Hence, asynchronous behaviour was implemented (Request/Acknowledge) instead of synchronous (Request/Response) where possible, in order to avoid the client blocking. A typical case for this was when the user would request in detail depiction of his energy data for a long period of time e.g. 10 months. Here one can either consider sending the request and polling later for results (hence the responsibility is at the client side) or give a callback URI to the server so that he can push the results whenever ready. Both strategies will have to consider several aspects e.g. the frequency of polls as well as operational aspects e.g. if the application is behind a firewall the respective port must be open etc. Using a publisher/subscriber model might be difficult, especially in the case of mobile phones, which are generally behind a firewall for security reasons. One alternative, yet to be explored, is the use of websockets. This technology, which is available in HTML5, is somewhat between the request/response and publish/subscribe models. The client can initiate a permanent connection to server, effectively giving it a direct route back to the client, and thus enabling it to deliver information when it is available.

An additional issue to consider is that for multiple data exchanges the applications should use one connection instead of establishing and destroying connections each time it is needed (this helps minimizing the latency). This has an impact on the server side since sufficient system resources must be available (HTTP is a connection oriented protocol which implies high availability of the server) and at sufficient capacity (e.g. CPU, memory, network bandwidth) to handle potentially large numbers of clients or spikes (when they send requests at very narrow timeslots).

Since the application developers do not have an overview of the number of energy services available and their API, it would be beneficial to have a Service Registry where one could search for services and their end-points. This will also ensure that whenever services are modified e.g. changing URI patterns and locations, the applications (clients) can discover them. Additionally this is considered beneficial for the infrastructure maintenance in order to add or remove services.

Security, trust and privacy are challenging issues especially associated with the emerging smart grid capabilities. Currently, the IEM does not focus on security, however, an effort was made to use standard approaches. For instance, only secure channels (all REST calls were made over HTTPS) were used, as well as basic HTTP authentication and authorization were used by all services provided by the platform. Clearly, precautions must be carefully considered for real-world deployments which might additionally include message signing and encryption of service hyperlinks.

5.3.3 Data Quality Assessment

High quality data sets are important especially as they impact other services. Since the data collected on the IEM platform is further used for analysis, without quality assessment one may be led to faulty results. Furthermore, when data is used for analysis on strategic decisions or other critical processes, outcome of the analysis may not be trusted. Auxiliary processes such as grid estimation, grid reinforcement and grid planning are mainly based on data coming from selected metering points or are computationally estimated.

Existing data sets of low quality might lead to invalid results. Thus, data cleansing and fixing corrupted data sets is an important step and the precondition for valid and successful data analysis.

5.3.3.1 Classification of quality problems (QP)

This sections analyses the quality issues of single attributes in single tuples: quality issues arising in y_i or t_i in a single tuple V_i.

Missing value: Missing values occur, if the value of a mandatory attribute is null. Due to the definition, that the attribute's value and time are both mandatory, the quality issue of missing value arises if:

$$y_i \in V_i = \mathit{null}, \text{ or} \qquad (QP1)$$
$$t_i \in V_i = \mathit{null} \qquad (QP2)$$

Syntax violation: Syntax violation arises, if the value of an attribute does not match an associated regular expression or grammar function. Any attribute value which is not covered by the regular expressions, is considered as syntax violation:

$$y_i \text{ must match } \texttt{[-]?([0-9]*[.]?[0-9]+|[0-9]+)} \qquad (QP3)$$
$$t_i \text{ must match } \texttt{[-]?[0-9]*} \qquad (QP4)$$

The regular expression function checks for y_i if it matches a double value, while it must match a long value.

Domain violation: There is a domain violation, if the value of an attribute is not part of the domain set associated with that attribute. Thus, a domain violation occurs if:

$$y_i \notin d_1 \qquad (QP5)$$
$$t_i \notin d_2 \qquad (QP6)$$

Violation arise if the value of y_i is negative/not numeric.

Unique value violation: The violation of unique values arise, if for a unique attribute, two attribute values are the same. A unique value violation appears if two t have the same value (i. e. two different t have the same time):

$$\exists t_i, t_j : t_i = t_j, \text{ while } i \neq j \qquad (QP8)$$

Violation of business domain constraint: A violation of business domain constraints arises if the given time series does not comply with these restrictions:

$$y \text{ must monotonic increase} \qquad (QP9)$$
$$\Delta t \text{ must be constant} \qquad (QP10)$$
$$\text{All tuples } V \in Y \text{ must be ascending sorted} \qquad (QP11)$$

The problem of missing tuples V is inherent to (QP10). Whenever a time series violate this constraint, it must be assumed, that the time series has missing tuples V, or does not fit in an expected resolution. Therefore another constraint was defined, which is violated, if the time series resolution does not fit into the expected resolution:

$$\exists (t_i - t_{i-1}) \neq \Delta t_{exp} : \Delta t_{exp} \text{ is the expected resolution} \qquad (QP12)$$

Furthermore a constraint was defined, that there must be a change in the metered value within a defined period of time. Several problems concerning the smart meter or the electrical installation within the facility in which the smart meter was installed, can cause constant meter readings. It was considered, that meter readings, which are constant for a certain time interval suffer from such a problem. Therefore, time series which did not met the following constraint were considered as invalid:

$$y_{i+k+1} > y_i \qquad \text{(QP13)}$$
$k \in \mathbb{N}^{>0}$: maximum allowed number of consecutive constant readings

In order to get time series with a valid minimum length, a restriction is proposed regarding the minimal length of a time series.

$$t_n - t_1 \geqslant t_{ml} \qquad \text{(QP14)}$$
t_{ml} defines the minimum length of the time series

Inconsistent duplicate: Let the similarity function f receive two values of an attribute; f computes the similarity between the attribute values and returns a real number between 0 and 1 [8]. Thus, the case of two readings having the same time point but the values of these readings differ, is considered as inconsistent duplicate. While the other way around, different reading time and same value, is not considered as inconsistent duplicate. Accordingly, inconsistent duplicate arise if:

$$t_i = t_j \wedge y_i \neq y_j, \text{ while } i \neq j \qquad \text{(QP15)}$$

Various possible quality problems were discovered and defined in this section. A formal definition of quality problems was adapted and used on the specific use case of energy time series. Even though the complexity of the used taxonomy approach was reduced because of the use case, energy data sets might be affected by various quality problems. Because the identified possible quality issues are very domain specific, a distinct system is considered to properly address the quality problems. This system is designed and described in the upcoming chapter.

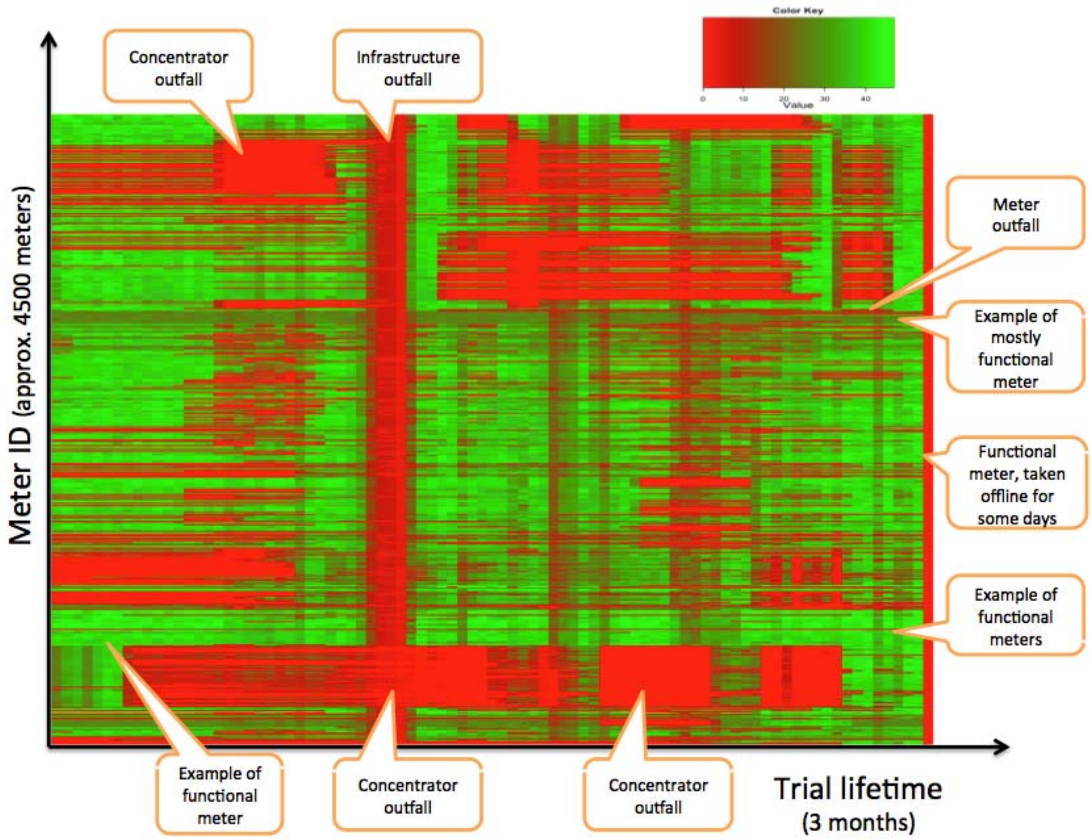


Figure 63 – Alginet Trial overview heatmap from the smart metering viewpoint

What is shown in Figure 63 is only the visual representation of the received readings. It shows an overview of the 3-month trial against the density of data (number of meter readings) received by the IEM. Some strictly “red” areas denote problems in the infrastructure (e.g., fallout of a concentrator etc.), previously defined as QP1 or QP2. A key event shown is also the infrastructure fallout for approx. 5 days, where all meters did not report data. We can also see per meter the reporting behaviour e.g. based on the variation of the spectrum for a specific meter ID.

Additionally in Figure 64 one can see the quantitatively representation of the collected data on IEM, analysed on daily basis. Similarly here events like infrastructure fallout can be identified, but we also get a quick view on the overall smart metering behaviour and the load (e.g., number of smart metering events, number of meters reporting measurements etc.) on the IEM side.

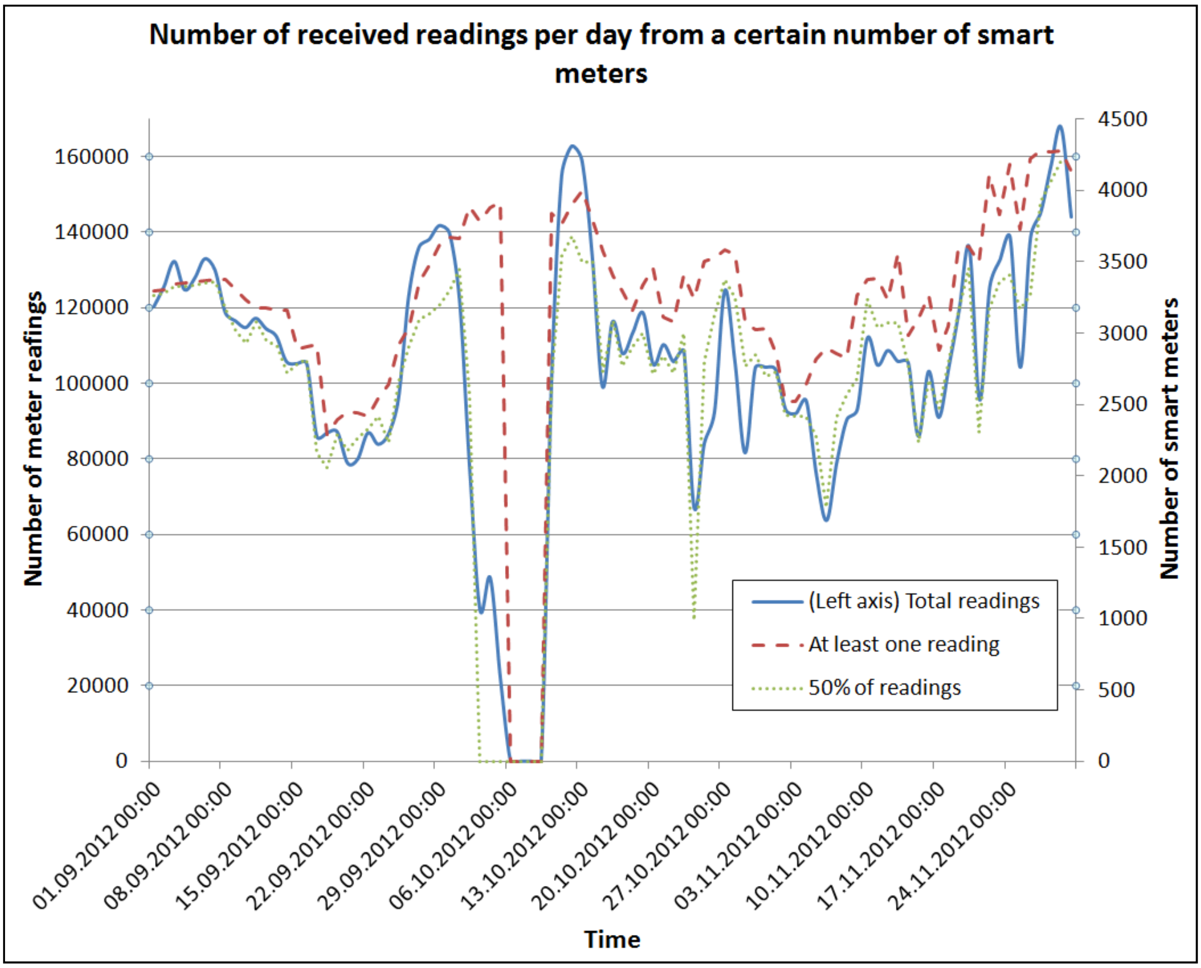


Figure 64 – Quantitatively measuring the collected meter readings in time and the count of smart meters responsible for the collected data

This figure represents the total count of received meter readings per each day of the second part of the project trial. We note that the number of received readings follows (as expected) the number of devices, indicating that the average number of received meter readings per device is quite stable. As previously mentioned, there is a gap of 5 days without received readings.

On the right vertical axis the number of devices with at least meter reading per day is shown. This curve shows that some days, even though the high number of devices was alive (could deliver meter readings), still an overall low number of meter readings was received. We can also see in Figure 64, than 73% of all devices (shown on the figure) have delivered more than 50% of readings during a day. Still for some days (excluding the outfall 6.10.2012 – 10.10.2012), additional analysis on the data revealed that all meters had less than 50% of readings delivered to IEM. This was especially visible before the total infrastructure fallout (which could indicate a warning sign for such events).

Although quality problems are hard to be visualized, Figure 63 and Figure 64 demonstrate QP1 and QP2 and bring to the picture the problem of missing meter readings, which impacts other aspects such as short-term prediction.

The identified quality problems have been motivated by the following facts:

- The infrastructure outfall produced between 6th and 10th October was produced by a failure on the server hosting the service in charge of retrieving data from the smartmeters in Alginet and publishing it via DCP. A problematic software update caused a CPU use of 100% over a period superior to 30 minutes. The server monitoring software automatically suspends the PC when such condition is detected. This issue was produced during a weekend that was followed by a Spanish bank holiday.

- The variation on the amount of data being received each day has several motivations. Since the smartmeters and concentrators being queried are used in a real exploitation system, they have been affected by the natural maintenance works of this exploitation work. In particular, the following issues happened during the trials:

- The communication network of Cooperativa Electrica de Alginet, in which the concentrators are included, was redesigned during the trials. IP addresses of the concentrators were progressively changed, as well as the way they access and get accessed remotely from the internet. Due to these works, concentrators did not communicate with the server in charge of retrieving the data 100% of the time.

- Some of the concentrators have had out-of-order-periods

5.3.4 Value-Added Analysis Example: Voltage Deviation Detection

Finding weak points within an electric grid is a highly complex process, that often involves sophisticated mathematical modelling and intensive numerical computation with large scale data, there many uncertainties and inaccurate factors that come with it [4]. For this reason, the computer-based decision-making systems [6] have become an essential tool for the distribution expansion planning. However, lack of fine-grained network measurements (together with other network information) constitutes a limiting factor. From this example one may estimate how important is the data quality in these scenarios.

Since IEM assured delivery of the smart metering data of the NOBEL trial, detailed measurements (at low cost) may be of significant importance. In [1] it is demonstrated how Voltage deviations, both high and low, within an electric grid can be identified. Although the sampling rate used in the NOBEL trial is low (30 minutes) every sample can be considered to take place within a uniform distribution of Voltage measurements. Larger set of the samples eventually can be used to produce the Voltage probability density function for every measuring point (i.e. smart meter) in the grid.

The deviations outside the boundaries are measured based on the nominal Voltage level 230V ±6%. As an example, the Figure 66 shows that many measurements are crossing the higher voltage boundary (>243,8V), and Figure 66 the lower voltage boundary (<216,2V).

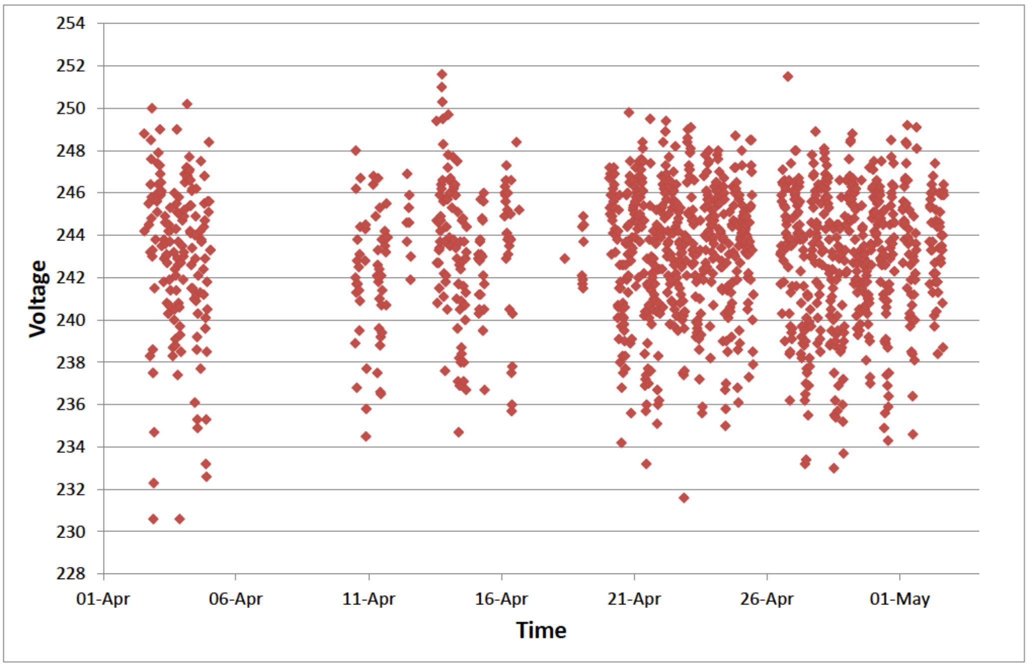


Figure 65 – Example of devices violating the higher voltage boundary

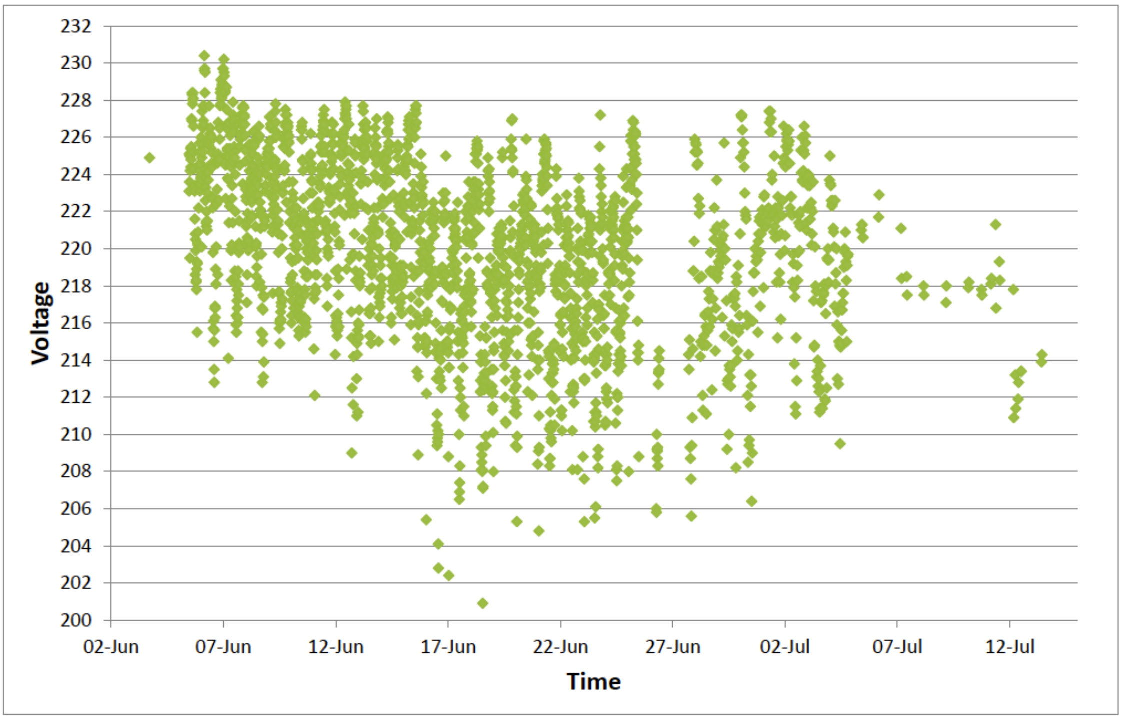


Figure 66 – Example of devices violating the lower voltage boundary

The data covers a period of more than one month and the set contains 1355 distinct measurements in total. Out of these, 617 measurements were identified going over the higher voltage limit, resulting in 45,54% of the measurements outside the allowed deviation zone. This example showed that with a greater resolution on the electricity measurements new insights may be obtained. The entire set for this evaluation holds 4470 smart meters being distributed within entire electrical infrastructure. Although the data set contains a large number of sensing points, the data for each smart meter is not available over the entire spectrum (due to experimentations in connectivity, platform development etc.). Nevertheless, existent measurements were enough to produce the voltage statistics for many devices in distinctive timeframes. Figure 67 depicts statistics for smart meters measuring voltage values beyond the lower voltage regulation.

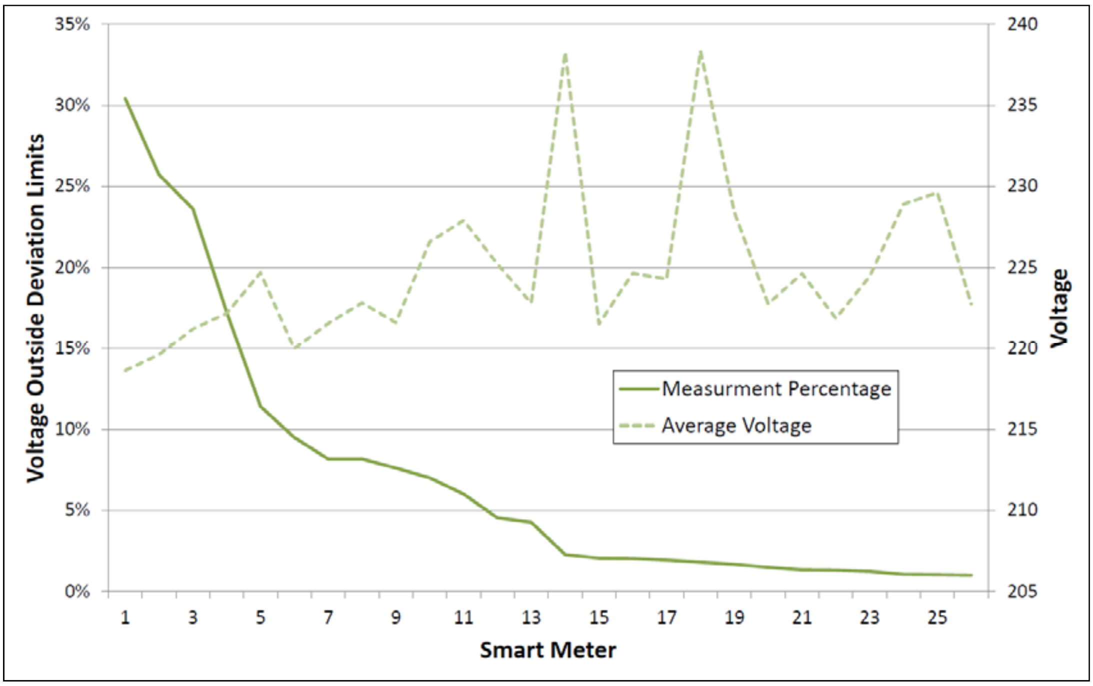


Figure 67 – Sorting smart meters by the violation rate of the lower voltage boundary

The 25 shown devices were selected for having more than 1% of measurements outside the 230V ±6%. They are sorted in function of the percentage of the measurements being outside the voltage deviation limit. The figure also depicts the averaged voltage for each of the smart meters, which seems to correlate with the measurements percentage curve.

Interestingly, the first 5 devices were being identified as having more than 10% of measurements outside the ±6% boundary. If smart meters are not malfunctioning, then the limits set by EN 60038 [7] are probably being violated. Although, remaining points do not seems to violate the specifications of the standard EN 50160, these points should be considered as possible weak points of the network. In any case, the result is that the functionality of the 5 devices should be checked for potential malfunctioning in the next maintenance opportunity, or grid reinforcement should be considered. In the latter case, one has also to carefully consider the identified point in the electricity infrastructure for any future grid expansion planning.

Figure 68 depicts the same as the Figure 67, but for higher voltage boundaries (>243,8V). Sorting is done from the most misbehaving devices to the least ones.

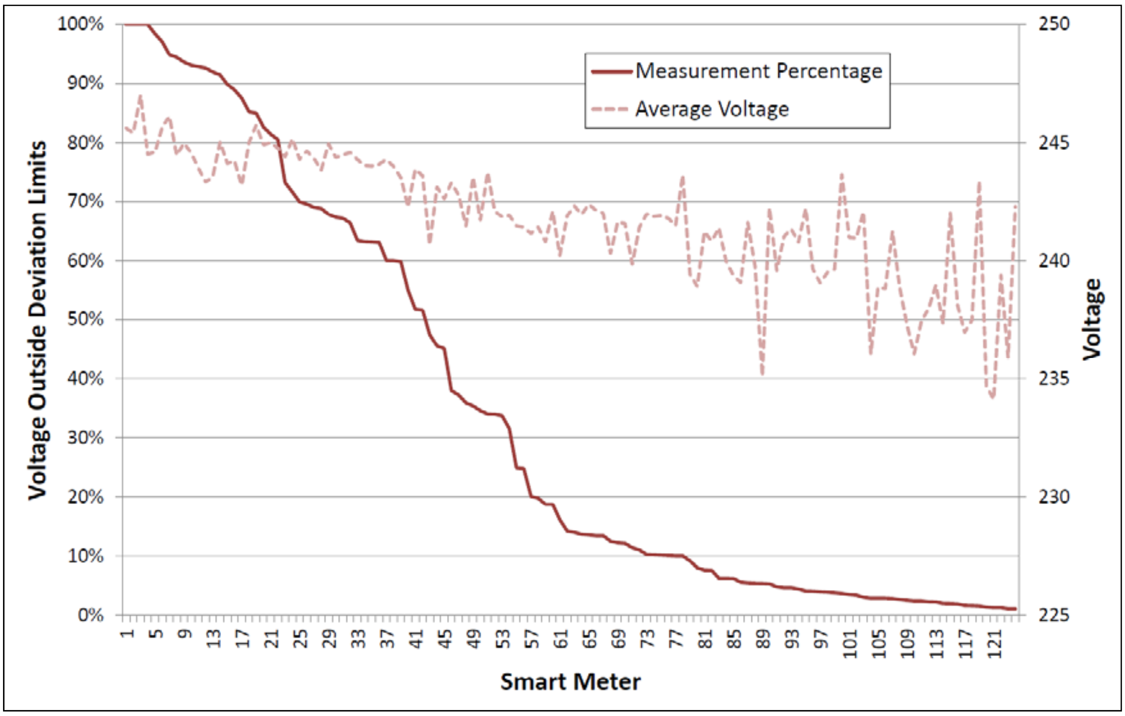


Figure 68 – Sorting smart meters by the violation rate of the higher voltage boundary

In contrast to the previous case, here we had more than 120 smart meters having at least 1% of measurements over the allowed deviation limit. Similarly to the previous case, it seems that both curves, measurement percentage and average voltage, are correlated. We can observe that more than 30 devices are having average voltage outside the limit. Also 80 smart meters violate the maximum voltage tolerance for more than 10% of the time. Indeed from the last example one clearly sees how important is high distribution of the measuring points, measurement quality and their resolution for analysis used by utilities for critical business processes.

5.3.5 Trial Technical Assessment

Within the trial we had the opportunity to evaluate under real conditions several aspects of the IEM platform. The developed services were used by the applications such as NOEM, BAF, and partly NOPL, an analysis of which is depicted in other sections of this document; here we focus on the core service evaluation aspects.

SLOC	Directory	SLOC-by-Language
20385	IEM	java=19817,xml=530,sh=27,jsp=11
9321	Market Sim	java=8767,xml=554
3014	Market Core	java=2982,xml=32
2246	NobelUtils	java=2167,xml=79
1068	ProductionSimulation	java=808,xml=260
910	Market-Entity	java=898,xml=12
808	Market-Kernel	java=796,xml=12
608	TimeSeries	java=597,xml=11
457	EnergyLoadSampler	java=364,xml=81,jsp=12

SLOC	Directory	SLOC-by-Language
388	GenerationMix	java=243,xml=145
234	Market Core Client	java=217,xml=17
108	Market Configuration	java=96,xml=12
85	Market Verification	java=73,xml=12
65	GoogleProtoBuf	xml=65
21	Market Time	java=16,xml=5

Table 48 Overview of IEM code statistics

Table 48 provides an overview of the current IEM source code snapshot as it is calculated by David A. Wheeler's '*SLOCCount*'. An indicative development cost is also given in Figure 69.

```
Total Physical Source Lines of Code (SLOC)                = 39,718
Development Effort Estimate, Person-Years (Person-Months) = 9.55 (114.59)
(Basic COCOMO model, Person-Months = 2.4 * (KSLOC**1.05))

Schedule Estimate, Years (Months)                         = 1.26 (15.15)
(Basic COCOMO model, Months = 2.5 * (person-months**0.38))
Estimated Average Number of Developers (Effort/Schedule)  = 7.56

Total Estimated Cost to Develop                           = $ 1,289,966
(average salary = $56,286/year, overhead = 2.40).
```

Figure 69 - Estimated IEM Development statistics

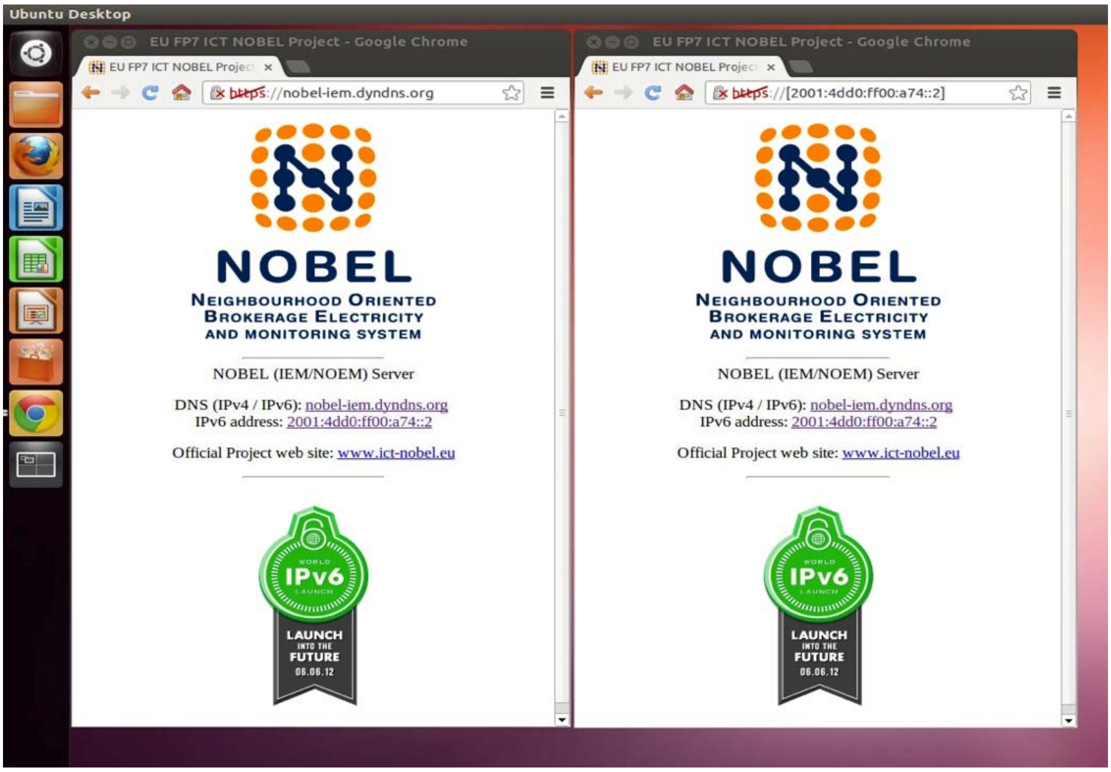


Figure 70 - IPv4/IPv6 support for IEM services

The IEM has been realized to support from day #1 IPv6, as shown in Figure 51. Hence its services were made available over IPv4 and IPv6, depending on the capabilities of the client. The IEM server successfully took part in the IPv6 day in June 2012.

Assessment of the actual server usage is made primarily via multiple log files (on application server, operating system, other utilities etc.) that have been analysed to collect information and stats shown on following graphs.

5.3.5.1 Service Request Analysis

Following the detailed specification of the IEM services as described in deliverable D4.3 [11], one can expect a different degree of utilization of them, depending on the core functionalities needed. The latter is also depicted in the following graphs, e.g. the utilization is shown via the number of service requests during the trial. Every service category is counted separately by the RESTful web service methodology i.e. through the assigned methods of the HTTP protocol. On the Figure 71 all services (for each of the 7 service categories) are merged and categorized in DELETE, GET, POST and PUT methods. The figure represents total number of requests from any invocation party e.g. service testing, NOEM, BAF). Due to the fact of the extreme difference in utilization, the vertical axis in Figure 71 is using the logarithmic scale. This graph does not give any result on the I/O requirements of the backend, but it is showing the distribution of any interested party for service invocation.

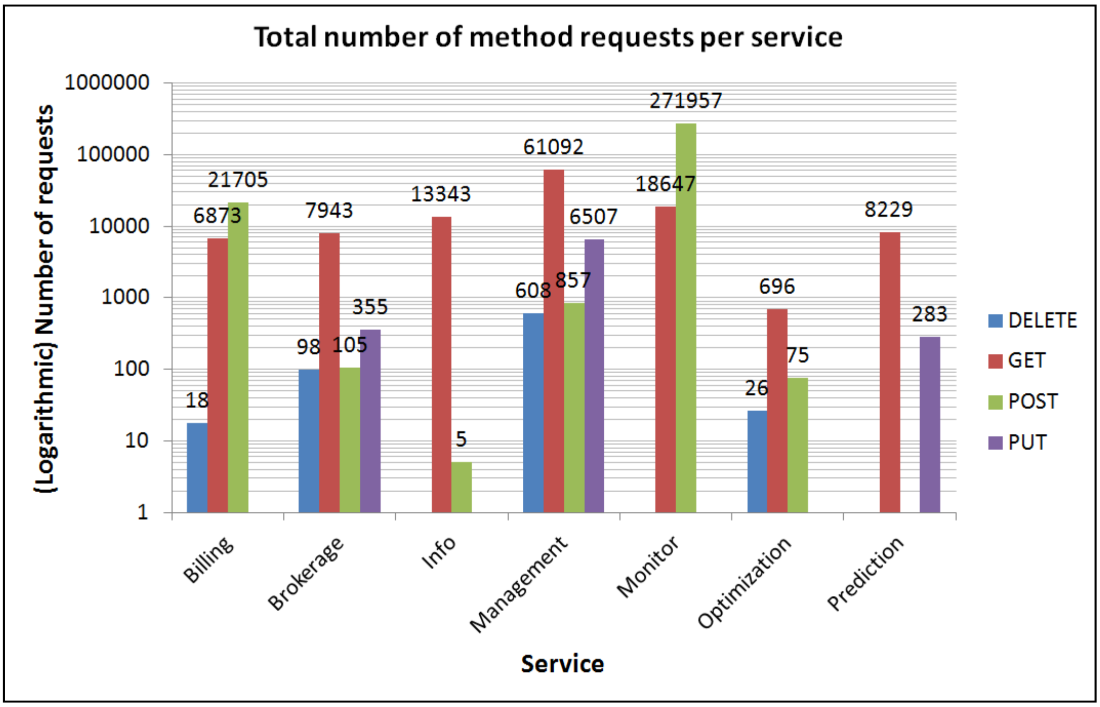


Figure 71 – Total count of categorized service invocation for different RESTful methods

The POST method for Monitoring services (or RESTful create) resulted by far over all the other services. This behaviour was expected since smart meter data has been streamed to the monitoring services. Interestingly the Billing service had a lot of POST requests, but further analysis revealed that this high number of requests was due the contract creation and their assignment to the customers (configuration for all customers).

All the service categories depicted a high number of requests for the GET method. From overall observation of the Figure 71 one can conclude that Management, Brokerage, Monitor and Billing services had the lion's share on usage. Similar is the behaviour depicted in Figure 72 where one can see the categorization per application. However in Figure 72 requests relevant to development and testing are not included.

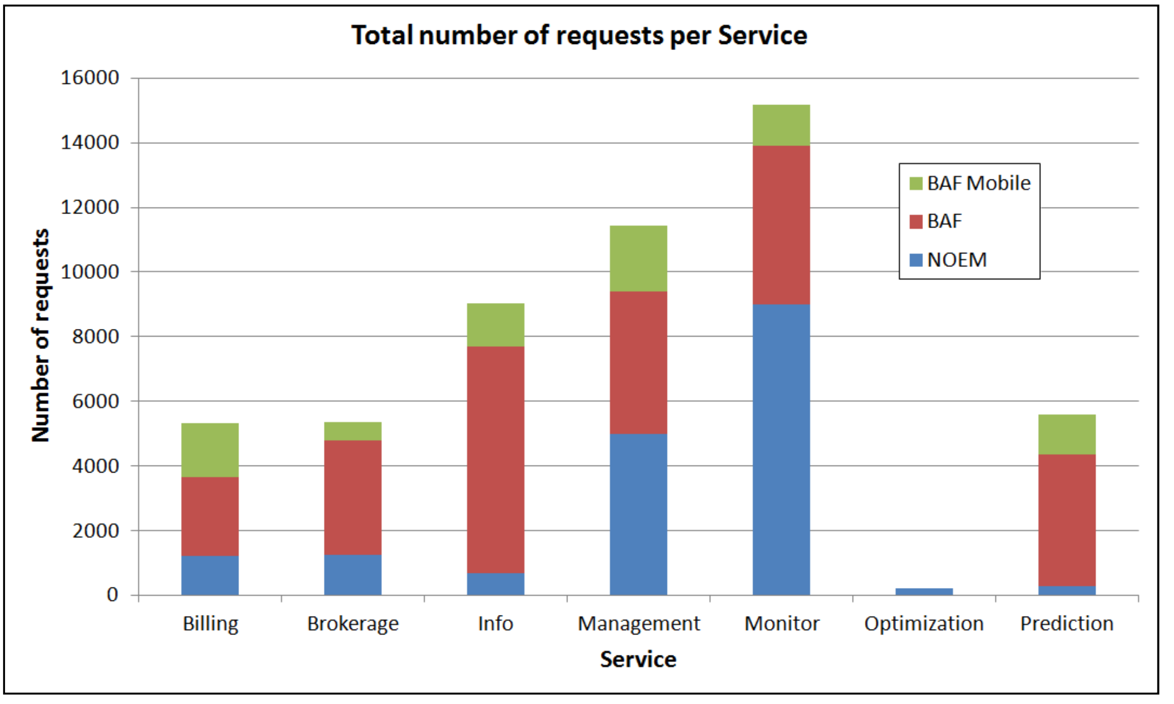


Figure 72 – The categorized service invocation count by all frontends

Figure 72 offers a view also on the way the different applications were designed. For instance the increased Management requests can be traced back to the authentication process during the log-in. Also the services that by default were queried on the opening screen of the application, led to the increased service usage.

A service invocation as depicted in the aforementioned figures, does not imply that that invocation was always successful (e.g. error or service misuse). All three frontend initiated requests, together with the development and testing, resulted in total of 420 000 service requests. Since the RESTful web services employ HTTP protocol, further analysis was made on the server response codes. These are classified as following:

- Success
  - 200 OK
  - 201 Created e.g. new customer created
  - 204 No Content e.g. if meter readings do not exist for a given timeframe
  - 412 Precondition Failed e.g. a prediction algorithm cannot be calculated without input of 4 week meter readings
- Unknown request
  - 404 Not Found
  - 405 Method Not Allowed e.g. deleting the total consumption which is automatically calculated from the received measurements
- Security issue
  - 401 Unauthorized
  - 403 Forbidden
- Misused service
  - 400 Bad Request e.g. incorrect input parameters
  - 406 Not Acceptable e.g. input parameters are not acceptable
  - 409 Conflict e.g. creating a device with already used identification
- Server error
  - 500 Internal Server Error i.e. service failure

Such analysis offers us better understanding of the service robustness and results are shown on the Figure 73.

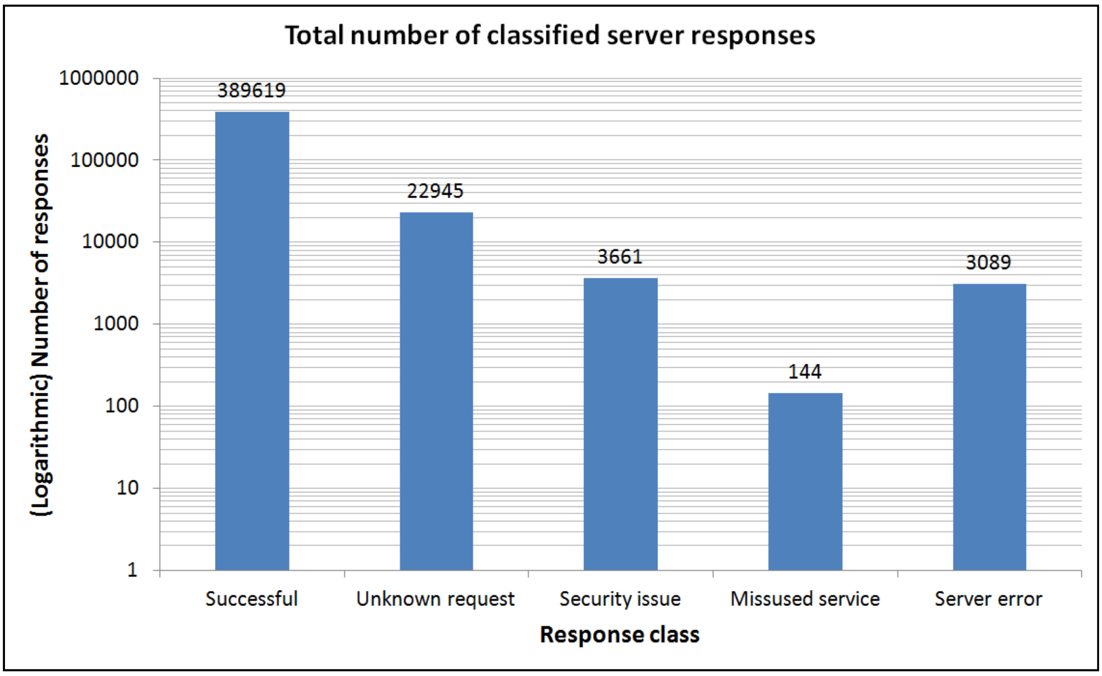


Figure 73 – The service robustness by HTTP response code classification

The service implementation can be considered as robust, since the majority of requests resulted in more than 92% on successful responses. Although the 'Server error' count resulted in less than 1% (0,7%), such a low percentage was quite surprising due the complexity of the services and the expected load. Of interest was also the results of the 'Misused service' classification, which revealed that even for adjustments done during the trial, new functionality could be integrated to the applications with minimal effort. We attribute this to the incremental development style as well as the extensive and up to date documentation as depicted in the living document D4.3 [11].

5.3.5.2 Service invocations by country

The IEM services were expected to be consumed during the trial, mainly from Spain where the trial was running and Greece (where the BAF portal was located), as well as Germany who were heavily involved in development and testing due to the IEM services and NOEM application. This is also depicted in the service invocations per country as identified by combination of IP addresses and whois (RFC 3912) registry information, and shown on **Figure 74**.

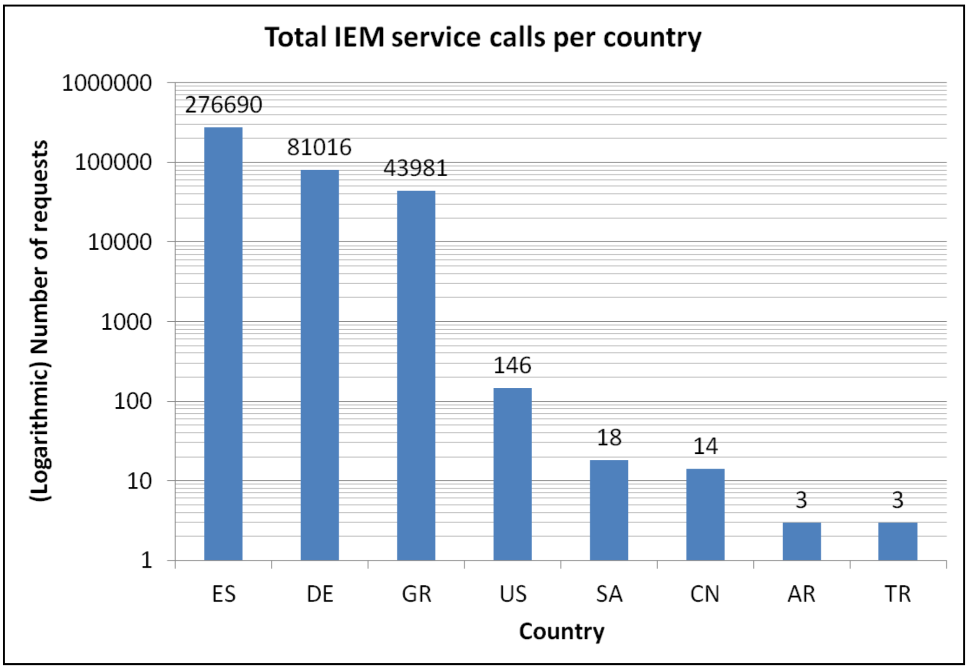


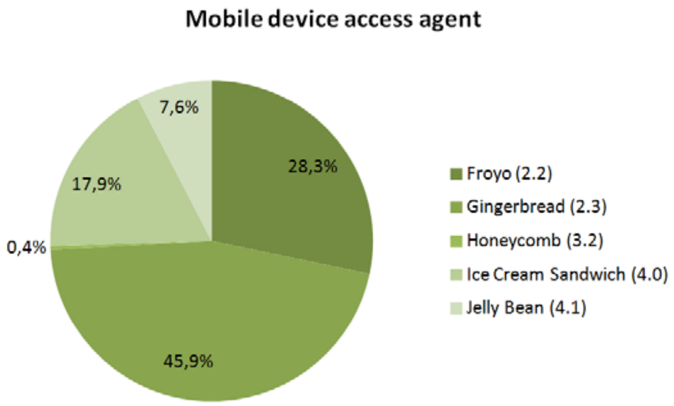
Figure 74 – Total invocation count of the services by origin country of requests

Although the project trial was running in Alginet (Spain - ES), it was not expected to have an overwhelmingly high number of services being invoked from Spanish IP addresses. This is due the fact that main frontend applications (BAF and NOEM) were running on application servers hosted on partner's premises i.e. BAF in Greece and NOEM in Germany. The mobile version of BAF of course resulted in requests originating from the country that the mobile device was logged in at that moment.

Additional analysis revealed that BAF Mobile is responsible for approximately 1% of requests from Spain, while approximately 98% of requests were invoking the monitoring service for data collection e.g. smart meter energy and other readings. Still these results are fully conceivable since the DCP root unit was deployed on the Spanish network (City of Alignet). This unit was simply responding to the subscription initiated by IEM to stream the trial smart metering data to the monitoring services.

5.3.5.3 Mobile Device

On the NOBEL survey [5] we discovered that energy consumers are interested in visualization of their energy data on personal mobile devices. The same can be witnessed in Figure 72 where one could see the significant percentage of service requests coming from mobile devices, i.e. android devices where the BAF mobile was offered. On Figure 75 service invocations are grouped by versions of the Android OS.



Version	Codename	API	Distribution
1.5	Cupcake	3	0.1%
1.6	Donut	4	0.3%
2.1	Eclair	7	2.7%
2.2	Froyo	8	10.3%
2.3 - 2.3.2	Gingerbread	9	0.2%
2.3.3 - 2.3.7		10	50.6%
3.1	Honeycomb	12	0.4%
3.2		13	1.2%
4.0.3 - 4.0.4	Ice Cream Sandwich	15	27.5%
4.1	Jelly Bean	16	5.9%
4.2		17	0.8%

Figure 75 – Service invocation from BAF Mobile divided by Android version and compared to the Dec 2012 Google Play distribution[3]

The Gingerbread version was used to almost half of requests (45,9%), which is in line to the world-wide statistics obtained by GooglePlay (as shown in Figure 75). The second ranked (with 28,3%) Froyo version is three times over the global distribution (of 10,3%), however this may be attributed mostly to the devices available for testing and demonstration. Interestingly enough, even the latest versions of Android are depicted e.g. Jelly Bean, which indicates the existence of some tech-savvy users that upgraded their mobile devices such as tablets and mobile phones as soon as the OS version was available (for Jelly Bean July 2012).

5.3.5.4 Server Resource Utilization

During the trials, the IEM which provided the services for all applications in NOBEL was hosted in an online SAP server farm. The configuration was moderate equipped with a dual-processor multi-core machine, 8 GB RAM and 150GB disk space. The server was reachable only via HTTPS running on port 443, and behind the enterprise firewall.

We provide here some indicative graphs showing the normal daily operation of the server, and the impact on its resources. All of the charts depicted refer to a single example day, and the behaviour is more or less similar in other days.

[3] http://developer.android.com/about/dashboards/index.html

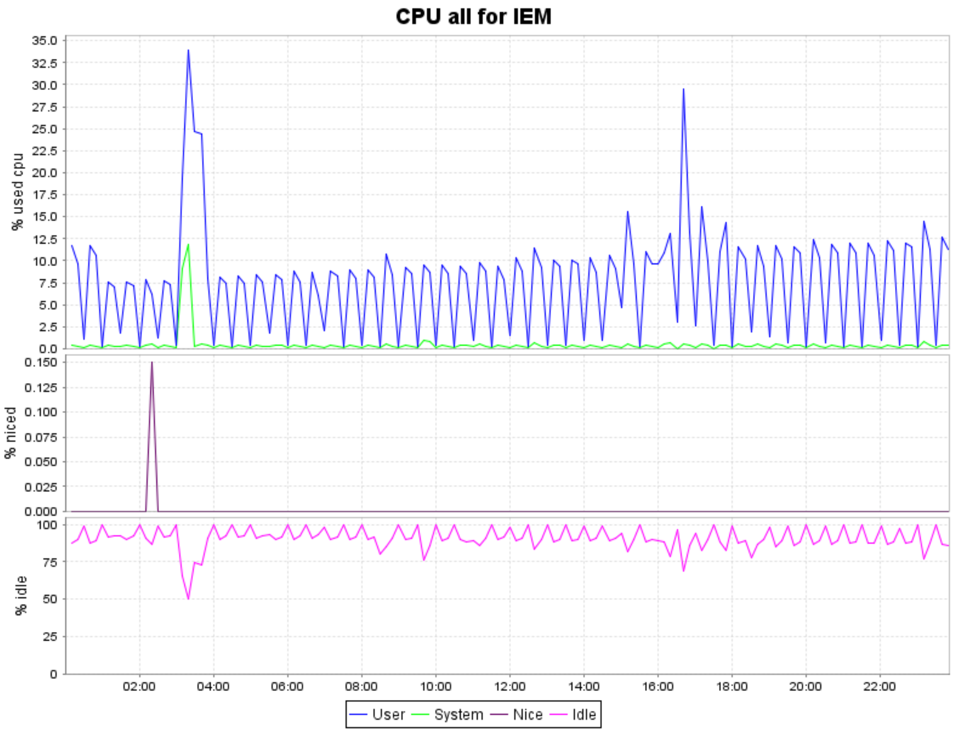


Figure 76 – Server combined CPU utilization (typical day)

Figure 76 shows that the CPU usage is moderate with some minor exceptions. The high levels of being idle indicate at first that potentially less horsepower would also be enough. However a more intense usage of the IEM services e.g. by a wider mobile BAF deployment would increase the CPU requirements significantly.

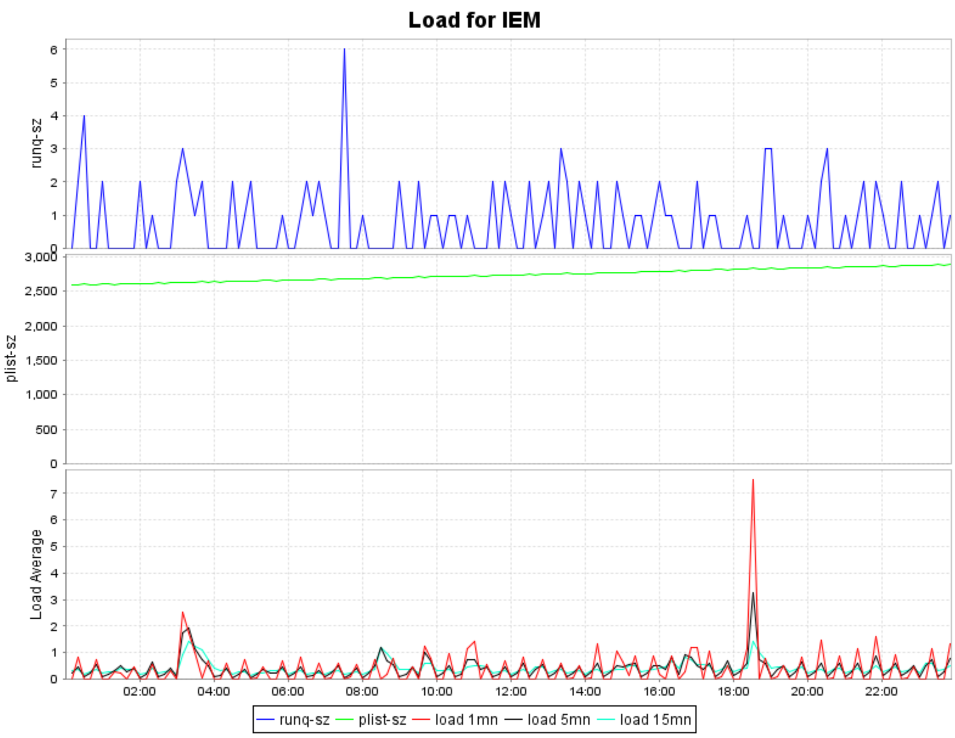


Figure 77 – Server Load view (typical day)

Figure 77 shows some info on the load, and considering our multi-CPU system, the graph reveals that usually mostly 1-2 of them were used with some exceptions.

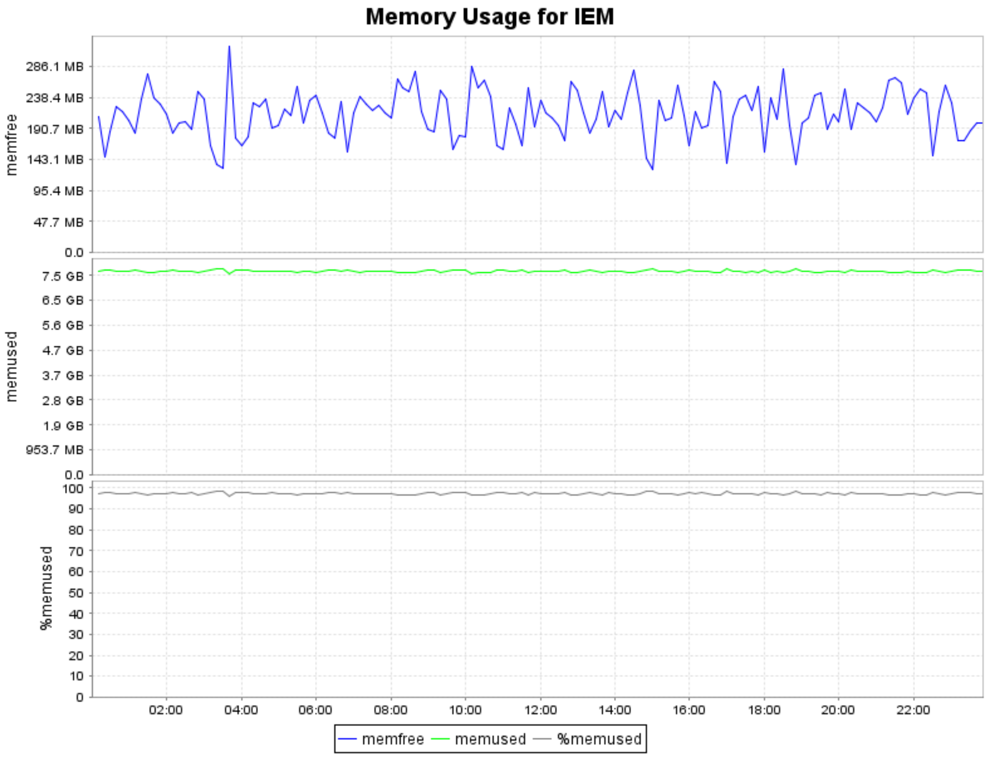


Figure 78 – Server memory usage (typical day)

Figure 78 shows the memory usage and the available free memory. We see that 8GB were used almost to the limit, and such multi-faceted functionalities as the IEM provides, especially the ones that do analytics, require more available memory.

5.3.5.5 Database statistics

The IEM server heavily relied on the database (DB) in order to hold all trial data. We provide here some statistics in order to show how our existing configuration related to the load induced during the trial. We have to mention here, that no optimizations have really been done on DB level, and many of our decisions where motivated rather by a learning interest and experimentation rather than rely on well-known tactics.

The entire DB requires 6,1 GB of hard disk space spread over approximately 40 different tables. We firstly identified the most space-consuming tables within the trial. Since the project trial features more than 5000 consumers (and even more distinct devices), the values on **Figure 79** are shown in percentage to the total DB size. Using these percentages one can estimate DB requirements for a future large-scale solution, as well as get a notion where good design decisions are required e.g. space or performance wise.

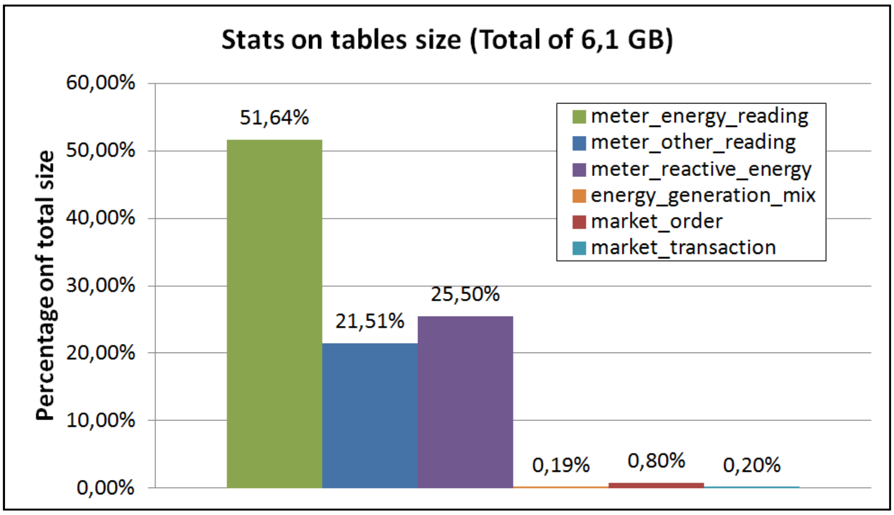


Figure 79 – The six most space consuming database tables of the trial

Interestingly Figure 79 reveals that 98,65% of the space was dedicated to the meter readings. Here three different readings per meter are shown: energy reading, levels of reactive energy and other relevant readings (such as Voltage, Power, etc.). All the rest of the 37 tables consumed only 1,35% of the total space.

The SQL queries executed during the trial i.e. Create, Read, Update and Delete (CRUD) operations are shown in Figure 80. As expected the biggest part is devoted to storage of data, as well as acquiring information from the DB.

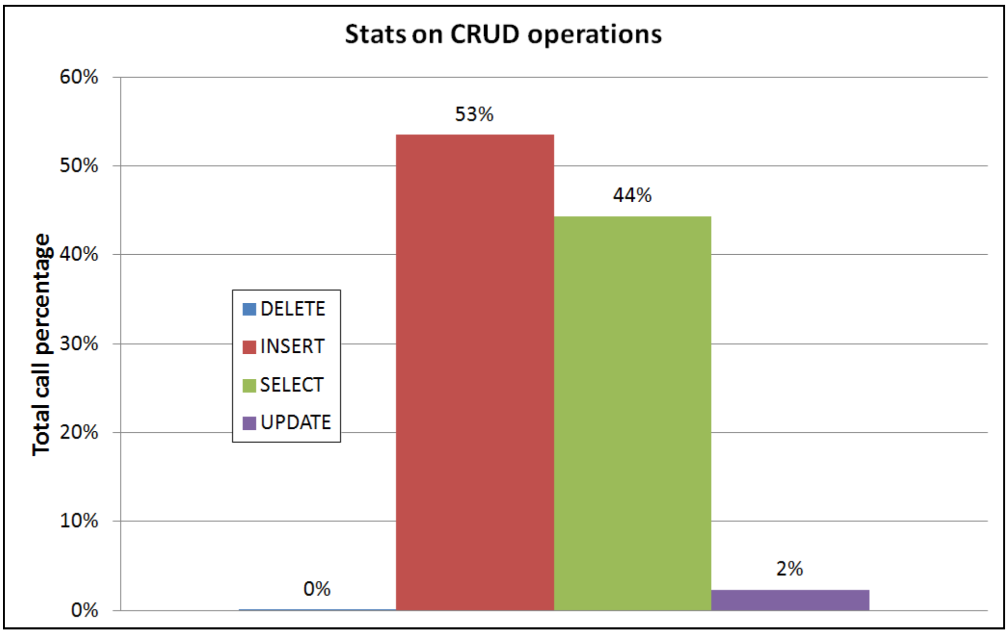


Figure 80 – Understanding the CRUD behaviour of the database

Since the combined tables for smart meter measurements are responsible for the DB size (as shown in Figure 79), it is not surprising to have such a high percentage of SQL INSERT queries. What is interesting is the high usage of the collected data. This was also validated by measuring the number of bytes exchanged i.e. bytes received at DB vs. bytes extracted from DB as depicted in Figure 81.

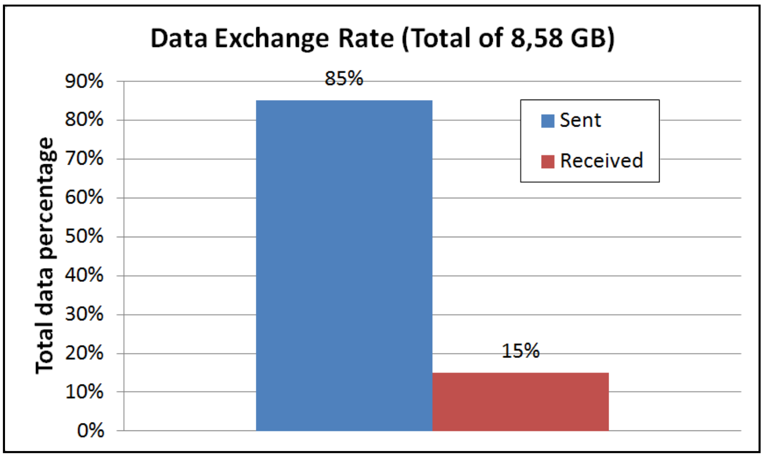


Figure 81 – Quantitative comparison of the DB data exchanged

Although **Figure 80** depicts high percentage of executed INSERT queries, further analysis revealed that every SELECT query in average resulted in almost 7 times more data (bytes) then INSERT. More specifically, 8,58GB was exchanged in total with an average SELECT of 4880 bytes and an average INSERT weight of 710 bytes.

From the data in Figure 80 and Figure 81, we can for instance consider that a real-world system implementing the functions offered by IEM should be able to handle increased incoming load while the actual outgoing load depends on the end-user application request rate. However, both incoming and outgoing data rate could be estimated based e.g. on the density of data metering or other information acquisition as well as functionality offered at the end-user application side.

The communication part does not really offer an insight on the server load. Especially when a simple service invocation might result in spikes in the server load due to massive data acquisition and analysis while the final transferred result may be of little bytes. Typical example might be the analytics over historic data that spawns a custom-defined timeframe of several weeks. Hence, careful design at DB level should consider the expected data flow as well as the service offering and restrictions on their functionalities.

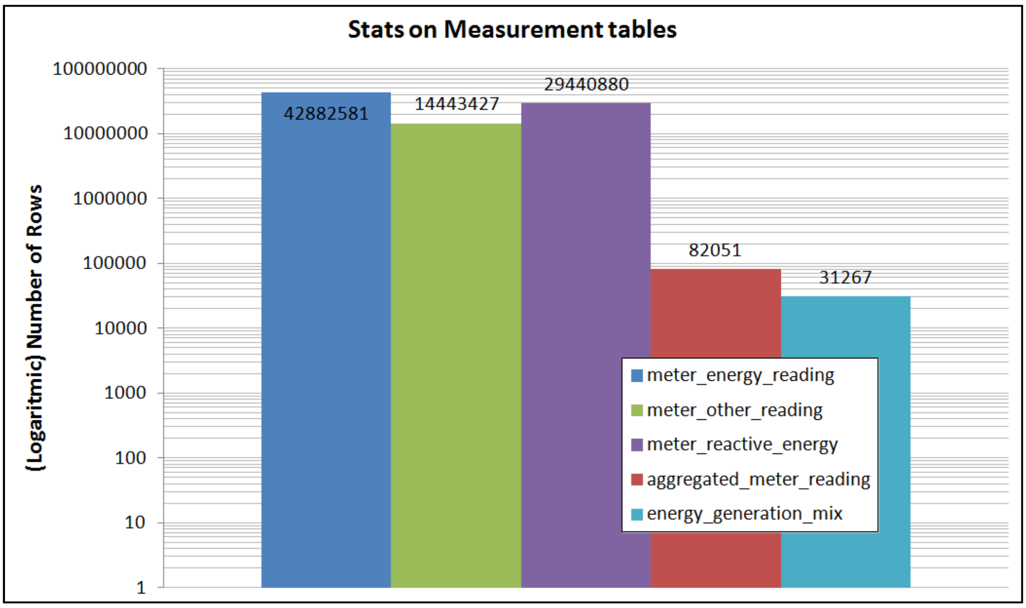


Figure 82 – Collection count of smart meter data and other energy related information

Figure 82 depicts the impact of meter data on the DB rows. It is important to notice that every row of the 'meter_energy_reading' contains value for only one metering register; however as some meters have a production register too, this introduces an additional row in the table. Interestingly we observe that the aggregation of the 15 minute energy consumption data, has 500 times less rows than energy measurements, which is an indicator of the data quality issues raised in the Data Quality Assessment part (section 5.3.3). This difference does not necessarily mean that meter readings are missing, but many other factors may impact this e.g. different meter reading resolutions, etc.

The Brokerage activities were also analysed as being in top 5 space consuming tables of the trial database. Figure 79 shows that 0,8% of the space was consumed by 'market_order' table and another 0,2% by the 'market_transaction' table (in total both tables were only 62 MB); details are shown on the Figure 83.

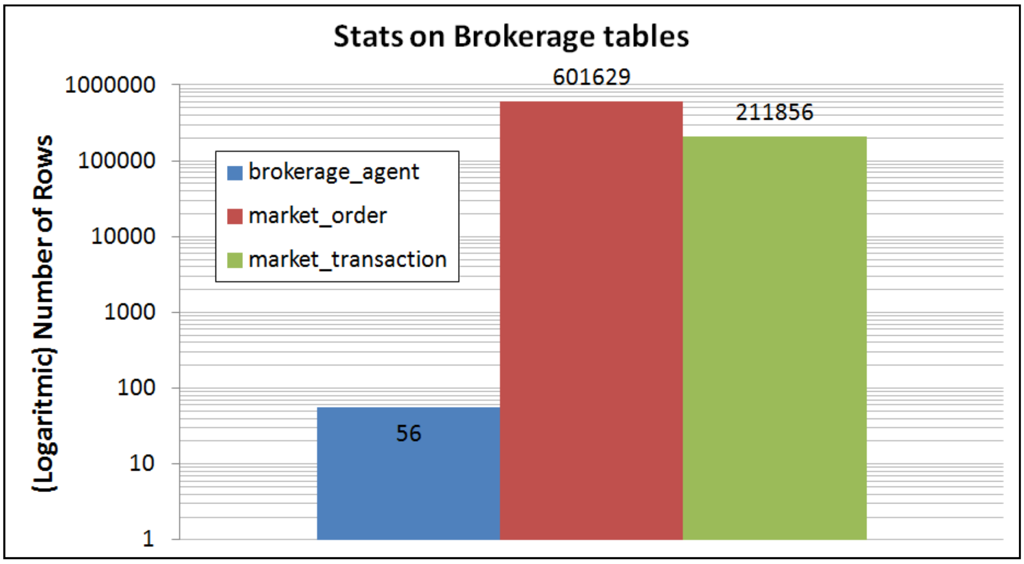


Figure 83 – Count on brokering activities

The table 'brokerage_agent' actually represents the number of existing Brokerage Agents (BAs) that act on behalf of the market participants. However these BAs are not necessarily active and their population depends on the participant's willingness to do automated trading (via the BA). We have witnessed within the trial an average of 10732 orders for each BA. Since every day contained 96 time slots for trading, it can be assumed that the number of orders (per each BA) is approximately constant (for the trading of within 4 months).

The security tables (shown on the Figure 84) provide a view on the authentication and authorization needs. Within the trial 45 different service access permissions were required, while 8 roles e.g. market participant, administrator, customer, etc. were defined in order to apply role-based authorization.

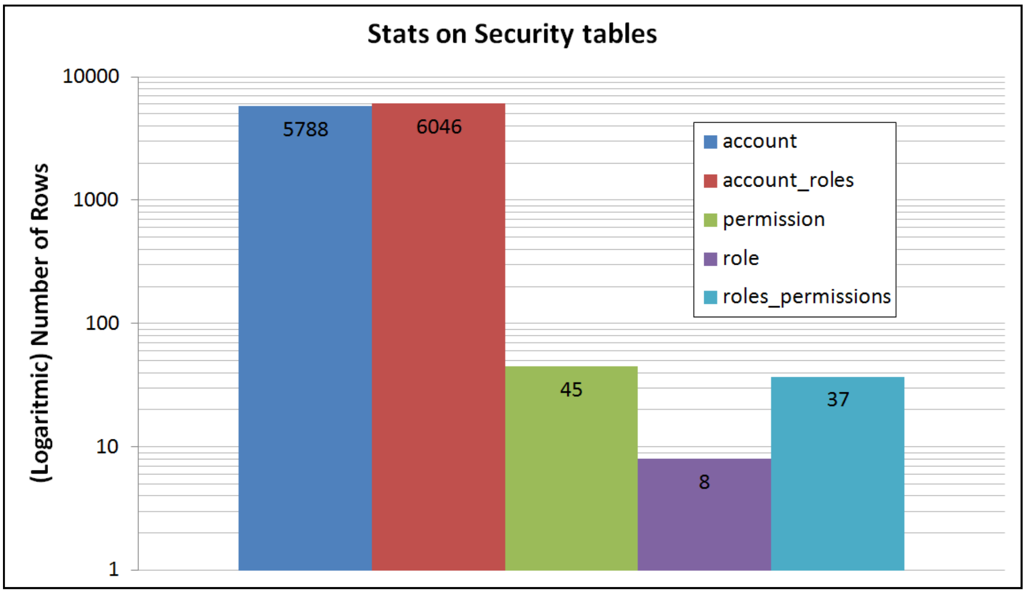


Figure 84 – Count in tables used to run IEM security

5.3.5.6 Service Performance

The host platform for the IEM services plays a key role on their performance. IEM has been designed to run on a distributed infrastructure and all of its components could (if wished) be installed in different systems (communication is done via REST for all interactions) with different computational, storage and communication capabilities that correspond to the expected load for those parts. We would like to mention again that our hardware configuration was moderate and no really optimisation techniques have been applied as mostly default configurations were used.

Optimisation in any aspect results as expected in better performance for the respective service. As an example, frontend applications located near (network-wise) to the IEM application server resulted in better response times due the higher network throughput; similarly mobile devices over unstable or low-bandwidth links were performing less than expected, especially when significant amounts of data had to be transferred via the network. The response time is measured from initialization of the request until the reception acknowledgment from the requester's side. Of course, there is also a dependency on how and which services are used and the amount of processing requested on the servier side as well as the data to be transferred. e.g. typically management tasks in the NOEM include visualizing hundreds or thousands of devices and customers, while single-user applications like BAF are invoking services for visualizing a single (the actual) client and few devices he owes. The payload of these two responses may differ more than 5000 times. Under these considerations, Figure 85 provides an insight on the performance measured for each frontend during the trial.

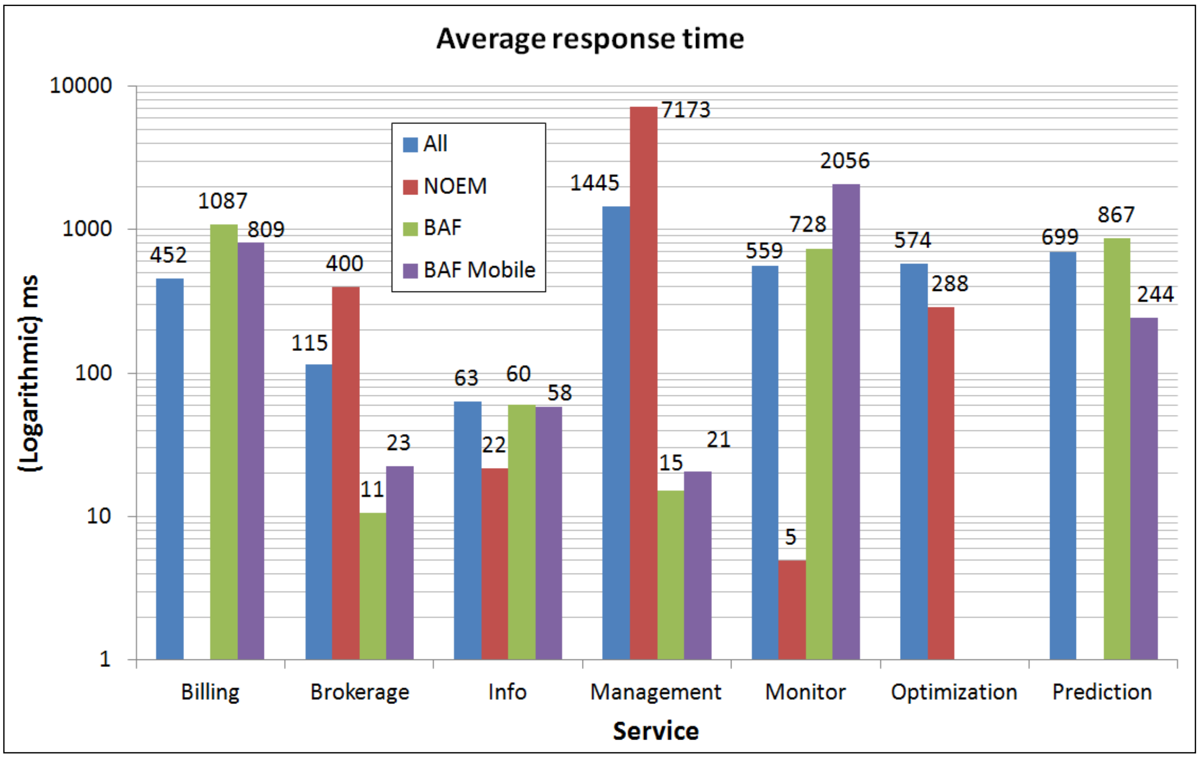


Figure 85 – Average response time per requester type for all type of services

Figure 85 depicts the average of all the requests (per Service category) coming from all frontend application in the project and also an average of all the requests received. One can see the different service behaviour under the considerations we mentioned. For instance the Monitoring services would be expected to have similar response times for all front-ends but since the NOEM web app was co-located with the IEM, there was no network delay; hence large chunks of data could be exchanged at a fraction of time it would have taken to transport them over multiple network hops.

The usage of the Management services indicates a high response time for requests coming from NOEM; however this can be fully justified as there are more the 5000 devices and more than 5000 customers, which would result in significantly higher payload transfer for Management services called by NOEM than the ones called BAF (where mostly operations were dealing with a single device). The same logic applies to other services like the Brokerage services.

5.3.5.6.1 Billing service performance

An overview of the service usage is depicted in Figure 86. As we can see 3 interesting cases were found and usually their performance depends on the DB optimization e.g. using indexes etc.

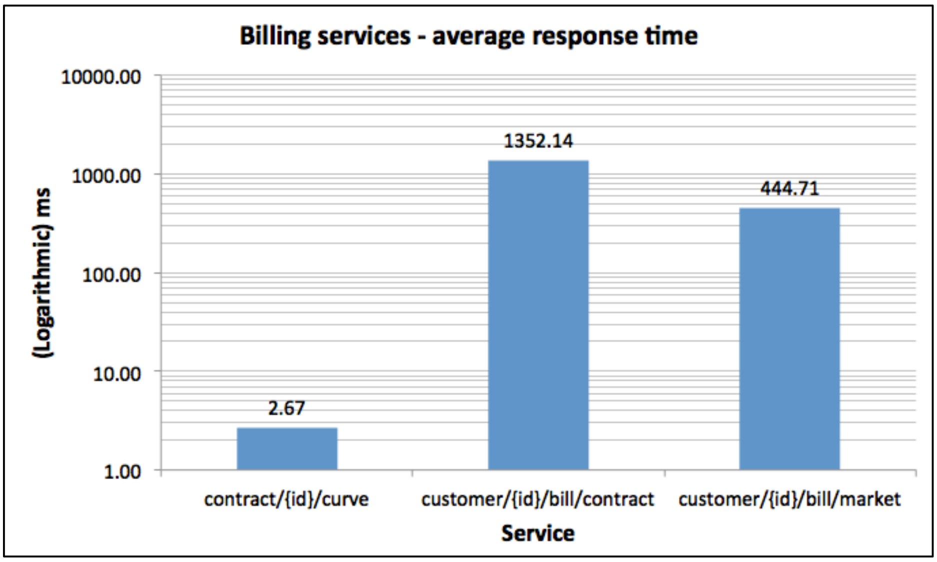


Figure 86 – Response times for the most consumed services of the billing category

From Figure 86 we can see for instance that to get the Price curve of a contract took in average only 2,67ms. Other operations e.g. the billing based on the contract (middle bar) was only 3 times slower then market billing (right bar), especially when considering the amount of data that had to be acquired and analysed as depicted in Figure 82 and Figure 83.

5.3.5.6.2 Brokering service performance

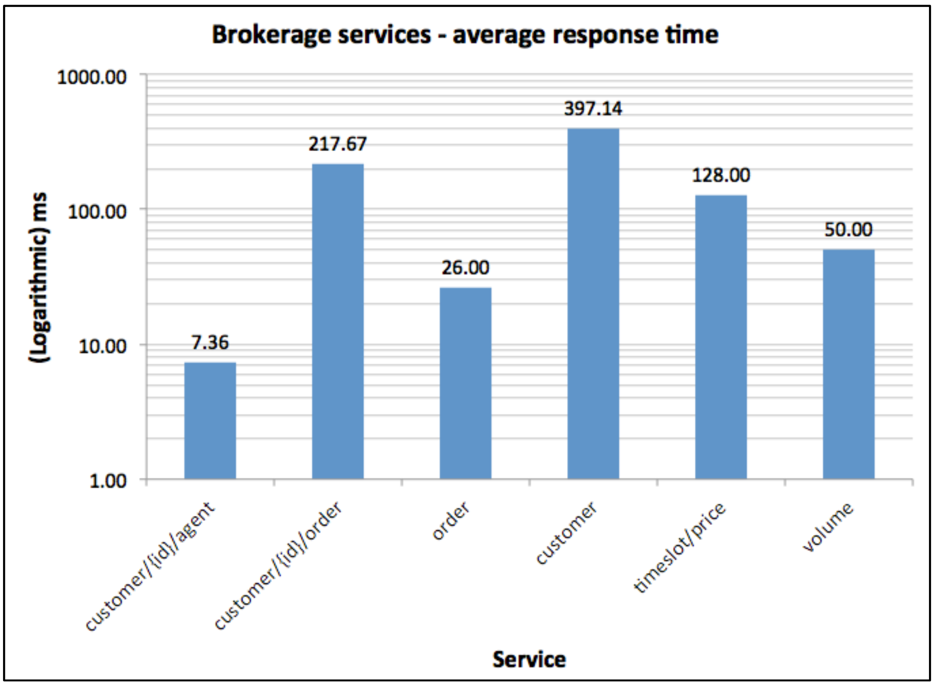


Figure 87 – Response times for the most consumed services of the brokerage category

Figure 87 provides an overview of the performance of the brokerage services. One interesting aspect is that the service fetching the orders of a specific customer (second bar) is slower in the response time than the service returning all the orders (third bar). Further analysis showed that the actual usage of the service from the client application introduced these delays (inefficient use of the service). The customer order service was not consumed with the time window parameter (TW) as advised in the deliverable D4.3 [11], but the application developers rather called the generic version of it (without parametrization) which resulted to delivering all customer's orders (and then we assume these were filtered on the application side). This is highly inefficient and has brought into attendance, the gap between introducing new functionality on the server side and having the developers on the client side taking advantage of it and not put down anything that "just works". To this end, for a system to be as high performing as possible both sides need to be in sync.

We additionally see that generally the timeslot/price and volume services had high performance times (compared to the rest), however they should be clearly much more optimized if they are to be part of a real-world stock-exchange like infrastructure where low execution times result to monetary benefits.

5.3.5.6.3 Information service performance

In D4.3 [11] one can see that Information services offer constrained functionality (as proof of concept) in comparison to the other services. For that reason, in the Figure 88 only two most frequently consumed services are depicted.

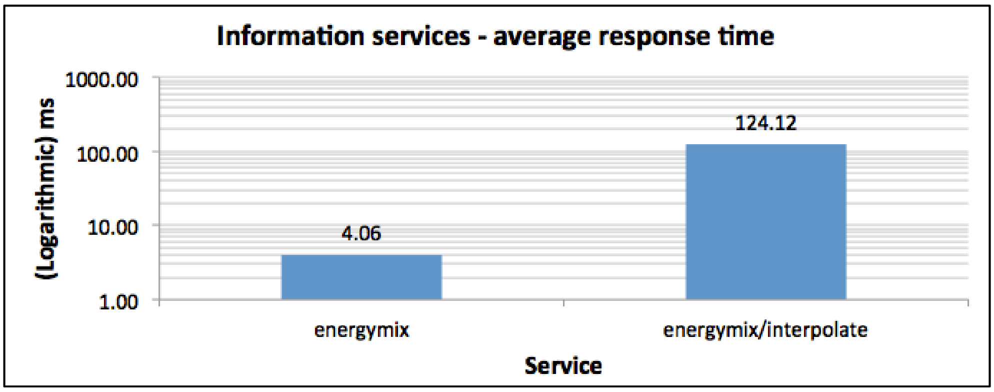


Figure 88 – Response times for the most consumed services of the information category

Both services were equally important (if judged by count of invocations) and highly consumed mostly by the BAF (as we can see in conjunction with Figure 72). We can note that the creation of curves for every generation source and its interpolation need to be optimized due to the high invocation frequency. The data of this service allow pre-processing, and hence optimisation can be made.

5.3.5.6.4 Management service performance

As we have already seen in Figure 71 and Figure 72, Management services were one of the most frequently service category. A detailed analysis, on frequently used management services is depicted in Figure 89.

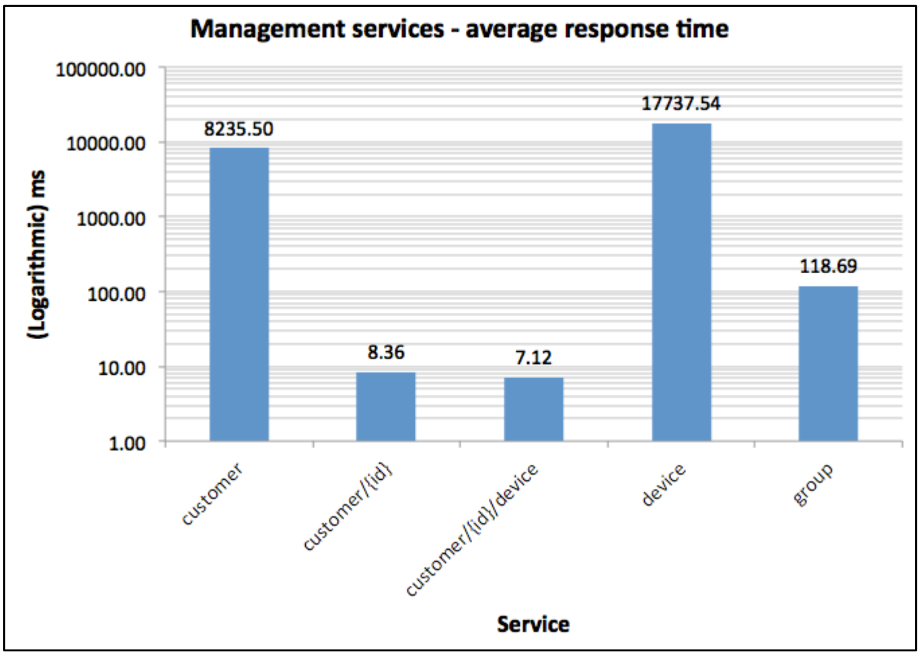


Figure 89 – Response times for the most consumed services of the management category

Obvious bottlenecks can be identified i.e., when invoking the service for all the customers (1st bar) and all the devices (4th bar). Even though light versions of these services were designed and implemented in the trial, the response times are too high. It is unclear whether the delay is affected by the data fetching time or the composition of the Google Protocol Buffer (GPB) message. Since experiments showed good performance with almost 10,000 times bigger tables, the delay might be attributed to the composition of the GPB messages or to the Java Persistence API (JPA). In our implementation there are JPA dependencies of the entities i.e. almost every device has location and information entity attached to it. If the light version of the service is not used, it is expected that Hibernate accesses in total 3+ tables through the DBMS. These two services are considered as two most critical points of the IEM optimization.

5.3.5.6.5 Monitoring service performance

Monitoring services were the most invoked ones during the trial. An overview of their response times is depicted in Figure 90.

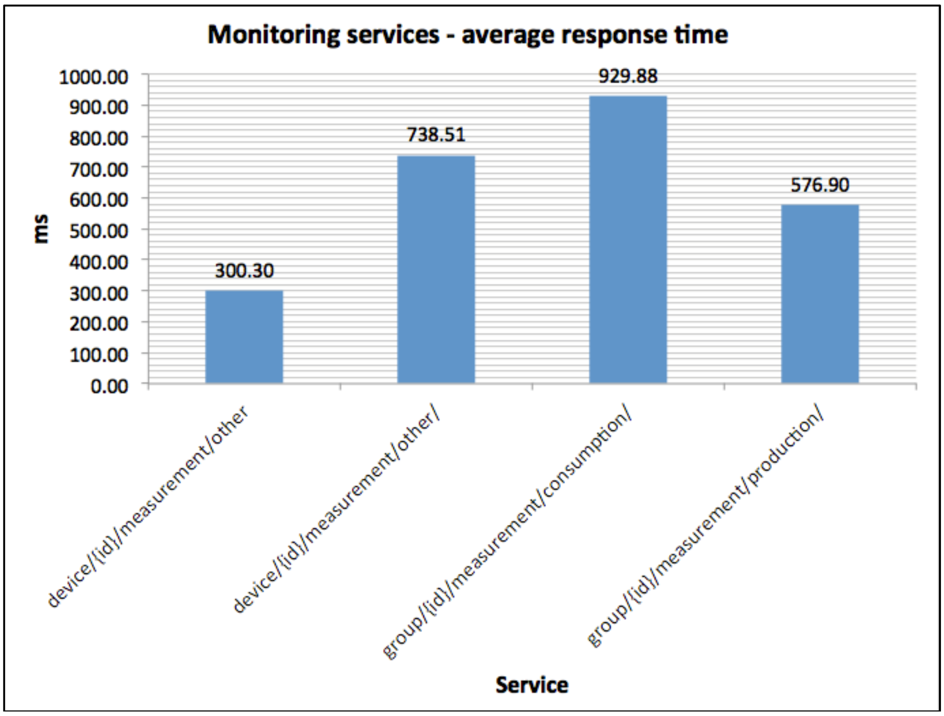


Figure 90 – Response times for the most consumed services of the monitoring category

Only one interesting fact was noticed, the difference between consumption and production. Since both, production and consumption, share the same DB table, it is expected to have similar response time. However results of the trial showed that these services were totally differently used. The difference in response time mainly comes from the fact that service consumers were more interested in the consumption readings and they analysed/visualized them over longer time periods. For example, most of the users wanted to see their monthly or weekly consumption, while production was rarely accessed on such a long time frames (it was rather used only for daily slots). Since for the trial the production was simulated (virtual PV panels for market participants), it seems that the actual virtual PVs were of less interest to the trial participants.

5.3.5.6.6 Optimization service performance

The optimization service is a collaborative one that does not depend only on the IEM side but also on the counterpart running on behalf of the prosumer. An overview of the average response time is seen in Figure 91.

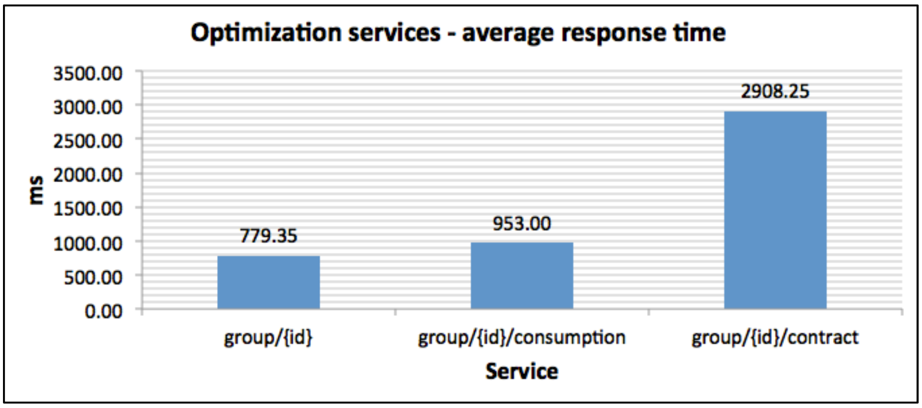


Figure 91 – Response times for the most consumed services of the optimization category

In **Figure 91** the middle bar represents the services of the first offer, where the NOEM operator can visualize the original offer of a flexibility group. The left bar represents the service used for the negotiation process. It is expected to have calculation process on the side that offers flexibility (in consumption or production) for both services and delay is fully justified. The contracting service (right bar), on the other hand is higher as confirming that an offer is accepted and thus contracted, takes additional time to store the actual flexibility contract between two parties. Flexibility services are promising [10], and there is a lot of space for improvement, including the negotiation process itself as well as the exchanged messages as defined in D4.3 [11].

5.3.5.6.7 Prediction service performance

Prediction services have a pivotal role in the NOBEL trial, especially as they are utilized by users (and their agents) in order to trade electricity online. What is interesting here is the introduction of new concept for user-defined customization/adjustment of the prediction. After execution of the prediction algorithm, to produce load prediction for consumption or production, the resulting curve may be further customized by end-users (as they may have context-specific knowledge not available to the prediction algorithm) and the finalized version of the prediction is offered via Prediction services (real-time adjustment of all dependent services e.g. overall neighbourhood prediction). The average response time of invoking these services is shown on the Figure 92.

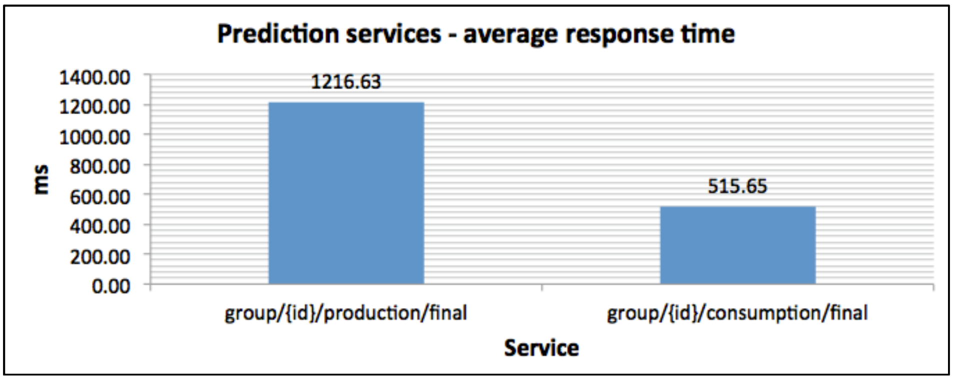


Figure 92 – Response times for the most consumed services of the prediction category

For the majority of the consumption data the resolution of 1 hour was available due to various issues raised in previous sections such as the data quality. The production data (which is simulated) was of 15-min resolution. However, since the prediction algorithm requires all the consumption and production points in the same resolution the interpolation algorithm is running over all the available measurements. Caching of the executed prediction may be a solution to higher response times.

5.4 NOEM assessment

The main metrics for the functional evaluation are: support for the envisioned requirements, responsiveness of the GUI, and the time taken for the realization of user requests.

5.4.1 Requirements Assessment

All the requirements for the NOEM outlined in D1.1 have been addressed. More specifically:

5.4.1.1 Localization (EMS_002)

This requirement specifies that the NOEM application should provide support for different languages. This requirement is met by allowing the user to choose between English and Spanish at the login screen (as proof of concept). This was implemented by externalizing all strings in the application. These strings are kept in a properties file that can then be localized by appending the appropriate localization ID to the file. For instance, the English form of the localized strings is stored in the *NOEM.properties* file, and the Spanish translation is located in the *NOEM_es.properties* file.

5.4.1.2 Monitoring of collected metering data (EMS_003/ EMS_006/EMS_009/EMS_010)

The requirements EMS_003, EMS_006, EMS_009 and EMS_010 deal mainly with the presentation of the metering data supplied by Alginet. The collection and storage of the metering information is responsibility of the IEM. The NOEM application calls the relevant IEM services to present the required data. The NOEM application provides the capability of monitoring the total demand reported by all the meters (Figure 93) as well as the demand and supply reported by individual meters (Figure 94). Furthermore, additional metering data, that is, voltage, active power, reactive power, frequency, current and power factor, can be viewed (Figure 95). This data can be queries for specific time periods using the available controls. Additional ‘shortcut’ buttons for ‘Next 15 Minutes’, ‘Last Month’, ‘Last Week’, ‘Yesterday’ and ‘Today’ are also provided along side the traditional manual date/time selection controls. The granularity of the monitoring data can also be selected (15 minutes, 30 minutes, 1 hour, or 1 day), except in the case of the ‘Overview’ tab which is set to an hourly granularity.

Figure 93: The 'Overview' tab showing the total demand and CO^2 emissions, as well as a summary table and generation mix.

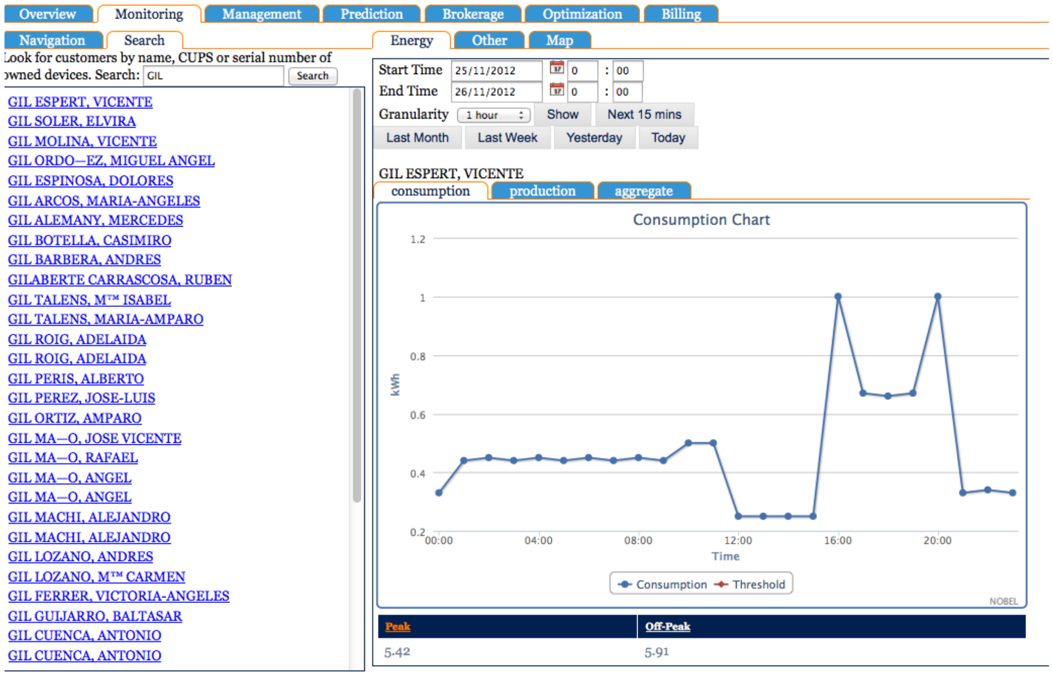


Figure 94 The 'Monitoring' tab showing a customer's daily demand profile.

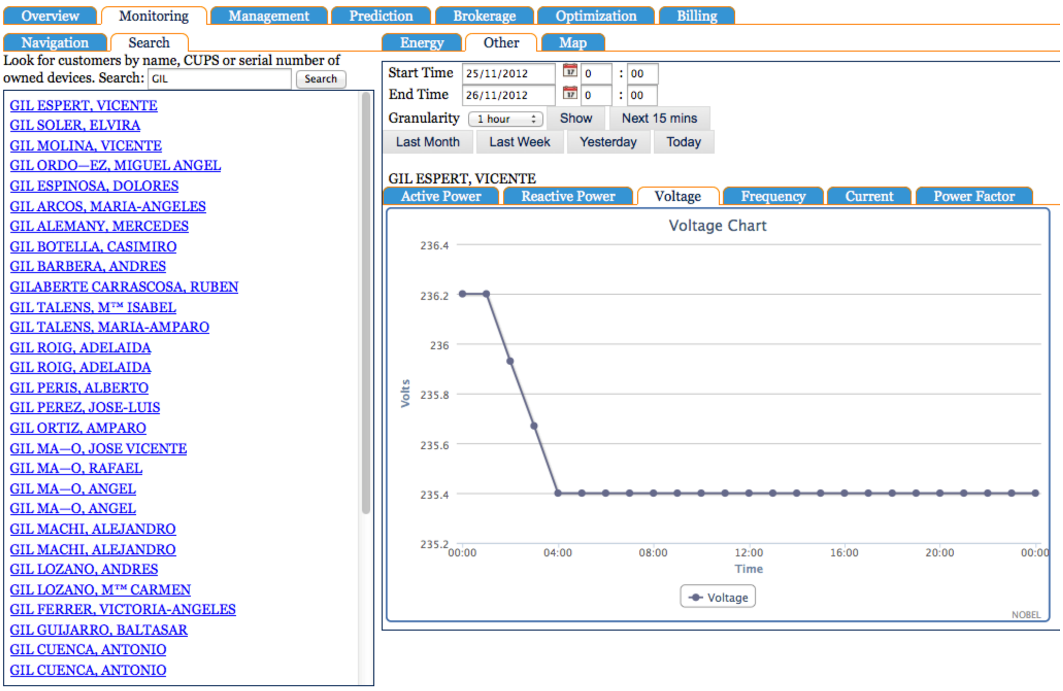


Figure 95 The 'Monitoring' tag showing the Voltage of a customer.

5.4.1.3 Auction Supervision (EMS_004)

The NOBEL market can be monitored and interacted with using the 'Brokerage' tab in the NOEM application. This tab is broken down into five different views: the 'Market' view, the 'Order Book' view, the 'Transactions' view, the 'Market Participants' view, and the 'Agents' view.

The 'Market' view (Figure 96) allows the user to view current and historical market prices and traded volume. The user can specify the time period of interest using the provided date/time selection controls.

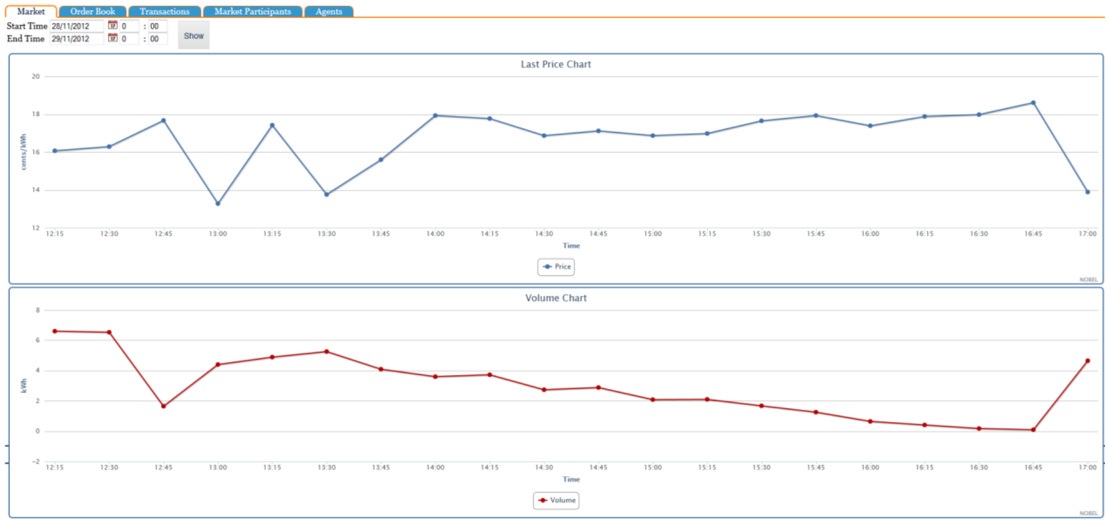


Figure 96 The 'Market' view showing the current prices and traded volume on the market.

The 'Order Book' view (Figure 97) allows the user to inspect the order book (the current buy and sell orders) for a particular trading timeslot. The timeslots for a specific time period (selected by the user by using the standards date/time selection controls) are presented to the user as list. The order book for a particular trading timeslot, selected by the user from the list, is then visualized as two tables: the 'Buy' table, which contains the buy orders, and the 'Sell' table, which contains the sell orders. The tables contain the following information for each order: order type (buy/sell), participant Id, the 'order form' (the constraints of the order, e.g. fill-or-kill, or standard), the quantity, the price, and the order status (open, partially filled, cancelled, etc.). The user can also cancel specific orders by selecting 'cancel', for that order.

Buy Table

Order Type	Participant ID	Order Form	Quantity	Price	Order Status	Acceptance Time	Action
BUY	18	STANDARD	190	19.42	PARTIALY_EXECUTED	2012-11-26 10:31:35	cancel
BUY	206	STANDARD	53	17.96	OPEN	2012-11-26 10:33:14	cancel
BUY	4596	STANDARD	435	17.52	OPEN	2012-11-26 10:31:52	cancel
BUY	2001	STANDARD	112	17.26	OPEN	2012-11-26 10:35:03	cancel
BUY	1099	STANDARD	129	17.16	OPEN	2012-11-26 10:32:35	cancel

Sell Table

Order Type	Participant ID	Order Form	Quantity	Price	Order Status	Acceptance Time	Action
SELL	184	STANDARD	12	17.6	EXECUTED	2012-11-26 10:32:30	cancel
SELL	197	STANDARD	9	17.59	EXECUTED	2012-11-26 10:35:00	cancel
SELL	168	STANDARD	10	15.5	EXECUTED	2012-11-26 10:32:12	cancel
SELL	170	STANDARD	30	15.49	EXECUTED	2012-11-26 10:30:09	cancel
SELL	174	STANDARD	5	15.41	EXECUTED	2012-11-26 10:32:44	cancel

Figure 97 the 'Order Book' view showing the buy and sell orders for a particular trading timeslot.

The 'Transactions' view is similar to the 'Order Book' view. However, instead of viewing the orders in a timeslot, the user can view the list of transactions that occurred in the timeslot. Current, there is no recourse for cancelling transactions. The transaction table presents the following information about a particular transaction: price, quantity, transaction time, buyer participant id, seller participant id, the buy order id, and the sell order id. The user can also inspect information about the participants (buyer and seller) as well as the order by selecting the participant or order of interest.

The 'Market Participants' view (Figure 98) allows the user to select a customer (or multiple customers) and enrol them into the market. Similarly, a customer (or multiple customers) can be removed from the market. This functionality is also realized through the 'Management' tab when editing the details of a single customer (Figure 99).

The 'Agents' view shows a table with all of the automated trading agents in the IEM along with information about the customer on whose behalf they are trading and the option to start or stop the agent.

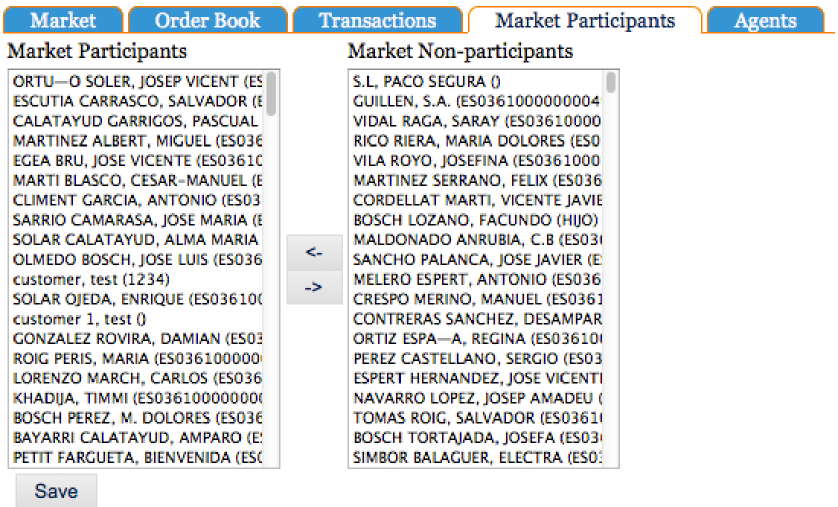


Figure 98 The 'Market Participants' view showing the list of market and non-market participants.

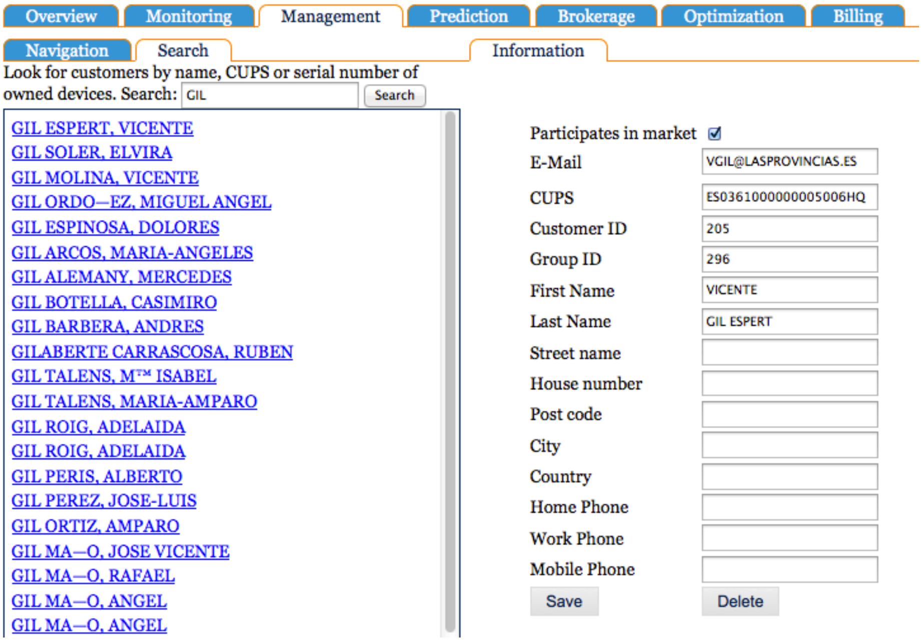


Figure 99 Setting a customer as a market participant through the 'Management' tab.

5.4.1.4 Management of Alarms (EMS_005)

The NOBEL application allows users to set thresholds for devices, customers, and groups (Figure 100). Thresholds could be in the form of power (W) or energy (kWh). If the customer's, device's, or group's consumption exceeds the threshold, an alarm could be sent to the user. Additionally, the NOEM provides the functionality for users to send messages directly to the customers (Figure 101). In this way, if a customer is seen to be misbehaving, or in need or a warning, the user can quickly notify the infringing user.

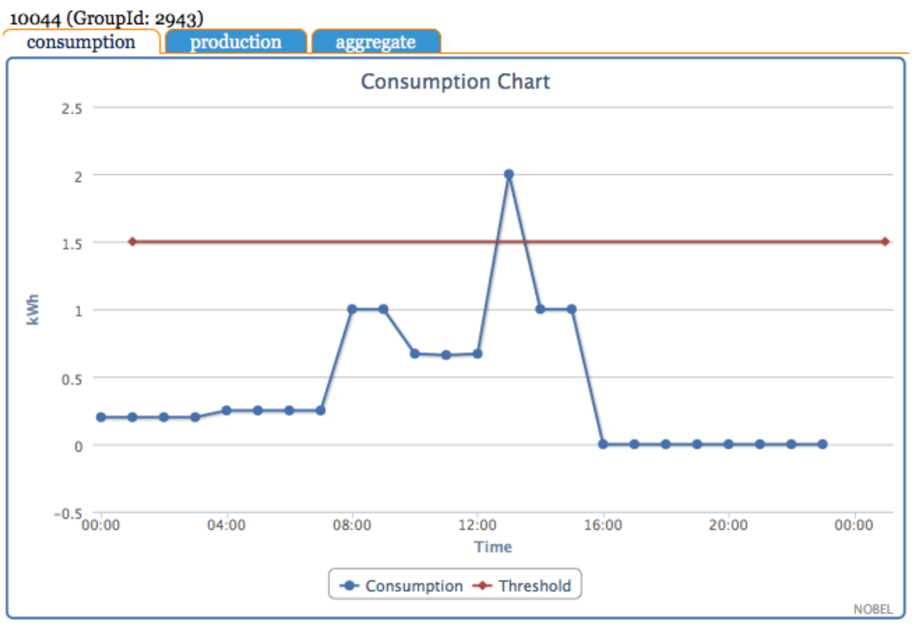


Figure 100 Consumption threshold.

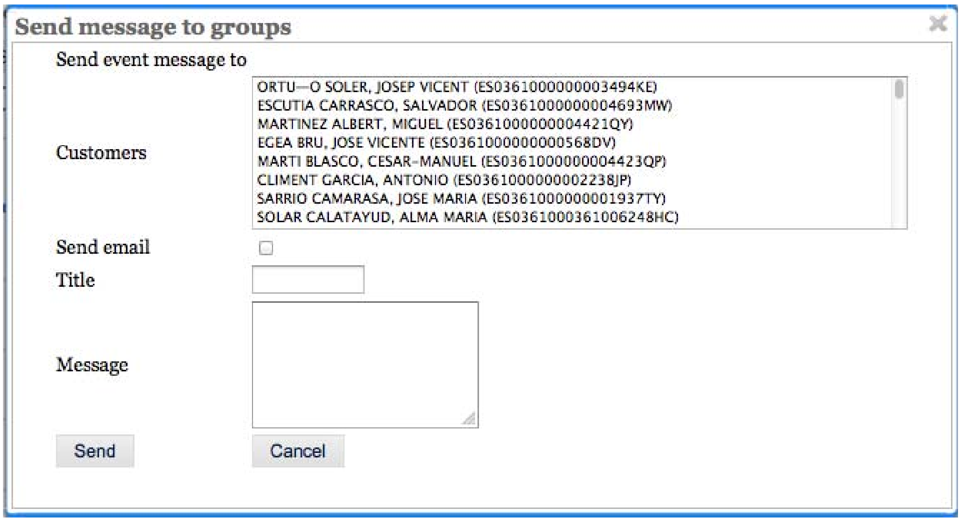


Figure 101 Contacting a Customer directly

5.4.1.5 Viewing the geolocation of the meters (EMS_007)

The geolocation of the meters can also be seen in the 'Monitoring' tab and selecting the relevant device or customer (Figure 102).

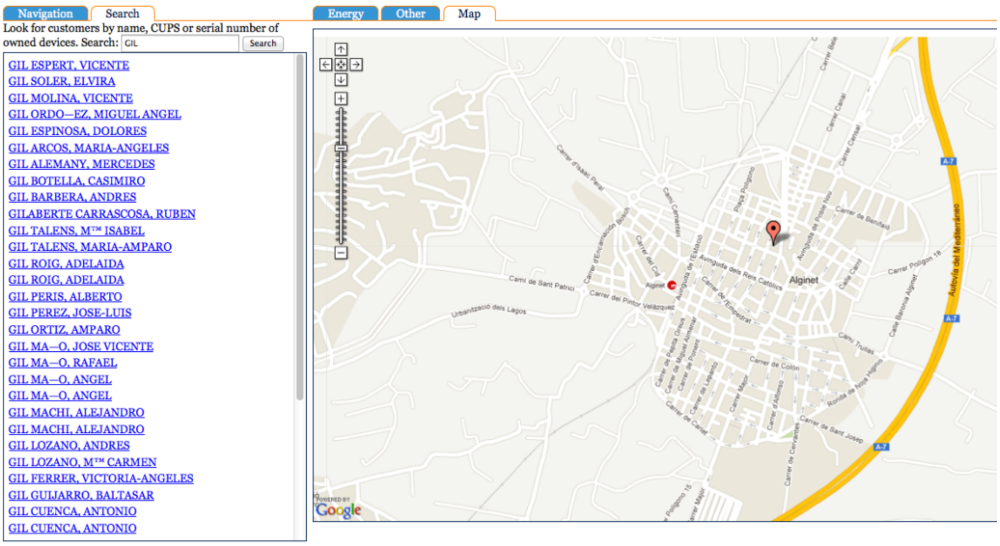


Figure 102 Viewing the geolocation of a customer.

5.4.1.6 Prediction Adjustment (EMS_008)

The NOEM application allows users to update the demand or supply prediction for individual customers, devices, or groups (Figure 103). Modifying the energy values, for the required intervals, is done through the table. The changes can be visualized in the graph. Once the user is satisfied, s/he the changes can be saved.

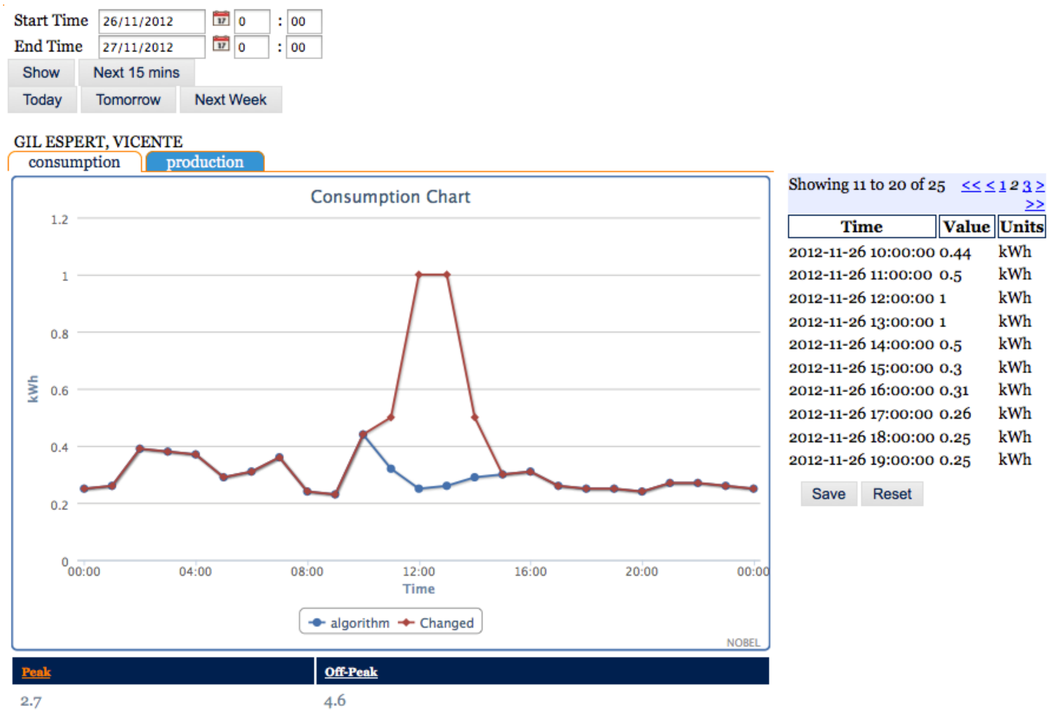


Figure 103 Modifying the demand prediction of a customer.

5.4.1.7 Visualizing and Manipulating Electricity Pricing (EMS_011/EMS_012)

Electricity price contracts can be create, viewed, modified and assigned through the NOEM application. A contract is modelled as a set of tariffs. Each tariff has a time period and a price. The user can create a new contract, or edit (or delete) a currently existing one. When created a new contract, or selecting an existing one, the user is presented with a chart depicting the tariff structure of the contract, and a table containing the individual tariffs (Figure 104). Existing tariffs can be removed and new tariffs can be added.

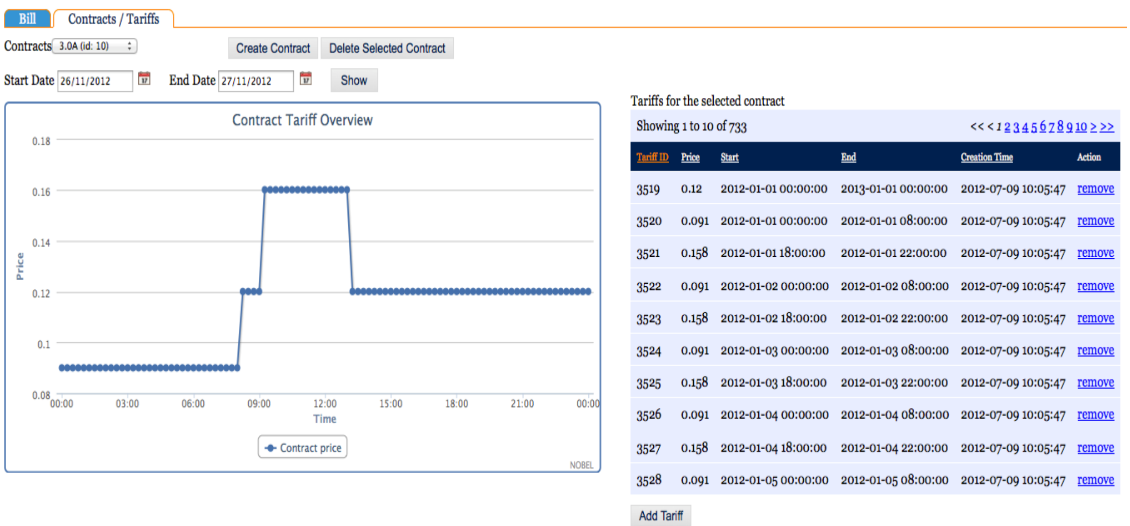


Figure 104 NOEM's contract creation functionality.

5.4.1.8 Accessibility of the NOEM application through a public IP address (EMS_013)

The NOEM application was available through publicly in the Internet through the URL: https://iem-dev.dyndns.org/NOEM.

5.4.2 Technical Assessment

SLOC	Directory	SLOC-by-Language
26105	NOEM	java=25841,xml=264

Table 49 Overview of NOEM code statistics

Table 49 provides an overview of the current IEM source code snapshot as it is calculated by David A. Wheeler's '*SLOCCount*'. An indicative development cost is also given in Figure 105.

```
Total Physical Source Lines of Code (SLOC)           = 26,105

Development Effort Estimate, Person-Years (Person-Months) = 6.15 (73.75)
(Basic COCOMO model, Person-Months = 2.4 * (KSLOC**1.05))

Schedule Estimate, Years (Months)                    = 1.07 (12.81)
(Basic COCOMO model, Months = 2.5 * (person-months**0.38))

Estimated Average Number of Developers (Effort/Schedule)  = 5.76
Total Estimated Cost to Develop                      = $ 830,236
(average salary = $56,286/year, overhead = 2.40).
```

Figure 105 Estimated NOEM Development statistics

5.4.2.1 Design Decisions and Implementation Experiences

In this section, the design decisions and implementation experiences related to the NOEM application are outlined and discussed. The discussion is centred on the frameworks and architectural paradigms chosen for the realization of the application.

The NOEM application makes use of the services provided by the IEM. The services are provided using a RESTful methodology and use Google Protocol Buffers as the messaging format. One of the main design decision taken during the design of the NOEM application is that it should be totally independent of the IEM. Therefore, all communication between the IEM and the NOEM would have to be done strictly through the services provided by the IEM, and it would not be able to benefit from, for instance, direct access to the database storing the IEM's data. No reliably maintained JavaScript library for Google Protocol Buffers could be found, as such, the decision was made to implement the NOEM using a J2EE (Java Enterprise Edition) framework, as opposed to creating a webpage using HTML or HTML5 and using the JavaScript to make the service calls to the IEM. By using such a framework, the server could make the service calls by using a REST library, the messages could be serialized and desearialized using the official protocol buffers library supplied by Google, and the framework would be in charge of business logic and rendering.

Given the requirements for the NOEM application, such as the need for charts (for the presenting the collected meter data) and showing the meters on a map (geolocation), the chosen framework would need to easily support these functionalities either natively or through 3rd party libraries built for the chosen framework. Additionally, the chosen framework would need to facilitate the development of the application by having native support for widgets such as trees, tables, lists, text fields, text areas, pop-up windows, an so on. Furthermore, it would need to easily support localization, to allow the user to choose between different languages.

While several frameworks were looked at as possible candidates, two stood out: Eclipse RAP (Remote Application Platform: http://www.eclipse.org/rap/) and Apache Wicket (http://wicket.apache.org/). Eclipse RAP is based on Eclipse RCP (Rich Client Platform), the platform on which Eclipse IDE is built. RAP application can be thought of as RCP application that is deployed on a server and accessed through a browser. The general look-and-feel is the same, and in fact, a RAP application can be converted in to an RCP application with minor modifications. Meaning that, should there be a need, a desktop version of the NOEM application could be created. However, after our initial tests, it was found that there was a large learning curve associated with the platform, and that even simple tasks were quite hard to achieve and involved many lines of code. Additionally, at least at the time, there were not many 3rd party libraries for RAP that easily supported Google Maps (for the geolocation) and charting. What was found was either cumbersome to use, or visually unappealing or lacking in features.

Apache Wicket, on the other hand, provides a fairly simple framework. Views are implemented as HTML files, and the matching elements, with their business logic, is developed directly in Java. The UI aspect of Wicket is closely related to Java Swing (Java's desktop GUI framework), which we already had some experience in, meaning a lower learning curve. Furthermore, there were many 3rd party libraries to choose from which add additional functionality in an easy to integrate and use manner. For these reasons, Apache Wicket was chosen as the underlying framework for the NOEM application.

Architecturally, the NOEM application is separated into four different areas: Data Access Objects (DAO), model objects, custom widgets, and tabs. The DAO layer is responsible for making the calls to the IEM services and translating the responses into the model objects used by the application. The model objects contain the information to be presented to the user by the widgets. A few reusable custom widgets were created. These were generally in the form of a collection of standard widgets. For instance, the navigation widget used in many of the functional areas of the NOEM application combine a tree widget with a set of buttons at the top. A tab represents a functional area in the NOEM (e.g. Overview, Monitoring, and Management). Each tab aggregates the functionality directed at a particular task, for instance, the 'Monitoring' tab has all the necessary controls for selecting a particular customer/device/group and browsing their current and historical energy demand/supply, as well as the other measurements supplied by the meters (e.g. voltage, active power, and reactive power). The tab panel presenting the tabs (Figure 106) was implemented as a wicket object called AjaxTabbedPanel. This means that the user can switch between tabs without the feeling that the whole page is being reloaded. In hindsight, this was a poor design decision. While it was good for user experience, it meant that the whole application is basically one page. This made analysing the access logs very difficult, as each tab does not have its own distinguishable URL.

Figure 106 The tab navigation panel.

The customer navigation widget relied mainly the tree view, which presented a hierarchical view of the devices, customers, and groups. Ultimately, this was a bad UI decision. Given the large numbers of devices and customers (around 5000), presenting all of these entities became very time consuming, as the IEM service's response time is quite large, the server response (on the NOEM side) consisted of a large number of entities encoded in HTML (for rendering in the browser), which take a long time to download and render. In order to mitigate this, the server settings were changed so that the responses would be compressed (minimizing the download time). Additionally, a cache layer was created on the NOEM, making it faster for it to server the browser with the necessary content, by not having to go to the IEM for every request. This increased the complexity of the NOEM since the cache needed to be managed. It might have been better to adopt a different UI approach, and also augmenting the relevant IEM services with paging. This way, a small number of entities could be requested and rendered. As more are needed, the pagination on the IEM services could be used to request the next set of entities.

The DAO layer was separated into interfaces and their implementation. This means, the NOEM application could be easily modified to be used with different methods of acquiring the data, for instance, a DAO implementation for getting the data directly from the database could be created, or it could be adapted to be used with a completely different set of web-services (as long as they could supply the same type data). For the current implementation, the Jersey Client API (http://jersey.java.net/) was used for the communication between the NOEM and the IEM. The Jersey Client API is tailor made for communicating with REST services, and simplified this process immensely.

The NOEM development process was generally smooth. However, because the UI is organized hierarchically (like HTML), it can sometimes be difficult to get a widget the information it needs, because it needs to travel down several layers of the hierarchy before reaching the relevant UI element. This some times leads to unnecessary message passing between objects that can complicate the implementation, and more importantly the maintenance and bug fixing effort.

The main 3rd party libraries used where wiquery-highcharts (https://github.com/hielkehoeve/wiquery-highcharts) and wicketstuff Google Maps V2 (https://github.com/wicketstuff/core/wiki). The wiquery-highcharts is a charting plugin based on the Highcharts library (http://www.highcharts.com/) that provides easy integration of Highcharts charts into Wicket application. The provided charts are visually appealing. However, the plug-in, did not provide full support for all Highchart features, such as adding a second y-axis (for multiple time series of different units). On the other hand, integration into the project was fairly easy and displaying and updating the charts was also straightforward. The wicketstuff Google Maps V2 plugin provides Wicket with support for the Google Maps API. This plug-in was a challenge to get working, and ultimately we only managed to get it to work in the Firefox browser. At the time, however, it was the only available Google Maps plug-in that we could find.

To conclude, given the requirements for the NOEM application and the limitations imposed by the IEM services, namely Google Protocol Buffers, Wicket was probably the right framework. However, there were some bad decisions regarding the UI components used that led to an increase in complexity. Wicket is a widely used framework for web applications, thus it has a big community and many projects augmenting its functionality. While using external plug-ins sometimes led to problems in their successful integration in the project, these problems were overcome and they provided most of the required functionality. However, ultimately, it would have been better if the IEM services supported plain standard messaging formats just as JSON and XML. This way, the NOEM application could have been developed as just a webpage, with all the service calls being done by the browser itself through JavaScript and AJAX. Additionally, a wider selection of APIs would be available for use (in terms of charting, maps, and perhaps others), making the development somewhat easier.

5.4.2.2 NOEM Response Times

The NOEM application serves data retrieved from the IEM through its REST service API. The retrieved data must then be deserialized, processed and formatted for presentation on the browser. In order to evaluate the response time of the NOEM, the response times for requests directed at the NOEM were extracted from the access log file to produce a "response time duration curve" that shows the percentage of requests for which the response times were above a particular threshold. As it can be seen in Figure 107, the NOEM generally performed well with roughly less than 5% of response times being above 1 second. The longest recorded response time was of about 5 minutes (300975 milliseconds). This was unusually high, the next highest being about 1.5 minutes (88747 milliseconds), and occurred while trying to login to the NOEM. Given the duration of the response time, we think it is likely the login attempt occurred while the server was starting up. The server probably tried to handle the request while waiting for the NOEM application to start-up.

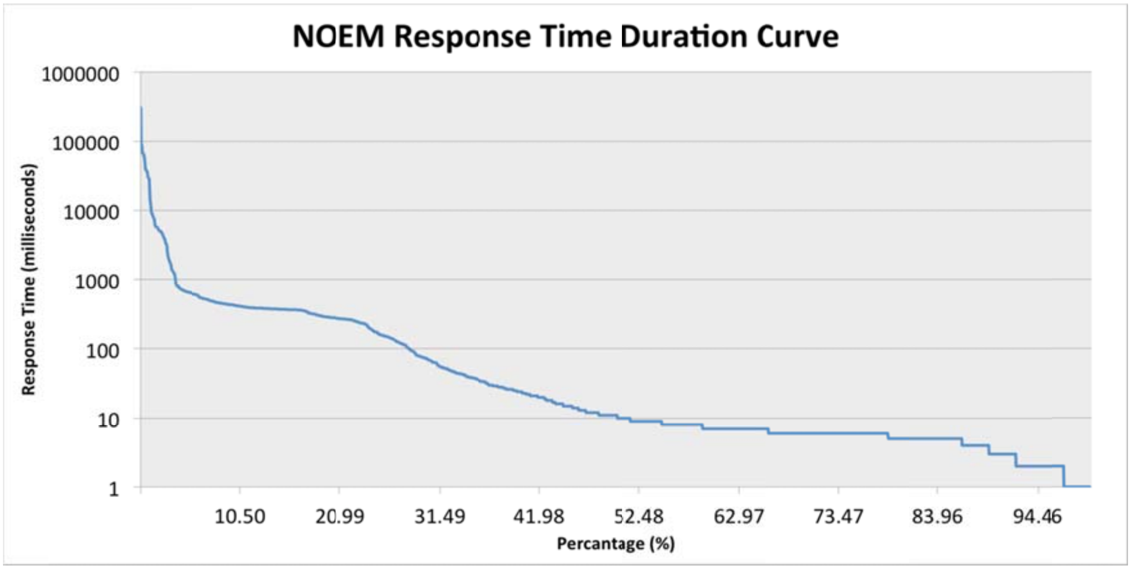


Figure 107 Response time duration curve for NOEM requests. The data is presented on a log scale.

Requests to the NOEM application cover everything from retrieving data from the IEM, to browser requests for any other element responsible for presenting the retrieved data and other UI elements, for instance, images, javascript files, css files, and html files. Some of these might maybe very quick to serve and might skew the response time duration curve. Therefore, the "response time duration curve" for the response times of IEM requests performed by the NOEM was also extracted from the access log file. As can be seen (Figure 108), only about 12% of the requests take 1 second or more, and 6% of requests take 10 seconds or more. The highest recorded value was 1 minute and 23 seconds (83015 milliseconds).

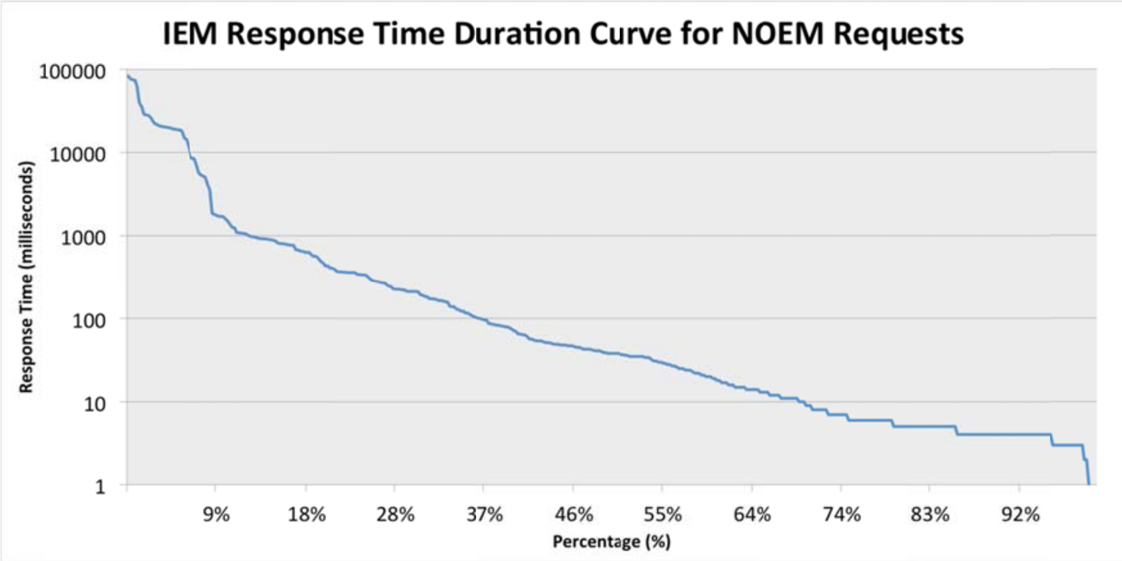


Figure 108 Response time duration curve for IEM requests made by the NOEM. The data is presented on a log scale.

The extracted access log file data shows that most of the time, the NOEM responds fairly quickly (i.e. 1 second or less ~95% of the time). However, response times can be quite long at times reaching 1.5 minutes at times. This sort of variability can be expected as some of the requests can be quite resource and computationally intensive, such as requesting interpolated time-series data for long time periods or large number of groups.

5.4.2.3 Tab usage Statistics

In order to extract the tab usage statistics, it was necessary to extract from the access log the IEM service categories (e.g. monitoring, management, optimization, etc.) that were called by the NOEM. It was not possible to look at the requests made to the NOEM directly, as due to the usage of the *AjaxTabbedPanel* as described in a previous section, the URLs generated by Wicket for the NOEM application generally unintelligible. However, by looking at the IEM service calls made by the NOEM, a suitable estimation can be made, since each tab basically groups the functionality offered by a particular IEM service category. For instance, the “Overview” and “Monitoring” tabs make use of the monitoring services; the “Management” tab makes use of the management services, etc. The results are depicted in Figure 109, where the number of requests by service category and type of request are shown. The type of request refers to the type of data operation the request targeted. That is, acquisition (e.g. retrieving historical data), creation (e.g. creating a new user or group), update (e.g. updating customer information), or deletion (e.g. deleting a contract tariff).

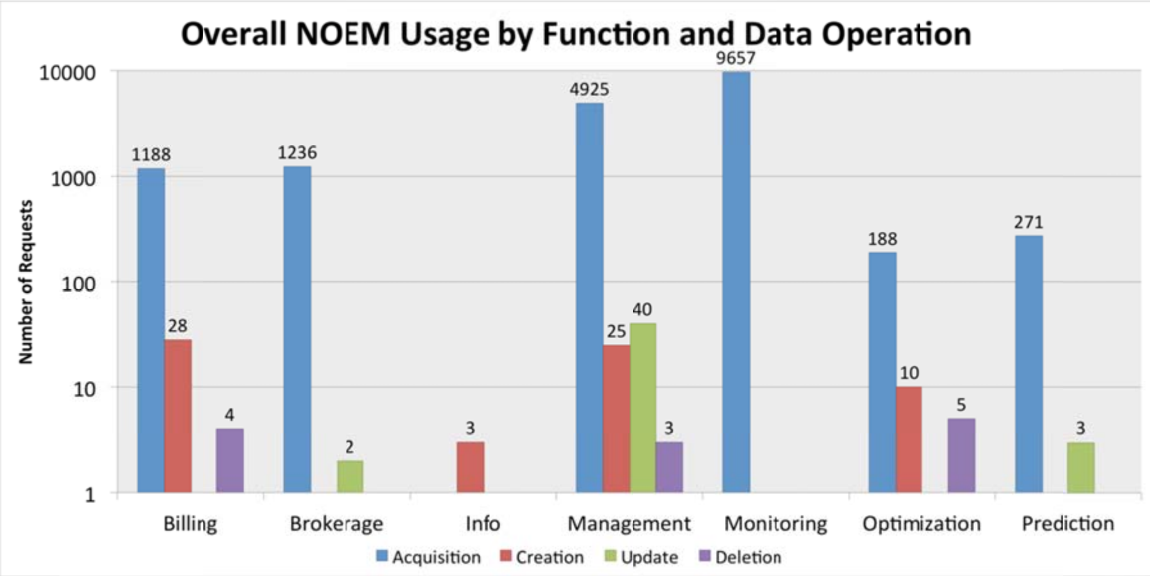


Figure 109 Overall NOEM usage by function and data operation

This chart depicts the number of requests performed by the NOEM users by type of request (data acquisition, creation, update or deletion) and by functionality. The data is depicted in a logarithmic scale.

As it can be seen, acquisition operations had the highest request counts across all service categories, particularly monitoring (i.e. viewing current and historical customer demand data), and management (i.e. viewing customer/device/group information). All other operations had fairly low request counts. This is possibly due to the fact that inserting customer and device information, which would likely yield the highest count amongst creation requests, was done outside the NOEM using dedicated custom tools (since manually entering the information for over 5000 customers, and their devices, would be too cumbersome).

5.4.2.4 Errors

Error statistics for the NOEM can be retrieved from the access log file through the HTTP response status code (http://www.w3.org/Protocols/rfc2616/rfc2616-sec10.html) of the responses returned by the NOEM. For instance, a status code 200 means the request succeeded, while a status code of 500 means the request failed due to an internal server error. In Figure 110 the percentage of successful and failed requests is depicted, where the criteria for a successful or failed request depended on the status code returned in the response.

That is:

- status 200 (OK), 302 (Found), 304 (Not Modified) were deemed successful, and
- 403 (Forbidden), 404 (Not found), and 500 (Internal Server Error) were deemed errors.

As can be seen, over 99% of the requests were successful.

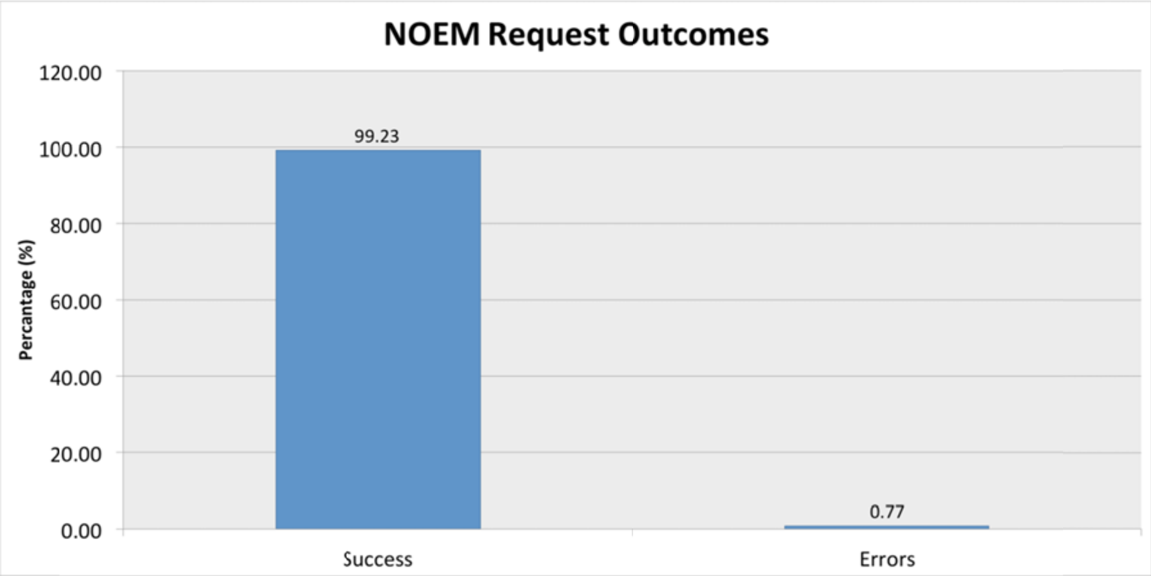


Figure 110 Outcomes of requests made to the NOEM

However, because the NOEM relies on the IEM for its data, it still must handle errors from the IEM requests gracefully, meaning these errors should be reported to the user. Therefore, while an IEM request might fail, it can still show up as a successful request for the NOEM user (i.e. in the form of a pop-window informing the user of the nature of the error). Therefore, similar statistics were collected for the response HTTP status codes of the NOEM requests performed on the IEM (Figure 111).

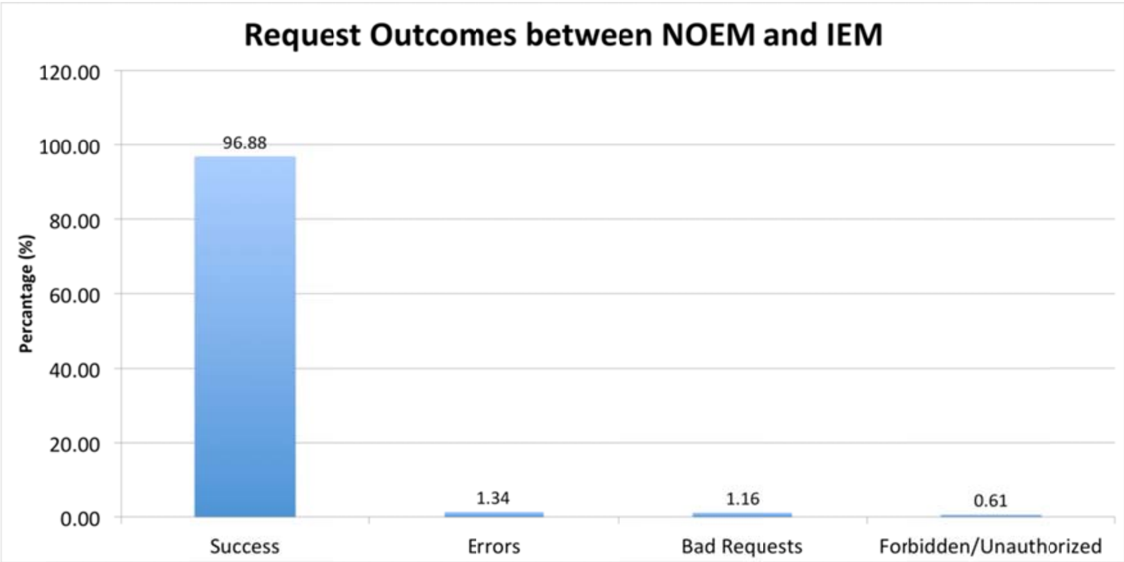


Figure 111 Outcomes of request performed by the NOEM on the IEM

In this case, there was a wider range of response codes collected, therefore they were grouped in the following categories:

- *Success* for status codes 200 (OK), 201 (Created) and 204 (No Content),
- *Errors* for status code (500),
- *Bad Requests* for status codes 304 (Not Modified), 400 (Bad Request), 404 (Not Found), 409 (Conflict), and 412 (Precondition Failed), and
- *Forbidden/Unauthorized* for 401 (Unauthorized) and 403 (Forbidden).

It should be noted that the categorization of the HTTP response codes is different between the NOEM requests and the IEM requests because they carry different meanings. In the case of the NOEM application, the response status codes are directed at browsers, which interpret the status codes to adjust their own functioning. For instance, a 304 (Not modified) could mean that a particular resource did not change (such as an image) therefore the browser can use its cached version of the resource. However, in the case of the IEM, a 302 could be returned if there was an error when trying to update a resource (such as updating customer information).

The results show a high percentage of successful requests (almost 97%). Of the remaining requests, only 1.34% were actually errors, 1.16% were errors generated through bad service calls, and 0.61% were calls to services to which the user did not have access too (it is likely that in these cases the user did not yet have its rights and privileges correctly set).

5.4.2.5 Country of Origin

The country of origin for a request in the access log file can identified by the combination of IP addresses and whois (RFC 3912) registry information. The number of requests originating from different countries was extracted and depicted in Figure 112. As can be seen, the great majority of requests originated from Germany and Spain. This is not surprising since the NOEM was developed and tested in Germany for use by the Spanish partners (ETRA and Alginet). Some fewer requests originated from the countries of other partners (CERTH in Greece, and SICS in Sweden). Interestingly, some requests originated in Canada, but this was the result of one of the colleagues testing the NOEM.

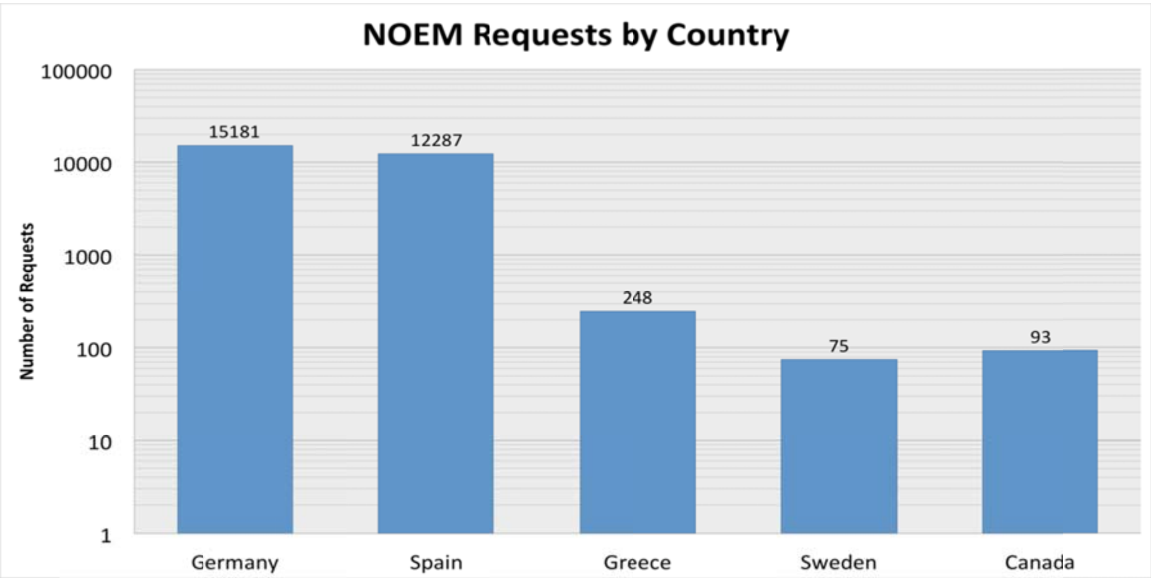


Figure 112 The number of requests that originated from different countries. The data is depicted in a log scale.

5.4.3 End-User Assessment

Alginet (main targeted end-user) used the NOEM application throughout the trial periods. Although there were several interactions during the design, development and even during the trials which led to continuous enhancements during both trials, we have also captured at the end of the second trial officially the feedback in a form of a questionnaire. The questionnaire covered usability aspects, such as perceived speed of information acquisition, as well as functional and design aspects.

In the questionnaire, Alginet was asked to rate each tab, or functionality, according to its usefulness and speed. The results are summarized in Table 50. All of the tabs received high ratings for speed. However, the management, brokerage and optimization tabs received low ratings for usefulness. The brokerage and optimization tabs exhibit simulated functionality; therefore it may have been difficult for Alginet to fully gauge the usefulness of these tabs. Additionally their functionality was partly trial-specific in order to be able to manage users, devices and trading. The management tab is not related to energy management, and as such, it did not feature heavily in Alginet's day-to-day business processes (in real world, this would be another view of existing management systems). The brokering is a mid- to long- term feature for the case energy trading is introduced, and understandably one has to become an expert on these processes in order to understand and manage them effectively, which at this stage is highly experimental. Finally the optimization tab was a proof of concept for a negotiation process that does not really exist at this level today, and in real-world would be again much more complex. This lets us derive that a lot of effort will be needed in the future not only on introducing new concepts, but actually making them understandable on their interworkings and impact, and train the operators on their usage, if smart grid visions are to succeed.

Functionality	Usefulness	Speed
Overview	5	5
Monitoring	5	4
Management	3	5
Prediction	4	4
Brokerage	2	5
Optimization	3	5
Billing	5	5
Customer Contact	5	N/A

Table 50 Summary of the perceived usefulness and speed of each functionality provided by the NOEM. The ratings are out of 5, with 5 being the highest rating

In general, the answers given to the questionnaire seem to suggest that the most important functionalities for Alginet are monitoring and prediction. Being able to have a bidirectional and multi-channel contact between the energy provider and customers is highly appreciated. Additionally automatic real-time bill prediction and generation is also rated highly given the answers. Not many comments for the improvement of the tabs were given, with the exception of the prediction and customer contact functionality; this was also expected due to the continuous integration feedback we have fostered. In the case of the prediction tab, a better UI for the update of the prediction was requested. As for the customer contact form, the addition of attachments was required.

In conclusion, given the answers to the questionnaire, the NOEM application was successful in meeting the speed and functionality goals set out by the project, while covering all business and technical requirements.

5.5 BAF Assessment

The main metrics for the functional evaluation were:

- the support for the outlined requirements,
- GUI design and implementation features

5.5.1 Requirements Assessment

Most of the outlined requirements from the deliverable D1.1 “Requirements Specification” have been supported. Some of these requirements decided not to be followed during the lifecycle of the project for different reasons. Analytically, these are:

5.5.1.1 Support of JME technology (BAF_004)

It was decided during the first year of the project to support Android OS platform rather than JME technology, devices that support MIDP. Android technology seemed to be most promising for market and technology aspects and nowadays it is obvious.

5.5.1.2 Devices have to support JSR 172 (BAF_005)

Due to the fact that it was decided to support Android OS platform, an appropriate API has to be followed for this technology and not the JSR 172, which is suitable for JME technology for SOAP web services only.

5.5.1.3 The STP should be free to customize the way the BAF present the information (BAF_012)

This initial requirement was not implemented. It was decided to provide a common presentation of data and figures to the STPs and support the use of STPs customized profiles (BAF_013) in order not to confuse them. By that, non-technical STPs users can be used it easy (BAF_027).

5.5.2 Technical Assessment

Most of the technical approaches were followed during the development of BAF applications had to do with the presentation of data to the standard prosumers.

5.5.2.1 Design and implementation decisions

The BAF application had to be developed to support web and Android OS platforms. Taken these into account, it was decided to build a common back-end and provide a different front end, a graphical user interface for each platform. The following figure illustrates the whole design stack and the reusable elements.

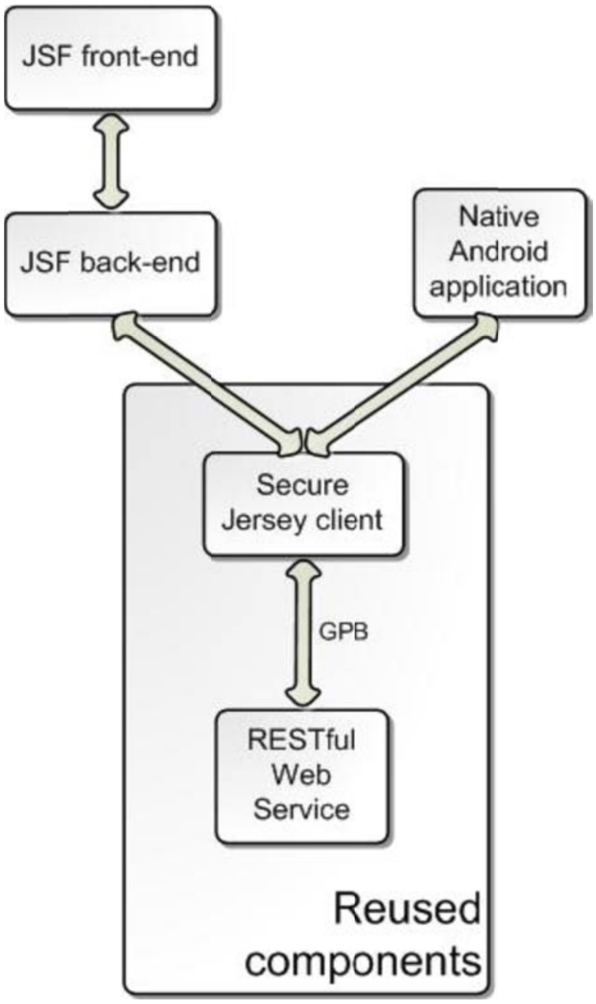


Figure 113 BAF application design stack and reused components

Some modifications in the source code according to the specifications of each platform were also taken place.

5.5.2.2 Web application decisions

It was decided to use the Java Server Faces (JSF) technology among different technologies. Then, a research was taken place in order to decide which JSF implementation tool will use. The Mojarra 2.0.3 JSF 2.0 implementation provided by Oracle (http://javaserverfaces.java.net/) and the PrimeFaces 3.0.M1 JSF component suite library (http://www.primefaces.org/) for the composite UI elements were decided to be used. Finally, the chart component used to visualize the smart meter's historical data is Flot 0.7 (http://code.google.com/p/flot/) which is an HTML 5 component controlled with javascript through JQuery. The whole research and study was taken place is contained at deliverable D5.1.1 "Validation of the first version of the End User Applications", at chapter "3.2 BAF".

5.5.2.3 Android application decisions

It was decided to create a "***native***" Android application supporting the minimum OS version 2.2. The limited screen size of the Android smart phone mandated the rendering of graphical charts in a landscape format rather than in portrait. A research among Android charting tool libraries was taken place and the RChart library (http://www.java4less.com/) was finally selected considering BAF application requirements. The whole investigation of these technologies are described at deliverable D5.1.2 “Validations applications report and prototypes”, at chapter “3.2 BAF”.

5.6 NOPL assessment

5.6.1.1 Evaluation plan revision

The experimental study design is reflected in summary in the following table.

Objectives	Indicators/Metrics	Data collection	Measurement conditions (Scenarios)	Success Threshold or comments
On-street equipment status monitoring	Delay between actual changes in the on-street equipment (for instance, lightning levels) and its reflection within the GUI NOPL Lost packets rate	Log files	Comm. based DCP and DCP-tunnel, lab testing on virtual devices running on separate networks. Real testing on devices installed in Alginet	Acceptable delays include those produced by the status of the network and the natural operation of DCP (order of milliseconds). Loss of information is not acceptable.
On-street equipment control	Delay between actual changes in the GUI NOPL (for instance, configuration of a new calendar) and its reflection within the on-street equipment	Log files	Comm. based DCP and DCP-tunnel, lab. testing on virtual devices running on separate networks (Real testing on devices installed in Alginet will not be performed, since it affects real environment)	Acceptable delays include those produced by the status of the network and the natural operation of DCP (order of milliseconds). Loss of information is not acceptable.
Statistical information retrieval	Loss rate on publications of statistical information on street equipment	Log files	Comm. based DCP and DCP-tunnel, lab testing on virtual devices running on separate networks. Real testing on devices installed in Alginet	On-street equipment publishes statistical information every minute. All this information must be retrieved by the NOPL in real-time (order of milliseconds). Loss of information is not acceptable.
Capability of adaptation to the market demand	Delay between request to achieve a certain consumption level, and its fulfilment	Log files	Comm. based DCP and DCP-tunnel, lab. testing on virtual devices running on separate networks (Real testing on devices installed in Alginet will not be performed, since it affects real environment and introduces non-controllable variables)	Results on real-life tests should depend mainly on the specific characteristics of the on-street hardware. By using virtual devices, this effect is removed, thus evaluating merely the delay introduced by NOPL and DCP themselves. Statistical information produced by the virtual devices must reflect that adaptation is achieved within 2 minutes. Statistical information is delivered every minute, so first statistical information packet received will still be affected by the previous state. For this reason, tests will rely on the second statistical information packet received

In order to design the actual tests to be carried out, an analysis on the indicators/metrics and success threshold must be perform. The objective is to identify which are the components in the final implementation of the prototype that play a role on these indicators, and, according to that, design the proper tests in the proper scenarios. The following table summarizes the key elements identified for each of the indicators.

Objectives	Indicators/Metrics	Key element
On-street equipment status monitoring	Delay between actual changes in the on-street equipment (for instance, lightning levels) and its reflection within the GUI NOPL Lost packets rate	Monitoring communication mechanism (DCP middleware)
On-street equipment control	Delay between actual changes in the GUI NOPL (for instance, configuration of a new calendar) and its reflection within the on-street equipment	Control communication mechanism (DCP-Rest)
Statistical information retrieval	Loss rate on publications of statistical information on street equipment	Monitoring communication mechanism (DCP middleware)
Capability of adaptation to the market demand	Delay between request to achieve a certain consumption level, and its fulfillment	IEM – NOPL communication mechanism (RESTful Web Services)

From the study summarized in the table below, two key elements of the system are identified: DCP middleware (for monitoring-related tasks evaluation) and DCP-Rest (for control-related tasks evaluation). By crossing the threshold table with the identified key elements, the different elements that need to be measured can be obtained.

Key element	Success Threshold or comments
DCP middleware	Acceptable delays include those produced by the status of the network and the natural operation of DCP. Loss of information is not acceptable.
DCP-Rest	Real-time behavior (delays under values reasonable for the system operation). Loss of information is not acceptable.
IEM – NOPL communication mechanism	NOPL must translate queries coming from IEM into actual on-street actions in real time

5.6.1.2 Test scenario

The prototype system is currently controlling a number of lamps in the town of Alginet, together with other simulated lamps used for laboratory testing. Both key elements identified for the evaluation in the section above are already operating on this test site, which makes the Alginet test site ideal also for the evaluation described here. In order to keep the normal operation of the system, a set of non-intrusive measurements has been identified in order to cover the objectives of this study.

Key element	Usage of the key element to be observed	Comments	Measurement source
DCP middleware	Publication of "ping" messages.	Segment controllers publish a PING message every 5 minutes, in order to inform NOPL that they are still operating. This usage has been chosen because its small period makes it possible to obtain a large enough number of samples for the study (other usages occur few times in a day, for instance lamp ON/OFF or luminosity changes)	Log files
DCP-Rest	Query for statistical information.	NOPL queries statistical information to all the Segment Controllers every 5 minutes. The mechanism used is similar to the one used in the control actions. This usage	Log files

		has been chosen because its small period makes it possible to obtain a large enough number of samples for the study (other usages occur few times in a day, for instance manual actions of the operator in the lamps)	
IEM – NOPL communication module	Reception of consumption/production queries	When a query for increase/reduction of consumption/production is successfully contracted by IEM, the IEM –NOPL communication module stores it on an internal queue. NOPL reads de queue every 10 seconds, checking the changes in the programs to be applied.	Log files

5.6.1.3 Particularities of the scenario

Since the indicators refer to communication delays and loss rates, the measurements will be absolutely influenced by the operation of the physical communication channel established between NOPL and the Segment Controllers installed in Alginet. The most critical element in the channel chain is the GPRS/3G connection used to connect the Segment Controllers to the Internet.

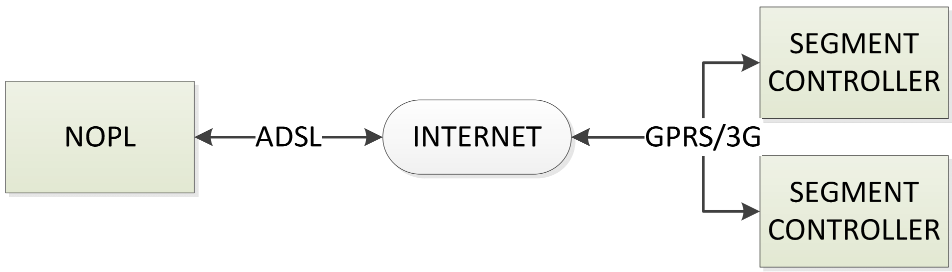


Figure 114 Communication structure between NOPL and on-street equipment

5.6.1.4 Baseline

In order to put the results of the study in the correct context, they should be compared with the actual delays and loss rate inherent to the physical layers of the communication channels. A good approach to obtain a reasonable baseline is to measure the delays and loss rate of pings to one of the Segment Controllers in Alginet.

Ping delay (seconds)	Frequency	% accum.
1	773	88,85%
2	86	98,74%
3	8	99,66%
4	0	99,66%
5	0	99,66%
6	0	99,66%
7	0	99,66%
8	0	99,66%
9	0	99,66%
10	0	99,66%
lost	3	100,00%

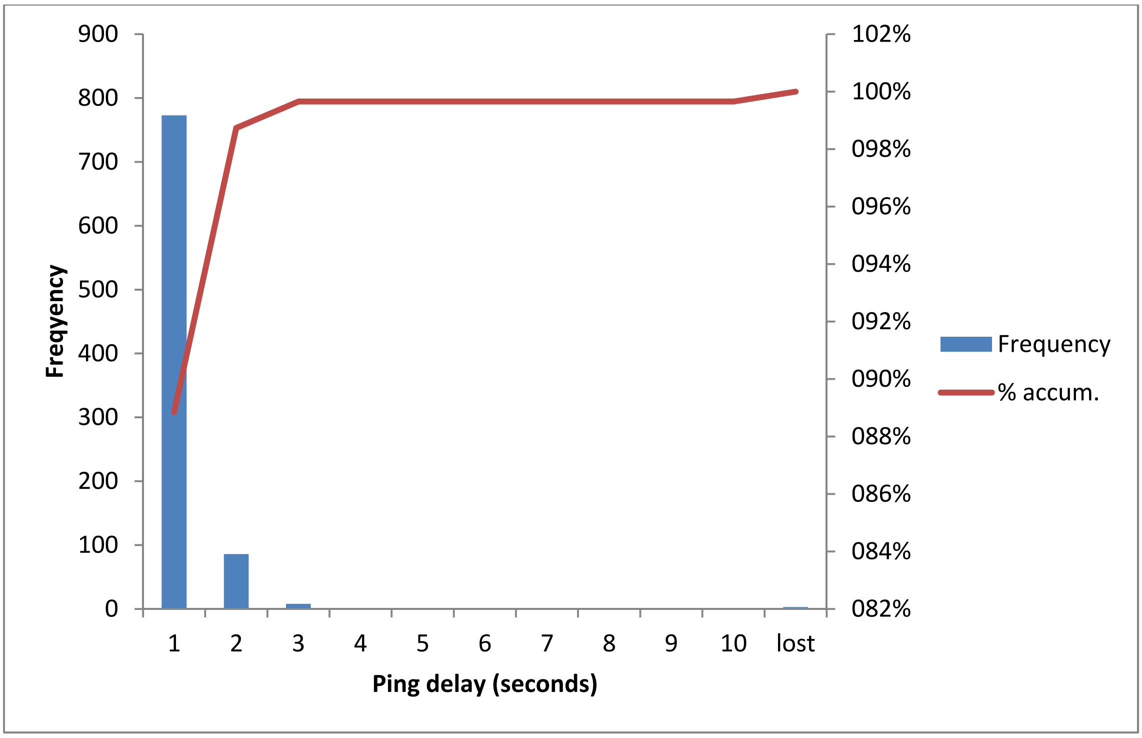


Figure 115 Histogram of ping delay between NOPL and on-street equipment

#

5.6.1.5 Tests results

DCP middleware

In order to measure the performance of the DCP middleware based communications, the PING messages being published every 5 minutes by the Segment Controller 3 (located at Avenida de los Reyes Católicos, Alginet) have been monitored during a whole day (21/11/2012).

Delay seconds from expected timestamp (seconds)	Frequency	% accum.
1	233	82,04%
2	30	92,61%
3	5	94,37%
4	0	94,37%
5	1	94,72%
6	4	96,13%
7	4	97,54%
8	2	98,24%
9	0	98,24%
10	1	98,59%
11	1	98,94%
12	0	98,94%
13	0	98,94%
14	0	98,94%
15	0	98,94%
lost	3	100,00%

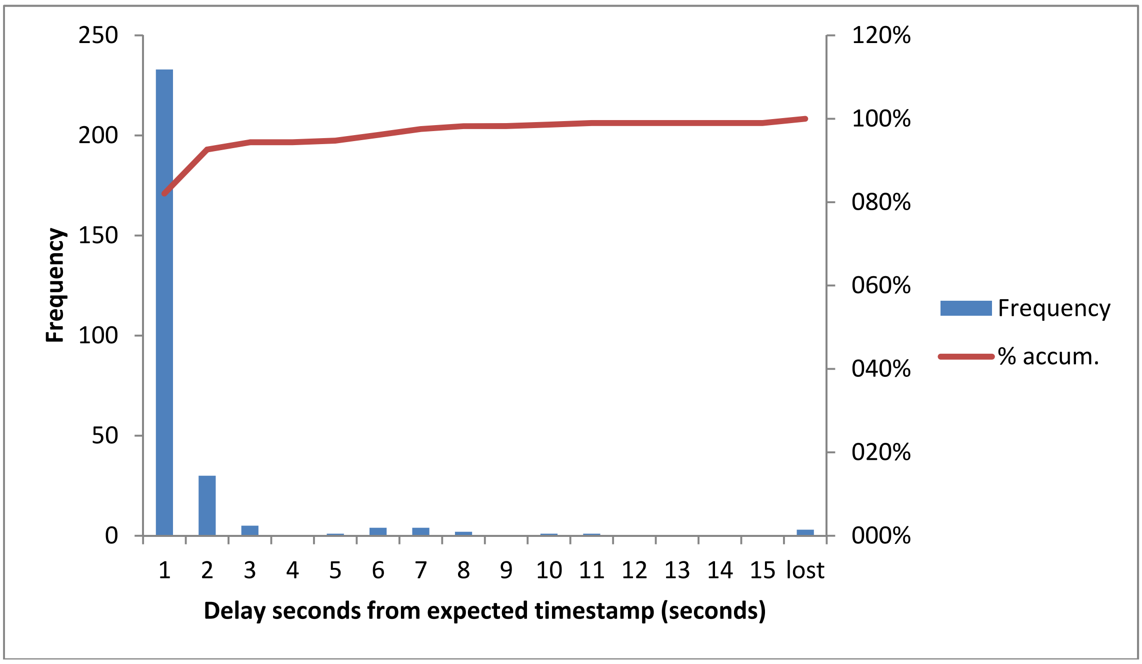


Figure 116 Histogram of delay of PING messages

The important results extracted from this test are:

- 94.37% of published items reach NOPL with a delay minor than 3 seconds, which allows the correct operation of the system and presents a similar behaviour to the identified in the baseline.
- The measured **loss rate is of 1.06% (acceptable for monitoring tasks)**. This loss rate can be explained by the occasional loss of signal suffered occasionally by the 3G routers used by the Segment Controllers to communication to the Internet.

DCP-Rest

In order to measure the performance of the DCP-Rest based communications, the queries for statistical data being performed every 5 minutes by the NOPL to the Segment Controller 3 (located at Avenida de los Reyes Católicos, Alginet) have been monitored during a whole day (21/11/2012).

Response time (seconds)	Frequency	% accum.
1	5	1,75%
2	2	2,46%
3	102	38,25%
4	98	72,63%
5	47	89,12%
6	12	93,33%
7	4	94,74%
8	7	97,19%
9	6	99,30%
10	2	100,00%
greater...	0	100,00%

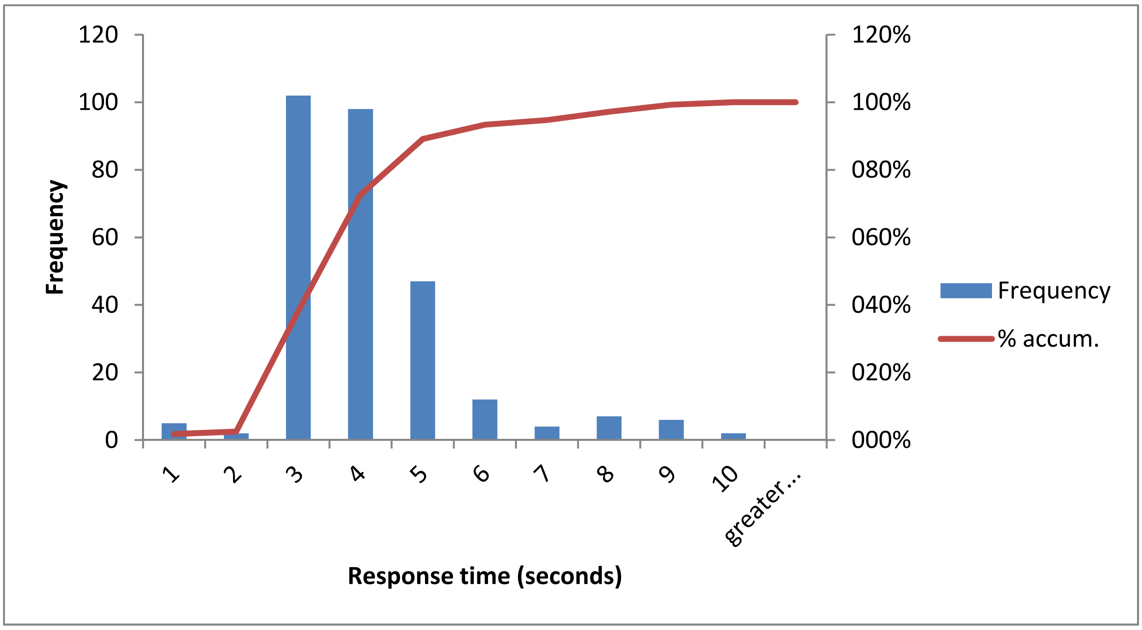


Figure 117 Histogram of delay of command's response

The important results extracted from this test are:

- **No loss rate is detected** in the communication mechanism used for control tasks (as required by the application).

- **Measured delays are in the range of those measured in the baseline**. The average delay is greater, due to the time used by the Segment Controller to compute the answer to the query before replying back. In any case, measured delays are good enough for the correct operation of the system.

IEM – NOPL communication module

In order to check the behaviour of the IEM – NOPL communication module, a number of queries have been triggered by using a testing application that emulates the behaviour of IEM with respect to this particular issue in order to automatize the testing tasks and make the test more complete.

The protocol defined between IEM and NOPL to perform and confirm (contract) the queries ensures that a certain (contract) is only applied once, preventing the existence of incoherent states between IEM – NOPL.

1. IEM asks NOPL for the available consumption or production in a certain time interval. NOPL responds with the corresponding curve
2. IEM sends NOPL a query for an increase or reduction of consumption / production; NOPL returns the closest acceptable request, with an associated ID.
3. IEM confirms the query by contracting it in a single operation. NOPL returns a confirmation representing that the contract has been applied.

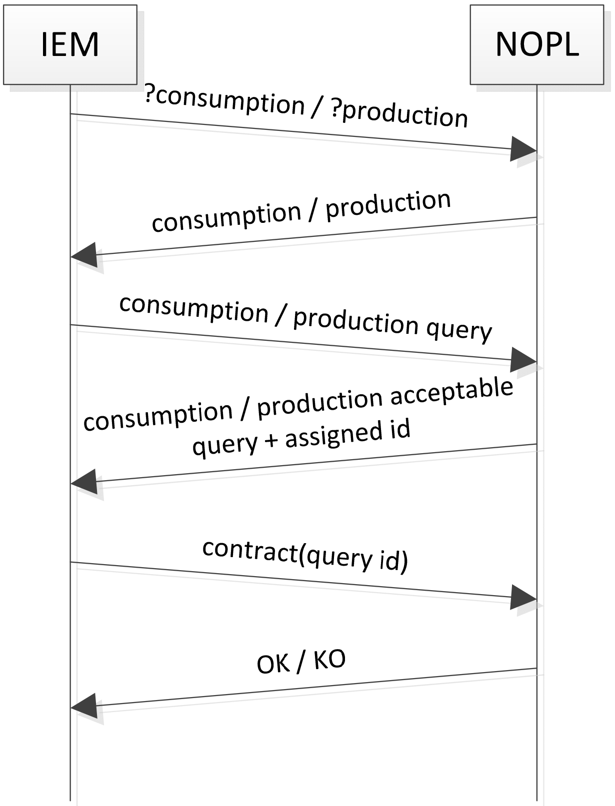


Figure 118 Message diagram of IEM - NOPL protocol

The tests performed have shown that NOPL activates the corresponding strategy in a time lapse of maximum 10 seconds since the contract to a certain query has been performed, in all cases.

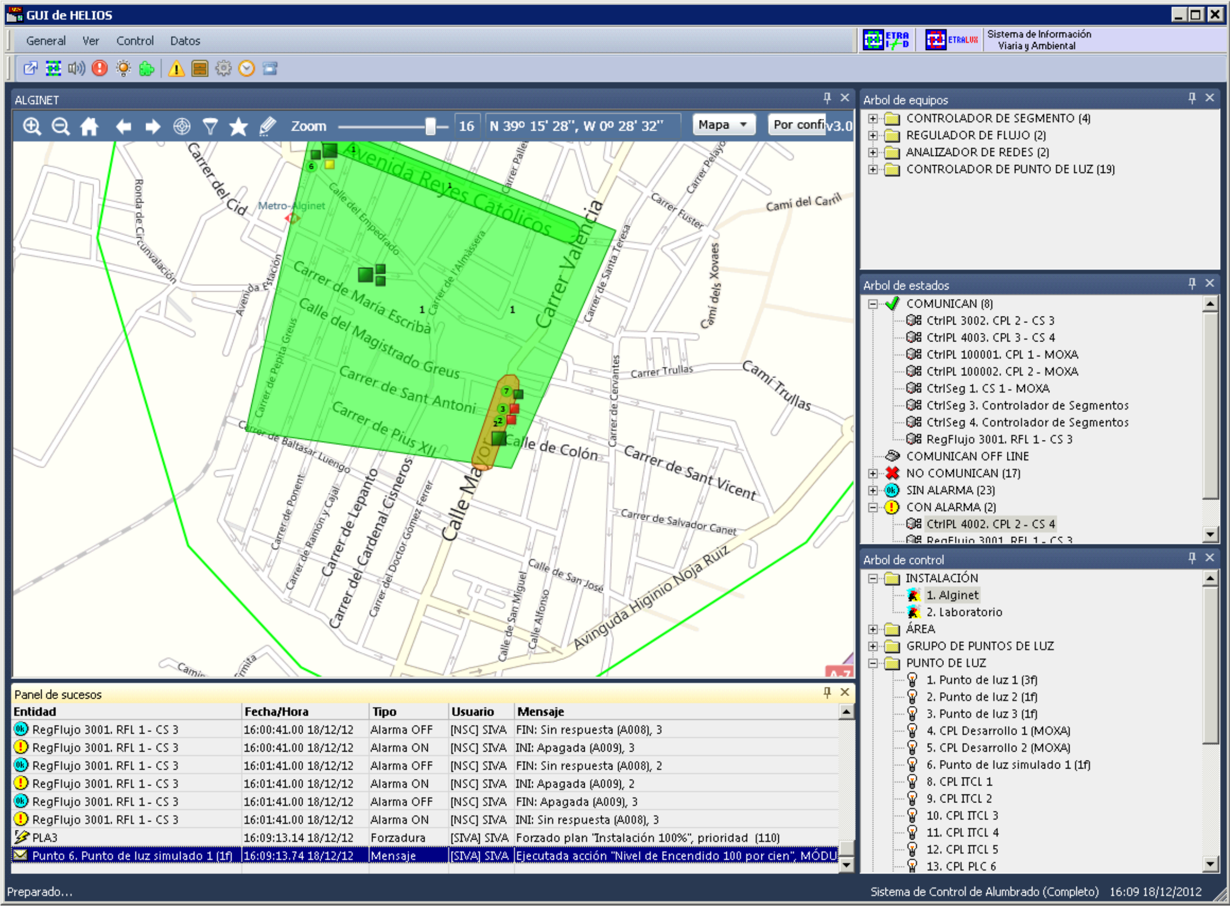


Figure 119 NOPL GUI showing messages of new strategy (Installation 100%) being applied

5.7 Integrated Testing

5.7.1 Methodology of testing

For the end-to-end IPv6 scenarios, the main delays are generated in the wireless network. The IEM- and NOEM-specific delays have been presented in their representative sections above. Therefore in this section the most effort is spent evaluating the integration of IPC and DCP. For the full integration tests, the metering data is further propagated to an IEM service instance, hence becoming available through a NOEM service instance.

Tests have been conducted both on hardware; on the lab mini-testbed, and in timing accurate emulated mode. Data has been logged through debug outputs on the nodes, through radio packet dumps and through recordings of meter reading messages arriving to a DCP root/to an IEM service instance.

5.7.2 Indicators measured and comparison to objectives

The evaluation has been structured around two related scenarios, following the descriptions in D7.1, (4.3.8), concerning smart meter monitoring and discovery, and on demand detailed monitoring. The basic indicators evaluated have been the meter reading message delays, meter reading message losses and the time it takes for a new device to join the network, get the relevant subscriptions and start delivering data.

The main objective as given in the evaluation plan has been to validate the correspondence with the results achieved in the individual component tests. This ensures that the business services can operate independently of whether the metering data is delivered thorough existing concentrators and/or though IPv6 enabled smart meters.

5.7.3 Monitoring and maintenance system evaluation

In this scenario the main metering monitoring functionality is evaluated, where meters are addressed all at once, and subscription readings are meant to reach all meters in a specific network.

5.7.3.1 Timeliness of communication

The timeliness of communication has been evaluated through measuring the delays between meter reading publication and delivery to the higher level services. These figures have been extracted from radio packet logs, where the TCP flows can be traced. The expected delays can also be calculated based on the per-hop link delays:

The delay for a single hop is close to 13 ms, the gateway overhead for one packet is 30 ms and one TCP session for meter reading delivery consists of four round-trips.

As a result, the ideal message delivery delay, until the TCP session is successfully closed, if there are no losses, range from around (8*13+4*30) = 230 ms, for a one hop case, to around (3*8*13+4*30) = 430 ms for a three hop case.

In a network with ongoing traffic, each network hop presents a 0-4% risk of packet loss, dependent on network topology and the load of the network. With a TCP timeout of one second, a simplified formula for the expected delay is given as:

#network hops*8*(13 + loss-rate*1000) ms.

The formula has been validated with the radio packet delay data, and has been found to give a good prediction of the expected average delays. For a network of 10 meters and one gateway, the measured average delay has been around 380 ms for nodes close to the sink, and close to 600 ms for nodes further away. This corresponds to a loss ratio of close to 2%. For a network of 20 meters and one gateway, the likelihood of losses increases to between 3% and 4%, resulting in average delays around 500 ms and 850 ms, respectively. This is for networks where every meter sends readings every minute. With less frequent readings, the loss ratio will go down, and thereby the average delays.

In addition, for the metering data to be stored, and reported as stored, in an IEM database, another 1200 ms is needed for the IEM callback. This callback time is independent on other meter data traffic, as the DCP root will cache and send data to the higher level services while also handling new data. These tests are done with an IEM instance running on a standard pc inside UDE, so the conditions are not optimized for speed.

5.7.3.2 Reliability of communication – meter reading message losses

In the smart meter usage scenarios we have studied, with reading interval down to 10 seconds, data older than one reading interval is of no use. Therefore it is more efficient to let a lossy tcp session timeout, and provide redundancy on a higher level through sending incremental reading updates. That way the monitoring service can induce the amount of energy spend based on the readings in the following messages, and can therefore tolerate certain message losses.

The message losses have been evaluated for a number of network topologies, with between 10 and 30 devices, and different loads, with subscription intervals between 10 and 120 seconds.

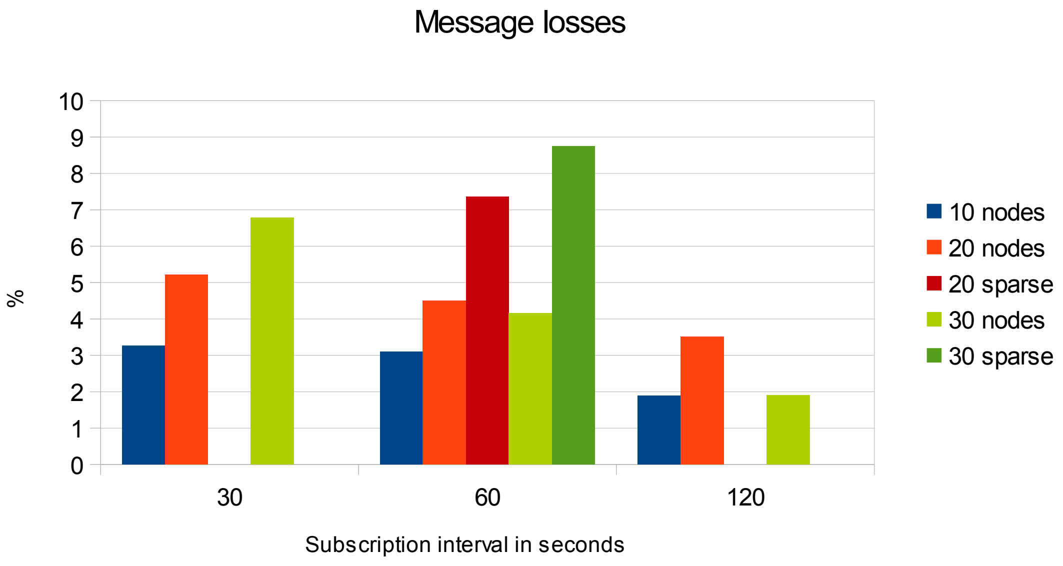


Figure 120: Subscription interval in seconds

For a moderately loaded network the losses are less than 2%. This number increases as the load increases, up to a point where a shorter reading interval would offer limited benefits.

The main 30-node network shows lower losses than the main 20-node network because it has higher node density, with a lower average number of hops to the gateway (1,86 vs 2,0). In the sparse network topology tests this is compensated; both the 20 and the 30 node topology has an average distance of 2,7 hops to the gateway. As expected the losses are larger for the larger network.

5.7.3.3 Subscription setup times

When new devices are added to create a new network, they will exchange routing information with each other after an initial bootstrapping delay, and learn about the closest gateway. When this is done, devices will send status/availability messages to the gateway, which checks if there are any relevant subscriptions that should be sent to the new devices (such as a subscription that is valid for all meters in a network). With routing setup parameters designed to reduce overhead, the network join procedure can take up to two minutes, before upwards and downwards links are established. Looking specifically at the case where a new subscription is made specifically for the new network after the basic routing information has been exchanged; the specific subscription setup time can be evaluated.

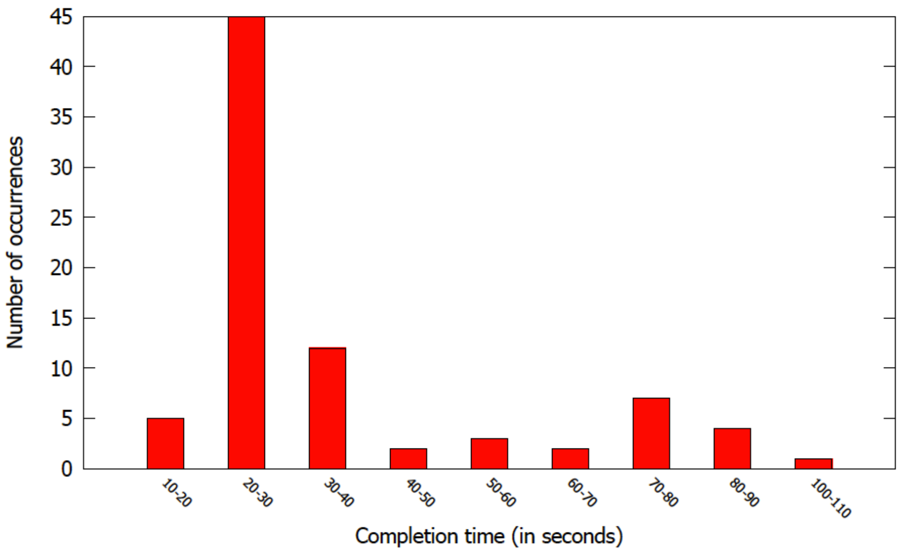


Figure 121 Histogram of the time it takes for all meters to report data after a new subscription

The figure shows a histogram with the distribution of completion times for making a new subscription to all meters in the mini-testbed, and having received new data from every node. The histogram shows that in the majority of the tests all the meters responded within a 30 second period, with a tail of cases with higher delays. The higher delays, especially the little peaks at 70 to 90 seconds, stem from cases where the subscription request for one meter was lost in the radio network. Since DCP uses periodic status/availability messages both for discovery and information about the state of the nodes including the currently known subscription, it takes some time for DCP to become aware of the message loss and reissue the subscription. This time is configurable – 60 seconds has been found to be a suitable trade-off for the evaluations. Technically a smaller refresh interval can be chosen, but at the cost of increased administrative messaging overhead. As a result, the DCP subscriber might need up to 60 seconds (or even more if the beacon messages are lost) to realize a request was lost, therefore the resend is subsequently delayed.

The mini-testbed offers a harsh radio environment, in the sense that the nodes were configured to enforce the formation of a multi-hop routing topology, even though they were technically within radio range. As a result, the nodes have experienced more traffic overhearing than otherwise. Corresponding tests using emulated networks show that the initial setup times will remain the same also for network sizes of 10 and 20 nodes, with the bulk of completion times in the 30 second range plus a few few trailing up to 100 seconds for the cases where a status/availability message has been lost.

Any new device added to the network will need to go through the network join procedure, including the delay of sending of subscriptions. The total delays will span between 30 seconds and three minutes. The delays are influenced by the load in the existing network and the number of hops from the gateway, but mostly dependent on the semi-random delays in the join procedure designed to minimize network traffic overhead if connectivity errors occurs.

5.7.4 On demand detailed monitoring evaluation

The previous scenario dealt mainly which treating all the meters the same. In contrast the on demand detailed monitoring scenario shows a way to utilize the possibilities to direct address specific meters, or subgroups of meters in the network.

The scenario has been done as a response to the identified need for better power quality monitoring, mentioned in previous IEM evaluation section and further detailed below, and in

[12].

5.7.4.1 On demand detailed monitoring business case

Power quality monitoring is one of the key issues of managing an electrical grid, which is becoming even more important with more distributed and more variable generation. Today expensive equipment allows monitoring of the power network at key points, but for cost reasons this cannot reach the residential end-user. To prevent an excessive need for specialized monitoring hardware, e.g. network analysers, it is proposed to engage the capabilities of modern smart meters which can monitor and report power quality events (e.g. voltage deviations). Subsequently a grid operator can follow up with actions in an affected area in order to analyse problems e.g. by increasing the sampling rate. Although the smart meter precision is not comparable to the precision of a commercial network analyser, in large numbers distributed smart meters forming a mesh network can provide sufficient information for power quality in an area while keeping the monitoring overhead and the cost low. It is shown that by using modern interoperable wireless communication protocols and Internet services, the proposed system has a high degree of flexibility, and good potential for scalability and resilience. The preliminary evaluation shows that the smart metering infrastructure, if coupled with suitable information and communication tools, can offer innovative value-added services and enhance existing business processes.

Several business benefits could be potentially achieved. Indicatively we mention:

- The DSO can have a proof of power quality delivered to the residential user. This enables the DSO and others, e.g. energy providers to be able to prove to the user that high quality electricity was delivered and that could contribute positively to the provider's reputation, which may bring new clientele or increase customer loyalty.
- The residential customer can monitor his own power quality and even do potential on-site immediate diagnostics for misbehaving electrical appliances that he may plug in his premises.
- The customer can make additional comparisons of energy providers not only based on price but also on the quality of electricity offered, and select his future contract in a much more conscious way. This may increase the competition among providers for high quality energy offerings.
- Power quality monitoring could be coupled with other envisioned smart grid services, e.g. device identification and better analytics, to better predict the potential effects of specific devices on network stability and improve early problem identification and preventive maintenance.
- The DSO can use the information acquired in order to optimize the voltage delivered, i.e. apply conservation voltage reduction (CVR) and volt/VAR optimization which may lead to reduction of energy.

An interesting question that is raised is to what degree these business requirements e.g. of residential customer power quality monitoring, with low-cost capabilities, can be satisfied, especially when taking into consideration the future smart meters deployed that are expected to be able to provide fine-grained data in high frequency metering. If sensor-wise the smart meters can deliver similar information both in quality and quantity, one may realise a “cheap” alternative for a specific subset of functionalities. To do so, the following actions are envisioned:

- Equip the smart meters with sensors that are able to monitor the parameters needed for power quality monitoring in a fine-grained form. To some extend this functionality is already built-in today. However, there are significant differences with respect to the monitoring intervals and their on-meter storage.
- Enhance the smart meters with modern communication capabilities so that they can communicate (e.g. over IP) on-demand the necessary data. The data itself should be in a standardized format so that other entities can operate on them (aggregate

them, process them in the network etc.). Additionally the existence of multiple alternative communication paths could enable information extraction and interaction during critical situations.

- Allow on-device customizable logic execution on the smart meters, so that external entities can configure or even program them with task specific logic. For instance it should be possible to increase the frequency of measurements on the power quality monitoring factors, set thresholds for them or even execute application logic on the meter for pre-processing of these factors.
- Provide an infrastructure where the smart meters and in-network services can interact in an open and standardized way. The infrastructure should enable collaboration and interaction for building up large-scale systems. Hence issues like scalability, lightweight communication, event-driven interaction, on-device and in-network processing are of interest.
- Support the integration and interaction with enterprise systems so that business processes take advantage of the infrastructure itself and changes to the enterprise level can easily lead to adjustments on the network and the smart meters to support the changes in business requirements

5.7.4.2 Timeliness of communication – the delay between the activation of detailed monitoring and delivery of first data

The main goals of the carried out experiments focus on the aspect of evaluating a subset of communication aspects of the 6LoWPAN mesh smart meter network and its interaction with the energy services, i.e. the delay between issuing a subscription, e.g. due to an alarm raised in the grid, and the reception of data from the smart meters. By doing so it is possible to evaluate if such actions for monitoring can be done in an acceptable time frame for the operators to capture the grid events.

When issuing a subscription request for detailed monitoring of a specific part of the network, the delay will depend on the existing load in the network. When the existing meter subscription has a reading interval of 60 or 120 seconds, the majority of new detailed subscription requests for up to four nodes will complete in less than 20 seconds. If the existing subscription has a reading interval of 30 seconds, the delays for all four meters to complete the new subscription will be up to a minute. The main reason for these delays are the high likelihood of other nodes between the recipient node and the sink being busy forwarding metering data.

5.7.4.3 Reliability of communication

Since the detailed monitoring will increase the load on the system, the likelihood of losses will also increase. The measurements in the following figure shows the increased losses when two nodes are targeted for the detailed subscription, with a 10 second interval.

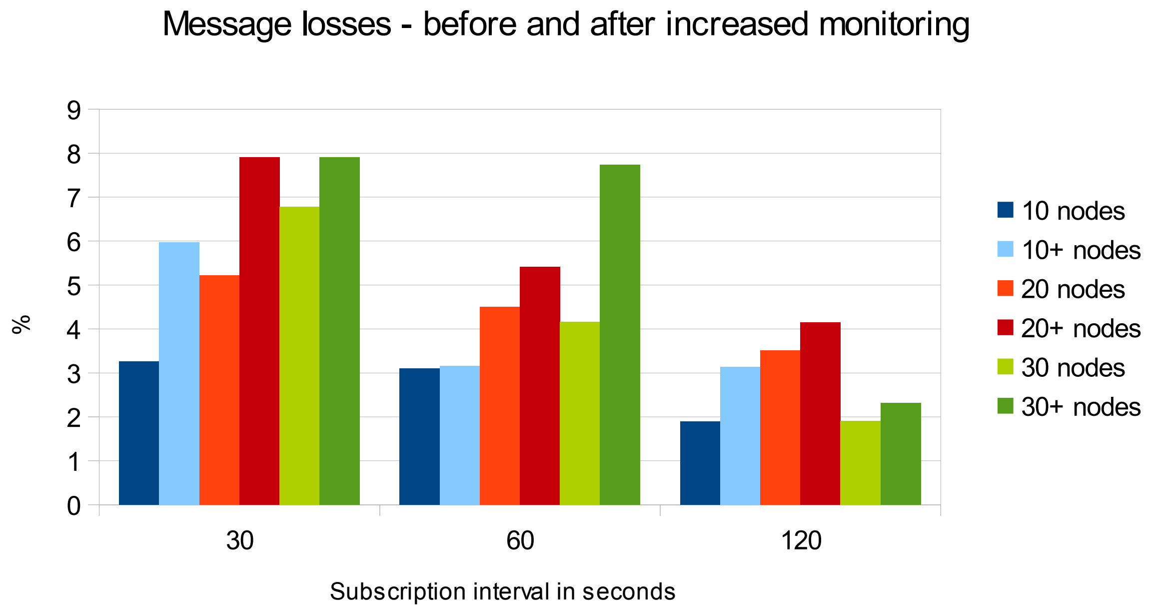


Figure 122: Message losses

As expected, the increased loss ratio is mostly noticeable for networks which already have a high initial load. If the metering reading interval is already as short as 30 seconds, further decreasing it to 10 seconds is of limited usefulness and is mainly evaluated to stress test the system. For the cases where the previous metering interval was 120 seconds, the extra load caused by the detailed monitoring can be handled with few additional losses.

5.7.5 Conclusions

The results from the integrated tests show that the individual components work together as could be predicted from individual component testing. The higher level services can operate oblivious of whether the data is coming from older (IPv4 or non-IP) smart meters, or from IPv6 enabled smart meters.

Regarding network configuration, the objective "integration of a new device must be realized with minimal human intervention" has been verified to hold, since the new device will automatically join the existing network and start reporting data, within acceptable time boundaries.

Many experiments have been done with the main meter reading interval for all meters being as short as 60 or even 30 seconds, to stress the system and verify usefulness in periods of high load. The cost is a constant high flow of messages. In practice, for stable networks, a longer default reading interval could be used, and instead use the possibility to do targeted on demand monitoring with shorter intervals when needed.

6 Overall Conclusions

This Deliverable presents the process of the analysis of the results (both objective and subjective) of the NOBEL pilots and simulation tests and proceeds to the overall evaluation of the project. Results are focused mainly on energy performance and savings, translated also in monetary values but also on technical performance, usability/acceptance assessment of the system by different types of users.

The NOBEL Pilots were conducted in Alginet of Spain and involved standard prosumers, senior prosumers and local grid DSO. Logging mechanisms and questionnaires were developed on to facilitate the evaluation process.

Considering necessary assumptions, reference scenarios were formed in order to provide a baseline for each pilot phase evaluation (section 2.4). As shown in Chapter 3, the NOBEL system managed to reach the initial expectations for energy savings. The reduction of energy consumption was 16,53% for standard prosumers (BAF application users) and 30% (average for the two types of hardware modifications of points of light) for the senior prosumers (NOPL application user). These results refer to the second phase of trials, where enhanced versions of the applications were provided to the users. The energy reduction led also to the reduction of CO2 emissions, which were calculated 17,2% reduced for standard prosumers and 30% (average value) for senior prosumers.

The economic benefit for the standard prosumers was a combination of the energy consumption reduction and the more beneficial energy trading within the market. The automatic agents seemed to contribute to higher revenues from trading clean energy in relation to manual transactions, increasing however slightly the costs for energy.

The social impact of the system is evident through the questionnaires and the user survey results, but also from energy usage results. Users are willing to alter their behavior, change existing business patterns and even pay slightly more expensive energy in order to be cleaner. The level of user satisfaction in terms of user interface usability and friendliness reached the Consortium targets, as the system was rated positively through post-pilot questionnaires.

The NOBEL developers handled technical problems observed in the first phase and integrate new features in the second, meeting the initially defined technical requirements.

Finally, costs and benefits were analyzed for all actors. NOPL was proved to be a beneficial investment both for its developer and user. NOEM and BAF developers benefits for a wider implementation of the system cannot be evaluated precisely and need a detailed study according to the specific needs. NOEM offers mainly qualitative benefits to the DSO but also economic benefits are foreseen. Finally, BAF users are the main beneficiary of the system, as the economic benefits are proved both through Alginet pilots and also simulations investigating scalability of the project.

The Business model identified as the more beneficial and desirable through CEA analysis is the Business model 3 " "Optional deployment for all end-users". Comparing the sub-scenarios, there is no difference as extracted through simulations, thus we can select the "Free Market" scenario as there is a pan-European tendency to repeal FiTs.

Finally, it should be mentioned that NOBEL is still an innovative prototype, and provided that, its performance and acceptance during the trials is considered to be successful and according the initial expectations.

7 References and Acronyms

7.1 Acronyms

Acronyms List	
API	Application Programming Interface
BA	Brokerage Agent
BAF	Brokerage Agent Front-End
CBA	Cost Benefit Analysis
CEA	Cost Effectiveness Analysis
COCOMO	Constructive Cost Model
CPL	Combined Programming Language
CPU	Central Processing Unit
CRUD	Create, Read, Update and Delete
CVR	Conservation Voltage Reduction
D	Deliverable
DB	Database
DBMS	Database Management System
DCP	Data Capturing and Processing
DSO	Distribution System Operator
EU	European Union
EV	Electric Vehicle
FIT	Feed In Tariff
GB	Giga Byte
GPB	Google Protocol Buffer
GPRS/3G	General Packet Radio service
GUI	Graphical User Interface
HTML	HyperText Markup Language
HTTP	Hypertext Transfer Protocol
ICT	Information and communications technology
ID	Identity
IEM	Enterprise Integration and Energy Management Services
IPC	Inter-process communication- Communications and HW Adaptation
IPv6	Internet Protocol version 6
IRR	Internal Rate of Return
J2EE	Java 2 Platform Enterprise Edition
JPA	Java Persistence API
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
kWh	Kilo Watt hour
LAN	Local Area Network

LED	Light-Emitting Diode
MIDP	Mobile Information Device Profile
NOBEL	Neighbourhood oriented Brokerage Electricity and monitoring system
NOEM	Neighbourhood Oriented Energy Monitoring and Control System
NOPL	Neighbourhood Oriented Public Lighting Monitoring and Control System
NPV	Net Present Value
OS	Operating System
PC	Personal Computer
PLMCS	Neighbourhood Oriented Public Lighting Monitoring and Control System
PLS	Public Lighting System
PV	Photovoltaic
QP	Quality Problem
RAM	Random-access memory
RAP	Remote Application Platform
PBP	Payback Period
RCP	Rich Client Platform
RES	Renewable Energy Sources
REST	Representational State Transfer
RFC	Request for Comments
SaaS	Software-as-a-Service
SEP	SEnior Prosumer
SLOC	Source lines of code
SQL	Structured Query Language
STP	STandard Prosumer
SUS	System Usability Scale
SWOT	Strengths, Weaknesses, Opportunities, Threats
TCP	Transmission Control Protocol
TOU	Time-of-Use
TSO	Transmission System Operator
UDP	User Datagram Protocol
UI	User Interface
URI	Uniform Resource Identifier
VAT	Value Added Tax
WAN	Wide Area Network
WP	Work Package
ZIP	Zero Intelligence Plus
XML	Extensible Markup Language
µCHP	Micro Combined Heat and Power

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