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Application of the ADDRESS conceptual architecture in four specific scenarios

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Executive Summary

One particularity of the ADDRESS conceptual architecture, as defined in its first deliverable document [D1.1], is its generality in the European context. It is generic because it does not take into account any specific national factors (e.g. the underlying generation mix, industry structure and regulatory framework, geography, etc.) nor does it assume anything about its actual technological or institutional requirements. In short, the ADDRESS conceptual architecture should be a template for developing active demand (AD) across the entire European electricity industry.

Albeit conceptually elegant in principle, this approach is limited by the less than ideal and practical realities on the ground. If the ADDRESS architecture is to be implemented, it is necessary first to pre-validate its technical and commercial feasibility and soundness prior to its deployment. Adopting a scenario approach suits quite well the kind of conceptual pre-validation we are seeking at this stage of the ADDRESS project (that is before taking the work into further detailed development stages in the technical project workpackages and before defining the contents and concept for the field validation activities).

Hence, the adoption of a scenario approach should serve as an exercise in envisioning how the conceptual architecture and the ADDRESS concepts could evolve in a number, four to be precise, of realistic European settings. We established that in the elaboration of the scenarios, four factors are to play key roles when assessing the potential evolution of an ADDRESS future. These are:

- The *geography* of the area where a scenario is developed. The geography here refers primarily to the climatic and general weather conditions of the area.
- The *characteristics and the density of consumers* in the area when and where a scenario is developed
- The *electricity industry infrastructure* (i.e. the generation mix and the market and regulatory context) in place in the area when and where a scenario is developed, and
- The *technological context* (i.e. primarily consumer end uses and network technologies) of the area when and where a scenario is developed.

The time scale of the evaluation of the scenarios is from now (2009-2010) until 2020. This time horizon may appear short when one acknowledges the radical industry changes implementing the ADDRESS architecture entail. Moreover, the scenarios reported in this document may be seen as being overly optimistic in the current economic climate. Nonetheless, the 2020 horizon is in synch with time scales implementing constraining targets for reducing greenhouse gas emissions in the EU and globally and there is as well political and business-driven will to get concepts like ADDRESS off the ground in the short to medium term to generate wealth and maintain the status of the EU as a model in developing innovative energy technologies.

In the evaluation of the four possible ADDRESS futures, we adopted an approach based on the assessment of the potential success of ADDRESS and its architecture in the horizon to 2020. Herein success is defined by a measure of global welfare improvements over the 2020 horizon brought about to the entire electricity supply chain (i.e. from central generators down to individual consumers) by the deployment of ADDRESS. Any given scenario thus arises because of

- The current position (in 2009-2010) and the expectation for change in the four key factors listed above which are exogenous to an ADDRESS deployment, and
- The gradual deployment of the ADDRESS conceptual architecture and the changes to the four key factors themselves driven by the deployment of ADDRESS.

This approach has the benefit of clearly identifying under which circumstances an ADDRESS deployment may be more or less desirable and potentially beneficial to the entire supply chain or only to sub-groups of industry players. This exercise provides the current generic ADDRESS conceptual architecture with a sanity check, and it also provides necessary guidance for adapting the architecture to particular situations in the real world to maximise its potential success. Likewise, it should also signal practical situations where deploying ADDRESS is not worth the effort and the investments in the horizon to 2020 (although it may be worth it in the longer term).

Highlights of the four scenarios in connection to the ADDRESS conceptual architecture

Scenario 1—Southern City

This scenario is illustrative of how ADDRESS may be deployed in an urban environment where there are significant numbers of domestic and small business consumers whose demand for electricity is driven primarily by cooling needs. The consumer population consists primarily of domestic consumers — a mix of young professionals, families with children and old age pensioners — with proximity shops and professional services offices. The local underground distribution network has been experiencing an increased frequency of plant overloads because of the steady increase in air conditioning demand.

At the national level, there is a thermally-dominated traditional generation park with an already significant number of large transmission-connected wind farms. These have increased the needs of the TSO for ancillary services and BRPs for short-term balancing flexibility. There is a well-established wholesale electricity market while small consumers have been introduced to retail competition only recently.

This scenario appeared to be the one with the most potential success. It combines two of the essential ingredients for a commercial success:

- A definite need for more affordable flexibility resources (like active demand) from both regulated and deregulated actors. This is generally due to the already large penetration of renewable energy in the electricity system which has been driving the growth in the demand for ancillary services and balancing services.
- The potential supply of active demand within the area of the scenario is quite high due to the:
    - High consumer density
    - High demand for electricity driven chiefly by the needs for space cooling, which is inherently flexible
    - Plug-in electric vehicles making an appearance later along the scenario horizon.

Because of these, aggregators start making their appearance quite early on. This is further enabled by the roll-out of a smart metering infrastructure and the availability of affordable and secure third party telecommunication infrastructures.

From the commercial perspective, active demand markets evolve from very *ad hoc* bilateral trades to formalised markets for flexibilities run by the national power exchange. Moreover, the regulator by about 2015 has to take action in laying out the basic rules for establishing the institutional framework needed to permit transparent active demand trading in distribution networks.

Scenario 2—Southern Countryside

This scenario is illustrative of how ADDRESS may be deployed in a rural environment where consumers are few, but where there may be significant agricultural load on small to medium-sized farms and where there is great potential for dispersed generation in the form of small wind, photovoltaics and biomass. At the national electricity system level, there are forecasted capacity shortages which will have to be fulfilled by bulk transnational electricity imports as old and dirty coal and oil-fired power stations are being decommissioned gradually. Therefore, there are pressures to modulate demand as a mean to ride through low capacity availability periods and to temper associated wholesale price swings.

The consumer population consists primarily of farms — with irrigation and farm produce primary processing loads — and domestic consumers — a mix of families with children and old age pensioners — with a few small shops and professional services offices grouped in a small village. The area is served by a long and aerial distribution network which still has headroom for demand growth.

This scenario appeared not to be the one with the most potential success. It combines only one of two of the essential ingredients for a commercial success:

- A definite need for more affordable flexibility resources (like active demand) from both regulated and deregulated actors. This is due to decreasing capacity margins at the wholesale electricity market level which provide incentives to shift on-peak consumption to off-peak periods.
- On the other hand, the potential for active demand within the area of the scenario is low because of the:
    - Low consumer density
    - Seasonal nature of the agricultural load.

Because of the need for flexibility at the national level, aggregators may start making their appearance quite early on; however, they show little interest in this rural area. It is only at a later stage once more and more distributed generation is connected in the area that the DSO shows interest in using active demand locally to manage its network better in light of this surge of generation.

In that situation it emerges that no aggregator is genuinely interested to operate in this area. This forces the DSO, supported by the regulator, to issue a call for tenders for an exclusive aggregation franchise over that area. The winning aggregator would obtain captive *consumers* and a captive *customer* (the DSO) over some time and, under some set rules, making the initial investment more likely to be profitable.

Scenario 3—Northern Suburban Village

This scenario is illustrative of how ADDRESS may be deployed in a suburban environment in the North of Europe where there are important numbers of domestic consumers and fewer small business consumers over a relatively wide area. The demand for electricity is dominated by lighting and other household appliances as space and water heating are either provided by gas or district heating, although heat pumps have started to appear. In the upstream electricity system, a vast majority of the installed generation capacity is based on hydro and numerous interconnections with neighbouring countries help securing sufficient and relatively cheap electricity supplies. Consumers have been introduced to retail electricity competition about a decade ago and have learned about the benefits of shopping around for their electricity.

The distribution network serving the population in the area is underground. The frequency of overloading cycles on cables and transformers is still low, and there are times in the year when demand is very low where the feeder voltages rise very close to the statutory limit. The socioeconomic makeup of the consumer population is relatively uniform and dominated by families with children and older family units whose children have left the household. The majority of people are well-educated and sensitive to environmental issues.

This scenario appeared to be the one with the least potential success from the point of view of the 2009-2010 boundary:

- There is plenty of affordable flexibility in the national electricity system thanks to a good supply of hydroelectric capacity and strong international interconnections.
- The potential supply of active demand within the area of the scenario is not high initially because of the:
    - Medium consumer density
    - Low demand for flexible electricity uses like space heating (heat is generally provided by district heating or fossil fuels while heat pumps remain few in number).

In this case, it is only once plug-in electric vehicles start appearing *en masse* within the community that the need for active demand arises for the DSO. Here the regulatory philosophy is to let the market decide the best way to organise trade. Therefore, a number of competing alternatives arise allowing for some aggregators to fail and businesses to consolidate.

Scenario 4—Mid-Latitude High-Rise Community

This scenario is illustrative of how ADDRESS may be deployed in a high-rise housing estate where there are important numbers of domestic consumers and several small business consumers serving the community over a relatively small land footprint. The demand for electricity is dominated by space heating in the winter and cooling in the summer months. The national electricity system is characterised by a significant number of large capacity thermal generation plants which are primarily nuclear. Just like the other scenarios, there is a well-established wholesale power market which is already integrated with neighbouring countries.

The distribution network serving the population in the area is underground and the frequency of overloading cycles on cables and transformers has reached unprecedented levels especially in the summer because of the air conditioning demand. The consumer population consists primarily of domestic consumers — a mix of families with children and old age pensioners — with shops, professional services offices, a community centre and schools. Traditionally, the consumers have been served by an integrated distributor-retailer who did offer alternatives to single flat tariffs. Retail competition has been introduced not long ago, and so far consumers have shown reluctance to switching retailers.

This scenario appeared to be quite interesting:

- There is a growing need for flexibility at the national level because of many more new bigger renewable energy projects are coming online. In addition, there is an explicit recognition by central generators that they can use active demand products as substitutes for some of their statutory ancillary services requirements.

- The potential supply of active demand within the area of the scenario is high because of the:
  - High consumer density
  - High demand from flexible electricity uses like space heating and air conditioning.

The original aspect of this scenario is the fact that the aggregator in this case might be the housing estate by itself which establishes the aggregator as a not-for-profit business serving the community. The ultimate goal here is to help the tenants to optimise their rising energy bills and mitigate the effects of fuel poverty. The main challenge in this case is to convince people on the estate to join the scheme.

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1. Introduction

1.1. Scope of the document

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The time scale of the evaluation of the scenarios is from now (2009-2010) until 2020. This time horizon may appear short when one acknowledges the radical industry changes implementing the ADDRESS architecture entail. Moreover, the scenarios reported in this document may be seen as being overly optimistic in the current economic climate. Nonetheless, the 2020 horizon is in synch with time scales implementing constraining targets for reducing greenhouse gas emissions in the EU and globally and there is as well political and business-driven will to get concepts like ADDRESS off the ground in the short to medium term to generate wealth and maintain the status of the EU as a model in developing innovative energy technologies.

In the evaluation of the four possible ADDRESS futures, we adopted an approach based on the assessment of the potential success of ADDRESS and its architecture in the horizon to 2020. Herein success is defined by a measure of global welfare improvements over the 2020 horizon brought about to the entire electricity supply chain (i.e. from central generators down to individual consumers) by the deployment of ADDRESS. Any given scenario thus arises because of

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1.2. Structure of the document

The document comprises the following sections:

- Section 2 describes the scenario-building philosophy used for ADDRESS. Specifically, it defines a new modelling approach for scenarios based on measured success for active demand.
- Section 3 presents the narratives of four specific scenarios for ADDRESS. We also include a discussion of the relative successes of the scenarios to underline the key success drivers for ADDRESS.
- Section 4 outlines the results of the critical analysis of the four scenarios in light of the ADDRESS conceptual architecture described in detail in [D1.1]. This section first identifies the assessment criteria for the suitability of the architecture. Then, the architecture is evaluated in against the background and the assumed evolution of the four scenarios to 2020.
- Section 5 provides general conclusions on the scenario building and analysis exercise by formulating questions, recommendations and guiding principles for the continuation of the work in the ADDRESS project.
- Finally, annexes containing supplementary information on the scenario scores and the scenario success evaluation tool complement the document.

1.3. Notations, abbreviations and acronyms

EC	European Commission
EU	European Union
WP	Workpackage
DOW	Description of Work
AD	Active Demand
BRP	Balancing Responsible Party
DSO	Distribution System Operator
TSO	Transmission System Operator
ICT	Information and Communication Technologies
SRP	Scheduled Re-Profiling
CRP	Conditional Re-Profiling
EB	Energy Box
PEV	Plug-in electric vehicle

Table 1, abbreviations

1.4. Acknowledgments

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- Joseba Jimeno and Nerea Ruiz (Scenario 1, Labein)
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- Corentin Evens (Scenario 3, VTT)
- Mario Russo (Scenario 4, Cassino)
- Christian Noce (Scenario 4, ENEL Distr)

Disclaimer: The views compiled in the scenario evaluations represent the personal opinions of the members of the panel and not necessarily those of their employers.

In addition to the authors and the panel of scenario evaluators listed above, these people contributed to the elaboration of the scenario work reported in this document: Andrew Paice (ABB), Stefan Melin (Vattenfall), Régine Belhomme (EDF SA), Alioune Diop (EDF SA), David Hirst (RLTec), Pieter Kropman (KEMA).

2. The ADDRESS scenarios

2.1. Description of the ADDRESS scenario methodology

The implementation of an ADDRESS future is expected to have an impact on society and its environment. This impact has to be measured in qualitative and quantitative manners (within the availability of appropriate and sufficient information) to determine as objectively as possible whether the implementation of active demand at the European or more local scale will be a success or a failure.

Each of the market participants in the energy industry has stakes or goals it is attempting to maximise or achieve. A stake — equally a goal here — is loosely defined here as something that is of interest and of concern to a market participant which may be *won* or *lost* (*attained* or *missed*). In the context of the scenarios we develop in this document, market participants have stakes[1] which can be won or lost as a result of the implementation of an ADDRESS future. Moreover, the magnitude of the gains or losses may be influenced by the geographical, industrial, political and societal environment of the market participants as well as the time dimension.

2.1.1. Motivating example

Let us consider, for example, one of the stakes of an aggregator: to maximise its profit out of its aggregation business. On the other hand, the stakes of this aggregator's consumers may include lowering their overall electricity bill while accepting possibly temporary and limited losses of convenience as a result of adjusting their normal consumption patterns. If the aggregators are not themselves electricity retailers, the load shifting behaviour of the aggregator's consumers could have an impact on the retailers. As the aggregators may not share the load shifting information of the consumers with the retailers, this means that retailers may end up having more difficulty in predicting accurately their load profiles and could result in lost profit and increased risks related to a higher volume exposure in the balancing market. Retailers in turn may increase their prices to consumers to cover the increasing cost of buying electricity from the balancing market and trading risk management products. Here, the aggregators may appear as winners and retailers as the losers.[2] Likewise, the small consumers may also be losing in the long run as well if the retailers indeed have to increase their rates to cover the uncertainty created by the aggregators. This may seem like an extreme and simplistic case, but it serves to illustrate the profound impact active demand (AD) could have on market participants. Moreover, the validity of the example may be different in systems with different balancing rules.

It could be well possible that certain deployments of AD technology and markets do not provide "win-win" situations for all or most market participants. As seen in the example above, the gain of the aggregator is at the expense of non-active small consumers, while there are mixed effects on the retailer (as the higher energy procurement cost could be passed on partially or entirely to all its consumers) and the consumers providing active demand (savings in electricity bills are obtained at the expense of inconvenience and possibly higher rates per unit of energy coming

[1] In the development to follow and the rest of this document, we shall use stake only to lighten up the text. Nevertheless, stakes and goals could be interchanged.
[2] We note that this may be for some time only. Recent history has shown how intermediate businesses get bypassed (e.g. booking of fights and hotels, high street music stores, etc.)

from the retailer). It is also important to note that non-active consumers (and hence consumers which are not “market participants” by definition), would also be affected by AD implementation because of the possible increase in electricity tariffs or reduction in electricity prices because of the change in demand. Therefore, it is necessary to take into account its impact over the entire electricity supply chain to determine the potential success of AD implementation objectively.

The following sections describe how the approach illustrated above was formalised to obtain a systematic approach for assessing the potential impacts as well as success or failure of an AD implementation in particular scenarios.

2.1.2. Methodology for stake-based approach

2.1.2.1 Who is involved?

The first logical step is to determine the actors who will be affected by AD along the time horizon of the scenarios. As it is prohibitive to list all possible actors, only representative actors are selected, as shown as an example in the first column of Table 2 (this table is here only for illustrative purposes; the full set of actors is provided in Annex A). This identification exercise is reported fully within [D1.1] for regulated and deregulated electricity market participants.

2.1.2.2 What are the stakes?

The next step is to determine the stakes of these representative actors. As shown in the first row of Table 2 (this table is here only for illustrative purposes; the full set of actors and their stakes, which we differentiate between short- and long-term, is provided in Annex A), the stakes are indexed by letters i.e. stake A, stake B and so on. Typical stakes for commercial entities include profit-making and risk minimisation. For consumers, this includes comfort, the amount of their electricity bill and altruistic values such as the associated satisfaction with helping reducing one’s carbon footprint. Alike in the previous step (2.1.2.1), the identification of the stakes is reported in [D1.1].

2.1.2.3 How are the stakes affected?

To determine the impact of AD on each of the stakes and for each of the actors, qualitative values (e.g. small gains, large losses, etc) are assigned to each stake, also as shown in Table 2. The way these qualitative indicators are arrived at is through the results of [D1.1], [IR5.1] as well as the intervention of experts from within the project consortium.

2.1.2.4 Conversion of stake qualitative values

The next step is to convert all the qualitative values of the actors-stakes matrix (e.g. like Table 2) to quantitative values through a mapping similar to what is found in Table 3. The grading being agreed upon may not be necessarily linear giving more impact to the highest gains and losses (as it is the case in Table 3).

Hence, qualitative stakes levels are converted to numerical values by mapping them through a grading like the one given in Table 3. For example, passing the stake qualitative values in Table 2 through the mapping of Table 3 would result in a numerical stake matrix like the one shown in Table 4. The reader should be aware that more thorough and systematic benefit assessments for selected actors are being carried out as part of WP 5 (Task 5.1).

2.1.2.5 Importance weights of the actors' stakes

Next, it is necessary for each actor to assign an "importance weight" on each of the stakes to indicate the relative importance of the different stakes for them. For simplicity, we could restrict the values of the stake importance weights for each entity to vary between 0 and 1, where 0 means no importance and 1 means full importance. Also, for consistency, we impose that the stake importance weights for a given actor always have to sum up to 1.

The importance weights for each stake and each actor are illustrated as an example in Table 5. In this example, it can be observed that the aggregators value Stake A four times more than Stake B. Again, the values in the table only serve the purpose of illustrating the concept.

Stakes / Actors	Stake A	Stake B	…	Stake Z
Demand aggregators	Highest gains	Negligible	…	Negligible
BRPs	Negligible	Negligible	…	Highest gains
Small "active demand" consumers	Small gains	Highest losses	…	Negligible
Small "non-active demand" consumers	Small losses	Negligible	…	Negligible
DSOs	Small gains	Negligible	…	Negligible
Traders	Negligible	Negligible	…	Medium gains
Equipment manufacturers	Highest gains	Negligible	…	Medium gains
Centralised electricity producers	Small gains	Negligible	…	Negligible
Regulators	Medium gains	Medium gains	…	Negligible
Retailers	Small losses	Negligible	…	Negligible
TSOs	Small gains	Negligible	…	Small gains
…	…	…	…	…

Table 2, Examples of the actors and stakes involved in the ADDRESS scenarios

Qualitative Value	Quantitative Value
Highest Gain	1.00
Large gain	0.50
Medium gain	0.25
Small gain	0.05
Negligible	0.00
Small losses	-0.05
Medium losses	-0.25
Large losses	-0.50
Highest losses	-1.00

Table 3, Example of converting stakes' qualitative values to quantitative values

Stakes / Actors	Stake A	Stake B	…	Stake Z
Demand aggregators	1.00	0	…	0
BRPs	0	0	…	1.00
Small "active demand" consumers	0.05	-1.00	…	0
Small "non-active demand" consumers	-0.05	0	…	0
DSOs	0.05	0	…	0
Traders	0	0	…	0.25
Equipment manufacturers	0.50	0	…	0.50
Centralised electricity producers	0.05	0	…	0
Regulators	0.25	0.25	…	0
Retailers	-0.05	0	…	0
TSOs	0.05	0	…	0.05
…	…	…	…	…

Table 4, Example results of the numerical conversion of qualitative stakes

Stakes / Actors	Stake A	Stake B		Stake Z
Demand aggregators	0.40	0.10	…	0.05
BRPs	0.50	0.20	…	0.30
Small “active demand” consumers	0	0.50	…	0
Small “non-active demand” consumers	1	0	…	0
DSOs	0.30	0.50	…	0
Traders	0	0	…	0.25
Equipment manufacturers	0.50	0	…	0.50
Centralised electricity producers	0.05	0.95	…	0
Regulators	0.25	0.50	…	0
Retailers	0.99	0	…	0.01
TSOs	0.25	0.70	…	0.05
…	…	…	…	…

Table 5, Example of stake importance weights

In a way similar to the assignment of the relative gains of the entities with respect to the stakes (in section 2.1.2.3), the assignment of weighting factors to the different stakes for the different entities is somewhat subjective between different stakes. In the case of some players, it may be possible to obtain objective values for the weights.

As a result, this assignment has to be executed in broad consultation with industry experts to provide good “average” representative weights based on a general agreement ensuring realistic relative values for the weights arising between the various stakes and entities for given scenarios. In the end, it is the relative values of the weights that matter, not their absolute values.

2.1.2.6 Gain-importance product values

The following step involves the calculation of gain-importance products for each of the actors and the stakes. These products serve to indicate the relative gain of an entity with respect to the importance this actor puts on a given stake.

This involves multiplying each element of the gain matrix in Table 4 by its corresponding element in the importance weight matrix in Table 5. The results of this calculation are illustrated in Table 6.

Hence, a high potential gain can be magnified by a large importance weight. Conceptually as well, a high potential gain may be downplayed if the stake has low importance and vice and versa. Practically, however, this is unlikely because most entities have few meaningful and important stakes to start with (i.e. Table 5 is generally sparse).

As an aside, the kind of gain downplaying effect just described may be seen most likely with consumers, who may not always have the knowledge of a high potential gain. From a policy point of view, this may indicate, for example, the need to deploy acceptance and education measures for consumers within the scenarios.

Adding the gain-importance products across all the stakes of a actor (i.e. over a row of Table 6) provides an indication of the potential for success (or failure) of active demand for that actor. A high positive "actor total" (see last column of Table 6) indicates success for the actor across its stakes while the opposite (negative "actor total") indicates failure. If we observe the example in Table 6, we see that active demand under this situation would be a great success for the aggregators. On the other hand, this case would be quite bad for the active consumers.

Similarly, summing the gain-importance products for a given stake across the entities (i.e. over a column of Table 6) provides an indication of the potential success (or failure) of active demand with respect to the fulfilment of that stake for all the actors. Hence, for example, according to Table 6, Stake A would generally be well served by active demand, while Stake B would be worse off.[3]

Ultimately, summing over the entire set of cells of the matrix (Table 6) gives a measure of the global welfare associated with a given scenario (the value in bold italics at the bottom right corner of Table 6). High positive values for the global welfare indicate a good level of success while the opposite would indicate failure.

2.1.2.7 Scenarios

One key aspect here is that the actor-stake gains and losses with respect to the development of active demand and the importance weight matrices illustrated in Table 4 and Table 5 varies across different parts of Europe and within different types of communities. Hence, we apply the same concept described above to measure qualitatively how the stakes of each actor might be affected along the time horizon of the different ADDRESS scenarios.

2.1.2.8 Cross-entity weights

The above description so far has assumed an egalitarian approach whereby all the actors are in a sense "equal" to each other with respect to the impacts of active demand. This is the case because we have not put weights on the relative "importance" of the actors within the functioning of the electricity supply chain or the provision/use of active demand products and services. This is unlike what we have done for the stakes in Section 2.1.2.5.

The scenario success measurement tool as it is could well be adapted to include such cross-actor weights through the development of an extra weight matrix for actors within the electricity supply chain. It would in turn be used to multiply once further the elements of the gain-importance matrix (Table 6). Again, the difficult aspect here is to set objectively the values of the weights; there are some methods to achieve this more systematically (see, for example, [Linares & Romero, 2002]), but we chose not to delve in those at this early stage of the project. This would clearly have an impact from the industry regulator's perspective when considering policies and rules for supervising the development of active demand. Coming back to the example in Table 6, this aspect would be quite relevant because we see that active consumers (i.e. those at the core of the ADDRESS vision) could have all to lose in spite of the fact that the net global success of the supply chain is positive and high. By making consumers "more important," this would be reflected

[3] Some stakes are not strictly additive, and therefore we may fall in double-counting if we are to quantify strict social welfare (in the economic sense).

by a greater impact of the negative score of active consumers on the global welfare thus providing an indication of the relative failure of this case. Alternatively, we might design correctly regulation so that the losers (consumers) are appropriately compensated by the winners, if there is a social benefit. At this stage, however, we decided to keep the egalitarian approach and avoid regulatory interventions here. There is still scope to revisit this assumption in later revisions of the scenarios.

Stakes / Actors	Stake A	Stake B		Stake Z	Actor total
Demand aggregators	0.4	0	…	0	0.4
BRPs	0	0	…	0.3	0.3
Small "active demand" consumers	0	-0.5	…	0	-0.5
Small "non-active demand" consumers	-0.05	0	…	0	-0.05
DSOs	0.015	0	…	0	0.015
Traders	0	0	…	0.0625	0.0625
Equipment manufacturers	0.25	0	…	0.25	0.5
Centralised electricity producers	0.0025	0	…	0	0.0025
Regulators	0.0625	0.125	…	0	0.1875
Retailers	-0.0495	0	…	0	-0.0495
TSOs	0.0125	0	…	0.0025	0.015
…	…	…	…	…	…
Stake total	0.893	-0.1	…	0.74	***1.533***

Table 6, Example gain-importance products

2.1.2.9 Level of success of different scenarios

We can then compare how a particular AD implementation affects the different actors or the society in general in different scenarios by monitoring the relative size of the following indicators:

1. Global success — tells us whether the electricity supply chain as a whole obtains more success (or less) in a scenario than in another one (e.g. scenario A is more successful than B if the global success of scenario A > global success of scenario B).
2. Stake total — gives us an idea of how each stake performs in different scenarios.
3. Actor total — this is useful to identify what kind of scenario is more favourable to a specific actor (e.g. we may observe larger gain in the profit stake for equipment manufacturers in scenario A while its profit stake may perform poorly in B).

This comparison can be made between one scenario and another or, as we mostly do here, at specific times of the evolution of a given scenario (e.g. at the beginning and at the end.)

2.1.2.10 Caveats about the methodology

The scenario methodology we have adopted is inspired by methods in Multi-Criteria Decision-Making; see, for instance [Keeney & Raiffa, 1993; Belton & Stewart, 2002]. These methods study how decisions are made when there are competing objectives with different agents within systems and when agents themselves have competing objectives as well. Nevertheless, we have not followed systematically all the associated rigour of those methods (as can be seen in [Linares & Romero, 2002], for example). The goal here is to establish gross consensual views early on in the project about how the concepts of ADDRESS could thrive and in which contexts. The lasting impact of this initial reflective exercise is its role as a conceptual analysis catalyst for the continuation of the development and validation activities of the project.

The scenarios are an integrative part of the work undertaken in ADDRESS. Therefore, they will be updated as the development and validation activities happen. As part of this ongoing process, there is scope to improve the level of detail and the rigour of the scenario methodology. A good example of such opportunities will arise with the development of the ADDRESS business cases for the aggregator, small domestic and commercial consumers and DSOs in WP 5. Similarly, systematic benefit analyses are ongoing also in WP 5. These will provide much more objective measures of success for some of the actors we consider here. Finally, the use of the same group of individuals to assess all scenarios concurrently would improve the consistency of the success evaluations.

2.2. ADDRESS success targets

What we defined above in the previous subsection is a *measuring instrument* to assess the relative level of success of active demand deployment scenarios. The ADDRESS project has an objective whereby active demand deployments should be successful in improving global welfare, albeit at different levels across time spans and different locations within the EU. Therefore, in the formulation of the ADDRESS scenarios we seek to establish paths of evolution (technical, regulatory, business and behavioural) which should give rise ultimately to successful improvements in the horizon to 2020 in typical European settings.

2.3. Defining factors for the background environment in the ADDRESS scenarios

The ADDRESS scenarios do not exist in a complete vacuum. They have to evolve within representative realities within the EU. Because of the immense diversity across the 27 countries of the Union and even within the countries themselves, we had to extract what are the factors which should define the scenarios. Thorough analysis and consultation among the experts of the ADDRESS Consortium concluded that the following four factors are determining in defining scenarios for active demand development and deployment:

1. Geography;
2. Consumer density and characterisation;
3. Electricity industry infrastructure (engineering, regulatory and business), and,

4. Technology.

We point out here that some of those have the opportunity to change over scenario time horizons, like technology, while others are essentially fixed (e.g. attributes associated with geography and in most cases consumer density in a given area). In addition, some of the changes to the defining parameters due to action by actors directly involved in the scenario (e.g. changes in industry regulation) while others may be due to actors or phenomena evolving not directly within the scope of the scenarios (e.g. introduction of personal electric vehicles.)

2.3.1. Geography

The geographical and physical contexts of the scenario locations are important aspects to consider in the characterisation of representatives realities of Europe. In that respect, the associated range of latitudes for an ADDRESS scenario is determining. It is clear from the results found in [D1.1] and other research projects (e.g. Intelligent Energy Europe's project *Smart-A*) that heating and cooling demands have the greatest potential to be "activated" by aggregators. Moreover, generally peaks in electricity demand correlate very well with peaks in household and small business heating and cooling demands. Therefore, it is at the extreme European latitudes which reside the highest potential for activating electricity demand in association with heating and cooling needs.[4] This is the case especially in southern regions where space cooling is driven chiefly by electricity unlike space heating which has a wider spectrum of associated energy carriers (e.g. gas, oil, district heating, biomass, etc.).

2.3.2. Consumer density and characterisation

Consumer density, which may be, for example, given in voltampere per square kilometre or by the number of consumer connection points per square kilometre, is a determining factor in assessing the potential for active demand in an area. Having more or less consumers in a given location can be indicative of typical network problems where active demand may be used to relieve them (e.g. transformer overloads in densely populated areas or voltage rise problems in low density areas). Likewise, consumer density is an indication of the commercial potential for aggregation and its associated cost per consumer (i.e. the kind of economies of scale can be realised by rolling out enabling technologies in particular areas.) In addition to consumer density, the socioeconomic fabric and the demographics of the underlying communities shape the degree with which active demand has the potential to emerge as those shape the potential for acceptance of AD concepts and enabling technologies.

In high density areas, the total load per feeder or substation may be important, and the number of grid connection points per feeder is large. Consumers are supplied generally by underground feeders or networks which may be meshed at medium voltage. Networks may be older and subject to congestion and depressed voltage problems. These are associated typically with high density of housing and commercial activity in central metropolitan areas and inner cities. The social and economic background of consumers within those areas is generally mixed with young educated professionals who may be early adopters of new greener technologies.

In low density areas, consumers are spread over great surface areas with usually long aerial/mixed aerial-underground radial feeders. The total amount of load depends on the

[4] We note, however, that this is currently changing especially with cooling as air conditioning becomes more and more widespread in the northern parts of Europe as well.

consumer category; this may include large irrigation and agricultural loads as well as small industries. The scope for developing distributed generation in these networks is high especially in zones with farming establishments (e.g. photovoltaics, small wind or biomass.) In those areas, ideas of environment protection and preservation of areas of great beauty could motivate consumers to adopt active demand principles in the expectation that AD could help avoid network infrastructure developments. The social makeup of those communities may, nonetheless, be less amenable to develop active demand because of the ageing demographics of the area.

2.3.3. Electricity industry infrastructure

Here we refer to the electricity industry infrastructure in general terms. This entails both the business and market scenes as well as the generation mix.

The electricity market context, the regulatory philosophy and policies at the national and EU levels shape the business background of the scenarios. Hence, in historically liberalised market structures with competition and market-driven incentives, it should be possible to create opportunities for new businesses like aggregation and service provision. In this case, the associated risks may be high and have to be borne by individuals and single businesses. On the other hand, market structures with stricter rules and regulations and with possibly more vertical integration may restrict new business opportunities and entry of new players.

Likewise, the electricity generation mix has an impact on the potential success of active demand development scenarios. As the supply-side is the traditional provider of network services, the make up of the generation mix as it evolves along the duration of scenarios is critical. In scenarios with a *flexible* generation mix, consisting of plenty of easily dispatchable and potentially fast-acting generating units like in hydro-dominated systems, the potential for active demand products and services to compete on an equal technical and economic footing with respect to generation resources may not be great. However, in cases where the generation mix is *inflexible*, that is having more technical constraints and less operational manoeuvrability and possibly more uncontrollable variability from large-scale renewables, active demand could be promised to a great future as a viable alternative to supply-side resources.

2.3.4. Technology

Technology is an important aspect to consider in the evaluation of potential success of active demand. Along the length of given scenarios, new technological developments are due to happen as well as changes in consumer appliance use and penetration. Moreover, the initial technology position of consumers and their attitudes towards it are key indicators of the potential success of active demand. Likewise, the initial state and the forecasted evolution of technology on the supply-side of the industry (i.e. in metering, communications, networks and generation) are enablers for change in the horizon to 2020.

Technological aspects influence scenarios according to two attributes. The first attribute of technology is its level of *intelligence*. Here intelligence refers to the capability of technology to monitor and properly adapt its functioning in response to changes in its operating environment. At the intelligent end of the spectrum on consumers' premises, we find the likes of smart appliances and smart homes which adapt to both endogenous and exogenous factors like the weather, building occupancy, electricity prices, and so on. Likewise, we encounter various flavours of Energy Boxes capable of enabling local consumer needs-driven optimisation of end uses. This is paralleled on the supply-side by the likes of distribution substation automation driven by real-time measurements and state estimation. At the other end of the spectrum, we find the standard household appliances and supply-side technologies whose only way to respond to change is by allowing for large and expensive levels of passive primary plant redundancies and comfortable operating margins.

The second attribute associated with technology is the intrinsic *size and flexibility of consumers' appliances energy uses* over time and space. The typical magnitude of the power demand of consumers in a given scenario is also critical. The larger this magnitude on average, the more potential there is for aggregators to modulate the high volume of demand. However, this theoretical volume potential is conditional to the end uses underlying the associated power demand. Some end uses are intrinsically flexible as the value arising from the conversion of electric power only requires a net energy input over a long time span (irrespective of the power input pattern) rather than specific second-by-second power requirements. For example, households relying on electrical heating possess great flexibility as keeping ambient temperatures within acceptable comfort levels does not require an exact timing of the power input. It is merely the cumulative power input over time that matters. This contrasts with the use of brown goods (i.e. televisions, computers, audio equipment, etc.) which require constant power input when in operation.

2.4. Procedure for the evaluation of the ADDRESS scenarios

Sections 2.1–2.3 fleshed out the conceptual building blocks of the ADDRESS scenario methodology, namely the scenario success measurement methodology and the primordial factors for defining the scenarios. This section outlines how these are integrated in a procedure to obtain the comprehensive scenario narratives found in Section 3.

The steps are:

1. Establish the scenario environment at the beginning of the scenario horizon (e.g. 2009-2010) by specifying the nature of the four defining factors laid out in section 2.3.
2. At the beginning of the horizon and given the assumptions about the underlying defining factors, have a panel of experts to grade
    a. The potential success of active demand in meeting the stakes of the selected industry actors, and
    b. The relative importance of each of the stakes to the actors.[5]
3. Repeat Step 2. for the end of the scenario horizon taking into account the potential evolution in the four defining factors. This can be repeated at a number of intermediate points along the horizon, if required.
4. Based on the results of Steps 2. and 3., formulate a narrative of the chain of events which should take place to evolve from the beginning to the end of the scenario horizon.
5. The process (Steps 1. through 4.) can be repeated to perform sensitivity analyses over the scenario underlying defining factors (set out in Section 2.3) to determine the robustness of the outcomes and the effects of changes in the assumed background changes on the scenario success.

[5] The stakes here for each of the actors are found in Annex A.

6. Cross-analyses of different scenarios are also possible to identify most suitable environments within which active demand could be deployed and where resources should be allocated in priority.

2.5. Role of the scenario evaluation panel

In Steps 2. and 3. of the scenario evaluation procedure in Section 2.4, the evaluation of the potential success of ADDRESS should be done by an *ad hoc* panel of industry experts. The role of the panel is to consider:

1. The expected evolution of the electricity industry globally and in the EU over the scenario horizon
2. The expected evolution of the electricity industry in the context of specific scenarios (as described in the scenario environment) over the scenario horizon
3. The relative importance of the various stakes of all relevant industry players and how these may change over the duration of the scenario horizon, and
4. The potential impact of deploying the ADDRESS conceptual architecture on the various stakes of all relevant industry players at different stages of the scenario horizon.

The central function of the evaluation panel should be focusing on Step 4 above where the experts should ask themselves the following questions regarding the scenarios:

- Is there a demand for flexibility that AD could fulfil? Now? Later? Who needs it? Who would benefit the most from it? Who would rather not see it appear?
- How good is (consumer-side) demand to provide that flexibility? What needs to be done, technologically and commercially, to make it better fit for purpose?
- What needs to happen over the scenario horizon to make the success of AD happen? Who will pay for it? Should there be changes in regulation? Should the behaviour of consumers be altered? How? Should new businesses and markets appear? When? In what form?

The narratives of the scenarios, as formulated in Step 4 of the procedure, reflect the answers to the above questions. In this document, we favoured the use of a panel in which specific individuals evaluated specific scenarios. This has the disadvantage that some of the outcomes of the scorings may appear inconsistent because different individuals can assign a different score in a similar situation. A better way to do this is to have several individuals either reaching a consensus or applying a voting rule on particular scores. The disadvantage of the latter approach is that the results may become biased and dominated by the individuals on the panel with better persuasion abilities. At this early stage of the project, we saw greater value in exploring a wider range of points of views from the panel members than to seek absolute consistency. We note, however, that as the scenarios will have to be revisited as the project evolves, its outcomes become more defined and some of the uncertainty is revealed, there should be scope to apply the other approach.

2.6. Structure of an ADDRESS scenario

Any one of the ADDRESS scenarios consists of the following parts:

1. At the beginning of the scenario horizon:

a. A general description of the geographical area of the scenario. This includes at least a general idea about the latitude and the type of human settlement (e.g. city centre, rural or suburban village, etc.) Other climatic factors may be added to reflect better the specificities of the area (e.g. availability of natural light, ambient humidity, etc.) The type of human settlement defines the small consumer density, the general types of buildings and energy using appliances, distribution network designs, technologies and possibly its age, the type of small businesses and the socioeconomic makeup of the community onto which the scenario focuses.
b. A general description of the local and national industry structure. This includes the generation mix and the business and regulatory frameworks.
c. An assessment by a panel of experts of the potential success of active demand at that time.

2. At the end of the scenario horizon:
   a. A general description of the terminal changes in the defining factors which are to be driven by factors exogenous to the deployment of active demand.
   b. An assessment by a panel of experts of the potential success of active demand at that time.
3. A narrative of the evolution of the defining factors in parallel to descriptions of the necessary deployment steps for implementing active demand (e.g. roll-out of new enabling technologies, emergence of new businesses and new markets and changes in regulation).

2.7. Conclusion

This section outlined the methodology for building the ADDRESS scenarios. The salient features of the methodology are:

- Scenarios focus on human settlements (i.e. cities, suburban areas, rural villages, etc.);
- Scenarios are driven by the availability of enabling technologies and potential commercial gains for aggregator and other market participants including small consumers; and,
- Scenarios are defined by their relative success at making the ADDRESS vision beneficial to most power system participants in the horizon to 2020. These specify paths of industry and business evolution for achieving those success targets by the end of the horizon.

3. Narratives of the ADDRESS scenarios

This section presents the four specific scenarios into which we are assessing the potential success of an ADDRESS deployment. As mentioned in the previous section, the description of each scenario starts with a portrayal of its background environment to set the stage at the beginning of the horizon (i.e. 2009-2010). This is followed by the results of the potential success assessment for the deployment comparing the situation now to what it could be in 2020. This assessment was performed by an *ad hoc* panel of experts from within the ADDRESS Consortium (see Subsection 1.4 for the list of panel members).[6] Finally, given the boundary conditions on the scenario success, we provide a narrative of the evolution of the defining factors, both endogenous and exogenous to ADDRESS, over the horizon while accounting for its effects on the industry players and their stakes.

3.1. Scenario 1—Southern City

3.1.1. Setting the stage

This scenario is illustrative of how ADDRESS may be deployed in an urban environment where there are significant numbers of domestic and small business consumers whose demand for electricity is driven primarily by cooling needs. At the national level, there is already a fairly significant amount of large transmission-connected wind farms. These have increased the needs of the TSO for ancillary services (reserves) and BRPs for short-term balancing flexibility.

3.1.1.1 Geography

This scenario is typical of a location in low-valued latitudes in the south of Europe. As a result, the main element of the demand for electricity in this scenario is driven by the need for space cooling in the summer months. There is heat demand in the winter time, but this demand is supplied only partially by electricity at the current time.

Those latitudes are also conducive to the installation of photovoltaics at consumers' premises.

3.1.1.2 Consumer density and characterisation

The scenario location here is a typical inner city residential neighbourhood with a very high density of supply service points per unit area (over 1000 per square kilometre). Moreover, there are many proximity shops and offices serving the local community (e.g. bakeries, small to medium stores, supermarkets, garages, medical practices, etc.)

The distribution network serving the population in the area is underground and is being upgraded little by little; part of the network is relatively new while a significant portion still needs work done. The frequency of overloading cycles on cables and transformers has been increasing at a steady pace in the last years with the ongoing increase in domestic space cooling needs. That has led also to problems of under-voltages at the annual peak.

The socioeconomic makeup of the consumer population is very diverse with a mix of young professionals, middle income families with children and old age pensioners. Most of the residents own their dwelling and live in flats or townhouses. People are generally sensitive to environmental issues, but mostly at a local scale.

3.1.1.3 Industry infrastructure

At the national industry level, things have been changing rapidly over the last 10-15 years. The vertically-integrated electric utilities had to separate constituting businesses into generation,

[6] Please note that the membership of this panel was not exhaustive of the entire electricity supply chain, however.

distribution and retail divisions while a single national TSO and a power exchange (with ties to neighbouring countries) have been set up. These changes have taken place due to changes in national energy legislation and EU-level policy.

The bulk of the wholesale energy trading is based on bilateral contracts with the power exchange offering extra liquidity across national boarders closer to gate closure. We assume competitive market, but there is a certain degree of regulatory intervention.

Consumers have been traditionally on single flat regulated tariffs offered by the local utility. However, as a result of changes in the industry regulation, consumers have only recently been allowed to switch electricity retailers. The regulated flat tariffs are due to be phased out completely in the next few years. Because this is a novelty and because of the intricacies of the switching process most consumers have opted so far to stay supplied by the incumbent retailer. However, government-sponsored national advertising campaigns and consumer advocates are promoting the potential financial benefits from switching especially in light of the steady rise in tariffs in the last five years. Moreover, consumers are given incentives by the state to buy high-efficiency appliances (especially for space cooling).

On the supply side, the generation mix is dominated by thermal generation (mostly coal and gas turbines). There is a smaller portion of the capacity coming from nuclear and from hydro. Hydro, however, is strongly correlated with seasons and is contingent on annual rainfall.

In recent years, national and regional governments have encouraged vigorously the development of renewable generation through the establishment of generous feed-in tariffs and subsidies. This resulted with a roll-out of many large transmission-connected wind farms and smaller-scale solar-powered generation installations. This has increased the needs for ancillary services from the TSO’s perspective to manage the increased uncertainty brought about by the large input of variable and intermittent generation. This also has had increasing impacts on the energy volumes being traded in the balancing market.

3.1.1.4 Technology

On the demand-side of the equation, as mentioned before, the main portion of electricity usage in this scenario is associated with space cooling in the summer months. For both domestic and small commercial consumers, most of the air conditioning equipment at consumers’ premises is based on stand-alone units with their own separate control; only very few are central building-wide systems. Many of the newer and popular air conditioning units also have embedded heaters for the winter time. The building stock is a mix of old, new and refurbished dwellings which are generally joined together over a street block. Therefore, the thermal capacitance of the buildings is significant entailing long temperature change time constants.

The next most important electricity need is associated with lighting. It is in mutation with the demise of the incandescent light bulb, and the expectation is that it will no longer be a significant portion of consumption in the next few years.

On the business consumer side, there is a significant load associated to office machinery which is usually on during business hours only. Unlike heating and cooling (and possibly lighting) these loads are not very flexible, although there is an expectation that they will become more energy efficient over the next decade. The same applies to brown goods located at domestic consumers’ premises.

A significant portion of the domestic consumers in this scenario are thought to be “early adopters” of new technologies. This entails that a good proportion of households have high-grade appliances which may have programmable options. Moreover, some flats with wealthier owners are already equipped with home automation equipment to control temperature, lighting, etc. Also, in response to the favourable government incentives, many homeowners and landlords have invested recently in rooftop photovoltaics systems. Finally, it is assumed that a very high proportion of households have access to the internet.

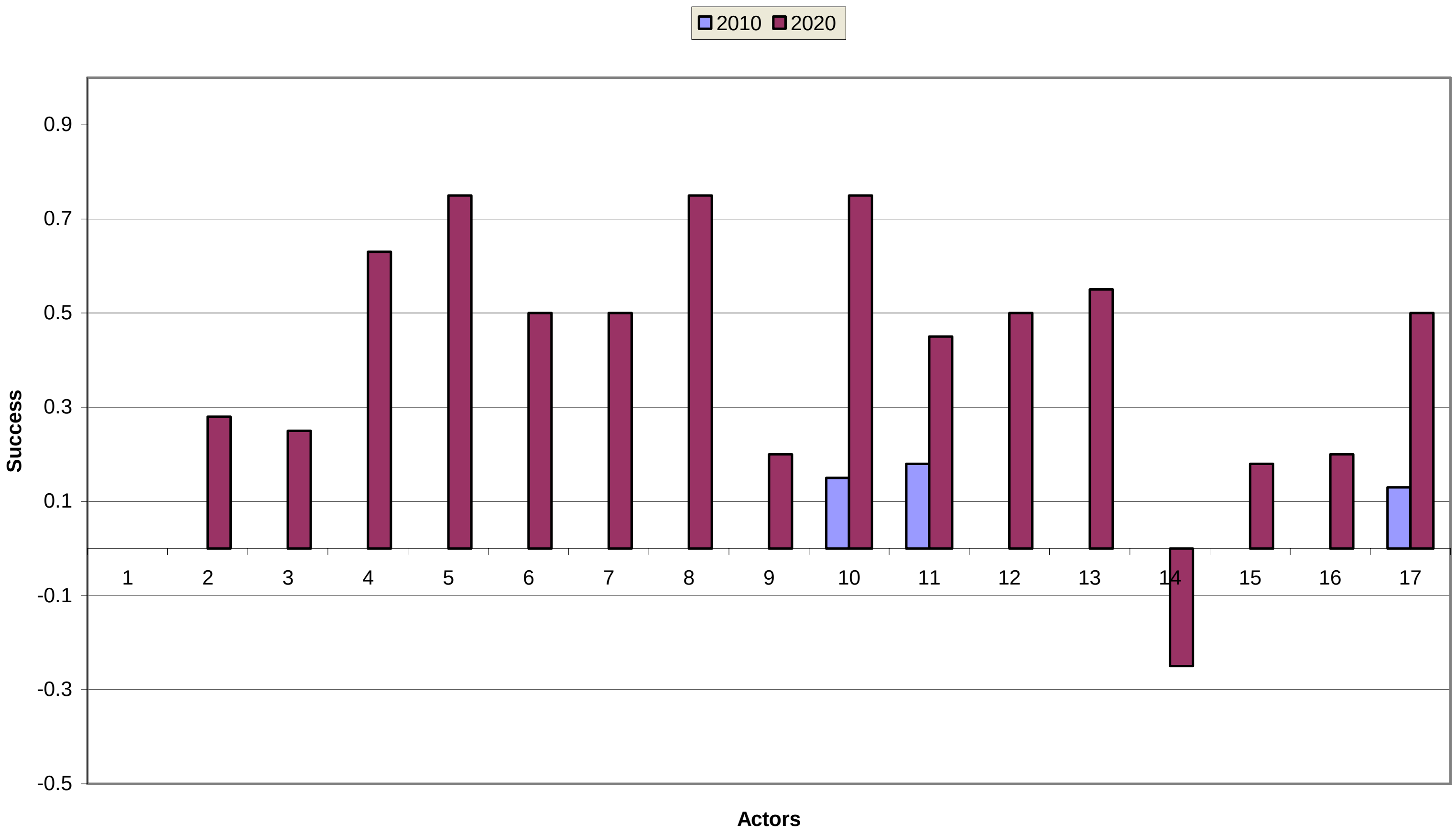
On the network side, the ongoing upgrades in the distribution infrastructure have introduced some level of substation automation in the area permitting fast remote and possibly automatic reconfiguration of the network as well as measurement functions at the low voltage level. This deployment is due to continue as upgrades and plant replacements keep moving along. Moreover, the industry regulator has mandated the distributor to roll out smart meters in the area by 2015. Lastly, competing telecom operators are deploying high-speed data networks in the area. These include both options based on wired and wireless solutions.

3.1.2. Success assessment

Based on the background information above, the expert panel evaluated this scenario. The success assessment at the time boundaries of this scenario for the development of active demand is illustrated for each of the actors in Figure 1 (see also Annex B for the numerical scores). This scenario sees significant potential success for active demand with a global success improvement of + 6.28 between 2009-2010 and 2020.

The salient features of the assessment are:

- At the beginning of the scenario horizon, only the regulator, equipment manufacturers and service providers see active demand as a factor having a positive aspect on their stakes.
    - o The regulator sees active demand as a potential additional resource to improve market efficiency and reduce costs accrued due to the increase in ancillary service and balancing needs.
    - o Service providers and equipment manufacturers envisage active demand to become a potential new revenue stream in the future through respectively the sale of services (e.g. metering, settlement and billing, telecoms, data management, etc.) and the sale of equipment (e.g. energy boxes, smart appliances, substation automation equipment, etc.)
- In the longer term, at the end of the scenario horizon, all but two of the actors see improvements in the fulfilment of their stakes due to the deployment of active demand:
    - o Central generators do not see any significant change while large consumers foresee a loss as aggregated active demand consumers have started to erode their market share in the provision of services to other market actors.
    - o The actors with the most potential to gain from active demand are primarily those with needs for flexibility which active demand can provide like Traders and Brokers, BRPs, retailers and renewable and distributed energy producers (decentralised energy producers, production aggregators and producers with regulated tariffs.)
    - o The other great winner here is the aggregator. Starting from nothing at the beginning of the scenario horizon, they develop into viable businesses by 2020.
    - o Both active demand and non-active demand consumers see potential good in the deployment of active demand. This comes primarily from the belief that active consumers will receive financial incentives from aggregators while the non-active demand consumers may face lower energy prices because the active consumers are making the entire electricity system more flexible.



Actor axis legend: 1. Centralised electricity producers; 2. Decentralised electricity producers; 3. Electricity producers with regulated tariffs and obligations; 4. Production aggregators; 5. Demand aggregators; 6. Traders; 7. Brokers; 8. Balancing responsible parties; 9. Retailers; 10. Service providers; 11. Regulators; 12. Distribution system operators; 13. Transmission system operators; 14. Large consumers; 15. Small "active demand" consumers; 16. Small "non-active demand" consumers; 17. Equipment manufacturers.

Figure 1, Potential fulfillment of individual stakes from the deployment of active demand in the Southern City scenario

- o The TSO and the DSO are seeing improvements in their stakes from the point of view of the improved network management flexibility active demand provides (through congestion management and better asset management practices).

3.1.3. Narrative

This scenario starts up with a clear challenge: The need for flexibility in the system is soaring because of the numerous large wind farms connected at transmission level. The TSO has accrued requirements for ancillary services while BRPs and other renewable energy producers need slack to better balance their positions going into real time. Moreover, the steady increase in the penetration of air conditioners has raised the value of the annual peak thus reducing the generation capacity reserve in the system.

Therefore, from early on in the scenario horizon there is scope to develop more sources of flexibility in the system as well as means to shift demand away from the annual peaks. Active demand is a clear contender since in this scenario there are plenty of flexible thermal appliances to be flexed in a relatively small geographical area which allows for economies of scale when deploying enabling technologies.

Hence, early on in the scenario (2010-2012), aggregators start to establish themselves to gather the flexibilities of mostly early adopters. Their main clients are the TSO and BRPs who will use packaged flexibility for balancing purposes. The regulator is well aware of the need for flexibility and has taken special actions to reduce the technical requirements for aggregators (i.e. by officially recognising that aggregators cannot be made equal to a centrally-dispatched generator.)

Originally, volumes traded are small and the agreements between the parties are made through bilateral negotiations for deregulated actors or following call for tenders in the case of the TSO. By 2015, volumes traded reach high levels as more and more consumers join one of the many aggregators present in the market and the completed roll-out of smart meters. Moreover, standard active demand product contract markets begin to appear and are traded on the national power exchange; we note here, however, that these contracts are for delivery at the transmission level only. At the same time, the increase in demand has picked up from the economic slowdown at the beginning of the decade. Hence, more and more of the active demand traded is looking at managing peaks especially for retailers. On the down side, one problem with this scenario as active demand develops relates to the damage done to retailers by the actions of aggregators who disturb their energy balance position going into real time. This leads retailers to start lobbying the regulator to relax the rules on retail and aggregation business functions.

Also, in the 2015-2020 timeframe, the number of plug-in electric vehicles (PEVs) is increasing year on year while the air conditioning demand has now reached a plateau after many years of growth. The impact of PEVs is significant for the DSO who now has to start using active demand to manage the extra loading (e.g. manage congestion, voltage, maintenance outages, etc.) As in the early 2010’s the DSO is dealing with aggregators on a more *ad hoc* basis to deal with problems raised by the PEV and air conditioning loads. Validation tasks are done with long lead times because the DSO is not yet equipped with the entire network analysis software and substation secondary infrastructure to do this 20-30 minutes ahead. As the scope of active demand in the distribution grid has become even more prominent by around 2017, the regulator has to step in to establish the rules of the game for active demand trading in distribution networks.

By 2020, there is healthy competition between aggregators, some of whom have developed niche areas (e.g. PEVs), and most of them are associated with one of the industry generation-retail incumbents. Consumers are generally content with the way aggregators deal with them as aggregators have handled rather well the issue of “response fatigue” over the years (i.e. the fact that consumers tend to respond less and less to stimuli as time goes by).

3.2. Scenario 2—Southern Countryside

3.2.1. Setting the stage

This scenario is illustrative of how ADDRESS may be deployed in a rural environment where consumers are few, but where there may be significant agricultural load on small to medium-sized farms and where there is great potential for dispersed generation in the form of small wind, photovoltaics and biomass. At the national electricity system level, there are forecasted capacity shortages which will have to be fulfilled by bulk transnational electricity imports as old and dirty coal and oil-fired power stations are being decommissioned gradually.

3.2.1.1 Geography

This scenario is typical of a location in low-valued latitudes in the south of Europe. As a result, the main element of the domestic demand for electricity in this scenario is driven by the need for space cooling in the summer months. There is domestic heat demand in the winter time, but this demand is supplied only partially by electricity at the current time. Yet, the bulk of the demand for electricity in this area comes from agricultural loads on a year round basis.

Those latitudes are also conducive to the installation of photovoltaics at consumers' premises. Moreover, land may be available to install some wind turbines, larger-scale photovoltaics and biomass generation.

3.2.1.2 Consumer density and characterisation

The scenario location here is a typical rural area dominated by farmland with sparsely-distributed supply service points. The bulk of the electricity demand in the area feeds into agricultural processes which include irrigation pumping and primary crop processing. These loads are obviously quite seasonal with well-defined peaks in the year. Domestic consumers are relatively few and concentrated in a small village centre with some small proximity shops.

The distribution network serving the population in the area is long and aerial and is in need of primary plant replacements because it has reached its usable lifetime and since there have been some small renewable generation projects which warrant upgrades. The network has had some faults in the recent past which have been triggered by ageing plant and the typical hazards encountered on such feeders. Still, the network capacity is still sufficient to meet the current demand.

The socioeconomic makeup of the consumer population is uniform dominated by mid-aged farm owners and agricultural workers with old age pensioners who own single family houses. The area has seen many of its younger people move to urban centres in the past 20 years. The average family disposable income is on the lower end and so is the average level of education. People are sensitive to environmental issues, and they are very keen on bringing in initiatives that could create jobs in the area.

3.2.1.3 Industry infrastructure

The industry infrastructure here is grossly similar to that of Scenario 1 (see Section 3.1.1.3.) The key differences are with the generation mix. At the current moment, there is very little transmission connected wind power unlike in Scenario 1. In addition, several of the older and dirtier coal and oil-fired power stations are due to be decommissioned in the next five years. This will lead to an expected shortfall in generating capacity which is due to be met by increased cross-border imports and new gas-fired combined-cycle power stations.

Furthermore, in recent years, national and regional governments have encouraged the development of renewable generation through the establishment of feed-in tariffs and subsidies. The success of the measures has been disappointing, however, as very little renewable capacity has been brought online.

3.2.1.4 Technology

On the demand-side of the equation, as mentioned before, the main portion of electricity usage in this scenario is associated with agricultural processes which happen at various times in the year (e.g. irrigation pumping, crop processing, etc.) For both domestic and small commercial consumers, the bulk of the consumption is associated with air conditioning. Most of the air conditioning equipment at consumers' premises is based on stand-alone units with their own separate control. Many of the newer and popular air conditioning units also have embedded heaters for the winter time. The building stock is rather old with thick-walled constructions. The thermal capacitance of the buildings is significant entailing long temperature change time constants.

The next most important domestic electricity need is associated with lighting. It is in mutation with the demise of the incandescent light bulb, and the expectation is that it will no longer be a significant portion of consumption in the next few years.

On the business consumer side (aside from agriculture load) the demand is quite small; the most significant demand is associated to office machinery which is usually on during business hours only as well as air conditioning and cooling appliances (fridges and freezers).

Few of the domestic consumers in this scenario are thought to be "early adopters" of new technologies. This entails that only few households have high-grade appliances which may have programmable options or have home automation equipment to control temperature, lighting, etc. Also, in response to the favourable government incentives, some homeowners have invested recently in rooftop photovoltaics. Finally, it is assumed that a good proportion of households have access to the internet.

On the network side, the infrastructure is essentially passive and cannot adapt to changing conditions. Moreover, the industry regulator has mandated the distributor to roll out smart meters in the area by 2012 for domestic consumers; businesses already have advanced meters installed. There are essentially no proposals for increasing the data bandwidth offer in the area at the moment because of the low consumer density.

3.2.2. Success assessment

Based on the background information above, the expert panel evaluated this scenario. The success assessment at the time boundaries of this scenario for the development of active demand is illustrated for each of the actors in Figure 2 (see also Annex B for the numerical scores). This scenario sees significant potential success for active demand with a global success improvement of +2.30 between 2009-2010 and 2020.

The salient features of the assessment are:

- At the beginning of the scenario horizon, most actors see great promise in active demand.
- Only the retailers are really concerned about the negative impacts of active demand on their stakes as they anticipate the negative effects of active demand on their abilities to make a reasonable commercial profit under an acceptable level of risk.

This is the case both at the beginning and the end of the scenario.

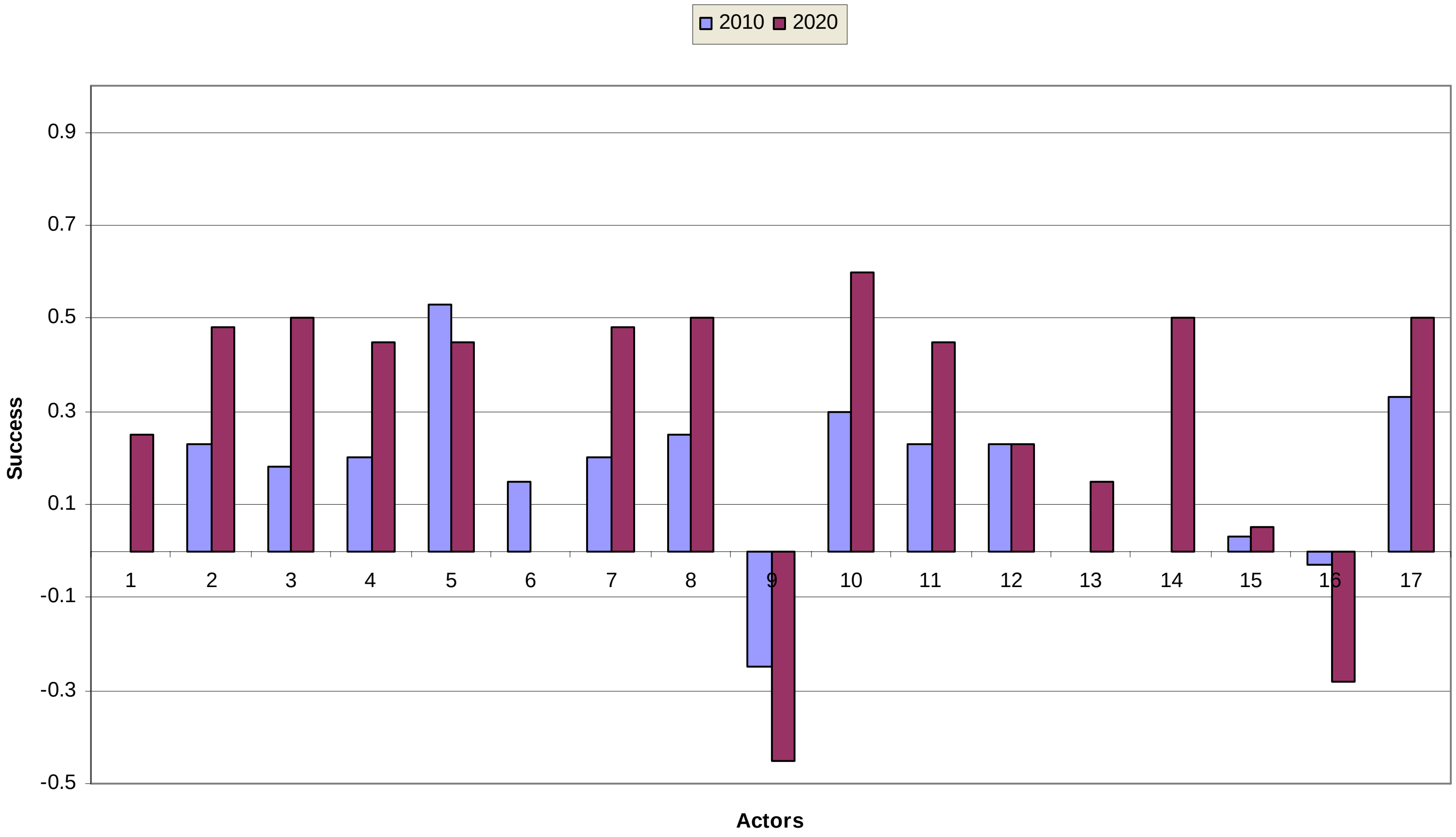
- Non-active demand consumers are also adversely affected. The belief is that retailers will try through them to recoup their expected losses due to their consumers working with an aggregator. As the scope for a year-long supply of active demand is limited, active consumers do not see either great promise in improving their stakes.
- Centralised energy producers foresee great promise with active demand as a way to transfer responsibilities to provide some ancillary services to aggregated active demand consumers. This should let generators maximise their capacity input in the wholesale market which will be often short of capacity.
- Large consumers unexpectedly realise that active demand forces the wholesale price down which suits them very well.
- Demand aggregators were overly optimistic at the beginning of the scenario horizon. In reality, there is not much commercial scope for demand flexibility aggregation in this scenario.
- The DSO is positive about active demand for helping with local network management as infrastructure investments are being delayed.
- Although it did not foresee stake gains originally, the TSO sees value in improving its investment strategy from the availability of active demand.

3.2.3. Narrative

In 2009-2010, there is a great level of enthusiasm in the industry about the potential of active demand. Aggregators start appearing in the 2010-2013 horizon with the intended purpose of offering peak shifting services on *ad hoc* bases to regulated and deregulated actors to help them minimise the impact of high wholesale price periods created by the shrinking capacity margins on the generation side. The new aggregators benefit from the smart metering infrastructure already in place in this scenario.

The main problem for the specific location of the scenario of interest here is the lack of a critical mass of small domestic and business demand to be shifted. The crop irrigation and processing loads are seasonal and do not represent useful flexible loads unless they correlate well with the occurrence of the annual peaks. The other problem in this scenario as active demand develops relates to the damage done to retailers by the actions of aggregators who disturb their energy balance position going into real time. This leads retailers to start lobbying the regulator to relax the rules on retail and aggregation business functions.

On the plus side, more and more of the farm owners and operators are responding to government incentives to develop distributed generation in the period between 2015 and 2020. Those incentives are designed to ease the capacity pinch at the national level. Therefore, there is plenty of new small wind, photovoltaics and biomass combined heat and power plants that start appearing on farmland. This increases the pressures on the medium voltage distribution network as at time now power flow is reversed from its natural direction and problems of voltage rises and congestion start to appear. As a result, the DSO begins to see active demand as a potential solution to tackle these problems. The difficulty here resides with the fact that there are few consumers and the manageable demand is not important either not making this area so interesting to aggregators from a commercial standpoint. In this case, the regulator (or the DSO with a mandate from the regulator) has to step in and offer an aggregator an exclusive franchise over the area and possibly regulated rates for a limited period of several years. The allocation of the franchise is done on a competitive basis in the form of call for tenders.



Actor axis legend: 1. Centralised electricity producers; 2. Decentralised electricity producers; 3. Electricity producers with regulated tariffs and obligations; 4. Production aggregators; 5. Demand aggregators; 6. Traders; 7. Brokers; 8. Balancing responsible parties; 9. Retailers; 10. Service providers; 11. Regulators; 12. Distribution system operators; 13. Transmission system operators; 14. Large consumers; 15. Small "active demand" consumers; 16. Small "non-active demand" consumers; 17. Equipment manufacturers.

Figure 2, Potential fulfillment of individual stakes from the deployment of active demand in the Southern Countryside scenario

3.3. Scenario 3—Northern Suburban Village

3.3.1. Setting the stage

This scenario is illustrative of how ADDRESS may be deployed in a suburban environment where there are important numbers of domestic consumers and fewer small business consumers over a relatively wide area. The demand for electricity is dominated by lighting and other household appliances as space and water heating are either provided by gas or district heating. In the upstream electricity system, a vast majority of the installed generation capacity is based on hydro and numerous interconnections with neighbouring countries help securing sufficient and relatively cheap electricity supplies.

3.3.1.1 Geography

The geography of this scenario location is typical of high latitudes in the north of Europe. As a result, the main element of the demand for electricity in this scenario is driven by lighting and other home uses. There is heat demand in the winter time, but this demand is supplied only partially by electricity at the current time as most dwellings in the area are connected to district heating plants or use gas or oil-fired heating systems.

3.3.1.2 Consumer density and characterisation

The scenario location here is a typical suburban area of a larger city with a small village centre where local shops and businesses concentrate. The consumer density is medium (100’s of service supply points per square kilometre).

The distribution network serving the population in the area is underground and is being upgraded little by little; part of the network is relatively new while a significant portion still needs to have work done. The frequency of overloading cycles on cables and transformers is still low, and there are times in the year when demand is very low where the feeder voltages rise very close to the statutory limit.

The socioeconomic makeup of the consumer population is relatively uniform and dominated by families with children and older family units whose children have left the household. The disposable income of most families is relatively high and most families own their dwelling (single family house or townhouses.) The majority of people are well-educated and sensitive to environmental issues.

3.3.1.3 Industry infrastructure

At the national industry level, things have been rather stable in the last decade after several years of fast-paced change resulting from liberalisation efforts in the 1990’s. The vertically-integrated electric utilities had been separated into generation, distribution and retail divisions while a single national TSO and a well-functioning transnational power exchange have been set up. These changes have taken place due to changes in national energy legislation prior to the enactment of EU-level policy prescribing industry restructuring.

The bulk of the wholesale energy trading is based on bilateral contracts with the power exchange offering extra liquidity at the transnational level closer to gate closure. The overall philosophy here is that the market will eventually find the right answer by rewarding winners and ousting losers. Entry into the markets is as free as possible, and generally no exceptions are being made to accommodate particular players.

Small domestic and business consumers have now been exposed to a competitive retail market for at least 10 years. There is already a critical mass of consumers ready to change retailers with a view to reduce their bills or to select green-type tariffs. Time-of-use tariffs are already popular for consumers with electric heating and legislation is already in place to allow for even more flexible pricing options at the domestic and small commercial levels. The favourable generation mix (see below) has also helped keep rates relatively low, rising only with inflation.

On the supply side, the generation mix is dominated by hydro generation. There is a smaller portion of the capacity coming from nuclear and from gas. Most of the hydro generation is associated with networks of waterways and reservoirs allowing for the flexible management of energy stocks (stored water) over timescales ranging from one week well into a year. The country is strongly interconnected with its neighbours and is generally a net exporter of energy. Moreover, the generation mix has proven quite useful in providing cheap balancing and long term (i.e. days to week) energy storage capabilities to some neighbouring countries with significant wind power generation capacity.

In recent years, national and regional governments have encouraged the development of renewable generation through the establishment of renewable energy subsidies. The results of those incentives have only been leading to gearing of R&D activities by energy sector manufacturers which used them for helping small-scale technology showcasing projects only.

3.3.1.4 Technology

As mentioned before, the main portion of electricity usage in this scenario is associated with household appliances and lighting which is already decreasing in significance with the demise of the incandescent light bulb. There is growing interest in heat pumps and in micro-combined heat and power units from homeowners with legacy gas and oil-fired heating systems. However, as the majority of the area is supplied by district heat, the scope for demand increases remains limited. The building stock is a mix of new and older separate single family dwellings based on timber frame constructions. Therefore, the thermal capacitance of the buildings may not be very significant entailing relatively short temperature change time constants.

On the business consumer side, there is a significant load associated to office machinery which is usually on during business hours only. These loads are not very flexible, although there is an expectation that they will become more energy efficient over the next decade. There is, nonetheless, a noticeable cooling load associated with food retailers in the village.

A significant portion of the domestic consumers in this scenario are thought to be “early adopters” of new technologies. This entails that a good proportion of households have high-grade appliances which may have programmable options. Moreover, some of the houses with wealthier owners are already equipped with home automation equipment to control temperature, lighting, etc. Finally, it is assumed that a very high proportion of households have access to the internet.

On the network side, the ongoing upgrades in the distribution infrastructure have introduced some substation automation in the area permitting remote reconfiguration of the network as well as measurement functions at the low voltage level. This deployment is due to continue as upgrades and plant replacements keep moving along. Moreover, the industry regulator has mandated the distributor to roll out smart meters in the area by 2015-2018. Lastly, competing telecom operators are deploying high-speed data networks in the area. These include solutions primarily based on fibre optic technology.

3.3.2. Success assessment

Based on the background information above, the expert panel evaluated this scenario. The success assessment at the time boundaries of this scenario for the development of active demand is illustrated for each of the actors in Figure 3 (see also Annex B for the numerical scores). This scenario sees significant potential success for active demand with a global success improvement of +1.13 between 2009-2010 and 2020.

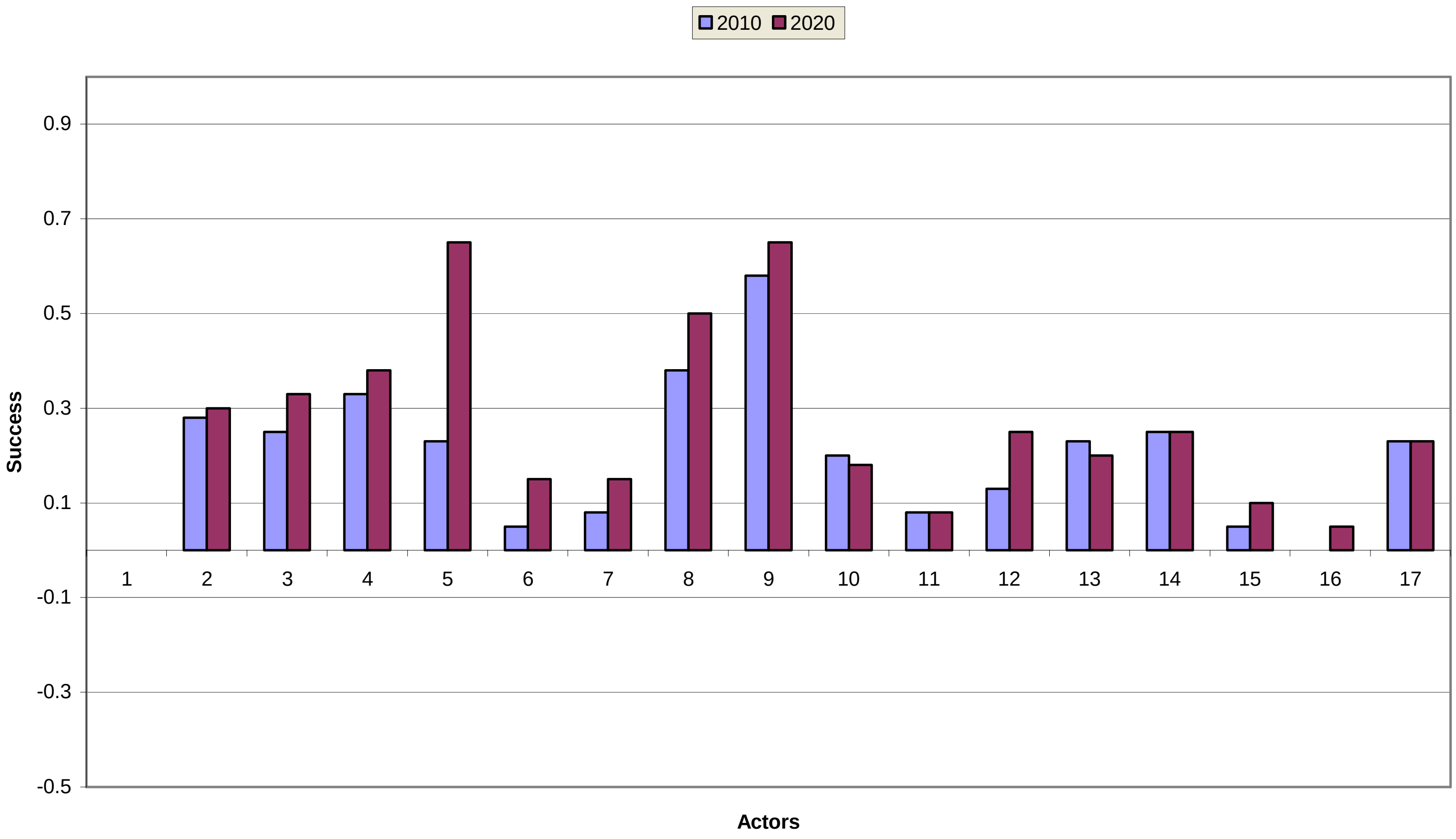
The salient features of the assessment are:

- Most actors foresee a potential improvement in the fulfilment of their stakes at the scenario horizon. Nevertheless, the overall improvement is not great because of the following reasons:
  - There is already plenty of flexibility available from the hydro generation
  - The potential flexibility of electrical loads themselves is low because the great proportion of electricity consumption is not for heating or cooling needs which has greater potential to be flexed
  - The distribution and transmission networks are not overly stressed at least at the beginning of the scenario horizon, and
  - Balancing and ancillary services requirements at the TSO level have not soared because of high penetration of large-scale wind or photovoltaic power stations.
- Those who foresee the greatest element of success are the actors who may use active demand to manage risks:
  - Decentralised and regulated tariff producers
  - Production aggregators
  - Traders and brokers
  - BRPs, and
  - Retailers.
- The TSO believes that active demand is going to increase the uncertainty in the system, and therefore see active demand not as positively in 2020 as compared to 2009-2010.
- The DSO sees great potential in active demand especially towards the end of the horizon because of the expected penetration of PEVs in area of the scenario.
- Aggregators are enthusiast about their potential success, especially towards the end of the scenario horizon as PEVs take off. They are not worried about unnecessary regulatory burdens which may affect their abilities to create new opportunities and improve their technical and commercial performance.

3.3.3. Narrative

At the beginning of this scenario, there is very little scope for developing active demand. This is for the following reasons: there is plenty of cheap flexibility and inherent energy storage available from the hydro generation and interconnections; the potential available volume of flexible demand is limited because electricity is not much used for space heating or cooling; and, the distribution network is generally healthy and lightly loaded.

However, the industry shows interest in active demand in spite of the above reasons. Aggregators are appearing as early as 2011-2012, and they are engaging some of the early adopters and people who are deeply concerned by climate change. This process is facilitated by the ongoing roll-out of smart metering and the increasing availability of high-end appliances which can be programmed to optimise energy use. Here the aggregators are taking advantage of the *laissez-faire* market philosophy and of the opportunities to offer a range of risk management options to deregulated actors and ancillary services to the TSO.



Actor axis legend: 1. Centralised electricity producers; 2. Decentralised electricity producers; 3. Electricity producers with regulated tariffs and obligations; 4. Production aggregators; 5. Demand aggregators; 6. Traders; 7. Brokers; 8. Balancing responsible parties; 9. Retailers; 10. Service providers; 11. Regulators; 12. Distribution system operators; 13. Transmission system operators; 14. Large consumers; 15. Small “active demand” consumers; 16. Small “non-active demand” consumers; 17. Equipment manufacturers.

Figure 3, Potential fulfillment of individual stakes from the deployment of active demand in the Northern Village scenario

With some time, standard active demand contracts start to appear and get to be traded by the national power exchange. By mid-decade, some of the retailers are starting to react to the adverse balancing effects created by the aggregators. Hence, a number of independent aggregators are purchased by some of the incumbent retailers. This allows for a better integration of the aggregation-retail functions. Nonetheless, some independent specialist aggregators remain and start making their mark by establishing good relationships with consumers possessing particular flexible loads (e.g. PEVs, heat pumps, etc.) These are particularly successful in providing balancing services to some of the larger-scale wind farms and combined heat and power plants which have been brought online since the beginning of the scenario horizon.

In the last five years of the scenario, the dominating factor becomes the fast penetration of PEVs in the suburban village area. The distribution grid is at times under stress, and there is a need to manage congestion and voltage drops. As a result, the DSO and aggregators begin to interact to solve those network problems first on a call for tender basis and later on through a formal market mechanism which is institutionalised in a way similar to TSO ancillary services markets.

3.4. Scenario 4—Mid-Latitude High-Rise Community

3.4.1. Setting the stage

This scenario is illustrative of how ADDRESS may be deployed in a high-rise housing estate where there are important numbers of domestic consumers and several small business consumers serving the community over a relatively small land footprint. The demand for electricity is dominated by space heating in the winter and cooling in the summer months. The national electricity system is characterised by a significant number of large capacity thermal generation plants which are primarily nuclear.

3.4.1.1 Geography

The geography of this scenario location is typical of mid-continental European latitudes. The main elements of the demand for electricity in this scenario are driven both by space heating and cooling.

3.4.1.2 Consumer density and characterisation

The scenario location here is a high-rise community housing estate in a typical suburban area of a large city. The community consists of several blocks of flats with proximity shops, a local market, service businesses and a community centre adjacent to schools.

The distribution network serving the population in the area is underground and is in need to be renewed and upgraded. These upgrades are scheduled to take place over the next five years. The frequency of overloading cycles on cables and transformers has reached unprecedented levels especially in the summer because of the air conditioning demand. This has also led to a few incidents where transformers tripped on thermal overloads.

The socioeconomic makeup of the consumer population is relatively uniform and dominated by families with children and old age pensioners. The disposable income of most families is low to medium, and families rent their dwelling from a housing trust or city council. The most of people are educated at least to secondary school level. Environmental issues are not sources of major concern as social matters of unemployment and poverty are clearly at the top of the local agenda.

3.4.1.3 Industry infrastructure

At the national industry level, things have been changing rapidly over the last 10 years. The state-owned vertically-integrated electricity utility had to separate its constituting business units into generation, distribution and retail divisions while a single separate national TSO and a power exchange (with ties to neighbouring countries) have been set up. These changes have taken place in reaction to changes in national energy legislation and EU-level policy.

The bulk of the wholesale energy trading is based on bilateral contracts with the power exchange offering extra liquidity across national boarders and closer to gate closure. The overall philosophy here is that the market may need some help in finding the right answer. Entry into the markets is not as free it could be because of licensing requirements, and at times exceptions are being made to accommodate particular players if they have legitimate business reasons or if it is in the national interest (e.g. to favour the development of an industry in the country.)

Consumers have been traditionally on single flat regulated tariffs offered by the distribution utility. Nonetheless, historically the retailer-distributor has been promoting alternative pricing options for its small domestic and business consumers. Those included time-of-use and critical peak pricing options.

As a result of changes in the industry regulation, consumers have only recently been allowed to switch to alternative electricity retailers. The legacy regulated flat tariffs (and alternatives offered by the integrated distributor-retailer) are due to be phased out completely in the next few years. Because this is a novelty and because of the intricacies of the switching process most consumers have opted so far to stay supplied by the incumbent retailer. Moreover, there is a sense that the incumbent retailer has been providing good value for money, and thus that switching is not worth it. However, government-sponsored national advertising campaigns and consumer advocates are promoting the potential financial benefits from switching especially in light of the steady rise in tariffs experienced over the last five years. Moreover, consumers are given incentives by the state to buy high-efficiency appliances (especially for space cooling and for heating).

On the supply side, the generation mix is dominated by thermal generation, mostly nuclear. There is a smaller portion of the capacity coming from hydro and gas. Hydro has some limited storage capacity which is insufficient to manage well dry and wet years.

Only recently, national and regional governments have started encouraging the development of renewable generation through the establishment of feed-in tariffs and subsidies. The success of the measures is yet to be assessed as not enough time has passed since the enactment of the incentive schemes. Nonetheless, there is a clear interest in developing such projects at the moment with many of them at the feasibility study and early construction phases.

3.4.1.4 Technology

As mentioned before, the main portion of electricity usage in this scenario is associated with space heating and cooling. The building stock consists of several high-rise concrete apartment buildings built in the late 1960's where each flat has an independent space heating and cooling system. The thermal capacitance of the buildings is large; however, the general quality of the windows and doors is poor and there can be significant heat loss through these.

On the business consumer side, there is a significant load associated cooling load associated with food retailers on the housing estate. Furthermore, there is an important aggregate demand corresponding to lighting and heating on commercial consumer premises.

Because of the generally lower disposable income and education, few domestic consumers in this scenario are thought to be "early adopters" of new technologies. This entails that a good proportion of households have lower-grade appliances with poor efficiencies without any programmable options. Finally, it is assumed that still about one in two households have access to the internet.

On the network side, the infrastructure is old and in need of upgrades. There is no substation automation at the low voltage level, while measurements are only available at the primary substation feeding the estate. Moreover, the industry regulator has mandated the distributor to roll out smart meters in the area by 2012. The installation has already started in some parts of the estate. Lastly, at the moment there are no particular plans to develop any new telecommunication networks in the area.

3.4.2. Success assessment

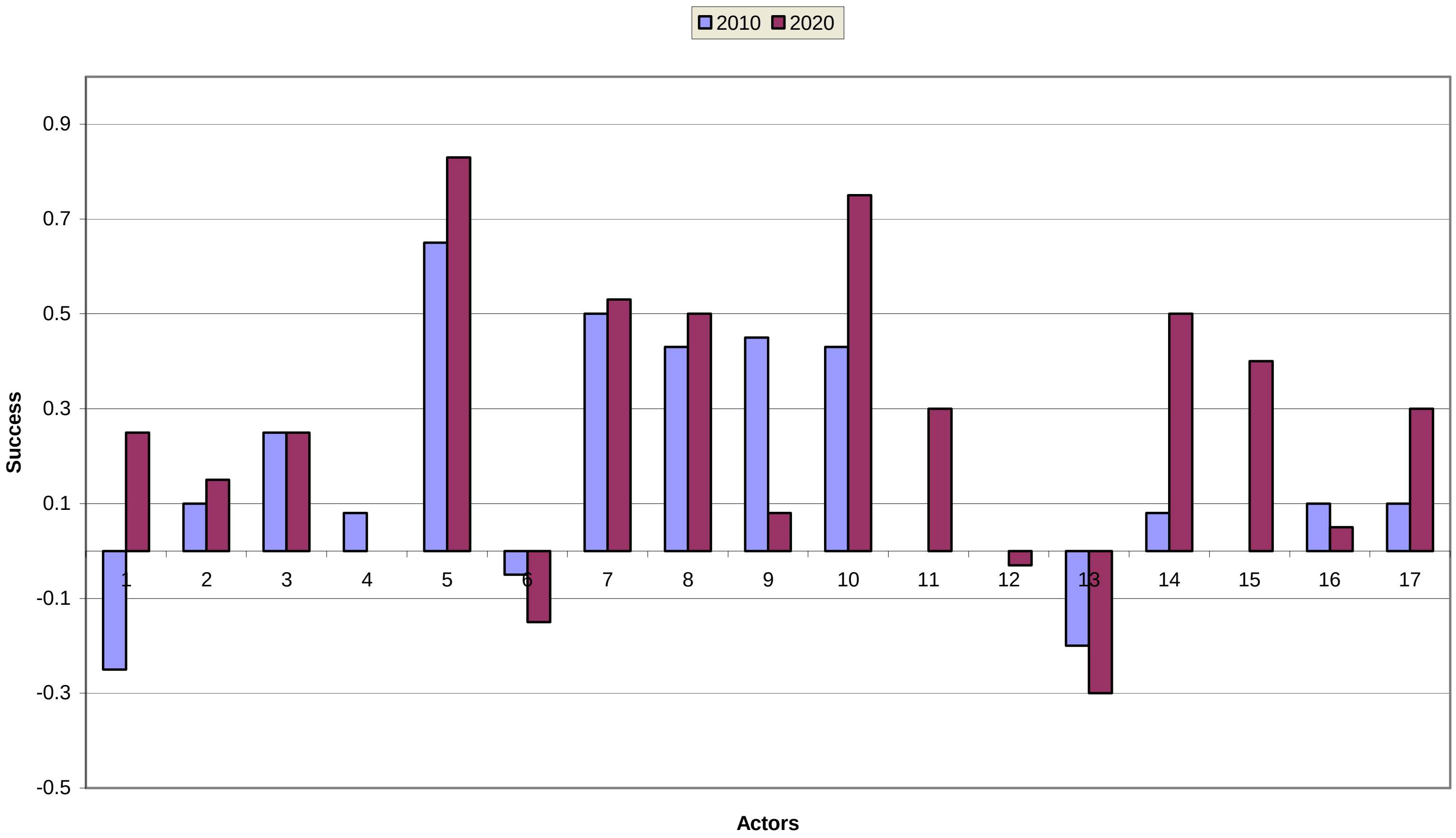
Based on the background information above, the expert panel evaluated this scenario. The success assessment at the time boundaries of this scenario for the development of active demand is illustrated for each of the actors in Figure 4 (see also Annex B for the numerical scores). This scenario sees significant potential success for active demand with a global success improvement of +1.75 between 2009-2010 and 2020.

The salient features of this scenario are:

- The main winners of this scenario are the active small consumers who manage to optimise their energy consumption with the help of the aggregator. Given the economic status of those consumers even small financial rewards and incentives do make a difference. The regulator is also encouraged by this factor. Nonetheless, there may be very few consumers who wish to engage with active demand principles and technologies. This reduces the scope for aggregation and local service provision especially.
- At the beginning of the scenario horizon, central generators are foreseeing negative impacts of active demand on their stakes because they perceive active demand as a threat to their share of the ancillary services market. The pattern is reversed at the end of the horizon, however, as they realise the potential of using active demand to subcontract some of their statutory ancillary service obligations and thus raise their net energy sales. Moreover, active demand allows central electricity producers to better optimise their operations over weekly periods.
- Here the TSO believes that active demand is going to damage its stakes throughout the scenario horizon because it expects that active demand will increase system uncertainty and make the system more difficult to manage. The perception within the TSO is that active demand products are fundamentally unreliable and difficult to predict and thus not appropriate to help run its network at the required standard.
- This is less so with the DSO who is expecting small decreases in short-term profits because of active demand. Negligible improvements are expected from the long-term investment perspective. This is linked to the difficulties in engaging consumers at the local level.
- The aggregators are positive about this scenario. Still, the potential success is hindered by the reluctance of most consumers to engage.

3.4.3. Narrative

At the beginning of the scenario horizon, the need for flexibility at the system level is limited. This is because there is sufficient supply of such resources from the generation side of the industry, and there are still no important renewable energy projects online with the potential to increase the need for ancillary services or balancing energy. On the side of the small consumers in this scenario, many of them are worried about their soaring energy bills.



Actor axis legend: 1. Centralised electricity producers; 2. Decentralised electricity producers; 3. Electricity producers with regulated tariffs and obligations; 4. Production aggregators; 5. Demand aggregators; 6. Traders; 7. Brokers; 8. Balancing responsible parties; 9. Retailers; 10. Service providers; 11. Regulators; 12. Distribution system operators; 13. Transmission system operators; 14. Large consumers; 15. Small "active demand" consumers; 16. Small "non-active demand" consumers; 17. Equipment manufacturers.

Figure 4, Potential fulfillment of individual stakes from the deployment of active demand in the Mid-Latitude High-Rise Community scenario

To help alleviate this problem of fuel poverty in the estate, the housing community proposes to establish itself as a not-for-profit aggregator as soon as the smart meters have finished to be rolled out in 2012. In this case, the housing estate is subcontracting its aggregation operations with a third party service provider.

It is nonetheless optional for the tenants to join the aggregation scheme. At first, the aggregator is working to offer balancing energy to deregulated players, retailers and BRPs for the most part. In this case, there is some reluctance in the industry as well as there is a perception that active demand should increase uncertainty and have negative impacts on some actors; this is the case of the TSO who sees more difficulties in predicting the volume of energy to be traded in the balancing mechanism. As the scheme is not-for-profit, the aggregator is able to pass on to its consumers interesting financial kickbacks.

With time (beyond 2015), central generators come to see more and more value in active demand as a reliable and affordable way to subcontract some of their statutory ancillary services obligations. This allows generators to concentrate on producing energy without having to part-load as much of their flexible capacity allowing for more potential commercial opportunities to materialise on the wholesale energy market.

With the success of the aggregation scheme on the housing estate, more consumers get to join; however, the numbers never go beyond a certain threshold as many consumers are still sceptical about the concept. Yet, the available flexible volume available with the aggregator keeps increasing as consumers continue buying new larger capacity air conditioners, heaters and entertainment goods. In addition, there is a small penetration of commercial PEVs which contribute to increase the flexibility potential. The DSO here does not get to reap much benefit for the development of active demand because of its early decade low voltage network refurbishment.

3.5. Cross-scenario analysis and critique

Scenario 1 is clearly the one with the greatest potential success for active demand. It has the two fundamental aspects for making aggregation a successful enterprise: (1) demand for flexibility from within the industry; and, (2) a great supply of flexibility in the energy end uses of the consumers. In that situation, unless there are significant technical or regulatory barriers, the case for aggregation appears to be straightforward. The real uncertainty remains in the timescales for the deployment of that flexibility. Another factor which is a key enabler of active demand is the timely implementation of a smart metering infrastructure. This is a technological factor which is common to all scenarios. Moreover, the earlier smart metering is deployed, the earlier aggregators will start appearing.

Scenarios 2 and 3, on the other hand, are plagued by the low end use volume that could potentially be aggregated. Scenario 3 also depicts a situation where the demand for extra flexibility by the industry could come more cheaply from the supply side. Still, both scenarios 2 and 3 describe how active demand could become a valuable asset at the local level for the DSO in order to manage better distributed generation and PEV load. These situations both require the establishment of a market institution at the distribution level (either through a competitive call for tenders or a more traditional auction mechanism.)

In the case of scenario 4, the consumers providing active demand are those with the highest potential for success. This is modulated by the relative fuel poverty that is affecting some of them. The community-based aggregator model also appears to be of interest in the context of social housing. The success of that scenario is not as high because of the relatively low demand for flexibility in the industry in general. This is due to change as more renewable generation gets connected.

4. Application of the ADDRESS conceptual architecture to the scenarios

The four scenario narratives in Section 3 were developed without an explicit reference to the ADDRESS conceptual architecture described in detail in [D1.1], aside possibly from the new role of the aggregator. This section evaluates the four scenarios and their outcomes in light of the ADDRESS architecture in [D1.1]. The goal here is to identify whether the architecture is well-suited to bring out the level of success anticipated in the four scenarios. In the event where the architecture fails to deliver certain conditions necessary for the full success of the scenarios, we recommend necessary adjustments and adaptations to the general conceptual architecture. The assumption here is, nonetheless, that the architecture is generally appropriate and that it should not require undergoing major modifications. In reality, the well-accepted belief is that changes to the architecture would be needed chiefly to accommodate national industry regulation.

4.1. Description of the methodology for the application of the architecture to the conceptual scenarios

The objective of this section is to describe the methodology used to assess the ADDRESS architecture by the evaluation of its application to the different scenarios reported in Section 3.

On the other hand, [D1.1] defines the commercial and technical architecture to be implemented in the ADDRESS project. The architecture has been designed to satisfy the following requirements:

- The market is liberalised allowing the participation of any actor in it.
- The actors in the electricity market are separated into deregulated actors, able to participate in the liberalised market, and regulated actors responsible for managing the networks (transmission and distribution).
- The distribution network is active allowing the flow of energy in any direction and, as a consequence, the energy and active demand transactions negotiated in the market have to be validated by the TSO at the transmission level and by the DSO at distribution level.
- The ancillary services market can take place at distribution level as well.
- Aggregation of resources allows for the participation in the market of small consumers and producers.
- Interactions between the different actors have been identified.
- The products that will be offered by aggregators through the architecture have been identified as CRP (conditional re-profiling) and SRP (scheduled re-profilling)
- ICT allows for effective communication between all the actors involved, to exchange signals and to access the consumption and generation measurements.
- The smart meter component has been included to allow the actors the access to consumption and generation measurements.

On the other hand, the design of the architecture resulted in the need for the following components:

- A commercial component to facilitate trade between the actors.
- A technical component to facilitate the validation of the commercial transactions and services contracted between the actors.

- The energy box to allow for the control of the flexibility resources at the consumer's premises and to interact with other actors of the architecture (in principle through the aggregator only, nonetheless).
- The signals that will activate the services offered by the consumers have been identified and defined.

The methodology presented here evaluates how well the ADDRESS conceptual architecture fits with the characteristics present in the different scenarios. With the assessment done in this work, potential gaps are identified and then improvements are proposed.

To evaluate how well the ADDRESS architecture adapts to the different scenarios, the requirements posted by them have to be analysed, and how they compare with the ones considered for the design of the architecture. Within them, the most relevant requirements of the scenarios are:

- AD potential enabled by the architecture
- Flexibility needs and services required
- Technology requirements
- Market structures and rules
- Any other issues

By analysing how well the ADDRESS architecture deals with those aspects in the scenarios, we ensure that it is valid for a vast spectrum of different situations or otherwise propose necessary amendments for particular cases.

The conclusions of the analysis will serve to refine or adapt the architecture as needed in further work packages. Regarding the aggregator and Energy Box, WP 2 is responsible of its detailed definition and implementation while DSO and TSO functions and interactions are investigated and implemented in WP 3. The communications aspects are also influenced by the architecture and the relationships between the different players and are studied in WP 4. Markets and business models are detailed as part of WP 5.

4.1.1. AD potential enabled by the architecture

This part of the methodology attempts to assess the AD potential identified in the scenarios and how it compares with the requirements considered for the design of the architecture. It is clear that in the scenarios with lower AD potential, the success of the ADDRESS architecture is poorer while for those scenarios with high AD potential, success is more likely and significant.

To evaluate the AD potential requirements of the scenarios, the parameters considered for the definition of the scenarios must be translated into parameters for evaluating the AD potential. The parameters used in the assessment of the scenario impact of AD potential parallel the defining factors stated in Section2.3. These are as shown in Table 7.

The qualitative evaluation of the aspects explained in the table gives the overall AD potential requirements of the scenarios and how the ADDRESS architecture is able to meet them.

Parameters in the scenarios	Meaning from the point of view of flexibility potential
Geography	
Climate area	The climate area has a direct impact on the degree of use of different electricity driven types of appliances. The way of life, behavioural and cultural aspects are different for different climate areas and may have a direct impact on the AD potential. The ADDRESS architecture implies high use of electricity resources within small domestic and commercial consumers; it is better suited in scenarios where the climate component implies it.
Consumer density and characterisation	
Consumer density	Consumer density indicates the number of consumers that could potentially participate in AD and be attractive for aggregators. The higher the consumer density the higher the AD potential. It could be thought that cities with high population have more potential than rural areas with less population. Moreover, the consumer density may indicate the presence of legacy communication infrastructures that could be used to enable AD as required by the architecture.
Consumer characterisation	Depending on the level of the consumer acceptance and socioeconomic level in the different scenarios the degree of flexibility will be greater or lower.
Electricity industry infrastructure	
Market and regulatory context	The ADDRESS architecture focuses on the liberalised industry with the markets at its core. However, it remains that experience worldwide shows that many demand-side integration initiatives are happening and have happened in regulated contexts. In fact, TSOs and DSOs can always offer consumers incentives through regulated retailers. Hence, the market component of the architecture is not necessarily essential in enabling the flexibility of demand.
Generation mix	Not applicable for this point.
Technology	
Smart technology penetration	ICT, smart metering and the energy box are key components of the architecture. The hypothesis is that with extensive and rapid adoption of smart home and smart grid technologies, the potential for the validity of the architecture is increased.
Usage of electric devices	Washing machines, dishwashers, clothes driers, air conditioners and heating systems have been identified as the most promising devices to be integrated in the energy box management system [D1.1]. Hence, the larger the use of the electricity using devices the higher the AD potential that could be reached.

Table 7, Flexibility potential

4.1.2. Degree of flexibility needed in the different scenarios

By evaluating the needs for flexibility of the actors involved, we can deduce the potential success that active demand solutions could have. In any case, this aspect is not related to the specifics of the ADDRESS architecture or implementations of AD solutions.

It is clear that the degree of success of the ADDRESS architecture will depend also on the degree of flexibility needed in each scenario; therefore, the higher the flexibility need, the higher the probability of success of ADDRESS and vice versa. This was well illustrated by the scenario narratives in Section 3.

The point where the specifics of the ADDRESS architecture may become unsuitable for given scenarios is when the potential market for AD solutions is shallow (i.e. when there is little demand for AD, or AD would be in high demand only from a single actor). In such a situation, the architecture with its aggregators and markets may be too onerous from an initial investment or general business points of view. Hence, there may be scope to recommend "light" versions of the ADDRESS aggregator (possibly in association with other industry players) and associated markets for such situations.

4.1.3. Technological needs for ADDRESS architecture implementation

These criteria evaluate the technological requirements imposed by the scenarios and how they compare with the ones considered for the design of the ADDRESS architecture.

The following technological aspects have to be considered:

- Communication infrastructure between different actors
- Required architectural components (e.g. EB)
- Requirements of smart appliances at consumer premises
- Distributed generation and storage devices integration at consumer premises
- Network management tools for TSOs and DSOs for AD solutions validation

According to the defining parameters being used in the scenario definition the following table (Table 8) shows their impact on the implementation of the ADDRESS architecture.

4.1.4. Adaptability of ADDRESS architecture to different market structures and rules

A key component of the ADDRESS architecture applicability to different scenarios is how well it can be adapted to different market structures. The European context nowadays presents different market architectures for trading energy and ancillary services. The integration of AD into the current and future electricity trading frameworks will probably lead to the creation of new markets (if allowed by the industry rules) and will also require adaptations of already existing market arrangements.

At the moment, the ADDRESS architecture interfaces with a generic market for trading the AD products defined in [D1.1]. WP 5 will further analyse the implications of different market structures, but at this point we can make a first assessment with respect to current market implementations.

In the case of pool-like markets, the required adaptation may have to come from reducing the minimum order sizes to ensure potential entry of aggregators. This adaptation is probably practical, but the accrued benefit may be slim depending on the scenario and when the change has to be implemented.

The case of bilateral trading structures appears more adaptable to the ADDRESS architecture concept of market. This is the case especially when encountering some industry players with very specific demand response needs and when the scope for active demand remains rather small.

The other key element of the ADDRESS architecture is the recognition of the need for trading structures overlaying distribution systems. In some scenarios, the current regulation may not allow this. Hence, adaptations on both the ADDRESS architecture and the regulatory sides must be undertaken.

Parameters in the scenarios	Meaning from the point of view of technology implementation
Geography	
Climate area	The technology requirements may be different in different climatic areas, due to the devices in use, network design practices.
Consumer density and characterisation	
Consumer density	It can be thought that higher levels of consumer density provide economies of scale when deploying the technological infrastructure implied by the architecture. Moreover, in high density areas, some of the necessary telecommunication infrastructure may already be in place.
Consumer characterisation	Early adopters and individuals with higher disposable income will be more likely to acquire high-end and intelligent appliances.
Electricity industry infrastructure	
Market and regulatory context	Different markets and industry rules (e.g. ownership of infrastructure) may pose different technological needs and challenges.
Generation mix	Not applicable at this point.
Technology	
Smart technology penetration	Smart appliances and network management technologies increase the potential success of the architecture by providing more levers to generate and exploit consumer-side flexibility.
Usage of electric devices	To be able to provide commercially-significant products (SRP & CRP), consumers via the aggregators must have electrical usages in sufficient volume and type (i.e. usages that can be flexed by the signals of aggregators.)

Table 8, Technological needs

4.1.5. Other issues affecting the application of the ADDRESS architecture

Other issues which are not covered directly in the definition of the scenarios could also have certain relevance when trying to apply the ADDRESS architecture to the scenarios. The following list defines those elements that may affect the implementation of the architecture:

- Number and size of DSOs

- Different balancing mechanisms
- Products different from those envisaged

The number of DSOs and their size might have an impact on the applicability of the architecture. Those regions with a large number of small DSOs (like in some northern countries) should have more difficulties for the implementation of the technical verification procedures required by the architecture [D1.1]. Such DSOs will probably not have the resources to implement the systems that deal with the purchasing and verification phase of AD actions. In these cases, the architecture may need to be adapted not to have to perform those verifications or do them in another way. On the contrary, in cases where there are few but larger DSOs, this will be simpler and probably more effective in terms of complexity and potential benefits accrued from AD use. In fact, in the case of the four ADDRESS scenarios, the assumption is that the specific locations belong to the service territory of a single DSO.

Regarding the balancing mechanisms, there are cases where BRPs exist and others in which the TSO, generators and retailers are the ones in charge of balancing their own positions. These differences may carry the need for the adaptation of the architecture and the relationships between players. These issues have been already detected in previous work such as in the analysis of the relationships between retailers, aggregators and BRPs [D1.1]. So the question here is how well can the architecture be adapted to the required information flows implied in contexts where the balancing functions and responsibilities are set differently?

Apart from the products already identified in the architecture, there could be cases where other services (e.g. limiting power over certain areas) could also exist. In which way can the architecture handle other kind of AD products and services?

4.2. Application of the ADDRESS conceptual architecture to the specific scenarios

This section provides critical analyses of the four scenarios defined previously in Section 3 as seen from the point of view of the ADDRESS conceptual architecture ([D1.1] and Figure 5 for a quick visual reminder) and the assessment criteria defined above. The analysis attempts primarily to identify conceptual flaws and any necessary adaptations to the architecture to make it suitable in the four scenarios. The salient results of the analysis feed into a set of recommendations and guiding principles for deploying the ADDRESS architecture in realistic settings as set by the scenarios. These are outlined in Section 5.

4.2.1. Scenario 1—Southern City

4.2.1.1 AD potential enabled by the architecture

This scenario has the following salient features when considering its AD potential:

- Large consumer density
- Large penetration of air conditioning whose demand is correlated with the system peak.

Therefore, the potential for active demand in this scenario is quite high even from the early years of the horizon to 2020. The potential grows even further with the introduction of PEV in the second half of the 2010 decade.

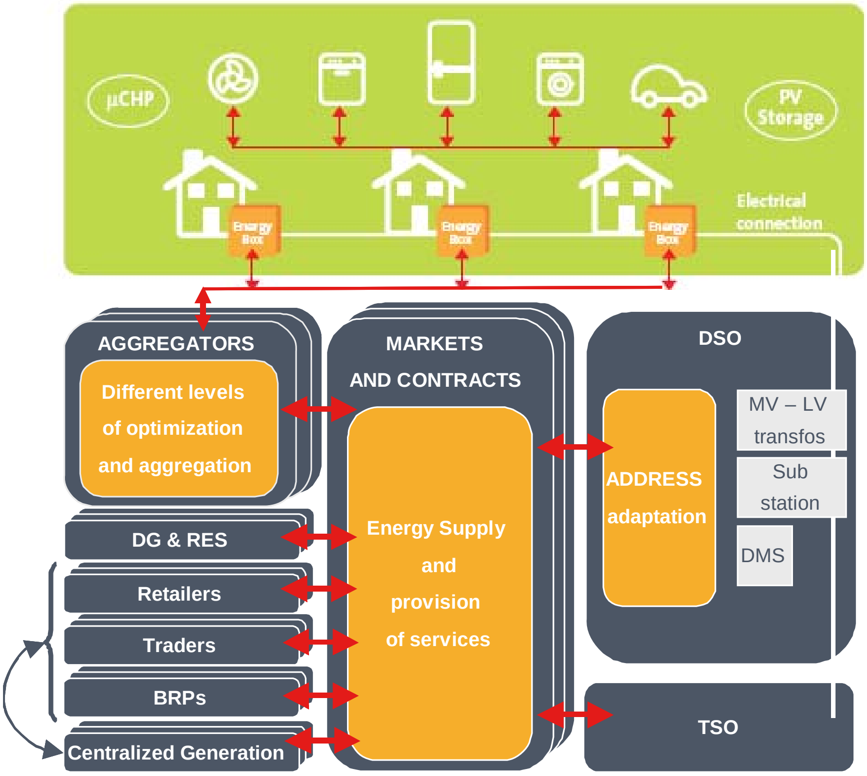


Figure 5, Simplified rendition of the ADDRESS conceptual architecture

The architecture serves to tap on this potential primarily through the coordination of the Energy Box and the aggregator. The Energy Box here does the following:

- Performs the local optimisation of occupant comfort and his/her AD-driven remuneration (possibly including the contribution of rooftop photovoltaics and storage on the premises).
- Can provide the aggregator with information about the consumption behaviour, appliance availability for providing flexibility and other signal response statistics.

On the other hand, the aggregator:

- Should be capable of assessing and characterising the consumer population by realising some level of economies of scale (in recruiting, reaching a critical mass of consumers rapidly, etc.) due to the high consumer density.
- The aggregator may be able to resort to relatively simple signalling strategies because of the “always on” and thermostatic nature of air conditioning (see for example [Callaway, 2009]) and PEV.
- Fine tuning of consumer response will be necessary to manage energy payback in an acceptable manner.
- Fundamental work is required to develop the potential of active demand beyond thermostatic loads like air conditioning.

4.2.1.2 Degree of flexibility required

At the current instant, the scenario outlines a definite need for energy balancing flexibility and ancillary services. This is also the case as time moves forward along the duration of the scenario horizon.

The actors who may definitely need active demand providing either balancing energy or ancillary services are the:

- TSO
- BRPs
- Production aggregators
- Producers with regulated tariffs
- Decentralised producers
- Traders & brokers
- Retailers

Therefore, there is a wide range of actors who may benefit from the introduction of active demand as envisaged by the architecture.

The DSO becomes another consumer of active demand later in the scenario when having to deal with network congestion and depressed voltages associated with the high demand for space cooling and charging PEVs.

In conclusion, when comparing Figure 5 and the list of actors seeing potential use for active demand, this situation is ideal. There is demand for AD across the industry even from an early stage.

4.2.1.3 Technological needs for ADDRESS architecture implementation

This scenario entails the following developments under the ADDRESS architecture:

- Communication infrastructure between different actors
  - **Consumer-aggregator**: According to the regulation and characteristics of the metering infrastructure in place, the meter may be the communication gateway between those two actors (where the *consumer* is effectively represented by an energy box). Otherwise, third party networks are available to enable two-way communication between the actors provided that appropriate encryption and network security measures are in place.
  - **DSO-TSO**: An adaptation of the current communication channels is required to pass on the network validation information with respect to active demand from the DSO to the TSO (for TSO validation) and back to the DSO (validation response from the TSO).
  - **Aggregator-customers[7] of AD**: The communication here happens over traditional electricity market channels (e.g. face-to-face negotiation down to automated electronic auctions).
- Required architectural components
  - The **Energy Box** is essential at consumers' premises to enable the active demand potential of the scenario.
  - **Smart meters** must be in place to measure consumption (in watts) over relatively short intervals of time (15-30 minutes) to be able to establish aggregator-consumer remuneration.

[7] *Customers* here are different from *consumers.* A customer of AD is an actor who buys an active demand product to provide itself with an active demand service. Consumers are the sources of active demand which are leveraged by aggregators.

- **Aggregators** must have a suite of software modules to perform:
  - Consumer portfolio characterisation and management (including location)
  - Optimal consumer signalling
  - Market offerings in the form of AD products
  - Revenue and risk management
  - Product delivery assessment
  - Settlement and billing
- **Customers of AD** need tools to assess how to evaluate which AD solution they should select and its associated value for specific operational and planning situations.
- There is a need to establish a regulated mechanism (which may have to be run by a regulated entity) **to confirm and assess aggregator product delivery**. This requires the mechanism to have access to the **infrastructure necessary to perform this function**. This is an open item of the architecture which is currently addressed in the elaboration of rules from settlement and billing in WP2, WP3 and WP5.

- Requirements of smart appliances at consumer premises
  - The energy box needs to be able to communicate with smart appliances (this could be one-way or two-way).
  - The energy box has to be able to issue commands which are understandable by all smart appliances. This entails that some actors must have some knowledge about the functioning of a wide range of appliances in order to integrate their models into the software of the energy box. More generally, this activity may be performed by the aggregators or other types of players depending on the business case, for instance, a service provider, the sellers of energy boxes, appliance manufacturers or the consumer itself with the information provided by the appliance manufacturers. It will depend on who owns and who operates the box.
- Distributed generation and storage devices integration at consumer premises
  - Much alike smart appliances, if all the potential of ADDRESS is to be exploited, distributed generation and storage at consumers' premises must be able to interface with the energy box.
  - The energy box must be able to include those devices in its internal optimisation.
- Network management tools for TSOs and DSOs for AD solutions validation
  - DSOs and TSOs must be able to establish the technical viability of active demand trades over their respective networks. For near-to-real time deliveries (20-30 minutes ahead), this needs to be achieved fast enough to signal all parties involved in the trades before product delivery actually starts.
  - DSOs and TSOs must have the means to provide the appropriate network information to the aggregators to
    - Make them aware of the limitations on their respective networks
    - Inform the aggregators about the marginal effects of changes in power injections across their respective networks (i.e. provide network

sensitivity matrices.)

4.2.1.4 Adaptability of ADDRESS architecture to market structures and rules

In the first few years of this scenario, the expected market environment for trading active demand would be bilateral and rather *ad hoc* whereby transactions are made between a single aggregator and a single other deregulated actor of the architecture. In the case of the regulated actors, their rules would have to be changed to accommodate the specific characteristics of active demand (e.g. an aggregator is not a generating unit with a single measurement point; minimum order sizes in ancillary services call for tenders may be too large for an aggregator to offer in, etc.)

Then as active demand starts to pick up, the generic "market" block in Figure 5 may become more and more organised as the volumes traded become significant. As mentioned in the scenario narrative, one plausible way forward with this is the elaboration of an active demand market run by the national power exchange. This market should be primarily targeting commercial actors in the architecture while the scope of the active demand product delivery would be at the national (i.e. transmission level) scale. Likewise, the TSO may be forced to change its rules regarding participation of active demand (as a resource) in the balancing market (especially with respect to minimum order sizes).

In fact, the new market run by the power exchange could be wider than just for the trade of active demand. This market should deal in "flexibility products" for which the shape of the power delivery over time is the primary attribute of the commodity while the actual energy delivered in association with the flexibility product might be of lesser commercial importance. The end result of this may entail that the standard products defined by the architecture may have to be modified to meet the requirements of the power exchange software, for instance. However, it is expected that the fundamentals of the SRP and CRP should be preserved.

The place where adaptability of market structures and rules will have to be of utmost importance will rest with the elaboration of the *institution* that is to run active demand/flexibility markets at distribution level. The key point here lies with the fact that in such instances, the DSO will most likely be the *customer* of active demand/flexibility much alike TSOs are *customers* of flexibility in the form of ancillary services. Moreover, the expectation is that distribution level markets for flexibilities will only be established for the duration of problematic periods for the DSO (and possibly other distribution-connected actors except consumers). In the end, the regulation is yet to be drafted and the markets have yet to be designed. The architecture in its current form is still very malleable, and we should not encounter significant problems in defining the necessary set of rules.

One aspect that stands out with respect to the DSO is the need to develop active demand trade validation tools early on in the 2010-2020 decade in spite of the fact that it may not benefit from AD until much later, if not at all. Could the DSO refuse AD on the grounds that it would require developing an entire suite of tools for that purpose? Most likely the regulator would force the DSO to go ahead, and would socialise the cost in the DSO rate base. How should this cost be allocated? Should the aggregators only be the ones to pay for this at the price of a higher barrier to entry? The issues of benefit and cost allocation are to be studied in detail at a later stage in the project. The expectation is to provide guidelines for the application of fair cost-benefit allocation principles.

Aggregators might need to be given regulatory assurances at the beginning of the horizon to support their investments in their computing and communication infrastructure as well as with the roll-out of energy boxes. These assurances may involve consumer minimum time switching rules (akin to those for retail contracts) which would disallow consumers to change aggregators before having spent certain minimum time under contract with the aggregator. In this case as well, aggregators may be constrained to "net out" the market positions of the retailers from whom they are utilising consumers. The regulator may take the position that the aggregator is essentially acquiring control over some retailers' consumers demand. Therefore, any actions by the aggregator modifying the balancing position of any retailer should be reflected in an exact netting of the corresponding retailer's balance position. This is to ensure no retailer is adversely affected by balancing market penalties. Said differently, because of its control and signalling actions towards consumers of a retailer, the aggregator has to take "ownership" of the change in demand off the retailer's balancing perimeter and then transfers that "ownership" to its AD product customer. As outlined in [D1.1], other options exist; however, given the context of that scenario, this is the most likely option to prevail here apart from the merger of aggregators and retailers.

Finally, small domestic and commercial consumers are vulnerable by their nature. Therefore, inasmuch the regulator may impose minimum contract lengths; the regulator has to provide safeguards for those consumers (e.g. low- to no-risk aggregator remuneration schemes, free energy boxes, an effective and efficient smart metering infrastructure and tailored engagement and user support measures.) At a higher level, the industry as a whole will serve consumers better if it enables standardisation of messages between energy boxes (from any aggregator) and smart appliances, home micro generation and storage (from any manufacturer).

4.2.1.5 Other issues

There are no other issues of concern with respect to this scenario.

4.2.2. Scenario 2—Southern Countryside

4.2.2.1 AD potential enabled by the architecture

This scenario has the following salient features when considering its AD potential:

- Low consumer density
- Peak demand driven by agricultural loads which are seasonal.

Therefore, the potential for active demand in this scenario is relatively low even towards the later years of the horizon to 2020.

The architecture serves to tap on this potential primarily through the coordination of the Energy Box and the aggregator. The Energy Box here does the following:

- Performs the local optimisation of occupant comfort and productivity and his/her AD-driven remuneration (most possibly including the contribution of distributed generation, potentially connected on the medium voltage grid, and storage on the premises).
- Can provide the aggregator with information about the consumption behaviour, appliance availability for providing flexibility and other signal response statistics.

On the other hand, the aggregator:

- Will find it hard to assess and characterise the consumer population by realising some level of economies of scale (in recruiting, reaching a critical mass of consumers rapidly, etc.) because of the low consumer density.
- The aggregator may have to resort to "fit for purpose" strategies to tap with

reasonable success the potential of the agricultural load (which may have very specific characteristics and end-use constraints.)

4.2.2.2 Degree of flexibility required

At the 2009-2010 boundary, the scenario outlines a definite need for flexibility to help some actors shift energy use from peak to off-peak periods because of the capacity shortage at national level. This is also the case as time moves forward along the duration of the scenario horizon.

The actors who may definitely need active demand for energy shifting are:

- Central electricity producers (for dealing with capacity shortages)
- TSO (for congestion management)
- Traders & brokers
- Retailers
- BRPs

Therefore, there is not much a wide range of actors who may benefit from the introduction of active demand as envisaged by the architecture, at least at the beginning.

The DSO becomes another consumer of active demand later in the scenario when having to deal with network congestion and high voltages associated with the further introduction of distributed generation in the rural area.

In conclusion, when comparing Figure 5 and the list of actors seeing potential use for active demand, this situation is not as good as with the previous scenario. There is demand for AD coming only from a rather limited, albeit not insignificant (retailers alongside traders and brokers), cross-section of the industry. DSO demand for AD is essentially conditioned on the appearance of sufficiently large amounts of distributed generation in the area corresponding to the scenario.

4.2.2.3 Technological needs for ADDRESS architecture implementation

This scenario entails the following developments under the ADDRESS architecture:

- Communication infrastructure between different actors
  - **Consumer-aggregator**: According to the regulation and characteristics of the metering infrastructure in place, the meter may be the communication gateway between those two actors (where the *consumer* is effectively represented by an energy box). Here, third party networks may not be available to enable two-way communication between the actors because of the low consumer density. This will require some adaptation of the architecture if the communication via the meter is restricted.
  - **DSO-TSO**: Same as in Scenario 1.
  - **Aggregator-customers of AD**: Same as in Scenario 1.
- Required architectural components
  - Same as in Scenario 1.
- Requirements of smart appliances at consumer premises
  - Same as in Scenario 1.
  - However, the agricultural applications (e.g. irrigation pumping) should have interfaces for the energy box to provide instructions.
- Distributed generation and storage devices integration at consumer premises

  - Same as Scenario 1.
  - In this scenario also, in the event where the distributed generation is of significant size, there may well be an actual conceptual disconnection between the generation and the energy box. In other words, one may consider the distributed generation as an actual *actor* of the architecture instead of it being integrated with the consumer's demand.
- Network management tools for TSOs and DSOs for AD solutions validation
  - Same as Scenario 1.

4.2.2.4 Adaptability of ADDRESS architecture to market structures and rules

The issues related to the adaptability of the architecture to market structures and rules are grossly similar to those of Scenario 1. Still, there are two elements which need mentioning:

- The narrative of the scenario is referring to a potential relaxation of rules for actors performing the dual function of retailer and aggregator. Allowing for this may allow for some interesting economies of scales as retailers already have relationships with consumers while it would deal automatically with the retailers' balancing anomalies introduced by the actions of independent aggregators (see [D1.1] and the previous discussion in Section 4.2.1.4). In this case, the regulator has to weigh the potential increases in benefits (e.g. making aggregation a simpler business, avoiding potential balancing problems for retailers, decreasing overall risk) against the potential loss in competition and innovation in the marketplace for aggregators as well as for retailers.
- Also, as mentioned in the scenario narrative, in low consumer density areas the scope for aggregation may be very limited because of the general low demand volume as well as the absence of the necessary communication infrastructure. In such cases on top of which the DSO would require support from active demand resources to manage a boom in distributed generation, the approach could be for the DSO to award an aggregation franchise over part of its service territory. The franchise would make all the consumers in the area captive of the aggregator who would have won the franchise call for tenders. The award of the franchise should be reviewed periodically and the winning aggregator would have to demonstrate that it is serving both the consumers and the DSO according to the rules set forth by the regulator. The key point here is that the rules should require the aggregator to act in the *public interest*, not that of consumers or the DSO only.

4.2.2.5 Other issues

There are no other issues of concern with respect to this scenario.

4.2.3. Scenario 3—Northern Suburban Village

4.2.3.1 AD potential enabled by the architecture

This scenario has the following salient features when considering its AD potential:

- Medium consumer density
- Relatively low thermally-driven electricity demand in the area because the vast majority of dwellings use district heating or oil/gas-fired heating systems
- Fast demand pick up in the 2015-2020 horizon as PEV start making their

appearance.

Therefore, the potential for active demand in this scenario is relatively low except towards the later years of the horizon to 2020 because of the PEV demand.

The architecture serves to tap on this potential primarily through the coordination of the Energy Box and the aggregator. The Energy Box here does the following:

- Performs the local optimisation of occupant comfort and the PEV battery state of charge and his/her AD-driven remuneration (possibly including the contribution of distributed generation and storage on the premises).
- Can provide the aggregator with information about the consumption behaviour, appliance availability for providing flexibility and other signal response statistics.

On the other hand, the aggregator:

- May find it hard to assess and characterise the consumer population by realising some level of economies of scale (in recruiting, reaching a critical mass of consumers rapidly, etc.) because of the low electricity demand.
- The interest of consumers in environmental issues and technology in general may help aggregators, nonetheless.
- The aggregator may have to resort to “fit for purpose” strategies to tap with reasonable success the potential of the non-thermostatic load present and which is more difficult to tap in (e.g. washing machines) as well as PEVs.

4.2.3.2 Degree of flexibility required

For now, the scenario underlines the fact that there is plenty of cheap flexibility within the generation mix. Therefore, the scope for active demand as a flexibility resource in the industry is still low. This is illustrated by the mostly small differential between the 2010 and 2020 scenario success scores for most of the actors (see Figure 3).

The DSO is the main potential consumer of active demand later in the scenario when having to deal with network congestion and depressed voltages associated with the high demand from charging PEVs. This is also the case of retailers and BRPs (to a smaller extent, however) as they have to deal with more and more sales volume uncertainty because of the increased PEV demand.

4.2.3.3 Technological needs for ADDRESS architecture implementation

All technological aspects are similar to those found in Scenario 1. We note, nonetheless, as the scope of AD would be very local here (i.e. DSO focused at best), there may be an opportunity to investigate under what circumstances the DSO-TSO-DSO validation steps could be avoided to simplify the applicable uses cases. Avoiding the need for a TSO sanity check could remove barriers to the development of active demand in such scenarios where there are not many actors who may have a genuine interest in it (like in Scenario 2).

4.2.3.4 Adaptability of ADDRESS architecture to market structures and rules

The characteristic of this scenario is its focus on local distribution network problems. Hence, the structural changes in the regulation must happen at distribution level. The discussion found in Scenarios 1 and 2 still applies; however, as we are in a context of *laissez-faire*, the assumption is that the DSO will have to deal with multiple aggregators each without substantial volumes available for trading. This may invariably increase transaction costs and stimulate consolidation of this sector of the industry. Therefore, it would not be surprising here to see retailers becoming aggregators from one day to the next rather than seeing independent aggregators thrive.

4.2.3.5 Other issues

In the event where the area considered in this scenario cuts through multiple DSO service areas, this reduces even more the attractiveness of active demand if significant seams issues arise. The regulator may not be compelled to intervene strongly, only asking neighbours to cooperate the best they can.

4.2.4. Scenario 4—Mid-Latitude High-Rise Community

4.2.4.1 AD potential enabled by the architecture

This scenario has the following salient features when considering its AD potential:

- Large consumer density
- Large penetration of air conditioning and heating which are present in cyclically correlating with the system summer and winter peaks respectively
- A good proportion of the consumers are reluctant to the concept of active demand.

Therefore, in theory the potential for active demand in this scenario is high even from the early years of the horizon to 2020 provided that consumer reluctance can be solved. The potential grows even further with the introduction of few PEV in the later half of the 2010 decade and as the successes of those consumers participating encourage others to join.

The architecture serves to tap on this potential primarily through the coordination of the Energy Box and the aggregator. The Energy Box here does the following:

- Performs the local optimisation of occupant comfort and his/her AD-driven remuneration.
- Can provide the aggregator with information about the consumption behaviour, appliance availability for providing flexibility and other signal response statistics.

On the other hand, the aggregator:

- Should be capable of assessing and characterising the consumer population by realising some level of economies of scale (in recruiting, reaching a critical mass of consumers rapidly, etc.) due to the high consumer density and its good knowledge of the tenant population in the housing estate.
- The aggregator may be able to resort to relatively simple signalling strategies because of the “always on” and thermostatic nature of air conditioning (see for example [Callaway, 2009]) and PEV.
- Fine tuning of consumer response will be necessary to manage energy payback in an acceptable manner especially because of the poor quality of appliances (e.g. high thermal conductivity of fridge-freezer walls) and the poor insulation of building walls, doors and windows.
- Fundamentals work is required to develop the potential of active demand beyond thermostatic loads. This is especially the case with entertainment appliances.

4.2.4.2 Degree of flexibility required

In 2009-2010, the scenario outlines a need for energy balancing flexibility and ancillary services. This is also the case as time moves forward along the duration of the scenario horizon.

The actors who may definitely need active demand providing either balancing energy or ancillary services are the:

- TSO
- BRPs
- Production aggregators
- Producers with regulated tariffs
- Decentralised producers
- Centralised producers
- Traders & brokers
- Retailers

Therefore, there is a wide range of actors who may benefit from the introduction of active demand as envisaged by the architecture. The scope for balancing energy increases as the years pass by because of the growing penetration of renewable energy resources connected to the system.

The DSO never becomes an important actor with respect to AD because of its investments in the local network early in the scenario horizon.

In conclusion, when comparing Figure 5 and the list of actors seeing potential use for active demand, this situation is almost ideal again if the consumer acceptance problem can be addressed. There is demand for AD across the industry even from an early stage. However, the aggregate demand for active demand may be relatively small in comparison to what is expected in Scenario 1 for example.

4.2.4.3 Technological needs for ADDRESS architecture implementation

They are the same as for Scenario 1. Particular care must be put on the technological interfacing with the consumers to reflect the desired level of engagement and expected understanding of the consumer population.

4.2.4.4 Adaptability of ADDRESS architecture to market structures and rules

This is the same as for Scenario 1. As with what has been noted just above, particular care must be taken in selling the idea of active demand to the consumers in this scenario. Moreover, this scenario requires some reflection about how to deal with not-for-profit aggregators. Should they be treated differently than others? Also, this case begs the question regarding what is the minimal viable size for an aggregator.

4.2.4.5 Other issues

There are no other specific issues in this scenario.

5. Conclusions and recommendations

This document summarised the reflection process within the ADDRESS project about the potential practical implementation of the ADDRESS conceptual architecture in the horizon to 2020.

Albeit conceptually elegant and rigorous in principle, the ADDRESS conceptual architecture needed to be put into context and pre-validated, technically and commercially, prior to its deployment. Adopting a scenario approach, we achieved this pre-validation goal before taking the work into further detailed development stages in the technical project workpackages and before defining the contents and concept for the field validation activities.

Hence, the adoption of this scenario approach served as an exercise in envisioning how the conceptual architecture and the ADDRESS concepts could evolve in four realistic European settings. We established that in the elaboration of the scenarios, four factors are to play key roles when assessing the potential evolution of an ADDRESS future. These are:

- The *geography* of the area where a scenario is developed. The geography here refers primarily to the climatic and general weather conditions of the area.
- The *characteristics and the density of consumers* in the area when and where a scenario is developed
- The *electricity industry infrastructure* (i.e. the generation mix and the market context) in place in the area when and where a scenario is developed, and
- The *technological context* (i.e. primarily consumer end uses and network technologies) of the area when and where a scenario is developed.

In the evaluation of the four possible ADDRESS futures, we adopted an approach based on the assessment of the potential success of ADDRESS and its architecture in the horizon to 2020. Success was defined by a measure of global welfare improvements over the 2020 horizon brought about to the entire electricity supply chain (i.e. from central generators down to individual consumers) by the deployment of ADDRESS. Any given scenario thus arises because of

- The current position (in 2009-2010) and the expectation for change in the four key factors listed above which are exogenous to an ADDRESS deployment, and
- The gradual deployment of the ADDRESS conceptual architecture and the changes to the four key factors themselves driven by the deployment of ADDRESS.

This approach had the benefit of identifying under which circumstances an ADDRESS deployment may be more or less desirable and potentially beneficial to the entire supply chain or only to sub-groups of industry actors. This exercise provided the current generic ADDRESS conceptual architecture with an overall positive sanity check, and it also provided necessary guidance for adapting the architecture to particular situations to maximise potential success. Likewise, it did signal practical situations where deploying ADDRESS may not be worth as much the effort and the investments in the horizon to 2020 (although it may be worth it in the longer term).

5.1. Review of the highlights of the specific scenarios with respect to the conceptual architecture

5.1.1. Scenario 1—Southern City

This scenario is illustrative of how ADDRESS may be deployed in an urban environment where there are significant numbers of domestic and small business consumers whose demand for electricity is driven primarily by cooling needs. The consumer population consists primarily of domestic consumers—a mix of young professionals, families with children and old age pensioners—with proximity shops and professional services offices. The local underground distribution network has been experiencing an increased frequency of plant overloads because of the steady increase in air conditioning demand.

At the national level, there is a thermally-dominated traditional generation park with an already significant number of large transmission-connected wind farms. These have increased the needs of the TSO for ancillary services and BRPs for short-term balancing flexibility. There is a well-established wholesale electricity market while small consumers have been introduced to retail competition only recently.

This scenario appeared to be the one with the most potential success. It combines two of the essential ingredients for a commercial success:

- A definite need for more affordable flexibility resources (like active demand) from both regulated and deregulated actors. This is generally due to the already large penetration of renewable energy in the electricity system which has been driving the growth in the demand for ancillary services and balancing services.
- The potential supply of active demand within the area of the scenario is quite high due to the:
    - High consumer density
    - High demand for electricity driven chiefly by the needs for space cooling, which is inherently flexible
    - Plug-in electric vehicles making an appearance later along the scenario horizon.

Because of these, aggregators start making their appearance quite early on. This is further enabled by the roll-out of a smart metering infrastructure and the availability of affordable and secure third party telecommunication infrastructures.

From the commercial perspective, active demand markets evolve from very *ad hoc* bilateral trades to formalised markets for flexibilities run by the national power exchange. Moreover, the regulator by about 2015 has to take action in laying out the basic rules for establishing the institutional framework needed to permit transparent active demand trading in distribution networks.

5.1.2. Scenario 2—Southern Countryside

This scenario is illustrative of how ADDRESS may be deployed in a rural environment where consumers are few, but where there may be significant agricultural load on small to medium-sized farms and where there is great potential for dispersed generation in the form of small wind, photovoltaics and biomass. At the national electricity system level, there are forecasted capacity shortages which will have to be fulfilled by bulk transnational electricity imports as old and dirty coal and oil-fired power stations are being decommissioned gradually. Therefore, there are pressures to modulate demand as a mean to ride through low capacity availability periods and to temper associated wholesale price swings.

The consumer population consists primarily of farms—with irrigation and farm produce primary processing loads—and domestic consumers—a mix of families with children and old age pensioners—with a few small shops and professional services offices grouped in a small village. The area is served by a long and aerial distribution network which still has headroom for demand growth.

This scenario appeared not to be the one with the most potential success. It combines only one of two of the essential ingredients for a commercial success:

- A definite need for more affordable flexibility resources (like active demand) from both regulated and deregulated actors. This is due to decreasing capacity margins at the wholesale electricity market level which provide incentives to shift on-peak consumption to off-peak periods.
- On the other hand, the potential for active demand within the area of the scenario is low because of the:
    - Low consumer density
    - Highly seasonal nature of the agricultural load.

Because of the need for flexibility at the national level, aggregators may start making their appearance quite early on at the national level; however, they show little interest in this rural area. It is only at a later stage once more and more distributed generation is connected in the area that the DSO shows interest in using active demand locally to manage better its network in light of this surge of generation in the area.

In that situation it emerges that no aggregator is genuinely interested to operate in this area. This forces the DSO, supported by the regulator, to issue a call for tenders for an exclusive aggregation franchise over that area. The winning aggregator would obtain captive *consumers* and a captive *customer* (the DSO) over some time and, under some set rules, making the initial investment more likely to be profitable.

5.1.3. Scenario 3—Northern Suburban Village

This scenario is illustrative of how ADDRESS may be deployed in a suburban environment in the North of Europe where there are important numbers of domestic consumers and fewer small business consumers over a relatively wide area. The demand for electricity is dominated by lighting and other household appliances as space and water heating are either provided by gas or district heating, although heat pumps have started to appear. In the upstream electricity system, a vast majority of the installed generation capacity is based on hydro and numerous interconnections with neighbouring countries help securing sufficient and relatively cheap electricity supplies. Consumers have been introduced to retail electricity competition about a decade ago and have learned about the benefits of shopping around for their electricity.

The distribution network serving the population in the area is underground. The frequency of overloading cycles on cables and transformers is still low, and there are times in the year when demand is very low where the feeder voltages rise very close to the statutory limit. The socioeconomic makeup of the consumer population is relatively uniform and dominated by families with children and older family units whose children have left the household. The majority of people are well-educated and sensitive to environmental issues.

This scenario appeared to be the one with the least potential success from the point of view of the 2009-2010 boundary:

- There is plenty of affordable flexibility in the national electricity system thanks to a good supply of hydroelectric capacity and strong international interconnections.

- The potential supply of active demand within the area of the scenario is not high initially because of the:
  - Medium consumer density
  - Low demand for flexible electricity uses like space heating (heat is generally provided by district heating or fossil fuels).

In this case, it is only once plug-in electric vehicles start appearing *en masse* within the community that the need for active demand arises for the DSO. Here the regulatory philosophy is to let the market decide the best way to organise trade. Therefore, a number of competing alternatives arise allowing for some aggregators to fail and businesses to consolidate (e.g. not disallowing the combination of retail and aggregation functions).

5.1.4. Scenario 4—Mid-Latitude High-Rise Community

This scenario is illustrative of how ADDRESS may be deployed in a high-rise housing estate where there are important numbers of domestic consumers and several small business consumers serving the community over a relatively small land footprint. The demand for electricity is dominated by space heating in the winter and cooling in the summer months. The national electricity system is characterised by a significant number of large capacity thermal generation plants which are primarily nuclear. Just like the other scenarios, there is a well-established wholesale power market which is already integrated with neighbouring countries.

The distribution network serving the population in the area is underground and the frequency of overloading cycles on cables and transformers has reached unprecedented levels especially in the summer because of the air conditioning demand. The consumer population consists primarily of domestic consumers—a mix of families with children and old age pensioners with relatively low income—with shops, professional services offices, a community centre and schools. Traditionally, the consumers have been served by an integrated distributor-retailer who did offer alternatives to single flat tariffs. Retail competition has been introduced not long ago, and so far consumers have shown reluctance to switching retailers.

This scenario appeared to be quite interesting:

- There is a growing need for flexibility at the national level because of many more new bigger renewable energy projects are coming online. In addition, there is an explicit recognition by central generators that they can use active demand products as substitutes for some of their statutory ancillary services requirements.
- The potential supply of active demand within the area of the scenario is high because of the:
  - High consumer density
  - High demand from flexible electricity uses like space heating and air conditioning.

The original aspect of this scenario is the fact that the aggregator in this case might be the housing estate by itself which establishes the aggregator as a not-for-profit business serving the community. The ultimate goal here is to help the tenants to optimise their rising energy bills and mitigate the effects of fuel poverty. The main challenge in this case is to convince people on the estate to join the scheme.

5.2. Guidance and questions for the continuation of the work in ADDRESS arising from the scenarios

The four scenarios summarised above provided some evidence regarding some issues and questions to focus on as we move forward with the development of the technical aspects of the project and their associated validation activities.

5.2.1. Consumers

With respect to consumers, the scenarios reminded us that:

- Determining how, how much and when people use electricity is primordial in the assessment of the potential success of an ADDRESS future.
- Knowing how the people involved feel about technology and how they interact with it will shape the response in size and over time.
- The emergence of two classes of small consumers—active and non-active—may lead to unexpected cross-subsidies which may be detrimental to ADDRESS. The question here really is: “As aggregators potentially hurt the business of retailers, would retailers to try recoup losses through higher rates for non-active consumers?” This has regulatory and business case implications which need proper addressing within the project.
- Providing a good consumer business case (with a good comfort-financial reward balance) is essential especially when people involved have to spend already large sums of money to pay their energy bills.
- Small domestic and commercial consumers are vulnerable by their nature. Therefore, inasmuch the regulator may impose minimum contract lengths; safeguards for those consumers must be provided from the get go (e.g. low- to no-risk aggregator remuneration schemes, free energy boxes, an effective and efficient smart metering infrastructure and tailored engagement and user support measures.)
- The industry as a whole will serve consumers better if it enables standardisation of messages between energy boxes from any aggregator and smart appliances, home micro generation and storage from any manufacturer.

5.2.2. Aggregators

With respect to aggregators, the scenarios reminded us that:

- Aggregators will emerge as businesses only if there is a genuine need for flexibility (which would be provided in the form of active demand here) in the electricity system, and
- Aggregators will emerge as businesses only if there is a genuine active demand resource available that can be tapped at a reasonable cost.
- Aggregators may emerge also as different entities than pure capitalistic businesses; aggregators for housing estates, farming cooperatives and so on, are also on the agenda. For example, town councils who provide housing to the fuel poor may be not-for-profit, but may also have a portfolio of generation and wish to match their demand to their generation to minimise their exposure to a future volatile energy market.
- The energy box and a smart meter are essential for a consumer joining an aggregator. Aggregators should lobby energy box and smart appliance manufacturers to ensure

home appliances are interoperable with all energy boxes.

- Aggregators might need to be given regulatory assurances early on to support their investments in their computing and communication infrastructure as well as with the roll-out of energy boxes. These assurances may involve consumer minimum time switching rules (akin to those for retail contracts) which would disallow consumers to change aggregators before having spent certain minimum time under contract with the aggregator.
- Aggregators may be constrained to "net out" the market positions of the retailers from whom they are utilising the consumers. The regulator may take the position that the aggregator is essentially acquiring control over some retailer's consumer demand. Therefore, any actions by the aggregator modifying the balancing position of the retailer should be reflected in an exact netting of the corresponding retailer's balance position. This is to ensure no retailer is adversely affected by balancing market penalties. Said differently, because of its control and signalling actions towards the consumers of a particular retailer, the aggregator has to take "ownership" of the change in demand off the retailer's balancing perimeter and then transfers that "ownership" to its AD product customer. As outlined in [D1.1], other options exist; however, given the context of that scenario, this is the most likely option to prevail here apart from the merger of aggregators and retailers.
- Allowing for the potential relaxation of rules on the dual aggregator-retailer functions this may allow for some interesting economies of scales as retailers already have relationships with consumers while it would deal automatically with the retailers' balancing anomalies introduced by the actions of independent aggregators. The overreaching aspect here, however, is for the regulator to weigh the potential increases in benefits (e.g. making aggregation a simpler business, avoiding potential balancing problems for retailers, decreasing overall risk) against the potential loss in competition and innovation in the marketplace for aggregators as well as for retailers.

5.2.3. DSOs

With respect to DSOs, the scenarios reminded us that:

- The need for active demand trade validation will incur costs to the DSO, which must be recovered and allocated—this is a joint aspect with the regulator. Could the DSO refuse AD on the grounds that it would require developing an entire suite of tools for that purpose? Most likely the regulator would force the DSO to go ahead, and would socialise the cost in the DSO rate base. How should this cost be allocated? Should the aggregators only be the ones to pay for this at the price of a higher barrier to market entry? As the issues of benefit and cost allocation are to be studied in detail at a later stage in the project, the expectation is to provide guidelines for the application of fair cost-benefit allocation principles.
- In low consumer density areas the scope for aggregation may be very limited because of the general low demand volume and the absence of the necessary communication infrastructure. In such cases on top of which the DSO would require support resources to manage a local boom in distributed generation, the approach could be for the DSO to award an aggregation franchise over part of its service territory. The franchise would make all the consumers in the area captive of the aggregator who would have won a competitive franchise call for tenders. The award of the franchise should be reviewed

periodically and the winning aggregator would have to demonstrate that it is serving both the consumers and the DSO according to the rules set forth by the regulator. The key here is that the rules should require the aggregator to act in the *public interest*, not that of consumers or the DSO only. In fact, in such situations, it may be reasonable to have the DSO perform the aggregation function itself as part of its regulated activities.

- DSOs will need to understand the trigger point when AD can no longer provide the services to allow it to manage security of supply and when the time has come to invest in network assets, preferably before the lights go out.
- At times, once the DSO invests in renewing and upgrading its network, it may lose interest in active demand.

5.2.4. Regulation

From the above discussions, we see how the role of the regulator is central in the consumer-DSO-aggregator equation of ADDRESS. The regulator has to essentially perform the following arbitrage between those three objectives:

1. Protecting small consumers.
2. Giving aggregators enough business and technical leeway as well as certainty and support for the start up of their activities.
3. Allowing DSOs to maintain a reliable network operation at a reasonable cost.

Specifically, with respect to regulation, the scenarios reminded us that:

- Markets for active demand should be left to emerge on their own as much as possible. However, aggregators may have to be given some assurances to make sure they can make a reasonable profit on their investments, at least for the first few years.
- Markets for active demand will probably be better known as markets for flexibility. The standardisation of the products and market clearing rules are most probably going to end up with national power exchanges (at least for flexibilities needed at transmission level).
- Regulators will have to think through on how to measure the delivery of active demand products for clarifying billing and settlement. Will that require a new infrastructure? Who should own it? Who will pay for it? Who should operate it?
- The issue of markets for active demand on distribution grids is common to almost all four scenarios. What are the approaches to take forward? Does this need a complete new institution in the electricity industry?
- The deployment of the ADDRESS architecture will have a cost and some expected benefits. How should those costs and benefits be allocated in the fairest way possible?

6. References

6.1. Project documents

[D1.1] – ADDRESS Deliverable D1.1.

[IR5.1] – ADDRESS Internal Report IR5.1.

6.2. External documents

[Belton & Stewart, 2002] – Belton, V. & Stewart, T. J. (2002). *Multiple criteria decision analysis*. Boston, MA: Kluwer Academic Publishers.

[Callaway, 2009] – Callaway, D.S. (2009). Tapping the energy storage potential in electric loads to deliver load following and regulation, with application to wind energy, *Energy Conversion and Management*, 50, 1389–1400.

[Keeney & Raiffa, 1993] – Keeney, R. L. & Raiffa, H. (1993). *Decisions with multiple objectives: Preferences and value trade-offs*. Cambridge, UK: Cambridge University Press.

[Linares & Romero, 2002] – Linares, P. & Romero, C. (2002). Aggregation of preferences in an environmental economics context: a goal-programming approach, *Omega*, 30, 89–95.

7. Revisions

7.1. Revision history

Version	Date	Author	Notes
0.1	06/04/2010	F Bouffard (UNIMAN)	First draft for revision.
0.2	08/04/2010	F Bouffard (UNIMAN)	First draft now including the Executive Summary and answers to the comments from Peter Lang.
0.3	26/04/2010	F Bouffard (UNIMAN)	Draft including answers to the comments from reviewers Peter Lang and Pedro Linares.
0.4	27/04/2010	F Bouffard (UNIMAN)	Minor edits for clarity.
0.5	19/05/2010	F Bouffard (UNIMAN)	Edits from TB comments.
1.0	31/05/2010	AMO,QM,QMO&PC	Document Approval

Annex A. Actors' stakes

The list below enumerates all of the 17 actors' stakes assessed in the scoring of the scenarios.

1. Centralised electricity producers
    a. Short term stakes
        i. Maximising profit
        ii. Minimising risk
    b. Long term stakes
        i. Optimising investments
2. Decentralised electricity producers
    a. Short term stakes
        i. Maximising profit
        ii. Minimising risk
    b. Long term stakes
        i. Optimising investments
        ii. Improving its capacity factor, controllability, dispatchability
        iii. Minimising risk
3. Electricity producers with regulated tariffs and obligations
    a. Short term stakes
        i. Maximising profit
        ii. Minimising risk
    b. Long term stakes
        i. Optimising investments
4. Production aggregators
    a. Short term stakes
        i. Maximising profit
        ii. Minimising risk
    b. Long term stakes
        i. Improving its capacity factor, controllability, dispatchability
5. Demand aggregators
    a. Short term stakes
        i. Maximising profit
        ii. Minimising risk
    b. Long term stakes
        i. Developing its consumer portfolio
        ii. Improving its capacity, controllability
6. Traders
    a. Short term stakes
        i. Maximising profit

      ii. Minimising risk
   b. Long term stakes
      i. Market access, transparency and regulation
      ii. Minimising risk
7. Brokers
   a. Short term stakes
      i. Maximising profit
      ii. Customer satisfaction
   b. Long term stakes
      i. Market access, transparency and regulation
      ii. Minimising risk
8. Balancing responsible parties
   a. Short term stakes
      i. Maximising profit
      ii. Minimising risk
   b. Long term stakes
      i. Capturing high-value customers
9. Retailers
   a. Short term stakes
      i. Maximising profit
      ii. Minimising risk
   b. Long term stakes
      i. Optimising its purchase-sale portfolio
10. Service providers
   a. Short term stakes
      i. Maximising profit
   b. Long term stakes
      i. Optimising its service offer portfolio
      ii. New business opportunities
11. Regulators
   a. Short term stakes
      i. Market access, transparency and regulation
      ii. Effective incentive and support schemes
      iii. Promoting standardisation
   b. Long term stakes
      i. Market access, transparency and regulation
      ii. Effective incentive and support schemes
12. Distribution system operators
   a. Short term stakes
      i. Maximising regulated profit

            ii. Minimising consumer interruptions
    b. Long term stakes
        i. Optimising investments
13. Transmission system operators
    a. Short term stakes
        i. Maximising regulated profit
        ii. Minimising consumer interruptions
        iii. Optimise the value of transmission assets
    b. Long term stakes
        i. Optimising investments
14. Large consumers
    a. Short term stakes
        i. Minimising electricity bill
    b. Long term stakes
        i. Optimising electricity purchase portfolio
15. Small “active demand” consumers
    a. Short term stakes
        i. Minimising electricity bill
        ii. Maximising comfort and productivity
        iii. Reliability of supply
    b. Long term stakes
        i. Transparency
        ii. Protection of the environment
16. Small “non-active demand” consumers
    a. Short term stakes
        i. Minimising electricity bill
        ii. Maximising comfort and productivity
        iii. Reliability of supply
    b. Long term stakes
        i. Transparency
        ii. Protection of the environment
17. Equipment manufacturers
    a. Short term stakes
        i. Maximising profits
        ii. Promoting standardisation
    b. Long term stakes
        i. New business opportunities

Annex B. Scenario scores

	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
Actors	**2009**	**2020**	**2009**	**2020**	**2009**	**2020**	**2009**	**2020**
Centralised electricity producer	0.00	0.00	0.00	0.25	0.00	0.00	-0.25	0.25
Decentralised electricity producer	0.00	0.28	0.23	0.48	0.28	0.30	0.10	0.15
Producer with regulated tariff and obligations	0.00	0.25	0.18	0.50	0.25	0.33	0.25	0.25
Production aggregators	0.00	0.63	0.20	0.45	0.33	0.38	0.08	0.00
Demand aggregators	0.00	0.75	0.53	0.45	0.23	0.65	0.65	0.83
Traders	0.00	0.50	0.15	0.00	0.05	0.15	-0.05	-0.15
Brokers	0.00	0.50	0.20	0.48	0.08	0.15	0.50	0.53
Balance responsible parties (BRP)	0.00	0.75	0.25	0.50	0.38	0.50	0.43	0.50
Retailers	0.00	0.20	-0.25	-0.45	0.58	0.65	0.45	0.08
Service providers	0.15	0.75	0.30	0.60	0.20	0.18	0.43	0.75
Regulators	0.18	0.45	0.23	0.45	0.08	0.08	0.00	0.30
Distribution system operator (DSO)	0.00	0.50	0.23	0.23	0.13	0.25	0.00	-0.03
Transmission system operator (TSO)	0.00	0.55	0.00	0.15	0.23	0.20	-0.20	-0.30
Large consumers	0.00	-0.25	0.00	0.50	0.25	0.25	0.08	0.50
Small consumers (active demand)	0.00	0.18	0.03	0.05	0.05	0.10	0.00	0.40
Small consumers (non active demand)	0.00	0.20	-0.03	-0.28	0.00	0.05	0.10	0.05
Equipment manufacturers	0.13	0.50	0.33	0.50	0.23	0.23	0.10	0.30
Global success	**0.45**	**6.73**	**2.55**	**4.85**	**3.30**	**4.43**	**2.65**	**4.40**

Table 9, Summarised scenario scores per actor