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Analysing energy innovation policies

Assessing the Dutch energy-innovation policy mix for the stimulation of energy storage technologies

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Abstract

An increasing penetration of sustainable and decentral energy production provokes a new challenge regarding managing and governing our energy system: coping with irregular energy provision by means of sustaining grid flexibility. For this, energy storage is one of the means. However, more technological and institutional innovation is needed in order to reduce costs, increase efficiency and to successfully adopt energy storage within our energy system. The central question is how the policy mix, that includes all policy instruments relevant for innovation of energy storage, is stimulating innovation and adoption of energy storage. This ex ante evaluation is relevant for providing recommendations for the adaptation of the innovation policy mix concerning energy storage.

Starting point of this analysis is that (i) sustainable energy innovations are in need for transformative policy that stimulates socio-technical change, meaning sufficient interaction between technology, people and institutions, and (ii) that they face challenges to become adopted within the current energy regime, as they have to compete with the fossil-fuel based energy regime that is supported by vested interests, economies of scale and by optimal institutional arrangements.

For answering this question, a policy mix assessment frameworks has been created. This framework includes conditions that, according to a literature search of the theoretical frameworks TIS & MLP, should be present in order to sufficiently stimulate innovation and adoption of sustainable energy technologies. The policy mix, that has been evaluated by means of desk research and interviews, should include niche creative and regime destructive policy programmes and relevant policy goals.

It is concluded that there is a strong niche creative innovation policy mix, which mainly is the result of a wide variety of technology push policy instruments. However, there is a serious lack of instruments that aim at market creation. Furthermore, adoption of energy storage is hampered by a variety of institutional barriers that have to be adapted in order to prepare the energy system and market for the adoption of energy storage technologies. These are mainly a consequence of outdated regulatory frameworks and a rigid energy market that both are too much focused on centralised energy production. Therefore, the main recommendations for the adaptation of the policy mix include aiming for market creating instruments (e.g. favourable tax regimes and standards), and the adaptation of institutional frameworks (e.g. the Electricity Law) that takes decentral generated energy production more into account.

Foreword

This research has been commissioned by the Netherlands Court of Audit. As research intern, I was engaged in a research project aiming at finding policy evaluation methods that are helpful for analysing whether innovation policy sufficiently supports energy transition processes. I hope that this research and the developed policy mix assessment framework are helpful for the Netherlands Court of Audit to use for future research projects. During my time as an intern, I have learned a lot about performing research for a High College of State and practically about many interesting innovation policy programmes, policy evaluations and about the Netherlands Court of Audit.

I would like to thank Marcoen Roelofs for his supervision during my nine months as an intern, and Dr. Frank van Laerhoven for its feedback on my research proposal and thesis.

Glossary

ACM	Authority Consumer & Market (*Autoriteit, Consument en Markt*)
DEI	Demonstration Energy Innovation (*Demonstratie Energie Innovatie)*
ETS	Emission Trading System
NCA	Netherlands Court of Audit (*Algemene Rekenkamer*)
NEN	Dutch Normalisation Institute (*Nederlands Normalisatie Instituut*)
PBL	Netherlands Environmental Assessment Agency (*Planbureau voor de Leefomgeving*)
R&D	Research and development
RVO	Netherlands Enterprise Agency (*Rijksdienst voor Ondernemend Nederland*)
SDE+	Stimulation Sustainable Energy Production (*Stimulering Duurzame Energieproductie*)
SIP	System Integration Programme (*Programma Systeemintegratie*)
SME	Small and medium-sized enterprises
TKI	Topconsortia for Knowledge and Innovation (*Topconsortia voor Kennis en Innovatie*)
TSE	Top sector Energy (*Topsector Energie*)
WBSO	*"Wet Bevordering Speur en Ontwikkelingswerk"*

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1. Introduction

1.1 An increasing share of renewable and decentralised generated energy

Currently, the role of fossil fuels is heavily under discussion and an increasing scarcity of fossil resources is inevitable. As a consequence, our energy systems need to be transformed fundamentally (Loorbach, Brugge & Taanman, 2008). For this, in the Netherlands, goals have been set for a 14% share of sustainable energy in 2020 and 16% in 2023 in the Energy Agreement (Energieakkoord) (SER, 2013). After the Energy Agreement has ended, the Dutch cabinet aims to stick to the European agreements of a 40% reduction of CO2-emissions in 2030 and of 80-95% in 2050. In order to reach these energy targets, an energy transition is needed (SER, 2013). Resulting from the energy transition, the amount of renewable generated energy will increase (ISPT, 2017). Renewable energy has already been supported through policy, and its recent cost reductions have made renewable energy cost-competitive with other types of energy and has thereby reinforced the central role for renewables in the new energy system. Moreover, there will be an increasing demand for electricity due to the replacement of oil and gas in large sectors as industry and transportation by electricity, as increasing electrification seems to be the current general trend (European Commission, 2016). Finally, there is a trend towards more decentralised electricity generation by new players in the energy market. Consumers will increasingly participate in energy markets as 'prosumers', i.e. they generate electricity for their own use and rely on the electricity grid for residual balance. Such prosumers for instance include household residents with solar panels or farmyards with small thermal power plants. (Van der Vegte, 2015 & European Commission, 2016, Agenschap NL, 2012).

1.1.2. The need for energy storage to account for grid flexibility

The developments described above provoke a variety of new challenges for managing and governing the Dutch energy system. Increasing penetration of renewable and decentralised electricity production makes the balance between supply and demand in electricity grids necessary and challenging. By nature, intermittent renewable sources such as wind and solar are not always available, since production of renewable sources depends on the weather. As a consequence, sustainable energy cannot always meet the demands of the energy consumers, and in other time periods, there will be a surplus of electricity. Consequently, flexibility on both the demand and supply side of electricity production and use is needed (Van der Vegte, 2015). Flexibility in the case of electricity grids can be defined as the ability to cope with increasing unpredictability and imbalance in demand and supply of electricity, while having a reliable supply of electricity (Van der Vegte, van Melzen & Van der Spek, 2016).

Energy storage is one of the key components in providing this flexibility and supporting renewable energy integration in the energy system. It is therefore expected to play a larger role in the Dutch electricity system. As energy storage can account for the irregular energy provision resulting from solar and wind energy, it can support the adoption of sustainable energy within the Dutch energy system. Therefore, advancements in energy storage will be of support for meeting national and European energy targets (European Commission, 2016).

1.1.3. Challenges for innovation policy regarding energy storage

Further optimisation of production processes and technological development in combination with stimulation of the market demand is needed for energy storage to become adopted in the Dutch energy system. In order to increase the role of energy storage the Dutch energy transition, more innovation is needed to reduce costs and improve the efficiency of the technologies. This will strengthen the business case for energy storage and supports the required energy transition (Nykvist & Nilsson, 2015; European Commission, 2016). Besides technological innovation, it is highly likely that also institutional innovation is needed, in order for energy storage to fit within institutional frameworks and to become adopted in energy markets (Van der Vegte et al., 2016). Moreover, challenges regarding grid flexibility ask for a more active involvement of civil-society, since many storage facilities can be placed on the residential or household level. For the adoption of energy storage, social innovation and taking security and privacy of civil society into account are necessary (Van der Vegte, 2015).

Thus, for the adoption of energy storage, not only technological innovation is needed. Innovation processes should take place with sufficient interaction between people, institutions and technology, which is called “socio-technical change” (Kemp, Avelino & Bressers, 2011; Nieminen & Hyytinen, 2015). Socio-technical change, a term linked to the sustainable transition and innovation literature, leads to “fundamental changes to a more sustainable configuration of a socio-technical regime, which entails not only new technologies, but also changes in markets, user practices, policy and cultural meanings” (Faber & Alkemade, 2011, p. 2). However, innovation and implementation of sustainable technologies such as energy storage is difficult. This is because fossil-fuel-related technologies are supported by vested interests and benefit from many years of experience, economies of scale, external costs of CO2-emissions, and have optimal institutional arrangements (Meelen & Farla, 2013). The strong fossil fuel regime, in which incumbents play a dominant role as well as the deep embeddedness of infrastructure, institutions and economy is difficult to transform (Bosman, Loorbach, Frantzeskaki & Pistorius, 2014; Loorbach et al., 2008; Turnheim et al., 2015). These factors make it challenging to adopt new technologies within the current energy system. It is proclaimed that this problem cannot be solved by intensifying current policies. Instead, the adoption of sustainable technologies within energy systems requires innovation on the system level, based on long drawn-out transformation processes that comprise technological, economic, socio-cultural and institutional changes (Kern & Smith, 2008). Because fostering radical innovation is considered as an important element of policy towards sustainable development, a focus on incremental innovation along established paths will not suffice (Steward, 2012). Therefore, there is a need for transformative innovation policy that is designed to overcome the inertia that prevents firms from experimenting with and using new technologies (Janssen, 2016; Nill & Kemp, 2009).

1.2 Problem definition

The above described innovation policy challenges bring along an increased need for the understanding of transition processes in order to better inform policy makers to adapt and modify innovation policy. This modification can lead to an improved stimulation of socio-technical change concerning energy storage. This however leads to analytical challenges, since it is difficult to analyse whether innovation policy sufficiently supports such processes of change. First of all, the high amount of (external) factors influencing such processes make it difficult to establish causality between innovation policy and transition processes. Secondly, there are large amounts of policy strategies and instruments relevant for the stimulation of a particular sustainable technology. Finally, the fact that socio-technical change is a timely process, makes ex-post evaluations and learning from those evaluations less relevant (Hassink et al., 2012; Janssen, 2016; Kocsis & Hof, 2016). Therefore, policy design scholars argue that it is possible and relevant to assess ex-ante the likely outcome of policy mixes (instead of individual policy programmes) by focussing on design criteria or 'conditions' that are hypothesised to be of importance for effective policy mixes (Kivimaa & Kern, 2016). Such a policy assessment can be used for the adaptation and modification of energy innovation policies in order to effectively stimulate the adoption of energy storage technologies within the energy system.

In order to perform this policy assessment, an assessment framework needs to be developed. By means of this framework, the policy mix relevant for innovation of energy storage will be evaluated on the extent to which it sufficiently meets conditions for socio-technical change. This will be done in order to come up with recommendations for modification and adaptation of the energy innovation policy mix concerning energy storage.

Short, energy storage potentially is an important mean for accounting for the fluctuated energy provision resulting from a larger share of sustainable energy production. However, technological, social and institutional innovation is needed in order to become adopted within the Dutch energy system. Therefore, this thesis aims at informing policy makers on how to adapt policy programmes and instruments that together form a mix. This is done by analysing the extent to which the policy mix meets conditions that should be present in order to stimulate innovation processes. This should lead to the adoption of energy storage within the energy system.

1.4 Research objectives

This research aims at:

1) Developing an assessment framework in order to analyse to what extent the Dutch energy innovation policy mix is stimulating an environment in which energy storage can be developed and adopted within the energy system. The aim is to formulate conditions that need to be present, that are hypothesised to effectively stimulate processes of socio-technical change by means of policy. This will be done by means of a literature study;

2) Gaining understanding about the Dutch energy innovation policy mix related to energy storage and elaborate on how these instruments are supposed to stimulate energy storage;

3) Analysing (by means of the assessment framework) how the energy innovation policy mix is stimulating energy storage, thus how technological as well as social and institutional innovation is stimulated.

4) The formulation of relevant points of improvements in order to modify and adapt the policy mix.

1.5 Research questions

In order to reach the research objectives, the following research question and sub-questions have been developed.

To what extent is the Dutch energy-innovation policy mix sufficiently supporting the development of technologies for energy storage, and how can this be improved?

Sub questions

1. What conditions should an assessment framework include for analysing a sustainable energy-innovation policy mix with regard to the stimulation of socio-technical change?

2. Where does the current mix of policy instruments with regard to energy storage consist of? And how are these policy instruments and programmes supposed to stimulate energy-innovation?

3. How is the Dutch energy-innovation policy mix stimulating the innovation technologies for energy storage?

4. What recommendations can be provided for adapting the policy mix concerning energy storage?

1.6 Societal relevance

This research has been commissioned by the Netherlands Court of Audit. As a high college of state, the Netherlands Court of Audit among others audits whether central government policy is implemented as intended. With the energy transition as one of the main societal challenges of the next decades, the Netherlands Court of Audit has started a discussion regarding the question on how to analyse and evaluate policy that has to deal with such a societal challenge, involving a broad variety of policy programmes and instruments and many needed institutional changes (NCA, 2017). Furthermore, as the energy transition will take place over long time-frames, the Netherlands Court of Audit among others aims at finding evaluation methods contributing to the adaptation and modification of policy programmes in order to adjust these programmes to the needs of the energy transition. This research contributes to these questions as it aims to develop a policy mix assessment framework that is able to take into account large mixes of policy programmes, needed institutional/regime changes and can be applied ex-ante in order to adapt those policy mixes. Moreover, this research contributes to a better adoption of energy storage as it aims to come up with policy recommendations for adapting policy mixes leading to sufficient technological, social and institutional innovations.

1.7 Scientific relevance

Previous research as well as policy evaluations analysed the effectiveness of individual policy instruments or programmes and their impact on the innovation and the diffusion of sustainable technologies. However, a broader perspective needs to be taken by analysing extensive mixes of policy instruments in order to analyse the role of innovation policy on processes of socio-technical change (Kern, Kivimaa & Martiskanen, 2017). Therefore, this research scientifically contributes to the development and use of innovation policy assessment frameworks by taking policy mixes into account. This research builds on previous performed research based on scholars that investigate the influence of policy mixes on sustainability transitions (Kivimaa & Kern, 2016). Their analysis on policy mixes has recently been performed and is in need for more research, as it is only applied to two cases and therefore not sufficiently developed. This thesis builds on their work by combining it with other theoretical frameworks (e.g. based on Meelen & Farla (2013)) in order to enrich the scientific literature with a more elaborated policy mix assessment framework. This assessment framework can also be applied to other sustainable technologies.

1.8 Readers guide

In chapter 2, a short background of energy storage will be provided. Subsequently, in the theoretical section (chapter 3), the notion of policy mixes will be discussed and it will be explained how the policy mix concerning energy storage will be defined. Furthermore, in this chapter, the theoretical frameworks that are used for the development of the policy mix assessment framework will be discussed. After this section, it will become clear what conditions for the stimulation of socio-technical change a successful policy mix is hypothesised to consist of. This is followed by the integrated assessment framework that will be used for the evaluation of the policy mix regarding energy storage. Thereafter, in the methodological section (chapter 4), the methodology for the policy mix assessment and data analysis will be elaborated upon.

The result section consists of two chapters. In chapter 5, the policy mix regarding energy storage will be defined. In chapter 6, the assessment framework will be applied to the policy mix, which will lead to results and policy recommendations. Finally, this thesis ends with a discussion of the results and methodological implications and a conclusion in which an answer to the research question will be given.

2. Background: energy storage in the Netherlands

According to the Platform Energy Storage NL, which is an interest association for energy storage, the importance of energy storage is not fully realised in the Netherlands and its value is not yet sufficiently utilised. Countries with higher penetration of renewable energy such as Germany, the United Kingdom and Australia are also in a further stadium with regard to energy storage. Consequently, for making the energy transition, as planned by the Dutch government, energy storage is expected to play a bigger role (Van der Vegte et al., 2016). Energy storage can provide alternatives to conventional solutions, and can help achieving the Dutch energy targets. In the next section, it will be elaborated what role energy storage fulfils or can fulfil within the energy system in general, what type of technologies are used for energy storage and what actors are active in the field of energy storage.

2.1 Grid flexibility

The market environment is rapidly changing with the increased variable electricity in the energy system and the increased deployment of a number of emerging sustainable energy technologies. Through creating and maintaining grid flexibility, energy storage provides benefits for many actors active in the energy system. Note that energy storage will always supplement other means to create grid flexibility. The four main means for creating a flexible electricity grid system are (1) demand response, for instance by means of flexible electricity pricing, (2) reinforcing the electricity grid (including interconnections of energy grids with neighbouring countries), (3) flexible production of electricity (which is currently the most important source of flexibility) and (4) energy storage. Note that storage is not to be seen as an end goal, but as a mean to sustain grid flexibility and a sustainable and reliable energy system. Grid reinforcement is seen as an expensive option and for a flexible energy production, there will always be made use of conventional technologies. Therefore, energy storage is expected to have lower social costs (Van der Vegte, 2015). Figure 1 schematically illustrates the four flexibility providers. The arrows indicate the direction in which the energy flows.

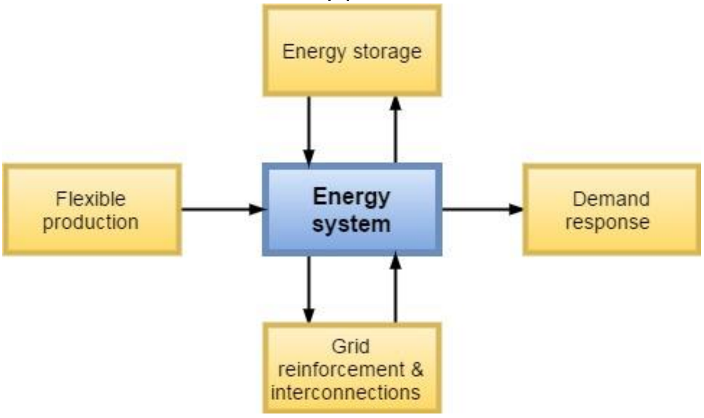

*Figure 1: Four means for sustaining grid flexibility (*Van der Vegte et al., 2016).

2.2. Functions of energy storage for the energy system

Besides creating flexibility of the electricity grid, energy storage can also contribute to the decarbonisation of other economic sectors by supporting the integration of higher shares of variable renewable energy in buildings, industry and transport. Furthermore, market aspects can be addressed with the storage of energy, since an increasing quantity of energy storage could reduce extreme price fluctuations and thereby reduce the volatility of energy prices and reduce costs of the overall energy system. It can also provide benefits in terms of energy security (European Commission, 2016). Moreover, energy storage can have high market value (compared to other means of sustaining grid flexibility) when trading energy on energy markets (e.g. APX market) by buying and storing when electricity prices are low (during peak loads) and selling it when prices are high (during energy shortages). Although grid reinforcement is a major mean for ensuring flexibility and security of the electricity supply, it is costly and therefore combining grid reinforcement with storage solutions can optimise grid costs (European Commission, 2016). Energy storage furthermore plays a large role in the energy transition since it can account for fluctuations resulting from wind and solar energy and is thereby increasing the role of solar and wind energy on the Dutch energy market (Van der Vegte et al., 2016). To illustrate: currently in countries with a higher share of sustainable energy generation, wind mills are switched off in order to deal with electricity peak loads. Furthermore, fossil fuel fired power plants have an important function in balancing the electricity system by means of flexible energy supply. However, for the energy transition, this fossil based solution will not hold anymore and using fossil fuel fired power plants only for adjusting fluctuation in the energy supply will become increasingly expensive (ISPT, 2016; Van der Vegte, 2015). Storage can also help reducing emissions from the conventional electricity generation, by facilitating a more efficient use of the existing assets and by reducing the carbon content of fuels (for instance by blending natural gas with renewable hydrogen) (European Commission, 2016).

To conclude, storage of energy can be of value on multiple terrains. It can be of value for the 'prosumers' that generate their own electricity and for the grid administrators by providing system services and economical value for many actors within the energy system.
The most important functions that energy storage can fulfil are:

- Temporarily storing energy (short or long-term):
  - In order to self-consume electricity (for instance for farmers with a high amount of solar panels on their farmyard);
  - To trade energy on energy markets by buying it when prices are low and selling when prices are low.
- Deliver system services:
  - Stabilisation of energy supply;
  - avoidance of congestion or overload on the grid;
  - Balance maintenance.
- Optimisation of industrial processes by facilitating a more efficient use of the existing assets.
- Security and reliability of electricity services.
- Support the development of renewable energy generators such as solar panels and wind turbines.

Annex 1 and 2 provide a clearer picture of energy storage technologies and relevant actors active in the field of energy storage.

3. Theoretical analysis

3.1 Policy mixes

In this section, the notion of policy mixes will be elaborated. For the analysis of the case-study, the Dutch policy mix concerning energy storage needs to be defined. The steps for defining such a policy mix will be provided in this section as well.

3.1.1. Literature background

Innovating entrepreneurs rarely use individual policy instruments as support for their innovating processes (Borrás & Edquist, 2013). Instead, they benefit from several policy instruments in order to reach their targets (E. Buddenbaum, expert session NCA, June 22, 2017). Borrás and Adquist (2013, p. 1519) state that "instrument mixes are created because the solution of specific problems requires complementary approaches to the multi-dimensional aspects of innovation-related problems". Furthermore, besides a mix of policy programmes or instruments, there are also institutional arrangements such as laws and regulations that stimulate or hamper the development of new technologies. Thus, policy instruments and institutional arrangements always are combined into mixes that address the complex and often multi-dimensional nature of innovation (Borrás & Edquist, 2013).

The concept of a policy mix is based on Kivimaa and Kern (2016) and Rogge and Reichardt (2016), who argue that innovation policy mixes are particularly important in the field of sustainability transitions. This is because transitions imply not only the development of disruptive innovations, but also of policies aiming for wider change in socio-technical systems, such as changing institutional arrangements (Kivimaa & Kern, 2016). It is thus increasingly recognised that innovation policy needs to involve the complex real world context by involving several policy instruments in different policy domains, with different rationales and at many levels (Kivimaa & Kern, 2016). In light of this research, policy mixes are defined as a combined set of interacting policy instruments (within the Netherlands) that are complex arrangements of multiple goals and that have direct or indirect impacts on the development of sustainable energy innovations (Rogge & Reichardt, 2016).

Creative destruction

Kivimaa and Kern (2016) suggest that policy mixes that combine "creative" and "destructive" policies are more likely to achieve transitions. *Creative policies* are policies aimed at creating niche-innovations and building effective innovation systems around them. This can be created by public policies that can act on both the demand and the supply sides to create favourable conditions for sustainable innovations. For the creative part of innovation, there are technology push and market pull policy instruments. *Technology push* relates to forces that affect the generation of new knowledge, such as financial policy instruments that aid R&D. *Market pull* policies on the other hand refer to those that shape the demand for innovations. Examples of market pull policy instruments include stringent environmental regulations or favourably tax regimes for sustainable energy technologies. Market pull instruments aim to restore competitive conditions between incumbent (e.g. fossil fuel driven) technologies and environmental friendly technologies which cannot reach their optimum performance without policy intervention that favours their competitive advantage against incumbent technologies (Costantini, Crespi, Martini & Pennacchio, 2015; Hannon, Foxon & Gale, 2015). *Destructive*, or regime destabilising policies on the other hand are aimed at destabilising currently dominant regime technologies, thereby creating openings for a faster take-off and sustained growth of niche innovations and thereby to replace incumbent (fossil fuel-related) technologies. Therefore, it is increasingly recognised that innovation policy is not only a matter of technology push instruments and market pull anymore. Hekkert and Vollebergh, (expert session NCA, June 22, 2017), who are innovation policy scientists stated that for analysing whether policy is stimulating transition processes, this only is possible by also including systemic instruments in such an analysis. *Systemic instruments* include the development or adaptation of institutions in order for technological innovations to be adopted within the energy system (Borrás & Edquist, 2013).

By making the distinction between creative and destructive policy instruments, Kivimaa and Kern (2006) built on Weber and Rohracher (2012), who call for a combination of “structural innovation policies” and “transformation-oriented innovation policies” to create more comprehensive policy mixes from the perspective of socio-technical transitions. By applying this concept of creative destruction in the context of public policy, Kivimaa and Kern (2016) aim at expanding innovation policy debates to go beyond policy mixes consisting of technology push and market pull instruments. They argue to consider a wider range of policy instruments which may contribute to both the creation, development and protection of niches as well the destabilisation of existing regimes

The notion of policy mixes is not a new phenomenon (Flanagan, Uyarra & Laranja, 2011), neither is the discussion that policy mixes have to take the complexity and dynamics of multi-actor and multi-level perspectives of sustainability transitions into account. However, the conceptualisation of Kivimaa and Kern (2016) of policy mixes for sustainability transitions based on the creation of niche-innovations and the destabilisations of regime factors is a rather new concept. The theoretical framework concerning niches and regimes (Multi-level perspective) will be discussed in section 3.3.

3.1.2. Defining the policy mix under analysis

In order to define a policy mix for a specific case, Borrás and Edquist (2013) and Reichardt and Rogge (2016) distinguish key activities in innovation systems that need to be fulfilled by a policy mix. This includes among others the policy strategy consisting of policy objectives and principle plans such as roadmaps to reach those targets. Furthermore, a policy mix aiming for system innovations thus should also consist of market pull, technology push and systemic instruments. For this research, these distinctions will be used for defining which policy instruments and strategies will become part of the policy mix regarding the technological development of energy storage.

Table 1: Key policy mix elements for defining the policy mix

Key policy mix elements		Examples from Borrás and Edquist (2013)
Policy strategy	Objectives (long-term targets)	Renewable energy goals
	Principal plans	Energy roadmaps
Instrument mix		
	Technology push	R&D provision programmes
		Competence building (training programmes for entrepreneurs)
		Creation of networks for knowledge diffusion
	market pull	Formation of new product markets
	Systemic instruments	Creation of organisations needed for the development of new fields of innovation or new policy organisations
		Creating and changing institutions (e.g. different environmental regulations, changing R&D investment flows)

Defining the policy mix is not yet sufficient for evaluating whether this policy mix is effectively aiming for socio-technical change. Therefore, in order to develop a more elaborated policy assessment framework, the remaining of this theoretical section will discuss two theoretical approaches developed for analysing transition processes: the technological innovation system (TIS) approach and the multi-level perspective (MLP). According to several scholars that study the link between innovation policy and socio-technical change, these two theoretical approaches could serve as a foundation for analysing policy that aims at long-term transformation processes of energy systems and are concerned with explaining and guiding the creation of environments in which particular new technologies can emerge (Alkemade, Hekkert & Negro, 2011; Smith, VoB & Grin, 2010).

Thus, in order to develop a more elaborated assessment framework for the policy mix under study, the remaining of this theoretical section focuses on the theoretical approaches developed for analysing transition processes and the role of policy on these processes. After the general explanation of the two approaches, their complementariness will be discussed.

3.2 TIS approach

3.2.1. General explanation

Technological Innovation Systems (TIS) is developed to study the emergence of new technologies, the formation of technology-specific innovation systems around them and particularly to identify weaknesses (e.g. a lack of knowledge exchange, visioning or trust) in the systems that could be tackled by public policy (Bergek, Jacobsson, Carlsson, Lindmark & Rickne, 2008; Hekkert, Suurs, Negro, Kuhlmann & Smits, 2007; Janssen, 2016). The TIS is a systemic approach emphasizing that innovation is "a collective activity involving many actors and knowledge feedbacks and that innovation processes are influenced by their institutional settings and corresponding incentive structures, including the market as well as governmental policy" (Gallagher, Grübler, Kuhl, Nemet & Wilson, 2012, p. 140). Rather than conceptualising the innovation process as a linear progression of scientific research, the innovation system framework postulates that the development and diffusion of innovation are influenced by the environment in which it is embedded (Bergek et al., 2008; Gallagher et al., 2012; Hekkert et al., 2007). Scholars studying TIS argue that the analysis of technology-specific innovation systems is crucial for understanding processes of socio-technical transitions (Kivimaa & Kern, 2016). The TIS approach offers a well-developed basis for understanding how technology emerges by discussing the conditions needed for creating, applying and diffusing new technologies (Janssen, 2016). The approach is suitable for assessing the development of a particular innovation system. An innovation system includes not only the technology. It is also built up of societal subsystems, actors and institutions that are contributing in one way or another, intentionally or not, to the emergence and production of the innovation (Hekkert et al., 2007).

Within the TIS, several system functions are distinguished as a part of an innovation system that are needed for successfully applying an innovation on a large scale. Innovations are successfully applied on a large scale when the process and activities that started with local experiments ended up with new practices that are now business as usual on a societal scale. A main theme in TIS thinking is that it urges policy makers to address the functions most severely hold back successful developments of innovations (Wieczorek & Hekkert, 2012). For the success of an innovation system, certain activities need to take place. These activities are the 'functions' of innovation systems and contribute to the development and diffusion of innovation (Hekkert et al., 2007; Meelen & Farla, 2013). The central idea behind the TIS functions approach is that, through cumulative causation, different functions strengthen one another and together lead to a positive, self-reinforcing dynamic ('motors of innovation'), allowing a technology-specific innovation system to develop (Kivimaa & Kern, 2016; Suurs & Hekkert, 2009).

3.2.2. Functions of the innovation system

Assessing the above described motors of innovation is possible by means of an analysis of the seven functions of the TIS (Gallagher et al., 2012; Hekkert & Ossebaard, 2010; Hekkert et al., 2007; Meelen & Farla, 2013):

F1: Entrepreneurial activities

Entrepreneurs are crucial for innovation and are thus on the basis of the innovation system. Entrepreneurs have to turn the potential of new knowledge, markets and networks into concrete actions to generate and take advantage of new business opportunities. They can both be incumbents who diversify their business strategy to take advantage of new developments or new entrants that have the vision of business opportunities in new markets.

F2: Knowledge development

The development of knowledge is a prerequisite for the development of new products and services. 'Learning by searching' and 'learning by doing' is here of main influence. This knowledge development can either be fundamental research (R&D) and experimenting. During experimentations, unknown challenges regarding the technology can become visible.

F3: Knowledge exchange/diffusion in networks

Knowledges exchange accelerates the knowledge development process. As a result of knowledge exchange, "the wheel does not have to be invented again". The typical organizational structure of an emergent innovation system is the knowledge network that facilitates the exchange of information.

F4: Guidance of the direction of search

Guidance of the direction of the search means making wishes and expectations towards a specific technology explicit by actors within the innovation system. (National) Governments can help guiding the direction of the search for instance by setting energy targets. Furthermore, a selection process is needed for a convergent development in the TIS. It consists of policy goals and the outcome of technical and economic studies and the expectations about technological options.

F5: Market formation

For (radical) innovations, markets are not always immediately available since they have to compete with embedded technologies that have easier access to markets. This reduces the willingness to invest in new technologies. Thus, activities that create markets are very much urged for. Governments for instance can create new niche markets by means of subsidising specific products or give priority to certain technologies by means of tax exemptions. Market creation policy, such as the development of standardisations and regulations are seen as crucial for innovation.

F6: Resources mobilization

Without sufficient resources that are needed as a basic input to all activities within the innovation system, creating new knowledge will be more difficult. These resources can be financial or human capital. Especially radical innovation needs availability of resources.

F7: Creation of legitimacy/counteract resistance to change

The development of a new technology often encounters resistance from the current socio-technical regime. A lobby to generate support for the technology is necessary. Many actors do not benefit from (newly) sustainable technological changes. This can reduce the market share and position of the new product or service, resulting in higher needs for resources and changes in innovation strategies. In order to develop well, a new technology has to become part of an incumbent regime, or even overthrow it. Existing sectors often are well organised and have high influence on the policy processes. For this, advocacy coalitions can function as a catalyst; they put a new technology on the agenda [F4], lobby for resources [F6] and favourable tax regimes [F5], and thus create legitimacy for a new trajectory, thereby grow in influence and thus have a strong lobby. This however is dependent on the available resources [F6] and the expectations [F4] associated with the new technology (Hekkert et al., 2007).

3.3 Multi-level perspective

3.3.1. General explanation

The multi-level perspective (MLP) on technological change is based on co-evolutionary development of technologies, institutions and social and economic subsystems. Within this perspective, it is assumed that socio-technical change in the system is possible only through the interactions of three levels: niches, regimes and landscapes (Geels & Schot, 2007).

Niches

The *niche* level refers to the level where innovations and experiments are taking place outside the regime. Within the MLP, novelties emerge in niches, which are 'protected spaces' such as subsidised demonstration projects, R&D laboratories or small niche markets where users have specific demands and are willing to support emerging (sustainable) innovations. These innovations have the potential to reform or even transform the existing regime. Where regimes tend to produce 'normal' innovation patterns, 'revolutionary' change originates, according to the MLP, in niches (Kemp, Schot & Hoogma, 1998). This is the level where variations to and deviations from the status quo can occur, such as new techniques, alternative technologies and social practices. Niches are crucial for transitions, since "they provide the seeds for systemic change" (Geels, 2012, p. 472).

Regimes

Novel technologies however must compete with technologies that benefit from well-developed systems around them. *Socio-technical regimes* constitute the mainstream and are at the centre of the MLP. This level combines institutionalised practices, structures and self-evident patterns. This level is the 'conservative' element in the model since established practices and associated rules enable and constrain incumbent actors in relation to existing systems. Institutionalised practices and structures may create *path-dependency* and *lock-ins* and changes within the regime tends to be incremental. This means that interests, rules and beliefs that guide private action and public policy is focused mainly on optimising rather than transforming systems (Geels, 2014). The notion of socio-technical regimes not only encompasses firms and engineering activities, but also social groups such as policy makers, users and special-interest groups. Thus, it is not only the industry that is the pivotal regime actor (Geels, 2012). According to Rip and Kemp (1998), the notion of a regime assumes that actor behaviour is constrained by rules located at the collective level of the regime, which cannot be changed easily by individual action. While the notion of socio-technical systems refers to measurable and tangible elements (e.g. infrastructure and regulations), the regime emphasises intangible rules on which actors draw concrete actions (Geels, 2012).

Landscape

The pressure to change comes from the *landscape* level. Landscape is the wide socio-technical context surrounding the regime, relating to material and immaterial elements at the macro level. It consists of general societal values and norms, political changes and society's infrastructure. These are factors the regime actors can affect only just a little or indirectly. But mostly, landscape developments are beyond the control of individual actors (Geels, 2014; Geels, 2012).

To conclude, the MLP is able to provide insights on how innovations in niches can enter the existing socio-technical regime with the help of societal pressure on the so-called landscape level (Meelen & Farla, 2013). This perspective posits that top-down landscape pressures and bottom-up development of several emerging niches can lead to the destabilisation of incumbent regimes, offering opportunities for niches to break through and overthrow the regime (Kivimaa & Kern, 2016). It is suggested that governance schemes which take the socio-technical complexity of transitions into account are more likely to generate effective transition policy (Kern, 2012; Smith et al., 2010). Smith et al., (2010) and Kern (2012) argue that policy needs to destabilise incumbent regimes, promote radical niches and promote processes to bring these niches into the mainstream. As the MLP is mainly a descriptive approach for analysing processes of change, policy analysis and predicting policy outcomes by means of the MLP is more difficult. Nevertheless, it is argued that a policy analysis by means of the MLP can foster policy learning about how well existing policy instruments contribute to the processes that might enable transitions (Kern, 2012).

3.4 Integrating TIS and MLP

3.4.1. Relevance of integrating TIS and MLP

Although the TIS framework and the MLP have emerged largely independent of each other, they aim at explaining similar empirical phenomena (innovation and transformation processes) and are based on conceptual common grounds (Markard & Truffer, 2008). First of all, both approaches acknowledge phenomena such as path dependency, lock-in effects and the non-linearity of processes of change. Second, they both highlight the importance of networks and learning processes together with the crucial role of institutions for successful innovation processes. Third, both frameworks have also been developed towards informing innovation policy making (Ibid).

According to Meelen and Farla (2013), the strength of combining the two approaches lies in its complementariness. While the MLP on long-term transitions recently has attracted quite some interest as a framework for dealing with long-term processes of transformative change, the TIS approach is still seen as the dominant perspective for devising innovation policy. However, the TIS approach stresses the importance of improving innovation capabilities of firms and the institutional settings to support them. Therefore, the approach is less suited for dealing with the strategic challenges of transforming systems of innovation, production and consumption, and thus with long-term challenges such as climate change or resource depletion. It is therefore suggested to consider insights from the MLP more prominently in a policy framework that is based on the innovation systems approach (Weber & Rohracher, 2012). The MLP complements the TIS approach since the TIS gives less attention to the roles and strategies that different actors have, and to the interaction between actors and institutions. Furthermore, within the TIS framework, less attention is given by the influence of socio-technical regimes, niches and landscape developments on the technology within the TIS (Kern, 2012). On the other hand, strategies and roles of different actors, their interactions and institutions are given less attention in the MLP. The TIS function framework is claimed to be more powerful for analysing such dynamic processes as actor strategies and institutional changes. However, the TIS does not take the context in which technologies develop that rigorously into account, which is one of the strengths of the MLP (Meelen & Farla, 2013).

3.5 Developing the integrated policy assessment framework

In this section, conditions that are required for the stimulation of socio-technical change will be elaborated. Together, these conditions will form the policy assessment framework. This assessment framework will be developed for the ex-ante evaluation on the extent to which policy mixes sufficiently support transitions and technological developments. The assessment framework is based on an extensive literature search of studies using the MLP and TIS to develop policy recommendations for improving innovation policy. The integration of both theoretical framework into assessment frameworks concerning policy mixes is based on the studies of Meelen and Farla (2013) and Kivimaa and Kern (2016), supplemented with other studies in the field of innovation policy and the approaches of TIS and MLP.

A focus in this assessment framework lies on two different types that have been highlighted to be of importance for sustainability transitions: the creation niche innovations and the destruction of regimes structures (Kivimaa & Kern, 2016). For the creation of niche innovations, the TIS functions approach offers a rather comprehensive list of innovation-inducing processes that policies can (potentially) address (Kivimaa & Virkamäki, 2014). In contrast, the destruction of incumbent regimes is a much more complex process and policy instruments aiming for regime destruction often are less abundant (Kivimaa & Kern, 2016). Nevertheless, Hekkert (2010) argues for consistent and long-term innovation policies that put pressure on (the lock-in of) the current technological regime. This is seen as a highly important condition for sustainability transitions.

The conditions, of which a successful policy mix should consist, according to the literature search, have been found mainly on the niche level, and to a lesser extent on the regime and landscape level. First, the conditions that should be present for the stimulation of niche creations will be discussed. Second, the regime destructive conditions will be discussed followed up by policy strategies in accordance with landscape developments. The assessment framework that combines all identified conditions will be presented in section 3.6.

3.5.1. Niche creative

TIS function 1: Entrepreneurial experimentation

Stimulating entrepreneurship: As entrepreneurs are identified as crucial for innovation (Geels, 2012), their entrepreneurial activities are highly important to be stimulated. Entrepreneurial experimentation is important among others for reducing of uncertainties as a consequence of testing of new technologies (Bergek et al., 2008). Furthermore policy needs to enable piloting, the stimulation of R&D activities and other forms of learning (Bergek et al., 2008; Kivimaa & Kern, 2016). R&D funding for the development and testing of technologies are at the core of niche-innovations (Bergek et al., 2008).

Relaxed regulatory conditions for experimenting: A technology and well-functioning innovation system around the technology can only evolve if there are “actors that explore and exploit new opportunities by conducting experiments, delving into risky and uncertain markets and technologies and challenging institutions” (Jacobsson & Bergek, 2011, p. 48). Regulatory conditions need to be sufficiently clear (Kivimaa & Kern, 2016). However, rules and regulations often can hinder experimental freedom. Relaxed regulatory conditions for experimenting include possibilities to have exemptions, or have less stringent regulatory frameworks that need to be complied to (Kivimaa & Kern, 2016). Van Alphen, Hekkert and Turkenburg (2010) argue that regulatory flexibility around demonstration projects leads to better insights in new systems. However, a strong regulatory framework would be helpful to minimise concerns in the public at large, which is related to function 7, that of legitimacy. Nevertheless, experimenting with different institutions such as rules and regulations is needed for transformational change, and thus must regulatory flexibility be facilitated.

TIS function 2: Knowledge development

R&D funding schemes: Mechanisms of learning are at the heart of any innovation process. Therefore, financing and facilitating R&D is crucial for innovation (Negro et al., 2008). This involves R&D funding schemes at multiple phases of technological innovation. This includes funding schemes for fundamental research, feasibility studies, pilot projects, etc.

Competence building: For fully optimising R&D funding schemes, it is argued that young entrepreneurs could benefit from complementary services other than financial aid, especially concerning their connection to external partners which could include specific services for young companies and coaching to starting entrepreneurs. Furthermore, advisory support programmes in parallel with their financial support can help entrepreneurs to seek the right markets. Finally, small firms should be assisted with preliminary market studies before they commit to a full project (Cunningham, Edler, Flanagan & Larédo, 2013). Therefore, Kivimaa and Kern (2016) argue for the importance of competence building programmes and training schemes as critical niche support.

Facilitation and funding of commercial scale demonstrations (higher order learning): Facilitating and financing commercial scale demonstration triggers learning-by-doing. Successful demonstrations increase options for further development and make hidden knowledge deficits visible (van Alphen et al., 2010). Therefore, commercial scale demonstrations are identified as crucial for innovation processes. These demonstration projects are in need of financial support, since often there are no customers yet that fully agree to pay for non-proved innovations (Ibid). Profit-seeking companies often are risk-averse and may be hesitant to invest in longer term and high risk learning projects, in particular demonstration projects on a large scale. For achieving commercial scale demonstrations, funding is needed in order for firms to set-up large scale experiments (Jacobsson & Bergek, 2011). According to Negro, Alkemade and Hekkert (2012), in the Netherlands, there is a trend observed where large budgets for R&D are provided while there are hardly any instruments available for large scale demonstrations and early market formation. Within this phase in the innovation process, there are high uncertainties about market success that are coupled with high investment costs for building production capacity. Since many innovations do not survive this large-scale demonstration/early market introduction phase, it is also called the 'valley of death', which should be prevented among other by means of public policy (Negro et al., 2012).

TIS function 3: Knowledge diffusion

Coordination of intellectual property rights: Van Alphen et al., (2010) state that protected intellectual property rights can hinder the diffusion of knowledge. Well coordination of intellectual property rights can increase knowledge diffusion, for instance by means stimulating open knowledge networks (Meelen & Farla, 2013; van Alphen et al., 2010).

Stimulation of platforms for knowledge diffusion: Strengthening the knowledge base and how that knowledge is developed [F2] is not only about R&D support but also about support for networks as network weaknesses can hinder knowledge development (Kivimaa & Kern, 2016). In order to have improved knowledge diffusion in networks, platforms and new spaces for learning need to be stimulated (Smits, Kuhlmann & Teubal, 2010).

TIS function 4: Providing guidance of the search

Targeted R&D funding schemes: It is argued that generic innovation policy is unlikely to be optimal for spurring innovations in clean power-generating technologies (Aalbers, Shestalova & Kocsis, 2013). Reasons for a more specific innovation policy can be to have the ability to guide innovation into a specific sector (e.g. sustainable electricity systems instead of unsustainable) and that electricity sectors are characterised by sector-specific knowledge accumulation processes. This means that advances in the clean electricity sector makes future advances in that sector more profitable or effective in comparison to the grey electricity sector. However, Aalbers et al., (2013) stress that a move towards less generic innovation should not fully be “picking winners”, since a certain amount of R&D diversification remains optimal. Governments should not entirely decide which technological directions are optimal for sustainability transitions.

Clear regulatory frameworks: Regulatory instruments use legal tools for the regulations of social and market interactions. Regulatory instruments can include laws, rules and directives. The logic behind using these types of instruments by governments is to make sure innovation processes taking place in a fair and safe manner. They should provide clearly defined boundaries of what is allowed and what is not allowed. However, as the goal of innovation processes is to come up with something new, unclear regulatory frameworks often can hinder the development of such innovations (Jacobsson & Karltorp, 2013). Furthermore, when regulations are not clearly defined for technologies or demonstration projects, they increase insecurities possibly leading to less investments from third parties (Borrás & Edquist, 2013).

TIS function 5: Market formation

Favourable tax regimes and/or tax exemptions: Since new technologies often have difficulties to compete with embedded technologies, favourable tax regimes can provide niche innovations with competitive advantages against incumbent technologies (Hekkert et al., 2007; Wieczorek, Hekkert, Coenen, & Harmsen, 2015).

Standardisation: Issues concerning standards are especially relevant for sustainability transitions, because sustainable technologies often differ significantly from existing technologies and thus require new standards. A lack of standards can hamper innovation processes. They for instance can include technological standards that requires safety of technologies, or standards and protocols concerning market rules (Smink, Hekkert & Negro, 2015). Market development is only possible when right standards are set. Therefore, they are seen as a powerful mean for supporting innovation (H. van der Wiel, expert session NCA, June 22, 2017).

Deployment subsidies: Hoppmann, Peters, Schneider and Hoffmann (2013) performed research on deployment subsidies in the solar PV industry, and concluded that deployment subsidies are generally effective in fostering technological innovations. They can be a highly effective catalyst for innovation activities since they provide much security that besides R&D, market formation is stimulated by public policy as well.

TIS function 6: Mobilisation of resources

Financial and human support: Adequate resources in terms of financial and human capital are not always present, but they often need to be mobilised on the system level. For a well-developed innovation system, large-scale development and diffusion of such technologies, massive funds generally are required (Jacobsson & Bergek, 2011). Mobilisation of resources is a general activity for most innovation funding schemes. Both financial as well as human capital is necessary as a basic input to all activities within the innovation system. For knowledge development [F2] concerning a specific technology, the allocation of sufficient resources is crucial. Thus mobilisation of resources is highly connected with function 2 of the TIS (Hekkert et al., 2007). However, resources are also needed for all phases of the innovation process. Innovation processes can be captured in different levels of *technology readiness* (Mankins, 1995). These are levels that cover all phases of the innovation process that are in need for the mobilisation of resources: the phases of discovery, development, demonstration and deployment (see Annex 3 for a more elaborated explanation on the TRL levels). With respect to human capital, a generic problem in (large scale) transformation processes is access to specialised human capital, which make human support highly important (Jacobsson & Bergek, 2011).

TIS function 7: Creation of legitimacy

Lobby practices: As stated in section 3.2, new technologies can face resistance from the current socio-technical regime. In order to become part of the new regime, advocacy coalitions need to lobby for their new needs and function as catalyst by putting the new technology on the agenda [F4], lobby for resources [F6] and favourable tax regimes [F5] (Hekkert et al., 2007). However, lobby practices are not a matter of policy but are the responsibility of other actors in the field of technological development.

Inclusion of entrepreneurs in policy making: Entrepreneurs and other relevant actors active in the innovation system should be included in policy making in order to create more legitimacy for newly developed technologies (Meelen & Farla, 2013).

3.5.2. Regime destruction

As stated before, policy instruments within policy mixes for (sustainable) innovation should not only focus on the creative side but also at the destructive side of the current socio-technical regime (Wesseling & Van der Vooren, 2016). "[..] solely relying on the emergence and growth of a variety of alternatives to replace incumbents systems will be too slow" (Kivimaa & Kern, 2016, p. 206).

Note that on the regime level, not all functions of the TIS are found to be stimulated by means of public policy. Put pressure on existing regime. As a result of the literature search, only functions 4 till 7 are part on the assessment framework.

TIS function 4: Providing guidance of the search

- Prepare regime for new technology: This is a broadly defined condition, but an indispensable condition according to Meelen and Farla (2013). Structures of the old socio-technical regime, that hamper the development and introduction of innovations, should be adapted in order to provide optimal circumstances for a newly emerged technology. These structures include institutions, predominant rules, organisations, infrastructures and routines (Meelen & Farla, 2013).

TIS function 5: Market creation

Weakening of existing regime: Tax policies and regulations for incumbent technologies (e.g. pollution taxes) can weaken the existing energy regime. According to Aalbers et al. (2013) do the economic advantages of sustainable technologies over unsustainable technologies largely depend on environmental policy stringency on the national level but mainly on the global level, such as global carbon taxation. The market for clean energy services and technologies would remain relatively small when carbon prices are not included in production and consumption processes. However, considering the current reluctance of many governments to sign even moderate environmental agreements, large increases of carbon taxes worldwide are, especially on the short-run, probably not feasible. Still, Aalbers et al., (2013) do not disregard carbon taxes and other environmental policies that are meant to internalise the environmental damage by polluters since ultimately, they are needed to create the markets for clean energy technologies.

Kivimaa and Kern (2016) found in their policy mix analyses of Finland and the UK few instruments that contribute to the destabilisation of existing regimes compared to instruments for niche support. First of all, destabilisation policies are politically difficult since phasing out for instance the use of coal and oil requires huge political endeavour and is therefore only possible under exceptional circumstances (Kivimaa & Kern, 2016). Secondly, designing policies with the aim to undermine existing regimes is challenging since they present a contradictory ideology to that of tradition innovation policy often aimed at economic growth instead of sustainable development (Alkemade et al., 2011). Nevertheless, the existence of control policies such as carbon prizing, regulations or emission trading systems will still be in need for further discussion.

Adapting and develop institutions: For the creation of markets, temporal subsidies and tax credits can be a first step. However, this should be in combination with changes in the institutional infrastructure. Therefore, regimes can be adapted to new technologies by changing institutions such as tax regimes fundamentally over the long time, or add new institutions that are (more) in favour of the new technology (van Alphen et al., 2010).

TIS function 6: Resource mobilisation

Withdrawing support for incumbent grey electricity technologies: Withdrawing support for incumbent technologies differs from the condition *weakening of the existing regime* that requires the introduction of instruments specifically focussing on regime destruction. Withdrawing of support for instance includes cutting R&D funding for non-sustainable technologies, removing subsidies for fossil fuel production. Kivimaa and Kern (2016) state that indirectly, the removal of support for fossil fuels is a measure for destabilising the high-energy regime with clear implications: reduced support for fossil fuel exploration and production may increase energy prices and, thereby, increases incentives for low energy innovations.

Creation of legitimacy / counteracting resistance to change

Policy advisory council with niche actors: Often, close relationships between government and key regime actors is seen as a major source of lock-in (Unruh, 2000). The destabilisation of regimes can also involve the replacement of actors, from incumbent actors to new ones (niche-actors). It is argued that the breaking up of established actor-network structures to bypass traditional policy networks to provide windows of opportunities for niche-innovation to break through within the new regime (Rotmans, Kemp, & Van Asselt, 2001).

Formation of new organisations linked to system change: Not only networks are in need for a change but also organisations. Actors can organise themselves around their particular interests (e.g. actors active in the extraction, transport and use of natural gas) and can therefore be a source of lock-in of (gas) energy systems. Therefore, new organisations need to be formed that take on tasks linked to system-change (Kivimaa & Kern, 2016).

3.5.3. Landscape level

As stated before, landscape developments can only be affected slightly. But mostly, landscape developments are beyond the control of individual actors (Geels, 2010). However, according to the MLP literature, it is of utmost importance to make use of landscape developments for policy-making, and to develop short-term and long-term policy goals that are in accordance with these developments. Thus, there are no specific policy instruments at the landscape level. However, policy strategies and principle plans in accordance with landscape developments should be present (Borrás & Edquist, 2013).

TIS function 4: Providing guidance of the search

Short term and long-term policy goals: According to Bergek et al. (2008), governments can provide guidance for the search [F4] by setting short term and long-term policy goals in relation to the technology. Although landscape developments are difficult to influence, they can open up 'windows of opportunities' for promising technologies. For the identification of such promising technologies, policy makers should be aware of the trends at the landscape level (Markard & Truffer, 2008). Thus, there is a need for long-term visions that are in accordance with the slow trends of the landscape developments, since long-term innovation policies can put pressure on (the lock-in of) the current socio-technical regime (Meelen & Farla, 2013).

The combined policy mix assessment framework will be provided in the next section.

3.6 Policy assessment framework

According to the literature carried out in the previous sections, should a policy mix consist of all the conditions that combined form the policy assessment framework as can be seen in table 2.

Table 2: Integrated policy assessment framework of policy mixes for innovation and socio-technical change

TIS function	Instrument mix	Instrument mix	Policy strategy
	Creative (niche support): Technology push, market pull & systemic instruments	**Regime destructive**	**Landscape development**
F1	*- Stimulation of entrepreneurship* *- Relaxed regulatory conditions for experimenting*		
F2	*- provision of R&D funding schemes* *- Stimulation of higher order learning: facilitate and subsidise commercial scale demonstrations* *- Competence building (training programmes, educational policies)*		
F3	*- Coordination of intellectual property rights* *- Stimulation innovation platforms or platforms for knowledge diffusion*		
F4	*- Targeted R&D funding schemes* *- Clear regulatory frameworks*	*- Prepare regime for new technology*	*- Short term and long term policy goals*
F5	*- Favourable tax regimes* *- Tax exemptions* *- Standardisation* *- Deployment subsidies*	*- Weaken existing regime: tax policies and regulations for incumbent technologies (e.g. pollution taxes)* *- Adapting and creating new institutions*	
F6	*- Financial: R&D funding, deployment subsidies, venture capital* *- Human: educational policies, labour-market policies*	*- Withdrawing support for incumbent grey electricity technologies*	
F7	*- Lobby practices for niche-technologies* *- Inclusion entrepreneurs in policy making processes*	*- Formation of new organisations linked to system change*	

4. Methodology

The following chapter will elaborate on the methodological approach that is used in order to achieve the objectives of this research.
Firstly, the sample selection strategy will be discussed (section 4.1), followed by the operationalisation of the conditions of the assessment framework (section 4.2). Third, the data collection strategy will be elaborated (section 4.3). Finally the data analysis method that is used to meet the research objectives will be discussed (section 4.4).

4.1 Sample selection strategy

The assessment framework will be used empirically to assess the policy mix concerning energy storage. Data for this assessment was primarily acquired through a multitude of semi-structured interviews. Semi-structured interviews allow for the exploration of respondent's ideas and perceptions with regard to complex topics and issues (Bryman, 2015). This type of interviews also allows probing for more information and clarification of answers. This study aimed at conducting around 15 Interviews as Guest, Bunce and Johnson (2006) state that data saturation occurs when at least 12 interviews are performed.

Methodological explanation of interview respondents

As stated in the theoretical section, within the MLP, it is assumed that socio-technological change in the system is possible only through the interactions of three levels: niches, regimes and landscapes. As a consequence, niche and regime actors have been contacted for conducting interviews. A main focus here lied on interviewing entrepreneurs, which is highly relevant since this group is identified as crucial for innovation (Geels, 2012). In order to have sufficient insights in the policy mix and policy challenges regarding energy storage, policy makers active in this field have been interviewed as well.

Gathering interview respondents

The interview respondents were found by searching the web for actors via platforms and interest groups such as "Platform Energy Storage NL" and via connections that the Netherlands Court of Audit has. Platform Energy Storage NL is a platform for the representation of interests of actors in the field of energy storage. Entrepreneurs, research institutes, grid administrators as well as policy makers are involved within this platform. They furthermore have a LinkedIn group which made it easy to contact interview respondents. Snowballing technique (other stakeholders of interest that have been mentioned during interviews) has been helpful to gather further relevant respondents.

19 emails have been sent to possible relevant actors for conducting the interviews. However, not all actors reacted on emails or phone calls, or were interested in giving an interview. With a total of 12 interviews, all four types of respondents have been interviewed.

Interview respondents

The following actors have been interviewed by means of semi-structured interviews:
- *Policy-makers* involved with policies regarding energy storage. These were civil servants involved within innovation policy making, including actors from Ministry of Economic affairs, Netherlands Enterprise Agency (RVO), and the Top sector Energy.
- *Niche actors* including: Start-ups or SME's that are active in entrepreneurial activities regarding energy storage. Also an actor from the entrepreneurial interest's organisation FME (fme.nl) has been interviewed.
- *Regime actors* were more difficult to identify in advance of the research. However, as grid administrators are deeply involved in innovation processes with regard to energy storage, they have been interviewed as well.

- *Researchers or knowledge institutes*. These included researchers studying the technologies of energy storage (DNV GL), or researchers studying policy issues with regard to technology and the energy transition (Netherlands Environmental Assessment Agency (PBL)).

See annex 4 for the overview of all interview respondents.

In advance of the interviews, respondents we informed on privacy and confidentially matters. If required by the respondent, the collected data was anonymised. Additionally, the interviewees were asked whether the interview may be recorded for coding purposes. This is done to meet the informed consent criteria of a scientific study (Bryman, 2015). First, an exploratory interview in order to acquire more feeling for the energy storage technologies and to understand the role government policy has been performed. The interview questions were fully based on the assessment framework that has been developed (table 2).

4.2 Operationalisation

The policy assessment framework developed in chapter three has been used as guidance for the development of indicators for analysing how the policy mix influences the dependent variable: socio-technological development of technologies for energy storage. These indicators have been operationalised into topics that were used as guidance to develop interview questions. With the help of the descriptions in the theoretical section of all conditions of the assessment framework, the indicators have been developed. See annex 5 for this operationalisation of the conditions described in the policy assessment framework into operationalised indicators. The interview questions, based on these indicators can be found in annex 6.

Although this research has been highly qualitative, the operationalisation has led to possibilities of value judgment concerning all conditions of the assessment framework. Not all interview respondents received the same interview questions. This mainly is a result of the variety of the roles of interview respondents (e.g. entrepreneurs were asked other questions than policy makers). As a consequence, it was difficult to score the frequency of certain topics that were discussed. This made scoring the indicators difficult. As a solution, scoring the indicators was based on whether there was consensus about certain discussed topics or whether there were mixed opinions or uncertainties. As a result, the conditions as developed in the assessment framework were able to be scored by plusses and minuses in order to provide a clear overview of how the conditions from the assessment framework are stimulated or hindered by the identified policy mix. “Very high” score on consensus means that all interview respondents agree that a certain framework condition is either very positively or very negatively influenced by the policy mix. “High” score on consensus means that most of the interview respondents agree that a certain framework condition is positively or negatively stimulated by the policy mix, however, some comments were made that point into a different direction. Neutral means that either there is a lack of information, or that there was no consensus about a specific framework condition. In table 3 the scoring system is provided.

Table 3: Scoring system of the operationalised framework conditions

Score	Explanation	Consensus
++	Very positively influenced by the policy mix	Very high: all interview respondents agree
+	Positively influenced by the policy mix	High: most of the interview respondents agree
-/+	neutral	No consensus / too many uncertainties
-	Negatively influenced by the policy mix	High: most of the respondents agree
--	Very negatively influenced by the policy mix	Very high: all interview respondents agree

4.3 Data collection

The most important form of data has been gathered by means of the semi-structured interviews. Besides interview questions based on the indicators in annex 5, the interview respondents have been asked questions about what all relevant policy instruments and programmes are that combined form the policy mix concerning energy storage. This has been done in order to make sure whether this list was complete. Not all respondents were asked the same interview questions. The selection of interview questions per respondent was based on the expertise of the interview respondent. For instance, entrepreneurs mostly were asked questions regarding their entrepreneurial activities and their opinion on regulatory freedom etc., while policy makers mainly were asked questions regarding policy instruments and programmes. The semi-structured interviews gave sufficient room for the respondents to give information and opinions on the matters that were, according to the interviewees, most relevant.

According to Yin (2003), the analysis of a case improves when diverse sources of data are included. Therefore, other data is collected by making use of additional sources such as scientific literature, grey literature (policy documents) and informal outputs such as websites and newspaper articles.
The grey literature consisted of:
- Webpages from RVO for identifying all relevant policy instruments regarding R&D funding and demonstrations etc. Furthermore RVO published results from pilot/demonstration projects regarding smart grid projects, of which some include energy storage demonstration projects.
- Newspaper articles from Energeia (FD media group), to become aware of all recent developments concerning energy storage: what projects are running, what recent discussions are about energy storage and to read about opinions of actors in the field.
- Formal output of the platform Energy Storage NL. In collaboration with all actors this platform has done research about the (institutional) barriers that energy storage technologies face within the Dutch innovation landscape. The platform has published a national action plan for energy storage and roadmaps towards innovation for storage technologies.
- Other policy documents providing information on relevant laws and regulations. This includes among others information documents on laws such as the Electricity Law (elektriciteitswet) and on descriptions of policy instruments.

4.4 Data analysis

A methodological implication of using semi-structured interviews and grey literature is that the indicators of the assessment framework could only be analysed in a qualitative manner. As all of the data was qualitative, getting valid conclusions was difficult and caution was needed with the generalisation of the results. In order to analyse the data, it was processed in the following manner. First, in addition to the audio records, notes and memos were made during the interview to serve as a starting point for the data analysis. Secondly, together with the audio records, these were used to make transcripts. Thirdly, the coding process started by carefully reading through the transcripts and labelling as many so called first-order concepts (open coding), while also filtering out non-related content. The data was coded according to the conditions that were created in the policy assessment framework (table 2). From the textual interviews, fragments were assigned to the codes they belonged to. In this step, it was important to be aware of an interpretation bias. There were fragments that fully agreed with the codes of the assessment framework. However, sections that seemed important but which cannot directly be assigned to a code were highlighted for further analysis. These fragments were re-evaluated for patterns to see whether they fitted to one of the assessment framework conditions.
For the data analysis, ATLAS-TI was used. This is a tool for qualitative analysis of large bodies of textual data and is currently tested by the Netherlands Court of Audit for its added value for the organisation.

As the coding process was finished, the next step was drawing conclusions upon the analysable data. Analysing all data had to lead to (i) a description of the relevant policy instruments that together form a mix, (ii) how this policy mix is stimulating the development of energy storage by focusing on niche creative and regime destructive elements, and (iii) how this can be improved. The grey literature served as an extra information source in order to fill in gaps that were not fully filled after analysing the interview transcripts.

4.5 Research steps

Figure 2 presents a schematic representation of the necessary research steps to achieve the stated research objectives (Verschuuren & Doorewaard, 2010).

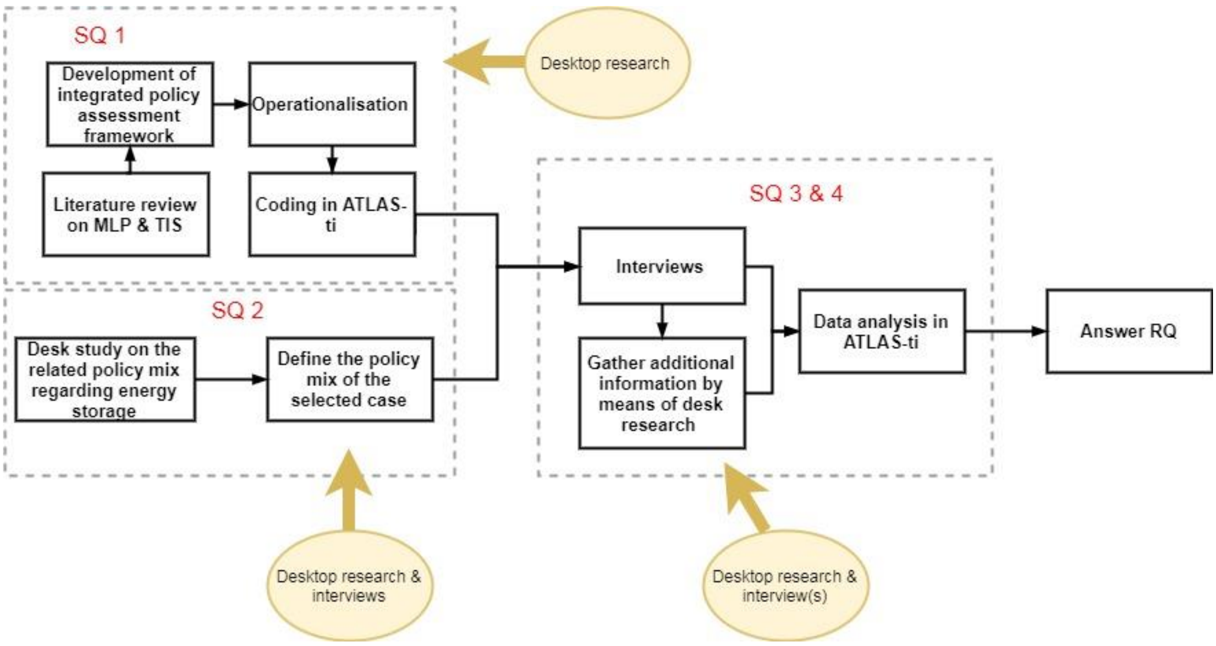

Figure 2: Research steps

5. Results: the policy mix

Before analysing how the policy mix influences innovation of energy storage technologies, the policy mix needs to be identified. This will be elaborated in this section. Firstly, all relevant 'creative' policy instruments (including technology push and market pull instruments) will be identified. Secondly, regime factors that are identified as a barrier for the development of energy storage will be discussed, followed by the identification of systemic instruments for the 'destruction' of these regime factors. Finally, the presence of principle plans that are policy targets and roadmaps will be discussed. The section ends with an overview of all relevant policy instruments, programmes and principle plans relevant for all conditions as elaborated in the assessment framework.

5.1 Creative energy innovation policy: technology push

In this section, first background information will be given on the creative Dutch energy innovation instrumentation in general, of which many policy instruments are used for fundamental research, R&D, experimentation and deployment. A focus in this background description lies on those policy instruments and programmes that were the result of a desk study as relevant for energy storage and that have been confirmed or supplemented by the interview respondents.

5.1.1. Enterprise Policy

The Ministry of Economic Affairs is the main innovation policy making government agency in the Netherlands. In 2010, this Ministry launched their new *Enterprise Policy.* The primary goal of this policy strategy was to strengthen the competitiveness and innovative abilities of the Dutch economy (Janssen, 2016). The new enterprise policy aimed to realise these ambitions through two main policy tracks: a generic track and a top sector track. This innovation and enterprise policy combined improvements in general framework conditions with targeted support to nine top sectors of the Dutch economy (van der Wiel & van der Kroon, 2014). Both policy tracks will be shortly introduced as they include the most relevant niche creative policy instruments and programmes with regard to innovation of energy storage technologies.

Generic enterprise policy track

The generic track is an "economic agenda" for the entire private sector. A primary aim of this generic enterprise policy is the stimulation of private spending on R&D. This track focuses on (i) the improvement of framework conditions to strengthen the innovation, (ii) reducing the burden of regulation, (iii) to improve access to risk capital and (iv) to underline the need for qualified staff and good interaction between the education system and the labour market. RVO (Netherlands Enterprise Agency) is the main organisation that provides this entrepreneurial policy support As this is a generic track, available generic instruments are open to all (innovative) enterprises in the Netherlands (Van der Wiel & Van der Kroon, 2014).

Besides the above described aims of this policy track, there is also a focus on reducing cost of R&D and hence to increase private R&D. The main policy instruments used for this for innovating in energy storage technologies is *WBSO ('Wet Bevordering Speur- en Ontwikkelingswerk').* This is a tax credit for R&D-personnel, which thereby lower the cost of R&D.

Specific enterprise policy track: Top sector approach

The Enterprise Policy also includes a specific *Top sector Approach*. This policy approach aims at improving the role that businesses have in innovation, with providing more room for entrepreneurial activities. Furthermore, the goal was to let start-ups and SME's profit more from scientific research by public knowledge institutes. This top sector policy approach is sector specific, in which central and regional governments are working together with knowledge institutes and enterprises on comprehensive agendas in public-private partnerships project (so-called "golden triangle"). The aim of this approach is that the applicability of scientific research for both commercial and social purposes increases the return on public funds devoted to research. For this, nine top sectors came into existence, which were sectors where the Netherlands is best at (Janssen, 2016; Van der Wiel & Van der Kroon, 2014). The top sector most relevant for energy storage is the *Top sector Energy (TSE)*.

Parties collaborating in the top sectors established so-called *Top Consortia for Knowledge and Innovation* (TKI's), which implement the research agendas in "innovation contracts". In these contracts, governments, companies and knowledge institutes form agreements on how resources, that are assigned for knowledge and innovation, will be used in each top sector to build on existing scientific knowledge and to meet the need for innovative solutions to societal challenges. The research agenda's, so-called "knowledge and innovation agendas" are set up by each top sector, and contain the content of what technological directions the top sector aims at, and what barriers for innovation need to be tackled. These agendas are carried out by TKI's (van der Wiel & van der Kroon, 2014).

Besides these innovation contracts, there are policy programmes that aim at financially supporting innovative firms and entrepreneurs within the specific top sectors. These instruments include:
- *TKI-surcharge*: This measure provides a top-up of 25% for every euro firms are spending on public-private research collaboration.
- *Direct TKI funding* for networking and advising activities.

Note that there is a broad variety of funding schemes resulting from the TKI's. However, the two above have been mentioned as relevant for energy storage.

Top Sector Energy

As energy innovation is in the portfolio of the Top Sector Energy (TSE), the TSE will be discussed below in more detail. The TSE consist of five TKI's, that all have their own role within innovation of specific energy systems: *TKI offshore wind*, *TKI energy and industry*, *TKI Urban Energy*, *TKI Biobased Economy* and *TKI Gas*. Furthermore, there are four more policy programmes within the TSE that are not part of a TKI:
- *Socially Responsible Innovation*: Aims at insuring that not only technological and institutional development takes place, but that there also is sufficient focus on social innovation;
- *International Export and Knowledge agenda*: focuses on international collaboration and knowledge exchange;
- *Human Capital Agenda*: focuses on how the energy transition not only creates employment, but also on how to deal with jobs within current energy sectors that will change dramatically;
- *System Integration*: This fourth programme is highly relevant for energy storage and will therefore later be discussed in more detail.

On a yearly basis, the TSE supports projects concerning energy innovation with around a 100 million euro on innovation funding schemes. Every TKI has its own specific R&D funding schemes. These include subsidies for feasibility studies (all TKI's), or R&D funding for specific technological directions relevant for their TKI (i.e. funding schemes for wind mill innovation from TKI Offshore wind). Furthermore, within the TSE, there is another funding scheme discussed by interview respondents as relevant for the innovation of energy storage that is not specifically assigned to TKI's: *Demonstration Energy Innovation (DEI).* This is a funding scheme developed specifically for commercial-scale demonstrations. For this demonstration subsidy programme, pilot-projects need to be finished successfully, and are ready to be introduced into the market. In this phase, the technology is proven to work but not yet on large scales. Funding is still necessary since firms have no customers and no evidence that the technology actually works on a large scale. Furthermore, in order to better support experimentation projects, actors that innovate with energy innovation technologies can apply for the *experimentation administrative decree (*NL: *experimenten AMvB*). This is a tender focused on creating regulatory freedom for experimentations. Consortia can apply for this tender in order to get an exemption of certain laws and regulations.

Other funding schemes

There are other relevant (technology push) creative policy instruments that are not a part of the *New Enterprise Policy.* These will be discussed in further detail. They include subsidy programmes from public agents such as NWO (Dutch institute for Scientific Research). NWO distributes subsidies to universities and other research institutes (financial contributions for these subsidies are originating from the Ministry of Education, Culture and Science). Therefore, it contributes to fundamental research, thus the explorative phases of innovation (RVO, 2015a).

Furthermore, the *SDE+ funding scheme* is the most important Dutch deployment subsidy in the form of an operation grant. Producers receive financial compensation for the renewable energy they generate. Production of renewable energy is not always profitable since the cost price of renewable energy is higher than the market price. SDE+ compensates producers for this unprofitable component for a fixed number of years, depending on the technology used (RVO.nl, 2017). However, as most of the energy storage technologies are not yet market ready, they do not make use of deployment subsidies. But this policy instrument is identified as relevant for providing more certainties for future investments.

Furthermore, besides the generic and top sector policy tracks, there are several other funding schemes that are used by entrepreneurs that innovate within energy storage. These include European, regional and local innovation funding schemes.

According to E. Buddenbaum (personal communication, May 3, 2017), who is secretary of the TSE, the specific and generic policy track combined have technology push instruments that cover all *technology readiness levels* (TRLs) of technologies (see annex 3), which is the central idea behind the development of the mix of technology push instruments that are described above.

The table below provides an overview of all funding schemes that have been mentioned in the interviews and grey literature concerning energy storage.

Table 4: Schematic overview of all identified technology push instruments and programmes relevant for energy storage on all TRL-levels

Phases in innovation system (TRL)	Funding schemes and policy programmes
Discovery	- NWO funding schemes - RVO entrepreneurial support programmes
Development	- WBSO - TSE funding schemes - TKI-surcharges - Funding for feasibility studies by System Integration Programme - RVO entrepreneurial support programmes
Demonstration	- Demonstration Energy Innovation (DEI) - RVO Demonstration administrative decree
Deployment	- SDE+

5.1.2. Creative energy innovation policy: market pull instruments.

In this section, the identified market pull instruments relevant for energy storage will be discussed. Market pull instruments are policy instruments which work to achieve their objective by increasing demand for products or services regarding with particular characteristics.

For energy storage, standard setting is seen as needed market-pull policy instrument. Standards can include requirements regarding the interoperation ability of storage technologies (e.g. that all technologies can be physically connected by means of interoperationable grid connection systems) or requirements concerning privacy and security of storage systems (A. Even & N. Kerkhof, personal communication, May 15, 2017). Furthermore, they can include standards on how to adopt energy storage and its related services within the rules of the energy markets. According to A. Even and N. Kerkhof (RVO) (personal communication, May 15, 2017), a lack of standardisation hampers innovation processes. Currently, there are no standards on how to fit energy storage technologies and services within the energy system and energy market. This is seen as a major barrier for the innovation and adoption of energy storage (J. Knigge, personal communication, July 11, 2017). Consequences of the lack of standardisation will be further discussed in section 6.1.5.

Other relevant market-pull instruments are tax regimes favouring the adoption of energy storage. These have not been identified. Instead, there only tax regimes have been identified that hamper the adoption and market creation of energy storage technologies and services. This will be discussed in the next section.

5.2. Regime destructive policy instruments: systemic instruments

5.2.1. Identification of institutional barriers and systemic instruments for the adaptation of institutions

Before identifying instruments for the destruction of the current socio-technical regime, institutional barriers, e.g. barriers resulting from formal institutions such as laws, regulations and market rules needed to be identified. After performing the interviews, several formal institutions that hamper development and adoption of energy storage were identified. These institutional barriers are discussed below. Furthermore, it will be discussed whether these barriers are currently under the process of adaptation and what systemic instruments for this are in place.

Electricity Law

The Dutch Electricity Law originates from 1998. This law sets rules for the energy market and actors active in the market. This law is in constant adaptation resulting from new developments within the energy market and system. However, according to several interview respondents, this law still is too much focused on a centralised energy provision: a focus lies on large-scale electricity generation by major private energy producers, long-distance transport of electricity, distribution to the consumers and the energy consumption of central generated electricity. Within this value chain, energy storage is not yet defined. Despite the increasing electrification, decentralised energy production and the acknowledged need for strategies that sustain grid flexibility, these needed activities are not yet included in the Electricity Law. This leads to unnecessary costs, uncertainties and other barriers that could be minimised by further updating the Electricity Law. The two main consequences mentioned as barriers for innovation and adoption of energy storage technologies resulting from the outdated Electricity Law are double energy taxations and uncertainties regarding the role that grid administrators can fulfil in grid flexibility projects. These will be discussed further below.

Effort has been put into the adaptation of the Electricity Law. The *Law Progress Energy Transition* (NL: *Wet Voortgang Energietransitie)* aimed at modernising this law and to fit it more closely to the needs of the energy transition. The aim is, by means of this law, to support the energy transition among others by clearly defining roles of public actors such as grid administrators and private market parties. It could therefore be seen as a systemic instrument aiming at adaptation of current legislation to the needs of transition processes.

Energy taxation

Actors (households or firms) that store energy are obliged to pay double energy taxation. First, taxes need to be paid by actors that store energy (taking it from the grid to charge storage systems) and again after discharging the storage systems (bringing it back to the electricity grid). There is much consensus among all interviewees that this leads to unnecessary high costs of energy storage systems. It is stated that these unnecessary costs are the result of the fact that the Electricity Law (that also is involved in energy pricing) does not recognise energy storage yet. These additional costs hamper the testing the technology but mainly it is a barrier for testing the business case of storage technologies.

The double energy taxation currently is under discussion. This is mainly a result of lobbies from interest organisations concerning energy storage (i.e. Platform Energy Storage NL). According to H. van der Spek (personal communication, May 29, 2017), secretary of the Platform, this tax regime will be diminished. When exactly however is not yet clear.

Role grid administrators

There are strict role divisions between private parties (i.e. energy producers) and public parties (grid administrators) within regulatory frameworks. These strict role divisions are a result of the privatisation of the energy market (J. Knigge, personal communication, May 9, 2017). According to the Electricity Law, grid administrators only have the mandate to distribute energy and to maintain electricity grids. Grid administrators thus are the main actors dealing with peak loads, congestions or fluctuations on the electricity grid. Increasing challenges for grid flexibility has led to discussions whether grid administrators are allowed to apply energy storage. Both interviewed grid administrators and entrepreneurs agree that grid administrators should be allowed to experiment with, and apply energy storage and demand response strategies. However, whether this role is fully granted to the grid administrators within regulatory frameworks is not sufficiently clear. They are allowed to experiment with some forms of energy storage, but for large-scale applications of energy storage, many restrictions are imposed. Private parties feel that energy storage is on the dividing line between what is public and what private energy management. Stored energy is taken away from the grid and thus not the responsibility of the grid administrators anymore. Furthermore, stored energy has a high market value, as stored energy can be traded on energy markets. Consequently, private parties fear rivalry with publicly funded grid administrators. Therefore they lobby for a restrained role for grid administrators within regulatory frameworks (J. Blom, personal communication, May 19, 2017; J.W. Eising, personal communication, May 12, 2017). Private parties furthermore do not see why they would not experiment with storage technologies and services. When energy storage has negative business cases, private parties can always be financially supported by means of public policy (Hylkema, 2014).

ACM (authority, Consumer & Market), the organisation that sets rules for energy system and markets, decided in March 2017 (within the Law Progress Energy Transition) that grid administrators only are allowed to apply energy storage when private parties are not willing to invest and apply it. This decision is backed by the argumentation that, in contrast to private parties, grid administrators get their investments back by means of regulated energy tariffs. When grid administrators apply energy storage, standard market processes will be disturbed (ACM, 2017).

Grid administrators however argue that as a result of transition processes in the energy system, clear boundaries between several sub systems (such as production, transport and provision of electricity and gas) will change or become blurred. Also, newly needed roles for actors arise. These processes bring along many uncertainties. Therefore, it is argued by interviewed grid administrators that it would not be wise to already make clear decisions concerning the mandates of grid administrators within the new energy system. The "only market parties, unless..." approach taken by ACM therefore is heavily criticised. Furthermore, it is stated that private parties are more risk-averse and therefore, they will be less interested in testing energy storage technologies, since many storage application still face negative business cases. Therefore, not only grid administrators, but also local governments, research institutes and environmental organisations argue that it is crucial for the energy transition to provide grid administrators with sufficient room for experimentation and implementation of strategies such as demand control and energy storage (Duijmayer, 2017a). Rigidly retaining by the government to the traditional roles that several actors have within the electricity system is seen as a large barrier for innovation processes concerning storage.

To conclude, there are currently no clear determinations about experimenting with or applying addition activities (e.g. energy storage) by grid administrators within regulatory frameworks. Discussions are still continuing, and their role will be clearer within adapting Laws, but grid administrators fear a restriction of the roles they can fulfil within innovation projects. This is seen as a major barrier for the adoption of, and experimentation with energy storage technologies.

Net Metering

Net metering (Dutch: "salderen") is a policy arrangement that provides tax benefits for small-users (households or utility buildings) that generate electricity with solar panels ('prosumers'). Electricity that is not used by a prosumer can be delivered back to the electricity grid with advantageous tax agreements. Net metering is an important stimulation for the adoption of solar panels on the household level. However, it is a barrier for the adoption of energy storage technologies. Net metering negatively influences the business cases of energy storage because net metering is less costly compared to energy storage. This is one of the major institutions disadvantaging the business case of energy storage technologies. Interest organisations concerned with energy storage prefer arrangements that are more in favour of energy storage. However, the goal of the net metering arrangement is to stimulate the adoption of solar energy, which therefore has an important role for the Dutch energy transition.

The net metering arrangement currently is heavily under discussion. Adapting the arrangement could potentially be beneficial for energy storage. An argument for adjusting the net metering arrangement is the fact that the tax exemptions for households with solar panels (of around 40 million Euros on a yearly basis) are paid by households that did not implement solar panels. Furthermore, by means of this arrangement, the electricity grid can be used as a 'battery' for decentral generated electricity, thereby passing on those cost to other actors in the energy system. Therefore, the Minister of Economic Affairs pleads for adjusting or end the arrangement to a more social one by 2020 (Kelder, 2017). Moreover, during the interviews it became clear that net metering is important for the adoption of solar-PV at the household level, and should therefore not be terminated only in order to stimulate storage. Nonetheless, it is argued by parties in favour of energy storage (not without any self-interest) that this arrangement is not sufficiently stimulating the energy transition, since the energy system will not be changed dramatically as fossil fuel generated power plants still are needed for backup electricity generation. It is argued that by means of energy storage, the dependence on those fossil fuelled power plants will decrease dramatically (B. Dibo, personal communication, May 23, 2017). It is not yet clear what the sequel regime will be, which leads to uncertainties regarding either the adoption solar PV technologies as energy storage.

Obligated connections to natural gas networks in residential areas

Phasing out natural gas in residential areas in 2050 is one of the means to reach the Dutch energy transition. This potentially makes way for 'all-electric' solutions, for which flexibility solutions (i.e. storage) are highly needed. Currently, in the Dutch Gas Law, it is stated that newly built residential areas are obligated to be connected with the natural gas network when this is demanded by customers. According to the grid administrators that have been interviewed, in order to make way for sustainable energy innovations, this obligation needs to be diminished.

Currently, diminishing the obligated natural gas connection is under discussion. In June 2017, the Minister of Economic Affairs published a proposal for the termination of this connection obligation. According to *Netbeheer Nederland,* the interest groups of all Dutch grid administrators, this is an important first step towards phasing out natural gas, and to make way for 'all electric' or other more sustainable solutions. This increases electrification in the built environment which promotes the need of energy storage. However, this does not yet mean that all new residential areas are not allowed anymore to be connected to the natural gas network. According to the proposal of the minister of Economic Affairs, municipalities can decide in collaboration with the grid administrators (Savelkouls, 2017 a). Although this is a first step, it clearly indicates that institutions are being adapted in order to make room for more sustainable energy solutions (Savelkouls, 2017 b).

Energy market

Not only is energy storage not defined in many regulatory frameworks, this is also the case for energy trade markets. As a consequence, the market value of energy storage (smart buying and selling energy on energy markets) is insufficiently explored. This is seen as a result from the lack of market pull instruments such as standards. Furthermore, there are several uncertainties about how to adopt stored energy within the energy market. For this, access to several types of data is required. There are important barriers identified with regard to data, which is insufficiently exchanged between market parties. Also, there is a lack of standards and protocols that need to be followed concerning data exchange, security and consumer privacy. Consequently, grid administrators lack sufficient data for fitting energy storage technologies within the energy system and its market. The major restricting actors for this lack of data exchange are incumbent energy producers (J. Knigge, personal communication, July 11, 2017). They possess large quantities of relevant data, which also should be accessible to actors that store energy. However, energy producers impose thresholds for many other actors to access data. It is argued that incumbent energy companies fear rivalry and fear losing their monopoly position with regard to data access since new roles within the energy system arise. Therefore, incumbent actors within energy markets shut down open data exchange. This is seen as a major barrier for the development of innovation of energy storage technologies. Furthermore, it is stated that incumbent firms are insufficiently open-minded towards new roles and services that need to be adopted within market structures (J. Knigge, personal communication, July 11, 2017). An important systemic instrument that aims at fitting energy storage within the energy market, and stimulates open data exchange is the TSE System Integration Programme. This programme will be discussed in the section 5.2.3.

5.2.2. Policy programmes for the weakening of the existing regime

According to several interview respondents, instruments that weaken the existing regime (i.e. carbon pricing), would create higher market value of many sustainable energy innovations. This includes an improvement of the role of energy storage. However, carbon prizing still is not applied in the Dutch energy system. Furthermore, there are no specific policy programmes identified that aim at the weakening of regime factors hampering the development of energy storage. This however is not mentioned as a relevant barrier during the interviews.

5.2.3. Formation of new organisations linked to system change: System Integration Programme

For the relevance of innovation concerning energy storage, it is of relevance to elaborate on the System Integration Programme (SIP), a programme that is part of the TSE.

There are no specific policy programmes or TKI's concerning energy storage within the TSE. This is due to the fact that energy storage is not a final goal but a mean for the optimisation of many sub-systems within the energy system. It can help optimising the use of wind energy (TKI Offshore Wind), integration of solar PV systems within the built environment (TKI Urban Energy), or stored by conversing into gas (TKI Gas). Energy storage is an important focal point of the SIP. Since the energy system can be viewed as "a system where technology and institutions are inexorably intertwined, and as a socio-technical system consisting of several interconnected sub-systems" (Verzijlbergh, De Vries, Dijkema & Herder, 2014, p. 2), the SIP has been developed in order to connect those sub-systems within the Dutch energy system (TSE Systeemintegratie, 2017).

The SIP therefore is not a TKI, but an intersecting theme. The programme aims at the following:
- Challenge TKI's and other relevant organisations in the Netherlands to take into account the changes in the system that result from innovation processes. This can help identifying bottlenecks within the energy system and to let the right actors address these bottlenecks.
- Increase knowledge generation and diffusion on what is needed in order to reach energy transition targets. It therefore tries to help identifying bottlenecks in innovation systems, what is needed to address these bottlenecks and who is needed to address these problems. The programme for instance organises knowledge sharing events.
- To identify institutional barriers and solutions for these barriers related to energy innovation within the TSE.
- Provide room for technologies that are not yet a part of a TKI. This is important for energy storage, since the SIP provides subsidies for feasibility studies concerning storage and conversion. After such studies, there is increased more knowledge on the application of the technologies, the business cases, which service it provides and finally which barriers are identified when developing such a technology. After a feasibility study, it can be decided whether it is interesting to include the specific technological development within a knowledge and innovation agenda of a specific TKI (Knigge, 2017).

Table 5: Institutional barriers and systemic instruments

Institutions in need for adaptation	Systemic instruments
Electricity Law	Law Progress Energy Transition
Energy taxation	No specific instruments: but under discussion
Role grid administrators	Law Progress Energy Transition
Net-metering	No specific instruments, but under discussion
Obligated connection to natural gas networks	Policy proposals for diminishing this obligation
Closed energy market	TSE System Integration Programme

5.3 Policy strategy and principle plans

As stated in the theoretical section, a policy strategy that includes clearly set targets in accordance with landscape developments is needed to provide sufficient guidance for the search. Therefore, in this section, policy targets, principle plans or roadmaps of relevance for energy storage will be discussed. In later sections, it will be discussed whether these policy strategies are providing sufficient guidance for the search.

5.3.1. Energy targets

In the Netherlands, energy policy is formed around the goal of achieving an international energy supply system that is secure, safe and sustainable (Kocsis & Hof, 2016). Energy targets have been set for a 14% share of sustainable energy in 2020 and 16% in 2023 in the Energy Agreement (SER, 2013). After the Energy Agreement has ended, the Dutch cabinet aims to stick to the European agreements of a 40% reduction of CO2-emissions in 2030 and of 80-95% in 2050. A larger role for sustainable energy production implies an increasingly important role for energy storage within the Dutch energy system.

5.3.2. Principle plans and roadmaps

In the Energy Agenda (Ministry of Economic Affairs, 2016), roadmaps concerning several technological directions have been developed. There are no specific roadmaps concerning energy storage. However, energy storage is included in the "Roadmap Off shore wind energy", in which is it stated that there need to be searched for possibilities for the synergy of off shore wind with other functions, among others energy storage. Furthermore, energy storage is occasionally mentioned in the roadmaps concerning power-to-gas solutions. Seasonal storage by means of hydrogen and ammonia is integrated in the Energy Agenda. The "Roadmap Flexibility" is slightly more specific, in which grid reinforcement is identified as a too expensive option. Therefore, there should be a larger focus on other strategies for sustaining grid flexibility. Flexible energy tariffs and energy storage are mentioned as is in need for more research and its feasibility, effects and changes in regulatory frameworks need to be further elaborated (Ministry of Economic Affairs, 2016). Furthermore, knowledge and innovation agendas (of 2016-2019) of several TKI's include energy storage within their innovation programmes. These programme lines among others include principle plans for the adoption of energy storage within residential areas, seasonal energy storage, the combination of energy storage with ICT services and to combine energy storage with developments concerning solar PV (TKI Urban Energy, 2016). As energy storage is integrated in the principle plans concerning central and decentral energy generation, smart grid projects and projects concerning data management, control and ICT, it could be argued that energy storage is well integrated within innovation programmes.

Table 6: Policy plans and roadmaps

Policy plans and roadmaps concerning energy storage	targets
Energy targets	14% in 2020, 16% in 2023, 80-95% in 2050
Energy Agenda	Inclusion of energy storage in off-shore wind, power-to-gas, and flexibility roadmaps
Knowledge and innovation agenda's	Adoption of energy storage in residential areas, industry & combination with solar PV developments, ICT services and seasonal storage

5.4 Policy mix for the stimulation of innovation and adoption of energy storage

The semi-structured interviews and desk-study have resulted in the figure below. For all conditions of the assessment framework, relevant policy programmes and instruments have been identified. Note that not for all indicators policy instruments or programmes have been identified. The question whether this policy mix sufficiently stimulates energy innovation and how it should be improved will be central.

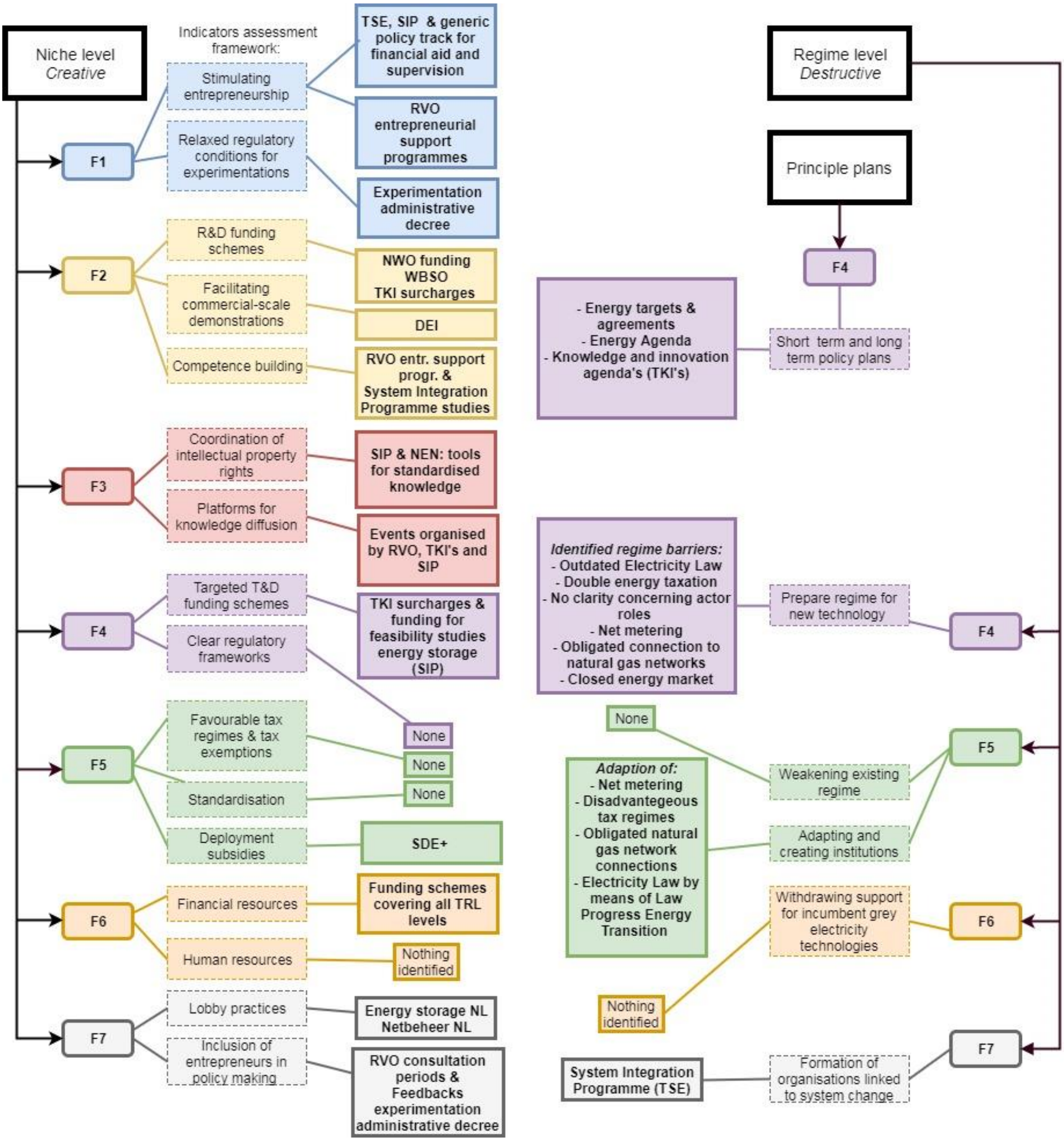

Figure 3: The policy mix with regard to energy storage

6. Results: Assessing the Dutch energy innovation policy mix with regard to energy storage

In the previous section, the policy mix that includes the relevant niche creative, regime destructive and policy strategies has been identified. In this section, it will be discussed whether this policy mix sufficiently meets the conditions that are elaborated in the policy assessment framework and Annex 5, and where improvement can be made.

6.1. Niche creative

6.1.1. Entrepreneurial activities

Stimulating entrepreneurship

There is a variety of activities and experiments concerning innovation of energy storage technologies. For instance, such entrepreneurial activities among others include placing large batteries near wind farms, at the residential level, usage of transport (e.g. electrical public transport) and placing flow-batteries at utility buildings or farmyards. Although there are several storage experiments with consortia (collaborations of actors with their own role within the research project) that include incumbent actors such as large energy generation companies (i.e. Nuon), most of the experimentations are still on a small scale carried out by SME's. Such entrepreneurial activities and experimentation on small scales can, compared to large-scale projects more easily deviate from stringent regulatory frameworks and have good access to funding (G. Dalessi, personal communication, May 5, 2017). Therefore, these entrepreneurial activities can be seen as activities within protected niche environments that do not directly have to compete with incumbent technologies. Furthermore, during the interviews with actors that participated within several experimentation projects such as entrepreneurs and grid administrators, it became evident that their entrepreneurial activities are besides often well-funded (along all TRL-levels), also well supervised by organisations such as RVO and the SIP. As a result, several demonstration and experimentation projects have been developed to show the viability of storage as a concept. Within the world of Dutch energy storage, many actors know each other personally. This is the result of a high amount of meetings organised by both governmental bodies such as RVO and the SIP, as well by meetings organised by interest groups such as Platform Energy Storage NL. The interview respondents indicated that as a result, there is a positive atmosphere among all actors which is seen as a driver for innovative activities. Furthermore, this familiarity between actors involved in innovation processes concerning storage makes it easier to find the right partners to collaborate with during R&D and demonstration projects.

Entrepreneurs feel that they are well funded and supervised for their entrepreneurial activities regarding energy storage. Therefore, this condition receives: ++

Relaxed regulatory conditions for experimenting

It is relevant to delve deeper into the regulatory flexibility that actors face during experimentation projects. Experimentations often are carried out in consortia. Examples of such consortia include the collaboration between grid administrators, energy providers or aggregators and research institutes such. Such experimentation projects are mainly at the local level, including residential areas (residential batteries), utility buildings, farmyards, or storage systems placed nearby electricity generators. For such local initiatives, the consortia often wish to deviate from the existing institutional frameworks in order to not only experiment with the technology and its business case, but also with new institutions and regulatory frameworks, which is needed for system changes.

The ACM (Authority and Consumption Market) sets certain regulatory conditions within the energy market and energy system. Within all innovation projects, consortia have to comply with these conditions. There is no doubt among all interviewees that such regulatory conditions are highly relevant for the protection of civil society. Although regulatory conditions thus are important for the greater good, there is consensus among the interviewed entrepreneurs and grid administrators that they should not hamper sustainable innovation processes.

While discussing demonstration projects with interview respondents, it became evident that there is a general trend in which there is a lack of regulatory flexibility especially for larger scale experimentations regarding energy storage. For consortia that experiment with energy storage, it is not possible to apply for exceptions for the double energy taxation, since taxations are in the portfolio of the Ministry of Finances. While the Ministry of Economic Affairs is responsible for well-developed policy for innovation, according to J. Knigge (personal communication, May 9, 2017) the Ministry of Finances has (rightly so) little understanding about innovation, and fears less tax revenues when changing such tax regimes. Furthermore, due to the strict role division between the transport and distribution (public) organisations on the one hand, and the production (private) organisations on the other, grid administrators have stricter rules to comply with. As a consequence, they experience limited room for experimenting with options for flexibility and their role in the energy transition in general. Finally, entrepreneurs that use chemical materials for their storage technologies argue that, while they agree on the relevance of strict regulations on using those materials, setting up experimentation projects is seriously hampered by these regulations. They have to get permission from multiple actors to experiment with chemical materials. This is often a timely and bureaucratic process. Finally, per experimentation case there will be looked whether consortia sufficiently comply with regulatory frameworks, instead of following standard protocols. This is a result of a lack of standards and protocols (G. Dalessi, personal communication, May 5, 2017).

This is not to say that there is no regulatory flexibility at all. The most important mean to apply for exemptions within the regulatory framework is the experimentation administrative decree. This tender provides much regulatory flexibility within experimentations with grid experiments (A. Even & N. Kerkhof, personal communication, May 15, 2017). This regulatory freedom is specifically granted in order to experiment with new products and services. Except from taxes, which are the responsibility of the ministry of Finances, it is possible to experiment with al kind of services, including developing own tariffs structures for electricity.

Opinions of entrepreneurs and grid administrators regarding this decree. On the one hand, it is stated by entrepreneurs that applying for the administrative decree at RVO is a bureaucratic process that takes much time before the exemptions are granted. This is seen as a barrier for innovation processes. The most frequent mentioned cause for this is that exemptions for regulations need to be coordinated by many parties including ACM, Ministry of Economic Affairs and RVO. The application process for certain exemptions before starting with experimentation projects are so timely that chances exist that those innovations are not that innovative anymore after the decree is granted (G. Dalessi, personal communication, May 5, 2017). Furthermore, H. van der Spek (personal communication, May 29, 2017) believes that few consortia make use of the experimentation administrative decree. This can be a result of the identified bureaucratic process or because there is a possibility of unfamiliarity of the experimentation administrative decree among entrepreneurs, which might result in fewer applications.

Other interview respondents do not fully agree with the needed regulatory flexibility for experimentation. It is stated by J. Blom (personal communication, May 19, 2017), who is innovation consultant at Alliander and board of the Platform Energy Storage NL that experiments, among others, are needed to identify what institutional barriers hamper the development of innovations or technologies. Consequently, there is no need to apply for certain exemptions beforehand.

Furthermore, by using the example of the double energy taxation, it is stated that if consortia, while preparing experimentation projects, are aware that this double taxation is a barrier for the experiment, you can already take that into account while testing business models, instead of applying for the timely administrative decrees (J. Blom, personal communication, May 19, 2017)

Many entrepreneurs and grid administrators agree that there is insufficient regulatory flexibility during experimentations. Regulatory barriers mainly include a limited role of grid administrators, unfavourable tax regimes and the lack of protocols when there is experimented with certain (chemical) materials. RVO is putting effort in the experimentation administrative decree in order to create more relaxed regulatory conditions. This decree is not fully identified as helpful. However, not all interviewees agree that this is an important barrier. Therefore, this condition receives: -

6.1.2. Knowledge development

Provision of R&D funding schemes

Within earlier sections, it is explained which policy instruments focus on R&D and fundamental research. According H. van der Spek (personal communication, May 29, 2017), the instrumentation regarding knowledge development for storage is quite good. This is mainly due to the fact that all TKI's are open for innovation projects concerning storage, which is widely used. Furthermore, research with regard to energy storage is well funded by means of the funding for feasibility studies by the SIP. According to H. van der Spek (personal communication, May 29, 2017), problems concerning innovation and development of technologies for storage do not lie with the instruments aiming at knowledge development. Furthermore, according to J. Groenewegen (personal communication, April 26, 2017), are besides the TSE a large amount of different R&D funding schemes on all governance levels. These include for instance *Horizon 2020* on the European level and regional and local funding schemes. This is seen as important, since currently costs prices of electricity storage facilities still are often too high for creating a positive business case. Fundamental research and R&D is highly needed in order to reduce costs (Van de Vegte et al., 2016).

Since there is much consensus on the well-funded R&D funding schemes, this condition receives: ++

Stimulation of higher order learning

Since it is recognised that in the Netherlands there is a well-developed instrumentation for R&D and fundamental research but not for commercial-scale demonstrations as a mean for higher order learning (Negro et al., 2012), the Demonstration Energy Innovation (DEI) funding scheme has been developed. As described in previous sections, the DEI is specifically meant for demonstration projects, stimulating higher order learning by helping to cover experimentation costs. This policy programme is widely used for energy storage technologies. As a result, several commercially viable projects have recently popped up.

However, according to J. Knigge (personal communication, May 9, 2017), large-scale demonstration still faces problems in the Netherlands. Pilot projects often go well, and pilot projects are extensively stimulated and funded. However, demonstrating on large scales includes using and demonstrating much more products and services related to the technology in order to demonstrate the functionality of the technology within the energy system. For avoiding the 'valley of death', more financial input is needed than currently is funded. Furthermore, the institutional barriers that consortia face while setting up experimentations are identified as a large barrier for higher order learning about innovation processes concerning energy storage.

Although commercial-scale demonstrations are well-funded, it is argued to still be insufficient. Furthermore commercial-scale demonstrations face institutional barriers making it more challenging to experiment with all kind of services and products concerning the technology that is tested. Therefore, this condition receives: -/+

Competence building

During the interviews, policy programmes for competence building or educational policies were identified as not relevant within this case or not mentioned as a barrier for the innovation processes concerning energy storage. The facilitation of feasibility studies by the SIP can be seen as an instrument for competence building, since it helps entrepreneurs identify the right market applications and possibilities of their innovative product. Furthermore, as RVO is specialised in helping entrepreneurs complying with rules and regulations and in finding the right business partners (as part of the *New Enterprise Policy)*, this could also be seen as a form of competence building.

No barriers have been identified concerning competence building. Since competence building is stimulated by RVO and the System Integration Programme, this condition receives: +

6.1.3. Knowledge diffusion

Coordination of intellectual property rights

Opinions about barriers for innovation processes as a consequence of protected intellectual property rights differ. According to J. Knigge (personal communication, May 9, 2017), intellectual property and related rights (such as patents laws) are seen as a barrier for synergy between knowledge institutions and the industry. This is a consequence of the liberalisation and privatisation of the energy market. Companies have built their revenue model on their own developed knowledge. The existence of protected intellectual property therefore is seen as legitimate. However, it is a barrier for energy innovation, since there is no common knowledge basis to continually build on.

The problems related to protected intellectual property rights are not fully acknowledged by all interviewees. According to H. van der Spek (personal communication, May 29, 2017), speed of innovation (lead time) is the most important strategy for protecting intellectual property. Procedures around applying for patents can be timely and can therefore be a limitative factor for technological developments. Therefore, the importance of protection of intellectual property is seen as less relevant.

The coordination of intellectual property rights however is an important goal of the SIP, with the aim to support policy makers and to stimulate investments by private parties. According to J. Knigge (personal communication, May 9, 2017), high investments (public and private) are needed for the stimulation of sustainable energy innovations. Such investments need to be based on solid, accessible and reliable information, which is often not accessible. This makes it for policy-makers and investors highly challenging to make confident decisions. Therefore the SIP, in collaboration with research institutes, consultancy organisations and the Dutch Normalisation Institute (NEN), aims at developing instruments and tools for developing models in which shared information and knowledge is combined. Based on this information, models have been developed that normalise shared knowledge, in order to let organisations, private parties and research institutes make decisions based on normalised information.

Although the barriers concerning intellectual property rights are not recognised by all actors, the System Integration Programme still aims at fruitful coordination of intellectual property. During the interviews however, results of this coordination did not yet become clear. Therefore, this condition receives: -/+

Stimulation of platforms for knowledge diffusion

According to all interview respondents, the stimulation of platforms for knowledge diffusion is highly relevant, but not the main task of the national government. Actors in the field know best what type of knowledge is needed and what other parties are relevant to collaborate with. Parties collaborate with others not only for knowledge sharing, but also in order to influence governmental policy or to form coalitions to start research and demonstration projects. Firms have personal interests in finding the right partners, and therefore they do not necessarily need governmental policy to find these partners. The most important platform concerning energy storage is the Platform Energy Storage NL. This platform came into existence without the help of policy action. Besides platform Energy Storage NL, as well the NL Association of Sustainable Energy and Smart Grid NL lead to a well-connected network of actors and to knowledge diffusion. For the case of energy storage, actors are well informed on which actors are all active in the field of energy storage. Actors know each other personally and energy storage in the Netherlands is seen as 'a small world' (J. Groenewegen, personal communication, April 26, 2017).

There are some activities concerning knowledge diffusion by government actors identified relevant for energy storage. RVO and several TKI's aim at more knowledge diffusion by means of organising meetings, symposia and congresses, and to share resulting knowledge with the ministry of Economic Affairs. Furthermore, organising meetings aiming at knowledge diffusion with regard to energy storage is an important goal of the SIP.

The importance of platforms for knowledge diffusion is acknowledged by all actors. However, this is not seen as the main task for the national government. However, there are policy activities identified relevant for energy storage and knowledge diffusion is not seen as a barrier. Therefore, this condition receives: +

6.1.4. Providing guidance of the search

Targeted R&D funding schemes

As elaborated earlier, there are no policy programmes or funding schemes specifically focused on energy storage technologies. There is consensus about the government to not focus on specific technologies, but to facilitate the development of technologies by the market.

TKI's however commonly have targeted funding schemes for certain technologies. This is different for storage technologies, since storage can support several other TKI's. As a consequence, there are no specific TKI-surcharges for energy storage. All TKI's within the TSE however are open for the integration of energy storage within their innovation projects, which is identified as stimulating. Furthermore, the SIP has a budget specifically for feasibility studies concerning energy conversion and storage. As a consequence, interview respondent stated that there is a good combination of generic and specific innovation policy instruments.

There is consensus that energy storage should not be funded by means of specific funding schemes. As all TKI's are interested and open for energy storage, innovation is well-funded. Therefore, this condition receives: +

Clear regulatory frameworks

No clarity about the role that grid administrators have in the regulatory framework

First of all, there is a lack of directives and control concerning mandates of parties concerned with energy storage implementation and experimentation. Current legislations have no mentions of the role that grid administrators should fulfil in energy storage projects. Updating the Electricity Law (by means of *Law Progress Energy* Transition) currently is under discussion, but results of this still are unsure. In updated legislation, the Ministry of Economic Affairs aim at defining a clearer role for grid administrators in smart grid and energy storage projects. This law however will be further discussed when a new cabinet is formed. Previous discussions about the *Law Progress Energy Transition* were stranded due to disagreements concerning the role of grid administrators in smart grid and storage projects (Duijnmayer, 2017a). As a consequence, waiting for a new cabinet to discuss this law brings even more uncertainty concerning legislations, which is identified as a barrier for innovation.

No clarity about what is allowed with regard to flexible energy pricing.

As stated before, many experimentations with products and services concerning storage are carried out in combination with experimentations with flexible energy pricing in order to investigate possible consumer behaviour as a reaction on price incentives. There however is much unclear about the extent to which flexible energy pricing is allowed in regulatory frameworks. According to A. Even and N. Kerkhof (personal communication, May 15, 2017), much is possible with regard to flexible energy pricing, as long as household residents/consumers are not financially deteriorated by such projects. If consumers do deteriorate from such projects, the consortia have to compensate this. For this, parts of the DEI can be used. However, according to grid administrators that carry out such projects, is this only applicable for small-scale experimentation projects and there is much uncertainty whether this is allowed for larger projects that include more households (B. Dibo, personal communication, May 23, 2017).

No clarity about the future net metering arrangement

As stated before, the net metering arrangement, in which households or utility buildings deliver back their surplus of electricity to the grid in exchange for tax benefits, is currently under discussion. It is expected that the net-metering arrangement will be put to an end or be highly adapted by 2020. What the sequel arrangement will be is not clear. According to the interviewed entrepreneurs, this uncertainty is a barrier for both the adoption of solar PV as for storage. The market requires more certainties in order to invest and adopt such technologies (H. van der Spek, personal communication, May 29, 2017; G. Dalessi, personal communication, May 5, 2017).

A. Even (personal communication, May 15, 2017), who is a strategy consultant and project manager of smart grid projects from RVO, RVO agrees that regulatory frameworks can be insufficiently clear and therefore hamper innovation projects. However, the importance of regulatory frameworks cannot be underestimated. Frequently, interest groups or consortia complain at RVO that regulations hamper their innovation projects without being sufficiently clear about the causes. Furthermore, RVO states that often, entrepreneurs or consortia do not put sufficient effort in the experimentation phase. As a consequence, entrepreneurs have insufficient knowledge about the regulatory frameworks they have to comply with. Therefore, RVO intensively stimulates entrepreneurs to first learn as much as possible from experimentations on how to comply with regulations. As a result, regulatory frameworks should become clearer.

There is consensus about the vagueness of regulatory frameworks. RVO however has programmes to help entrepreneurs to comply with regulatory frameworks. This condition therefore receives: -

6.1.5. Market creation

Favourable tax regimes / tax exemptions

(Un)favourable tax regimes

No tax regimes have been identified that are in favour of energy storage. The most frequent mentioned disadvantageous tax regime is the earlier discussed double energy taxation, which is a result of the fact that energy storage is not defined in the Dutch Electricity Law (H. Van der Spek, personal communication, May 29, 2017) This has negative consequences for the business case of storage systems and creates an unfair playing field between energy production and storage, since the energy producers do not have to pay an additional tax. Furthermore, within energetic terms, there are higher taxes on electricity compared to natural gas. It is argued by several parties that scaling up energy innovations of among others flexibility options is disadvantaged by these tax regimes (Den Ouden, Van Aken, & Kooiman, 2016).

Applying for tax exemptions

Applying for tax exemptions for the double energy taxation often is difficult, since the Ministry of Finances is not involved in innovation processes. On small scales, consortia however are able to set their own (flexible) tax regimes in order to experiment with flexible energy pricing. When still taxation revenues are missing, this is payed up by using parts of the DEI subsidy scheme.

Instead of favourable tax regimes, there are unfavourable tax regimes identified, which negatively influences business cases of energy storage technologies. Furthermore, applying for tax exemptions is difficult. Therefore, this condition receives: --

Standard setting

As stated before, a lack of standards regarding energy storage has been identified as a major barrier. Also according to Den Ouden et al., (2016), this might be one of the most underestimated issues concerning energy storage. Standards are highly needed for developing certificates. These certifications are crucial for improving the finance ability of innovations and make them applicable within the current energy system. According to the Platform Energy Storage NL, the TSE should have a more active role in stimulating firms to adopt certain standards (e.g. energy performance norms for energy storage) to reduce costs of energy storage and for a faster and cheaper adoption within the energy market (FME, 2015).

RVO is putting effort in developing such standards in collaboration with the NEN. For this, as much information and data as possible is gathered about all RVO funded experimentation projects (DEI) about the types of that are needed for smart grids and flexibility services. By means of this data, RVO is developing standards for smart grid projects that also include storage technologies (RVO, 2015b). Such standards include requirements regarding the interoperation ability of storage technologies or requirements concerning privacy and security of storage systems (i.e. data privacy requirements). However, according J. Knigge (personal communication, July 11, 2017), this still is insufficient, but highly needed for market creation: applying novel technologies is unnecessarily expensive when energy sub-systems, programmes and data are due to a lack of standards, insufficiently cooperated with each other.

Although standard setting is currently under development, a lack of technical and market standards is identified as a major barrier for the adoption and market creation of energy storage technologies. RVO however puts effort in developing standards, but his is identified as insufficient. Therefore, this condition receives: -

Deployment subsidies
Most energy storage technologies are not yet in the implementation phase. As a consequence, entrepreneurs in energy storage did not made use of the SDE+ deployment funding scheme. Nonetheless, the existence of the SDE+ provides more future based confidence for private organisations to invest in sustainable innovation projects.

However, according to interviewees, there is a mismatch between the amount of SDE+ deployment subsidies already funded to wind energy and solar PV innovation projects and the amount of funding available for energy storage projects. The growth of intermittent sustainable energy sources goes jointly with the growth of energy storage and back-up generation capacities. It is stated that technologies for conversion of redundant sustainably generated electricity to hydrogen or ammonia (for seasonal storage or for the natural gas network) is sufficiently developed to receive the SDE+ funding scheme. However, there is insufficient attention from policy programmes to conversion solutions (Duijnmayer, 2017 b).

Since most energy storage technologies are not yet in the deployment phase of the innovation process, the effect of deployment subsidies is not yet clear. They however create more future based confidence for investments. Due to some negative other comments, this condition receives: +

6.1.6. Mobilisation of resources

Financial resources
As elaborated in earlier sections, there is a high amount of funding schemes that cover all TRL-levels and are provided on many governance levels. This research has not focused on how much public funding is specifically assigned to storage technologies and whether this is in accordance with the needs of actors in the field. However, it became evident during the interviews that there is much consensus that the mobilisation of financial resources is well-organised and well-funded. According to the interviewed entrepreneurs, there is much choice between financial innovation stimulating instruments, especially when including European policy frameworks (e.g. Horizon 2020) and local funding schemes.

There is much consensus on the sufficient amount of financial resources that is being provided to all TRL-levels of the innovation process. Therefore, this condition receives: ++

Human resources
During the interviews, little became clear about human resources attributed by the national government for energy storage innovations. However, there is also no barrier for innovation of energy storage identified that is related the facilitation of human resources. The TSE has incorporated a Human Capital Agenda in order to facilitate better employment within the changing businesses and jobs needed for the energy transition. By means of the Human Capital Agenda, the TSE aims to educate more students for jobs in sustainable energy innovative technologies and to ensure that the changing energy system still offers sufficient employment and labour. The central idea behind the design of the TSE Human Capital Agenda is that ensuring sufficient employment opportunities will lead to a provision of human resources (Human Capital Agenda, 2017).

Not much has become clear about human resources that are assigned to innovation of energy storage. Therefore, this condition receives: +/-

6.1.7. Creation of legitimacy

Inclusion of entrepreneurs in policy making

RVO includes entrepreneurs in policy making by organising consultation periods and by gathering valuable information about experimentation projects that were facilitated by the DEI. Information resulting from these consultation periods and demonstration projects is bundled and passed on to the Ministry of Economic Affairs. During consultation periods, entrepreneurs are required to substantiate what type of policy they need and how regulations hinder the development of their innovative services or products. Exceptions on regulatory frameworks granted via the experimentation administrative decrees are evaluated on the question whether such exemptions should be granted permanently. Furthermore, RVO often has consultation moments with actors such as grid administrators or entrepreneurs to discuss whether regulations from ACM or the ministry of Economic Affairs can be me more flexible. As a consequence, RVO is well-informed about bottlenecks within policy frameworks (A. Even & N. Kerkhof, personal communication, May 15, 2017). This is positively backed by the grid administrators and entrepreneurs that have been interviewed.

Furthermore, there is an effective lobby from interest groups such as the Platform Energy Storage NL. These lobbies for improved policy and regulatory frameworks concerning energy storage are well received by policy making organisations such as the Ministry of Economic Affairs. According to H. van der Spek, who is cluster manager energy at FME and lobbyist for the Platform Energy Storage NL, the Ministry of Economic Affairs handles wishes from many interest groups really well (H. van der Spek, personal communication, May 29, 2017). Furthermore, within the discussion about the new net-metering arrangement, the Platform Energy Storage NL is well involved. The Ministry of Economic Affairs carefully listens to all interest groups before making final decisions (H. van der Spek, personal communication, May 29, 2017)

Entrepreneurs have many possibilities to be included in policy making processes. Therefore, this condition receives: ++

Lobby practices

There are no forces identified that lobby against the development of energy storage specifically. However, according to the interview respondents, there still is a need for lobbying against the institutional barriers that have been identified during this research. Especially actors that are part of the Platform Energy Storage NL lobby for the needs of energy storage innovations within Dutch regulatory and institutional frameworks. Interview respondents stated that the Platform has good access to the right policy making organisations i.e. the Ministry of Economic Affairs. It is stated that such lobby processes are helpful for gathering the right needs of innovations regarding energy storage (H. van der Spek, personal communication, May 29, 2017; G. Dalessi, personal communication, May 5, 2017; J. Blom personal communication, May 19, 2017). For instance, in collaboration with the grid administrators' interest organisation (*Netbeheer Nederland*), the Platform lobbies for a more extensive role for grid administrators within energy storage innovation projects. Furthermore there is a lobby process that aims at diminishing unfavourable energy taxes such as the earlier discussed double energy taxation. According to H. van der Spek (personal communication, May 29, 2017), this is a timely process, but when more awareness concerning energy storage is created among policy makers, the double energy taxation will be diminished. Finally, the Platform Energy Storage NL is lobbying for an adapted net metering regime that provides more room for energy storage, since they argue that storage will better serve the energy transition compared to grid reinforcements as a consequence of net metering. It is backed by interview respondents that interest groups and actors are successfully lobbying for the needs of energy storage within policy frameworks.

There is consensus that the lobbies in favour of energy storage can be effective. It is furthermore stated that policy makers (Ministry of Economic Affairs) handles wishes from various interest groups really well, which however is a timely process. Therefore, this condition receives: +

6.2 Regime destructive

Overall, as a result from the semi-structured interviews, it became evident that the stimulation of niche innovations, thus the 'creative' part concerning socio-technological development stimulated by means of policy is relatively easier than the 'destructive' part of transition processes. As elaborated in the theoretical framework, structures of the old socio-technical regime that hamper the development and introduction of innovations should be adapted (Meelen & Farla, 2013). Changing or adapting regime rules such as laws and regulations, and the inclusion of control policies are identified as crucial by the respondents. This is mainly as a result of the observation that the development of technologies for energy storage is mainly hampered by laws, regulations and unclear regulatory frameworks. According to most of the respondents, institutional barriers are the most important obstructing factors compared to technology constraints. As discussed in section 3.2, physical infrastructure often is identified as an important barrier for technological transition processes. However, the interview respondents do not fully agree with physical infrastructure as a barrier, since storage is an addition to the energy system that will not dramatically change the physical energy distribution networks. It is furthermore argued that existing infrastructure should be used in order to reduce costs. Therefore, the main focus of this section lies on institutional barriers rather than technological and infrastructural barriers.

6.2.1. Providing guidance for the search

Prepare regime for new technology

As a consequence of the regime structures such as institutional barriers discussed in section 5.2.1, it can be stated that the energy regime is not yet fully prepared for the adoption of energy storage technologies. H. van der Spek (personal communication, May 29, 2017), came up with recommendations for a better preparation of the regime for energy storage. He stated that institutional barriers can better be tackled when energy storage is recognised within the energy system and related policy frameworks. He argued that when storage will be accepted as a fourth pillar (next to production distribution and consumption) in the national energy system and related legislation, laws and policy frameworks, they only have to be adapted instead of fully revised. This would thus lead to a better preparation of the energy regime for energy storage. This would also create a fair level playing field with other means for flexibility, since for instance grid reinforcement and flexible energy production have less complex regulatory frameworks to deal with, but are expected to lead to higher social costs. The extent to which energy storage will be accepted as a fourth 'pillar' is not yet clear. It is already under discussion on the European level (European Commission, 2017). However, many actors agree that energy storage should not be a focal point for national en European policies. The most common argument for this is that it is always best to first try to make use of the available energy, and only storing it when fully necessary (Van de Weijer, 2017).

Energy storage is not yet sufficiently recognised within the energy system, markets and regulatory frameworks. This leads to an unfair level playing field regarding other flexibility solutions that have higher social costs. Thus, the regime is insufficiently prepared for energy storage. Therefore, this condition receives: --

6.2.2. Market creation

Weakening existing regime

There are no specific policy programmes identified that aim at the weakening of regime factors hampering the development of energy storage. Interview respondents acknowledge that regimes do not need to be fully overthrown in order to make way for energy storage technologies. Instead, regimes need to be adapted by tackling the institutional barriers discussed in previous sections. However, it is acknowledged that for the development of sustainable energy innovations, regime destabilising policy programmes are needed in order to stimulate sustainable energy innovations. There are policy programmes that focus more generally on the weakening of current energy regimes. These include for instance the Emission Trading System (ETS). During the interviews, it became evident that there can only be hypothesised about the role that such programmes have on energy storage. First of all, the ETS is a highly complex phenomenon, and is set on the European level and thus difficult to influence on the national level. It is argued by J. Ros (personal communication, May 16, 2017), that the ETS is not sufficiently stimulating sustainable energy innovation, since the emission ceilings are too high. As a consequence, there will be no dramatic changes in the energy system resulting from ETS. It is furthermore acknowledged that the stimulation of energy innovation cannot go without carbon pricing. According to E. Buddenbaum, (personal communication, May 3, 2017), insufficient amounts of sustainable energy initiatives will arise as long as we do not include carbon prizing. Options for carbon prizing, for instance according to the ‘pollution pays principle’, are generally acknowledged as potentially beneficial for energy storage. For instance, production of hydrogen by means of natural gas is less expensive compared to “power-to-gas” technologies: conversion of abundant electricity to hydrogen for energy storage. However, the ‘grey hydrogen’ production has a much higher carbon footprint. Only with carbon prizing can sustainable technologies for conversion used for storage compete with the more environmental unfriendly conversion technologies (Duijnmayer, 2017b). These however are politically difficult choices, since it should be prevented that firms shift their production processes to other countries. This would be disastrous for the competitiveness of Dutch and European economies. Furthermore, it is highly likely that firms then shift their activities to countries with even lower environmental standards, leading to the shift of environmental problems. (J. Ros, personal communication, May 16, 2017). Furthermore, according to J. Knigge (personal communication, May 9, 2017), when weakening the existing regime, it is really important to take winners and losers of the energy transition into account. As a consequence of the energy transition, many jobs will change, possibly leading to resistance of interest groups and civil society. To illustrate, the TKI gas within the TSE for instance clearly shows how interests groups concerning specific technologies group together in order to maintain their interests. The TKI gas currently is innovating on gas related solutions (power-to-gas). The innovating activities of the TKI Gas mainly are driven by the fact that natural gas interest groups aim at keeping their role within the Dutch energy system. The TKI gas has own interests, which is legitimate, and therefore they innovate on existing paths. It is thus of main importance to keep in mind the roles and employment that will change or vanish as a consequence of weakening regimes. Such issues make policy frameworks aiming at the weakening of the regime and creating markets for niche innovations highly complex.

> No specific policy programmes have been identified aiming at the weakening of the current socio-technical regime. General policy instruments for regime destruction (e.g. ETS) are argued to be insufficient. However, destabilising current regimes has many societal consequences. Therefore, this condition receives: -

Adapting institutions

During the interviews, it has been discussed which institutions and regulatory frameworks are currently in the process of adaptation. E. Buddenbaum, who is besides secretary of the TSE an innovation policy advisor at the Ministry of Economic Affairs argues not to focus too much on adapting institutions and regulatory frameworks concerning sustainable energy innovations, since still around 90-95% of our energy is based on non-renewable resources (personal communication, May 3, 2017). In contrast, grid administrators and entrepreneurs argue in favour of adapting institutions in order to provide more room for sustainable energy innovations. In section 5.2.2., it has been elaborated which institutions are under the process of adaptations. This section discusses whether these adaptations are sufficient according to the interviewees.

Net metering arrangement

Adapting this policy arrangement potentially can be positively influence business cases of energy storage systems, since it might become more cost effective to use self-generated electricity. However, there are many uncertainties about the sequel regime. These uncertainties are seen as barriers for investing in both solar energy systems as well as storage technologies (Duijnmayer, 2016). Currently the net metering arrangement is being re-evaluated and the Minister of Economic Affairs includes the possibilities of energy storage within the discussions on adapting this arrangement.

Double energy taxation

As discussed in previous sections, the double energy taxation negatively influences the business cases of energy storage facilities. However, according to H. van der Spek (FME), as a result of the consensus of many actors concerning the unnecessary costs resulting from this double taxation, this will be adapted in the near future as a result of lobby practices (personal communication, May 29, 2017).

Obligated connection to natural gas networks

As discussed in section 4.2, obligated physical connections of natural gas networks (of residential areas) within regulatory frameworks are being diminished. However, this is only a first step towards the elimination of natural gas, which provides room for all-electric and more sustainable energy innovations.

Electricity law and Law Progress Energy Transition

The *Law Progress Energy Transition* aims at adjusting the Electricity Law and related legislations to the needs of the energy transition. During the interviews, it became evident that opinions regarding this law differed. First of all, interviewed policy makers, of which E. Buddenbaum (personal communication, May 3, 2017) argued in favour of this law. He stated that it will bring more clarity about role distributions, leading to better innovation and transition processes. Grid administrators on the other hand (J. Blom, personal communication, May 19, 2017; J.W. Eising, personal communication, May 12, 2017; B. Dibo, personal communication, May 23, 2017) argued against this law. According to grid administrators, demarcating the role of grid administrators in smart grid and energy storage projects is short-sighted and too much focused on favouring profit-making firms. Although this law aims at better stimulating the energy transition, it insufficiently considers energy storage as an important technological development which leads to incorrect role divisions (Straver, 2016). As stated before, no decision on this law have been made yet.

To conclude, there is some development in the adaptation of institutions that are more in favour of energy storage. However, much remains unclear regarding sequel regimes and regarding role distributions. The focal points discussed above are not an exhaustive list. This only is a result from the interviews. Future research should tell whether these adapting developments will sufficiently support the adoption of innovation of energy storage.

The main institutional barriers that have been identified are under the process of adaptation. The role of grid administrators still seems a difficult point of discussion, and much remains unclear regarding adaptation of regimes. Therefore, this conditions receives +/-

6.2.3. Mobilisation of resources

Withdrawing support for incumbent grey electricity technologies

Within the current policy frameworks concerning energy storage, there are no withdrawals of support identified for incumbent non-sustainable electricity technologies. This however is complex, which is mainly a result of interests in current technologies, related services and the huge political endeavour that is needed for withdrawing support. However, during the interviews, it was not stated that support for incumbent technologies is seen as a large barrier for energy storage technologies.

There are no policy programmes identified aimed at withdrawing support for incumbent grey electricity technologies. This however is not identified as an important barrier for innovation. Therefore, this condition receives -/+

6.2.4. Creation of legitimacy

Replacement of regime actors in policy advisory councils with niche actors

As stated in the theoretical section, often lock-ins are partly caused by close relationships between regime actors and policy makers (Unruh, 2000). However, during the interviews, such close relationships have not been identified. Consequently, not statements can be made about whether regime actors are replaced by niche actors in policy advisory councils.

Since this condition has not become sufficiently clear, this condition receives: +/-

Formation of new institutions linked to system change

The most striking new organisation that has been developed in order to stimulate system changes within the energy system and thereby stimulation innovation of energy storage technologies is the SIP. As elaborated earlier, the SIP aims at connecting several sub-systems within the energy system. For energy storage technologies specifically, this programme has been worked out well. The SIP funded and supervised many feasibility studies about certain energy applications. After such studies, it could be decided by which TKI those technological applications could be accommodated. According to E. Buddenbaum (personal communication, May 3, 2017), the SIP is highly functional in linking individual technological issues together. Identifying how several sub-systems together stimulate the energy transition is one of the strengths of this programme. Furthermore, the programme has been developed in order to prevent that TKI's were too much focused on their own 'tunnel vision' (i.e. TKI gas innovation only in gas solutions). Instead, as a result of the SIP, other TKI's with vested interests now can better determine how to integrate several energy sub-systems. As a consequence, lock-in effects resulting from vested interest of all TKI's will be prevented (J. Knigge, personal communication, May 9, 2017). Finally, the SIP has been identified as a relevant organisation for strengthening the networks around the innovation system of energy storage.

As the System Integration Programme is identified as a successful formation of an organisation aimed at system change, this condition receives: ++

6.3. Landscape developments

6.3.1. Short-term and long-term policy goals

The current governmental policies concerning energy innovations are mostly focused on the short term, with a focus on reaching the 2023 energy targets (reaching 16% of sustainable energy production in the Netherlands). Financial support is built on reaching these targets in a cost efficient manner. According to Den Ouden et al. (2016), are entrepreneurs insufficient stimulated by this short-term policy focus, resulting in uncertainty regarding long-term policy after 2023. Among others, there are uncertainties about the energy types that will be chosen to be leading the energy transition. An increased policy focus on electrification for instance might increase possibilities of energy storage. According to the interviewed grid administrators and entrepreneurs, there is a lack of clear decisions and visioning about those energy targets. To illustrate: the Netherlands has developed itself as a large natural gas economy. However, as a consequence of a variety of landscape developments (i.e. increasing risks of earth quakes in the province of Groningen), there is increased pressure on the role that natural gas will have in the Dutch economy. When looking at the energy targets that have been set, the role of natural gas is likely to be heavily diminished. However, neither in the long or short term there are clear decisions on the role of natural gas. These uncertainties about long-term developments reduce certainties concerning investments in technological innovations (Den Ouden et al., 2016).

Generally, a variety of firms argue for the importance of a clear climate law with concrete intermediate goals. This provides much more certainties within the investment climate concerning sustainable energy, which can be highly beneficially for energy storage (Financieel Dagblad, 2016).

To conclude, during the interviews, there was much criticism on the short-term visioning of the national government. According to G. Dalessi (personal communication, May 5, 2017), businesses are be created by clearly set goals, since those goals provide more guidance of the search, which is currently identified as insufficient.

Since it is stated by the interview respondents that short-term and long-term policy goals are insufficiently for providing guidance of the search, this condition receives: -

6.4 Overview of the results and recommendations for the adaptation of the policy mix

Table 7, 8 and 9 summarise the results of this research. In this section, the main findings are discussed it will be elaborated on what these results mean for the policy mix regarding energy storage. Also recommendations for the adaptation of the policy mix regarding energy storage will be given as well as the actors for which the recommendations apply to.

6.4.1. Policy recommendations

First of all, it should be noted that energy storage should not be seen as an end goal for policy frameworks. The final goal is sustaining a secure energy grid that is able to cope with increasing decentral energy generation and with increasing fluctuations resulting from of a higher amount of sustainable generated energy. Secondly, as stored energy will face losses in terms of capacity, it is stated that a focus should be on using energy rather than aiming at storage. Third, it should be noted that the Netherlands currently has one of the most secure energy grids in the world, with the lowest amount of blackouts of energy systems. Therefore, there is a lack of urgency regarding the need for energy storage.

Nevertheless, an increasing amount of sustainable generated energy within our energy system potentially leads to problems that can be prevented among other by means of energy storage. For an improved stimulation of socio-technical development concerning energy storage, that includes technological, institutional and social innovation, this research has led to the policy recommendations formulated in the following section.

Creative niche stimulation

Table 7: Results instrument mix for creative niche support

TIS function	*Assessment condition*	*Result*
F1	*- Stimulation of entrepreneurship*	++
	- Relaxed regulatory conditions for experimenting	-
F2	*- provision of R&D funding schemes*	++
	- Stimulation of higher order learning: facilitate and subsidise commercial scale demonstrations	-/+
	- Competence building (training programmes, educational policies)	+
F3	*- Coordination of intellectual property rights*	+
	- Stimulation innovation platforms or platforms for knowledge diffusion	+
F4	*- Targeted R&D funding schemes*	+
	- Technology specific targets	-/+
	- Clear regulatory frameworks	-
F5	*- Favourable tax regimes & tax exemptions*	--
	- standard setting	-
	- Deployment subsidies	+
F6	*- Financial resources*	++
	- Human resources	-/+
F7	*- Lobby practices for niche-technologies*	+
	- inclusion of entrepreneurs in policy making	++

Technology push instrumentation

The *Technology push* part of the creative policy mix is identified as stimulating. Entrepreneurial activities are well-financed and supervised. This is mainly a result of the generic and top sector policy approach developed by the Ministry of Economic Affairs and of the fact that all TKI's are open for energy storage. Second, entrepreneurs are positively included in policy making processes. Finally, the SIP is an important mean for the stimulation and integration of energy storage within policy programmes.

Experimentation projects and regulatory frameworks

Experimentations however are in need for additional support by means of less strict regulatory frameworks. The experimentation administrative decree has been introduced in order to provide more regulatory flexibility. However, this decree is identified as bureaucratic with timely application processes. Furthermore, unclear regulatory frameworks lead to uncertainties, mainly regarding the role that grid administrators can fulfil within energy storage (experimentation) projects. Their role within regulatory frameworks should not be limited. Grid administrators are the main parties that have to deal with peak loads and congestions within the electricity grid. Furthermore, they aim at grid flexibility solutions with the lowest social costs. As they are public agents, society has to bear the costs made by grid administrators. Since energy storage technologies (mainly due to net metering and double energy taxation) often face negative business cases, grid administrators fear that private parties are insufficiently willing to invest in and experiment with loss making activities. Thus, while further discussing the *Law Progress Energy Transition,* these arguments provided by grid administrators should be involved. A clearer regulatory framework regarding role distributions within the energy system should be implemented while on the other hand, the ACM needs to stay open-minded towards new roles that need to be fulfilled within a changing energy system. Therefore, it should be acknowledged by policy makers (e.g. ACM) and energy incumbent energy firms that for fully transforming the energy system into a more sustainable one, new actors and roles will arise. Accordingly, regulatory frameworks should not be fully focused on a centralised and fossil fuel based energy system.

Policy recommendation 1) Provide grid administrators with sufficient room for experimentation, and to identify the role they can best fulfil within energy storage projects (to RVO, ACM and Ministry of Economic Affairs).

Policy recommendation 2) Acknowledge that that for fully transforming energy systems, new actors and roles will arise. Therefore, regulatory frameworks should not be built on a centralised energy system (to RVO, ACM and Ministry of Economic Affairs).

Market creation

Another major barrier that has been identified within the niche creative policy instrumentation is a lack of market creating policy instruments: unfavourable tax regimes and absence of standardisations hamper market creation. Firstly, instead of tax regimes that favour the market value of energy storage, only unfavourable tax regimes have been identified, mainly in the form of the double energy taxation. Market rules should be adapted to accelerate the development of self-generated energy and storage, and to make self-generation and consumptions smarter. For this, a legal definition of energy storage should be implemented. The double energy taxation and other grid charges that are applied to self-consumed and stored electricity have a dis-incentivising effect on progressive smartening of decentralised energy generation. Therefore, prosumers should not be exposed to any taxes on the electricity they self-generate, consume and store. This is a widely shared opinion of all interviewees. Currently, there is a lobby process going on to eliminate this double taxation. However, this is a difficult process, since the Ministry of Finances decides on this and not the Ministry of Economic Affairs that aims at stimulating sustainable innovations. According to all interviewees however, this taxation regime has to be taken down in order to scale up technologies and to create a higher market value for energy storage technologies.

Secondly, there is a lack of standards regarding energy storage. This has several consequences. First of all, this hampers the organisation experimentation projects. While organising an experimentation project, per case, it needs to be investigated beforehand whether there will be complied with certain regulatory frameworks and conditions. This is a timely process. If improved standards and protocols are created for energy storage, innovation processes will proceed more rapidly. Second, the lack of standards (e.g. performance standards) leads to slower market adoption and leads to higher costs. It is argued that standards are positively influencing the organisation of experimentation projects (time-wise) and that it opens up market possibilities for energy storage. Therefore, according to interview respondents, development standards should be a focal point for policy.

Finally, data exchange, which is of main importance for the adoption of energy storage technologies within the system and energy markets, is inhibited by incumbent energy producing companies. Incumbent (centralised and private) energy producers fear new forms of rivalry as a consequence of new roles and services that come into existence along with the energy transition. The SIP should continue finding methods for opening up data exchange networks. Furthermore, standards with regard to data exchange can be helpful for stimulating data exchange.

Policy recommendation 3) Adapt market rules to accelerate the development of energy storage by implementing a legal definition of energy storage in regulatory frameworks (to ACM).

Policy recommendation 4) Do not expose prosumers with any taxes on electricity they self-generate, consume and store (to Ministry of Finances).

Policy recommendation 5) The development of standards should be a focal point for policy. This includes standards for data exchange, safety and privacy, interoperationability and performance standards (to RVO, TSE and more specifically SIP).

Policy recommendation 6) Continue developing methods for open data sharing between incumbents and new market entrants (to SIP).

Systemic instruments for regime destruction

Table 8: Results instrument mix for regime destruction

TIS function	*Assessment condition*	*Result*
F4	*- Prepare regime for new technology*	--
F5	*- Weaken existing regime: tax policies and regulations for incumbent technologies*	-
	- Adapting and creating new institutions	-/+
F6	*- Withdrawing support for incumbent grey electricity technologies*	-/+
F7	*- Replacement of regime actors in policy advisory councils with niche actors*	-/+
	- Formation of new organisations and networks linked to system change	++

Compared to other sustainable technological innovations such as wind energy or solar power generation, energy storage is not disruptive since it does not replace other technologies. It should be seen as a mean for sustaining a flexible energy grid, thereby supporting the role of sustainable energy within the energy transition. As a consequence, it is stated by interview respondents that the current regime does not have to be fully overthrown in order to create an environment in which energy storage can be adopted within the energy system. The regime however is in need for adaptation since regime structures i.e. market structures and routines, formal institutions and habits seriously hamper the adoption of energy storage. This is in line with the starting point of this research, that stated that creative niche policy stimulations are not sufficient for new technologies to become adopted within socio-technical systems. Furthermore, it can be speculated that the energy system and energy market are not sufficiently open for new actors and actor roles that arise along with new services and activities. As a result, the energy regime is insufficiently prepared for the adoption of energy storage. Therefore, technology constraints of energy storage are a less important barrier compared to its institutional barriers.

The most important solution that has been discussed by interview respondents is that energy storage should be recognised as a fourth pillar (besides production, distribution and consumption of energy), in order to become part of the energy system and its markets. In this way, the most relevant institutional adaptations in regime structures only have to be adapted. Therefore, instruments that weaken (e.g. carbon prizing) or reduce support for the existing energy regime are seen as relevant for stimulating the adoption for energy storage, but is not to be seen as a focal point for policy.

Adaptation of institutions

Although systemic instruments that aim at the adaptation of regime structures are identified, the question whether this leads to a better adoption of energy storage technologies remains unanswered and there is still much criticism among the interview respondents concerning these systemic instruments.

First of all, an important institutional adaptation is the effort that is being put in updating the Electricity Law in line with the needs of the energy transition. This occurs by means of the *Law Progress Energy Transition*. This can be seen as an important systemic instrument for the adaptation of current formal institutional frameworks. However, the law is still under discussion and it is argued that this law will even have a more restricting role for grid administrators within energy storage projects. As argued in the previous section, actors (i.e. ACM) should not limit the roles of grid administrators yet in these laws and regulations.

Secondly, there is much consensus that the net metering arrangement should be adapted. However, this argument is not without any self-interest of parties in favour of energy storage, since this has been developed in order to stimulate the adoption of decentralised solar energy generation. Nonetheless, by delivering decentral generated electricity back to the grid, the electricity grid functions as a large battery and thus fossil fuel driven power plants will always be necessary for backup generation. Therefore, energy storage can help diminishing the role of fossil fuel driven power plants, only if the net metering arrangement will be diminished.

Finally, for creating more room for all-electric technologies to develop, the role of natural gas should be further decreased. Diminishing obligated connections to the natural gas networks in natural gas areas is a first step, but further decreases of the role of natural gas are needed.

Policy recommendation 7) Include energy storage as a fourth pillar within the energy system (to RVO, ACM and Ministry of Economic Affairs).

Policy recommendation 8) Adapt the net-metering arrangement while taking the requirements for successful adoption of energy storage technologies into account (to Ministry of Economic Affairs).

Policy recommendation 9) Further diminish the role of natural gas, in order to create an environment in which sustainable energy innovation can further develop (to Ministry of Economic Affairs)

Policy goals based on landscape development

Figure 9: Results policy strategy

TIS function	Assessment condition	Result
F4	- Short term and long term policy goals	-

Short-term and long-term policy targets are seen as insufficient for guiding developments of energy storage technologies. Policy programmes are too much focused on short-term energy goals, leading to uncertainties regarding policy goals after 2023. This is illustrated by ill decision-making regarding the role of natural gas within the energy transition, which is highly likely to influence the need for energy storage. As a consequence, investing in sustainable energy innovations, including energy storage technologies is insufficiently stimulated. Thus, clear policy goals for after 2023 and goals concerning the role of natural gas are needed. Moreover, uncertainties regarding future arrangements (such as net metering) should be reduced by means of policy plans, in order to stimulate private investments in sustainable energy innovations that include energy storage technologies.

Policy recommendation 10) Set clearer energy transition goals after 2023, and make clearer decision about what type of energy production will be leading (to Ministry of Economic Affairs and TSE).

Discussion

In this section, the methodological value of the policy mix assessment framework, the value of the theoretical frameworks and the value for the NCA will be discussed.

Methodological value of the assessment framework

First of all, there was no solid basis to predicate upon the weight of one indicator compared to another. Therefore, all indicators have been treated as equally important. However, it is highly likely that per case, one indicator (e.g. the coordination of protected intellectual property rights) is less important than another indicator (e.g. the adaptation of regime structures). As a consequence, this research has not fully been able to come up with focal points for policy recommendations.

Secondly, while developing the assessment framework, there were some implications for the operationalisation of the formulated conditions and for the development of interview questions based on the operationalised indicators. For instance the indicator ´mobilisation of financial resources´ was more convenient to operationalise (‘type of financial resources,’ and ‘the extent to which that is identified as sufficient’) compared to e.g. the condition ‘adaptation of regime structures’. This last condition is a more complex phenomenon to perform research on and to discuss during interviews. More specific indicators for each condition are needed, particularly on how to interpret conditions such as ‘prepare the regime for the new technology’. As a consequence of these difficulties in operationalising, the results were only to be presented in a qualitative and descriptive manner. Therefore, establishing causality between the operationalised indicator and result is challenging.

Third, during the literature analysis for the development of the assessment framework, most conditions are based on the stimulation of technological innovation and the adaptation of formal institutions. The conditions thus mostly focus on existence of contributions by the government in the realm of subsidy programmes, tax exemptions and on policy goals. The framework to a lesser extent includes factors such as social innovation. Questions as “how is dealt with changes in employment?” will remain largely unanswered when purely focussing on the conditions of the assessment framework. Further research should include e.g. social acceptance of energy storage as well.

Fourth, not all conditions have been received as sufficiently relevant. First of all, it is argued by all interview respondents that the formation of platforms for knowledge diffusion is not necessarily to be stimulated by means of governmental policy. As firms and other organisations have a personal interest in finding partners to collaborate and share knowledge with, such platforms come into existence without governmental policy. Furthermore, targeted R&D funding schemes and technology specific targets were not identified as fully relevant, since it is argued that the government should let the market decide what the best technological directions are to focus on.

Finally, many observations during the research seemed to apply to multiple framework conditions. For instance, the lack of standards and protocols has been identified as a factor limiting market creation, but also as a limiting factor for knowledge and data sharing and the setup of experimentation projects. Before applying the assessment framework to other sustainable energy innovations, it should be revised to see which conditions are sufficiently relevant to include, and how they can be weighted.

Nonetheless, analysing the conditions as developed in the policy mix assessment framework has led to interesting insights in the many conditions regarding the specific case of energy storage. It has provided insights in the influence of the policy mix on innovation processes regarding energy storage and perceptions of actors active within the field. Furthermore, it has provided a solid basis for identifying the relevant policy mix for niche stimulations, and the identification of regime structures that need to be destabilised.

Discussion of theoretical approaches

The theoretical approaches that have been used (MLP & TIS) are not primarily focused on analysing the influence of specific policy on processes of socio-technical change concerning a technology. Instead, they are more focused on analysing interactions between institutions, policy, actors, financial infrastructure and physical infrastructure. The emphasis of this research has been on the influences of the policy mix regarding the socio-technical development regarding energy storage. Consequently, the implications of interactions between other relevant processes, such as actor involvements or (private) financial infrastructures, are to a lesser extent analysed within this research. As a consequence, a clear overview of the innovation system regarding energy storage is lacking. Wieczorek and Hekkert (2012) provide the steps for setting up such a systemic analysis, which should be implemented in further research.

Furthermore, as stated before, inclusion of social acceptance of energy storage technologies is a factor that has been missed while developing the assessment framework. As this framework is based on TIS and MLP, it can be seen as a serious drawback of both theoretical approaches. While focusing on the role of incumbent structures, entrepreneurs and policy, there has been no focus on the question whether energy storage is desired by society. Also other scholars (e.g. Bening, Blum & Schmidt (2015)) argue that within the TIS framework, 'clean' technologies are often implicitly assumed to be socially desirable, without putting much effort on investigating whether this is true.

Nonetheless, the theoretical approaches have provided a solid basis for the development of an assessment framework that includes conditions that are needed for a policy mix to sufficiently stimulate processes of socio-technical change. Moreover, these theoretical frameworks seemed to be familiar to several interview respondents, which were greatly supporting the value of the interviews.

Value of this research for the Netherlands Court of Audit

This research has been written as part of a research internship at the Netherlands Court of Audit (NCA). The research assignment was to perform a literature search on the methodological implications for evaluating the effects of energy-innovation policy on transition processes, and to come up with a methodology for analysing the effectiveness of energy-innovation policies stimulating the energy transition. For the NCA, the main result of this research is the assessment framework as developed in section 3.6. The case of energy storage has been used as a mean to illustrate the value of the policy mix assessment framework. This research has not included the term 'effectiveness', since this framework provided a basis for qualitatively describing influences of policy mixes rather than establishing strong causality. In the previous section, it has been discussed what needs to be adapted before applying the assessment framework to analyses of other energy-innovation policy mixes. However, the NCA can use the assessment framework a starting point for analysing transition processes (influenced by policy mixes) in order to develop recommendations for the adaptation of policy and regulatory frameworks. Furthermore, the notion of *creative destruction* (based on the MLP) has been of value for the formulation of interview questions, which can be of value for the NCA as well.

Discussion on methodologies

In this section, the methodology and the used data will be discussed.

First of all, one of the main results of this research has been the difficulties concerning the role of public organisations within regulatory frameworks. However, only grid administrators and no private parties that lobby against a more expanded role of grid administrators have been interviewed. Moreover, the ACM, that set actor rules within the energy system, is not included in the interviews. This has consequences for the validity of the results. Future research should also include private parties and the ACM in order to discuss the new arising roles within energy systems and to discuss the distribution of these roles. The same question regarding validity applies to the results concerning incumbent energy producers and the identified lack of data exchange, which is an important barrier for the development of energy storage. As no energy producers have been interviewed, it was not possible to discuss the motivations of incumbent firms regarding a more open data exchange towards new actors within the energy market. Furthermore, how attempts of the SIP for a more open data exchange result in adaptations of strategies of incumbent firms also has not been included in this research.

Secondly, a focus of respondents lied on storage in residential areas by means of batteries and to a lesser extent on conversion to gas (power-to-gas). Actually, energy storage has a much broader function. Energy storage also fulfils a function within mobility and heavier energy users (industry processes). Further research should also include other applications for energy storage in order to create a more comprehensive overview of the policy mix.

Third, the limited time to perform this research has resulted in a suboptimal explanation of all analysed conditions. For instance, the lack of standards has been identified as one of the most important barriers for innovations of energy storage technologies. A comprehensive analysis on how standards should be developed did not fit within the time provided for this research.

Fourth, this policy analysis was not fully able to exclude factors influencing the results other than policy influences. To illustrate, while assessing 'stimulation of entrepreneurship', private investments or other motivations were not included. Therefore, rival explanations other than the influence of the policy mix are not given.

Finally, the used interview method has led to some negative implications for this research. The aim was to interview several actor groups (entrepreneurs, researchers, policy makers and grid administrators). Thus, different interview questions were asked to different respondents. Consequently, as all respondents discussed different topics, not all framework conditions were sufficiently discussed. Furthermore, the amount of consensus, which was used for the value judgement of the conditions, sometimes consisted on only two or three opinions, as not all interviewees discussed the same topics.

Recommendations for further research

As a consequence of the theoretical and methodological implications described above, the following suggestions for further research are given:

1) Include analyses regarding social acceptance of energy storage in order to come up with recommendations for policy regarding social innovation;
2) Perform a more extensive literature search on the questions whether all discussed conditions are sufficiently relevant;
3) Create, by means of an extensive literature search, more specific indicators concerning each condition in order to perform a better analysis of the effects of policy mixes on innovation processes;
4) Discuss the interactions between the TIS functions, actors and institutions in order to gain a better overview of the innovation system regarding energy storage. Steps for such a systemic analysis are provided by Wieczorek and Hekkert (2012);
5) Involve incumbent energy producers, other private firms and the ACM in order to create a more comprehensive picture of the problems and solutions with regard to data exchange, the effects of policy programmes on incumbents firm strategies and their visions on the role of public grid administrators within energy storage projects;
6) Include the role of energy storage in mobility and industry in in order create a more comprehensive overview of the influence of policy mixes on energy storage in general;
7) Perform a more comprehensive research on the influences of standards and other market-pull instruments on energy storage in order to come up with more specific policy recommendations.

Conclusion

This research has investigated the role of governmental policy on technological and institutional innovation regarding energy storage. Actors in the field that innovate will always make use of a variety of policy instruments and programmes. Therefore, this research focused on the influence of the relevant policy mix concerning energy storage, rather than evaluating the influence of individual policy instruments. This ex ante evaluation is used for developing recommendations for the adaptation of the innovation policy mix.

Starting point of this analysis was that first of all, sustainable energy innovations are in need for transformative policy that stimulates socio-technical change, meaning sufficient interaction between technology, people and institutions. Secondly, energy innovations often face challenges in becoming adopted within the current energy regime. Thus, innovation policy should not only focus on creation of new technologies, but also on the destruction of current regime factors. For this, the following research question has been defined:

To what extent is the Dutch energy-innovation policy mix sufficiently supporting the development of technologies for energy storage, and how can this be improved?

In order to answer the research question, first of all, a policy assessment framework has been created, based on two complementary theoretical approaches that can be applied to study the link between innovation policy and socio-technical change: *Technological Innovation System framework* and the *Multi-Level Perspective.* Secondly, an overview of the relevant policy mix regarding energy storage has been provided. Subsequently, by means of performing semi-structured interviews, it has been analysed whether the policy mix sufficiently stimulated all individual conditions as developed in the policy assessment framework. This analysis has led to a variety of results and recommendations that provided an answer on the research question.

As a result of the generic and specific Top sector policy approach of the Ministry of Economic Affairs, the provision of financial resources and other forms of policy support, entrepreneurial activities concerning energy storage are well stimulated. However, regime structures seriously hamper innovation of energy storage.

For energy storage to become adopted in the energy system, should laws and regulations, incumbent actors and other structures within the energy system and market shift their focus away from old habits that mainly focusses on large-scale production, distribution and consumption of energy. It should be acknowledged that, as a result of the energy transition and increasing decentralisation of energy production, new products and services will arise. Energy storage is one of those newly developing technologies and services. Only if regulatory and institutional frameworks will be adapted, and the energy market is open for new products and services, energy storage can be sufficiently adopted within the Dutch energy system.

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Annex

Annex 1: An overview of energy storage technologies

When discussing which technologies for energy storage currently exist, it should be noted that energy storage is multifunctional in the sense of ensuring flexibility: energy storage can vary between milliseconds, a couple of hours or days, or even for whole seasons. A good mix of renewable energy systems (in particular solar and wind) can in itself contribute to a balanced operation over certain timeframes. However, for instance the variation of solar energy generation (with peaks around noon and low generation over darker part of a day) is typically not in line with the daily consumption profiles of consumers. The same goes for annual energy consumption patterns (with longer days in summer and shorter days in winter). Moreover, cloud coverage can cause significant changes in electricity generation even over the course of minutes, which causes a specific challenge to the grid. This illustrates the various timeframes in which the electricity grid needs to be balanced (European Commission, 2016). The preferable type of storage depends on the amount of electricity that is needed to be stored, the required storage time, energy density, the required response time and on the cost of storage (ISPT, 2017; Van de Vegte et al., 2016). Together with the efficiency and the costs of the storage technology, these characteristics have a direct impact on the business cases through the revenue that the storage can generate on the markets through services and benefits (European Commission, 2016).

Electricity can be stored mechanically (e.g. flywheels and hydroelectric stations), thermally (heat storage), chemical (e.g. conversion to gasses as hydrogen (H2) and ammonia (NH3)) and electrochemically (by means of batteries).

Mechanical storage

Mechanical storage means that storage technologies store energy in various forms of kinetic and/or potential energy:
- Pumped hydro storage is the most mature technology, and accounts for a major share of storage capacity globally (around 97%). However, because of the Dutch geographical landscape, pumped hydro storage is not playing a large role within the energy storage technology landscape.
- Flywheels store electrical energy as kinetic energy by increasing rotational speed of a disc rotor on its axis. Flywheels are already in use in the Netherlands (on a small scale), since they are highly suitable for frequency control. This is due to the short response time, usually in the order of milliseconds to seconds. However, the amount of power that can be stored within flywheels is relatively limited.

Thermal storage

Thermal storage converts electricity to heat, which can be stored in various types of materials. The heat can be converted back to electricity through steam turbines. The main advantage of thermal storage is that in can have large capacities. Furthermore, the stored heat can be used for heating for instance for households.

Chemical storage

Chemical storage means converting electricity to other energy forms such as gas and is typically named as a “power-to-gas” solution. Chemical storage is mostly based on hydrogen production. By means of electricity (electrolysers), water can be split into hydrogen (H2) and oxygen. Subsequently, the H2 and nitrogen out of the air can be converted to ammonia (NH3). Produced hydrogen or ammonia (or further processed to methane) can be stored in a variety of ways, including gas form which can partly be used as additional gas within the natural gas grid networks, or in tanks of underground storage facilities. Advantages of chemical storage are that it can be stored over longer periods of time and that the gas can be used for a variety of purposes. Disadvantages of power-to-gas solutions are the low energy efficiency of the conversion processes.

Electrochemical storage

Electrochemical storage encompasses storage in batteries. This is the most common form of electricity storage in the Netherlands. The characteristics of the battery depend on the specific battery technology that is applied. Batteries are generally suitable for relative short duration of storage, and they have (in most cases) fast response times. Batteries are mainly suitable for medium or low-voltage distribution networks, such as batteries in residential areas or households with many solar panels on their roofs or in electrical driven cars. Batteries can be placed in homes, at the electricity grid but also connected to an electricity generator such as windmills. They cannot fully take over the household energy from the grid, but they can help managing grid flexibility by storing certain amounts of electricity or put certain amounts of electricity back at the grid. The mostly used batteries in the Netherlands are:
- Lithium-ion batteries: Are emerging as one of the fastest growing battery technologies for grid applications. They have already significantly benefited from R&D investments, which were aimed at commercialising their use in the electronics and transport applications.
- Flow batteries: Flow batteries are a type of rechargeable battery, where this recharge ability is provided by two chemical components that are dissolved in liquids contained within the system and most commonly separated by a membrane. The fundamental difference between conventional batteries and flow cells is that energy is stored as the electrode material in conventional batteries but as the electrolyte in flow cells. Flow batteries often have long life-spans and do not need heavy metals for their construction (European Commission, 2016; Van de Vegte et al., 2016)

Annex 2: An overview of actors active in innovation processes regarding energy storage

Within innovation system, actors play a crucial role (Wieczorek & Hekkert, 2012).
For the innovation system concerning energy storage, the following actors are identified as the most important:

- **Companies**: Start-ups and SME's that innovate for new and improved technologies for energy storage. These include for instance:
  - Elestor BV: Specialised in hydrogen/bromine flow batteries, mainly applicable for utility buildings such as schools;
  - V-Storage: Makes use of old batteries from for instance busses for making large battery systems for energy storage;
  - Jules Energy: Specialised in IT services and software for having financial advantages among others for trading energy and storage systems.
  - FME: Is not an entrepreneurial organisation itself, but an interest organisation for entrepreneurs. FME has a large role in the lobby for storage technologies at the national government and started with the organisation of the Platform Energy Storage NL, that aims to connect all important actors with each other for knowledge diffusion and collaborative research.
- **Government**: Innovation policy mainly is the responsibility of the Ministry of Economic Affairs and its agent the Netherlands Enterprise Agency (RVO) This agency encourages entrepreneurs in sustainable and innovative business. They consult entrepreneurs and provide most of the funding schemes described in section 5.1.2. RVO contributes to many research and demonstration projects concerning smart grids and applications of storage technologies. For this, the agency among others help entrepreneurs with finding business partners, to comply with laws and regulations and with finding the right knowledge.
- **Research institutes**, these include:

- ECN (Dutch Energy Research Centre): Their goal is to integrate renewable energy into the electricity system by developing revenue models and policy instruments for the integration of renewable energy in the energy system and by developing technologies for the storage of energy and for aligning supply and demand.
- DNV GL: A research and consultancy organisation specialised in energy issues. They have an important role within the energy storage development in the Netherlands by develop roadmaps for the development of storage technologies.

- **Civil society**: These include mainly the end-users of storage technologies on the household level. Within this research, no civil society actors have been interviewed. Actors that were interviewed (e.g. grid administrators and SME's however, performed during demonstration project social research on the wishes of the civil society.
- **Grid administrators**: In the Netherlands, grid administrators are public organisations. Energy production is the responsibility of private organisations. Grid administrators are responsible for the distribution of energy (electricity, gas, warmth etc.) to consumers and companies. An expected increased amount of energy that is produced by means of solar and wind energy, more decentralised energy production and more electrification makes it for grid administrators more challenging to deal with problems such as congestion and peak loads at the electricity grid. Grid administrators are looking for new ways of distribution, by means of experimenting with new forms of ICT, demand response and storage. "Netbeheer Nederland" is the interest group related to all Dutch grid administrators, and lobby's for their interest.

Annex 3: TRL levels

TRLs are a systematic measurement system that supports assessments of the maturity of a particular technology and the consistent comparison of maturity between different types of technology (Mankins, 1995). The TRL consists of nine levels:

TRL level	Phase of policy	Short description (Mankins, 1995)
1	**Description**	Basic principles observed and reported
2		Technology concept and/or application formulated
3		Analytical and experimental critical function and/or characteristics proof-of-concept
4	**Development**	Component and/or breadboard validation in laboratory environment
5		Component and/or breadboard validation in relevant environment
6		System/subsystem model or prototype demonstration in a relevant environment (ground or space)
7	**Demonstration**	System prototype demonstration in a space environment
8		Actual system completed and "flight qualified" through test and demonstration (ground or space)
9	**Deployment**	Actual system "flight proven" through successful mission operations

Annex 4: Interview respondents

	Name	Organisation	Function
Entrepreneurs	**Guido Dalessi**	Elestor BV (specialised in the development of bromine/hydrogen flow-batteries	CEO
	Bob Weehuizen	Proton Ventures (specialised in applications for ammonia, of which conversion to gas for storage is one of the possibilities).	Project Engineer
	Hans van der Spek	FME – Entrepreneur interests organisation for technological industry	Cluster manager energy & Secretary Platform ESNL
Policy makers	**Ed Buddenbaum**	Ministry of Economic affairs & Topsector Energy	Policy advisor & Secretary TSE
	Joris Knigge	Mentes Advisory & System Integration Programme (TSE)	Programme manager System Integration (TSE)
	Arja Even	Netherlands Enterprise Agency (RVO)	Programme and strategy advisor
	Nicole Damen - Kerkhof	Netherlands Enterprise Agency (RVO)	Projectleader smart grids
Knowledge institutes	**Jasper Groenewegen**	DNL GL – Energy research and consultancy	Specialist energy storage
	Jan Ros	Netherlands Environmental Assessment Agency (PBL)	Researcher of energy transition and policy implications, specialist in energy systems
Grid administrators	**Jos Blom**	Alliander	Innovation and strategy consultant & Board Platform ESNL
	Jan Willem Eising	Alliander	Projectmanager strategy & innovation. Project "buurbatterij"
	Bismarck Dibo	Enexis	Projectmanager asset management. Project "buurbatterij: Jouw energiemoment 2.0"

Annex 5: Indicators for all conditions in the assessment framework

Annex 5 a: Niche creative

TIS Function	Condition	Indicators
F1	**Stimulating entrepreneurship**	- Extent to which entrepreneurs in general feel that they are well-supported by means of governmental policy (e.g. by means of funding and supervision)
	Relaxed regulatory conditions for experimenting	- The existence of regulatory barriers for experimentation within innovation projects - Existence of regulatory flexibility/policy programmes to apply for exemptions for regulations within experimentations. - Extent to which these programmes provide sufficient regulatory freedom for experimenting (according to interview respondents)
F2	**R&D funding schemes**	- Presence of and access to R&D funding schemes - Extent to which the amount of funding schemes is identified as sufficient
	Stimulation of higher order learning	- Presence of and access to funding schemes and policy programmes for the funding and supervision of commercial-scale demonstrations - Extent to which funding and supervision of commercial-scale demonstration is identified as sufficient
	Competence building	- Presence of policy (or other governmental) programmes that focuses on coaching of entrepreneurs, or for seeking right markets, business partners, or how to comply with regulatory frameworks - Extent to which competence building programmes are identified as sufficient
F3	**Coordination of intellectual property rights**	- Extent to which protected intellectual property rights are seen as barrier for innovation - Existence of policy action for the coordination of protected intellectual property rights - Extent to which the coordination of intellectual property rights is identified as sufficient in order to not hinder knowledge diffusion processes
	Stimulation of platforms for knowledge diffusion	- Existence of policy programmes that stimulate platforms for knowledge diffusion - Extent to which (possibly) existing platforms for knowledge diffusion are identified as sufficiently stimulating knowledge diffusion
F4	**Targeted R&D funding schemes**	- Consensus on the need for targeted funding schemes - Existence of targeted R&D funding schemes - Consensus on the question whether targeted R&D funding schemes are in optimal combination of generic innovation policy
	Technology specific targets	- Consensus on the need for technology specific targets - Existence of technology specific targets - Extent to which technology specific targets currently are providing sufficient guidance of the search

	Clear regulatory frameworks	- Extent to which regulatory frameworks provide sufficient clear boundaries of what is/what not is allowed. - Existence of policy programmes to help entrepreneurs complying with regulatory frameworks
F5	**Favourable tax regimes and tax exemptions**	- Existence of tax regimes in favour of the technology - Existence of tax regimes disadvantaging the technology - Possibilities to apply for tax exemptions for disadvantaging taxes regimes - Extent to which tax regimes are identified as sufficiently in favour of the technology - Extent to which applying for tax exemptions is sufficiently stimulating innovation processes concerning the technology
	Standard setting	- Existence of standards concerning the technology - Extent to which standard setting is identified to sufficiently stimulating innovation
	Deployment subsidies	- Existence of deployment subsidy programmes - Extent to which deployment subsidies are identified as sufficiently stimulating the technology
F6	**Financial support**	- Mobilisation of financial resources: which policy programmes? - Extent to which mobilisation of financial resources are identified as sufficient
	Human support	- Mobilisation of human resources: which policy programmes? - Extent to which mobilisation of human resources are identified as sufficient
F7	**Lobby practices**	- Identification of lobby practices in favour of the technology - Extent to which lobby practices are sufficiently picked up by the national government
	Inclusion of entrepreneurs in policy making	- Extent to which entrepreneurs are included in policy making processes - Extent to which the inclusion of entrepreneurs in policy making is identified as sufficient.

Annex 5b Regime destructive

TIS function	Condition	Indicators
F4	**Prepare regime for new technology**	- The extent to which regime structures (institutions, market rules, infrastructure etc.) are sufficiently able to adopt energy storage within the energy system.
F5	**Weakening existing regime**	- Existence of policy programmes weakening the existing regime (i.e. tax policies, regulations, environmental policy stringency, ETS) - Extent to which policy programmes weakening the existing regime stimulate niche developments concerning the new technology.
	Adapting en developing new institutions	- Identification of institutions in need for adaptation - Extent to which identified institution are under the process of adaptation - Extent to which adaptation processes are sufficiently support developments concerning the new technology.
F6	**Withdrawing support for incumbent grey electricity technologies**	- Identification of withdrawing policy programmes that support incumbent regime technologies - Extent to which withdrawing policy programmes that support incumbent regime technologies is sufficiently stimulating the new technology
F7	**Replacement of regime actors in policy advisory councils with niche actors**	- Identification of shifts in policy advisory councils from regime actors to niche actors - Extent to which shifts in policy advisory councils sufficiently stimulates the new technology
	Formation of new organisations linked to system change	- Identification of new organisations linked to system change that stimulates the new technology - Extent to which the formation of new organisations sufficiently stimulates the new technology

Annex 5c Landscape developments

TIS Function	Condition	Indicator
F4	**Short-term and long-term policy goals**	- Identification of all relevant short-term and long-term policy goals (e.g. energy targets, roadmaps) - Extent to which identified policy goals are providing sufficient guidance for the search

Annex 6: List of interview questions

General opening questions

1) What is your role, or your company's/organisations role within energy storage?

2) What do you think is the value of energy storage for the energy transition? And how will the role of energy storage develop within the Netherlands?

3) What can you tell me about all relevant policy instruments regarding energy storage, is the following list complete? (show at that time current list of policy instruments)

Niche creative

4) What can you tell me about the influence of governmental policy on entrepreneurial activities regarding energy storage of SME's or other firms? (In the sense of e.g. financing, supervision, competence building, finding the right business partners, to comply with regulatory frameworks)

5) What types of policy instruments are in place for the stimulation of entrepreneurial activities? Do you see gaps in governmental policy programmes for the stimulation of entrepreneurial activities?

6) To what extent are entrepreneurs included in policy making processes? What types of programmes are in place for that and do you identify this as sufficient?

7) What can you tell me about the room (in the sense of regulatory flexibility) regarding experimentation projects for energy storage? What types of barriers are in place for experimentation projects? What policy programmes are in place for increasing regulatory flexibility regarding demonstration projects? Is there sufficient clarity regarding regulatory frameworks?

8) What type of knowledge networks (e.g. platforms) are in place regarding energy storage / what are important means for the knowledge diffusion among actors active within innovation processes of energy storage? What is the role of the national government in this?

9) Are there problems regarding knowledge diffusion? E.g. closed knowledge resulting from protected intellectual property rights? How is that coordinated?

10) Do you think there is a need for specific (innovation) policy regarding energy storage, or specific policy goals regarding energy storage, and why? What type of specific policy is currently adopted within policy frameworks, is there specific policy missing?

11) What can you tell me about the role of energy storage within the current energy market? How is it being adopted? What type of barriers are in place regarding market adoption? What type of market pull instrumentation is in place regarding energy storage (e.g. standardisation, tax regimes or others?)

12) Are there tax regimes in favour or disadvantaging energy storage? And how? How should tax regimes be adapted?
How is deployment of energy storage adopted within policy frameworks? Do you identify deployment policy instruments as sufficient, and why?

13) Are there other barriers in place regarding innovation of energy storage technologies that have not been mentioned while answering the previous questions?

14) What type of lobby processes are in place in order to increase the position of energy storage within policy and the energy market? How does the government deal with these lobby processes?

Regime destructive

15) Are there currently vested interest that lobby against energy storage? What are major institutional barriers for the adoption of energy storage that should be adapted? Do you see any policy processes concerning the adaptation of current policy frameworks or other institutions with regard to energy storage? Do you identify these processes as sufficient, and why?

16) What is furthermore necessary for current regime (energy market, energy system, policy frameworks, institutions) to become prepared for the adoption of energy storage? Do you think the current regime currently is sufficiently prepared for the adoption of energy storage, and why?

17) Are there (effective) policy instruments and programmes in place for the destruction of the current energy regime (e.g. ETS, carbon pricing) and how does this affect the development of energy storage technologies? Do you think these types of policy instruments are sufficiently relevant for the development of energy storage, and why?

18) What organisations are in place that aim at integrating energy storage within the current energy system (e.g. System Integration Programme (what is its role and to what extent is it sufficiently stimulating the development of energy storage?))

Policy strategy

19) What are the most relevant policy goals, agendas or roadmaps that are relevant for the development of energy storage? Do these goals provide sufficient guidance towards the development and innovation of energy storage, and why?