



ELSEVIER

# Environmental Innovation and Societal Transitions

journal homepage: [www.elsevier.com/locate/eist](http://www.elsevier.com/locate/eist)



## Interactions between systemic problems in innovation systems: The case of energy-efficient houses in the Netherlands

Alco Kieft<sup>a,\*</sup>, Robert Harmsen<sup>b</sup>, Marko P. Hekkert<sup>a</sup>

<sup>a</sup> Utrecht University, Innovation Studies, Copernicus Institute of Sustainable Development, PO Box 80115, 3508 TC, Utrecht, The Netherlands

<sup>b</sup> Utrecht University, Energy and Resources, Copernicus Institute of Sustainable Development, PO Box 80115, 3508 TC, Utrecht, The Netherlands

### ARTICLE INFO

#### Article history:

Received 25 November 2015  
Received in revised form  
30 September 2016  
Accepted 2 October 2016  
Available online xxx

#### Keywords:

Innovation system  
TIS  
Energy-efficient houses  
Problem interaction  
Systemic problem  
Blocking mechanism

### ABSTRACT

The innovation systems approach offers a framework to identify what inhibits the generation, diffusion and implementation of innovations. It prescribes that interventions should target systemic problems that inhibit the system from functioning well. In current literature, systemic problems are typically identified independent from each other, after which interventions are formulated for each one separately. The following will argue that, next to the problems themselves, also the interactions between the problems are of key importance when designing intervention strategies. We analyze the Dutch energy-efficient housing innovation system and conclude that neglecting interactions between systemic problems may not only lead to inaccurate problem diagnosis, but also to ineffective or even counter-productive interventions.

© 2016 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

## 1. Introduction

Literature on innovation systems advocates that both the complex interaction between actors and the prevailing institutional infrastructure strongly affect the speed and direction of innovation (e.g. [Edquist and Johnson, 1997](#); [Chaminade and Edquist, 2010](#)). Although initially the innovation systems approach focused on nations ([Lundvall, 1992](#)), additional strands have emerged for sectors ([Malerba, 2002](#)), regions ([Cooke et al., 1997](#)) and technological domains ([Carlsson and Stankiewicz, 1991](#); [Carlsson et al., 2002](#); [Hekkert et al., 2007](#)). Nowadays, the most common term for the latter is Technological Innovation System, or TIS ([Bergek et al., 2008](#); [Markard and Truffer, 2008](#); [Jacobsson and Jacobsson, 2014](#)). Since the innovation systems approach helps to identify how innovation can be stimulated, it has become a popular framework with both researchers and policy makers.

The innovation systems framework breaks with the neoclassical policy rationale based on market failures, as the latter is deemed unfit for the non-linear and complex nature of the innovation process. Instead of targeting market failures, interventions should target problems that inhibit the system from functioning well. Problems that may be targeted are, for instance, a lack of seed capital that restricts entrepreneurial startups or a negative image of a technology that inhibits demand.

\* Corresponding author.

E-mail addresses: [a.c.kieft@uu.nl](mailto:a.c.kieft@uu.nl), [alcokieft@gmail.com](mailto:alcokieft@gmail.com) (A. Kieft), [r.harmsen@uu.nl](mailto:r.harmsen@uu.nl) (R. Harmsen), [m.p.hekkert@uu.nl](mailto:m.p.hekkert@uu.nl) (M.P. Hekkert).

<http://dx.doi.org/10.1016/j.eist.2016.10.001>

2210-4224/© 2016 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

Different terms have been used to indicate problems in innovation systems, including systemic problems (Chaminade and Edquist, 2010; Wieczorek, 2014), system failures (Klein Woolthuis et al., 2005; Weber and Rohracher, 2012) and blocking mechanisms (Bergek et al., 2008).<sup>1</sup>

Although especially the term blocking ‘mechanism’ suggests that feedback plays an important role to understand problems in innovation systems, problems are, to the best knowledge of the authors, not conceptualized as such. Even though some literature mentions that problems in innovation systems reinforce each other (Johnson and Jacobsson, 2001; Klein Woolthuis et al., 2005), the overviews and categorizations of potential problems are presented as lists and thereby suggest conceptual independence (see e.g. Chaminade and Edquist, 2010; Klein Woolthuis et al., 2005; Negro et al., 2012; Weber and Rohracher, 2012). Case studies also reflect this conceptual independence of problems since they generally discuss problems one by one (see e.g. Faber and Hoppe, 2013; Patana et al., 2013; Wieczorek et al., 2013).

The main premise of this paper is that problems in innovation systems often interact, and may form ‘mechanisms’, that in turn prevent the innovation system to develop. In order to further explore this we carried out a case study of the Dutch energy-efficient housing innovation system. Our aim is to answer the following question: Does an innovation system analysis giving explicit attention to problem interactions yield contrasting or additional insights compared to an analysis of independent problems?

## 2. Theory

This section will introduce two central concepts from the innovation systems framework, namely system structure and key processes, will explain how these concepts are used to identify problems and formulate interventions, and discuss why this current practice may lead to difficulties during the analysis process. The different innovation systems strands (National, Regional, Sectoral and Technological) will be discussed collectively, because, even though they slightly differ in how they define and use central theoretical concepts, they all follow the same rationale in relation to problems: unsatisfactory system performance is caused by problems that pertain to the system structure.

The structure of any innovation system consists of structural elements that interact. There is a broad consensus in the literature that Actors, Interactions between actors (networks), and Institutions are structural elements of an innovation system. Furthermore, authors often make use of additional elements, such as Technology or Infrastructure in TIS literature (Chaminade and Edquist, 2010; Jacobsson and Bergek, 2011; Jacobsson and Jacobsson, 2014; Klein Woolthuis et al., 2005; Markard and Truffer, 2008; Wieczorek and Hekkert, 2012). It is generally agreed that there are many interactions and feedback loops between these structural elements (Bergek et al., 2015; Carlsson et al., 2002; Chaminade and Edquist, 2010; Edquist and Johnson, 1997; Jacobsson and Jacobsson, 2014; Markard and Truffer, 2008; Wieczorek and Hekkert, 2012). This multitude of interactions and feedback loops between structural elements is what makes an innovation system so complex.

It is difficult to judge or measure whether the structure itself is ‘good’ or not. For example, if ten entrepreneurs are active in a system, is that sufficient? To tackle this conceptual issue, the focus was shifted from the structure only to a combination of structure and key processes (often called functions). Under this new reasoning, the structure is considered ‘good’ if these functions are satisfactorily fulfilled. In contrast, if the function fulfillment is unsatisfactory the structure must be considered ‘not good’, and this will result in a system that does not develop at all or that develops in a ‘stunted fashion’ (Bergek et al., 2008). Although the use of functions is most prominent in TIS literature (Bergek et al., 2008; Hekkert et al., 2007), they have also been formulated for other innovation system strands (e.g. Edquist and Johnson, 1997; Galli and Teubal, 1997). Since it is easier to judge or measure the quality of functions than the quality of structural elements, their addition has made the framework more practical for analysts.

Structure and functions are two sides of the same coin, or as Markard and Truffer have put it: “two intertwined sides of the same object, the system” (p. 601). Due to the mutual dependence of structure and functions, the preferred approach to identify problems in innovation systems is to perform a combined structural/functional analysis (Bergek et al., 2008; Wieczorek and Hekkert, 2012). Both Bergek et al. (2008) and Wieczorek and Hekkert (2012) propose a stepwise analysis approach, and although the prescribed steps slightly differ, they have much in common: (1) an overview of the system structure is created, (2) the current system performance is determined through a functional analysis (3) for the weak functions the underlying problems that pertain in the system structure are identified, and (4) interventions are formulated to alleviate these problems, thereby improving the function fulfillment and thus the system performance. Functions are in this way placed ‘in between’ the system structure and system performance.

Literature on innovation systems mentions in some places that problems interact. For instance, “[...] there is a range of obstacles [...], which may act independently but are likely to reinforce one another” (Johnson and Jacobsson, 2001), or “Most problems in the innovation system will not be uni-dimensional but will consist of a complex mixture of causes and effects [...]” (Klein Woolthuis et al., 2005). Despite this, problem interaction has not yet received much conceptual attention. For instance, literature that discusses potential problems in innovation systems relates most problem categories to single structural elements (a.o. Chaminade and Edquist, 2010; Klein Woolthuis et al., 2005; Negro et al., 2012; Weber and Rohracher, 2012). Chaminade et al. (2012) puts it this way: “almost each author has his or her own list of potential systemic problems” (p.1477), to subsequently add that the types of problems discussed in literature “can be pinned down

<sup>1</sup> These terms have nuances of meaning to which we come back in the Theory section.

to infrastructure problems, [actor] capability problems, network problems, institutional problems and transition and lock-in problems” (p.1477).<sup>2</sup> Others hint at the conceptual relation between problems and structural elements (Jacobsson and Bergek, 2011),<sup>3</sup> or explain that analysts should determine whether “the weakness of the function has something to do with actors, institutions, interactions, or infrastructure [emphasis added]” (Wieczorek and Hekkert, 2012). Evidently, there is room for exploring the conceptual value of problem interactions in innovation systems.

The limited theoretical attention for problem interactions also reflects on case studies, as these – not infrequently – present a single independent problem to underlie a weak function.<sup>4</sup> For instance, Patana et al. (2013) mention in their discussion of the Finnish life science innovation system that actors in the field are too scattered, leading to difficulties in deciding on a concerted direction. In this example, there is probably another problem that underlies this scattered nature of the field, among other possibilities, a wide spatial distribution of actors, a lack of trust, or possibly a lack of financial means to organize regular meetings. A second example – related to the function mobilization of resources – comes from the analysis of the European Wind TIS by Wieczorek et al. (2013). They find that “in the future, if the offshore wind system develops, the scarcity of specialized, deep water vessels may [...] become a serious constraint” (p304). Yet, it is not explained why this situation may arise, even though this can be a result of problems related to, for instance, difficulties for vessel suppliers to get loans (financial infrastructure) or a lack of skilled personnel (human infrastructure). These examples show that the identification of independent problems often leaves questions open about what made them arise, thus posing challenges for formulating interventions. This does not imply that any innovation system analysis contains loose ends; analysts often implicitly give attention to what causes what in their text. Yet, especially for more complex innovation systems it is very challenging for an analyst to oversee all problems and all interactions without an explicit analysis of how problems interact.

Authors have used a variety of terms to indicate ‘problems’ in innovation systems; each with its own nuance of meaning. First, the term ‘systemic problem’ is generally used to indicate weaknesses that pertain to the internal system structure (endogenous problems). Second, the term blocking mechanism – prominent in especially TIS literature – points at any factor<sup>5</sup> that causes weak function fulfillment. These factors can reside either inside (endogenous) or outside (exogenous) the system (Johnson and Jacobsson, 2001; Bergek et al., 2008). Finally, although the term system ‘failure’ has been used as synonym for systemic problem by some authors (Klein Woolthuis et al., 2005), it is also increasingly employed to indicate broader issues with an innovation system (Weber and Rohrer, 2012). As it is now, the conceptual link between the terms systemic problems, blocking mechanism and system failure is not clear.

In this paper, we focus on the conceptual link between the terms systemic problems and blocking mechanisms and – based on the insights from our case study – propose a reconceptualization in such a way that interactions between problems become conceptually part of them.<sup>6</sup> Instead of using the term blocking mechanism to indicate a problematic ‘factor’, we use it to indicate a real ‘mechanism’ that consists of interacting systemic problems. Such a blocking mechanism will usually include systemic problems that pertain to the internal system structure (endogenous systemic problem), but can also contain problems from its context (exogenous systemic problem). Note that, by including exogenous problems in the term systemic problems, we give it a broader meaning than what is currently prominent in literature. This reflects the increased attention for the system context in recent literature on innovation systems (e.g. Bergek et al., 2015). Under this new conceptualization, weak function fulfillment and weak system performance may thus be caused by a blocking mechanism that consists of interacting systemic problems. To illustrate how this may work during an innovation systems analysis, our case study makes use of these adapted meanings of the terms systemic problem and blocking mechanism.

We based the selection of our case study on the expectation that an explicit analysis of how systemic problems interact has added value especially for innovation systems that share one or more of the following related characteristics: mature, locked-in (Unruh, 2000), making a transition, and strongly structurally coupled with contextual systems. First, mature systems are often relatively large which leads to many feedback loops between elements of the system. Second, such systems are often locked into certain technological combinations. For example, the Dutch energy-efficient housing innovation system can be considered a mature sectoral innovation system that is locked into the combination of using little insulation with gas-based technologies for heating. Lock-in is not necessarily problematic; such a system may have developed effective routines to deal with problems. However, when a transition is desired, this locked-in nature of the system will inhibit change and may become the source of problems itself. In our case study, the system is making the transition toward building highly energy-efficient houses,<sup>7</sup> and the advent of new technologies (e.g. better insulation materials, renewable energy technologies etcetera), is increasingly putting pressure on current routines. What is more, mature systems often have strong structural

<sup>2</sup> The problem category of ‘transition and lock-in problems’ does at first sight involve feedback. However, as Klein Woolthuis et al. (2005) persuasively argued, ‘lock-in’ is the result, rather than the cause of unsatisfactory system performance and can thus not be classified as a problem category.

<sup>3</sup> They mention: “Indeed, all the four types of system failures identified by Klein Woolthuis et al. (2005) in their synthesis and re-categorisation of previous literature on system failures are related to structural components [...]” (p46).

<sup>4</sup> Some case studies do give explicit attention to how problems interact (e.g. Totin et al., 2012; Amankwah et al., 2012). However, these case studies loosely make use of the innovation systems framework, do not systematically explore what the additional explanatory power of such an approach is, and how this links up to the theoretical concepts prominent in the innovation systems approach.

<sup>5</sup> For instance, Bergek et al. (2010) mention that blocking mechanisms are “factors that provide obstacles to the development of functions” (p131), and Jacobsson and Karltorp (2013) use the terms factors and blocking mechanisms interchangeably.

<sup>6</sup> In the discussion section we reflect further on the conceptual link with the term ‘system failure’.

<sup>7</sup> This is in line with the European goal of building only ‘nearly-zero energy’ houses by 2020 as introduced in Council Directive 2010/31/EU on the energy performance of buildings (recast) [2010] OJ L153/13 [EPBD recast]. To define highly energy-efficient, the definition of a nearly-zero energy building from

couplings with their context (Bergek et al., 2015). Problems that express themselves in such systems often have their origin outside of the immediate system boundaries, making it fruitful to analyze how the problems inside and outside the system interact. In our case study for instance, strong structural couplings with TISs of non-renewable technologies must be broken down, whereas structural couplings with TISs of renewable technologies must be created or strengthened. Additionally, since buildings are inherently tied to a certain location, this innovation system is strongly affected by the Dutch geographical and political context structures, e.g. in the form of the strong Dutch political belief in decentralization as we will see in the case study (Section 4.1). The combination of these characteristics makes the innovation system of energy-efficient houses in the Netherlands a good candidate for exploring the merits of an explicit analysis of problem interactions.

### 3. Method

The data necessary to map systemic problems, their interactions, and possible blocking mechanisms that these form, came from the combination of interviews with practitioners and supplementary literature. The interviews were held with multiple stakeholders involved with highly energy-efficient houses. We used snowball sampling to identify potential interviewees. In total, 23 semi-structured interviews were conducted – lasting on average two hours – with government officials, project managers of housing associations, private project developers, construction companies and advisors/consultants. We collected supplementary literature to clarify statements given by the interviewees, e.g. the exact contents of mentioned laws and regulations. Adding interviews and literature to the analysis stopped when this no longer led to new insights (theoretical saturation).

To determine how the systemic problems in this innovation system interact, it is important to know in which phase of the building process they arise. Our definition of these phases was based on the Dutch NEN 2574 norm (NEN, 1993),<sup>8</sup> to which a Land preparation phase was added. This led to the following phases (1) the Land preparation phase which includes the construction of basic infrastructures (roads, utility networks etcetera), (2) the Program phase which includes the formalization of goals and ambitions by project initiators, (3) the building Design phase and finally (4) the Construction phase. After the interviewees had mentioned a specific problem, they allocated it to a certain phase of the building process. Then, they were asked to explain what had caused this problem to arise and how this problem affected later phases of the building process. This led to elaborate descriptions of how problems interact.

Cards that resemble flashcards or playing cards were used to structure the interviews (see Fig. 1). There were three types of cards available: (1) cards for problem categories, (2) blank cards and (3) cards for phases of the house building process. There were problem category cards for each of the structural elements and functions of an innovation system, for instance, the card 'rules and regulations' related to the structural element Institutions, and the card 'financial resources' related to the function Mobilization of resources. These problem category cards were meant to provide the interviewees with ideas for problem categories, although the possibility of adding additional problem categories was constantly stressed. The interviews started by asking what problems inhibit building highly energy-efficient houses in the Netherlands and in which building phase these problems manifest themselves. For each problem mentioned, a problem category card was placed on the table underneath the building phase card to which it corresponds. Interviewees could then specify the problem by writing on a blank card and placing it on top of the problem category card. If interviewees mentioned a problem that did not directly relate to the building process, the card was placed on the left side of the unfolding overview. This led to overviews of cards (for an example see Fig. 1) that were not only accompanied with elaborate explanations for each problem separately, but also with explanations about how they interact.

The interviews were recorded and transcribed into text. Data analysis consisted of coding and grouping relevant textual fragments from both the interviews and the supplementary literature.<sup>9</sup> During this process, guidelines were used for *initial coding* (Charmaz, 2006), *open coding* (Strauss and Corbin, 1998) and *focused coding* (Charmaz, 2006). Next, a diagram was created to show how the identified problems interact (Fig. 2 in Section 4.1). The process of creating the diagram resembled the process of *axial coding* (Charmaz, 2006). The elaborate explanations that interviewees had given of 'what caused what' formed the basis for the interactions in the diagram. Subsequently, a storyline was written to accompany the diagram, which was structured according to seven main umbrella themes that grouped problems with a certain common ground. A preliminary version of the diagram and the storyline were discussed and validated in a meeting with five experts on energy-efficient houses.

The final step consisted of linking the identified systemic problems to the structural elements, the system functions, and to categorize them as national, sectoral or technological. Categorizing problems as national, sectoral, or technological was straightforward for some problems, but in many cases the allocation process was fuzzy. For instance, some problems may have both national and sectoral characteristics (e.g. national regulations about how the land market is organized), while

the EPBD recast is used: "a building that has a very high energy performance [ . . . ]. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby" (p.18).

<sup>8</sup> The Use/Exploitation phase was dropped because it falls outside the research scope. Additionally, the Elaboration phase – of which tender activities and price setting are part – was not explicitly used during the interviews because these activities are increasingly made part of earlier phases (see case study description).

<sup>9</sup> For this purpose, the Computer Aided Qualitative Analysis Data Software (CAQDAS) NVivo was used. NVivo qualitative data analysis software; QSR International Pty Ltd. Version 10, 2012





Fig. 1. Photo portraying how cards were placed by one of the interviewees.<sup>10</sup>

others have both sectoral and technological characteristics (e.g. construction companies causing technical problems because of a knowledge insufficiency regarding energy-efficient technologies). If allocation was difficult, sectoral was chosen over technological and national over sectoral. For linking the systemic problems to structural elements and system functions we used the definitions from [Wieczorek and Hekkert \(2012\)](#). The results of this final step can be found in [Table 1](#) in Section 4.2.

To explore the question whether explicit attention for problem interactions during an innovation system analysis yields contrasting or additional insights compared to an analysis of independent problems, the data was analyzed in three steps. First, two sets of systemic problems that both form a blocking 'mechanism' were selected from [Fig. 2](#) and were subsequently analyzed. Second, the gained insights were compared to the output of an analysis that only identifies independent problems (for which the results would have resembled [Table 1](#)), and third, the outcomes of our analysis were compared to an earlier innovation system study of the same empirical domain ([Faber and Hoppe, 2013](#)).

## 4. Results

The current situation in the Dutch innovation system of energy-efficient housing can only be understood against the backdrop of its history. From the end of World War II to the beginning of the 1990s, the Dutch house building sector was characterized by a high degree of central planning. The national government took the lead in reconstruction activities after World War II and decided on the areas where new houses were allowed to be built. To achieve high efficiency, house construction was organized in large projects in which whole neighborhoods were erected and this led to the dominance of larger construction companies, as only these could deliver the required capacity for constructing whole neighborhoods. Additionally, row houses became the norm because these could be built efficiently in series. Then, in the beginning of the 1990s, the national government decentralized responsibilities for constructing houses to municipalities and other local stakeholders, for instance, housing associations and private project developers. To incentivize these local stakeholders to take up this responsibility it was decided to restructure the land market, which provides the starting point for discussing the identified problems and their interactions.

### 4.1. Interactions between problems in the innovation system of Dutch energy-efficient houses

This section provides a storyline to accompany all problems and their interactions as shown in [Fig. 2](#). These problems fall within three problem themes, namely *Land market*, *Project-based approach* (the standard house building process followed in the sector) and *Resources*.<sup>11</sup> Each box represents one problem and the connecting lines signify which problems interact. The

<sup>10</sup> Most interviewees placed more cards. This example was chosen for visual clarity.

<sup>11</sup> Presenting and discussing all problem themes proved infeasible because of space limitations. A complete description of all identified problem themes can be found in [Kieft et al. \(2013\)](#). The other main themes were *Conservatism*, *Building Concepts*, *EPC* (Dutch calculation methodology for energy-efficiency of buildings) and insufficient *Room for Experimentation*.

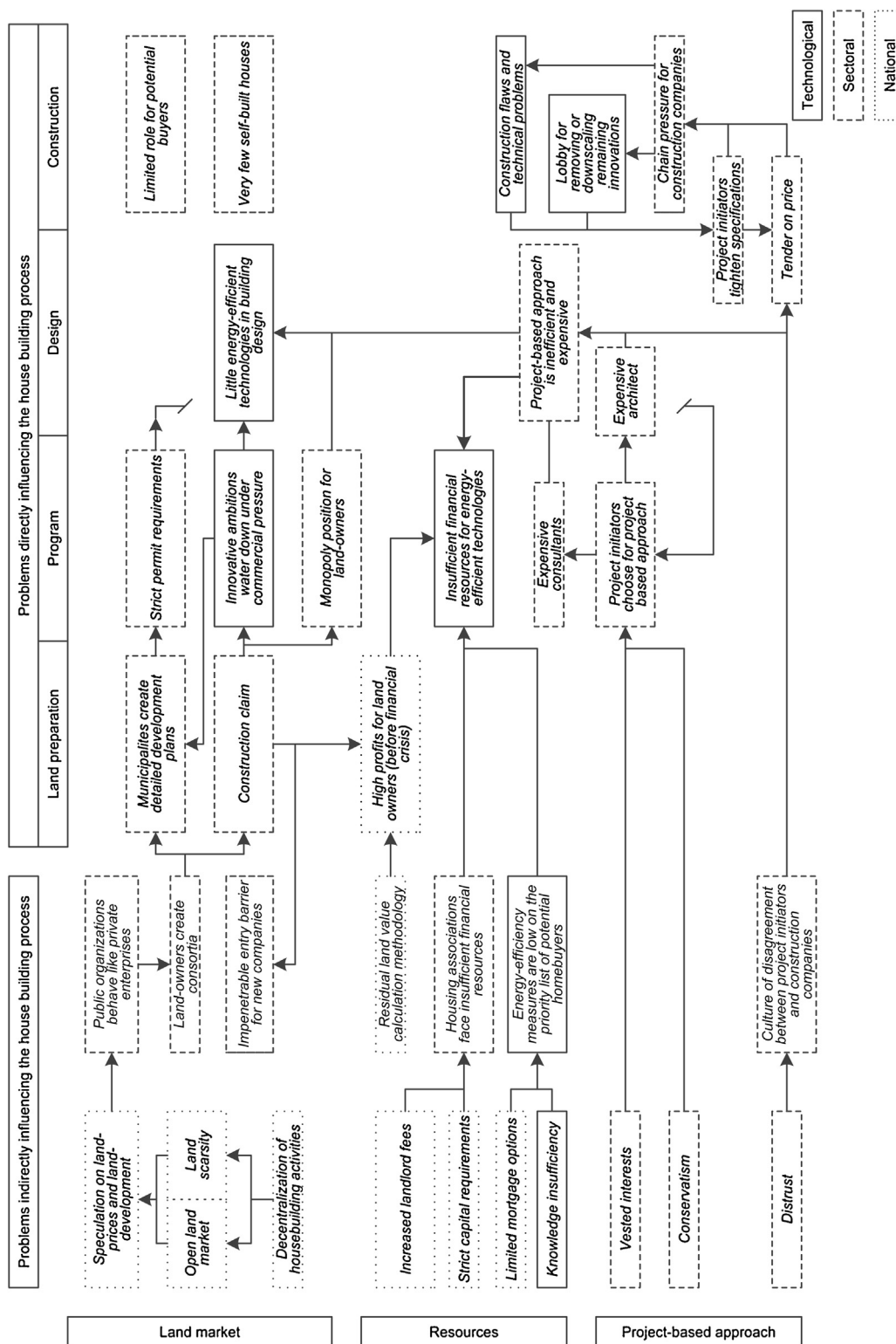


Fig. 2. Problems and their interactions in the Dutch innovation system of highly energy-efficient houses.

different box outlines show whether a problem was allocated as sectoral, national, or technological (see Method section). Problems are placed underneath the building phase in which they arise and next to the problem theme they belong to. Problems that only indirectly influence the house building process are shown in the most left column. In the storyline below, the terms in *italics* correspond to the boxes in Fig. 2.

The first theme – *Land market* – starts with the *decentralization of housebuilding activities* that took place in the beginning of the 1990s. Decentralization was facilitated by setting strict restrictions on the space allotted for development, and additionally by creating an *open land market* in which private actors could compete for this allotted space. This created *land scarcity* which made land-prices skyrocket whenever a municipality decided to designate an area for constructing houses (this changed temporarily when the financial crisis hit in 2009). The national government hoped that high potential gains on land would persuade stakeholders to enter the land market and start housebuilding activities, thereby removing the need for national subsidies (Tijdelijke Commissie Huizenprijzen, 2013). Indeed, *speculation on land-prices and land development* became a profitable business which led to the involvement of private project developers and later also to the involvement of large construction companies and housing associations. As a result, most of the land in the Netherlands that has development potential came into the hands of speculating stakeholders.

*Public organizations* started to *behave like private enterprises*. Housing associations moved away from their core public task of providing cheap social housing and became active in the private segment. Municipalities – tempted by potentially high profits – also started to develop new housing areas more aggressively. The historic divide between public and private stakeholders faded.

Close interactions between public and private stakeholders at the beginning of the house building process became the norm. The designated land for a new house building project is usually owned by multiple stakeholders (mostly private project developers, housing associations and municipalities). Since ‘the one who owns the land has the right to build’, these landowners are forced to collaborate. Therefore, these *landowners create consortia* in which decisions are made in consensus.

Land preparation activities, such as building the road and utility networks, are usually supervised by the municipality. To organize this efficiently, most municipalities first buy all the land from the other landowners, and grant them a so-called *construction claim* that gives them the right to buy the land back after land preparation activities are finished. These construction claims create a *monopoly position for landowners* as they are the ones that hold the development rights, even though they no longer own the land. In this way, construction claims form an almost *impenetrable entry-barrier for new companies*.

During the consensus processes that are typical within the consortia of landowners *innovative ambitions water down under pressure of commercial interests*. Although municipalities are often ambitious in terms of reaching high energy-efficiency, other landowners are often profit driven and thus disfavor any increase in construction costs. Their *monopoly position* provides them with strong bargaining power, resulting in *few energy-efficient technologies in building design*. As a response, *municipalities create detailed development plans* with strict demands regarding building design and set *strict permit requirements*.

To distribute land profits among consortium members, the *residual land value calculation methodology* became widespread. This methodology subtracts all costs, for instance construction costs and land preparation costs, from the combined selling-price of the houses. What remains is called the residual land value, which is then distributed among consortium members. In this way, rising house prices increase the already *high profits for landowners (before the financial crisis)*.

As most houses in the Netherlands are developed and designed by companies that own the land (which allows them to make profit out of land development), the Netherlands counts *very few self-built houses*. Potential buyers have to accept the design choices made by the consortia that construct the houses. In other words, there is a *very limited role for potential buyers* (future home owners) in the first phases of the house building process, making this innovation system characterized by an extreme form of supply push.

The second problem theme – *project-based approach* – collects all problems related to the traditional way of organizing building projects in the Netherlands. In this approach, a specific development plan that satisfies the *strict permit requirements* from the municipality is created for each project. Subsequently, an architect is asked to create a design which is then built by a construction company. In relation to the project-based approach, interviewees mentioned a deeply rooted *distrust between project initiators and construction companies, or a culture of disagreement*. To understand why, we have to take a closer look at what happens within the *project-based approach*.

*The project-based approach is inefficient and expensive* in both the program phase and in the design phase. Project initiators spend large amounts of resources on creating the initial development plans, usually assisted by *expensive consultants and expensive architects*. Although initial designs often include innovative sustainable technologies, these are often removed to offset the high costs of the program and design phases and ultimately lead to *little energy-efficient technologies in building design*. What is more, project initiators (which can be either a private project developer or a housing association) organize a *tender on price* and thus grant the project to the construction company that accepts the lowest profit margin. This creates so-called *chain-pressure for construction companies*, who subsequently *lobby for removing or downscaling remaining innovations* to reduce the cost of training their employees. Additionally, costs are reduced by working fast, which leads to *construction flaws and technical problems*. Unsatisfied with the final build quality, *project initiators tighten specifications* for the next project, and, by doing so, increase the *chain pressure for construction companies*. To defend their profit margin, construction companies subsequently try to claim additional costs and file suit if this is not accepted by the project initiator. Some interviewees blame the ‘conservative’ construction companies for this situation, while others blame the ‘unprofessional’ housing associations.

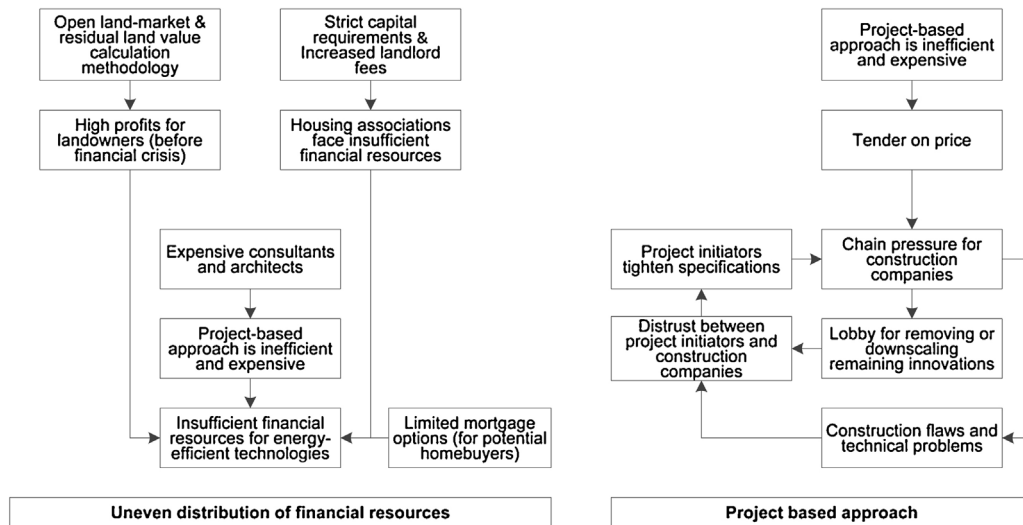


Fig. 3. Blocking mechanisms in the Dutch innovation system of highly energy-efficient houses.

The use of so-called building concepts provides – in theory – an alternative for the inefficient project-based approach. A building concept is a standardized design method that combines standard building components in different ways to create varieties in building design. Using a building concept has the potential to reduce the high costs of both the program and the design phase since the creation of a specific development plan for each new-to-build area can be simplified. This not only reduces the activities of the project initiator, but also reduces the need for consultants and architects. However, persuading project initiators to choose for a building concept is difficult. There are strong vested interests in ‘keeping things as they are’, because many organizations benefit from the project-based approach. In general, *conservatism* is high among established parties (project initiators, consultants and architects) leading to a strong *lobby for the project-based approach*. *Project initiators keep choosing for the project-based approach*, even though more efficient approaches are available.

The third and final problem theme – *Resources* – combines all problems related to finances. The first two themes already mentioned the *inefficient and expensive project-based approach* and the *high profits for landowners (especially before the financial crisis)*. These profits are rarely used to fund energy-efficiency measures<sup>12</sup>; instead, most municipalities use the land profits to increase the general municipal budget and private project developers just increase their profits. For the limited take up of energy-efficiency, private project developers point at the fact that *energy-efficiency measures are low on the priority list of potential homebuyers*. They attribute this firstly to *limited mortgage options* to finance energy-efficiency measures, and secondly to a *knowledge insufficiency* about the benefits of living in a highly energy-efficient house. In addition, *housing associations face insufficient financial resources*, because of *strict capital requirements* that inhibit investments and *increased landlord fees*.

Table 1 provides an overview of how all problems identified in this research relate to the main concepts of the innovation systems framework. This table represents the results we would have had if we had stopped the analysis after identifying only independent problems.

#### 4.2. Independent problems versus interacting problems

In this section, we explore the question whether attention for problem interactions yields contrasting or additional insights compared to an analysis of independent problems. First, we select from Fig. 2 two sets of problems that together form a blocking ‘mechanism’, under the new meaning of the term as a mechanism that consists of interacting systemic problems. Then, we analyze these two mechanisms and reflect on whether the same insights would have emerged if the analysis was stopped after independent problems were identified (Table 1). Third, we compare our results to an earlier innovation system study of the same empirical domain (Faber and Hoppe, 2013). The two selected sets of systemic problems and their relations are placed into Fig. 3.

The first blocking mechanism (left side of Fig. 3) consists of a set of systemic problems that together lead to an *uneven distribution of financial resources* in the system. Together, these problems thus negatively influence the function Mobilization of resources (Table 1). Collectively analyzing them shows that, while there are multiple problems that directly relate to housing associations and potential homebuyers which makes them experience *insufficient financial resources for energy-efficient technologies* (strict capital requirements, increased landlord fees and limited mortgage options), concurrently the

<sup>12</sup> Some housing associations did use land profits from one project to develop ambitious highly energy-efficient houses in another.



**Table 1**  
Identified systemic problems related to structural elements and functions.

System function:	Systemic problems:	Structural element:
Entrepreneurial activities	<ul style="list-style-type: none"> <li>– Impenetrable entry barrier for new companies</li> <li>– Open land market</li> <li>– Land Scarcity</li> <li>– Landowners create consortia</li> <li>– Construction claim</li> <li>– Monopoly position for land-owners</li> </ul>	Actor/Interactions Institutions Infrastructure Interactions Institutions Institutions
Knowledge development	<i>Interviewees mentioned no problems related to knowledge development.</i>	–
Knowledge diffusion	<ul style="list-style-type: none"> <li>– Knowledge insufficiency (of potential homebuyers)</li> <li>– Distrust (between housing associations and construction companies)</li> </ul>	Actors Actors/Institutions
Guidance of search	<ul style="list-style-type: none"> <li>– Decentralization of housebuilding activities</li> <li>– Conservatism</li> <li>– Public organizations behave like private enterprises</li> <li>– Municipalities create detailed development plans</li> <li>– Project initiators tighten specifications</li> <li>– Innovative ambitions water down under commercial pressure</li> <li>– Project initiators choose for project-based approach</li> <li>– Strict permit requirements</li> </ul>	Institutions Institutions Actors Actors/Institutions Actors Actors/Interactions Actors Actors/Institutions
Market formation	<ul style="list-style-type: none"> <li>– Decentralization of housebuilding activities</li> <li>– Open land market</li> <li>– Limited role for potential buyers</li> <li>– Very few self-built houses</li> <li>– Energy-efficiency measures are low on the priority list of potential homebuyers</li> <li>– Few energy-efficient technologies in building design</li> <li>– Lobby for removing or downscaling remaining innovations</li> </ul>	Institutions Institutions Actors Infrastructure Actors Infrastructure Actors/Infrastructure
Mobilization of resources	<ul style="list-style-type: none"> <li>– Strict capital requirements (for housing associations)</li> <li>– Increased landlord fees (for housing associations)</li> <li>– Housing associations face insufficient financial resources</li> <li>– Limited mortgage options (for potential homebuyers)</li> <li>– Expensive consultants and architects</li> <li>– Residual land value calculation methodology</li> <li>– Land Scarcity</li> <li>– Speculation on land-prices and land-development</li> <li>– High profits for land-owners (before financial crisis)</li> <li>– Tender on price</li> <li>– Chain pressure for construction companies</li> <li>– Project-based approach is inefficient and expensive</li> <li>– Insufficient financial resources for energy-efficient technologies</li> </ul>	Infrastructure Infrastructure Actors/Infrastructure Infrastructure/Institutions Actors Institutions Infrastructure Actors Infrastructure Institutions Interactions Interactions/Institutions Infrastructure
Creation of legitimacy	<ul style="list-style-type: none"> <li>– Vested interests</li> <li>– Conservatism</li> <li>– Construction flaws and technical problems</li> <li>– Project initiators choose for project-based approach</li> <li>– Lobby for removing or downscaling remaining innovations</li> </ul>	Actors/Institutions Institutions Infrastructure Actors/Institutions Actors/Infrastructure

*project-based approach is inefficient and expensive, and there are high-profits for landowners.* In other words, solving the problem of *insufficient financial resources for energy-efficient technologies* as experienced by housing associations and potential homebuyers, can also be achieved indirectly, by reducing the profits for landowners (through restructuring the land market), and by making the building process more efficient (through changing the project-based approach). Analyzing these problems collectively provides the insight that the real problem seems to be an uneven distribution of financial resources among actor groups, making direct intervention on all problems not necessary or desirable.

If our problem analysis would have stopped after independent problems were identified, and the results would thus have resembled [Table 1](#), recommendations would have been different. They probably would have included interventions for all identified problems, for example increasing the maximum mortgage options for potential homebuyers, and easing the strict capital requirements and lowering the landlord fees for housing associations. However, taking into account that these problems interact, reveals that increasing financial resources of homebuyers and housing associations will likely only lead to higher profits for landowners as a result of the residual land value calculation methodology (Section 4.1). Such interventions would clearly not achieve the goal of increasing investments in energy-efficient technologies. To put it in other words: the ‘additionality’ of such interventions is questionable ([Chaminade and Edquist, 2010](#)).

The earlier innovation systems analysis of the same empirical domain ([Faber and Hoppe, 2013](#)) did not reveal all systemic problems that form this first blocking mechanism. They mention that low income homebuyers experience difficulties in getting a mortgage and that the project-based approach is a source of sectoral fragmentation, but do not mention the high costs of the project-based approach, or the problems related to the land-market, such as the residual land value calculation

methodology. Continually searching for an underlying problem – which was a fundamental part of our analysis – led to more problems being revealed and thus increased insights compared to this earlier innovation systems analysis of the same empirical domain.

The second blocking mechanism (right side of Fig. 3) relates to how project initiators and construction companies react to each other during the building process. Analyzing these problems collectively provides the following insight: project initiators and construction companies both blame the other and take protective measures against each other. Project initiators blame the construction companies for their lobby to remove or downscale innovations from the project, and for construction flaws and technical problems. However, construction companies see this as a logical reaction to the chain pressure created by the tender on price together with tight project specifications. If we look at this more closely, all of these ‘problems’ only arise when the *inefficient and expensive project-based approach* is followed. This raises the question: is the project-based approach itself not to blame? Changing to an alternative house building process has the potential to alleviate all these problems in one go, for example by using Building Concepts.

If this innovation systems analysis was stopped after independent problems were identified; in other words, if the results would have resembled Table 1, interventions would have probably been formulated for all identified problems. For instance, that project initiators should tender on more criteria than only price, that construction companies should be involved earlier in the house building process, and that employees of construction companies need additional training to install new technologies. Although such interventions may have some effect, they focus on symptoms and keep the underlying problem intact, namely the expensive first phases of the project-based approach.

The earlier innovation systems analysis of the same empirical domain by Faber and Hoppe (2013) does identify multiple of the systemic problems that are part of this second blocking mechanism, but largely overlook that they interact. They mention that there is a “myopic competition on prices” (p636), a ‘circle of blame’ in which actors “have no difficulty in recognizing shortcomings of other agents” (p634), and a sectoral fragmentation that is caused by the project-based approach. Our analysis not only revealed additional problems (for example the chain pressure for construction companies and their lobby for removing or downscaling innovation), but also how these systemic problems collectively form a blocking mechanism.

Due to the differences between the innovation systems analysis of Faber and Hoppe (2013) and our analysis, it is not surprising that also the interventions put forward vary. Faber and Hoppe (2013) focus on encouraging sectoral integration, and on “setting project tendering conditions that favor cooperation on a wider set of sustainability criteria” (p636). In other words, they focus on interventions that try to improve the current project-based approach. This contrasts with our analysis that showed why the project-based approach may itself be part of the problem, and how the inefficiency of the project-based approach is itself preceded by an inefficient land-market. Restructuring the land-market, in combination with opting for an alternative approach to organize the house building process, for instance by using Building Concepts, may provide better results.

## 5. Discussion

The explicit attention that we gave to how problems interact – both during data collection and analysis – added explanatory power to our innovation system analysis. The use of the building phases during the interviews stimulated the interviewees to mention how problems interact: if they mentioned a problem and allocated it to a certain phase of the building process, they would often start mentioning additional problems from an earlier or later phase in the building process. This led to rich data: more problems were identified compared to an earlier analysis of the Dutch sectoral innovation system (Faber and Hoppe, 2013). In addition, the insights gained from this analysis into how problems interact made it possible to identify two blocking ‘mechanisms’ that consist of interacting systemic problems. Analyzing these mechanisms showed that direct intervention on all identified problems is in this case not necessary and that targeting only the symptoms probably has counterproductive effects. Our findings have three main implications for the policy formulation process.

First, analyzing systemic problems as mechanisms may reveal that some ‘problems’ are actually symptoms of other problems. When this happens, it should signal a policy maker that a single targeted intervention on the underlying problem may be more fruitful than formulating interventions for all problems separately. Unfortunately, it is often more difficult to intervene on an underlying problem compared to intervening on a symptom. An example from the first mechanism discussed in this paper is that intervening on how the land-market is organized will probably create more resistance from vested actors compared to reducing the landlord fees for housing associations. If a policy maker cannot target the underlying problem because of such practical reasons, she/he should also be careful with targeting the symptoms only, because our analysis showed that such interventions may be negated by reactions elsewhere in the system and have counterproductive effects. To conclude, the act of problem diagnosis is just as important as the act of intervention formulation itself, and should get the attention it deserves.

Second, this study sheds some additional light on the question whether policy makers should strive for gradual or radical institutional change. Some authors have emphasized that substantial institutional change can be achieved through a gradual process (Mahoney and Thelen, 2010). However, in relation to our case study, it is highly questionable if the project-based approach and the land-market can be changed through such a gradual process. For example, although incremental changes have made building projects today vastly different from fifty years ago, the general idea of how houses ought to be built has remained the same (the project-based-approach). Although further gradual institutional change may lead to efficiency improvements in the project-based approach, it will not lead to its demise. If policy makers have the ambition to alleviate

the whole blocking mechanism, for instance by replacing the project-based approach with an approach that revolves around building concepts, it is necessary to strive for more radical policy change, or punctuation (Kern, 2011, 2014).

The third implication for policy formulation is that the best place to intervene is often not in the system itself, but in its context. A blocking mechanism under its new meaning will often consist of a combination of internal systemic problems and contextual systemic problems. Since the problems that form the mechanism interact, an intervention on a contextual problem may indirectly lead to the alleviation of internal systemic problems. To reveal blocking mechanisms that go beyond the immediate system boundary, an analyst needs to trace the origin of internal systemic problems, which will lead him/her to contextual problems. In practice, this means that additional interviews are held when problems are identified for which cause or consequence remains unclear. Such a process will reveal structural couplings between the innovation system and its context. The variety of used shape outlines in Fig. 2 signifies that there are many structural couplings between the technological, sectoral and national parts of this innovation system. Additionally, tracing the origin of internal systemic problems in the system context also reduces the risk of loose ends in an innovation systems analysis. For example, at first it was not clear to us what was causing the lack of financial resources for potential homebuyers and housing associations. This 'loose end' signaled us to perform additional interviews and ultimately led to the identification of contextual problems that were underlying this lack of financial resources, namely issues related to how the land market is organized.

The alternative conceptualization of the terms blocking mechanism and systemic problem used during the case study contributed to its explanatory power. Seeing a blocking mechanism as a 'mechanism' that consists of interacting systemic problems stimulates an analyst to reveal how problems interact. An analyst can do so by adding an additional analysis step after independent problems have been identified. What is more, a broader meaning of the term systemic problem that incorporates not only internal systemic problems (endogenous), but also contextual systemic problems (exogenous) stimulates an analyst to give attention to the system context. This conceptual adaptation does justice to the recent discussion about the importance of system context (Bergek et al., 2015). One key issue for further consideration is the conceptual clarity of the term system 'failure'. As already mentioned in the Theory section, this term is sometimes used as synonym for systemic problem and sometimes to indicate broader issues with an innovation system.<sup>13</sup> More work is necessary to get the conceptual link clear between system failures and the conceptualization of blocking mechanisms and systemic problems as proposed in this paper.

Although the innovative approach presented in this paper proved useful during our case study there are still areas that need further consideration. This approach makes performing an innovation systems analysis more complex, requiring high analytical skills and more time. It also raises additional questions. For example, when are sufficient problems from the context taken into account and when can the analysis stop? How should an analyst cope with conflicting perceptions of interviewees on how the problems are related? In addition, questions remain open about the applicability of the approach for different types of innovation systems. For instance, is this approach only useful for more mature and locked-in innovation systems that are going through a transition, or also for other types of innovation systems? To make the approach more practical for analysts, performing additional case studies may prove favorable.

## 6. Conclusion

The innovation systems approach is already a powerful framework to find ways for stimulating innovation. It strives to improve the performance of the innovation system by identifying systemic problems and by formulating interventions that may alleviate these problems. However, a discussion of literature on problems in innovation systems revealed that the complexity focus of the framework is not so apparent in how the framework identifies problems and formulates interventions. This led to the premise that the innovation systems framework may benefit from more attention to how problems interact and can form mechanisms. The main question that this paper explored is: Does an innovation system analysis giving explicit attention to problem interactions yield contrasting or additional insights compared to an analysis of independent problems?

A case study of the innovation system related to building energy-efficient houses in the Netherlands was carried out during which we gave explicit attention to how problems interact. We used an innovative interview method that led to the identification of more problems compared to an earlier study of the same empirical domain. Additionally, we changed the meaning of the term blocking mechanism into a 'mechanism' that consists of interacting systemic problems. This led to the identification of 'mechanisms' of interacting problems, instead of to the identification of independent problems. In the case of energy-efficient houses in the Netherlands, many problems can be traced back to how profits from land are distributed among stakeholders, and to the project-based approach as the dominant organizing principle of the building process. Earlier studies have focused on interventions that increase the efficiency of the project-based approach, and in this way overlook the possibility of moving toward an alternative organization of the building process, for instance based on building concepts. These findings indicate that understanding how systemic problems interact and form mechanisms is of key importance for designing policy measures and intervention strategies. Neglecting problem interactions in innovation systems may not only lead to inaccurate problem diagnosis, but also to ineffective or even counterproductive interventions.

<sup>13</sup> For instance, in Klein Woolthuys et al. (2005) the terms *systemic failure* and *system failure* are used interchangeably and mean the same as the term *systemic problem* in Wieczorek and Hekkert (2012), whereas in Weber and Rohracher (2012) the term *structural system failure* is a synonym for systemic problems, while the term *transformational system failures* indicates broader system issues.

This paper showed that the innovation system framework may benefit from more explicit attention to how systemic problems interact, influence each other, and may form mechanisms. This may be achieved by conceptually recognizing that links between systemic problems provide important explanatory power and contribute to accurate problem diagnosis. Areas for further consideration are the type of innovation systems for which an analysis of interacting problems as ‘mechanisms’ is most fruitful, at which point to stop such an analysis and how to turn the approach into a more practical analysis tool. In addition, the link between the concepts of blocking mechanisms and systemic problems as used in this paper, and the concept of system failures needs to be further explored. To conclude, increasing attention for interactions between systemic problems contributes to an innovation systems framework that is well positioned to diagnose problems and formulate interventions.

## References

- Amankwah, K., Klerkx, L., Oosting, S.J., Sakyi-Dawson, O., Van Der Zijpp, A.J., Millar, D., 2012. Diagnosing constraints to market participation of small ruminant producers in Northern Ghana: an innovation systems analysis. *NJAS—Wagening. J. Life Sci.* 60–63, 37–47, <http://dx.doi.org/10.1016/j.njas.2012.06.002>.
- Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A., 2008. Analyzing the functional dynamics of technological innovation systems: a scheme of analysis. *Res. Policy* 37 (3), 407–429, <http://dx.doi.org/10.1016/j.respol.2007.12.003>.
- Bergek, A., Jacobsson, S., Hekkert, M., Smith, K., 2010. Functionality of innovation systems as a rationale for and guide to innovation policy. In: Smits, R., Kuhlmann, S., Shapira, P. (Eds.), *The Theory and Practice of Innovation Policy, an International Research Handbook*. Edward Elgar, Cheltenham, pp. 115–144.
- Bergek, A., Hekkert, M., Jacobsson, S., Markard, J., Sandén, B., Truffer, B., 2015. Technological innovation systems in contexts: conceptualizing contextual structures and interaction dynamics. *Environ. Innov. Soc. Transit.* 16, 51–64, <http://dx.doi.org/10.1016/j.eist.2015.07.003>.
- Carlsson, B., Stankiewicz, R., 1991. On the nature, function and composition of technological systems. *J. Evol. Econ.* 1 (2), 93–118, <http://dx.doi.org/10.1007/BF01224915>.
- Carlsson, B., Jacobsson, S., Holmen, M., Rickne, A., 2002. Innovation systems: analytical and methodological issues. *Res. Policy* 31 (2), 233–245, [http://dx.doi.org/10.1016/S0048-7333\(01\)00138-X](http://dx.doi.org/10.1016/S0048-7333(01)00138-X).
- Chaminade, C., Edquist, C., 2010. Rationales for public policy intervention in the innovation process: a systems of innovation approach. In: Smits, R., Kuhlmann, S., Shapira, P. (Eds.), *The Theory and Practice of Innovation Policy, an International Research Handbook*. Edward Elgar, Cheltenham, pp. 95–114.
- Chaminade, C., Intarakumnerd, P., Sappasert, K., 2012. Measuring systemic problems in national innovation systems. an application to thailand. *Res. Policy* 41 (8), 1476–1488, <http://dx.doi.org/10.1016/j.respol.2012.04.004>.
- Charmaz, K., 2006. *Constructing Grounded Theory: A Practical Guide Through Qualitative Research*. Sage Publications Ltd., London.
- Cooke, P., Uranga, M.G., Etxebarria, G., 1997. Regional innovation systems: institutional and organisational dimensions. *Res. Policy* 26 (4–5), 475–491, [http://dx.doi.org/10.1016/S0048-7333\(97\)00025-5](http://dx.doi.org/10.1016/S0048-7333(97)00025-5).
- Edquist, C., Johnson, B., 1997. Institutions and organizations in systems of innovation. In: Edquist, C. (Ed.), *Systems of Innovation: Technologies, Institutions and Organizations*. Pinter, London, pp. 41–63.
- Faber, A., Hoppe, T., 2013. Co-constructing a sustainable built environment in the Netherlands—Dynamics and opportunities in an environmental sectoral innovation system. *Energy Policy* 52, 628–638, <http://dx.doi.org/10.1016/j.enpol.2012.10.022>.
- Galli, R., Teubal, M., 1997. Paradigmatic shifts in national innovation systems. In: Edquist, C. (Ed.), *Systems of Innovation: Technologies, Institutions and Organizations*. Pinter, London, pp. 342–370.
- Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S., Smits, R.E.H.M., 2007. Functions of innovation systems: a new approach for analysing technological change. *Technol. Forecast. Soc. Change* 74 (4), 413–432, <http://dx.doi.org/10.1016/j.techfore.2006.03.002>.
- Jacobsson, S., Bergek, A., 2011. Innovation system analyses and sustainability transitions: contributions and suggestions for research. *Environ. Innov. Soc. Transit.* 1 (1), 41–57, <http://dx.doi.org/10.1016/j.eist.2011.04.006>.
- Jacobsson, T., Jacobsson, S., 2014. Conceptual confusion – an analysis of the meaning of concepts in technological innovation systems and sociological functionalism. *Technol. Anal. Strateg. Manage.* 26 (7), 811–823, <http://dx.doi.org/10.1080/09537325.2014.900171>.
- Jacobsson, S., Karltorp, K., 2013. Mechanisms blocking the dynamics of the European offshore wind energy innovation system—challenges for policy intervention. *Energy Policy* 63, 1182–1195, <http://dx.doi.org/10.1016/j.enpol.2013.08.077>.
- Johnson, A., Jacobsson, S., 2001. Inducement and blocking mechanisms in the development of a new industry: the case of renewable energy technology in Sweden. In: Coombs, R., Green, K., Richards, A., Walsh, V. (Eds.), *Technology and the Market, Demand, Users and Innovation*. Edward Elgar, Cheltenham, pp. 89–111.
- Kern, F., 2011. Ideas, institutions, and interests: explaining policy divergence in fostering “System Innovations” towards sustainability. *Environ. Plan. C Gov. Policy* 29, 1116–1134, <http://dx.doi.org/10.1068/c1142>.
- Kern, F., Kuzemko, C., Mitchell, C., 2014. Measuring and explaining policy paradigm change: the case of UK energy policy. *Policy Polit.* 42, 513–530, <http://dx.doi.org/10.1332/030557312X655765>.
- Kieft, A.C., Harmsen, R., Laerhoven, F., Hekkert, M.P., 2013. Innovatie in de woningbouw: Een innovatiesysteemanalyse. Copernicus Institute of Sustainable Development, Utrecht University for the Dutch Ministry of the Interior and Kingdom Relations. Retrieved from: [http://www.researchgate.net/publication/258240192\\_Innovatie\\_in\\_de\\_woningbouw\\_-\\_Een\\_innovatiesysteemanalyse](http://www.researchgate.net/publication/258240192_Innovatie_in_de_woningbouw_-_Een_innovatiesysteemanalyse).
- Klein Woolthuis, R., Lankhuizen, M., Gilsing, V., 2005. A system failure framework for innovation policy design. *Technovation* 25 (6), 609–619, <http://dx.doi.org/10.1016/j.technovation.2003.11.002>.
- Lundvall, B.A., 1992. *National Innovation System: Towards a Theory of Innovation and Interactive Learning*. London, Pinter.
- Mahoney, J., Thelen, K., 2010. A theory of gradual institutional change. In: Mahoney, J., Thelen, K.A. (Eds.), *Explaining Institutional Change: Ambiguity, Agency, and Power*. Cambridge University Press, New York, pp. 1–37.
- Malerba, F., 2002. Sectoral systems of innovation and production. *Res. Policy* 31 (2), 247–264, [http://dx.doi.org/10.1016/S0048-7333\(01\)00139-1](http://dx.doi.org/10.1016/S0048-7333(01)00139-1).
- Markard, J., Truffer, B., 2008. Technological innovation systems and the multi-level perspective: towards an integrated framework. *Res. Policy* 37 (4), 596–615, <http://dx.doi.org/10.1016/j.respol.2008.01.004>.
- NEN, 1993. *Construction Drawings – Arrangement of Data on Building Drawings (NEN 2574:1993 nl)*. NEN, Delft.
- Negro, S.O., Alkemade, F., Hekkert, M.P., 2012. Why does renewable energy diffuse so slowly? A review of innovation system problems. *Renew. Sustain. Energy Rev.* 16 (6), 3836–3846, <http://dx.doi.org/10.1016/j.rser.2012.03.043>.
- Patana, A.S., Pihlajamaa, M., Polvinen, K., Carleton, T., Kanto, L., 2013. Inducement and blocking mechanisms in the Finnish life sciences innovation system. *Foresight* 15 (6), 428–445, <http://dx.doi.org/10.1108/FS-10-2012-0081>.
- Strauss, A.L., Corbin, J.M., 1998. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*. Sage Publications, Thousand Oaks.
- Tijdelijke Commissie Huizenprijzen, 2013. Kosten koper; een reconstructie van twintig jaar stijgende huizenprijzen. Tweede Kamer 2012–2013, 33 194, nr. 3.

Please cite this article in press as: Kieft, A., et al., Interactions between systemic problems in innovation systems: The case of energy-efficient houses in the Netherlands. *Environ. Innovation Soc. Transitions* (2016), <http://dx.doi.org/10.1016/j.eist.2016.10.001>



- Totin, E., Van Mierlo, B., Saïdou, A., Mongbo, R., Agbossou, E., Stroosnijder, L., Leeuwis, C., 2012. Barriers and opportunities for innovation in rice production in the inland valleys of benin. *NJAS—Wagening. J. Life Sci.* 60–63, 57–66, <http://dx.doi.org/10.1016/j.njas.2012.06.001>.
- Unruh, G.C., 2000. Understanding carbon lock-in. *Energy Policy* 28 (12), 817–830, [http://dx.doi.org/10.1016/S0301-4215\(00\)00070-7](http://dx.doi.org/10.1016/S0301-4215(00)00070-7).
- Weber, K.M., Rohracher, H., 2012. Legitimizing research, technology and innovation policies for transformative change: combining insights from innovation systems and multi-level perspective in a comprehensive ‘failures’ framework. *Res. Policy* 41 (6), 1037–1047, <http://dx.doi.org/10.1016/j.respol.2011.10.015>.
- Wieczorek, A.J., Hekkert, M.P., 2012. Systemic instruments for systemic innovation problems: a framework for policy makers and innovation scholars. *Sci. Public Policy* 39 (1), 74–87, <http://dx.doi.org/10.1093/scipol/scr008>.
- Wieczorek, A.J., Negro, S.O., Harmsen, R., Heimeriks, G.J., Luo, L., Hekkert, M.P., 2013. A review of the European offshore wind innovation system. *Renew. Sustain. Energy Rev.* 26, 294–306, <http://dx.doi.org/10.1016/j.rser.2013.05.045>.
- Wieczorek, A.J., 2014. *Towards Sustainable Innovation: Analysing and Dealing with Systemic Problems in Innovation Systems (Doctoral Dissertation)* (Retrieved from <http://dspace.library.uu.nl/handle/1874/301675>).