Householders as co-producers: lessons learned from Trondheim's Living Lab

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Abstract

As energy systems shift from central to distributed production and a combination of these, the lines between the traditional 'supply side' and 'demand side' become increasingly blurred. Passive consumers are expected to become active, providing flexibility to the system, and eventually morphing into 'prosumers', producing and consuming energy. The use and practices related to new solutions and technologies are often taken for granted, and there is a remarkable lack of studies on how implicated publics make sense of their role in this transition. In this paper, we seek to draw lessons from the way in which users have been engaged with a zero emission building. The paper presents results from experiments conducted in the Trondheim Living Lab, which explores the relation between radical technological change, domestic life and energy use. The Trondheim Living Lab is a newly built, 100 m^2, detached single family home that is planned to reach a zero emission balance. The qualitative experiments, conducted in the laboratory between October 2015 and April 2016 involves six groups of residents, each living in the house for 25 days. The empirical material consists of interviews, direct observation, diary records, photography and self-filming, as well as detailed quantitative records of energy consumption and indoor climate. The Trondheim Living Lab offers a unique opportunity to better understand the way in which stakeholder engagement and co-production has been attempted through two avenues: the living lab, and prosumption. This paper reviews these two concepts, and provides lessons learned about how co-production and engagement successfully can be achieved.

Introduction

In recent years there has been an increasing trend to attempt to engage users, consumers, citizens or the public by government, industry and research communities. Examples entail calls to employ 'citizen-centric' approaches or to 'engage' the public (e.g. European Commission 2014; Karvonen & van Heur 2014). Such efforts are welcome, but they are not straightforward. Public engagement is more difficult in practice than in theory because different actors aim to reach goals that could serve their own interests more than other (e.g. Devine-Wright 2011; Barnett et al. 2012; Tan 2012). Therefore, there is a need to critically examine the use of concepts that claim to engage users and to co-produce achievements. In order to gain a better understanding of engagement and co-production, this paper studies the use of two concepts in a real-world context. These are the 'living lab'; an arena thought to act as an intermediary between producers and users in cities, and the energy 'prosumer'; the idea that people will act as both producers and consumers of energy.

Both concepts entail an expectation that users will engage with a technology, and that this engagement is part of a process of co-production; that different stakeholders can come together to understand each other's contexts and jointly produce outcomes. Thus, the questions posed in this paper are; what types of user engagement with have we seen in the Trondheim Living Lab[1], and in which ways have outcomes been co-produced? In other words, the main point of this paper is to discuss user engagement in order to understand better how co-production has been enacted in a real-life context; the Trondheim Living Lab. Such enhanced understanding is necessary if we want to guarantee that transitions to sustainable societies have broad support and that transitions are anchored in and influenced by public concerns. Trondheim Living Lab is a 100 m^2 detached single-family building that is planned to reach a balance of zero greenhouse gas emissions over the course of a projected lifetime of 60 years. This living lab is a physical building, although living labs can also be a carried out in a larger geographical area or as a singular event such as a festival. This paper takes the point of departure that prosumers and living labs are experimental concepts yet to be filled with meaning.

The paper proceeds as follows; the next section further delineates the concepts of prosumption and living labs and underlines their focus on co-production. The methodology for this paper is then outlined. After that, 'prosumption' and 'living lab' are discussed and analysed in the context of the Trondheim Living Lab. The last section concludes and reflects on the usefulness of the two concepts in the Trondheim case, and beyond.

Prosumers, living labs and co-production

ENERGY PROSUMERS

Prosumption combines the two words production and consumption, and was introduced by futurist Alvin Toffler in his book the Third Wave in 1980. Toffler held that in the 'third wave' the line between producer and consumer will be progressively blurred because of a return to production for own use (similar to the 'first wave', agrarian society, when people were producing for their own use), and away from production for exchange (as during the 'second wave', the industrial society where production and consumption were separated). As he formulates it (Toffler, 1980, p. 275):

> whether we look at self-help movements, do-it-yourself trends, or new production technologies, we find the same shift toward a much closer involvement of the consumer in production. In such a world, conventional distinctions between producer and consumer vanish.

Today, the concept is still used to denote the changes in the way transactions used to be performed with a clear producer, e.g. of furniture, and a clear buyer. A do-it-yourself activity such as building your own couch from IKEA, for example, can be considered a prosumer activity (Ritzer 2014). With the increasing use of Information and Communication Technology (ICT), we have seen a revolution in user-generated content on the Internet, often referred to as the Web 2.0, where YouTube, Twitter and Facebook include many examples (Ritzer and Jurgenson 2010). In this respect, as production becomes increasingly decentralised, it entails greater activity and responsibility on the part of the consumer or user. In other words, prosumption implies a more active and engaged user. Moreover, the concept questions the artificial division between production and consumption, and invites a focus on the difference between use value (e.g. what the energy is used for) and of exchange value (e.g. money) (Humphrey and Grayson 2008).

In the energy domain, the concept of prosumer has revived lately due to an increase in microgeneration technologies of renewable energy combined with an increasing use of smart technologies (e.g. Juntunen 2014). Ellsworth-Krebs and Reid (2016) bring the literature on prosumption into the energy context, and show how the concept is useful in understanding households and communities that generate and use their own heat and/or electricity. Ellsworth-Krebs and Reid (2016) find that the energy prosumption literature tends to be limited mainly to solar PV electricity generation, which is unfortunate, as a large amount of literature exists on everyday life and heating technologies that can expand our understanding of what prosumption is, and how it affects energy demand (e.g. Winther and Wilhite 2015; Gram-Hanssen et al 2016; Rinkinen and Jalas 2016). Thus, dividing between heating and electricity prosumption opens up avenues for asking questions about the way in which experiences and motivations vary along with the diversity of microgeneration technologies (e.g. wood firing, solar hot water, ground source heat pumps and wind power, in addition to PV panels).

Another focus within prosumer research is the emphasis on co-creation (e.g. Ritzer 2014), co-production (Olkkonen et al. 2016), or co-provision (Ellsworth-Krebs and Reid 2016). These notions emphasise that the household is not the only producer – there is also an existing energy provision network out there, which used to be the only producer. Olkkonen et al. (2016) point out that energy companies should update their business models to 'embrace prosumer relations and community involvement', since prosumers are new stakeholders who can change and potentially disrupt the way in which energy traditionally has been sold and used. Thus, the concept of prosumer is useful because it not only denotes changes in the household, but also in the traditional way that electricity has been generated. In other words, electricity prosumption has been accompanied by increased decentralization that would challenge established networks. Note, however, that these processes would be different for heat prosumption, since technologies for central and local heating are very diverse depending on the country (they can be wood firing, gas/oil heating, or various types of electrified heating systems).

In the case of the Trondheim Living Lab, we should look for two main things; 1) to what extent are energy (heat and power) microgenerating entities impacting the everyday life of users, and 2) to what extent is microgeneration impacting established production systems?

LIVING LABS

Curtis (2015: II) defines living labs as a

> … user-centred, open innovation ecosystem that seeks to engage academia, industry and municipalities along with the community in the processes of co-creation and co-generation of products, processes or services in a real-world context.

Living labs can be physical entities, such as a building or a neighbourhood, they can exist in parts of or in a whole city; they can be virtual; they can happen over a limited span of

1. Throughout the paper 'Living Lab' refers to the Trondheim Living Lab, and 'living lab' refers to the concept.

time such as in a festival; or they can be an arena; an approach to innovation; a process or a user-centered method in 'real-life' contexts (Curtis 2015). The labs have amongst other things been called urban living labs, urban labs, or urban sustainability transition labs, and there are no common understandings of what they are supposed to do (Curtis 2015). Although 'user' and 'citizen' is used interchangeably, all living lab projects appear to have in common that they introduce the user/citizen as the key stakeholder in the experimentation process (Schliwa and McCormick 2016). This is typically justified under the heading of 'co-production' or 'co-creation', meaning that various stakeholders can come together to understand each other's contexts. In this way, stakeholders can 'work together to frame research that delivers more effective solutions' (Evans et al. 2015: 1). This synthesis of knowledge and joint understanding within an experimental context is thought to pave the way for innovations. According to Evans et al. (2015), co-production can be framed in two ways; one is to consult users and stakeholders so that sets of complementary projects could be planned and ultimately end up offering holistic solutions, and second is that the experimental focus allows for gradual learning year by year, which over time can provide a coherent basis for action.

A literature review by Voytenko et al. (2016) identifies five key characteristics of living labs that address sustainability challenges and opportunities created by urbanisation. These are 'geographical embeddedness', 'experimentation and learning', 'leadership and ownership', 'evaluation and refinement' and 'participation and user involvement'. 'Geographical embeddedness' means that living labs typically are placed in a geographical area with a clearly defined purpose in that context. 'Experimentation and learning' means that living labs are often used in a concrete experiment with the aim of testing a particular technology, solution, idea or policy in a real world condition, where the aim is to induce social and/or technical change. The success of living labs in terms of sustainability and low carbon transition depends on good 'leadership and ownership', and the success of a particular living lab is determined through proper 'evaluation and refinement'.

With respect to the fifth point, 'participation and user involvement', Voytenko et al (2016) point out that a living lab should not end up being merely a demonstration project, in which users have no say whatsoever, but should engage 'local population and context'. Voytenko et al (2016: 50) warn that

> … an important practical challenge for many [living lab] projects lies in how to achieve the inclusion of all key relevant stakeholders (both active and passive), account for their interests and thus re-politicise this new form of urban governance that corporate-led partnerships and scientific modes of governance might threaten.

However, Voytenko et al (2016) do not give any advice on how to best include and engage users. Therefore, in the Trondheim Living Lab context, it is interesting to see how the lab is performing in view of these five key characteristics and, more importantly, to draw some conclusions from the way in which users were or were not engaged.

To summarise: co-production is already assumed in the prosumption case since consumers produce their own energy, whilst the concept of a living lab wants to use co-production as a way to innovate and improve technologies. In both cases, engagement of users is a means to achieve these goals.

Methodology

The Trondheim Living Lab is a 100 m^2 zero-emission building completed in 2015 and located on the outskirts of the main campus of NTNU, Gløshaugen. The building has been the home for six groups, each group living there for a 25-day period. The house is built with an aim to reach zero-emission over a 60 year period. This can be achieved by minimizing energy demand for the operation of the house, and harvesting solar energy so that production is larger than demand on a yearly basis (Goia et al 2015). Some of the technologies included in the house are 40 cm thick walls filled with rock wool insulation, a ground source heat pump, a balanced mechanical ventilation, LED lighting, a large south-facing double skin window, solar thermal panels, roof-integrated PV, and a complete set of the most energy-efficient household appliances, such as dishwasher, oven and washing machine. See Figure 1. For a complete description of all the included technologies, see Goia et al (2015) and Finocchiaro et al (2014).

The research design is similar to a 'quasi-experiment' as defined by Moses & Knutsen (2007, p. 62) where a group is se-

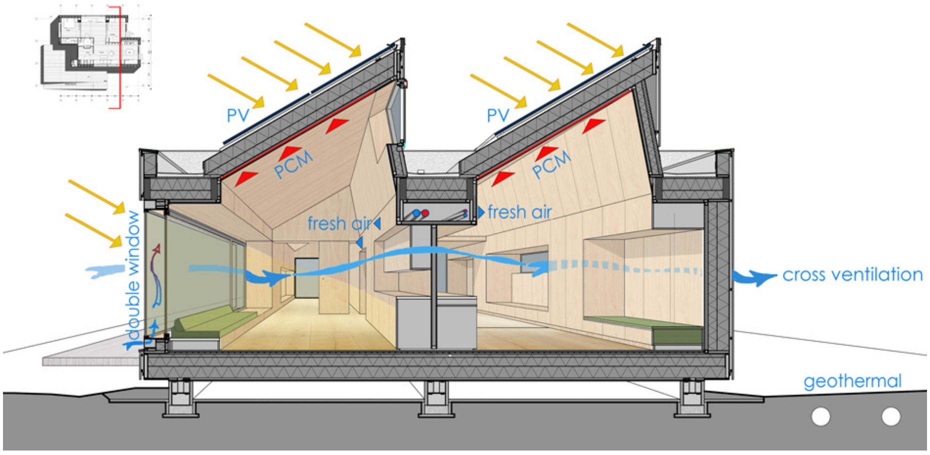

Figure 1. Cross section of the Trondheim Living Lab. Source: Finocchiaro et al. (2014).

lected based on some criteria and tested after a 'treatment' has taken place. In this case, the 'treatment' would be living in the lab for 25 days. Each group was asked to make the Living Lab their home, trying to use it as they would normally use their own houses. The two groups in each category 'student', 'family' and 'elderly' were selected based on availability in each segment, and the degree of similarity between the two groups in terms of age and number of children (for the families). The categories were decided beforehand based on who were thought to be relevant; students were relevant because they are a target group for these technologies in the future, families because they are the largest group of residents in detached houses in Norway, and elderly because the Norwegian population is aging and these houses will be for the future generation. The research design can be considered a variant of a 'qualitative experiment', since it contains elements of experimental design fused with qualitative strategies (Robinson and Mendelson 2012).

The data in this paper has been collected using a mixed-methods approach in which mostly qualitative data is complemented by measurements of energy and indoor climate logged every 30 second during the whole 25-day period. The qualitative data has been collected based on a mixture of interviews, participant observation, diary records, a 'notebook for guests', and a camera which participants could use for self-filming. Three groups of stakeholders were interviewed; five interviews with a total of seven people were made with the electricians, carpenters, engineers and architect who built and planned the lab. 18 interviews with the occupants were carried out before, during and after their stay. The interview during the stay was conducted after around 16–18 days of residence for each group, and the after-interview was conducted around 25 days after the stay. In the interview after the stay, data of energy use and indoor climate were shown to the occupants, and perceived versus actual use discussed. This was done by first asking the occupants which devices they thought used the most energy, before showing the actual results. Lastly, two telephone interviews were carried out with NTNU electricity grid managers, to understand the effects of Living Lab power production on the grid. This makes a total of 25 semi-interviews (Kvale 1996), see Table 1.

Occupants kept daily diaries in an effort to get an overview of the routines in the house regarding when the house was in use, and what type of activities were undertaken, such as cooking, cleaning, visits, dinners and so on. These diaries also had a section where the participants could write their thoughts, reflections and experiences with the Living Lab during their stay. After the residential experiments were finished, a focus group meeting was conducted with participants from all the groups where experiences were exchanged, compared and contrasted. In order to make the experience as realistic as possible and to preserve the privacy of the occupants we had a 'no-media' policy during the living experiment. A weakness as concerning results in terms of total energy consumption is that participants in the living experiment did not have to pay for the energy used in the project. This is not seen as a problem for this particular study, as we are not comparing energy end use as part of our findings.

Trondheim Living Lab and prosumption

THE HOUSEHOLD PERSPECTIVE

Electricity

The Living Lab has 48 PV modules installed on the two roof slopes of the building, with a total installed power of 12,5 kWp. Total annual production was approximately 9,000 kWh in 2016, representing a negligible amount compared to the total NTNU

Table 1. Overview of interviews.

Type of interview	Number of people	Number of interviews
Craftsmen, engineers and architect	7	5
Occupants: before, during and after stay (children not part of interviews)	12	18
NTNU power grid managers	2	2
Total	21	25

Table 2. Overview of the groups.

Group #	1	2	3	4	5	6
Category	Student	Student	Family with children	Elderly	Family with children	Elderly
Details	Male and female couple, 22 years old. Live in a 52 m² student apartment, built in 1964.	Two female friends, 20 and 21 years old. Live in a shared apartment together with three other roommates, built in 1905.	Mother 31 years old and father 36. Son 6 years old and daughter 2. Live in an attached house of 185 m², built in 2007.	Husband 81 and wife 68. Live in a detached house of 170 m², built in 1980.	Mother 31 years old and father 37. Two daughters of 3 and 2 years old. Live in a detached house of 135 m² plus 70 m² garage, built in 1987.	Husband 61 and wife 56. Live in a semi-detached house of about 120 m², built in 1959.

Trondheim annual consumption of 90,000,000 kWh. The occupants of the lab had a display, as Figure 2 shows, with the options to set the temperature in each room, and with display of the average indoor temperature, CO_2 level, humidity, pressure and electricity usage. The electricity usage display would show a negative figure if the building was producing more power than it used.

When occupants were asked about the solar PV production and about the display, they generally thought it was interesting to see when they were producing, but it did not affect the way they would use technologies or perform their everyday practices to any extent. The answer was largely that 'we don't do anything very differently here to our home'. Some of the groups felt that they were using more electricity there than at home. Particularly the student groups said that since they did not have to pay for the electricity, they were not as careful about turning off the lights and so on.

When asked if there were things they thought could be improved, group 5 mentioned that they would have liked to get more information about the different technologies in the house. The husband said that he wanted to know more about:

> … the solar collectors and the solar PV system: what happens in these processes right now? Are we using or producing power? I would have liked to have the opportunity to control the different technologies on my phone, so I could read the production and pay attention. The display here is useful, though, because at home I would have to run down to the basement, and that is not so much fun … (Husband, group 5)

In other words, some occupants did not think that they had been included enough with the way that the electricity generation system was working. They did think the display that was there was useful, because it was more conveniently placed. Nevertheless, most groups thought that they had been given enough information about the system, and were not particularly interested in learning more about the solar power production. Indeed, when asked about environment and climate concerns, most groups mentioned that they were recycling, but few comments were connected to the way in which they were using electricity. This suggests that the Living Lab could have engaged the occupants more effectively if more information about the electricity production system and the current PV power production had been given to them.

Heating

Staying warm at home was a 'hot topic' for all the occupants of the Living Lab. In contrast to electricity production, where the occupants have little influence over production at home but wanted more insight in Living Lab, several of the groups had a more active heating system at home (firewood or electric radiators), and experienced a more passive system in Living Lab. The six groups had different set-ups for staying warm in their original homes: Two of the groups had electric heating, one group had district heating and three groups had air to air heat pumps in addition to firewood ovens. Within Living Lab, the main heat source came from underfloor heating. The underfloor heating circulated hot water that had been heated either by a ground-source heat pump, or by two façade-integrated solar thermal panels. Other heat sources were the heated air through the ventilation system, and heat from the south-facing window.

One student group reported that it was warmer for them in the lab than at their home. One reason for this was that it did not cost them anything to keep it warmer in the lab, but the extra effort it took to change the heat in the lab was also a contributing factor; they had to use a monitor located in the entry hall to regulate the temperature in each room.

> There are no ovens here that you can adjust the temperature on when it gets warm. We cannot regulate anything on the radiator here, and we have to go out in the hall and that's an effort. We just put it on an average temperature that we are happy with. (Student, group 1)

For the other student group, the stable temperature in the lab became visible only after they had returned back to their original home. In the interview after the stay, they reported that in their apartment:

> … there is a draught from the windows and the floor is cold. We have to close all the doors between rooms because there is a temperature difference. But there [in Living Lab] the temperature was the same everywhere so we did not have to be concerned about that. I didn't even have to wear socks! (Student, group 2)

Figure 2. The Living Lab display.

Without thinking about it until after the stay, they automatically accepted the temperature control system in the lab. This means that the stable and warm temperatures of Living Lab were 'invisible' because they were comfortable, and thus only became visible after the 25-day Living Lab period had finished. Therefore, the knowledge these students had of active temperature regulation at home was replaced with a passive regulation in the Living Lab.

For the elderly couples the stable temperatures and the difference between active and passive regulation was also prominent. For them, the difference was that they could not use firewood for quick heat increases, as they would normally do at home. Group 6 explained that they would keep the regular indoor temperature around 20 degrees or lower, and typically heat with firewood as they got home in the afternoon. As the husband explained:

> I like to light the fire when I come home and feel half-frozen. I think the heat from the firewood oven is warm and nice. (Husband, group 6)

Moreover, for the two men in the elderly groups, heating with the wood oven was not only something they did to stay warm but rather something they also loved doing either as a hobby including collecting firewood, or just for fun. The husband in group 6 jokingly said that he 'has so much firewood he needed to "get rid of"'. In his free time, he would spend hours in the forest collecting firewood with all the equipment of a professional lumberjack: chain saws, protective gear, tractor and hanger. Therefore, an important element of his leisure time was missing in the Living lab.

The wife in group 4 explained that heating the house took a long time:

> … cooling and heating takes a long time here. At home, we can use the heat pump, electricity and the firewood oven. You can heat yourself out of the house if you like, and my husband would not hesitate to do that. (Wife, group 4)

Similarly, group 4 wrote in their diary: 'we can adjust the temperature up and down. But I wonder; what is the real temperature here? How quickly can we notice the change?' In other words, the time it took to get warm was important to their comfort, and the quick temperature increase from a wood heating was lacking. Group 6 found a work-around for this problem: They set the temperatures a bit warmer than they usually would keep it, and then cooled the house quickly by opening the roof windows when needed. Nevertheless, since there was no wood oven in the Living Lab, the two elderly groups felt that the cosy time around the fireplace was lacking, that their skills of wood collecting and heating were useless, and their habit of rapid heating made the stable temperatures of the Living Lab feel strange. Thus, the active microgeneration technologies that these groups had at home were starkly missed when they lived in the lab with a more passive heating system.

THE SYSTEM PERSPECTIVE

As outlined above, prosumption also implies understanding how the established production system is affected by the microgeneration technology in question. Since heating systems in the house were electrified (a ground source heat-pump and a boiler), electricity is the relevant provision network to study. For this reason, the NTNU electricity grid operators were contacted to understand their perspective. The NTNU electricity grid has a license to be operated by NTNU, and is therefore independent from the operation of the rest of the Trondheim grid, although the grids naturally are connected. The Living Lab was therefore an interesting small-scale case to see the effects on a limited area of microgeneration. Apart from Living Lab, there is only one small building that produced solar power, the rest of the power is generated outside of the NTNU grid. The effects from the Living Lab production appeared to result in no changes at all in the operation of the NTNU grid. The power that was delivered from Living Lab was consumed immediately, and with no visual effects on operation, as mid-day (when the sun was shining) electricity consumption typically was high.

The NTNU grid managers were not used to the idea that a building could produce more energy than it consumes. This was exemplified by one of the operators. He explained that as they were inspecting the connection point showing total production versus consumption of Living Lab electricity, they were surprised to find a negative value; i.e. the NTNU grid had received more power than delivered to the building. Since this figure normally would be a positive number, they at first thought the measurement equipment was faulty. In other words, should there be an increase in prosumption activities at NTNU, grid-management routines may be impacted, and might require more active management of surplus energy. This would suggest that grid operators become more engaged with prosumption activities in the future. The operators generally were excited about the increase in buildings with their own generation capacity at the NTNU campus planned in the near future. Therefore, although new and unfamiliar, the change was not something that was unwanted from their point of view.

Trondheim Living Lab and user engagement

The main point of consideration here is to look more closely at the various ways in which stakeholders of the Trondheim Living Lab have become engaged with the project and have been catalysts for co-production. This paper has been informed by three types of stakeholders: 1) the craftsmen, engineers and the architect behind the building, 2) the occupants during the qualitative experiment, and 3) the operators of the NTNU grid. Of relevance here are mainly 1) and 2), as the grid operators did not have any further experience with the Living Lab project apart from attaching a cable to the building. Table 3 summarises the general performance of the Trondheim Living Lab, according to the key characteristics outlined by Voytenko et al. (2016).

As the main point of this paper is to discuss user engagement, the last point 'participation and user involvement' is now assessed more closely. To start with the craftsmen, engineers and the architect, the general feedback from them was that constructing the Living Lab had been a major learning experience with a 'steep learning curve'. What was new for the craftsmen, however, was not necessarily the techniques used for construction, but rather to take part in a research project with several involved partners and stakeholders—something that from their perspective increased the construction time considerably.

Table 3. Performance of the Trondheim Living Lab.

Key characteristic as defined above	Trondheim Living Lab
Geographical embeddedness	The Trondheim living lab has a clearly defined area, located at the university campus. For technology demonstration and testing purposes the location is good, but not ideal for living purposes as it was close to an intersection and near large amounts of students passing by at all hours of the day.
Experimentation and learning	The building is designed to perform as a zero emission building, and attempts to test the integration of new energy saving and producing technologies. All involved disciplines have reported a steep learning curve.
Leadership and ownership	The project was led and owned by SINTEF and NTNU, and appeared to function well.
Evaluation and refinement	No evaluation has been conducted hitherto, apart from technical experiments and adjustments made accordingly. This paper can be considered a part of the evaluation of the living lab, but no formal, overarching evaluation of the lab has been conducted or is planned.
Participation and user involvement	Interviews have been held with the involved engineers, craftspeople and architect. A user experiment has been conducted, and six groups have lived inside the building. Several comments about the functionality and performance of the house have been reported by occupants, but no action has been undertaken in terms of improvement potential. See discussion.

Some of the involved engineers and craftsmen were concerned about the economic viability of the project. As one put it:

> It will be extremely expensive. If this building can save all the resources it has spent is difficult to say. If everyone would produce their own electricity, then no one would need electricity! I imagine that somewhere in the system this is not good. It's the same as if everyone would have an electric vehicle right now, it would not be so… (Engineer)

A concern about prices was also echoed with the carpenter that was interviewed:

> It is an advantage that the building is good for the climate, but I think more about the customers and the population regarding prices: it might get too expensive for them. This is my job, so if I build a plus house or a passive house is the same, but perhaps this type of solution is more suitable for large buildings that actually use more energy. (Carpenter)

In other words, if future zero emission buildings get too expensive, the craftsmen and engineers were concerned that there would be less to build in the future, and consequently less work for them. This concern can be translated as a somewhat sceptical or critical perception of the project, and thus a somewhat weak engagement from their side.

The occupants that took part in the living experiment mentioned different and rather unexpected effects from living in the lab. For instance, one of the student groups that lived in the house decided to try out vegetarianism during the same period. Another curiosity that applied to all the occupants occurred as they returned home to their original homes: most groups felt they had too many things, and some decided to get rid of things or to take down wall-decoration and so on. One of the elderly couples said in the interview after the stay: 'After I came home it felt so messy here. I could manage with a third of all the things I have here'. Lastly, one of the elderly groups that lived in the house enjoyed the household appliances that were used in the lab so much that they decided to acquire the exact same models for their home. We may therefore say that the Living Lab experiment in itself engaged the occupants, but in somewhat unexpected ways. The expectation was mainly to understand how the various aspects of the zero emission building was negotiated, yet one of the effects of staying there was that people started reflecting on their environmental practice in their original homes.

Another arena in which the living lab appeared to engage people was through the media. There was a large interest in the project, and more than 150 groups of people applied to take part in the user experiment. Moreover, during and after the living experiment, several journalists contacted the researchers and wanted to write stories on the project. As we had a no-media policy during the living experiment there was no media coverage about the occupants' experiences, but several with project managers and researchers at SINTEF (a large, independent research organisation involved in the project) and NTNU. The online media search tool Retriever shows a total of 38 media articles online and in physical papers and magazines, and this does not include the contributions on television and radio. The interest was large in Trondheim, and many people had heard about the 'futuristic house' at the NTNU campus. This outreach definitely engaged the public, and the experimental and demonstration focus of the Trondheim Living Lab was a contributing factor.

In other words, as the building was designed for demonstration purposes as well as for living experiments, the house was both a 'show room' and a 'living room'. This led to a design that was somewhat new and foreign to the occupants, but which may have led to an increased interest by the media and research communities inside and outside of Norway. The 'demonstration' purpose may, indeed, have led to larger public engagement than the residential experiment. Thus, we can make a distinction in terms of engagement; engagement on the one hand can be about 'enticing' or 'enrolling' the public—i.e. a more quantitative engagement, and on the other hand about 'critiquing', 'testing' and 'learning' a proposed idea. When users actually lived in the house and offered constructive feedback, the engagement was more qualitative—and time will tell if this latter engagement and feedback will be implemented in the next round of experiments.

Conclusions

The future energy consumer is likely to take on new and more active roles than the present one. As this paper has pointed out, such a development is amongst other things manifested in the terms 'prosumer' and 'living lab', and they both assume that users will be active in the process of energy production and use in one way or another. The aim of this paper has been to understand how co-production has been enacted in a real-life context; the Trondheim Living Lab.

Looking at prosumption in the Living Lab, this paper found that heating routines changed considerably for several of the groups that lived in the lab, whilst electricity usage did not see any large changes, although several groups reported that they used more electricity when in the lab. The reason for the latter result can be explained by the fact that participants in the living experiment did not have to pay for the electricity used in the project. Moreover, the occupants did not have a personal attachment to the microgeneration technologies chosen in the Trondheim Living Lab. In other words, if users had been involved in the selection and purchase phase, they might have experienced a more personal attachment, and paid closer attention to the performance of the PV system. This is therefore a considerable limitation in how the Living Lab project engaged users.

The paper also found that heating and electricity prosumption experiences differed considerably: whilst some groups were used to more active heating management at home (firewood and electric radiators) and came to a more passive system in the Living Lab, for electricity consumption the groups came from a passive system, but wanted more involvement with the Living Lab system. This suggests that attempts to engage and co-produce should not be generalised, but must look at each energy source in question in order to devise relevant inclusion mechanisms and feedback.

The paper also studied the wider system effects, and there were indications that local grid managers saw the PV power production from the Living Lab as interesting but still negligible in terms of total electricity needs. The NTNU grid managers were somewhat bewildered by the Living Lab, since they were not used to buildings producing their own energy. This bewilderment can in itself be considered a form of engagement, as it made them reflect over new and different ways of organising electricity production and consumption.

This paper found that the Trondheim Living Lab still had some work to complete in order to achieve co-production. At the level of the occupants, co-production happened differently in the 'living lab' and 'prosumer' cases: in the case of 'prosumption' there is an expectation that users are 'automatically' co-producers whilst in reality they are not included in the way electricity and heating is performed; i.e they are 'passivised'. In the case of the 'living lab' there have been high expectations that occupants will be engaged and can co-produce at some stage, but there appears to have been few instances where feedback from the occupants has been or will be taken into consideration. In other words, providers appear to be arrogant or ignorant of how much users could or should be included. For future living lab projects, a recommendation would be to involve stakeholders at an earlier stage and in different ways: different types of user groups can be included, consulted, interviewed or surveyed in order to ensure an outcome that is better grounded in the public in question.

As this paper has shown, in the Trondheim Living Lab, co-production appears to have been achieved through avenues other than at the occupant level. Stakeholders were engaged through three identified avenues: 1) through the involvement of and interaction between craftsmen, engineers, project managers, researchers and architects, 2) through the living experiment itself and the attention it got in the media, and 3) through research and publications connected to the living experiments. These conclusions imply that a distinction in public engagement work can be made; engagement on one hand can be about 'enticing' or 'enrolling' the public—i.e. a more quantitative engagement, and on the other hand about 'critiquing', 'testing' and 'learning' a proposed idea—i.e. a more qualitative engagement.

It should be an aim for future policy development and research about smart sustainable cities and neighbourhoods to embed both types of engagement in order to ensure that proposed solutions are solidly anchored in actual experiences of representatives of the public. This means that if future projects want to include notions about user or citizen engagement, they must do more than putting words on paper. There should be coordinated efforts between a multitude of stakeholders, with a specifically allocated slot of time and money that ensure that various stakeholders—and, perhaps, particularly occupants—come together and consider several aspects of how users can be engaged and results co-produced.

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