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Towards a holistic user innovation policy

Lars Bengtsson [a, *], Charles Edquist [b]

[a] Division of Innovation Engineering, Department of Design Sciences, Faculty of Engineering – LTH, Lund University, 22100 Lund, Sweden
[b] CIRCLE, Lund University, 22100 Lund, Sweden

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ABSTRACT

This paper aims to synthesize previous user innovation policy proposals into an adapted systems of innovation framework, on which a future holistic user innovation policy for the household sector can be based. We do this in three steps. First, we introduce the systems of innovation framework as a comprehensive basis for a holistic approach to innovation policy. Second, we identify and review policy proposals made by user innovation researchers and categorize them according to ten key activities in the systems of innovation framework. Third, from a systems of innovation perspective, we synthesize the policy proposals identified into an adapted framework including determinants specific for user innovation in the household sector. The synthesized proposals are intended to strengthen the systemic and multi-causal effects of policy on household sector user innovation in a country, region, or sector. Future policies for user innovation may, on this basis, be instrumental in avoiding mono-causality, or the concentration on only a few policy instruments in a proposed policy.

1. Introduction

Traditionally, innovation research has viewed the firm as a producer of innovations inspired by Schumpeter's early studies (Schumpeter, 1934). A linear model of innovation where the innovation process starts in corporate or university research and development has dominated strongly (Godin, 2006), viewing customers and users as passive recipients of innovations (von Hippel, 2005). This *producer-centered innovation model* has strongly affected innovation policies at the national, regional, and firm levels (Smits, 2002) and resulted in linear planning practices related mostly to the supply side such as road maps (Konrad and Böhle, 2019). In general, innovation policies are skewed and partial focusing mainly on the supply side and on the "R" in R&D-activities, largely ignoring the demand side (e.g., public procurement) and "D"-activities, such as education, skills formation, training, prototyping, and demonstration activities (Edquist and Hommen, 1999).

Another innovation model has been referred to as the *user-centered innovation model* (von Hippel, 2005) highlighting the role of users in the innovation system (Geels 2004). While producers innovate mainly to sell their new products (innovations), end users in the household sector innovate mainly to satisfy their personal needs, (e.g., de Jong et al., 2015; Tabarés and Kuittinen, 2020; von Hippel, 2005; von Hippel et al., 2011).[1] We here define user innovators as individuals in households

* Corresponding author.
E-mail addresses: lars.bengtsson@design.lth.se (L. Bengtsson), charles.edquist@circle.lu.se (C. Edquist).

[1] Firms that innovate for their own internal needs are also user innovators, but in this paper, we focus only on user innovators in the household sector, i.e., individuals that innovate for their personal needs.

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that expect to benefit from pursuing innovations via their use of the innovation (von Hippel, 2005; von Hippel et al., 2012). From a governance perspective, this innovation model is often referred to as the democratization of innovation (von Hippel, 2005) or a distributed form of innovation governance (Konrad and Böhle, 2019; Schneider and Lösch, 2019).

In contrast to the business and government sectors, households are mostly viewed as consumers in the economy: "*A household is defined as a group of persons who share the same living accommodation, who pool some, or all, of their income and wealth, and who consume certain types of goods and services collectively*" (SNA, 2009: 81). Due to the strong dominance of the producer centered innovation model and the traditional view on households as consumers, policy researchers and policymakers have largely overlooked the user-centered innovation model and the importance of user innovations for a country's, region's or sector's innovativeness (von Hippel, 2005, 2017). This is reflected in official innovation statistics which focus mainly on firms and their producer innovation activities (Gault, 2012, 2019; Godin, 2006) even though the 2018 edition of the Oslo Manual now includes innovations by all actors in all economic sectors, including the household sector[2] (Gault, 2019; OECD/Eurostat, 2018).

Over time, research evidence regarding the size and importance of user innovation in the household sector has been growing (for a recent overview see von Hippel 2017 and Table 1 below). Table 1 lists seven different national surveys of user innovation indicating significant proportions of the adult population (1.5%–7.3%) developing new products or improving (modifying) products for their personal use. In absolute numbers, this means that in the US there are 16 million user innovators and in Japan 3.9 million user innovators.

Table 1 also shows that only a minor portion of the user innovations get diffused (5.0%–21.9%) and mostly through peer-to-peer diffusion. The Finnish (Kuusisto et al., 2013) and Swedish (Bengtsson, 2015) national surveys show that only 6%–7% of the diffused user innovations, i.e., equivalent to 1%–2% of all user innovations, are diffused through commercial channels such as adopted by established firms or through new ventures. Thus, the national surveys have uncovered untapped potentials of user innovation in the household sector (e.g., Bengtsson, 2015; Kim, 2015; von Hippel et al., 2012). The surveys point to three untapped potentials: (1) potential to increase relatively low levels of user innovation in some countries (e.g., Kim, 2015), (2) potential to increase overall diffusion of user innovations in some countries (e.g., Ogawa and Pongtanalert, 2011) and (3) potential to increase user innovations diffusion through commercial actors, such as transfer to established firms or the user innovator starting a new venture (e.g., Bengtsson, 2015).

To mitigate these problems, researchers in the field have proposed innovation policies to support and strengthen user innovation on a national (e.g., Baldwin and Von Hippel, 2011; Gambardella et al., 2016; Henkel and Von Hippel, 2004) and sectoral (Nielsen et al., 2016) level. However, the proposed policies are discussed as implications based on the researchers' user innovation studies and not explicitly anchored in an innovation policy framework (see section 3). As far as we know, no academic paper has focused on user innovation policy development to more systematically advance innovation policy issues in the field. This paper aims to synthesize previous household sector user innovation policy proposals and integrate them into a holistic systems of innovation policy framework to guide future planning and policymaking.

We will develop the holistic innovation policy framework in three steps. First, we will introduce the systems of innovation framework as a broad basis for a holistic approach to innovation policy (section 2). Second, we will review policy proposals made by user innovation researchers and categorize them according to the ten key activities (see Fig. 1) in the systems of innovation framework (section 3). Third, we will, from a systems of innovation perspective synthesize the policy proposals into an adapted systems of innovation framework (section 4). The proposals are intended to strengthen the systemic, multicausal, and holistic features of future policy regarding user innovation in the household sector in countries, regions, or sectors.

Concerning the research literature on innovation policies for user innovation in the household sector we make two main contributions:

Table 1
The proportion of the population developing or improving consumer products for personal use and the proportion of user innovations diffused

Country	Finland [a)]	Japan [b)]	South Korea [c)]	Sweden [d)]	UK [e)]	US [b)]
Percentage of the population (eq nr of people) developing or improving consumer products for their own use	5.4% (0.17 M people)	3.7% (3.9 M people)	1.5% (0.54 M people)	7.3% (0.435 M people)	6.1% (2.9 M people)	5.2% (16.0 M people)
Percentage of innovations diffused (whereof peer-to-peer) and ((whereof commercially, i.e., own start-ups or through estbl firms))*	18.8% (15.7) ((6.0))	5.0% (n.a.) ((n.a.))	14.4% (n.a.) ((n.a.))	21.9% (17.8) ((6.8))	17.0% (n.a.) ((n.a.))	6.1% (n.a.) ((n.a))

Notes: * = some innovations are diffused both peer-to-peer and commercially, thus figures may exceed the total percentage of innovations diffused.
Sources: [a)] Kuusisto et al., (2013); [b)] Ogawa and Pongtanalert (2011); [c)] Kim (2015); [d)] Bengtsson (2015); [e)] von Hippel et al., (2012).

[2] In the October 2018 edition of the Oslo Manual the definition of innovation is the following: "a new or improved product or process (or a combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)." Fagerberg et al. (2012), focus on innovation studies as an emerging field of knowledge. The paper identifies the core contributions to the literature of this area as well as the most influential scholars and the central research environments in the field.

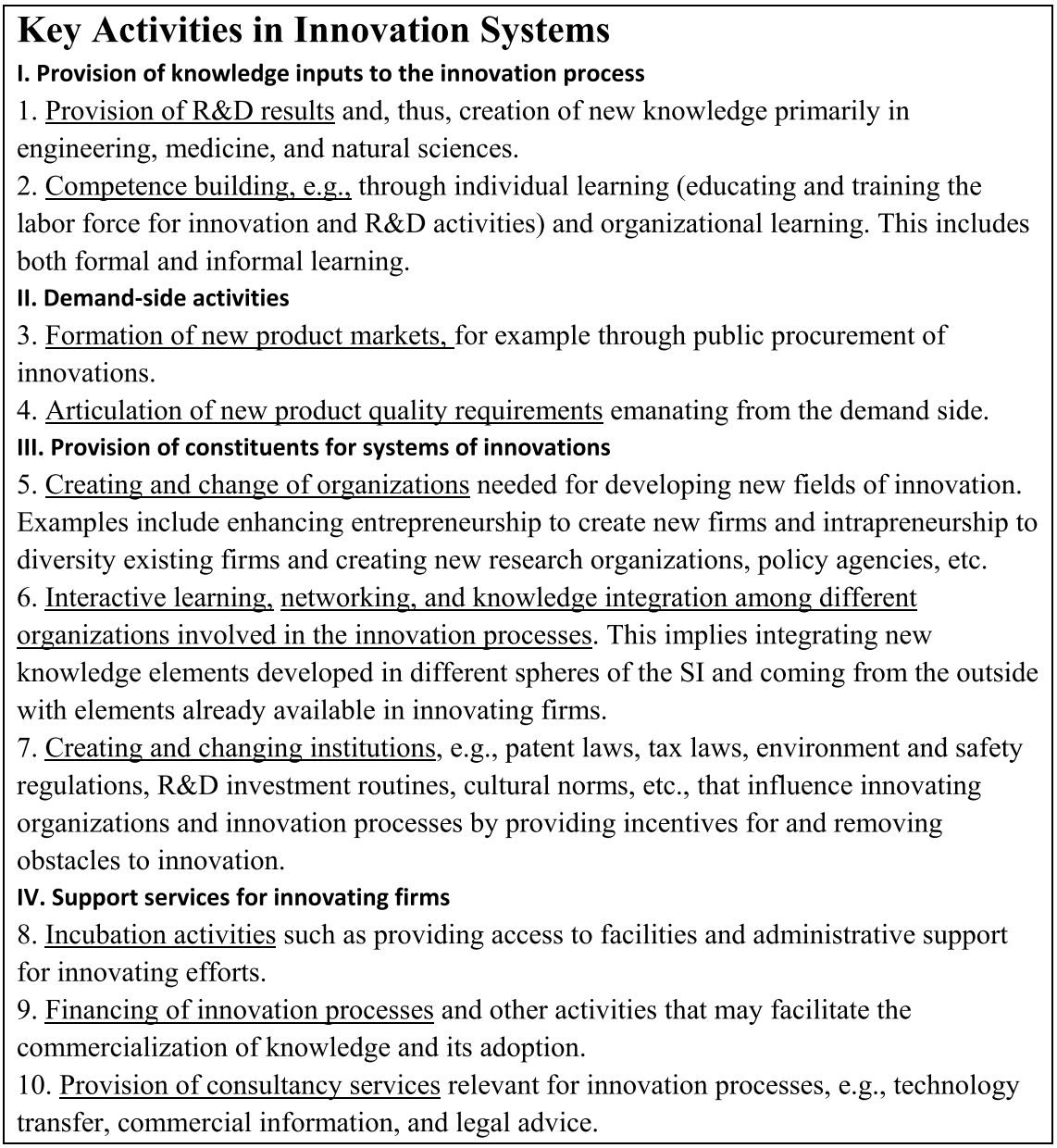

Fig. 1. Key activities in Innovation Systems. Source: (Borrás and Edquist, 2019).

- First, in the review of 22 publications with policy proposals on user innovation (section 3), we find that the publications lack an integrating innovation policy framework. Most of them limit their policy proposals to a few policy activities, i.e., the innovation policy proposals are partial and mono-causal. In contrast to the linear view of the innovation process, user innovation researchers predominantly adopt an institutional view of the innovation process.
- Second, based on a systems of innovation framework, we propose a future holistic innovation policy framework adapted to user innovation. It is centered on ten key activities and policy instruments related to them (see Fig. 1 in section 2). Our proposals effectively provide policy development support to policy researchers, policymakers, and politicians stressing the multi-causal and non-linear features of the user innovation process.

2. The systems of innovation approach

There are many definitions of systems of innovation in the literature. Some of them are broader or narrower in their character (e.g., Bergek et al., 2008; Borrás and Edquist, 2013; Carlsson, 1995; Edquist, 1997, 2005, 2019; Freeman, 1987; Lundvall, 1992; Nelson, 1993). Various complementary approaches have, over time, evolved such as the national, regional, and sectoral systems of innovation (Dahesh et al., 2020).

We define systems of innovation to include "all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion, and use of innovations" (Edquist, 1997: 3; Edquist, 2005: 184). We make this definition instrumental by specifying ten key activities in innovation systems.[3] This definition is much broader than other definitions found in the literature, e.g., Lundvall (1992), and especially Nelson (1993), as shown in Edquist (2005).[4] Our definition also includes a stronger emphasis on the demand-side as a source for innovation, for instance by highlighting the important role of public procurement to enhance innovation (Edquist and Zabala-Iturriagagoitia, 2012, 2015, 2020) and generally of user activities (Geels, 2004).

In other words, the version of the systems of innovation framework that we use here is a broad (wide, comprehensive, and multi-causal) version (cf. Chen et al., 2018). It includes all determinants that may influence innovations (Borrás and Edquist, 2019; Edquist, 1997, 2005, 2019). However, the role of household users as sources of innovation, has previously not been emphasized in the writing on systems of innovation. A developed version of the systems of innovation framework adapted to user innovation in the household sector will be presented and discussed in sections 3.2, 4, and 5.

In Fig. 1 below, Borrás and Edquist (2013) describe the ten key activities in the innovation system by giving examples of relevant policy instruments to stimulate, develop, and diffuse innovations in a multi-causal manner.

The activities in Fig. 1 are not ranked according to importance. It may be utilized as a checklist to analyze factors influencing innovation processes. The important thing with this approach is that it – in principle – attempts to include all determinants of innovation, holistically. When it comes to policy design, concerning the systems of innovation framework, the logic of additionality is important. In policy research, it usually refers to the logic that public policy actors should have a supporting or supplementing role (Borrás and Edquist, 2019; Edquist, 2019) to private actors. This policy research logic of additionality is a guiding principle when identifying policy problems as well as determining how and to what extent the public sector may best support and add to private and public actors' undertakings and accomplishments (Borrás and Edquist, 2019; Edquist, 2019).[5]

Innovation policy within a holistic approach is here seen as a division of labor between what private and public organizations do. Within such an approach, two conditions must be fulfilled for public intervention in a market economy to be motivated:

- Private organizations are not successful in fulfilling the policy objectives that are formulated. In other words, a policy problem exists.
- Public organizations must have the ability to solve or mitigate the problem.

These two conditions show the central importance of additionality in solving policy problems. It implies that policy actors must not replace, duplicate, or crowd out what private or other innovation actors (can) accomplish. They should rather support or supplement the actions of the private sector. Additionality is closely related to the identification of policy problems and to determining how and to what extent policy actors can best support and "add to" what private actors, including the household sector, can accomplish and are willing to undertake. Additionality is sometimes called 'market supplementation' (Borrás and Edquist, 2019; Edquist, 2005, 2011, 2019).

The list of activities in Fig. 1 was originally developed primarily with innovations carried out by firms and demand-side activities in mind. In the current contribution, we focus on innovations carried out by users in the household sector. We intend to adapt the systems of innovation framework to the peculiarities of user innovation. Such adaptations are discussed in the rest of this paper.

3. A review of policy instruments for user innovation policies in the household sector

There are three types of diffusion mechanisms for user innovations: (1) peer-to-peer sharing, (2) new venture creation by the user innovator (user entrepreneurship), and (3) adoption by commercial producers (von Hippel et al., 2011). Although user innovators are often positive towards revealing their innovations free of charge, only a minor part is diffused (ca 5%–20%), primarily through sharing with peers. This is understandable given the often limited interest, incentives, and

[3] See Fig. 1. It should here be mentioned that there are no reasons to exclude any determinants of innovation processes when trying to explain innovation processes or when selecting policy instruments in designing innovation policies.

[4] Lundvall and Nelson concentrate on one or a few determinants of innovation processes in their definitions of systems of innovation, Lundvall on the institutional set-up and the production structure, and Nelson on organizations supporting R&D.

[5] Our choice of using 'policy problem' instead of 'market failure' is conscious and intentional and the notion of policy problem is wider than that of market failure. These issues are discussed in Borrás and Edquist (2019): chapters 2 and 3.

capabilities of the user innovator to diffuse widely. To mitigate the problem of limited diffusion of valuable user innovations and knowledge related to user innovations, e.g., ideas, blueprints, designs, prototypes, researchers in the field have proposed innovation policies to support and strengthen user innovation on a national (e.g., Baldwin and Von Hippel, 2011; Henkel and Von Hippel, 2004; Gambardella et al., 2016) and sectoral (Nielsen et al., 2016) level. We will now review these policy proposals.

3.1. Selection of reviewed papers

Normally, when you conduct a review and synthesis of policies, such as innovation policies (e.g., Edler et al., 2013), you start by identifying studies evaluating the impact and effectiveness of implemented policy instruments in much the same way as for research reviews. Then you review and analyze the policy evaluations and the evidence for impact and effectiveness. As a final step, you synthesize those policies that have similar policy objectives and have shown to be effective and complement each other under certain conditions.

In our case, we do not have any policy evaluations to review, i.e., we do not have any national or sectoral policies targeting user innovation in the household sector to study. Instead, we have identified policy proposals (that have not been implemented) in the relevant research literature. We have reviewed these proposals and categorized their intended impact according to which key activity in our systems of innovation framework they belong. This has enabled us to conclude whether (a) the proposed policies are partial or holistic as well as, (b) determining what types of individual policy instruments most or least commonly proposed (in terms of the ten activities). Finally, (c) we have synthesized the policy instrument proposals into a holistic innovation policy. The results follow below.

We have consulted the research literature for policy proposals aimed to stimulate and support user innovations in society. We have reviewed two types of research literature: 1) papers or reports that present national surveys of user innovations and that include policy proposals, and 2) academic papers in the user innovation domain,[6] which include policy proposals on the national, regional, or sectoral level.

The first category, *national surveys*, was identified by recent overviews of such studies in von Hippel (2017) and Franke et al. (2016). As the publications for the Japanese and U.S. surveys (Ogawa and Pongtanalert, 2011, 2013) did not propose any national or sectoral policies they are not included in the review. The second category, *academic publications addressing user innovation*, was identified by a search in the SCOPUS database. We used the following search strings: "Household sector innovat*" AND "polic*" which yielded one publication, "Consumer innovat*" AND "polic*" which yielded eight publications and, "User innovat*" AND "polic*" which yielded 48 publications, "prosum*" AND "innovation*" AND "polic*" yielding 25 publications, i.e., 82 publications in total. The publications were from the period 2004–2019. Removing duplicate papers and non-relevant papers, e.g., papers only addressing firm user innovation, or only dealing with open source communities, or only on prosumption and not related to innovation issues, we identified 18 relevant papers containing policy proposals related to user innovation in the household sector. Thanks to our systematic method to identify papers, we claim that we have identified all the papers that should be included in a survey with the objective we have.

In all, we included 22 studies, i.e., 4 national surveys and 18 academic papers, as relevant for our review. They are listed in appendix A with the author(s), title, a short description of the study, and a list of the policy proposals mentioned in the paper. Each policy proposal is also categorized by indicating the number of the key activity in the systems of innovation framework described in Fig. 1 above. While the number of reviewed papers may seem limited, we believe that we have included all published national surveys and papers on user innovation research in the household sector that contains policy proposals.

3.2. Analysis of policy proposals

We will now analyze the policy proposals in the literature reviewed (please see Appendix A for an overview and details in each reviewed paper) by identifying:

- policy problems and objectives, and
- key activities addressed in the policy proposals

We analyzed the content in each paper by first identifying their stated policy problems and the policy objectives related to household user innovation. For example, in von Hippel et al.'s (2012) study of UK household user innovation the authors discuss two policy problems 1) incomplete official innovation statistics related to household user innovation, and 2) underestimation of user innovation as a complement to producer innovation (von Hippel et al., 2012: 1677). Later in their paper, they discuss the policy objective of increasing social welfare (von Hippel et al., 2012: 1678). We then moved on to identify the policy proposals in each paper. In the Von Hippel et al. study (2012: 1678) they list four policy proposals: 1) routinely measure consumer innovation, 2) increased investments in technical education, 3) reduce the costs of communication among consumer innovators, and 4) incorporate data on consumer innovation in official statistics. We then categorized each policy

[6] All national surveys and academic papers selected in this review use the terms "user" (individuals not firms), "consumer", or "prosumer innovation". Thus, the policy proposals are intended for user innovators in the household sector.

proposal concerning its implied key activity in the systems of innovation framework. For example, the four policy proposals mentioned in the Von Hippel et al. study (2012) were categorized as follows:

1) routinely measure consumer innovation – this implies changing the statistics institution to permanently include user innovation = key activity seven,
2) increased investments in technical education – this implies the input of additional technical competence = key activity two,
3) reduce the costs of communication among consumer innovators – this implies facilitating and coordination of interactive learning between user innovators = key activity five,
4) incorporate data on consumer innovation in official statistics – same as policy proposal one above, changing the statistics institution = key activity seven.

We did so for all papers as shown in Appendix A. The categorization of policy proposals according to implied key activity is shown in the last column within brackets.

3.2.1. Policy problems and objectives

Policy problems and policy objectives are connected in the sense that a policy problem is perceived when it hinders reaching the desired state, a policy objective. The most commonly mentioned policy problem in the review is the limited diffusion of valuable user innovations (e.g., Bengtsson, 2015; Brem et al., 2019; Halbinger, 2018; Kuusisto et al., 2013). This is a policy problem because it limits the policy objective of *increasing social and economic welfare* (e.g., Baldwin and Von Hippel, 2011; Gambardella et al., 2016; Henkel and Von Hippel, 2004). Henkel and Von Hippel (2004) discuss three social and economic advantages connected to carrying out user innovation in the household sector: a) Increased economic and social value as user innovators develop niche products for small market segments with specific needs which are unprofitable for large producer firms, b) Reduction of producer firms' commercial failures in new product development as user innovations give producers important information about consumer needs that are often hard for large producers to detect due to its sticky and tacit nature; and, c) Complementarity between user innovations and producer firm innovations in the sense that knowledge spills over from households to producers combined with the fact that producers have superior knowledge and resources to improve and diffuse innovations. The papers in this group do however differ in the way they describe the nature of the policy problem. Some researchers highlight the lack of knowledge of the phenomenon, i.e., official and reliable statistics on user innovation (e.g., Bengtsson, 2015; Gault, 2012, 2019; von Hippel et al., 2012). Without official statistics the prospects of getting policy attention are meek. Other researchers view the current legal frameworks, e.g., IP-regulations, as a major obstacle for user innovation diffusion as many user innovations are modifications of existing products (e.g., Baldwin and Von Hippel, 2011; Haefliger et al., 2010; Henkel and Von Hippel, 2004). Yet another group highlights the lack of various resources and support structures, such as lack of relevant skill sets and education (e.g., Gault, 2019; Kim, 2015), support structures such as maker spaces (e.g., Halbinger, 2018) and crowdfunding market places (Brem et al., 2019).

One study discusses the policy problem of low levels of user innovation in South Korea compared to more advanced countries (Kim, 2015). The policy objective is the same, increased social and economic welfare, but here combined with the policy objective to contribute to the transition of a new type of economy in South Korea, the creative economy (Kim, 2015).

The policy objective of transitioning to a new type of economy and society is at the center of the second most common group of mentioned policy problems and policy objectives. In this group, the policy objective is the *transition to an environmentally sustainable society* (e.g., Jalas et al., 2017; Nielsen et al., 2016) or more specifically contributing to a *sustainable energy transition* (e.g., Brown et al., 2019; Hyysalo et al., 2013a, 2013b; Leiva et al., 2016). User innovators involved in sustainable innovations tend to innovate more for the benefit of others than for themselves (Nielsen et al., 2016) and thus to be driven more by passion and idealism (Seyfang et al., 2013) compared to traditional household user innovators. Most papers in his group argue that the policy problem is limited levels of innovation activities and diffusion of valuable environmentally sustainable innovations emanating from the household sector (Hyysalo et al., 2013a, 2013b; Jalas et al., 2017; Nielsen et al., 2016). However, other authors argue that there are more basic problems such as lack of appropriate technologies (Ahl et al., 2019; Leiva et al., 2016), appropriate legal frameworks (Heldeweg, 2017; Leiva et al., 2016), and legitimacy for user innovations as a source for societal change (Jalas et al., 2017).

3.2.2. Key activities and policy instruments addressed in the policy proposals

As described in section 2, the systems of innovation framework (Borrás and Edquist, 2019; Edquist, 2005, 2011) describes ten determinants or key activities that influence the development, diffusion, and use of innovations. In the review of user innovation policy proposals, we have found that the ten determinants in the systems of innovation framework still could be used to categorize, structure, and describe important determinants in the user innovation processes. However, we have also identified some differences in the characteristics of these determinants. These are described below and compared with typical systems of innovation framework determinants in Table 2. In column 2 typical determinants of the systems of innovation are outlined. In column 3 we exemplify with typical determinants of the adapted systems of user innovation in the household sector according to the reviewed papers. In column 4 we give examples of policy instruments related to each key activity.

Table 2
Comparing typical determinants in the systems of innovation framework with typical determinants in a household sector user innovation system.

Key activity in SI model	Typical determinants in SI framework	Typical determinants in household sector user innovation	Examples of policy instruments to support user innovation in households
Key activity one R/D-results	Provision of R&D-results, basic and applied research	Provision of existing products, data, blueprints, components, problems for experimental development	Relaxing patent laws for own modification and use. Public sector opens up problems, data, knowledge assets. Support open innovation strategies for firms.
Key activity two Competence	Skilled labor, formal and informal learning	Science, technology, innovation (STI) education Education in problem solving, modularity, and collaboration Informal learning in communities	Increase level of STI education, Support education in problem-solving, modular, and collaborative skills. Support offline and online user communities.
Key activity three Formation of new product markets	Public procurement of innovations Creation of standards	Public procurement of user innovations Standards for joint production and consumption between firms, public utilities, and households	Individuals to take part in public procurement for innovation and simplify deliverables, i.e., concepts, blueprints, prototypes. Public sector organizations encouraged to use crowdsourcing and competitions. Incentives to adopt interoperable technical systems.
Key activity four Articulation of new prod qualities	Customers Safety regulations	Users' unique needs and demands	Relaxing patent laws for own modification and use. Public sector opens up problems, data, and knowledge assets. Support open innovation strategies for firms.
Key activity five Creating and changing organizations	Entrepreneur-ship Intrapreneur-ship	User entrepreneurship User innovation communities Producer firms open to innovating users	Start-up and seed programs for user entrepreneurs. Support offline and online user communities. Support open innovation strategies for firms.
Key activity six Interactive learning	Coordination of public and private research	Coordination of user innovators Coordination of producer and user innovation Coordination of public organizations' development activities and user innovation Coordination of non-profit organizations' development activities and user innovation Interoperability of technical systems Coordination of RTI-policy processes and user innovators	Support offline and online user communities. Public sector opens up problems, data, knowledge assets. Support open innovation strategies for firms. Incentives to adopt interoperable technical systems. Promote local and regional interactions and networks. Open up policy processes to citizens incl user innovators.
Key activity seven Creating and changing institutions	IPR laws Tax incentives	Household user innovation in national statistics Creating "fair rights" - Rights to modify for own use New types of licensing such as Creative Commons Recognition of maker culture Regulatory sandboxes and legal disruptive experiments From supply points to consumption/production spots	Official statistics regularly measure user innovation. Relax product liability regulations for producers when modified for own use. National strategy for use of Creative Commons-licenses. Public sector directives to invite for experimentations of public services. Introduce regulatory sandboxes.
Key activity eight Incubation activities	Science parks Incubators Firm accelerators	Maker spaces for user innovators Incubators for user innovators	Public organizations such as universities set up maker spaces and incubators for user innovators. Support to firms for setting up maker spaces.
Key activity nine Financing	Internal capital markets Venture capital Public seed funds	Micro-grants to user innovators Public seed funds to user entrepreneurs Crowdfunding for user innovators	Micro-grant programs to user innovators and communities. Seed funds to user innovators and entrepreneurs.
Key activity ten Consultancy services	Provision of technical and law experts	Provision of technical expertise, certification services, grant application services, marketing expertise, business development expertise, law expertise to user innovators	Expert vouchers to user innovators and communities. Access to expert advice through public maker spaces.

The provision of R&D results (key activity 1) normally includes basic research, applied research, and experimental development by producing firms themselves or from universities. User innovators rarely perform basic research themselves because of their orientation towards solving their problems and because of lack of resources; they usually focus on experimental development when they develop new solutions primarily by modifying and adapting existing products, components, or data (e.g., Hyysalo, et al., 2013a; Kuusisto et al., 2013; Nielsen et al., 2016). Thus, the provision of producers' and public sectors' problems, blueprints, components, products, and data are a much more important knowledge input for user innovators than basic and applied research. The provision of these knowledge assets could be increased by policy instruments such as relaxing patent laws (Henkel and Von Hippel, 2004), public sector organizations opening up data and other

knowledge assets (Nielsen et al., 2016), and supporting firms' adoption and use of open innovation strategies (Gambardella et al., 2016).

Skilled labor, both formally and informally educated and trained, is an important determinant in the systems of innovation framework (key activity 2). This is true also for user innovation as it is especially prevalent among higher educated people, in particular by persons having a science or technical education (e.g., Bengtsson, 2015; Kim, 2015). However, there are also some additional competences related to user innovation that seems more important than for individuals in producing firms. Individuals need to possess specific innovation skills, i.e., problem-solving, design, modular and collaborative skills (e.g., Gault, 2019; Nielsen et al., 2016). Moreover, collaboration in communities and network forums is important for informal learning between user innovators (Hyysalo et al., 2013b; Kim, 2015). The supply of skilled labor in science, technology, and innovation (STI), as well as in skills in problem-solving, design, modular and collaborative skills may be stimulated by governments through their education policies (von Hippel et al., 2012) increasing investments in STI educations as well as more interactive and project-driven didactic education (Bengtsson, 2015).

New product markets are created by producing firms themselves but also with the support from the public sector in the form of public procurement in early stages and standardization activities (key activity 3). User innovators in the household sector are demand-side actors as they normally innovate for their consumption. Users of consumer products have been shown to innovate entirely new products and product categories such as new sports equipment such as rodeo kayaks (Hienerth, 2006), digital music services (Bengtsson, 2015), and agricultural equipment (Douthwaite et al., 2001). Public procurement for innovations can be a key activity when searching for new types of products and services (Mergel, 2018). In many countries, only firms are permitted to make bids in public procurement disqualifying individuals (Bengtsson, 2015). Moreover, in public procurement for innovations deliverables are most often specified as fully functional products making the threshold for user innovators even higher. Allowing individuals to take part in public procurement for innovations and specifying deliverables in the form of concepts, blueprints or low-fidelity prototypes could be a policy instrument to stimulate user innovation participation (Bengtsson, 2015). The creation of standards is normally regarded as a key activity to create new product markets. For user innovators, this seems to apply mostly to the energy sector where prosumers find it difficult to innovate new products due to being defined as only consumers of energy with no production or storage capabilities (Brown et al., 2019) hindering them from innovating new products and business models in the distributed energy market (Leiva et al., 2016). Here various incentives from the government to develop or adopt interoperable technical systems could be suitable policy instruments (Brown et al., 2019).

The creation of new product markets by user innovators seems much less common than user innovators modifying and adapting existing products and components (e.g., Bengtsson, 2015; von Hippel et al., 2012). This implies that user innovators primarily articulate the needs and demands for new product qualities (key activity 4), mainly to customize to specific usages and user contexts (Hyysalo et al., 2013a). Users' modifications of existing products in the form of ideas, concepts, designs, prototypes, or fully functional modified products are then important activities to articulate new product qualities (Nielsen et al., 2016). Again, relaxing patent laws (Henkel and Von Hippel, 2004), public sector organizations opening up data and other knowledge assets (Nielsen et al., 2016), and supporting firms' adoption and use of open innovation strategies (Gambardella et al., 2016) might be suitable policy instruments to facilitate user innovators' modification activities.

New organizations, for example in the form of entrepreneurship and intrapreneurship (key activity 5) are important activities in systems of innovation. Similarly, user entrepreneurship (e.g., Bengtsson, 2015; Brem et al., 2019), i.e., that a user innovator starts a new venture, is an important activity to diffuse user innovations. In addition, the review has revealed several other types of organizations that are important to user innovators, such as online and offline communities and forums (e.g., Hyysalo et al., 2013a; 2013b). In terms of changing organizations the reviewed literature focus on the producer firms' R&D or innovation organization, and suggest it should open up to user innovations, employing a more open innovation strategy based on specialization and complementarity with innovating users (Gambardella et al., 2016). Policy instruments include usual programs to increase entrepreneurship through startup programs and seed funds, supporting user innovation communities, and the adoption of open innovation strategies by firms (Kuusisto et al., 2013).

The relations and interactions among the different organizations (key activity 6) are vital to the functioning of an innovation system. Usually, this key activity includes coordination activities mainly between public research at universities and research institutes and private research in firms, i.e., university-industry interaction. As user innovation seldom involves interaction with basic research at universities or firms, interactive learning related to user innovation in the household sector has another character. Here coordination activities concern interaction between user innovators (e.g., von Hippel et al., 2012) to facilitate interactive learning and peer-to-peer diffusion, and coordination between user innovators and producer firms (e.g., Gambardella et al., 2016) to facilitate commercial diffusion. A third and fourth type of coordination concerns interaction between public organizations and user innovators, and different non-profit organizations and user innovators (Gault, 2019) to facilitate interactive learning and diffusion through these channels. In the energy sector, innovating prosumers would benefit from better coordination and interoperability between prosumers in P2P microgrids (Ahl et al., 2019) as well as integration and interoperability of all meters in as smart meter infrastructure (Brown et al., 2019). In addition, policy instruments of supporting user innovation communities (Hyysalo et al., 2013b), public sector organizations opening up data and other knowledge assets (Nielsen et al., 2016), supporting firms' and non-profit organizations' adoption and use of open innovation strategies (Gambardella et al., 2016; Gault, 2019), promoting local and regional networks (Nielsen et al., 2016) and opening up public policy processes to citizens (Warnke and Schirrmeister, 2016) are proposed as policy instruments to increase and facilitate interaction related to user innovation.

Creating and changing institutions, i.e., rules (key activity 7) is central for all kinds of innovations, but seems especially important for innovations carried out by users in households. This goes for IPR regulations, tax incentives, rules concerning the environment and safety, official statistics, etc. They may provide incentives as well as obstacles for producers as well as user innovators. In the user innovation literature, the obstacles have been mostly discussed in the form of overly strict IPR-regulations prohibiting user innovators from modifying producers' products (e.g., Henkel and Von Hippel, 2004). Creating some kind of "fair rights" to allow for own modifications as well as safe havens to freely use and reveal modifications are central themes in creating spaces for user modifications (Baldwin and Von Hippel, 2011). Moreover, several papers advocate the increased use of new types of open licensing schemes such as Creative Commons-licenses for IPR-holders to open for further development, modifying, and adapting their products (e.g., Bengtsson, 2015). Other institutional changes that are deemed important are integrating user innovation in official innovation definitions and national statistics as well as the creation and nurturing of a "maker culture" (e.g., Gault, 2012, 2019) and using democratic mechanisms when developing research, technology, and innovation policies (Warnke and Schirrmeister, 2016) and allocating public innovation funding (Brem et al., 2019). In the energy sector, a new definition of users in households as both consumers and producers of energy is an important institutional change, i.e., changing from being a supply point to an energy spot (Leiva et al., 2016). The complexity of technical, organizational, safety, and legal issues in the energy sector makes it difficult to change the governing institutions in the energy sector to allow for more prosumer activity and innovation. Thus, regulatory sandboxes (Ahl et al., 2019) and legal experiments (Heldeweg, 2017) are two key activities to handle these complexities.

Incubation activities (key activity 8) are usually related to the forming of new technology-based ventures which require specific office spaces, administrative competence, and so on. Science parks, incubators, and accelerators within large firms are important activity spaces for such incubation activities. User innovators are often weaker than established firms regarding resources needed for pursuing innovation, for example, administration, office space, laboratories, and expensive equipment. Therefore, the availability of incubators and maker spaces seems important to user innovators (e.g., Halbinger, 2018) to facilitate and enable experiments, modifications, and informal learning.

Financing (key activity 9) generally concerns the availability of capital for innovation activities, in the form of firm internal markets, venture capital, and public investment funds. For user innovators, micro-grants, and seed programs are the most important activities in the financing, including micro-grants for the establishment and operation of communities and forums (Hyysalo et al., 2013a; 2013b). As peer-to-peer diffusion is important for user innovations crowdfunding platforms for user innovators to finance their activities, increase diffusion, and support user entrepreneurship is a key financial resource (Brem et al., 2019).

Provision of consultancy services (key activity 10) generally concerns the availability of specialized competences in technologies and law. For user innovators, individuals can be expected to lack many of the competencies which may be needed for the development of innovations. Large producing firms often have access to these services within the firm, or can afford to acquire them, while user innovators must rely on private relationships (if any) if there are no public or subsidized services available. So easy and affordable access to such expert knowledge and consultancy services would benefit user innovators (e.g., Kim, 2015).

4. Towards a future holistic user innovation policy for the household sector

Innovations are developed and diffused in and between innovation systems, influenced by the determinants of innovation processes, specified in the form of the ten key activities. By influencing these determinants, public agencies can, through their policies, influence the innovation processes (Edquist, 2011). The determinants of innovations, and the sub-set of these that constitute innovation policy instruments, influence innovation processes in two ways:

1. They may affect the trajectories of the innovation processes (e.g., innovations are developed for using the sun or using coal).
2. They may change the speed, or pace of these processes along with the various directions.

Concerning influencing innovation processes the reviewed papers suggest two dominant policy problems: 1) limited user innovation activities, and 2) limited diffusion of valuable user innovations. The reviewed papers relate these two policy problems to two different policy objectives: 1) Increasing social and economic welfare, and 2) Strengthening and speeding up the sustainability transition.

The selection and design of instruments to mitigate these policy problems in line with policy objectives can be done by using the list of ten key activities. When selecting a mix of policy instruments, it is important to keep in mind the multi-causal nature of the innovation process. Normally the selection and mix of instruments represent at least all four major groups of key activities (Fig. 1) and ideally all ten key activities (and possibly others). A holistic innovation policy looks at the whole innovation system and avoids a partial and linear view.

The review of key activities and policy instruments reveals that the 22 papers propose a *partial* agenda of policy proposals, i.e., limiting the policy discussion to one or a few key activities. For instance, several papers (Baldwin and Von Hippel, 2011; Gault, 2012; Haefliger et al., 2010; Henkel and Von Hippel, 2004) discuss only one key activity, (the changing of institutions). They address mainly changes in patent laws, implicitly describing only one type of cause to the policy problem. From a

Table 3
Number and percentages of policy proposals per key activity and main types of determinants in reviewed papers.

Key activity	1 R&D	2 Education	3 New markets	4 New prod qual	5 New organizations	6 Learning Interactions	7 New institutions	8 Incubation	9 Finance	10 Consultancy
No. of policy proposals	6	8	2	2	5	18	19	5	4	2
Percentage of policy proposals	8.4%	11.2%	2.8%	2.8%	7.0%	25.4%	26.8%	7.0%	5.6%	2.8%
Percentage of policy proposals according to main types of determinants	Inputs – 19.6%		Demand-side – 5.6%		Constituents or institutions in the innovation system – 59.2%			Support services – 15.4%		

systems of innovation framework perspective, these are examples of *mono-causal* views of the policy problem and mono-causal designs of innovation policies. The fact that the proposed key activities in the literature are partial and in several of them mono-causal is quite surprising, the reason being that innovation researchers have for quite some time held the view of innovation processes as being complex and multi-causally determined (Borrás and Edquist, 2019; Edquist, 2005,2019).

Table 3 lists the number of policy proposals related to each of the ten key activities and the main types of determinants in the reviewed papers (see appendix A for details of the policy proposals in the papers). The linear view of innovation processes and the producer-centered innovation model, focus policy attention on the knowledge inputs of the innovation system (key activities one and two). However, user innovation research indicates that knowledge inputs are important for user innovation (19.6% of the policy proposals) but much less important than the (59.2% of the policy proposals)constituents of the innovation system (mainly key activities six and seven), i.e., the interactions and institutions in the innovation system. It suggests an institutional view of the innovation process. The constitutional (or institutional) key activities are often described as constraints or bottlenecks by user innovation researchers, e.g., hindering user innovators from modifying existing products or components due to patent laws and/or lacking interactions with companies and organizations. This finding suggests that the constituents or institutions of the innovation system need to be changed to increase the effect of other key activities.

Key activities one and two (knowledge inputs) are the second most proposed policies after the institutional key activities. These proposals concern opening access to company resources such as products, components, and blueprints and public organizations' resources such as open data. They also stress education to increase users' capabilities, i.e., STI-education, modularity, and design. Once the institutional constraints are relaxed, access to solutions' resources and capabilities become critical. In turn, this means that the key activities related to supports services, i.e., incubation, financing, and expert services (eight, nine, and ten), become increasingly relevant in a relative sense (15.4% of the policy proposals).

Key activities three and four, demand-side activities, receive the least number of proposals in our review (5.6% of the policy proposals). This might be since user innovators are demand-side actors themselves. Many of these proposals concern public organizations employing procurement in such a way that it can enhance innovations. They also use various kinds of competitions to involve user innovators in the search for new solutions for public services.

Based on our review, a holistic innovation policy for user innovators in the household sector would suggest an initial emphasis on institutions and learning interactions, concurrently stimulating access to relevant knowledge inputs, supporting infrastructure of support services as well as stimulating other demand-side actors. In Fig. 2 we have presented an example of a holistic household user innovation policy. In the example, we depart from the policy problem of limited diffusion of valuable user innovations emanating from the household sector and the policy objective of increasing social and economic welfare. It indicates an emphasis on policies changing the constituents of the innovation system which will then affect policies on knowledge inputs, support services, and other demand-side factors.

5. Concluding discussion

This paper has aimed at synthesizing existing user innovation policy proposals expressed in the literature into an innovation systems framework that has been adapted to user innovation in the household sector. User innovators are individuals in households that expect to benefit from pursuing innovations via their use of the innovations. There are almost no documented examples of public policies having been used to support or influence user innovation. Hence there are no existing policies or policy evaluations that we could review or study. If we want to discuss innovation policies to support user innovation it is, therefore, necessary to find some alternative basis upon which such a discussion can be based.

As one option, we have identified policy proposals concerning user innovation (that have not been implemented but proposed) in the relevant research literature. We have reviewed these proposals and categorized their intended impact according to which activities in our version of the systems of innovation framework they belong. In all, we included 22 studies, i.e., 4 national surveys and 18 academic papers, as relevant for our review. They are listed in appendix A with the author(s), title, a short description of the study, a list of the policy problems, policy objectives, and policy proposals mentioned in the paper. Our review of proposed user innovation policies in academic literature has resulted in four main findings.

First, the two major policy objectives for user innovation policy proposals have been to increase a society's social and economic welfare and to contribute to a society's sustainability transition.

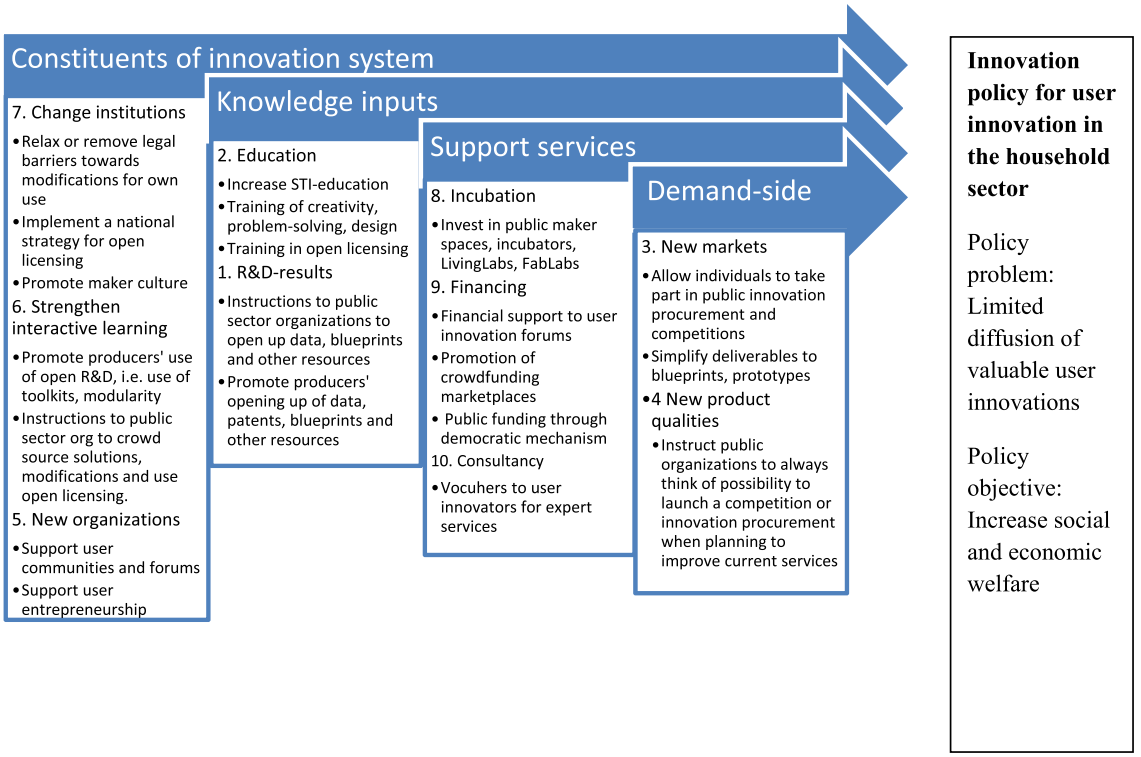

Fig. 2. A holistic user innovation policy for the household sector.

Second, two innovation policy problems dominate in the reviewed papers: (1) the limited capacity and capabilities of the user in the household sector to innovate, i.e., to *create* new products and processes, and (2) the limited *diffusion* of valuable user innovations to potential users, the latter policy problem receiving most concern in the literature.

Third, the proposed user innovation policies in the current research literature are generally partial and restricted to one or a few key activities in innovation systems.

Fourth, the character of the key activities (or determinants) related to user innovations is partly different from the activities in the general systems of innovation framework. Proposed user innovation policies have a much stronger emphasis on the institutions of the innovation system compared to a more linear view of the innovation process in the general systems of innovation framework.

The findings makes contributions towards user innovation research. We have not found any prior research focusing on user innovation policies. The papers we have reviewed discuss some policy implications related to their empirical studies of user innovation. They do so without any framework or theory of public policies. Our findings of proposed public policies to support user innovation in society, and their categorization according to a systems of innovation framework, and the tendency of them being partial and mono-causal, is therefore, a contribution to user innovation research.

Moreover, there is also a contribution towards systems of innovation research. Based on the peculiarities of user innovation, such as an emphasis on modifications of existing products or components, limited resources, competences, and networks, we modified and *adapted* the ten key activities and policy instruments to accommodate this situation. Generally, the list of adapted key activities and policy instrument is much more oriented towards supporting modifications and adaptations of already existing products, components, processes, blueprints, prototypes, and the like. Thus, our contribution echoes the suggestion by Edquist and Zabala-Iturriagagoitia (2020) to generally include demand-side actors in the innovation systems framework and specifically users as suggested by Geels (2004).

In conclusion, we will now discuss the research and policy implications of the four findings.

Most of the reviewed papers limit their policy proposals to one or a few policy activities in the innovation system. In other words, the innovation policy proposals are partial in all cases and mono-causal in most cases. There is no paper in the review that recognizes a need to design policies that address all or most of the determinants as listed in Fig. 1 (section 2) to solve a policy problem. The fact that the proposed policies in the literature are partial and most of them mono-causal is quite surprising, the reason being that innovation researchers have for quite some time held the view of innovation processes as being complex, non-linear, and multi-causally determined. Thus, future user innovation research needs to be better aligned with

current thinking and research on non-linear and multi-causal innovation processes when doing research and proposing innovation policies. This implies integrating an innovation policy framework, such as the systems of innovation framework.

In general policy proposals, and also in general policies actually implemented, the most common policy instrument addressed is related to R&D. This has been the case for decades and has been labeled "the linear view". Our finding here is that "an institutional view" is more common for user innovation policy than for innovation policy in general. This is good news as it means a step away from the linear view of innovation. However, the next step for user innovation research would be to integrate a *holistic* innovation policy framework adapted to user innovation. As we have proposed it is centered on ten key activities and policy instruments related to them (see Table 2 and Fig. 2).

The national surveys of user innovation in the household sector have empirically shown that user innovation activity is quite large (1.5%–7.3% of a country's population, see Table 1), especially regarding consumer products. Thus, it has a substantial effect on the economic and social welfare of society. The empirical evidence of user innovation activity related to sustainability transitions is weaker, but case studies in the energy sector, provide indications of high activity of incremental user innovations (modifications) to diffuse more efficient energy technologies in the households. The indicated size of user innovation activity and level of sustainability engagement from users demonstrates that user innovation in the household sector is a major source of innovation. In this way, the policies may affect economic growth, social wellbeing, and sustainability transition in a substantial way. User innovation policies can also influence which *trajectories* that innovation processes follow, including influencing them in a more sustainable *direction*. For these reasons, politicians, decision-makers in companies, and public sector organizations should care for and support user innovation in the household sector.

However, the national surveys and the academic literature revealed that some countries and sectors had a low level of user innovation activities (Table 1). While it is hard to know what level of user innovation that corresponds to an optimal performance level, it is evident that some countries, such as South Korea and Japan, have a much lower actual level of user innovation than, for instance, Sweden and the UK. The countries with low levels may wish to take public policy action to raise the level and intensity of user innovation in the household sector. The second policy problem, low levels of diffusion of valuable user innovations, seems to be more universal according to results from the national surveys. In all surveyed countries only a minor fraction of user innovations, ranging from 5% to 21.9% of all innovations, are diffused. The main diffusion mechanism is peer-to-peer interaction. This implies that diffusion, through commercial diffusion, i.e., user entrepreneurship and transfer to companies is limited. This second policy problem seems to be shared by many countries. This might call for public action as proposed by all national surveys in our review.

The practical implication for policy-makers consists of examples of suitable policy instruments for each key activity (see Table 2) and discussed the need to put an initial emphasis on changing the constituents of the innovation system followed by policy instruments related to the other key activities to effectively provide policy support to user innovation (see Fig. 2). As innovation processes are complex, interactive, and multi-causal, the systems of innovation framework imply consideration of interrelatedness between innovation policy instruments. We argue that the policy integration of user innovation in the national, regional, and/or sectoral systems of innovation will not only benefit the user innovators themselves but also producing firms as well as public organizations and governance of innovation. The reasons are that producing firms and public organizations can focus their resources on development activities that user innovators do not engage in. They can also avoid commercial failures or delays in the sustainability transition, support the diffusion of household user innovations, and thus make the overall innovation system more efficient. In addition, governance of innovation will become more distributed and practice-oriented (Schneider and Lösch, 2019) and anchored in household users' needs and problems.

However, the most important reason for future integrating policies on user innovation is the following: As far as we know, no state or public agency has managed to formulate and implement a coherent policy concerning user innovations in the household sector. This has simply not happened in practice. What has happened is that researchers have proposed partial policies. The "traditional" and still dominating view is proposals that are "linear". The alternative identified here is a partial view that is "institutional". Our perspective, our analysis, and our conclusions are highly relevant in developing a future user innovation policy that can actually be implemented. Such a policy should be holistic rather than partial, irrespective of whether it is also linear or institutional.

6. Limitations and future research

Our study has several limitations. First, while we have taken great care in identifying all national surveys and published papers on user innovation in households which entails policy proposals, we might have missed some studies. Future studies could benefit from updating our search as well as searching in other databases. Second, all of the national surveys and the published papers are based on empirical material from developed countries. All except one national survey, the survey on South Korea (Kim, 2015), is based on empirical studies in Western countries. We acknowledge the need to tailor user innovation policies to specific country contexts such as developing and Asian countries (cf. Hang and Chen, 2021) and the need for future studies on user innovation and appropriate user innovation policies in such country contexts. Third, it needs to be re-iterated that our study is based on policy proposals and not on actual policies in use. Future studies should be done on the implementation and the performance of user innovation policies to determine their effect on the national innovation activities and trajectories in different economic sectors.

Declaration of competing interest

The authors declare that there is no conflict of interest.

Appendix A. National surveys and academic papers proposing policies for user innovation in the household sector

Author	Title	Description of study	Policy problem	Policy objective	Policy instruments related to key activity – see Fig. 1
1) National surveys					
von Hippel et al. (2012) *Management Science*	Comparing Business and Household Sector Innovation in Consumer Products: Findings from a Representative Study in the UK	National survey of UK consumer innovators and comparison with innovation activity in the business sector	• Innovation statistics incomplete • Underestimation of consumer innovation as complements to firms	• Increase social welfare	• Routinely measure consumer innovation (7) • Increased investments in technical education (2) • Reduce the costs of communication among consumer innovators (6) • Incorporate data on consumer innovation in official statistics (7)
Kuusisto et al. (2013) *Research report*	Consumer Innovation in Finland	National consumer innovation survey in Finland, intensity and diffusion of consumer innovations	• A fraction of user innovations are implemented and even smaller fraction spread to other economic actors	• Increase social welfare	• Increase user innovation research (7) • Promotion of infrastructures and ecosystems, e.g., fab labs, innovation offices, and tool kits (8) • Increasing users' innovation capacity, e.g., education in STEM-sectors, modular design skills (2) • Revision of IP regimes and up-dating of IP management skills (7) • Support user innovation communities, entrepreneurship, and adoption into producer firms (5, 6)
Kim (2015) *Asian Journal of Technology Innovation*	Consumer user innovation in South Korea: An international comparison and policy implications	Study examining the extent to which individual consumers develop and share user innovations in South Korea	• South Korean consumers less active innovators relative to consumers in advanced countries. • Diffusion of valuable consumer innovations limited	• Increase social welfare • Support South Korean industry to find unmet needs and develop new products • Part of building a creative economy in South Korea	• Emphasis on creativity and problem-solving skills in education (2) • Provide platforms for user innovators to access technical experts, certification services, financial support, related firms, marketing services and entrepreneurship training (6, 10) • Support user innovation communities with user-friendly toolkits. (6) • Measure user innovation activities (7)
Bengtsson (2015) *Research report*	Consumer Innovation in Sweden	National survey of consumer innovation in Sweden and policy implications	• Diffusion of valuable consumer innovations limited	• Increase social and economic welfare	• Support measurement of user innovation (7) • Regulations neutral to innovator's background (7) • Support capacity development for consumer innovation in the school system and user groups (2) • Support infrastructure and eco-system of consumer innovation

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Author	Title	Description of study	Policy problem	Policy objective	Policy instruments related to key activity – see Fig. 1
					like Makers Spaces. Membership could qualify for government support programs (8) • A national strategy for Creative Commons licenses. Increase use of Creative Commons licenses, i.e., government agencies and public organizations (7) • Authorities and public organizations increase use of competitions and innovation procurement (3, 4)
2) Research papers with policy proposals					
Henkel and Von Hippel (2004) *The Journal of Technology Transfer*	Welfare Implications of User Innovation	The implications of adding innovation by users to existing models of social welfare that currently assume innovation by manufacturers only	• User innovations are kept private leading to duplicate work and less subsequent innovations	• Enhancing social and economic welfare • Increased ec and soc value as user innovators develop niche products • Reduction of producer firms' commercial failures • Complementarity between user innovations and producer firm innovations	• Remove legal and technical barriers for reverse-engineering products or modifications (7) • Reduce overly strong IP protection (7)
Haefliger et al., 2010 *Research policy*	Under the Radar: Industry entry by user entrepreneurs.	Study of a group of firms founded by users of video games	• Protected assets hinder user innovators and user entrepreneurs to innovate in other industries	• Enhancing social and economic welfare	• Incentivize rights holders to enter flexible and informal copyright agreements with prospective user entrepreneurs (6, 7)
Baldwin and Von Hippel (2011) *Organization Science*	Modeling a Paradigm Shift: From Producer Innovation to User and Open Collaborative Innovation	Assessment of producer innovation relative to user innovations by individuals and firms engaging in open innovation	• The assumption that producer innovation needs IPR for tech and ec progress is too stark. • Non-level playing field between closed and open innovation	• Increase personal freedom • Increase social welfare	• Expansion of "fair use" rights and safe to freely use and reveal innovation-related information (6, 7)
Gault (2012) *Science and Public Policy*	User innovation and the market	Inclusion of user innovation in official statistics	• Consumer innovation not defined as user innovation by official innovation statistics	• Contribute to a culture of innovation • Economic growth	• Change the Oslo manual to allow for measurement of user innovation by consumers (7) • Consumer innovation should be recognized by competitions, prizes or in other forms (7) • Support for open licensing structures (7)
Hyysalo et al. (2013a) *Energy Policy*	User innovation in sustainable home energy technologies.	Study of 192 user inventions or modifications in heat pumps and wood pellet burning systems in Finland	• Users provide important modifications in the market creation for renewable heating technologies	• Climate change mitigation • Speed up the development and proliferation of distributed renewable energy technologies	• Support for modularity and adaptability that users might utilize in order to modify and adapt to their own needs (1, 6) • Support for users forums to diffuse and create new markets for renewable technologies (5)
			• User innovators lead to behavioural change	• Citizens as active players in the	• Financial support to facilitating online

(*continued*)

Author	Title	Description of study	Policy problem	Policy objective	Policy instruments related to key activity – see Fig. 1
Hyysalo et al. (2013b) *Science & Technology Studies*	Internet forums and the rise of the inventive energy user	Study of online forums for modifiers of heat pumps in Finland	among energy consumers	realization of energy and climate policy	forums in energy and climate sector (9)
Nielsen et al. (2016) *Journal of cleaner production*	Sustainable user innovation from a policy perspective: a systematic literature review	Literature review of end-users role in the development of sustainable products	• End users lack skills and resources to contribute to sustainability transformation • End users lack networks and access to resources interact around sustainability solutions	• Involving end users in sustainability transformation • Speeding up sustainability transformation	• Policies aimed at enabling sustainable end-user innovators with skills and resources: o Formal education such as in organic farming (2) o Support of intermediaries such as online forums, co-operatives, e.g., micro-grants (5, 9) o Open data public authorities, e-g., transport sector (1) • Policies aimed at facilitating sustainable end-user innovators bridging gaps o Open source platforms making product designs or blueprints available for modifications (1) o Awards and competitions to crowdsource solutions (3, 4) o Producers providing sustainability-oriented toolkits (1, 6) o Sustainable Living-Labs involving end-users (8)
Warnke and Schirrmeister (2016) *Futures*	Small seeds for grand challenges—Exploring disregarded seeds of change in a foresight process for RTI policy	Study of a new workshops with lead users, demand pioneers related to research, techn and innovation foresight practices	• End users not involved in RTI policy foresight processes	• Making policy priorities in investments Research, Technology, and Innovation	• Support demand-led research, technology, and innovation policy by organizing workshops for demand pioneers, lead users to integrate their opinions into the RTI policy process (1, 6)
Gambardella et al. (2016) *Management Science*	The User Innovation Paradigm: Impacts on Markets and Welfare	A model of demand-side innovation explaining the conditions under which firms find it beneficial to support and harvest user innovations	• Producers tend to switch to user-augmented innovation strategies too late	• Increasing social and economic welfare	• Encourage producers to utilize specialization and complementarity with innovating users (6) • Incentives for corporate R&D to be more open to innovating users (6) • Reduce producers' switching costs to complementing user innovation (6) • Increase the share of innovating users: education, access to cheap design creation, sharing technologies, and promotion of a "maker culture" (1, 2, 6, 7) • Improving user capabilities: access to innovation design and self-production technologies (1, 6)

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Author	Title	Description of study	Policy problem	Policy objective	Policy instruments related to key activity – see Fig. 1
Leiva et al. (2016) *Renewable and Sustainable Energy Reviews*	Smart metering trends, implications, and necessities: A policy review	Trends in the energy sector that smart metering infrastructure creates and implications for prosumer innovations	• Lack of appropriate regulations for smart metering hindering end users innovation activities • Lack of smart grid and meter operator competence	• Increase energy efficiency	• Meters integrated into a smart metering infrastructure, e.g., for prosuming households, to allow for new products and services (6) • Scrap concept of supply point for households, replace with "energy spot" for production and consumption services (7)
Heldeweg (2017) *Journal of Cleaner Production*	Legal regimes for experimenting with cleaner production – Especially in sustainable energy	Legal designs that accommodate legally disruptive experiments towards enhanced sustainability with a smart energy system	• Laws hindering, not allowing and not enabling innovators, experimentation for uptake of new technologies	• Enhanced sustainability	• Two legal frameworks that may be used for disruptive experiments, e.g., for prosumers of energy, exceptional derogation and experimentation by devolution (6,7)
Jalas et al. (2017) *Journal of cleaner production*	Everyday experimentation in energy transition: A practice-theoretical view	Practice theory frames sustainability transitions as distributed experimentation of active citizens	• Lack of broad consensus and legitimacy for sustainability transition • Broad social change discredited as policy instrument	• Involving local actors in sustainable practices • Speed up sustainability transition	• Reframing energy and climate policy as partly engaging and involving local actors in the sustainability transition through everyday experimentation (6) • Support peer-to-peer learning networks (6)
Halbinger (2018) *Research Policy*	The role of makerspaces in supporting consumer innovation and diffusion: an empirical analysis	Survey of 558 makerspace participants worldwide. Innovation and diffusion rate higher than in consumer innovation surveys	• Under-diffusion of consumer innovations	• Increase social welfare	• Public investment in makerspaces to increase consumer innovation rate and diffusion rate (8)
Brown et al. (2019) *Energy Policy*	Prosumers in the post subsidy era: an exploration of new prosumer business models in the UK	The diffusion of smart meters, li-ion batteries, peer-to-peer trading platforms and electric vehicles are opening up a range of new business models	• Existing energy markets and regulatory frameworks in most countries are not aligned with prosumers, i.e., actors that both produce and consume energy	• Sustainable energy transition	• Ensure interoperability of smart meters with prosumer activities (6) • Supplier hub needs to be replaced so they are compatible with P2P-models (7)
Ahl et al. (2019) *Renewable and Sustainable Energy Reviews*	Review of blockchain-based distributed energy: implications for institutional development	Peer-to-peer (P2P) micro-grids and blockchains can support renewable energy consumers and prosumers	• Distributed and intermittent renewable energy sources demand new technologies to ensure expansion	• Contribute to environmental sustainability and socioeconomic growth	• Support community-building of P2P -microgrids of prosumers (5) • Use regulatory sandboxes to support institutional development supporting P2P-microgrids (7)
Gault (2019) *Foresight and STI Governance*	User innovation in the digital economy	The impact of digitalization on user innovation	• Presence in official statistics necessary for innovation policy • New skills needed for user innovators due to rapidly developing digital economy	• Latest version of innovation definition in Oslo Manual now includes user innovations in all economic sectors • Investment in grassroots innovation culture	• Educating people to function in a digital world (2), provision of maker spaces with tools, databases, expert advice (8, 10) • Improving the skill sets of users collaborating with business (2)
Brem et al. (2019) *Technological Forecasting & Social Change*	How crowdfunding platforms change the nature of user innovation – from problem-solving to user entrepreneurship	User innovators utilization of crowdfunding to obtain funding for innovation activities and start firms	• Limited diffusion of user innovations due to lack of financing and other entrepreneurial capabilities and resources	• Support user entrepreneurship	• Crowdfunding marketplaces for user innovators to support user entrepreneurship (5, 9) • Public innovation funding distributed using a "democratic" crowdfunding mechanism (9)

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