Paper intended for track 6 – Organizations and industries in sustainability transitions

Running in packs or walking alone? Exploring conditions for innovation system building for solar PV

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Abstract:

Technologies involved in sustainability transitions require build-up of well-functioning innovation systems. Actors can play important roles by deliberately shaping institutions and legitimacy, which often relies on collective action and thus on alignment of interests. This paper addresses important knowledge gaps concerning actor and value chain conditions for alignment of interests and needs. We explore how actors` policy needs align or diverge along the value chain of the technological innovation system (TIS) for solar photovoltaics (PV) in Norway, and whether needs concern technology specific or broader sectoral institutions. Our analysis is based on data from a survey of Norwegian firms with activities in the PV field. We observe heterogeneity in and between value chain segments, but also some shared needs linked to increase of investment support for deployment within the downstream value chain segment. We do however find that actors in up- and downstream segments express differing needs and levels of satisfaction with current policy frameworks. We also observe that up- and downstream segments relate differently to the electricity sector, with an indication of conflicting needs among value chain segments with regards to the relation to sectoral institutions. Whereas upstream actors expressed policy needs related to specifically to the solar PV TIS and not to broader sectoral institutions, downstream actors articulated policy needs related to both the solar TIS *and* broader sectoral institutions. Needs for change at the sectoral level could be assumed to be particularly challenging to legitimize since they are likely to involve conflicts and contestation. From our analysis, we can see that some of this contestation may even come from another value chain segment of the same TIS (upstream). We conclude that heterogeneity and conflicting needs in and between value chain segments, constitute conditions that may challenge collective action for system building.

1 Introduction

Technologies necessary for sustainability transitions require build-up of well-functioning innovation systems. Actors` engagement in altering or building up new institutions, such as regulations and policies, is an important part of system building (Kukk et al., 2015; Kukk et al., 2016; Musiolik et al., 2018). While central actors in some cases can play pivotal roles, system building often entails collective action and actor running in packs to gain legitimacy, which relies on the alignment of interests and needs (Bergek, Jacobsson, & Sandén, 2008; Musiolik et al., 2018). Similarly, shared visions and expectations among actors, and development of networks to create constituencies is important in the formation of niches (Raven et al., 2010; Schot & Geels, 2008).

With increased attention to policy, and conditions for policy, there has in the sustainability literature been an interest in studying networks and coalitions (Jacobsson & Lauber, 2006; Markard et al., 2016; Normann, 2017). Many of these studies have emphasised the need to analyse how coalitions compete over influence on agenda setting and policy formulation. Building on the concepts of socio-technical regimes and niches, such studies typically depict the contestation between incumbent regimes and groups representing niche technologies (Hess, 2014). Actors in the socio-technical regime will overlap significantly with the actors in the dominant advocacy coalition, which will lead to policy stability. From an advocacy coalition perspective, policy change can occur if a sufficient number of new actors join the minority coalition or if actors previously in the dominant coalition change their core beliefs (Kern & Rogge, 2017; Markard et al., 2016).

It seems to us that most of the studies within sustainability transition studies that look at coalitions, networks and policy focus on conflicting goals between coalitions representing regime actors and coalitions representing niche actors. A prescription for regime change will then often be to strengthen coalitions or networks based around niche technologies (Kern et al., 2014; Rip & Kemp, 1998). However, strengthening coalitions is more difficult and complicated than what is sometimes assumed in the literature. For instance, there has in the TIS literature been a recent interest in the potential conflicting interests between different niche technologies, thus shifting the focus from regime-niche dynamics to niche-niche dynamics (Bergek et al., 2015, p. 55). In technologies that involve a heterogeneous set of actors, we might therefore expect similar conflicts of interest in terms of knowledge requirements, resource demands, and importantly, policy. A barrier to strengthening coalitions based around a single TIS might thus be that the actors within this TIS have different policy needs, which in turn might stand in the way for collective efforts to lobby for policy change.

Our point of departure is that system building and alignment of interests and needs (or lack thereof) potentially occurs in settings with heterogeneous actors spread along (global) value chains, that interact with institutional structures in the broader context of maturing technological innovation systems (TIS), such as sectors (Bergek et al., 2015).

While system building has emerged as an important topic related to debate on the formation of technological innovation systems, we still know little about the conditions for collective action. Particularly when it occurs in potentially heterogeneous settings as noted above. This motivates our interest in exploring the conditions for system building, and we do this by focusing on the extent to which different firms in a TIS have different and shared views on policy, including policy needs. Second, we want to explore the extent to which divisions can be consolidated, or the extent to which heterogeneity in terms of policy needs and articulation of such needs hampers the potential for collective action.

The purpose of this paper is to analyze the conditions for collective action by focusing on actors' policy and regulatory needs along two related dimensions; along the value chain and in relation to sectors. We address the following research questions: (1) how do policy needs align (or not) along the value chain of a TIS, and (2) how do policy needs relate to the sectoral contexts of the TIS?

Our study is motivated by current gaps linked to understanding *conditions* for collective action in innovation system building and broader socio-technical transitions literature. Musiolik et al. (2018) highlight the need for studies of system building processes that potentially also involve contestation, i.e. both competition and cooperation. We take a first step in that direction in this paper and argue that we first need to understand the conditions for system building, by exploring actors` needs and interests. Similarly, Smith et al. (2010) underscore the need for studies that address the conditions for building common agendas among niche actors. Smith et al (2005) suggest that we should study how actors with different visions, expectations and requirements may still come together and form coalitions that unite behind certain common policy goals. We thus address key gaps identified both in innovation systems literature specifically, and broader socio-technical transitions literature more generally. We contribute to the TIS literature with an analysis of actors` needs along the value chain, and relations to broader sectors. We contribute to transitions literature more generally by shedding light on how interests are shared among the actors, or whether there is a large heterogeneity in needs that potentially hamper the ability to run in packs as part of the system building process.

Empirically we focus on the innovation system for solar photovoltaics (PV) in Norway, which offers a relevant vantage point to study firms at different levels of the PV value chain. Based on a survey with Norwegian solar PV firms, we map actors along the value chain, identify their characteristics and potential interactions with sectoral institutions based on the articulation of policy needs. From this we observe whether policy needs converge or diverge across the value chain, and finally assess at which level institutional change to meet actor`s needs would need to occur (i.e. technology specific regulation or change on broader sectoral levels).

The paper is structured as follows. Section two discusses the theoretical background, while section three introduces our analytical and methodological framework. In section four we present our results, and discuss these in light of our theoretical and analytical framework in section five. We conclude and discuss the conceptual and policy implications of our analysis in section six.

2 Theoretical framework

2.1 Innovation system building

The development and diffusion of novel technologies requires the formation of well-functioning innovation systems, through the build-up of system structures. Generally, it is acknowledged by TIS scholars that these structures include institutions and networks, alongside the entry of a variety of actors, such as firms, universities and industry associations along the whole value chain. Many of these structures may not be in place during the formative phase of a TIS - thus the need for structural build up (Bergek, Jacobsson, Carlsson, et al., 2008; Hekkert et al., 2007; Hillman et al., 2008). This process of TIS formation is highly uncertain, cumulative and may stretch long periods of time. A key challenge is that institutions seldom are well aligned to new technologies, and thus successful system formation often entails institutional change, formation of coalitions (networks) and engagement of actors (Bergek, Hekkert, et al., 2008).

TIS scholars have previously highlighted legitimation as a key process and requisite for build-up of new industries that can trigger mobilization of resources, the formation of markets and gaining political influence. The process of legitimation is thus intimately tied to change and alignment of institutions and relies on the conscious and deliberate actions and strategies of actors (Bergek, Jacobsson, & Sandén, 2008; Musiolik et al., 2018). Institutions include hard regulations (policies, standards etc) and soft norms and cognitive rules, which enable and constrain actors. The alignment of institutions reduce uncertainties and risks that can be present due to problems with market formation and unclear or weak expectations for a technology (Bergek, Jacobsson, & Sandén, 2008).

The focus on deliberate actions to address such challenges is central to the literature of *innovation system building*. This perspective has been introduced to put more emphasis on the deliberate activities of system actors in shaping their environment, in particular with regards to shaping institutions (Hellsmark & Jacobsson, 2009; Kukk et al., 2015; Kukk et al., 2016; Musiolik et al., 2018).

Particularly the perspective on innovation system building emerged as a response to a perceived criticism regarding the lack of attention to agency in TIS studies (Musiolik et al., 2018). Therefore system building perspectives include a focus on the micro level strategies and activities of actors.

Two differing modes of legitimation were identified in Bergek, Jacobsson, and Sandén (2008). Firstly, and most commonly, actors in an emerging TIS can conform to prevailing institutions. However, in many instances existing institutions may provide barriers or be misaligned to the novel technology. Such situations require the more challenging processes of influencing institutions to align with the TIS, either by attempting to adjust existing or develop new institutions (Bergek, Jacobsson, & Sandén, 2008).

Similar notions can be found in the distinction between `fit -and-conform` and `stretch-and-transform` strategies to how niches either fit into or transform existing regimes and selection environments (Smith & Raven, 2012). Both strategies can help empower niches so that they can compete with regime technologies. However, a central point is that strategies that involve policies that support technologies without changing the broader selection environment involve less conflict. This is because strategies that involve policies that change the selection environment are more likely to run into power struggles and politics. This perspective thus emphasizes the entangled development of novel technologies, and highlights the potential challenges of novel technologies when emerging in a broader context of established institutions embedded in regimes. While previous studies have shown how differing strategies (`fit-and-conform` or `stretch-and-transform`) have been pursued over time and across different industries (Raven et al., 2016), we focus on how conditions for such strategies vary among actors and along the value chain.

2.1.1 Innovation system building and TIS-context

While the TIS approach serves as a framework for technology specific analysis and implications, recent developments in the field have started to conceptualize interactions between specific technological fields and broader system contexts more. Arguably, a technological field like solar PV interacts in various ways with other technologies (other RETs) as well as broader sectors (energy sector, building sector, infrastructure etc).

Musiolik et al. (2018) argue that system building is about shaping technology specific institutional structures. While this is certainly important, the recent debates on TIS-context interactions and discussions on the role of niches in regime change, also emphasize interactions with broader institutional dimensions, such as those of established sectors (Bergek et al., 2015; Smith & Raven, 2012). For example, low-carbon technologies may be subject to particularly challenging system building contexts since novel technologies are introduced in a setting with well-established technologies and institutions in the energy system (Bergek, Hekkert, et al., 2008). From such a perspective, system building may not only concern build-up of TIS specific structures, but also influencing broader institutions in order to facilitate strengthening of the TIS. Innovation system building thus not only occurs in already heterogeneous settings within a specific technological field, but also in interaction with broader institutional settings (Bergek et al., 2015). We believe it is worthwhile to include the TIS-context perspective in the analysis of policy needs in system building, particularly given that discontinuous technologies potentially relate conflictingly with established sectors. Gaining legitimacy in such settings may therefore be particularly challenging (Bergek, Hekkert, et al., 2008; Dolata, 2009).

We expect that needs to transform sector level institutions, such as changing market structures or regulations in the electricity or building sector, will be more challenging than adapting to prevailing institutional setups. In turn such efforts may require differing system building strategies since established sectors already are highly institutionalised and stable (Bergek et al., 2015).

TISs can interact in different ways with various sectors, ranging from complementary to conflictual interaction types (Hanson, 2017; Mäkitie et al., 2018; Sandén & Hillman, 2011; Wirth & Markard, 2011). In an analysis of the relations between the PV and energy intensive processing industry sector Hanson (2017) shows how TIS-sector interactions can include complementarities, amongst other through provision of early TIS structural foundations through sharing of system structures with established sectors that enable resource flows. In an analysis of the impact of the oil and gas sector on dynamics in the offshore wind industry Mäkitie et al. (2018) revealed a large structural overlap between sector and TIS, particularly on the actor dimension, due to large presence of diversifying oil and gas companies. This overlap was shown to contribute positively to certain functions such as knowledge development and entrepreneurial experimentation. On the other hand, they argued that overlaps led to lack of commitment and weak coordination of collective entrepreneurship. This case showed how interactions between a TIS and a sector can be both negative and positive related to different system functions. Mäkitie et al. (2018) and Hanson (2017) focus on influence from sector to TIS. Stephan et al. (2017) further illustrate how a TIS interacts with multiple sectors along its value chain. In an analysis of the Swiss bio-SNG TIS Wirth and Markard (2011) show how some sectors primarily serve as inputs (forestry, sawmill) while others are primarily linked to outputs of the TIS (gas and electricity supply).

2.2 Alignment of interests and needs

System building is not a new concept. Hughes (1979) used system building to describe prominent individuals that orchestrated and addressed 'reverse salients' in large technical systems. As a contrast to earlier conceptions of system building, \`modern\` modes of system building in technologically and organizationally complex settings often require more collaborative and collective approaches to system building. While some powerful firms or the state may pursue single actor mode system building, collaborative and collective system modes are assumed to be more prevalent (Musiolik et al., 2018). The institutional entrepreneurship literature similarly highlights the necessity for actors to work across organizational boundaries and act collectively (Suchmann, 1995). Indeed the formation of coalitions to \`run in packs\` has been argued to be central in institutional entrepreneurship (Van De Ven, 2005). Such modes then rely on distributed agency and resources, and thus occur in multi-actor settings (Musiolik et al., 2018).

As a consequence, the alignment of interests and needs among the actors of a TIS is assumed as central to such collective system building (Musiolik et al., 2018). Similarly the development of shared visions and expectations holds a central position in perspectives on socio-technical transitions (Raven et al., 2010; Schot & Geels, 2008; Smith & Raven, 2012). We link the discussion of interests and needs to actor and supply chain heterogeneity of a TIS in the following section.

3 Analytical and methodological framework

With the above theoretical background as a foundation we develop our analytical and methodological framework for analyzing conditions for innovation system building in this section. We focus on two main issues: (1) actor and value chain characteristics and (2) policy needs.

3.1 Analyzing actor and value chain characteristics

While current literature on system building has made important progress in developing a thinking concerning agency and action to influence institutions, we argue that we still lack an understanding of the conditions for such collective action. Since system building relies on the deliberate actions and strategies of TIS actors, we would argue that one key condition is the characteristics of actors that populate the TIS. Particularly, it is worth noting that the TIS actor category has been defined to include a heterogeneous set of actors spread along the value chain (upstream and downstream), involving many differing types of activities and interests (Bergek, Jacobsson, & Sandén, 2008; Hillman et al., 2008). In the case of solar photovoltaics (PV) this includes firms producing materials, components, machinery, electricians, engineering firms, lead users etc. The range of actor types that potentially would be linked to a TIS is of course dependent on system boundary setting, and is a methodological issue. However, if we are to take the suggestions to include firms across the value chain as a starting point for defining the innovation system structure seriously, we believe it to be worthwhile to explore how the potential heterogeneity relates to the conditions for system building.

3.2 Analyzing policy needs

Our empirical analysis of actors` expressed policy and regulatory needs is based on data from a survey with PV firms, described more in section 3.5. We analyse survey reponses along two main dimensions: (1) type of policy needs and (2) whether policy needs are linked to technology specific or sectoral change.

3.2.1 Type of policy need

In order to distinguish between differing types of policy needs for innovation system building we follow the policy instrument typology proposed by Rogge and Reichardt (2016). The authors underline how transition settings require combinatory and coherent policy making that encompass both supply and demand, but also importantly systemic issues. As such, the framework extends and builds upon extant typologies, such as those proposed by (Edler & Georghiou, 2007).

The typology suggested by Rogge and Reichardt (2016) includes three primary types of instruments; economic instruments, regulation and information. These types of instruments may in turn serve different purposes; technology push, demand pull and systemic issues, resulting in 9 possible type-purpose combination (which also may overlap) (Rogge & Reichardt, 2016). The authors underline the potential of linking their perspective on policy mixes to the TIS perspective. In this paper we take a step in this direction by employing the policy instrument typology to analyses the policy needs of TIS actors. In our analysis of survey responses we rely on this typology and interpret responses first with regards to type and secondly with regards to purpose.

3.2.2 Policy needs for technology specific vs. sectoral change

In order to empirically analyze and capture TIS-context interactions we focus on whether conditions for system building in terms of policy needs are linked to influencing institutions to support development of the TIS in technology specific terms, or whether needs are linked to change in sectoral institutions.

We use the following logic to determine whether survey responses could be interpreted as expressing technology specific policy needs, or needs to change broader sectoral levels. We define the technology specific needs to include new policies or change in existing policies and regulations that directly target PV with potential of contributing to developing the PV TIS. We define needs for sectoral change as policies or regulations that directly would affect broader sectors by changing sectoral structures to enable TIS growth. This includes needs to transform sectoral institutions.

Clearly, there is no clear-cut distinction between technology specific and sectoral dimensions since the potential results of implementation of technology specific policies (for instance implementation of feed-in tariffs) could impact broader sectors, for instance by increased shares of intermittent power and the effects on electricity grids and other energy sources. However, since we are interested in policy needs from a system building perspective in this paper, and not effects and impacts of policies and instruments, we make a distinction between whether the policy or regulation in itself would influence sectors or the technological field of PV directly.

As an example, increased public investment support for PV would potentially affect PV actors, but not necessarily directly affect actors and institutions in broader sectors (except for potentially less support for other technologies/solutions). Such a need would be categorized as technology specific, since potential effects on the sector would depend on the actual impact and effectiveness of the technology specific instrument, which is a matter out of the scope of this article. If policy needs are linked to change in policies or regulations in specific sectoral contexts, such as change to grid tariffs, we assume that such measures would impact sectoral institutions and actors more directly. We define such needs as sectoral change policies and regulations.

We argue that distinguishing between these dimensions is useful from the system building perspective because it illustrates whether policy needs are linked to the stimulation of technology development within existing selection mechanisms (fit-and-conform), or whether TIS actors are aiming to change sectoral institutions in order for the TIS to develop (stretch-and-transform).

3.3 Analytical framework

Based upon our previous discussion Figure 1 sums up our analytical framework. We focus on TIS actors` policy needs and analyze how they may differ among value chain segments. As a next step we analyze how policy needs would relate to system building strategies linked to conforming with existing institutions or whether they could be linked to transforming sectoral institutions to further strengthen the TIS.

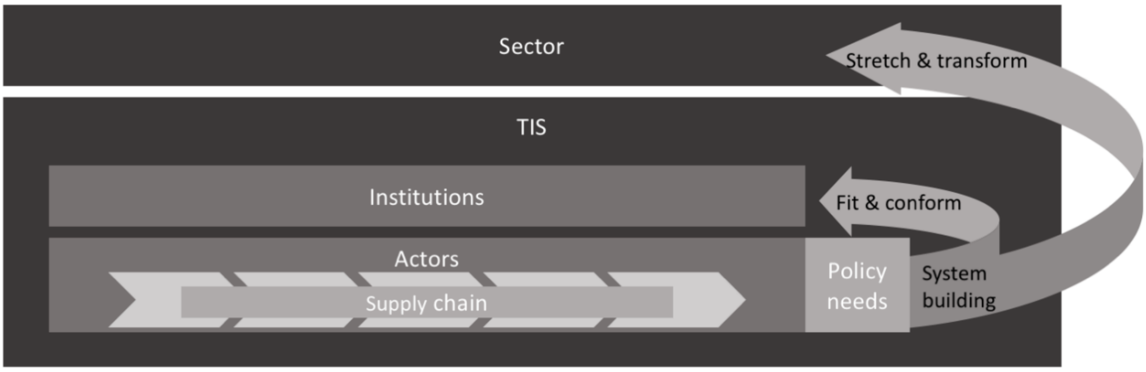

Figure 1: analytical figure

3.4 Case selection

We apply our framework to the analysis of the innovation system for solar PV in Norway. This case is relevant related to our proposed framework due to how Norway is one of the few European countries that has maintained some supply side manufacturing capacity of silicon materials, ingots and wafers. The emergence of a PV TIS in Norway has been analyzed in (Hanson, 2018) which shows how production of silicon and wafers emerged in the mid 1990s. Industry emergence was based on the foundations of the established metallurgical and broader processing industry sector. In terms of policies, the industry has mainly been relying on R&D funding, and PV has remained as a priority area within national R&D strategies for low-carbon solutions (Energi21, 2014). Hanson et al. (2011) discuss the use of technology push strategies mainly through implementation of R&D funding as pervasive within the Norwegian context. PV manufacturing capacities in some firms have been maintained in the face of rapid price drops and fierce international competition, particularly with the advent of rapid growth in Chinese manufacturing capacities. Hanson (2017) does however point out that challenges remain with reaching a TIS growth phase.

PV deployment in Norway remains limited, with cumulative installations of 45MWp in 2017. Up until 2014 deployment was mainly occurring in the off-grid segment, primarily on holiday cabins. From 2014 and onwards deployment rates have increase particularly in the grid-connected segment, on commercial buildings in particular. Demand side policies have not been implemented to any large extent, mainly due to lacking incentives to use PV as a means to decarbonize the power sector, which is mainly based on hydropower. Some instruments do however exist. Enova (owned by the Ministry of Climate and Environment), provides investment support for residential buildings. Norway and Sweden implemented a joint green-certificate policy, but registration fees as well as measuring and reporting costs make certificates suitable to only to larger commercial and industrial installations. Some municipalities have introduced investment support schemes, but these have been reported to be short lived or receiving limited financing (Multiconsult & AsplanViak, 2018)

The presence of companies at the beginning of the value chain (silicon/ingots) as well as the end of the value chain (system integration/installation) in the Norwegian context enables us to analyze interests of a heterogeneous set of actors and across several value chain segments.

3.5 Methods and data

Data for this study is drawn from a survey of Norwegian firms engaged in the solar industry. The sample for the survey was put together from membership in industry associations, industry reports, and desk research. The criteria for inclusion in the sample was that the firm was Norwegian and that we had reason to believe the firm had delivered, or had ambitions to deliver, products or services to the solar industry. The original sample consisted of 141firms. The survey was web-based and conducted in March-April 2017. 79 firms responded to survey. 5 of these were incomplete and 9 were responses by firms that reported to have no ambitions in the solar industry, and thus not relevant for the survey. A total of 65 firms were left in the data set, which represents 46,1% of the total sample (minus the firms that were not in the solar industry).

The questions in the survey covered topics such as basic information about the firm, position in supply chain, engagement in other industries, motivations for entering the solar industry, R&D activities, markets, public policies, and collaborations. The questions that were most relevant for the analysis in this paper concerned the position in the solar energy supply chain, the firms' core industries (reflecting the sectoral context), and the firms' satisfaction, needs, and engagement with policy (reflecting conditions for system building). In the survey, respondents also had the opportunity to respond openly to the following question posed to elicit information about actors` perceived policy and regulatory needs: *"In an ideal world, which change in Norwegian public policy would support your activities in PV the most? (This could include strengthening/change of existing instruments, removal of instruments/regulations or introduction of new policies/regulations."*

4 Analysis

4.1 Description of sample

The data consists of 65 Norwegian firms that have either delivered (55), or have ambitions to deliver (10), products or services to the solar industry. 45 per cent of these firms have *solar energy* as their core industry. Around 30 per cent of the firms are primarily engaged in *energy/power* and *construction* (Figure 2).

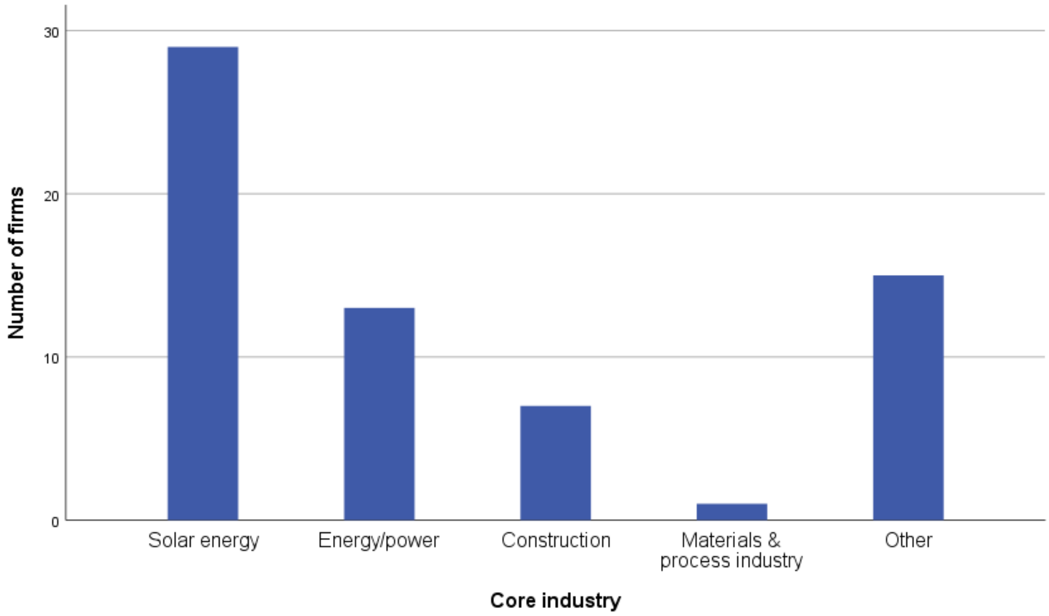

Figure 2 Core industry as reported by survey respondents

That many of the firms are primarily involved in other industries than solar energy is reflected in responses to questions about turnover related to solar energy Figure 3. More than half of the firms responded that less than 10 per cent of total turnover was dedicated to solar in 2017.

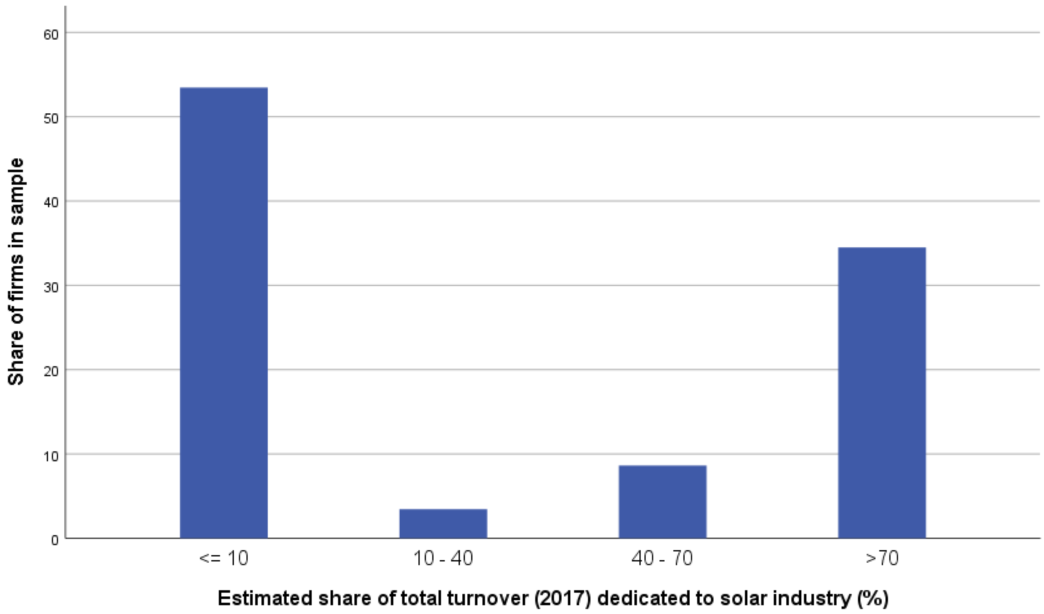

Figure 3 Distribution of firms in groups, depending on share of total turnover in 2017 attributed to solar industry

The sample consists of firms in all parts of the value chain for solar energy. Many of the firms deliver downstream products or services such as those related to installation and construction (17), but there are also firms engaged in upstream activities such as cells/modules (5) and silicon (3).

In this paper, we have been interested in exploring heterogeneity across the value chain, specifically in relation to policy needs. To do so, we have grouped the firms into two levels of aggregation, dependent on their position in the solar energy value chain. The first level of aggregation consists of five groups: 1) Upstream (silicon, wagers & ingots, cell/module, electrical components and cables), 2) Power & Grid (solar park owners, utilities, energy companies), 3) Project development (design, finance and other consultancy), 4) Installation and construction (incl. O&M), and 5) Other. The second level of aggregation consists of only two categories: Upstream and downstream (see Figure 4). Due to the limited number of respondents in the survey (which reflect the overall size of the solar industry in Norway), most of the analysis explore the differences between upstream and downstream firms.

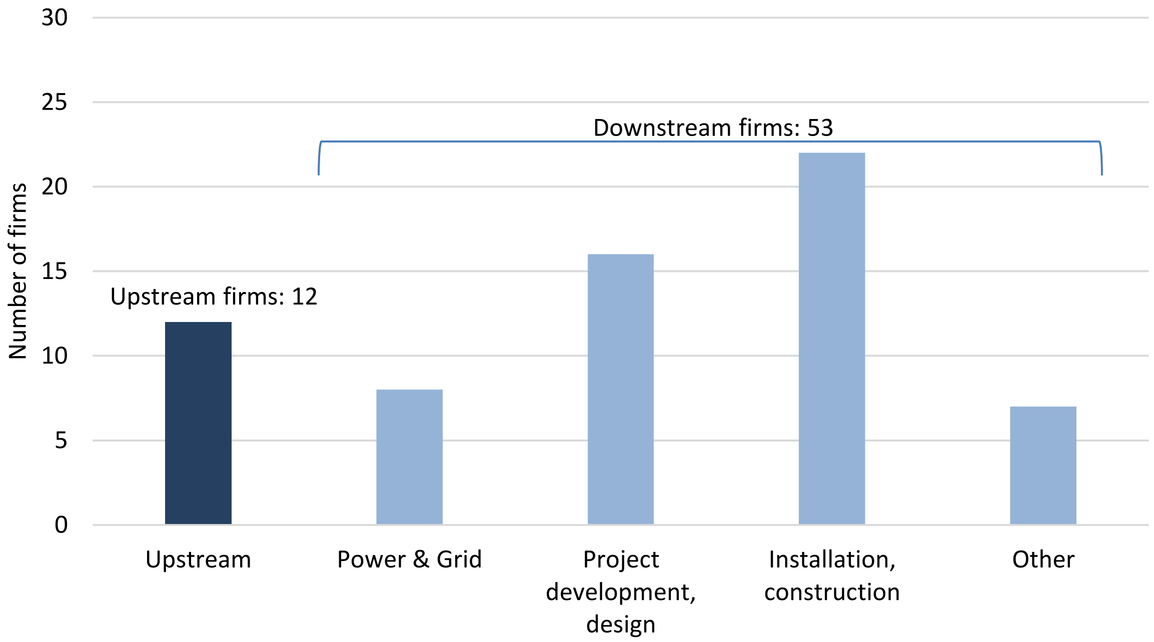

Figure 4 Distribution of firms across value chain, aggregated.

Nearly three-quarters of the respondents (72 per cent) stated Norway as the most important market for solar energy products or services. It is particularly in the areas of installation and project development and design where most of the firms are oriented towards domestic markets. Many of the firms oriented towards international markets are positioned in upstream activities (Figure 5)

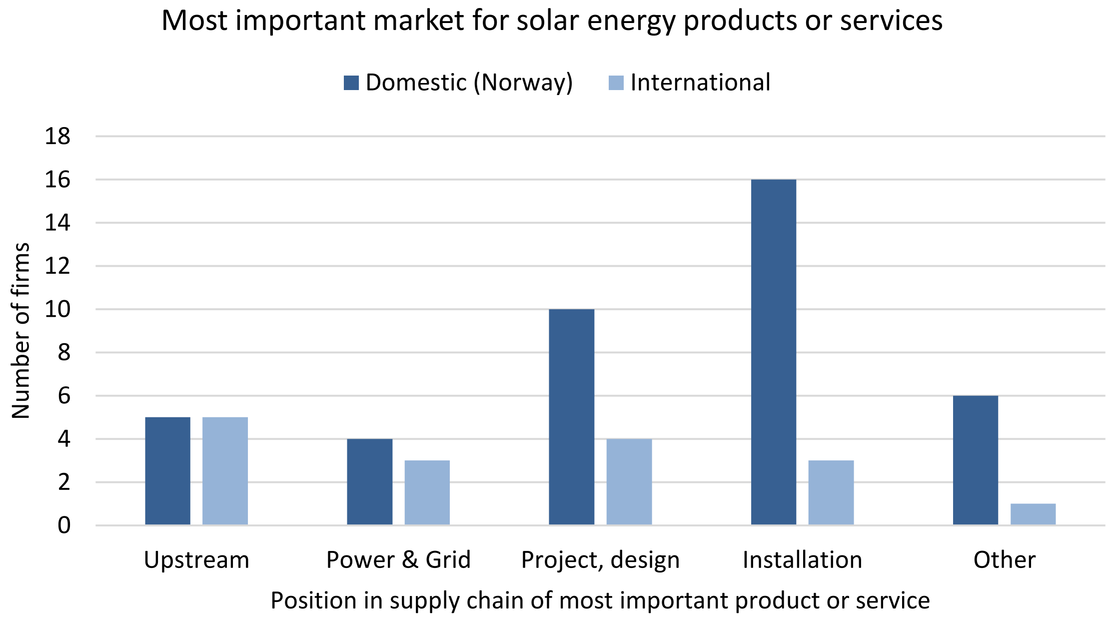

Figure 5 Most important market for solar energy products or services

4.2 Policy needs and satisfaction across the value chain

4.2.1 Policy satisfaction

The results show that around 20 per cent of the respondents are *not satisfied* with Norwegian policies for supporting their activities in solar energy. Whereas 16 per cent are *mostly satisfied*, only 2 per cent are *fully satisfied*. However, we observe differences with regards to policy satisfaction depending on position in value chain. Figure 6 shows that whereas more than half the upstream firms are fully or mostly satisfied with existing policies, less than 10 per cent of the downstream firms report the same level of satisfaction.

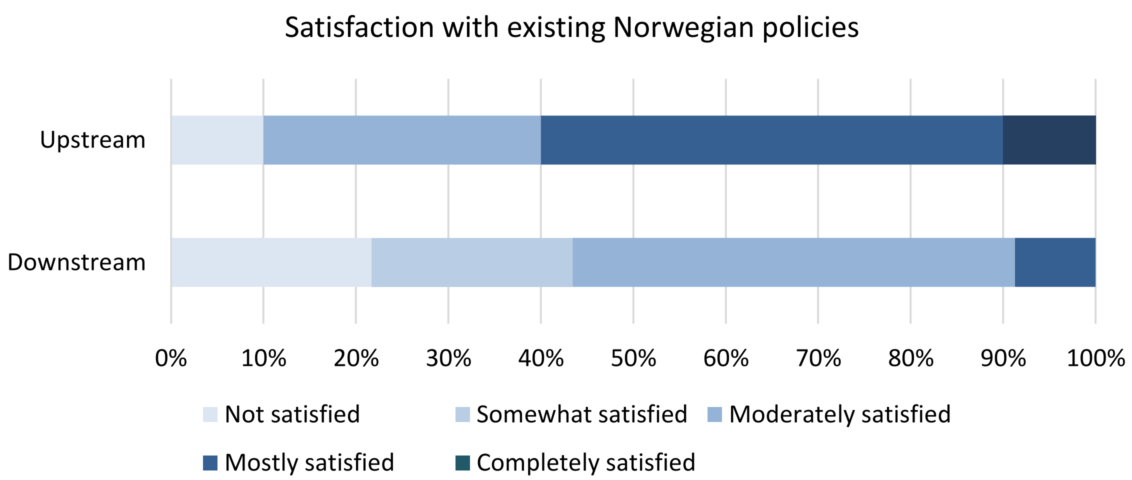

Figure 6 How satisfied firms are with existing Norwegian policies for supporting their activities in the solar industry. Split between upstream and downstream firms.

4.2.2 Policy needs

We also asked the firms which policy changes they would like to see, which would aid their efforts to succeed in the solar energy industry. This question was open ended, resulting in a wide variety of responses. From Figure 7 we can observe a large variety of policy and regulatory needs both within and across value chain segments. Furthermore, we see heterogeneity reflected in the amount and range of responses that are only mentioned once by one actor. We make two main observations:

First, investment support for PV is one policy need that is mentioned more frequently and thus shared between actors both within and between value chain segments linked to downstream. However, even within this group of needs we see some heterogeneity. While some respondents express need of general increase, others express need for increased support for more specific sectors (agriculture, commercial buildings). Overall the expression of needs for more investment for PV is however not surprising since PV deployment only recently has started picking up, as discussed in section 3.4.

Second, we observe that a majority of needs could be linked to fit-and-conform system building strategies, particularly linked to shaping existing financial instruments such as investment support or export finance, to accommodate better for PV. Needs that would relate to stretch-and-transform system building strategies are mainly linked to regulatory change in the electricity sector, and are expressed by actors in the downstream segments. These needs include change in tariffs and grid access, as well as expressions of needs of higher power prices and harmonization with EU electricity markets.

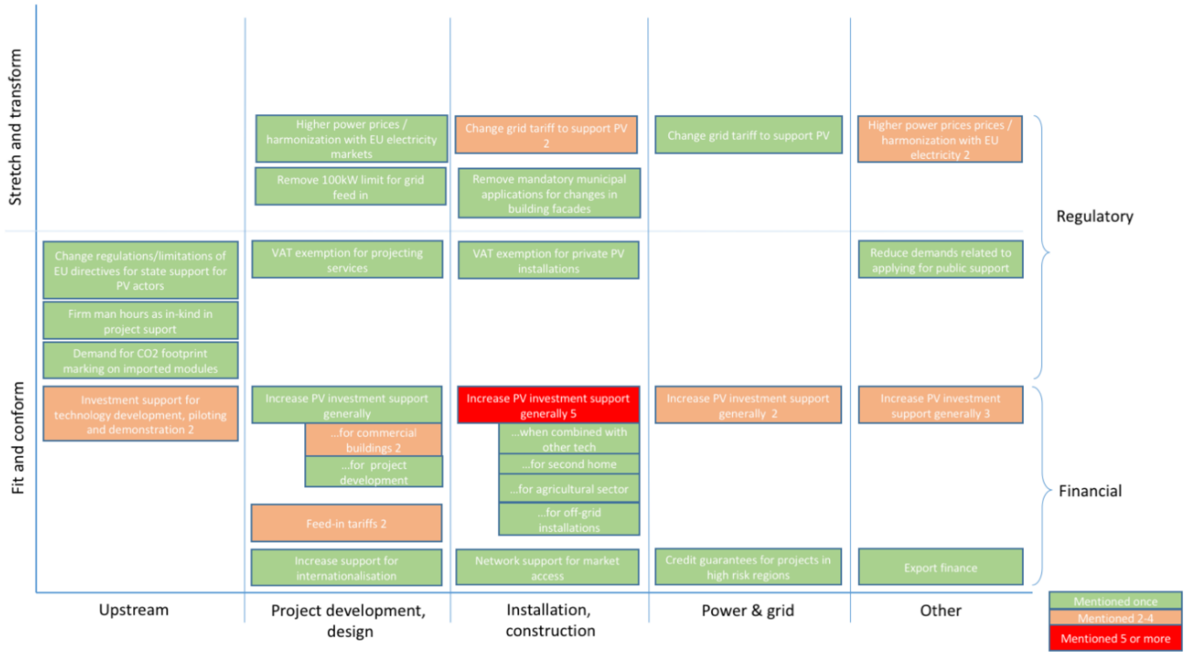

Figure 7 Which Norwegian policy measures would contribute most to firm's activity in solar energy industry?

We used the distinction between fit-and-conform and stretch-and-transform policies, as outlined in section 2.1 to categorize the firms' policy needs in three categories[1]. From Figure 8, we can see that the need for policies that change the sector selection environment (stretch-and-transform) is more prevalent among downstream firms.

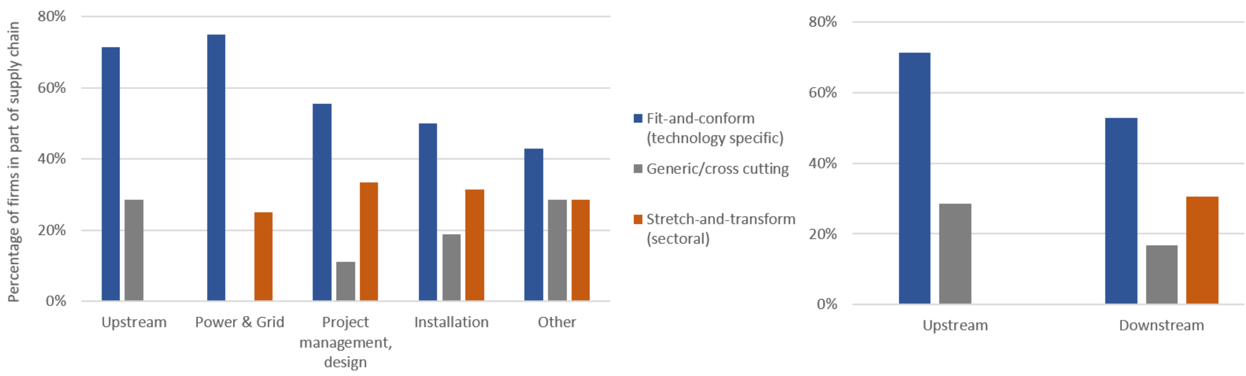

Figure 8 Policy needs categorised and depending on position in solar industry value chain.

The articulated policy needs is somewhat reflected in the firms' perception of the importance of different types of policies (Figure 9).

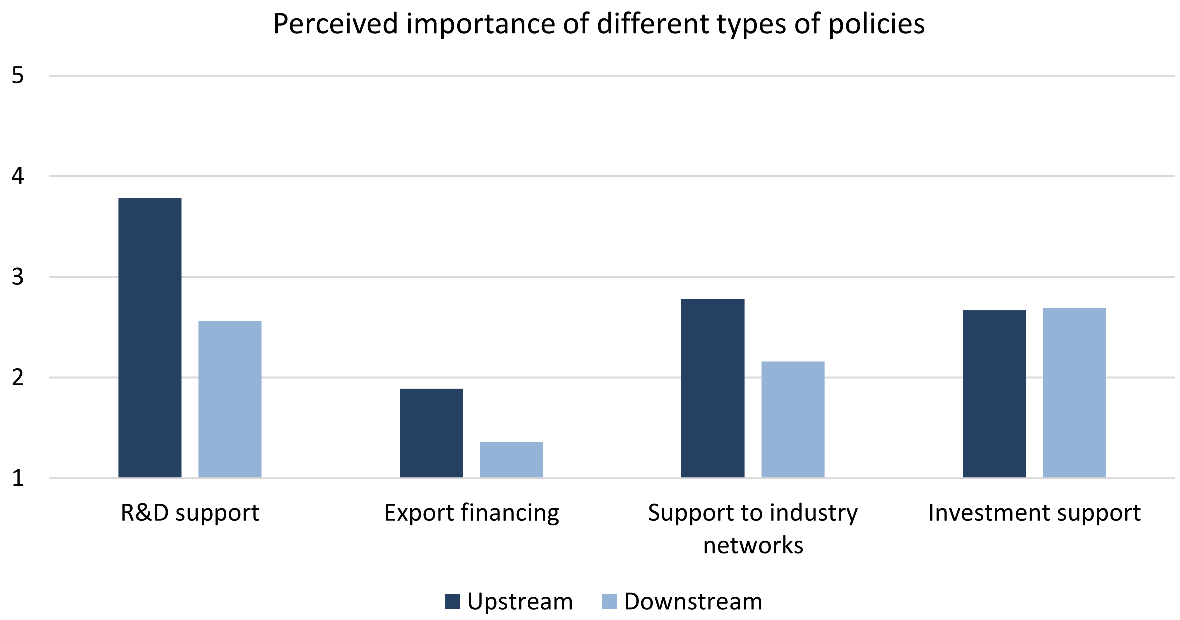

Figure 9 Perceived importance of different types of policy instruments for their activities in the solar industry. Firms responded on a scale of 1 to 5 where 1 equals *not important* and 5 equals *very important*.

[1] We labeled the final category *generic/cross-cutting*, as we saw no way of placing some of the articulated needs in any of the two categories developed by Smith and Raven (2012).

5 Discussion

To sum up the findings from the survey of Norwegian solar energy firms, we make two general observations that are relevant for a discussion about the possibility for running in packs. First, firms categorized as upstream firms are more satisfied with the existing policies for solar energy in Norway. These firms also report that the different types of policies and support available has been more important for their activity in solar energy. This may be due to how firms in this segment have had a longer and larger presence within the Norwegian context than some of the firms in the downstream segment. Moreover, upstream firms highlight R&D support particularly, which is not surprising considering that most of these firms are engaged in R&D intensive segments of the solar industry.

The second observation is that firms engaged in downstream activities of the value chain more often call for policy changes that would require stretch-and-transform system building strategies targeted at the sector selection environment. These actors thus express needs to change electricity sector institutions particularly, such as grid and tariff structures, in order for the TIS to develop. Typically, these changes involve politics and contestations, and are generally more difficult to obtain. Thus, the group of firms that is the least satisfied with current policies is also the group that require the most substantial policy change. We believe this also shows that there is a certain heterogeneity along the value chain with potential implications for institutional alignment and abilities to run in packs.

Some of the needs expressed by downstream actors (increasing power prices and harmonization with EU electricity markets) may not only be challenging to legitimize, but are also in direct conflict with the interests of actors in the upstream segment. The needs to change such institutions in the electricity sector, conflict with upstream actors needs of access to cheap and sufficient power supply for energy intensive processing and manufacturing (silicon, ingot casting etc). Although the need to maintain low power prices was not expressed in the survey (since the question in the survey was concerned with changes in policies), previous studies have noted the access to cheap power a key condition for locating manufacturing in Norway, and in particular regions (Hanson, 2018; Klitkou & Coenen, 2013). Interestingly, electricity is thus a key input sector to the upstream part of the PV value chain, while downstream segments provide output and express needs of transforming institutions of the electricity sector. Our framework underlined how TISs can relate to sectors in differing ways (both complementary and conflicting). Our analysis thus shows how different value chain segments of one TIS thus can have both complementary and conflicting relations to the same sector. Although we cannot assess to what extent actual system building activities have been mobilized to address this need, our analysis shows that conditions may be more conflicting between value chain segments of one TIS when it comes to influencing sectoral institutions.

Finally, Findings from the survey show how actors express a range of differing policy needs, and our analysis shows that many of them could be interpreted as `isolated`, i.e. that they are not shared by other actors in the TIS. We do however also observe some needs that are shared by several actors, which could constitute issues that provide foundations for more collective system building. Taking our framework into consideration, this suggests that there at least exist conditions for running in packs regarding some particular issues such as increasing deployment investment support. These issues are however not shared across all value chain segments.

6 Conclusions and implications for future research

In this, paper we aimed to explore two main conditions for innovation system building; how policy needs align (or not) along the value chain of a TIS and how needs relate to the sectoral contexts of the TIS.

As expected, we observed heterogeneity in policy needs across and within value chain segments. Some needs frequented more often and also across some segments. A main conclusion is however that we did not observe needs that spanned all value chain segments. A main difference can be observed between up- and downstream segments both in terms of satisfaction with existing policy frameworks and instruments, as well as in terms of needs for change or new policies and regulations. An implication of this study is that it may be worthwhile to analyze upstream and downstream TIS segments separately when analyzing cases of system building or even for performing a functional analysis, given that firms differ both in underlying characteristics and needs.

Another implication of our framework and analysis is that we observe needs linked to both `fit and conform` and `stretch and conform` system building strategies. Whereas upstream actors expressed policy needs related to specifically to the solar PV TIS and not to broader sectoral institutions, downstream actors articulated policy needs related to both the solar TIS *and* broader sectoral institutions. We can assume that the needs for change at the sectoral level will be particularly challenging to legitimize since they are likely to involve conflicts and contestation. From our analysis, we can see that some of this contestation may even come from another value chain segment of the same TIS (upstream).

While we have limited the analysis to exploring the conditions for system building in terms of policy needs, we have not analyzed system building initiatives in themselves. How, and to what extent these observed heterogeneous needs across the value chain are linked to actual system building activities is a matter of future studies. We further limited our focus on system building linked to policy. An interesting path for future research would be to explore several cases of system building and shaping differing kinds of institutions (akin to Musiolik et al. (2018) across differing value chain segments to explore more in depth how actors are able align their interests in system building activities.

A further limitation of this study is the sole focus on firms. Non-firm actors such as users, intermediaries, researchers and others may play important roles in system building. Future studies could thus include broader sets of actors that potentially could exhibit differing interests than firms with regards to the value chain perspective on system building.

In terms of policy and strategic implications, our paper in its very nature explicates a large range of needs for policy as articulated by the survey respondents. From a policy maker perspective it is however likely that the heterogeneity among needs can be `off-putting`. This suggests that a strategic implication concerns actors` collective ability to articulate clear cut and selective policy needs, which in turn relies on a process of alignment.

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