Utrecht University & PBL Netherlands Environmental Assessment Agency

An electricity system with renewable, distributed generation

Exploring future visions, barriers and drivers

Master thesis

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Abstract

Due to concerns about climate change, and fossil fuel dependency there is an increasing interest in the transition from the current fossil fuel based electricity supply system towards an electricity supply system with an emphasis on renewable resources. Also in the Netherlands a transition towards an electricity supply system with a significant contribution of renewable distributed generation (RDG) gains interest. In order to guide the direction of this transition, shared future visions are necessary. Therefore, the objectives of this research are to explore future visions on an electricity supply system with significant RDG in order to assess the extent to which these visions are shared. This was done by exploring the content of the visions, and barriers that could stimulate or hamper the transition towards such a system. This data was collected via semi-structured qualitative interviews among selected actors. On individual vision level the alignment was relative low. The main similarities were found on the use of demand side management. Aligned clusters of visions that could be identified were on control types to balance the system and on the inclusion of storage.

Content

1 Introduction

Due to concerns about climate change, and fossil fuel dependency there is an increasing interest in the transition from the current fossil fuel based electricity supply system towards an electricity supply system with an emphasis on renewable resources (IEA, 2002). The electricity supply system includes a broad range of technical components and technologies, as well as different actors and institutions that contribute to supplying the end-user with electricity.

In the Netherlands a transition towards an electricity supply system with a significant contribution of renewable distributed generation (RDG) gains interest (Meeuwsen et al., 2008; Ministry of Economic Affairs, 2008). Such a transition is triggered by drivers (Hughes, 1987). RDG includes technologies such as solar-pv, wind turbines and biomass digestion. This transition is the focus of this paper.

A transition towards a system in this direction can expect to face barriers, because a system with a significant contribution of RDG represents a radical change in comparison to the current electricity supply system (Ackermann et al., 2001; Faber & Ros, 2009; Künneke, 2008; Pepermans et al., 2005; Raven, 2006; Verbong & Geels, 2010). This radical change requires substantial changes in both technological components, institutions and the linkages between them, such as consumers who change into co-producers. Moreover, the electricity supply system is characterized by a strong interdependency between the technological components and institutions. This interdependency makes it difficult to alter or substitute elements of the system, because such changes affect the functioning of other elements of the system (Hughes, 1987). The barriers can be found in technologies which are not compatible with the new system, and in the regulative and normative institutions, such as regulations and standards; which are optimized for the functioning of the current electricity supply system (Scott, 2008).

In order to guide the direction of the transition, shared future visions are necessary (Berkhout, 2006). A shared future vision guides the actions of actors. It contributes to identifying alternatives, defining barriers, monitoring progress, building actor networks, and marshalling resources for the transition. The actors who express such visions can be interdependent actors who are active in the current system. But they can also be actors who do not play a role in the current system, and who want to play a role in the new system. This research compares the different RDG visions. This comparison is made to explore whether shared visions exist. In order to asses to which extent a vision is shared, this focus is not only on the elements of the different visions, but also on the barriers and drivers that the different actors identify. These barriers and drivers provide information as to whether the actors share ideas on the transition path that is necessary to reach a particular vision. Furthermore, the assessment in shared drivers and barriers indicates the potential of visions to become shared.

The creation of visions by the different actors is triggered by the drivers that they perceive (Hughes, 1987). A driver could for example be the political concerns on climate change. The realisation of visions is hampered by the barriers that actors perceive. A barrier could for example be that a vision requires consumers to become co-producers. Sharing the same drivers and/or barriers indicates a partial alignment. This partial alignment can lead to a full alignment when the actors align also the content of their visions.

The objectives of this research therefore are to gain insights in the different future visions of actors on an electricity supply system with a significant contribution of RDG, as well as on the perceived barriers and drivers that influence the transition towards such a system. So, this paper seeks to address the following questions:

1. *What are the future visions of actors on an electricity supply system with a significant contribution of Renewable Distributed Generation in the Netherlands, and to what extent are these visions shared?*
2. *Which barriers do actors perceive that hamper the transition of the electricity supply system towards the system of their preference?*
3. *Which drivers do actors perceive that trigger the transition of the electricity supply system towards the system of their preference?*

Section 2 presents the theoretical concepts on system transition. Section 3 presents the operationalisation of the theory, and the method for data collection and analysis. Section 4 presents the results. Section 5 compares the findings with literature and discusses the limitations of the findings. Section 6 summarizes the main findings presents the implications, and gives suggestions for further research.

2 Theoretical framework

The theoretical framework discusses four theoretical concepts: Large technical systems, future visions, drivers and barriers. First, this chapter discusses large technical systems and innovation processes in this system. Second, this chapter discusses the role of future visions in these innovation processes. Third, this chapter discusses the drivers which can trigger these innovation processes. Fourth, this chapter discusses the barriers which can hamper these innovation processes.

2.1 Large technical systems

An electricity system can be characterised as a large technical system (LTS). "Technological systems contain messy, complex, problem solving components. They are both socially constructed and society shaping. Among the components in technological systems are physical artefacts. Technological systems also include organisations, and they incorporate components usually labelled scientific. Legislative artefacts can also be part of technological systems. Natural resources also qualify as system artefacts" (Hughes, 1987, p. 51). More precise LTS's can be seen as "complex heterogeneous systems of physical structure and complex machinery which (1) are materially integrated, or 'coupled' over large spans of space and time and (2) support or sustain the functioning of very large numbers of other technical systems" (Joerges, 1998, p. 24). Next to physical elements, large technical systems also encompass non-physical elements, such as specific regulations, norms and actors (Markard & Truffer, 2006).

Regarding the electricity supply system, this paper defines the electricity supply system as '' a set of different actors, institutions and technical components and their relationships that serve the purpose to supply consumers with electrical power" (Markard & Truffer, 2006, p. 613). The first dimension, *actors,* includes elements such as energy service companies (ESCO), local energy organisations (LEO), distribution system operators (DSO), the transmission system operator (TSO), governmental agencies, knowledge institutes, and equipment manufacturers.

The second dimension, *institutions,* is "… comprised of regulative, normative and cultural-cognitive elements that, together with associated activities and resources, provide stability and meaning to social life” (Scott, 2008). Two key dimensions can be identified as vital pillars of institutions: the regulative and the normative pillar (Scott, 2008). The regulative pillar refers to regulatory processes, which involve the capacity to establish rules, inspect others’ conformity to them, and as necessary, manipulate sanctions, rewards or punishments in an attempt to influence future behaviour. The normative pillar refers to the prescriptive, evaluative, and obligatory dimension of social life. This includes values and norms. Values are conceptions of the preferred or the desirable, together with the construction of standards to which existing structures of behaviours can be compared and assessed. Norms specify how things should be done; they define legitimate means to pursue valued ends. Normative systems define goals or objectives, but also designate appropriate ways to pursue them. The electricity supply system includes institutions such as sector specific regulations, and technical norms as well as institutions such as power exchanges.

The third dimension, *technical components,* includes elements such as generators, transformers, power lines, switches as well as control and metering devices. The boundaries of the LTS are defined by the broad range of power consuming appliances including motors, lighting equipment or heaters (Markard & Truffer, 2006).

An important characteristic of an LTS is the high degree of interdependency between the various elements. Consequently, removing or altering elements affects the functioning of other elements in the LTS (Hughes, 1987). These elements are interdependent in several ways (Markard & Truffer, 2006). The actors are interdependent due to *contractual, legal, economic or informal* linkages. Most of the technical components are *physically* connected with each other, and are *technologically* interrelated, due to adaption. The institutions are interdependent via co-evolution with the other elements to assure the compatibility and inter-operability of the systems’ elements. To illustrate, when a new type of generator which is based on new principles is deployed, safety standards are developed to ensure a safe generation. When afterwards variations of this type of generator are deployed, they are built according to these existing safety standards.

Due to this interdependency of the elements the development of the LTS tends to be strongly path-dependent. Consequently, innovation processes in the energy system are more incremental than radical (Hughes, 1987). A new electric appliance, for example, needs to meet customer needs, but must also be compatible with the other technical components; moreover it has to comply with safety standards. During these processes actors, institutions and technical components can disappear and new actors, institutions and technical components can arise. Also in linkages between the actors, institutions and technical components changes can occur.

Nonetheless, sometimes radical innovations do occur, these are significant changes in the systems that change the principles on which the LTS is based. In the early days of the electricity system for example, the transmission regime was based on direct current (DC), which was later substituted by AC (alternating current) (Hughes, 1987). This had a significant effect on the system, due to the different scientific principles on which AC is based compared to DC. Consequently, other elements needed to be adapted to this new form, such as all the appliances which were adapted to use DC. This paper defines a system transition as: an accumulation of radical changes in actors, institutions and technological components of the LTS that change the principles on which the LTS is based.

2.2 Future visions

In a system transition shared future visions are necessary to guide the direction of the transition (Berkhout, 2006). Due to the interdependency between the actors, institutions and technical components, the actions of the different actors need to be aligned in order to let the LTS function properly. This alignment in actions is also necessary in the new LTS. A shared future vision contributes to this alignment of actions.

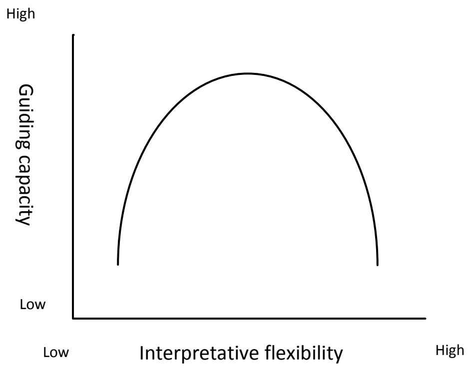

Figure 1: Future visions and the effect of their interpretative flexibility on guiding capacity

Two visions of two actors are shared when they include the same *actors, institutions and technical components.* Such a shared vision can have a guiding capacity on the actions of the interdependent actors. This vision then aligns the actions of the actors in order to enable a transition. Two visions that are not exactly the same can still be shared, for example when one vision gives a more specific description of the actors, institutions and components that are also described in another vision. This is captured by the concept of the interpretative flexibility of the future vision (Bijker, 1995). Higher interpretative flexibility leads to a greater number of allies supporting the vision. However, too much flexibility leads to interpretative instability, which harms the capacity to guide the actions of the actors (Figure 1). (Berkhout, 2006; Eames et al., 2006).

To illustrate, if we compare the electricity system in Berlin of the year 1920 with the system of London of the same year we find a significant difference (Hughes, 1987). The electricity in Berlin was supplied by 6 large scale power plants. While, the electricity in London was supplied was supplied by 50 small power plants. If German power plant builders and English grid builders of the year 1920 had to build a new system for a new city together without communicating and aligning their visions, then the grid builders would have based the capacity of the grid on many small power plants, while the power plant builders would have build just a few large power plants. This would have lead to a conflicting situation where the grid could not handle the high load of the large power plants. If in this situation both the builders of the power plants and the builders of the grid had communicated and aligned their visions on the future supply system for that city, then their actions would had complemented each other.

2.2.1 Elements of future visions

Future visions can be considered as “collectively held and communicable schemata that represent future objectives and express the means by which these objectives will be realised” (Berkhout, 2006). Actors create future visions that are aligned with their interests and with their resources (Berkhout, 2006). In stable LTS’s dominant interests direct the pace and direction of change, while in times of significant selection pressure these relations become disrupted. This provides opportunities for alternative future visions on the LTS (Eames et al., 2006).

In a transition a future vision has several important functions for the actors to guide their actions (Berkhout, 2006; Smith et al., 2005). The vision contributes in identifying plausible alternatives, contributes to defining the problems, helps to stabilise the actors’ activities, it contributes to building actor networks, and it helps in marshalling resources.

Future visions have three characteristic features: objectives, technologies, and orders (Berkhout, 2006). *Objectives* are the qualitative or quantitative expression of novel future outcomes. *Technologies* are the means for achieving these objectives. *Orders* are a set of social and institutional relationships in which objectives can be met. The future visions of the actors in the electricity supply system consist of communicable schemata which describe the future actors, institutions, technical components and their linkages in the LTS.

In the objectives part of the future vision an expression of a novel future outcome of an LTS is presented. To illustrate an expression could be: an LTS that supplies electricity to the Netherlands with the least possible amount of CO_2-emmissions. The vision then is further specified in the orders, and technologies part. In the technologies part of the future vision, an actor defines which *technical components* are needed in the future electricity supply system that is presented in the objectives part. In the DC to AC example a technical component could for example have been an adapter for existing appliances to make them compatible with the new LTS. In the orders part of the future vision, an actor defines which *actors*, *institutions* and *linkages* between them are needed in the future electricity supply system that is presented in the objectives part. In the DC to AC example an order could for example have been an agreement between al the actors on the frequency used to transport the current.

The different elements of the visions and their application on the LTS are summarized in Table 1.

Table 1: Vision elements described in LTS terminology

Vision element	In LTS terminology
Objectives *the qualitative or quantitative expression of novel future outcomes*	Expressions of a novel future LTS that supplies electricity. This expression contains a general description of a plausible future electricity supply system from the perspective of the actor.
Technologies *means for achieving these objectives*	The *technical components* which are needed in the future LTS that meet the objectives of the actor.
Orders *a set of social and institutional relationships in which objectives can be met*	The *actors*, *institutions* and linkages between them which are needed in the future LTS that meet the objectives of the actor.

Thus, the three different vision elements, objectives, technologies, and orders contribute in presenting a complete in depth expression of the future LTS that supplies electricity. In this section it is stated that the interpretative flexibility of a vision affects its guiding capacity on the future actions of interdependent actors. A too low interpretative flexibility of a vision and a too high interpretative flexibility of a vision reduces the visions' capacity to guide the future actions of actors. In order to get insights in the interpretative flexibility of a future vision this research also observes the barriers and drivers which are made explicit in the visions. Drivers are factors that trigger a transition. Barriers are system elements which need to be adapted or substituted in order to enable a transition. The drivers and barriers and their function in system transitions are more deeply discussed in section 2.3.

2.3 System transitions, drivers and barriers

A system transition does not occur spontaneously but is usually triggered by internal or external drivers. Internal drivers have to do with the expansion in scope and size of the LTS (Hughes, 1987). An LTS can be seen as an organism which expands in size and scope over time. When this expansion is hindered by one or more system elements, innovative activities focus on substituting or adapting these elements. If within the LTS no solutions can be found, then the LTS is triggered to change radically in order to expand. In this situation, the need to expand is a driver for transition. DC was unable to transmit over long distances therefore it hindered expansion. AC was able of transmitting over long distances. Consequently, DC was substituted by AC.

External drivers have to do with technological developments in related fields of knowledge and changes of preferences in the public and political domain (Markard & Truffer, 2006). The R&D on gas turbine technology in aeronautics, for example, gave an impulse to the development of CCGT (combined cycle gas turbines) power plants (Islas, 1997). Regarding changes in preferences, an example is the change of political interest towards the importance of security of supply. This led to the deployment of nuclear power plants, because they provided a better security of supply than other fossil fuel based plants (Markard & Truffer, 2006).

An actor makes these drivers explicit by explicitly mentioning the specific factor or factors that drives the transition of the LTS towards his preferred direction. Internal drivers, which are on growth of the LTS, overlap with the orders and technologies part of a vision. External drivers, which are on developments in related fields of knowledge and changes in preferences in the political and public domain, overlap with the objectives part of a vision.

Drivers are not the only factor influencing a transition. There are also barriers which influence a transition. Barriers are institutions, technical components, or actors which need to be adapted or substituted in order to successfully complete a transition.

Institutions are the earlier mentioned elements such as sector specific regulations, and technical norms, which are part of the current LTS. These institutions can have characteristics which make them incompatible with elements of the future LTS. When these institutions need to be substituted or adapted to enable a transition they are indicated as barrier. In emerging sectors existing institutions can play a significant role in hampering the transition (Aldrich & Fiol, 1994; Sine et al., 2005; Suchman, 1995). To illustrate, if for the deployment of small scale generators the costless connection scheme for large scale generators needs to be extended with a costless connection for small scale generators, then this connection scheme is a barrier for transition.

Technical components are the earlier mentioned elements such as generators, transformers, power lines, switches as well as control and metering devices, which are part of the current LTS. These components can have characteristics which make them incompatible with elements of the future LTS. When these existing components need to be substituted or adapted to enable a transition they are indicated as barrier. To illustrate, if for the deployment of wind turbines the existing grid needs to be substituted for a grid with a higher capacity in order to accommodate the peaks in capacity which are caused by high wind speeds, then this grid is a barrier for transition.

Actors are the earlier mentioned elements such as energy service companies (ESCO), distribution system operators (DSO), the transmission system operator (TSO), and equipment manufacturers, which are part of the current LTS. In emerging sectors actors can play a significant role in hampering the transition (Sine et al., 2005; Suchman, 1995). These actors can have characteristics which make them incompatible with elements of the future LTS. When these actors need to be substituted or need to changes its behaviour to enable a transition they are indicated as barrier. To illustrate, when a system operator always connect its consumers for a peak capacity of 14 Ampere, but the new LTS consists of consumer appliances with a peak demand of 17 Ampere, the routines of this system operator has to be substituted to connect customers using a connection with a higher capacity, then the current routine is a barrier for transition.

An actor makes these barriers explicit by explicitly mentioning the specific system element or system elements that need to be substituted or adapted in order to enable a transition of the LTS towards his preferred direction.

The different elements of the drivers and barriers and their application on the LTS are summarized in Table 2.

Table 2: Barriers and drivers described in LTS terminology

	Element	In LTS terminology
Perceived barriers *System elements which need to be adapted or substituted in order to enable a transition*	***Institutions*** *regulative and normative elements that, together with associated activities and resources, provide stability and meaning to social life*	Regulative institutions, such as sector specific regulations and normative institutions such as technical norms that hamper the transition towards an LTS of the actors' preference.
	Technical components	Technical components, such as generators, transformers, power lines, switch as well as control and metering devices that hamper the transition towards an LTS of the actors' preference.
	Actors	Actors, such as system operators and power producers and their perceptions and routines that hamper the transition towards an LTS of the actors' preference.
Perceived drivers *Factors that trigger a transition*	***Internal*** *LTS expansion in scope and size*	Internal drivers, such as the need for efficient long distance transmission. These drivers overlap with the technologies and orders part of a vision
	External *technological developments in related fields of knowledge and changes of preferences in the public and political domain*	External drivers, such as the developments on gas turbines in aeronautics that boosted CCGT, and the change of political preferences towards security of supply. These drivers overlap with the objectives part of a vision.

2.4 Conceptual model

The theoretical framework is summarized in Figure 2. If the vision expressed by a respondent includes actors, institutions, and technological components that are also included in other visions, then the guiding capacity of such a vision increases, i.e, the vision is shared. We expect that visions that are very specific have a low interpretative flexibility and therefore a low guiding capacity. On the other hand, if a vision is very general, its interpretative flexibility is very high, and its guiding capacity also decreases. If the different actors perceive the same drivers and/or barriers, then the guiding capacity of their visions increases, because the likelihood that their visions become shared increases. Alignment in drivers aligns the objectives of the respondents. A vision that includes the elements of both actors would result in a shared vision. Alignment in solely barriers means that actors perceive the same barrier, but envision different elements to substitute or adapt the hampering element. A vision that includes the substituting elements of both visions would make the vision shared.

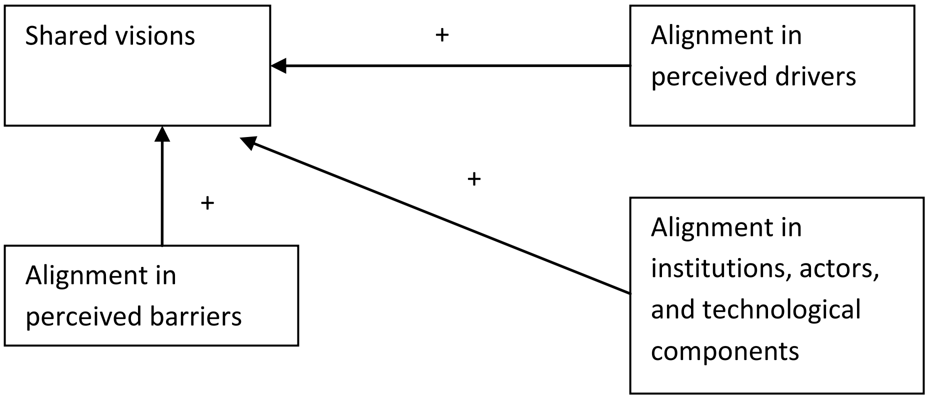

Figure 2: Conceptual model

3 Methodology and data

In order to enable a clear comparison, the future visions, the perceived barriers, and the perceived drivers were collected from actors who are active in the Netherlands, thereby keeping the institutional context for all the future visions the same. These actors were selected via a snowball method. The snowball started at specialists on RDG at the Netherlands Environmental Assessment Agency and attendees of a seminar on RDG. An overview of the respondents is presented in Table 3.

Table 3: List of respondents included in the research

Actor	number	Function respondents
Energy service company (ESCO)	5	manager sustainability, manager external affairs, innovation officer, manager metering, CEO
Local energy organisation (LEO)	3	director, co-founder, board member
Distribution system operator (DSO)	3	innovation manager, head of innovation, director asset management
Ministry of economic affairs (Gov)	1	senior policy advisor
Transmission system operator (TSO)	1	business planner
Expert (Exp)	4	senior consultant, director, chairman, project leader
Other actors (Oth)	3	founder (manufacturer of balancing technology), project leader (incubator), director strategy (lobby organisation)
Total	**20**	

The data on future visions, perceived barriers, and perceived drivers was collected by conducting semi-structured qualitative interviews with the respondents presented in In order to enable a clear comparison, the future visions, the perceived barriers, and the perceived drivers were collected from actors who are active in the Netherlands, thereby keeping the institutional context for all the future visions the same. These actors were selected via a snowball method. The snowball started at specialists on RDG at the Netherlands Environmental Assessment Agency and attendees of a seminar on RDG. An overview of the respondents is presented in Table 3.

Table 3 (Baarda et al., 2005). This data was collected during interviews of 1 hour. During a semi structured interview, the interviewer asked the respondent to describe his/her vision of a future electricity supply system with a significant contribution of RDG. When the respondent did not address specific themes himself/herself, then the interviewer introduced new themes using a topic list, which is included in the last column of Table 4 (Baarda et al., 2005). To illustrate, when a respondent solely discussed production technologies, then the interviewer asked whether there were also technologies in the domain of metering that were relevant to mention. As discussed in the theory, the objectives and external drivers overlap. And the internal drivers overlap with the orders, and technologies part of the vision. The drivers were therefore not specifically introduced. The data was complemented with publicly available documents from the actors on electricity supply systems with RDG, such as vision documents and company websites.
After collecting the data, the transcripts and documents were labelled according the second column of Table 4. A fragment was labelled as indicating an *objective* when it included a full or partial expression of a future LTS. A fragment was labelled as describing a *technical component* when it included a technical component that was included in the vision of the actor. This was also done when the fragment concerned an *actor or an institution*. A fragment was labelled as a *barrier* when the fragment included a description of a technological component, actor, or institution that in the view of the respondent hampered the transition towards the LTS that was included in his/her vision. The average number of labels per interview was 25. Per fragment more labels were possible.

Table 4: Operationalisation of theory (continues on next page)

Concept	Dimension	Indicator
Future visions	Objectives / internal drivers	Expression of the future LTS
	Technological components / external drivers	Components for: production, transport, application, metering
	Actors / external drivers	Commercial actors, governmental actors, consumers
	Institutions / external drivers	Regulations, norms
Perceived barriers	Technological components	Similar as future visions
	Actors	Similar as future visions
	Institutions	Similar as future visions
Perceived drivers	Internal	Expansion in scope or size
	External	Changes in political preferences, developments in related fields of knowledge

A barrier, driver or LTS description (in terms of actors, institutions and technical components) can then be described as a set of such labels. When two of such sets are identical, they describe shared visions (case 1). Two visions are also considered shared in this research when the set of labels associated with the first vision is a subset of the set of labels associated with the other vision (case 2). The smaller set of labels then is the vision with the higher interpretative flexibility.

When visions are not completely shared (i.e., as in the latter of the two cases described above) it is important to also consider the content of the labels. Within each category of labels some labels can coexist within a certain category whereas others cannot. To illustrate, a driver for transition could be a more sustainable electricity supply system. Another driver for transition could be the reduction of green house gas emissions. In this case the drivers are different. Despite of this difference, the drivers can coexist, because a more sustainable electricity supply system also implicates a reduction of green house gas emissions. A second illustration, the label fossil fuel fired power plants can coexist with the label gas fired power plants, because fossil fuel fired power plants is a higher level of aggregation than gas fired power plants.

When labels are exclusive visions, they are only aligned with visions that contain the exact same labels, or no specification on that category of labels. The number of sets of labels that contain such an exclusive label is a measure of alignment. For non-exclusive labels the number of label sets that contain that label is a measure of the alignment of that barrier, element or vision. The extent to which two label sets indicate shared visions can then be measured by calculating the occurrence of the elements of a label set in other label sets. Per visions this element counts are then summed giving an indication of sharedness.

Next to an analysis on individual vision level, the visions were also compared on cluster level. In order to form these clusters, the visions were clustered based on similarities in the objective part of the visions within a specific category. To illustrate, if several respondents envisioned an LTS where the balance between demand and supply was coordinated via top down control, then these visions were clustered. While if several other respondents envisioned an LTS were the balance between demand and supply was balanced via bottom up control, then these were clustered to form a different group. In the same routine as for the visions, the alignment between the groups was assessed to give an indication on the sharedness between the groups.

4 Results

The 20 visions on a future LTS with a significant contribution of RDG and the related barriers are presented in this chapter.

The objectives of the visions all focus on an LTS in which demand changes from rigid to manageable. In other words, in the current LTS fluctuations in production and in demand are balanced by dispatchable generators and power plants with a high ramping speed, while in the new system these fluctuations can also be balanced by applications with a buffer capacity.

The main differences in objectives were found in the inclusion and exclusion of storage, and the control of the system. In these visions 36 different technologies were mentioned, ranging from currently available to technologies that are not (yet) commercially available. With respect to actors and institutions, 7 actors were mentioned and 4 institutions. Concerning barriers 35 barriers were mentioned. 15 of these barriers were in the actor domain, 7 in the institutional domain, and 4 in the technological domain.

The first section of this chapter gives a short overview of the objectives of the visions per actor group. The second section discusses the envisioned LTS's by presenting the technologies, actors, and institutions in each vision. The third section of this chapter compares the findings on alignment and interpretative flexibility for the groups that were indicated based on the similarities in the objectives part of the visions. The final section summarizes the results on alignment and interpretative flexibility.

4.1 Objectives

The future visions consisted of a description of a future electricity supply system with a significant contribution of RDG. In these descriptions the technologies, actors, and institutions were described. The main issues that were discussed in the visions were on keeping the system on balance in an efficient manner and enhancing system robustness. The main differences between the visions were found on the deployment of storage in the LTS and on controlling mechanisms for balancing the system and preventing grid congestion. Other differences were found on economic, environmental, and security issues.

The vision of the DSO's consisted of an electricity supply system with a better operational efficiency of the distribution network than in the current situation. The DSO's also mentioned storage as technology to prevent grid congestion and also to keep the system on balance. Differences were found with respect to the control of production. Two DSO's included both top down and bottom up control (vision 1&3), and one DSO solely included top down control in its vision (2). Another difference was on the operational efficiency of power plants. In one vision this efficiency that had to be increased (1), the others did not discuss this issue. One vision also emphasised that it was important to exploit the available potential for RDG (2). This same vision also emphasized the improvement of the sustainability of the electricity supply system (2). And, together with vison 3, the related reduction on green house gasses was emphasized. Vision 2 also emphasized the need to decrease the fossil fuel dependency of the system.

The five ESCO's did have no further similarities in their visions on the LTS. Four of the ESCO's did mentioned an LTS with top down control for production (4, 5, 6, 7), while the fifth mentioned a bottom up LTS (8). These same four also emphasized that components in the LTS needed to be profitable. Also four ESCO's mentioned storage as option to balance the system (4, 6, 7, 8). Three ESCO's mentioned that their envisioned LTS would increase the economic efficiency of the system as a whole (4, 7, 8). Two others agreed with the DSO's on the operational efficiency of the distribution network that needed to be increased (4, 5). Also two ESCO's agreed with the DSO's on contributing to the exploitation of the available potential with their envisioned LTS (4, 7). There was solely one ESCO that included that their envisioned LTS would contribute to the affordability of electricity (4). Two ESCO's also emphasized that their LTS would contribute in increasing the economic efficiency for the end-user (5, 8). One ESCO emphasized the importance of reducing GHG emissions (4). One other ESCO emphasized the importance of decreasing the fossil fuel dependency (6).

Also in the visions of the four experts no similarities could be found. Two experts included storage in their envisioned LTS (9, 10). Regarding the control, three experts had with their LTS the focus on bottom up control (9, 10, 11), and one mentioned in his vision both bottom up and top down control (12). Also two experts mentioned that their envisioned LTS would contribute to the increase of the operational efficiency of the distribution network (9, 12). One of them did also include the better efficiency of power plants, and the better efficiency for the system as a whole as an objective (9). The other did also include the enhancement of the affordability, and the improvement of the system robustness (12). Three experts mentioned the importance of increasing the economic efficiency for the end-user (9, 11, 12). Two emphasized the need to improve the sustainability of the electricity supply system (10, 12). One emphasized that his envisioned LTS would contribute to the decrease in fossil fuel dependency (11).

The fifth actor, the three LEO's, also didn't share their visions. Only one of them included storage (13). Regarding control, only one LEO envisioned an LTS with a top down control (13). The other did not specify the control. Two of the LEO's envisioned an LTS where components are deployed to make profit (14, 15), and one of them also included that his envisioned LTS contributes in increasing the efficiency of the distribution network (14). Two of the LEO's mentioned the importance of stimulating the local economy (13, 14). This last one was not mentioned at the other actors. An explanation could be that only the activities of a LEO can stimulate the local economy, because a LEO uses local investors to invest in the generators that are deployed locally.

The sixth actor, the Government, did not explicitly included storage in his envisioned LTS. Regarding control he also did not make an explicit inclusion. Though, his envisioned LTS did include affordable electricity, and high system robustness. And the government also emphasized the importance of improving the sustainability of the electricity supply system.

The second solely actor, the TSO, included storage in his vision. Regarding control this actor focused on top down control. Furthermore, the TSO envisioned a robust LTS. The TSO also stressed the importance of reducing the GHG-emissions.

The last group of actors, which contains of a lobby organisation (18), an incubator (19), and a manufacturer of balancing technologies (20), differed in their envisioned contribution of storage. Only two of them included storage in their visions (18, 19). On control one actor envisioned a bottom up system (20), and another did mention both top down and bottom up (19). The third did not specify control (18) Two actors envisioned an LTS that increases the operational efficiency of the distribution network, and also generates profits on the deployed assets (19, 20). These same two actors also stressed the importance of improving the economic efficiency for the end-user (19, 20). One actor emphasized the importance of improving the sustainability of the electricity supply system (18).

In summary, visions share the objective of a transition to a system with manageable demand. Objectives differ with respect to whether the future system is controlled in a top-down or bottom up manner. Furthermore, actors belonging to the same group do not always share a vision, for system control this is true for all actor types. This could mean that the differences in visions are not solely actor related. This could also mean that the resources and/or interests of the different respondents within the actor differ significantly.

4.2 Technologies, actors, and institutions

The actors, institutions and technologies[1] that were described as part of the 20 visions are presented in Table 5, where a '1' indicates that the technology is included in a particular vision, the "Total" column indicates the level of alignment of an element with the different visions, and the bottom row on the bottom indicates the specificity of a vision.

[1] Consult (Faber & Ros, 2009) for more details on the technologies

Table 5: envisioned actors, institutions, and technologies (table continues on next 2 pages).

	DSO			ESCO					Exp				LEO			Gov	TSO	Oth			Total
Vision	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
Actors																					
current producers	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**19**
ESCO's	1		1	1	1	1	1	1	1	1		1	1	1	1		1	1			**15**
passive co-producers	1	1		1	1	1	1			1		1	1				1	1	1		**12**
active co-producers	1		1	1	1			1	1		1	1							1	1	**10**
LEO's	1				1							1	1	1	1			1		1	**8**
commercial parties	1				1				1	1		1								1	**6**
housing corporations																		1		1	**2**
Institutions																					
flexible capacity tariff	1	1	1		1			1	1		1	1				1			1	1	**11**
Central dispatching	1			1	1	1	1					1	1				1		1		**9**
local balancing markets	1							1	1	1		1							1		**6**
virtual trading platforms	1				1						1							1	1	1	**6**
flexible electricity tariffs			1							1		1		1	1						**5**
Production technologies																					
solar-pv	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**20**
chp	1	1	1	1	1		1	1	1		1	1				1	1	1	1		**14**
wind turbine		1	1			1					1	1	1	1		1	1	1		1	**11**
fossil fired power plant							1			1		1	1	1		1	1			1	**8**
biomass digestion						1							1	1				1			**4**
solar power plant (EU)						1										1	1	1			**4**
wind turbine (north EU)						1										1	1	1			**4**
gas fired power plant		1		1									1			1					**4**
CCS		1		1		1											1				**4**
Nuclear power		1				1										1					**3**
Geothermal													1					1			**2**
tide													1					1			**2**
fuel cell									1								1				**2**

	DSO			ESCO					Exp				LEO			Gov	TSO	Oth			Total
Vision	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
coal gasification				1													1				**2**
coal fired power plant		1				1															**2**
biomass gasification													1								**1**
Balancing technologies																					
heat pump	1	1	1	1	1		1	1	1			1	1	1		1	1		1	1	**15**
electrical vehicle	1	1	1	1	1			1	1	1		1	1		1	1		1	1	1	**15**
washing machine	1		1	1				1		1		1									**6**
freezer			1			1		1	1		1						1				**6**
fridge								1									1	1		1	**4**
dishwasher	1							1										1			**3**
Electric boiler												1								1	**2**
cold store			1																		**1**
air-conditioning																	1				**1**
Storage technologies																					
hydro power	1	1	1	1		1		1	1								1				**8**
stationary battery	1								1	1							1	1			**5**
compressed air						1		1		1							1		1		**5**
hydrogen						1	1						1				1				**4**
fly wheel	1																1				**2**
capacitor						1															**1**
metering & control technologies																					
smart meter	1	1		1	1			1		1		1	1	1		1	1		1		**12**
software agent	1							1	1		1				1	1				1	**7**
Inter connector							1	1		1		1				1	1				**6**
IT							1							1			1				**3**
sinus filter										1											**1**
Total	**20**	**14**	**13**	**14**	**13**	**16**	**10**	**18**	**15**	**15**	**9**	**19**	**16**	**11**	**7**	**15**	**24**	**18**	**12**	**15**	

For the actors, institutions, and technologies first the elements and its overall alignment are discussed, then the alignment within the actors is discussed. Then the interpretative flexibility of the visions is discussed.

4.2.1 Actors

First when we consider actors we notice that the current electricity producers are still considered to be of importance in a future system with a large share of RDG (mentioned in 19 visions). This means that the visions have a high level of alignment on this actor. The same is also true for the ESCO's. This actor was mentioned in 15 visions. The other actors, passive co-producers (12), active co-producers (10), LEO's (8), and commercial parties (8), and housing corporations (2) had a lower alignment.

Between the actor domains also differences were found in alignment. Within the ESCO domain there was a relative alignment on passive co-producers (4 out of 5), while this was lower for other actors. This could indicate, that it is in the interest of the ESCO's to have a system with passive co-producers instead of active co-producers, which is likely because in this way the ESCO could keep control of the production. Within the LEO domain there was a relative alignment on LEO's as part of the future system (3 out of 3), while this was lower at other actors. It seems that other respondents do not see the advantage of this actor in the future system. An explanation could be that the LEO does not play a significant role in the current system, and is therefore not mentioned by the current actors. Moreover, more different actors means less control for the current actors. The LEO itself has an interest to play a role in the future system, and therefore it is likely that the LEO includes himself in the future system. Within the domain of other actors, there is a high alignment on housing corporations (2/3). These corporations are solely mentioned in this domain. An explanation could be similar to the explanation on the case of the LEO, these players want to play a role in the new system and therefore use opportunities in unexploited areas.

To sum up for the actor domain, the overall alignment is high on current producers and ESCO's. Within the actor domains the alignment is high for passive co-producers in the ESCO domain, for LEO's in the LEO-domain, and for housing corporations in the other domain.

4.2.2 Institutions

Regarding the institutions all the institutions had a relative low alignment. Flexible capacity tariff was mentioned in 11 visions. A flexible capacity tariff can be deployed to prevent net congestion via real time pricing based on the load factor. An explanation could be that the respondents that didn't include the tariff perceived a barrier that was in their perception impossible to overcome. Another explanation could be that they perceived the current manner of preventing net congestion, namely increase the net capacity, as a valid institution, and therefore did not include this institution. The second, central dispatching (9), enables third parties to schedule and dispatch generators and/or applications from a distance. The third, local balancing markets (6), work according a similar principle as the APX (Amsterdam Power Exchange) only on a local scale; virtual trading platforms (6), which is a platform that enables balancing via peer-to-peer trade instead of trading via spot prices, and flexible electricity tariffs, which are electricity tariffs that are based on the real time price instead of the hedged tariffs of the current system. These latter three institutions are all institutions to balance supply and demand, in other words competing institutions. A vision should therefore include all three institutions to increase its guiding capacity.

Between the actor domains also differences were found in alignment. The LEO's and the TSO do not include a flexible capacity tariff in their visions, while the institution is significantly mentioned at other actors. An explanation for the LEO's could be that net congestion is not an issue which they perceive as important, due to their relative low contribution in production compared to the current producers. An explanation for the TSO could be that they perceive a flexible tariff as too risky for preventing congestion. Moreover, they emphasized in the objectives the importance of a robust system. Secondly, only the experts significantly mention local balancing markets in their vision (3/4). Moreover, virtual trading platforms are only emphasized by the respondents in the last column of the table (3/3), and are almost not present at other actors. Thirdly, the institution central dispatching had relative high counts at the ESCO's compared to the other actors (4/5). These differences could be explained by the different interests of the actors. The ESCO's want to stay in control, the experts are looking for workable solutions in the interest of all actors to balance the new system, and the actors in the last column try to enter the market with new concepts.

To sum up for the institutional domain, the overall alignment was relative low. This is explained by the fact that the different institutions addressed the same issue, namely balancing the system. Within the actor domains, the experts had a high alignment on local balancing markets, central dispatching had a high alignment in the domain of the ESCO, and the virtual trading platforms had a high alignment by the actors in the last column.

4.2.3 Technologies

Concerning the production technologies solar-pv had a relative high alignment (20), followed by chp (14), wind turbines (11). This could be explained by the fact that these are relatively common technologies with proven results. The other production technologies had a lower alignment: fossil fired power plants (8), biomass digestion (4), solar power plant (EU) (4), wind turbine (north EU) (4), gas fired power plant (4), CCS (4), Nuclear power (3), Geothermal (2), tide (2), fuel cell (2), coal gasification (2), coal fired power plant (2), biomass gasification (1). The low count for the large scale power plants can be explained by the fact that some respondents used the general description, namely fossil fired power plants, while others used a more specific description. Notable is the number of envisioned technologies that do not play a significant role in the current system. Fuel cells, tide, and CCS for example are uncommon technologies. Biomass digestion, coal gasification, CCS, and biomass gasification are not production technologies itself. These latter technologies have a complementary role in the production process. Worth wile mentioning is that the technologies included both renewable and fossil technologies. Moreover, the visions included both central as distributed generators. Between the actor domains no specific differences were noticed.

Regarding balancing technologies the heat pump (15) and electric vehicle (15) had a relative high alignment. The alignment of the other technologies was relative low: washing machine (6), freezer (6), fridge (4), dishwasher (3), electric boiler (2), cold store (1), and air-conditioning (1). Interesting is, that even if the majority of these technologies are common technologies; none of them plays a significant role in actively balancing the system. Also remarkable is the inclusion of electric vehicles and heat pumps. These technologies compete with existing alternatives, electric vehicles with fuel based vehicles, and heat pumps with gas based heating. The technologies differ in type of buffer used, these are buffers in: chemical, thermal, and time. Between the actor domains no specific differences were noticed.

Considering storage technologies hydro power (8), the stationary battery (5), and compressed air (5) had a relative high alignment. Hydro power could be explained by its common use in other countries, and compressed air by its low conversion loss. Other technologies were: hydrogen (4), fly wheels (2), and capacitors (1). The third technological category, storage technologies, is like balancing technologies also interesting as a total, because storage does not play a significant role in the current LTS. The technologies differ in principles used, some focus on chemical storage, while others focus on storage based on physical principles. Storage is remarkable as a total category, due to the complete absence of storage technologies in 7 visions. Storage was especially absent at the LEO's (1/18) and the experts (4/24).

Regarding metering & control technologies the smart meter had a relative high alignment (12), followed by the software agent (7), interconnector (6), and IT (3). Software agents represented consuming or producing technologies and were able to act in the interests of these technologies. Smart meters enabled a digital registration of production and consumption. Moreover the meters could be monitored on a distance. Sinus filters reduced unwanted frequencies from the produced current. On metering & control an interesting aspect is that three visions (3, 5, 18) did not include any metering & control technologies. Four visions did include relative many technologies (8, 10, 16, and 17).

4.2.4 Interpretative flexibility

Regarding the interpretative flexibility the most specific vision is vision nr 17, the TSO and the vision contains 24 out of 47 elements, followed by nr 1 (DSO, 20 elements), nr 12 (Expert, 19), nr 18, (lobby organisation, 18), nr 8, (ESCO, 18), nr 6, (ESCO, 15), nr 16, (Government, 15), nr 9, (Expert, 15), nr 20, (Manufacture of balancing equipment, 15), nr 10, (Expert, 15), nr 4, (ESCO, 14), nr 2, (DSO, 14), nr 3, (DSO, 13), nr 5, (ESCO, 13), nr 19, (Incubator, 12), nr 14, (LEO, 11), nr 7, (ESCO, 10), nr 11, (Expert, 9), followed by the most general vision, nr 15, (LEO, 7). No specific patterns on actor type and level of interpretative flexibility could be indicated. Remarkable, though, is that the vision of the government is relative specific according the counts, while you expect that this vision should be the most general one in order to guide the other visions. An explanation for this could be that the government leaves the system development to the market and solely protects the public interest by the development of policy.

4.2.5 Overall alignment

Regarding the LTS elements, three labels were indicated as labels that can coexist with other labels. These were in the actor domain the current producers, and commercial parties. And in the production technology domain the fossil fuel fired power plants.

Regarding the overall alignment (on label matching with inclusion of the coexisting characteristics of several labels) none of the visions is exactly aligned with another vision. For partial alignment. The most general vision (nr 15) had no alignment with other visions. In other words, the small set of LTS elements of vision 15 is not aligned with other larger sets of LTS elements. This is also true for the second general vision, nr 11. The third general vision, nr 7, though, was aligned with vision nr 17. Vision 17 differed only on the technology dimension. The elements on which this vision differed were in the production domain the inclusion of: wind turbines, solar power plants (EU), wind turbines (north EU, CCS, fuel cells, and coal gasification. In the domain of balancing applications these were: freezers, fridges, and air-conditioning. In the storage domain, these were: hydro power, stationary batteries, compressed air, and fly wheels. In the domain of metering and control this was solely the inclusion of smart meters. Remarkable is that the two visions were different actors, this implicates that vision nr 7 also integrates interests and resources of other actors. The fourth most general vision (nr 3), again, was not aligned with other visions.

To summarize, the alignment between the visions is relatively low. This is mainly caused by system elements related to balancing the system, which differ between the visions, as well as the inclusion of storage which also differs between the visions. Regarding the interpretative flexibility of the visions, visions nr 15, 11, and 7 have the highest interpretative flexibility. Solely vision nr 7 is aligned with one other vision (nr 17), which is remarkably the most specific vision. Vision 7 has therefore the highest potential to become a guiding vision.

4.3 Barriers

This section relates the differences in visions to the differences in perceived barriers. The barriers are presented in Table A. After discussing the alignment within the barriers and the visions, the barriers are related to the visions.

Table A: Barriers that hamper a transition

	DSO			ESCO					Exp				LEO			Gov	TSO	Oth			Total
Vision	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Actors as barriers																					
Sector players have interest in central and fossil based technologies		1		1	1	1			1	1	1	1				1			1		10
low awareness of scarcity and environmental effects							1		1				1		1	1	1	1	1	1	9
sector routines focussed on central production				1	1		1	1	1			1	1			1				1	9
no consensus on standards for smart technologies			1		1				1	1		1	1							1	7
uncertainty on economic feasibility of storage			1	1		1	1					1		1		1					7
uncertainty on influence of end-user behaviour			1						1	1		1	1			1					6
uncertainty on market readiness of technologies								1			1	1		1	1			1			6
interdependent players do not cooperate sufficient					1		1					1				1		1			5
no consensus on role DSO	1		1						1			1				1					5
uncertainty on public acceptation				1		1	1			1						1					5
end-user routines adapted to always electricity	1			1			1		1												4
governmental policy is inconsistent		1				1	1							1							4
commercial parties focus on short term profit		1									1							1			3
single player limited influence, only on a small part of the system				1			1									1					3
sector players work with outdated information													1					1			2
Institutional barriers																					
R standard profile small consumers				1				1	1			1				1	1		1		7
R DSO not allowed to differentiate in capacity			1					1	1			1				1				1	6
R free ETS for existing power plants						1												1	1		3
R DSO not allowed to supply electricity	1								1			1									3
R energy tax on transported electricity	1														1	1					3
R costless connection for large scale generation																		1	1		2
R DSO tariff based on operational efficiency			1									1									2
R labour regulation							1					1									2
R high bank guarantees for grid ownership needed																				1	1
N Generators are assessed on their kWh-price	1			1		1	1				1	1		1	1	1			1		10
N installation sector has a low capacity				1						1	1				1				1		5
N Storage is assessed on conversion loss						1	1												1		3
N assessment business case for storage on actor level	1								1												2
N Generators are assessed on their GHG-emissions						1											1				2
N Generators are assessed on their areal space they claim														1		1					2
N Generators are assessed on their payback time												1							1		2
Technological components as barriers																					
grid and metering technologies adapted to centralized production	1	1		1			1			1	1	1				1				1	9
better isolation in buildings						1	1					1					1				4
limited net capacity	1			1														1			3
secure network													1	1							2
Total	8	4	6	11	4	9	13	4	11	6	6	17	6	6	5	15	4	8	9	6	

R = regulative institution, N = normative institution

The barriers in Table A are categorized according the theoretical concepts.

In the actor domain the alignment was relative high on the barrier that sector players have interest in central and fossil based technologies (10). With this barrier the respondents meant that a player, such as an ESCO has a significant interest in generating electricity with his large scale power plant. The second barrier was the low awareness on scarcity and environmental effects (9). With this barrier the respondents meant that that the end-users are not aware of their energy consumption as well as the effect of their energy consumption on the environment. The third barrier was that sector routines are focused on central production (9). With this barrier was meant that the behavior of the actors were all focused on a central system. To illustrate, the DSO connects its end-users based on their consumption, and does not take into account the potential future production of electricity on that location. The fourth barrier was that there is no consensus on standards for smart technologies (7). With this barrier was meant that there are no standards for concepts such as communication protocols to enable communicate between two different technologies. The fifth barrier was that there is uncertainty on the economic feasibility of storage among the actors (7). With this barrier was meant that some actors perceive that storage is too expensive compared to other balancing methods. The sixth barrier was the uncertainty on influence on end-user behaviour (7). With this barrier was meant that it is not sure whether end-users will change their behaviour when a price incentive is given to do so. The seventh barrier was the uncertainty on market readiness of technologies (6). With this barrier was meant that ESCO's only invest in a technology when it has proven results that fit their expectations. The eighth barrier was the fact that interdependent players do not cooperate sufficient (5). With this barrier was meant that interdependent players all act in solely in their own interest and do not cooperate in order to fit the interests of more actors. The ninth barrier was that there was no consensus on the role of the DSO (5). With this barrier was meant that the DSO can keep playing his current role, but it is also possible that the DSO for example could start facilitating the local balancing market by providing a platform and implementing flexible capacity tariffs. The tenth barrier was that there was uncertainty on public acceptation of distributed generators (5). With this barrier was meant that generators, such as wind turbines, could encounter opposition from the public. This opposition is related to issues such as safety and aesthetical interests. The eleventh barrier was that the end-user routines are adapted to always electricity (4). With this barrier was meant that end-users want to use appliances whenever they perceive this as necessary. The twelfth barrier was that governmental policy is inconsistent (4). With this barrier was meant that the government fluctuates with its policy towards renewable production. The thirteenth barrier was that commercial parties focus on short term profit (3). With this barrier was meant that investments of commercial parties, such as ESCO's are focused on technologies with a relative short payback time. The fourteenth barrier was that a single player has limited influence, only on a small part of the system (3). With this barrier was meant that a single player himself only can substitute or change several elements of the system. So even if that player wanted to change the whole system, it was not possible. The fifteenth barrier was that sector player's work with outdated information (3). With this barrier was meant that sector players based their investment decisions on outdated information.

In the domain of regulative institutions as barriers, the alignment was relative high on the standard profile for small consumers. With this standard profile is meant that small consumers don't pay the real-time price for their electricity but that this price is hedged via tariffs based on a standard user profile (7). The second institution was that the DSO is not allowed to differentiate in capacity (6).

With this institution was meant that the DSO connects every end-user according a standard capacity. The third institution was that existing power plants received ETS (Emissions trading schemes) (3). With this institution is meant that only new power plants had to pay a fee for their CO_2-emmissions. The fourth institution was that the DSO was not allowed to supply electricity (3). With this institution is meant that that DSO's, due to their monopolistic character are not allowed to supply electricity. The fifth was the energy tax on transported electricity (3). With this barrier is meant, that for electricity that is transported over a grid that is owned by a DSO or TSO tax has to be paid. The sixth was the costless connection scheme for large scale generation (2). With this barrier is meant that large power plants and other central generators are connected without paying the costs for it. The costs for connecting small scale generators have to be paid for by the owner of the generator. The seventh institution was that the DSO tariff is based on operational efficiency (2). With this barrier was meant that DSO's are punished with a lower tariff when their efficiency is benchmarked lower than other DSO's. The eighth institution is the labour regulation. With this barrier was meant that labour regulation restricts the capabilities of the installer, such as the maximum weight that they are allowed to lift. The ninth institution was the high bank guarantees that are needed for grid ownership (1).

In the domain of normative institutions as barriers, the alignment was relative high on the institution that generators are assessed on their kWh-price (10). With this barrier is meant that a potential investor in generators uses the kWh-price as an important indicator for making his investment decision. The second institution was that the installation sector has a low capacity (5). With this barrier is meant that the installation sector, especially the grid related, is scaled to maintain the current system and not to implement radical changes on a large scale. The fourth institution is that storage is assessed on conversion loss (3). With this barrier is meant that investors use the conversion loss of storage to decide whether they will invest in a certain technology or not. The fourth is the assessment of the business case for storage on actor level. With this barrier is meant that actors do not combine the different interests of the interdependent actors in assessing whether the inclusion of storage leads to a successful business case. The fifth institution is that generators are assessed on their GHG-emissions. With this barrier is meant that investors use the GHS- emissions of a generator in assessing their investment decision. The sixth barrier is that generators are assessed on their areal space they claim (2). With this barrier is meant that due to land scarcity investors include in their investment decision the areal space needed to deploy the generator. The seventh institution is that generators are assessed on their payback time (2). With this barrier is meant that investors include the payback time of a generator in their investment decision.

In the domain of technological components as barriers, the alignment was relative high on the fact that the grid and metering technologies are adapted to centralized production (9). With this barrier was meant that technologies, such as switches, grid, electric transformers, and meters are adapted for a system with one directional current. The second barrier was that the isolation in buildings is improving (4). With this barrier was meant that the heat demand in houses decreases due to better isolation. The third barrier was that the net had limited capacity (3). With this barrier was meant that the net capacity was adapted to current applications and generators and not to radical changes in one or both of those. The fourth barrier was that the electricity supply system had a secure network (2). With this barrier was meant that the yearly operating time of the network was significant high.

To summarize, in the actor domain barriers with a relative high alignment were: the interest in central and fossil based technologies by the sector players, the low awareness of scarcity and environmental effects, and the sector routines that were focused on central production. In the domain of regulative institutions the barriers with high alignment were: the standard profile for small consumers, and the DSO that was not all to differentiate in capacity. In the domain of normative institutions the barriers with high alignment were: the fact that generators are assessed on their KWh-price, and that the installation sector has a low capacity. In the domain of technological components the barrier with the relative highest alignment was that the grid and metering technologies were adapted to centralized production.

4.4 Analysis of alignment and interpretative flexibility

As stated in the objectives, the main differences were found on system control and on storage. These two dimensions were used to analyse the alignment between the visions. Regarding control the groups were identified as: group that did mention top down control, group that did mention bottom up control, and group that did mention both top down and bottom up control. In four visions the system control was not made explicit. Regarding storage the groups were identified as: group were storage was mentioned and group were storage was not mentioned.

In this section the alignment between the system elements and barriers is tested along the above described groups. First the alignment is assessed between the three control groups. Then the alignment is assessed between the two storage groups.

Table 6 presents the vision elements, and barriers that are aligned with solely the group top down control.

Table 6: Visions elements, and barriers that are aligned with solely the group top down control (Table continues on next page)

	top down (td)							Total
Vision	**5**	**2**	**4**	**6**	**7**	**13**	**17**	
Production technologies								
biomass digestion				1		1		2
solar power plant (EU)				1			1	2
wind turbine (north EU)				1			1	2
gas fired power plant		1	1			1		3
CCS		1	1	1			1	4
Nuclear power		1		1				2
Geothermal						1		1
tide						1		1
coal gasification			1				1	2
coal fired power plant		1		1				2
biomass gasification						1		1
Balancing technologies								
Airco-conditioning							1	1
Storage technologies								
hydrogen				1	1	1	1	4
capacitor				1				1
metering & control technologies								
IT					1		1	2
Actors as barriers								
governmental policy is inconsistent		1		1	1			3
single player limited influence, only on a small part of the system			1		1			2
sector players work with outdated information						1		1
Institutional barriers								
N Generators are assessed on their GHG-emissions				1			1	2

	top down (td)							Total
Vision	**5**	**2**	**4**	**6**	**7**	**13**	**17**	
Technological components as barriers								
secure network						1		2
Total	**0**	**6**	**5**	**10**	**5**	**8**	**8**	

The group solely top down consists of 7 respondents. Regarding the vision elements that were aligned with solely the top down group (15), the following can be stated. The group did not include any specific actors or institutions. Concerning technologies, the group included 11 specific production technologies: biomass digestion, solar power plants (EU), wind turbines (north EU), gas fired power plants, CCS, nuclear power, geothermal power, tide, coal gasification, coal fired power plants, and biomass gasification. The only specific balancing technology that was mentioned was the air-conditioning. For storage two specific technologies were mentioned: hydrogen and the capacitor. Concerning the technologies for metering & control also one specific technology was mentioned, namely IT. This implicates that the visions in the top down group have a relative wide scope by including production facilities from other countries within the EU. The inclusion of technologies such as CCS and coal gasification implicates that this group emphasizes central production facilities. Regarding the alignment this implicates that the solely top down group deviates in 15 vision elements from the other groups.

These vision elements matched with 5 barriers. The vision elements matched with actors (3), institutions (1), and technological components (1). Regarding the actors the specific barriers were: governmental policy was inconsistent, that a single player had limited influence, and that sector player's worked with outdated information. Concerning the institutions the specific barrier was that generators were assessed on their GHG-emissions. Though, this institution is unlikely to change in the light of the societal importance of GHG emission reduction. This barrier was most of the times mentioned in combination with chp, which emits GHG during electricity production. Concerning the technological components the specific barrier was the secure network. Also this institution is unlikely to change in the light of the importance of a secure electricity grid. An explanation could be that this barrier was included by only one vision, which was the vision had the highest emphasis on RDG technologies, such as tide and geothermal. In this context a more unstable grid connection would increase the need for distributed generators.

The interpretative flexibility for this group was on average 6.

To summarize, the group solely top down consists of seven respondents. Regarding the alignment, the group differs in 15 vision elements, and five barriers from other groups. The average interpretative flexibility of the group is 6.

Table 7 presents the vision elements, and barriers that are aligned with solely the group bottom up control.

Table 7: Vision elements, and barriers that are aligned with solely the group bottom up control

	bottom up (bu)					Total
Vision	**11**	**20**	**8**	**9**	**10**	
Actors						
housing corporations		1				**1**
metering & control technologies						

	bottom up (bu)					Total
Vision	**11**	**20**	**8**	**9**	**10**	
sinus filter					1	**1**
Institutional barriers						
N high bank guarantees for grid ownership		1				**1**
Total	**0**	**2**	**0**	**0**	**1**	

The group solely bottom up consisted of 5 respondents. Regarding the vision elements that were aligned with solely the top down group (2), the following can be stated. The group did not include any specific institutions. Concerning the actors, the group included one actor, namely housing corporations. Concerning technologies, the group did not include specific production technologies, balancing technologies, or storage technologies. Regarding metering & control technologies the group included solely a sinus filter.

Regarding the barriers no barriers were mentioned in the actor domain, and no barriers were mentioned in the domain of technological components. Regarding the institutional domain, one institution was mentioned, namely the high bank guarantees for grid ownership. Though, this barrier was not explicitly mentioned in combination with housing corporations. It could, however, be possible that also for housing corporations that do want to become grid owner this institution is perceived as barrier.

The interpretative flexibility for this group was on average 1.5.

To summarize, the group solely top down consists of five respondents. Regarding the alignment, the group differs in 3 vision elements, and on barrier from other groups. The average interpretative flexibility of the group is 1.5.

Table 8 presents the vision elements, and barriers that were aligned with solely the group that included both top down and bottom up control.

Table 8: Vision elements, and barriers that are aligned with solely td+bu

	td+bu				Total
Vision	**12**	**1**	**3**	**19**	
Balancing technologies					
cold store			1		1
Institutional barriers					
R energy tax on transported electricity		1			1
R costless connection for large scale generation				1	1
R DSO tariff based on operational efficiency	1		1		2
N Generators are assessed on their payback time	1			1	2
Total	2	1	2	2	

The group that included both bottom up and top down control consisted of 4 respondents. Regarding the vision elements that were aligned with solely the top down group (1), the following can be stated. The group did not include any specific actors or institutions. Concerning technologies, the group did not include specific production technologies, or storage technologies. Regarding balancing technologies, the group included solely a cold store.

Regarding the barriers no barriers were mentioned in the actor domain, and no barriers were mentioned in the domain of technological components. Regarding the institutional domain 4 barriers were mentioned. These were the energy tax on transported electricity, the costless connection for large scale generation, the DSO tariff that was based on operational efficiency, and one normative institution, that generators were assessed on their payback time.

The interpretative flexibility for this group was on average 1,75.

To summarize, the group both bottom up and top down consists of five respondents. Regarding the alignment, the group differs in 1 vision element, and on 4 barriers from other groups. The average interpretative flexibility of the group is 1,75.

Table 9 presents the vision elements that were aligned with the group bottom up and the group that included both top down and bottom up control.

Table 9: Vision elements, and barriers that were aligned with the group's bottom up and td+bu

	bottom up (bu)					td+bu				Total
Vision	**11**	**20**	**8**	**9**	**10**	**12**	**1**	**3**	**19**	
institutions										
local balancing markets			1	1	1	1	1		1	6
virtual trading platforms	1	1					1		1	4
flexible electricity tariffs					1	1		1		3
Balancing technologies										
dishwasher			1				1			2
Electric boiler		1				1				2
metering & control technologies										
software agent	1	1	1	1			1			5
Actors as barriers										
uncertainty on market readiness of technologies	1		1			1				3
no consensus on role DSO				1		1	1	1		4
Institutional barriers										
R DSO not allowed to differentiate in capacity		1	1	1		1		1		5
R DSO not allowed to supply electricity				1		1	1			3
N assessment business case for storage on actor level				1			1			2
Total	3	4	5	7	2	7	8	3	2	

The two groups, solely bottom up (5), and both bottom up and top down (4), consisted of 9 respondents. Regarding the vision elements that were aligned with this combined group (5), the following can be stated. The group did not include any specific actors. Concerning institutions (3), local balancing markets, virtual trading platforms, and flexible electricity tariff were included. Remarkable was that in the bottom up cluster the respondents did choose for local balancing markets or for virtual trading platforms. This could implicate that these two institutions of balancing the system could not be deployed together. Concerning technologies (3), the group did not include specific production technologies or storage technologies. Regarding balancing technologies, the group included the dish washer and the electric boiler. Regarding metering and control, the group included the software agents.

Regarding the barriers (5) no barriers were mentioned in the domain of technological components. Regarding the actor domain 2 barriers were mentioned, these were the perceived uncertainty on market readiness of technologies, and the lack of consensus on the role of the DSO. It seems that the future role of the DSO's and related issues are important in this group.

Regarding the institutional domain 3 barriers were mentioned. These were that the DSO was not allowed to differentiate in capacity, that the DSO was not allowed to supply electricity, and one normative barrier, that storage was assessed no actor level.

The interpretative flexibility for this group was on average 5.

To summarize, the combined group of BU and TD+BU consists of 9 respondents. Regarding the alignment, the group differs in 6 vision elements, and on 5 barriers from other groups. The average interpretative flexibility of the group is 5.

Table 10 presents the vision elements, and barriers that are aligned with the groups top down and the group that includes both top down and bottom up.

Table 10: The vision elements, and barriers that are aligned with the groups top down and td+bu

	top down (td)							td+bu				Total
Vision	**5**	**2**	**4**	**6**	**7**	**13**	**17**	**12**	**1**	**3**	**19**	
Institutions												
Central dispatching	1		1	1	1	1	1	1	1		1	9
Storage technologies												
fly wheel							1		1			2
metering & control technologies												
Actors as barriers												
uncertainty on economic feasibility of storage			1	1	1			1		1		5
interdependent players do not cooperate sufficient	1				1			1				3
Institutional barriers												
R free ETS for existing power plants				1							1	2
R labour regulation					1			1				2
N Storage is assessed on conversion loss				1	1						1	3
Technological components as barriers												
better isolation in buildings				1	1		1	1				4
limited net capacity			1						1			2
Total	2	0	3	5	6	1	3	5	3	1	3	

The two groups, solely top down (7), and both bottom up and top down (4), consisted of 11 respondents. Regarding the vision elements that were aligned with this combined group (1), the following can be stated. The group did not include any specific actors. Regarding the institutions, the group included the institution central dispatching (9/11). This implicates that for a system that is coordinated centrally central dispatching is and not any specific institutions. Concerning technologies (1), the group did not include specific production technologies, balancing technologies, or metering technologies. Regarding storage technologies, the group included the fly wheel.

Regarding the barriers (5) no barriers were mentioned in the domain of technological components. Regarding the actor domain 2 barriers were mentioned, these were the perceived uncertainty on market readiness of technologies, and the lack of consensus on the role of the DSO.

Regarding the institutional domain 3 barriers were mentioned. These were that the DSO was not allowed to differentiate in capacity, that the DSO was not allowed to supply electricity, and that storage was assessed no actor level.

The interpretative flexibility for this group was on average 4.

To summarize, the combined group of TD and TD+BU consists of 11 respondents. Regarding the alignment, the group differs in 2 vision elements, and on 7 barriers from other groups. The average interpretative flexibility of the group is 4.

Table 11 presents the vision elements, and barriers that are aligned for the two groups top down and bottom up.

Table 11: The vision elements, and barriers that are aligned for both top down and bottom up

	top down (td)							bottom up (bu)					Total
Vision	**5**	**2**	**4**	**6**	**7**	**13**	**17**	**11**	**20**	**8**	**9**	**10**	
Production technologies													
fuel cell							1				1		2
Balancing technologies													
fridge							1		1	1			3
Actors as barriers													
uncertainty on public acceptation			1	1	1							1	4
commercial parties focus on short term profit		1						1					2
Total	0	1	2	1	2	0	2	1	1	2	2	1	

The two groups, solely top down (7), and solely bottom up (5), consisted of 12 respondents. Regarding the vision elements that were aligned with this combined group (2), the following can be stated. The group did not included actors and institutions. Regarding technologies storage technologies and metering & control technologies were not included. For production technologies the fuel cell was included, for balancing technologies the fridge was included.

Regarding the barriers (2) no barriers were mentioned in the domain of institutional barriers, and no barriers were mentioned in the domain of technological components. The two barriers in the actor domain were the uncertainty on public acceptation, and the fact that commercial parties focused on short term profit. Remarkable in this group is that the respondents that included the LTS elements, did not mention the barriers that were mentioned by the respondents that did not include the LTS elements. A possible explanation could be that the respondents that did not include the LTS elements perceived barriers that were unable to solve. Another explanation could be that the respondents did not make the technologies explicit during the interview.

The interpretative flexibility for this group was on average 2.

To summarize, the combined group of TD and BU consists of 12 respondents. Regarding the alignment, the group differs in 2 vision elements, and on 2 barriers from other groups. The average interpretative flexibility of the group is 2.

Table 12 presents which system elements, and visions were aligned with all three groups.

Table 12: The System elements, and barriers that are aligned with all three groups

	top down (td)							bottom up (bu)					td+bu				Total
Vision	5	2	4	6	7	13	17	11	20	8	9	10	12	1	3	19	
actors																	
ESCO's	1		1	1	1	1	1			1	1	1	1	1	1		12
passive co-producers	1	1	1	1	1	1	1					1	1	1		1	11
active co-producers	1		1					1	1	1	1		1	1	1	1	10
LEO's	1					1			1				1	1			5
commercial parties	1								1		1	1	1	1			6
institutions																	
flexible capacity tarrif	1	1						1	1	1	1		1	1	1	1	10
Production technologies																	
chp	1	1	1		1		1	1		1	1		1	1	1	1	12
wind turbine		1		1		1	1	1	1				1		1		8
fossil fired power plant					1	1	1		1			1	1				6
Balancing technologies																	
heat pump	1	1	1		1	1	1		1	1	1		1	1	1	1	13
electrical vehicle	1	1	1			1			1	1	1	1	1	1	1	1	12
washing machine			1							1		1	1	1	1		6
freezer				1			1	1		1	1				1		6
Storage technologies																	
hydro power		1	1	1			1			1	1			1	1		8
stationary battery							1				1	1		1			4
compressed air				1			1			1		1				1	5
metering & control technologies																	
smart meter	1	1	1			1	1			1		1	1	1		1	10
Inter connector					1		1			1		1	1				5
Actors as barriers																	
Sector players have interest in central and fossil based technologies	1	1	1	1				1			1	1	1			1	9
low awareness of scarcity and environmental effects					1	1	1		1		1					1	6
sector routines focussed on central production	1		1		1	1			1	1	1		1				8
no consensus on standards for smart technologies	1					1			1		1	1	1		1		7
uncertainty on influence of end-user behaviour						1					1	1	1		1		5
end-user routines adapted to always electricity			1		1						1			1			4
Institutional barriers																	
R standard profile small consumers			1				1			1	1		1			1	6
N Generators are assessed on their kwh-price			1	1	1			1					1	1		1	7
N installation sector has a low capacity			1					1				1				1	4
Technological components as barriers																	
grid and metering technologies adapted to centralized production		1	1		1			1	1			1	1	1			8
Total	16	11	18	9	12	12	14	11	15	14	18	15	22	18	13	16	

The three groups, solely top down (7), solely bottom up (5), and both bottom up and top down (4) consisted of 16 respondents.

Regarding the vision elements that were aligned with this combined group (19), all dimensions were represented. In the actor dimension (5) ESCO's, passive co-producers, active co-producers, LEO's, and commercial parties were mentioned. In the institution dimension (2) flexible capacity tariff and virtual trading platforms were mentioned. In the production technology domain (3) chp, wind turbines, and fossil power plants were mentioned. In the balancing technology domain (4) heat pump, electrical vehicle, washing machine, and freezer were mentioned. In the storage domain (3) hydro power, stationary battery, and compressed air were mentioned. In the metering & control domain (2) smart meter, and inter connector were mentioned.

Concerning the barriers, 10 specific barriers were mentioned. Regarding the barriers, all dimensions were represented. In the actor domain (6) the respondents mentioned, that sector players had significant interests in fossil based technologies, that among end-users there was a low awareness of scarcity and environmental effects, that the routines in the sector were focused on central production, that there was no consensus among the actors the standards for smart technologies, and that end-user routines were adapted to always electricity. Regarding the institutional barriers (3) the respondents mentioned the standard profile for small consumers (regulative), that generators are assessed on their kWh-price (normative), and that the installation sector has a low capacity (n). Regarding the technological components (1) the respondents mentioned that grid and metering technologies were adapted to centralized production.

The interpretative flexibility for this group was on average 15.

To summarize, the combined group of TD, BU, and TD+BU consisted of 16 respondents. Regarding the alignment the group differs in 19 vision elements, and on 10 barriers from other groups. The average interpretative flexibility of the group is 15.

Table 13 presents vision elements, and barriers that were included in solely the storage group.

Table 13: Vision elements that were included in solely the storage group (table continues on the next page)

	Storage													Total
Vision	**18**	**2**	**4**	**6**	**7**	**13**	**17**	**8**	**9**	**10**	**1**	**3**	**19**	
actors														
institutions														
Production technologies														
CCS		1	1	1			1							4
Geothermal	1					1								2
tide	1					1								2
fuel cell							1		1					2
coal gasification			1				1							2
coal fired power plant		1		1										2
biomass gasification						1								1
Balancing technologies														
dishwasher	1							1			1			3
cold store												1		1
air co							1							1
Storage technologies														
hydro power		1	1	1			1	1	1		1	1		8
stationary battery	1						1		1	1	1			5
compressed air				1			1	1		1			1	5
hydrogen				1	1	1	1							4
fly wheel							1				1			2
capacitor				1										1
metering & control technologies														

	Storage													Total
Vision	**18**	**2**	**4**	**6**	**7**	**13**	**17**	**8**	**9**	**10**	**1**	**3**	**19**	
sinus filter										1				1
Actors as barriers														
end-user routines adapted to always electricity			1		1				1		1			4
sector players work with outdated information	1					1								2
Institutional barriers														
R free ETS for existing power plants	1			1									1	3
R costless connection for large scale generation	1												1	2
N Storage is assessed on conversion loss				1	1								1	3
N assessment business case for storage on actor level									1		1			2
N Generators are assessed on their GHG-emissions				1			1							2
Technological components as barriers														
limited net capacity	1		1								1			3
Total	8	3	6	9	5	5	9	4	7	3	8	1	4	

The storage group consisted of 13 respondents. Regarding the vision elements that were aligned, the following can be stated. The actor domain and the institutional domain were not included in this group. Regarding the production technologies (7) CCS, geothermal, tide, fuel cell, coal gasification, coal fired power plants, and biomass gasification were mentioned. Regarding the balancing technologies (3), dishwashers, cold stores, and air-conditioning was mentioned. Regarding storage technologies (6), hydro power, stationary battery, compressed air, hydrogen, fly wheel, and capacitors were mentioned. Regarding metering & control technologies the sinus filter was mentioned.

Concerning barriers, 9 barriers were mentioned. All domains were included. In the actor domain (2) barriers that were mentioned were that the end-user routines were adapted to always electricity, and that sector players work with outdated information. In the institutional domain (5) the respondents mentioned the free ETS for existing power plants, the costless connection for large scale generation, that storage is assessed on conversion loss, that the business case for storage is assessed on actor level, and that generators are assessed on their GHG-emissions. Regarding the technological components as barriers (1) the respondents mentioned limited net capacity.

The interpretative flexibility for this group was on average 6.

To summarize, the solely storage group consisted of 16 respondents. Regarding the alignment the group differed in 17 vision elements, and on 9 barriers from other groups. The average interpretative flexibility of the group was 6.

Table 14 presents the vision elements, and barriers that were included in solely the group that did not mention storage in their vision.

Table 14: Vision elements, and barriers that were included in solely the group that did not mentioned storage

	No storage							Total
Vision	**14**	**15**	**16**	**5**	**11**	**20**	**12**	
Balancing technologies								
Electric boiler						1	1	2
Institutional barriers								
N Generators are assessed on their areal space they claim	1		1					2
N high bank guarantees for grid ownership						1		1
Total	1	0	1	0	0	2	1	

The no storage group consisted of 7 respondents. Regarding the vision elements (1) that were aligned, the following can be stated. No specific technologies were included in the domains of actors, institutions, production technologies, storage technologies, and metering & control technologies. Regarding the domain of balancing technologies the electric boiler was included.

Regarding the barriers, no barriers were included in the actor or technological domain. In the institutional domain (2) the respondents mentioned that barriers were assessed on their areal space they claim, and the high bank guarantees for grid ownership.

The interpretative flexibility for this group was on average 0.7.

To summarize, the solely no storage group consisted of 7 respondents. Regarding the alignment the group differed in 7 vision elements, and on 2 barriers from other groups. The average interpretative flexibility of the group was 0,7.

Table B presents the vision elements, and barriers that were included in both the storage group and the group were storage was not mentioned.

Table B: Vision elements, drivers, and barriers that are included in both the storage and the no storage mentioned group (Table continues on next page)

	No storage mentioned							Storage														Total
Vision	**14**	**15**	**16**	**5**	**11**	**20**	**12**	**18**	**2**	**4**	**6**	**7**	**13**	**17**	**8**	**9**	**10**	**1**	**3**	**19**	
actors																					
current producers	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	19
ESCO's	1	1		1			1	1		1	1	1	1	1	1	1	1	1	1		15
passive co-producers				1			1	1	1	1	1	1	1	1			1	1		1	12
active co-producers				1	1	1	1			1					1	1		1	1	1	10
LEO's	1	1		1		1	1	1					1					1			8
commercial parties				1		1	1									1	1	1			6
housing corporations						1		1													2
institutions																					
flexible capacity tariff			1	1	1	1	1		1						1	1		1	1	1	11
local balancing markets							1								1	1	1	1		1	6
virtual trading platforms				1	1	1		1										1		1	6
flexible electricity tariffs	1	1					1										1		1		5
Production technologies																					
solar-pv	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
chp			1	1	1		1	1	1	1		1		1	1	1		1	1	1	14
wind turbine	1		1		1	1	1	1	1		1		1	1					1		11
fossil fired power plant	1		1			1	1					1	1	1			1				8
biomass digestion	1							1			1		1								4
solar power plant (EU)			1					1			1			1							4
wind turbine (north EU)			1					1			1			1							4
gas fired power plant			1						1	1			1								4
Nuclear power			1						1		1										3
Balancing technologies																					
heat pump	1		1	1		1	1		1	1		1	1	1	1	1		1	1	1	15
electrical vehicle		1	1	1		1	1	1	1	1			1		1	1	1	1	1	1	15
washing machine							1			1					1		1	1	1		6
freezer					1						1			1	1	1			1		6
fridge						1		1						1	1						4
Storage technologies																					
metering & control technologies																					
smart meter	1		1	1			1		1	1			1	1	1		1	1		1	12
software agent		1	1		1	1									1	1		1			7
Inter connector			1				1					1		1	1		1				6
IT	1											1		1							3
External drivers																					
increase the economic efficiency for the end user				1	1	1	1								1	1				1	7
improve the sustainability of the electricity supply system.	1		1				1	1	1								1				6
decrease the fossil fuel dependency					1				1		1										3
stimulate local economy	1												1								2
Actors as barriers																					
Sector players have interest in central and fossil based technologies			1	1	1		1		1	1	1					1	1			1	10

	No storage mentioned							Storage													Total
Vision	**14**	**15**	**16**	**5**	**11**	**20**	**12**	**18**	**2**	**4**	**6**	**7**	**13**	**17**	**8**	**9**	**10**	**1**	**3**	**19**	
low awareness of scarcity and environmental effects		1	1			1		1				1	1	1		1				1	9
sector routines focussed on central production			1	1		1	1			1		1	1		1	1					9
no consensus on standards for smart technologies				1		1	1						1			1	1		1		7
uncertainty on economic feasibility of storage	1		1				1			1	1	1							1		7
uncertainty on influence of end-user behaviour			1				1						1			1	1		1		6
uncertainty on market readiness of technologies	1	1			1		1	1							1						6
interdependent players do not cooperate sufficient			1	1			1	1				1									5
no consensus on role DSO			1				1									1		1	1		5
uncertainty on public acceptation			1							1	1	1					1				5
governmental policy is inconsistent	1								1		1	1									4
commercial parties focus on short term profit					1			1	1												3
single player limited influence, only on a small part of the system			1							1		1									3
Institutional barriers																					
R standard profile small consumers			1				1			1				1	1	1				1	7
R DSO not allowed to differentiate in capacity			1			1	1								1	1			1		6
R DSO not allowed to supply electricity							1									1		1			3
R energy tax on transported electricity		1	1															1			3
R DSO tariff based on operational efficiency							1												1		2
R labour regulation							1					1									2
N Generators are assessed on their kWh-price	1	1	1		1		1			1	1	1						1		1	10
N installation sector has a low capacity		1			1					1							1			1	5
N Generators are assessed on their payback time							1													1	2
Technological components as barriers																					
grid and metering technologies adapted to centralized production			1		1	1	1		1	1		1					1	1			9
better isolation in buildings							1				1	1		1							4
secure network	1												1								2
Total	20	13	32	20	17	22	40	19	19	23	18	21	18	19	20	23	19	22	18	20	

The combined group consisted of 20 respondents. Regarding the vision elements (29) that were aligned, the following can be stated. Regarding the domain actors (7) current producers, ESCO's, passive co-producers, active co-producers, LEO's, commercial parties, and housing corporations were mentioned. In the institutional domain (4), the institutions flexible capacity tariff, local balancing markets, virtual trading platforms, and flexible electricity tariffs were mentioned. In the production technology domain (9) the technologies solar-pv, chp, wind turbines, solar power plants (EU), wind turbines (EU), gas fired power plant, and nuclear power were mentioned. In the balancing technologies domain the heat pump, electrical vehicle, washing machine, freezer, and fridge were mentioned. No storage technologies were mentioned.

Concerning barriers, 25 barriers were mentioned. All domains were included. Regarding the actor domain (13) the respondents mentioned that the sector players have interest in central and fossil based technologies, that end-users had a low awareness of scarcity and environmental effects, that sector routines are focussed on central production, the lack of consensus on standards for smart technologies, the uncertainty on influence of end-user behaviour, the uncertainty on market readiness of technologies, that interdependent players do not cooperate sufficient, the lack of consensus on the role of the DSO, the uncertainty on public acceptation, that the governmental policy is inconsistent, that commercial parties focus on short term profit, and that single players have limited influence. Regarding the institutional domain (9) the respondents mentioned the standard profile for small consumers, that the DSO was not allowed to differentiate in capacity, that the DSO was not allowed to supply electricity, the energy tax on transported electricity, the DSO tariff that was based on operational efficiency, the labour regulation, that generators are assessed on their kWh-price, that the installation sector has a low capacity, and that generators are assessed on their payback time. Regarding the technological components as barriers (3) the respondents mentioned that the grid and metering technologies were adapted to centralized production, the improvement of isolation in buildings, and the secure network.

The interpretative flexibility for this group was on average 21.

To summarize, the both storage and no storage group consisted of 20 respondents. Regarding the alignment the group differed in 29 vision elements, and on 25 barriers from other groups. The average interpretative flexibility of the group was 21.

The main results of the chapter are summarized below. The visons were fully aligned on the change from a rigid to a manageable demand. The main differences between the 20 visions were on the type of system control: top down (7), bottom up (5), both top down and bottom up (4), and 4 did not mention a control type. The other dimension was on the inclusion of storage (13), and not mentioning storage (7). In these visions 36 technologies, 7 actors and 4 institutions were mentioned. Concerning barriers 35 barriers were mentioned.

Regarding the interpretative flexibility of the visions, visions nr 15, 11, and 7 had the highest interpretative flexibility. Solely vision nr 7 is aligned with one other vision (nr 17), vision 7 has therefore the highest potential to become a guiding vision.

The following barriers in the different dimensions had a high overall alignment. In the actor domain that sector players have interest in central and fossil based technologies (10), the low awareness of end-users on scarcity and environmental effects (9), and the sector routines that are focussed on central production (9). In the institutional domain that generators are assessed on their kWh-price (10), the standard profile for small consumers (7), that the DSO is not allowed to differentiate in capacity (6), and that the installation sector has a low capacity (5). In the technological domain that grid and metering technologies were adapted to centralized production (9), and the improvement of isolation in buildings (4).

The results from the comparison of the three groups with different control types are summarized in Table 15.

Table 15: Summary of the comparison of the control types groups.

Group combinations	Aligned LTS elements	Aligned barriers	Total
All three	19	10	**29**
Both bu and td	2	2	**4**
Both td and td+bu	1	7	**8**
Both bu and td+bu	5	5	**10**
Solely Top down (td)	15	5	**20**
Solely Bottom up (bu)	3	1	**4**
Solely Td+bu	1	4	**5**

Table 15 presents the alignment of the different groups on the LTS elements, and barriers.

Regarding the interpretative flexibility of the different groups the following can be stated. The top down group is included in three group combinations. Taking the sum of all totals of which the top down group is a part of gives 29+ 4+8+20= 61 for its interpretative flexibility. The bottom up group is included in three combinations, this gives 29+4+10+4= 47. The both top down and bottom up group is included in three groups, this gives 29+8+10+5= 52. So, regarding the interpretative flexibility on group level the bottom up group (47) has the highest interpretative flexibility, followed by the both bottom up and top down group (52), and the top down group (61).

Regarding the alignment the following can be stated. The TD group is aligned in three groups, this gives 29+4+8= 41. So, the percentages of the elements that are aligned are 41/61 = 67% (aligned elements and barriers/total TD). The BU group is aligned in three groups, this gives 29+4+10 = 43. So, the percentages of the elements, and barriers that are aligned are 43/47 = 91%. The TD+BU group is aligned in three groups, this gives 29+8+10= 47. So, the percentages of the elements that are aligned are 47/52 = 90%. To summarize, regarding the alignment of the groups the elements, and barriers of the BU group (91%) have the highest alignment, followed by the TD+BU group (90%), and the TD group (67%).

The results from the comparison of the two groups with and without storage are summarized in Table 16.

Table 16: Summary of the comparison of the group with and without storage.

Group combinations	Aligned LTS elements	Aligned barriers	Total
Both storage & No storage	29	25	**54**
Solely storage	17	9	**26**
Solely no storage	7	2	**9**

Table 16 presents the alignment of the different groups on the LTS elements, and barriers.

Regarding the interpretative flexibility of the different groups the following can be stated. The Storage and no storage group were both included in one group combination.

Regarding storage, taking the sum of the two totals of which storage group is a part of gives 54+26= 80 for its interpretative flexibility. Regarding no storage, taking the sum of the two totals of which the no storage group is a part of gives 54+9= 63 for its interpretative flexibility. So, regarding the interpretative flexibility on group level the no storage group had the highest interpretative flexibility (63), and the storage group the lowest (80).

Regarding the alignment the following can be stated. Both the storage and the no storage group are aligned in one group, for both storage and no storage this is 54. So, regarding storage the percentages of the elements, and barriers that are aligned are 54/80 = 68% (aligned elements, and barriers /total storage). So, regarding no storage the percentages of the elements that are aligned are 54/63 = 86%.

5 Conclusions & Discussion

The objectives of this research were to explore the future visions of actors on an electricity supply system with significant RDG in order to assess the extent to which these visions are shared. This was done by exploring the content of the visions, as well as the barriers that could stimulate or hamper the transition towards such a system. Based on these results the degree of sharedness was assessed of the singular visions, as well as of the grouped visions.

The overall sharedness of the visions is relative low. Solely one vision was shared with one other vision. In the objective part of the visions, the visions differ significantly on two dimensions; the system control to balance the system and the inclusion of storage. Though, the visions were aligned on the demand side of the system. All the visions included a change in the demand from rigid to manageable. In the elements part of the visions, the majority of the elements were not included in many other visions. This relative low inclusion by other respondents was also true for the barriers.

The sharedness of the visions on group level is relative high. Regarding the different control types to balance the system the following was indicated. In the BU group 91% of the vision elements, and barriers mentioned in this group are shared with at least one other group, followed by the TD+BU group (90%), and the TD group (67%). Also in the storage dimension the alignment is relative high, 86% for the no storage group, and 68% alignment for the storage group.

Several remarks can be placed at the conclusions. The first remark is that the results implicate that the respondents solely envision a future electricity supply system with a significant contribution of

RDG. Though, also competing visions with a smaller emphasis on RDG do also exist among the respondents (TenneT, 2008). The second remark is that several actor types have a higher number of representatives in the data set; this gives these actors a higher weight in assessing the alignment. The third remark is that the data was collected at a limited number of actor types, this excludes potential alternative visions of other actor types. The fourth remark is that the results are in general based on a limited number of respondents; this can exclude alternative visions on the system. The fifth remark is that the respondents were questioned in a general matter. Consequently, the articulated visions could be incomplete. This incompleteness could be an explanation for the relative low alignment between the visions.

These findings suggest that broader insights are needed on the Dutch electricity supply system, in order to include all potential futures. These insights should also be collected from a broader number and type of actors in order to increase the validity of these results for the Dutch electricity supply system. Moreover, the findings suggest that more insights are needed in whether the respondents would include specific elements in their visions that they have not included in their current visions, because these insights could contribute in assessing the alignment. Moreover, conflicting aspects could be indicated.

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