Research Centre on
ZERO EMISSION
NEIGHBOURHOODS
IN SMART CITIES

THE ROLE OF ECO-VILLAGES IN REACHING ZERO EMISSION NEIGHBOURHOOD (ZEN) GOALS

Literature study on Eco-villages versus ZEN performance indicators

ZEN MEMO No. 29 – 2020

Shamita Chaudhary and Helge Brattebø | NTNU Industrial Ecology Programme

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Norwegian University of Science and Technology (NTNU) | www.ntnu.no
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https://fmezen.no

Preface

Acknowledgements

This memo has been written within the Research Centre on Zero Emission Neighbourhoods in Smart Cities (FME ZEN). The authors gratefully acknowledge the support from the Research Council of Norway, the Norwegian University of Science and Technology (NTNU), SINTEF, the municipalities of Oslo, Bergen, Trondheim, Bodø, Bærum, Elverum and Steinkjer, Trøndelag county, Norwegian Directorate for Public Construction and Property Management, Norwegian Water Resources and Energy Directorate, Norwegian Building Authority, ByBo, Elverum Tomteselskap, TOBB, Snøhetta, Asplan Viak, Multiconsult, Sweco, Civitas, FutureBuilt, Hunton, Moelven, Norcem, Skanska, GK, Nord-Trøndelag Elektrisitetsverk - Energi, Smart Grid Services Cluster, Statkraft Varme, Energy Norway, Norsk Fjernvarme and AFRY.

The Research Centre on Zero Emission Neighbourhoods (ZEN) in Smart Cities

The ZEN Research Centre develops solutions for future buildings and neighbourhoods with no greenhouse gas emissions and thereby contributes to a low carbon society.

Researchers, municipalities, industry and governmental organizations work together in the ZEN Research Centre in order to plan, develop and run neighbourhoods with zero greenhouse gas emissions. The ZEN Centre has nine pilot projects spread over all of Norway that encompass an area of more than 1 million m^2 and more than 30 000 inhabitants in total.

In order to achieve its high ambitions, the Centre will, together with its partners:

- Develop neighbourhood design and planning instruments while integrating science-based knowledge on greenhouse gas emissions;
- Create new business models, roles, and services that address the lack of flexibility towards markets and catalyze the development of innovations for a broader public use; This includes studies of political instruments and market design;
- Create cost effective and resource and energy efficient buildings by developing low carbon technologies and construction systems based on lifecycle design strategies;
- Develop technologies and solutions for the design and operation of energy flexible neighbourhoods;
- Develop a decision-support tool for optimizing local energy systems and their interaction with the larger system;
- Create and manage a series of neighbourhood-scale living labs, which will act as innovation hubs and a testing ground for the solutions developed in the ZEN Research Centre. The pilot projects are Furuset in Oslo, Fornebu in Bærum, Sluppen and Campus NTNU in Trondheim, Campus Mære in Steinkjer, Ydalir in Elverum, Campus Evenstad, NyBy Bodø, and Zero Village Bergen.

The ZEN Research Centre will last eight years (2017-2024), and the budget is approximately NOK 380 million, funded by the Research Council of Norway, the research partners NTNU and SINTEF, and the user partners from the private and public sector. The Norwegian University of Science and Technology (NTNU) is the host and leads the Centre together with SINTEF.

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Abstract

This memo reports findings from a literature study on a growing grass root community phenomenon called *Eco-villages.* These are communities formed by people with the intention of co-existing in a manner that reduces their impact on the environment. Eco-villages can be found in almost every part of the world, and, although built on common principles, they face their contextual challenges in their own unique ways. This report analyses these communities based on the seven key performance indicators established by the ZEN Research Centre (http://www.fmezen.no) in order to gauge their performance and see how they could help the Centre reach its goals of a zero-emission neighbourhood.

Despite limited availability of quantitative data, we find that eco-villages perform well in most of the categories. Their emphasis on early stage planning and mutual support of sustainable everyday practices in later stages results in a high uptake of sustainable technologies. Moreover, they are able to overcome barriers of embodied emissions, mobility and user behaviour unpredictability that current ZEN pilot projects face and present a potential point of collaboration and learning for the ZEN Research Centre. Beyond ecological sustainability, eco-villages are also seen to alleviate many social issues by decreasing loneliness, increasing autonomy of the elderly, inclusion of traditionally marginalised communities etc.

The report identifies a recent *fourth wave* of eco-villages in which these communities rather than secluding themselves are trying to incorporate themselves into urban areas and presents an interesting point of entry for the ZEN Research Centre and warrants more research in this direction. For the case of Norway, the report presents an introductory case study on an eco-village in Hurdal municipality, to show that Norway is ready for its eco-village revolution. This study acts as a starting point for future studies and presents a list of important literature and potential case studies.

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1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) in its Fifth Assessment Report (AR5) presented buildings as a critical piece of a low-carbon future and crucial for sustainable development. The building sector in 2010 accounted for 32% of the global final energy demand and 19% of energy-related carbon dioxide emissions. 24% of the energy demand was attributed to the residential sector (IPCC, 2014). With a goal of mitigating direct and indirect lifecycle emissions from buildings, the Zero Emission Building (ZEB) Research Centre worked on emission reduction opportunities at the scale of buildings, while this scope had to be expanded to emission reduction opportunities at the neighbourhood scale in the Zero Emission Neighbourhood (ZEN) Research Centre. The goals of the research therefore broadened to perform a more holistic assessment of lifecycle GHG emissions, keeping in mind emissions also from associated arenas such as mobility, infrastructure, networks and on-site energy (Lausselet, Borgnes, & Brattebø, 2019; Lausselet, Ellingsen, Strømman, & Brattebø, 2019; Lund, Lausselet, & Brattebo, 2019; Resch, Lausselet, Brattebø, & Andresen, 2020; Yttersian, Fuglseth, Lausselet, & Brattebo, 2019).

A typical ZEN project incorporates criteria from zero lifecycle GHG emissions to spatial quality and economic viability, as can be seen in Table 1. Eco-villages present an example of grassroots innovation where people take charge of living more sustainable lifestyles and reducing their impact on the environment. This includes areas like food, mobility, housing design and construction, energy demand etc. There are over 1000 eco-villages registered around the world, and their increasing popularity and effectiveness make them an ideal case study for the ZEN Centre.

This brings us to the research question – "*How can eco-villages help the ZEN Centre reach its goals?*"

In this report, we present a study of available literature on eco-villages, and analyze it based on the criteria specified by the ZEN Centre for the assessment of a ZEN project. Rather than net zero emissions, we use a threshold limit on carbon emissions per capita to identify successful eco-villages according to the carbon footprint (CF) goals calculated by Tukker (2016) as per the Paris Agreement. These eco-villages can later be used as case studies. We also present an introductory case study on the first eco-village in Norway in the Hurdal municipality, to show the potential of eco-villages in Norway.

1.1 What is the goal of a ZEN project, and how is it different from a ZEB project?

In order to reduce emissions from the built environment, multiple approaches have been applied. One of the earlier approaches was the ZEB or the Zero Emission Building which focused on a reduction in emissions associated with the lifetime of a building. This meant a reduction in operational (direct and indirect emissions for the operation) and embodied (from the construction phase) emissions.
With the onset of ZEN, the goals became a little wider. The ZEN Research Centre in their annual report of 2018 defined a neighbourhood as "a group of interconnected buildings with associated infrastructure, located within a confined geographical area" and go on to define a zero-emission neighbourhood as one that "aims to reduce its direct and indirect greenhouse gas (GHG) emissions towards zero over the analysis period." The emissions were calculated based on certain categories, assessment criteria, and KPIs defined by the research centre. The seven categories and their corresponding assessment criteria and KPIs are shown in Table 1 (Woods, Remøe, Hestnes, & Gustavsen, 2018).

		Category	Assessment criteria and KPIs	Units
1		Plan, design and operate buildings and associated infrastructure components towards zero life cycle **GHG emissions**.	Total GHG emissions. GHG emission reduction.	tCO_2eq $kgCO_2eq/m^2BRA/yr$ $kgCO_2eq/m^2BAU/yr$ $kgCO_2eq/capita$ % reduction to base case
2		Become highly **energy efficient** and powered by a high share of new **renewable energy** in the neighbourhood energy supply system.	Energy efficiency in buildings (several sub-criteria). Energy carriers (several sub-criteria). Self-consumption/generation.	$kWh/m^2BRA/yr$ kWh/yr per energy carrier % per energy carrier
3		Manage energy flows (within and between buildings) and exchanges with the surrounding energy system in a smart and **flexible** way.	Power/load performance (several sub-criteria). Load utilization factor. Power/load flexibility.	kW % kW
4		Promote **sustainable transport** patterns and smart mobility systems.	Mode of transport. Access to public transport.	% share Meters, frequency
5		Plan, design and operate with respect to **economic sustainability**, by minimising total life cycle costs.	Life cycle cost (LCC).	NOK $NOK/m^2BRA/yr$ $NOK/m^2BAU/yr$ NOK/capita
6		Plan and locate amenities in the neighbourhood to provide good **spatial qualities** and stimulate **sustainable behavior**.	Demographic needs and consultation plan. Delivery and proximity to amenities. Public space.	Qualitative No. of amenities, meters, distance Qualitative
7		Development of the area is characterised by innovative processes based on new forms of cooperation between the involved partners leading to **innovative solutions**.	Yet to be developed.	Yet to be developed

Table 1: The categories, assessment criteria and KPIs for a ZEN project

1.2 Current ZEN projects and greenhouse gas emissions

There are currently nine pilot projects of the ZEN centre – Ydalir in Elverum, Furuset in Oslo, NTNU Campus and Sluppen in Trondheim, Zero Village Bergen, Lø in Steinkjer, Nyby in Bodø, Fornebu in Bærum, and Campus Evenstad in Hedmark. Of these, none have managed to successfully reach their goal of zero emissions yet. Lifecycle assessments do however indicate pathways for GHG emission reduction in the most cost-effective manner. The findings across papers point at three main factors – materials, mobility and behavioral change. The focus is on developing early stage planning tools so that emission heavy elements can be identified early on and mitigated.

Early stage assessment tools developed by the centre find that buildings are responsible for 52% of the emissions followed by mobility with 40% of the emissions (Lausselet, Borgnes, et al., 2019). Within buildings, studies suggest focusing on building materials as operation energy standards exist in most countries and will continue to tighten over time (Moschetti, Brattebø, & Sparrevik, 2019). It is further suggested that compensating for lifecycle GHG emissions through the use of renewables is insufficient. Even with increased wall insulation, PV panels and a redesigned roof form, it was found that although all operational emissions were able to be compensated for only 60% of the embodied emissions could be compensated for (Kristjansdottir et al., 2018). An LCA on Ydalir highlighted that mobility operation is responsible for 21-46% of the emissions while building materials for around 24% (Lund et al., 2019). These findings are in line with those of (Hertwich & Peters, 2009) who list shelter (including its construction), mobility and food as the three factors having the largest effect on the environmental impact of a household.

This raises the questions - *is compensating for emissions enough?* What about planning to cut emissions at source? This is where the focus on early planning stages becomes crucial.
The LCA models developed consider user behavior as a factor of uncertainty (Lausselet, Borgnes, et al., 2019). The authors suggest that a bottom up approach driven by behavioral change could lead to a reduction of other factors as well. This is illustrated by a study on carbon footprint in the UK (Minx et

al., 2013). Carbon footprint is a measure of all direct and indirect (upstream) greenhouse gas emissions (in CO_2eq) of an activity, regardless of where they occur, i.e. locally, nationally or globally. This study found that the carbon footprint is driven by socio-economic factors (growing income, education, car ownership, decreasing household size) rather than by geographic or infrastructural drivers.

1.3 Eco-villages – "intentional" communities with an aim to live more sustainably

Eco-villages come under the category of "co-housing", which in turn are a type of "intentional community". Intentional communities is a broad term for communities that "voluntarily come together for the purpose of ameliorating perceived social problems or inadequacies" (Andreas & Wagner, 2012). As a subset of that, co-housing is "collectively built and self-managed housing clusters, co-housing for short" that are known for their "vivid social networks and healthy environment". The concept of co-housing gained momentum in the 1980s and today forms an international network of living with shared spaces in a variety of management forms (Tummers, 2015). Some common characteristics of co-housing as defined by Durrett and McCamant (1988) in their book *Cohousing: A contemporary approach to housing ourselves* are - the participatory process, intentional site design, common facilities, resident management, non-hierarchical structure and decision making process, and no shared community economy. Apart from this, some authors talk about some other features such as optimum community size, purposeful separation of the car, shared meals, varied levels of responsibility for the development process (Scotthanson & Scotthanson, 2004) and non-ideological community, non-hierarchical community (Ann Zabaldo, Principal Architect, Cohousing Collaborative LLC).

Co-housing finds its roots in utopian, feminist and communitarian movements of the nineteenth and twentieth century (Williams, 2005). With its focus on personal autonomy and communal solidarity, it has also proved to be a successful model of living for the elderly (Labit, 2015; Pedersen, 2015). Williams (2002) addresses the phenomena of a rising number of single-person households and how co-housing could help counter its impacts on increased consumption of energy, goods and space.

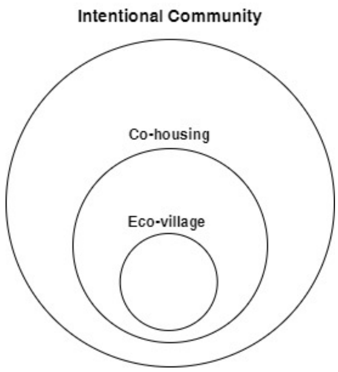

Figure 1: Author's visualisation of the three concepts of Intentional communities, Co-housing and Eco-villages as a Venn diagram

The intentions of a collectively built and self-managed co-housing can be many – from creation of community for the handicapped in Norway (Bang, Bakker, Christensen, & Levinson, 2003) to improving lives of working parents and their children in Sweden (Williams, 2005). That is how we came across eco-villages. An eco-village is a traditional or intentional co-housing with the goal of leading a more "socially, culturally, economically, and ecologically sustainable" lifestyle. These four aspects of sustainability define the four pillars of an eco-village, or as the Global Eco-village Network website calls it – the *Areas of Regeneration* and are a common theme across all eco-villages.

The historical development of intentional communities has been defined in waves. Wave 1 was practicality driven – need for childcare, support and socializing for families with working or single parents and a need for community for them. It was mostly limited to northern Europe (Denmark, Sweden and the Netherlands). Wave 2 was about the need for community and mainly encapsulates the spread in the USA during the 1980's and 90's. Wave 3 began in the 1990's and took place in Australia and south-east Asia, and was about encouraging the mixing of communities of different affluence, household type and ethnicity (Williams, 2005). The fourth and the most recent wave attempts to integrate the eco-village within the larger society. This has commonly been seen in the form of urban eco-villages, for instance when integrating student co-ops in the local community. A good example of the forth wave is also the Hurdal Eco-village in Norway. These communities coalesce with dominant societies rather than escaping and are less alienated from mainstream culture. As a departure from previous residents who wanted to be isolated and amongst people with similar beliefs only, the new wave of eco-villagers claim their reason for doing this is to not only lead more sustainable lifestyles, but to also set an example of sustainable living for local citizens, while some do this as activism to change housing regulations, raise environmental awareness etc. (Ergas, 2010)

From the literature we studied, we found an ongoing debate about which unit to use for measuring the life cycle impact of eco-villages. Two units – the ecological footprint (EF) and the carbon footprint (CF) - have emerged as the most commonly used in all studies. While the EF was established as the better unit to evaluate the overall sustainability of an eco-village, the ZEN Centre has established some performance metrics of its own (Table 1). Hence, for this study we focus on CF as the metric.

2. Case study Hurdal Eco-village

Figure 2: Hurdal Eco-village near Oslo
(image source: https://miro.medium.com/)

Hurdal Eco-village (http://www.sustainablevalley.no/english.html) presents a potential case study or collaboration point for a ZEN project. The Hurdal municipality is located in Akershus County, about 80 km from Oslo and is comprised of 2910 inhabitants as of 2016. It is the first municipality in Norway to facilitate the construction of an eco-village. Today the eco-village has 70 residential units, with an ambition of adding another 130 in the next few years. The figure below shows where Hurdal and the eco village are located.

Figure 3: Hurdal Eco-village near Oslo

According to the website, the municipality's stated ambition is "to be a plus society by 2030, which implies that Hurdal will be carbon neutral or better, experience economic growth, and provide improved quality of life to inhabitants and visitors”. This is in line with category 1 of the ZEN criteria (Table 1).

Hurdal has gone through two distinct phases of development – a self-building phase and one where they involve a developer. This makes it an interesting case study as it presents an intersection between mainstream sustainable architectural practice and eco-villages in Norway. This collaboration brings about a shift in the perception of the eco-village by local residents of the municipality, where the initial skepticism turned into admiration of the eco-village residents’ lifestyle choices. (Westskog, Winther, & Aasen, 2018)

Phase I, which lasted from 1996 to 2009, started with the establishment of the eco-community *Kilden Økosamfunn*, who were inspired by the wave of intentional communities around Europe and North America and wanted to establish an eco-village in Norway. They rented a farm called Gjøding that covered 146 acres of land, 40 acres of which was arable. The members of the community used straw and wood to make houses, following principles of traditional ecological architecture. It took the community members a long time to establish the village (10 years), and they faced difficulties with permits and legalities. An eco-village cooperative was established in which each member owned a share of the farm and had a say in the decision-making process. The initial inhabitants bore the costs of establishing the eco-village, with the idea that subsequent newcomers to the village will have to pay a certain amount to join.

Phase II was made in collaboration with GAIA Architects, an umbrella organisation for architectural firms interested in contributing to sustainable design. Collaborating with an architecture firm meant that the legal and financial expertise and the associated risk was borne by professionals with relevant experience in the fields. The second phase also opened the eco-village to outsiders (the locals from the municipality) where they could come participate in the social events and activities of the eco-village. This marked a significant functional shift from the first phase, and in line with the fourth wave of intentional communities. Aktivhus (Daughter Company of GAIA) provided modular, eco-friendly housing to Hurdal. They balanced ideals of ecological architecture with national regulations (such as the TEK 10 and zero emission requirements) and available support schemes. The homes were made with natural materials, had natural ventilation, maintained healthy indoor climate, energy efficient construction etc. They installed solar cells on roofs, introduced ‘smart technologies’ into homes, and even installed monitoring equipment in some homes for documentation and research.

The outcome of this was that while the residents enjoyed the professionally built homes, and even admired the time-consuming creative process, unfortunately Aktivhus went bankrupt, leaving people feeling very helpless and dissatisfied with the lack of servicing. People were also disappointed with their lack of autonomy in the whole process as that was a big part of the eco-village community.

However, their ‘acceptance’ amongst the local community sharply increased hereafter.
The intention for joining the eco-village was either to join a community where people shared similar values on sustainable living and secondly to inspire social change with respect to food, housing, transport and how people live together - and bring this form of living to the mainstream.

3. Findings and discussion

Early studies claim that '*shared living*' (such as co-housing or eco-villages) could reduce the ecological footprint from smaller households (one to two person households), reducing individual consumption of energy and resources (Williams, 2002) and even occupying less land as they are more densely built (Moos et al., 2006). The impacts of this can be seen in reduced space heating, more effective uptake of sustainable technologies, etc. Studies compare co-housing as having the same principles of reduced car ownership, urban sprawl and resource consumption as new urbanism (Williams, 2005) while newer studies are more inclusive of co-housing into mainstream planning and call it '*participative urbanism*' (Tummers, 2015). We can see this as the fourth wave of intentional communities attempting to connect with communities outside their own. The findings from the literature study that are relevant to ZEN projects have been organized as per the categories defined in Table 1 as follows.

GHG Emissions: An eco-village strives to minimize its impact on the natural environment. While zero emissions is an overtly stated goal in few eco-villages (Hurdal for example), eco-villages appear to strive for holistic sustainability, with minimization in carbon emissions being an active thought in the early planning stages (Marckmann, Gram-Hanssen, & Christensen, 2012). Literature presents conclusive evidence for the fact that eco-village communities manage to reduce the ecological footprint (EF) and the carbon footprint (CF) of the community when compared to their mainstream counterparts. The only exception to this case has been a study of three Finnish eco-villages which were located in remote rural areas which led to high transport emissions overpowering their mainstream counterparts (Daly, 2017). In Daly's study, it is notable that out of the 23 eco-villages studied, although most showed reductions in footprint, only five managed to reach a "sustainable" ecological footprint level (assuming available global biocapacity to be 1.7 gha/pp). For the CF using studies, there was no target CF stated. Hence, we use a baseline value of 2-2.5 tCO2/capita/year as estimated by Tukker et al. (2016) in order to meet climate targets in 2050 as per the Paris Agreement. This limit as per the study is only met by Konohana Family Community in Japan, Munksøgård and Svanholm Collective in Denmark and the Sieben Linden community in Germany.

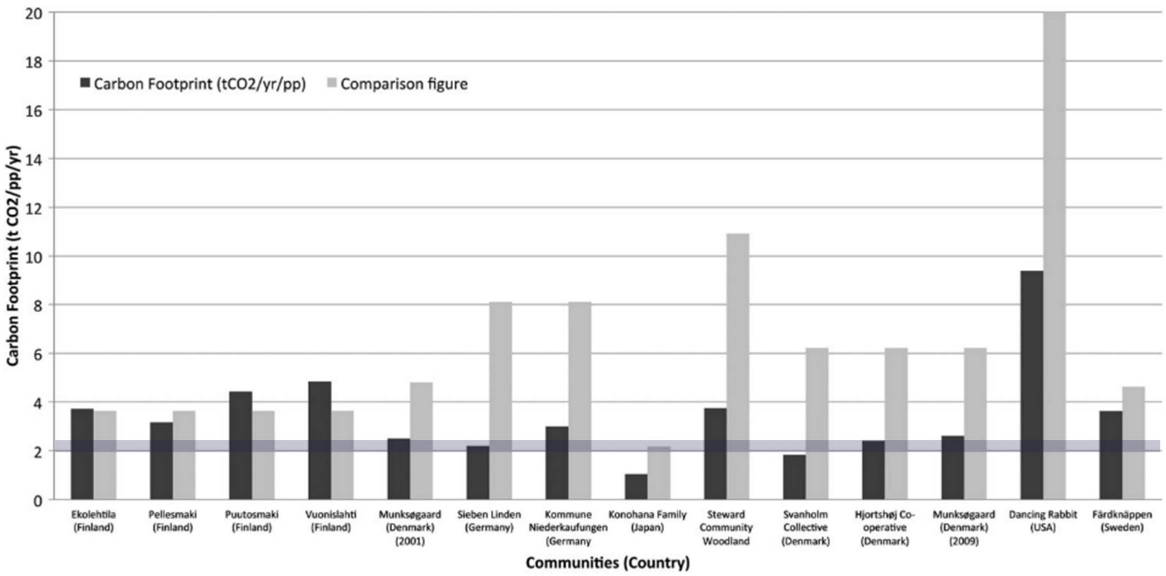

Figure 4: Carbon Footprint of studied eco-villages (Daly, 2017). The blue line indicates target CF in 2050 to meet our climate targets as per (Tukker et al., 2016).

Energy efficiency and use of Renewables: The use of sustainable design and construction practices, such as the use of local materials for construction, passive techniques for solar radiation management and good insulation for the buildings is a common practice in eco-villages. (Daly, 2017) These practices are effective in reducing energy demand and associated lifecycle emissions. Some communities were found to be self-sufficient in meeting their energy needs due to the use of renewables, while most relied on renewables at least partially (Daly, 2017). Co-housing/eco-villages were found to promote community involvement and uptake of technology. Thorough discussions on which technologies would be most suitable for the community during the early planning stage and mutual support of sustainable everyday practices ensures commitment to the cause. (Marckmann et al., 2012) The combination of physical design, strong social capital, and shared principles and goals of reduced environmental impact was found to remove barriers and provide opportunities for sustainable practices to be established, grow, and evolve within the communities. Moos et al (2006) extends this hypothesis to explain the lower impact from food, transportation, water, electricity and natural gas for heating as well. While space sharing in eco-villages and co-housing has the potential to reduce consumption of resources and energy, especially by smaller households, this has not been adequately substantiated in the literature. This was an important claim from many early studies on co-housing, but later studies found that these communities did not manage to attract enough participation from one and two person families. (Marckmann et al., 2012)

Sustainable Transport: In the case of transportation, it was found that the community design in the first place prohibits automobile travel. Secondly, the nature of the co-housing community encourages car-pooling, co-working and communal activities that potentially reduce travel as well (Moos et al., 2006). So far eco-villages had been located in rural areas or remote areas away from urban life. This was seen in some cases to increase emissions from transport to the point that they outweigh emissions from mainstream urban counterparts, such as the case of the three Finnish eco-villages (Daly, 2017). However, with the onset on the fourth wave of intentional communities where eco-villages are being incorporated into urban areas, reliance on public transport and other city infrastructure which can further reduce transport emissions.

Economic Viability: Co-housing has been considered a "high quality and highly sustainable alternative" to mainstream housing due to its affordability apart from other environmental and social factors (Williams, 2005). They can prove to be good examples of affordable housing as they are largely self-built using local materials and construction techniques, while minimizing resource use and environmental impact. The initial plot of land on which it is developed can be bought or rented. Or it can even be a retrofit in an existing building. Many eco-villages require newcomers to pay a membership fee as the initial members have borne the cost of establishing the village, however most eco-villages have activities that make it economically sustainable. Utilities such as electricity, water, and waste management costs are minimal as the communities rely on renewable sources of energy, have reduced water consumption and recycle and manage their own waste. With the fourth wave, there is also the reduced cost of urban sprawl. Some studies however show that eco-villages and co-housing built privately, such as those for ageing people, have a tendency to be exclusive, catering only to the elite.

Innovative Solutions: Co-housing and eco-villages are innovative solutions to many of the perceived environmental and social problems we face today. They are examples of grass-root initiatives of people taking charge of how they want to live and co-creating that life for themselves. These communities are known for their increased gender-equality, increased autonomy and well-being of the elderly, and social inclusion of marginal groups of society. In addition to that, these communities exhibit reduced environmental impacts and a better quality of life as well. Each community is located in its unique context and there is scope to learn from each unique community about how it deals with its local problems. The communities reduce impacts in a variety of ways – reduced transportation dependence and car sharing, growing food locally and reducing meat consumption, having community spaces and reduce heated floor space, sewing and repairing their own clothes, reduced consumption of goods and even making the aged more self-reliant thereby reducing the need for external infrastructure for them, etc.

4. Conclusions

Based on the evaluation of literature and case study findings, we provide the following conclusions:

1) Eco-villages show promise for reduction of emissions when compared to mainstream communities. This includes emissions from the building (construction and operation), food (vegetarianism, reduced meat consumption, locally grown food, shared meals), transport (co-working spaces, car-pooling), and consumption of goods. However, there is insufficient quantitative data on "how much" co-housings and eco-villages contribute to zero-emission neighbourhoods. The unit of measurement is divided between CF (13 studies), and EF (12 studies), with EF being claimed as a preferable unit of measurement. Of the EF studies, only five eco-villages managed to meet the sustainable EF level, and even amongst those five the confidence level is not high (Daly, 2017). No such case was presented for CF. According to Tukker (2016) in order to stay within the 2°C limits, as per the Paris Agreement, per capita emissions need to be limited to 2-2.5 tons CO_2 per capita by 2050. This limit is currently met by Konohana Family Community in Japan, Munksøgård and Svanholm Collective in Denmark and the Sieben Linden in Germany.

2) Each eco-village is unique to its context, which makes it hard to make over-arching assumptions from various case studies. However, each case study can provide us an insight into how a community can lower its emissions. The uniqueness of each project is also cited as a potential reason for the lack of quantitative data (Tummers, 2015). Certain discrepancies in ways CF is calculated is noted by Daly (2017), with some accounting for services, government and capital investment, while other studies not outlining their assumptions on these categories clearly. The CF of the studied eco-villages yield different results, which is expected. The Japanese Konohana Family Community showing 1.0 tCO2/yr/person while the Dancing Rabbit in USA showing 9.4 tCO2/yr/person (Daly, 2017). Most eco-villages had lower CF compared to mainstream counterparts, except for the three communities in Finland with high transportation emissions.

3) There isn't enough information available on space sharing as a norm in eco-villages, potentially due to the unique nature of each project. Smaller living spaces go against the cultural inclinations of people but can be countered if thought about at an early planning stage (Marckmann et al., 2012). Hence it is hard to make conclusive statements about the emission reduction due to space sharing. For example, in the Sieben Linden eco-village, there is a limitation on how many square meters each person may inhabit. In 2016 it was around 38 sqm/person, including 11 sqm community and 27 sqm residential space. When divided into individual, shared and service areas - there was 15 sqm/person for individual use, 6 sqm/person that is shared and 6 sqm/person for services. (Bocco, Gerace, & Pollini, 2019)

4) The early planning stage seems to be very important and thoroughly done, with discussions at length on sustainable technologies to be deployed, use of water, waste management etc. However, as was seen in the second phase of the Hurdal EV, with the entry of the developer, the people had lesser involvement in the planning process. The scope for collaboration actively with ZEN principles can be done at this stage, provided there is active participation from the resident community. One may wonder if the results from the eco-villages can be

achieved by replicating the other aspects of the development in order to mainstream it, but the community participation and the bottom-up approach to neighbourhood planning is crucial.

5) Mainstreaming eco-villages, as can be seen in the fourth wave of intentional communities, for example, the Hurdal eco-village, can be an effective way to create a link with society. It increases their acceptance amongst local population and prevents eco-villages being labelled as *'too alternative'* or '*hippie*' and showcased as a working examples of sustainable living to others instead (Westskog et al., 2018). Munksøgård, which is also a builder developed EV in Denmark and which was, when studied in 2009, at less than 50% CF of a mainstream counterpart, also seems like a promising case study.

6) Studies show that intentional communities contribute qualitatively apart from quantitatively to sustainable development (Kunze, 2012). Apart from the environmental benefits, eco-villages and co-housing alleviate many social problems. Diverse groups of people, social cohesion and stronger social bonds lead to greater autonomy that can improve the quality of life of ageing populations. With their roots in theories of communalism and feminism, these communities can be a good learning ground for increasing gender equality through community design (Williams, 2005). They are also known for social inclusion of marginalised sections of society, such as handicapped and disabled people.

Norway is ready for its eco-village revolution. Historically the movement has had Nordic and Scandinavian roots, but its popularity has been limited to Denmark. Norway could benefit from the case studies from its neighbouring countries and further its research towards zero emission neighbourhoods by investing in this.

5. Final remarks from the authors

Eco-villages and co-housing present a viable alternative to some mainstream planning theories such as new urbanism and transit-oriented development. Many of the goals that these theories are trying to achieve have already been achieved and documented by eco-villages as shown in the studies cited in this report. There is a need to mainstream these community living schemes in order to alleviate various social and environmental problems that we currently face. The onset of the fourth wave of eco-villages in that regard presents an exciting opportunity to incorporate sustainable living into urban settlements and gain more acceptance about these ideas from the general population. A key component of these grass root initiatives is the participation of people in the development of community housing and a sense of autonomy after construction. Collaboration with developers and architects can ease the process of constructing these communities, however the early planning stage of any neighbourhood development project must include the people who are going to occupy the neighbourhood. The ZEN Centre should at the early planning stages of its projects also involve the people who will occupy the space, and existing eco-villages/co-housing serve as a great learning platform. Eco-villages as a concept seem to be gaining momentum in Norway, and this is a great time to build on the momentum and learn from these grass root initiatives of people.

Some of the most noteworthy authors on this topic is Marckmann, Moos, and Daly. Along with that is Meltzer who has not been directly cited here but was a big influence in most papers.

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