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Towards Climate Neutrality through Integrated Energy Planning – a Cross-Country Comparison and Case Study Analysis of Positive Energy District Concepts between Switzerland and Norway

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1 ABSTRACT

Reaching for the Global Sustainability Goals, cities play a prominent role as from a geographical view they are identified as the main area for global emissions. On the other hand, they play a prominent role in putting global goals into local policies and means and at the same time embedding them in local context with site specific demands and settings. The Positive Energy District (PED) Concept is currently evolving based on the Strategic Energy Transition (SET) plan of the European Union member states and contributions from different initiatives. A common understanding or definition is not yet in place. Creating districts in the built environment that produce more energy than they consume embedded in a holistic approach to reduce energy demand and produce renewable energy is seen as one means to reach climate neutrality. As the first PEDs are developing all over Europe, we have little knowledge on how the PED concept is implemented nationally and how first PED projects develop within the specific national contexts. We ask: What are the concepts and approaches towards PED developments in Switzerland and Norway? What learnings can we extract from these projects? What are the implementation strategies and how are functional issues addressed?

By looking at different recent developments of PEDs in Switzerland and Norway, we describe the characteristics of national approaches towards PEDs. By deepening the description of 2 respective case-studies in the two countries, we analyse how PED approaches are implemented within the specific context. We compare the PED concepts, local implementation and functional issues to analyse the approaches. Our research is based on literature and document analysis and qualitative interviews.

The results show that different implementation concepts require different measures. From the analysis of the results, the conclusions are that integrated energy planning is more important than ever. Understanding the different dimensions of sustainable development in combination with energy supply and consumption is important to plan and realise settlements that not only contribute significantly to reducing energy consumption and securing the location of energy infrastructure (generation, distribution, storage), but also in terms of long-term sustainable development and specifically climate neutrality.

Keywords: climate neutrality, integrated energy planning, certification, PED, positive energy districts

2 INTRODUCTION

Climate change challenges the ambitious goals that regulators have put in place by setting more and more aggressive energy-related building and community requirements based on the Sustainable Development Goals of the UN. The concept of Energy Master Planning (EMP) can help initiate a better planning and implementation process to fulfil these goals. In the EU, reaching for the greenhouse gas reduction goals of the Paris Agreement, stakeholders on all geographical and organisational levels from nations, regions, cities and communities are challenged. Following bottom-up approaches for energy planning on the neighbourhood level is a promising attempt to reduce energy demand, increase efficiency and lower the carbon footprint in a multi-stakeholder approach (David, Schoenborn, 2018). Reaching for the Global Sustainability Goals, cities and communities play a prominent role as they are geographically the main cause for emissions and on the other hand play a prominent role in putting global goals into local policies and means and at the same time embedding them in the local context with site specific demands and settings.

The Positive Energy District (PED) Concept is currently evolving based on the Strategic Energy Transition (SET) plan of the European Union member states. A common understanding or definition is not yet in place. Creating districts plants in the built environment that produce more energy than they consume embedded in a holistic approach to reduce energy demand and produce renewable energy is seen as one means to foster the clean energy transition in the EU and at the same time reach climate neutrality.

The basic principle of Positive Energy Districts (PEDs) is to create an area, capable of generating more energy than consumed on a yearly basis and being agile/flexible enough to respond to the variation of the energy market (SET Plan 2019). In a new initiative of the European Commission, Positive Energy Districts are envisioned as "are energy-efficient and energy-flexible urban areas or groups of connected buildings which produce net zero greenhouse gas emissions and actively manage an annual local or regional surplus production of renewable energy. They require integration of different systems and infrastructures and interaction between buildings, the users and the regional energy, mobility and ICT systems, while securing the energy supply and a good life for all in line with social, economic and environmental sustainability." (JPI UE 2020).

3 PROBLEMS/APPROACHES TOWARDS PEDS ON DIFFERENT (GOVERNANCE) LEVELS

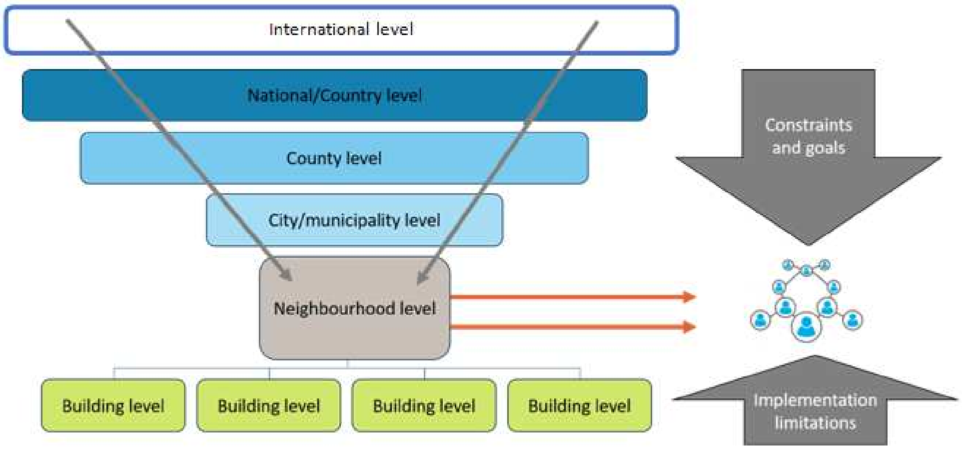

Fig. 1: Different levels of planning constraints in PEDs

3.1 Concept and approach

Significant additional energy savings, reduced emissions, and increased energy security can be realised by considering holistic solutions for the heating, cooling and power needs of energy communities, on district scale, comprising a group of buildings. As a result, considerable literature has become available, including both guidance and assessment tools aimed at EMP at the neighbourhood and district level as e.g. campuses (DOE 2013; Huang et al. 2015; Energy Plan 2019; BREEAM 2019; LEED 2019). But the existing guidance and tools do not seem to be fully solving the challenges. Energy planning consists in determining the optimal mix of energy sources to satisfy a given energy demand. The major difficulties of this approach lie in its multi scales aspect (temporal and geographical), but also in the necessity to consider the quantitative (economic, technical) but also qualitative (environmental impact, social criterion) criteria (Schiefelbein et al. 2017).

In order to be able to apply principles of a holistic approach to neighbourhoods and districts, often coined community energy planning in the literature, and to provide the necessary methods and instruments to master planners, decision makers, and stakeholders, it is essential to identify and frame the constraints that bound the options towards an optimised energy master planning solution (Sharp et al. 2020). Existing master planning guidance available indicates that identifying and establishing project goals is a critical first step (Jank, 2017). Sharp et al. (2020) compared EMP in several countries and analysed these constraints (Sharp et al. 20120). The results show that successful energy master planning is highly dependent on a thorough understanding of framing goals and constraints, both local and regional, and their associated limitations that will dictate the optimum master planning design. Haase and Baer (2020) pointed out that as more and more countries push to improve the efficiency, environmental impact, and the resilience of their buildings and neighbourhoods, the need for early and comprehensive energy master planning on neighbourhood and district level is critically important.

3.2 Implementation aspects of PEDs

The development of districts requires a distinct understanding of the actual situation as well as a vision of the future district to be able develop suitable pathways for the transition. In order to be able to do that, a district needs to be modelled in detail with several buildings. This allows a sufficiently detailed model so that the future district can actively manage their energy consumption and the energy flow between them and the wider energy system. The energy master planning process requires an analysis of different scenarios, which include new construction to different levels of energy efficiency, major renovation of all or some buildings comprising building stock under consideration with deep energy retrofit of these buildings, minor renovations with energy-related scope of work, or demolition of some old buildings. That is why we are doing a case study with two countries, and the respective "programmes" towards PED. What are the national approaches towards PEDs in Switzerland and Norways and how do they manifest in PED projects? What learnings can we extract from the early planning and implementation phase of these projects?

3.3 Functional issues of PEDs

In many cities, the necessary legal and strategic frameworks for the realisation of PED/PENs are not yet in place. Very often, there is also a lack of a planning culture in city administrations or the personnel resources available might be insufficient. In particular, the transformation of large (brownfield) areas to climate neutral city districts has a big potential for the development of PED/ but needs cooperation between administration, industry, and research. That is because a PED should not only aim to achieve an annual surplus of net energy. Rather, it should also support minimising the impact on the connected centralised energy networks by offering options for increasing onsite load-matching and self-consumption, technologies for short and long-term storage, and providing energy flexibility with smart control. PEDs can include all types of buildings and they are not isolated from the energy grid (JPI 2020). In the research community PED is a rising concept to shape cities into carbon neutral communities in the near future (Brozovsky et al. 2021). Reaching the goal of a PED requires firstly improving energy efficiency, secondly cascading local energy flows by making use of any surpluses, and thirdly using low-carbon energy production to cover the remaining energy consumption. Smart control and energy flexibility are needed to match demand with production locally as far as practical, and also to minimise the burdens and maximise the usefulness of PED on the grid at large. Additionally, the PED concept under development stretches the holistic integrated approach towards PEDs development to realise synergies between sectors and also to incorporate the realisation of aligning goals as e.g. integration of mobility, etc.

4 METHODOLOGY

This research adopts a qualitative-comparative case study method. Qualitative-comparative analysis is useful for highlighting similarities and differences between cases through the study of phenomena in various contexts (Hopkin, 2010). This approach enables a comparison of two national PED programmes in Norway and Switzerland, from which we draw insights on the approaches towards fostering of PED development in the respective national context.

5 CASE DESCRIPTIONS

5.1 Norway

5.1.1 Concept and approach

Norway is in a unique position regarding PED developments to investigate early stage implementation of PEDs. Not only is Norway's power system based on renewable energy with the electricity production based mainly on hydropower, but the initiative for PED development in Norway comes from the highest policy levels and influences research and innovation programmes for energy efficiency and urban development, positioning Norway as a European leader in a decarbonised electricity system. The PED development with the focus on local generation is an indirect consequence, since with the increasing decarbonisation of other energy demands, more generation and higher energy efficiency will be needed. Furthermore, in the Norwegian context, energy efficient solutions should become the preferred choice for consumers in the future (Royal Norwegian Ministry of Petroleum and Energy).

Already in 2008, the Norwegian Parliament decided that Norway should become “carbon neutral” by 2050 and recently Norway enhanced its nationally determined contribution under the Paris Agreement to reduce emissions by at least 50 per cent and towards 55 per cent compared to 1990 levels by 2030 (Norwegian Government) .

The Norwegian government has predominantly been focusing on reducing consumption in the building sector as a whole, with the state enterprise for energy efficiency, Enova, instituting a number of appliance and product labelling measures to influence household purchasing decisions. Enova also manages the Energy

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Fund, which is a government fund established to ensure a long-term, and stable source of finance for energy efficiency and the promotion of renewable energy.

There is no specific regulation for PEDs, so the policy framework consists of different laws and regulations, guiding principles, white papers and standards which influence the implementation of PEDs. As Norway is a three-tier unitary state, with a governance system that includes the national government, elected county councils at the regional level, and municipalities with elected councils at the local level, the policy framework is formed on these levels (Dannevig, 2016) Prominent to name here is the adoption of EU directives with relevance to the EEA (including Norway): The Energy Performance of Buildings Directive (EPBD) and Energy Efficiency Directive (EED). Through these, which have yet to be completely transposed and adopted in Norway, progressively stricter efficiency requirements are being put into force. The Norwegian Building Authority has been tasked with implementing the EPBD and reaching its goals, including making all new buildings nearly zero-energy buildings by 2020 (Brekke, 2020) For the energy sector, the national energy laws (Act on the production, transformation, transfer, turnover, distribution and use of energy etc. (Royal Norwegian Ministry of Petroleum and Energy) require the development of energy and climate plans on the municipal level. The National Water and Energy Directorate (NVE) introduced the Plus customer arrangement to enable the rise of prosumers in Norway.

Even though Norway is not an EU member state, the country participates in the EU Emission Trading System. It is believed that Norway may play a more important role in reducing emissions abroad by exporting more renewable energy than it already does (Haase, Löfström, 2015) The development of PEDs in Norway will strengthen the position of Norway to export renewable energy and thereby help contribute to global greenhouse gas emission reduction goals.

Criteria	Key Performance Indicators
GHG emission	Total GHG emissions in tCO2eq/m2BRA/a; kgCO2eq/m2BAU/a; tCO2eq/capita, GHG emission reduction % reduction compared to the base case
Energy	Energy efficiency in buildings (Energy efficiency in buildings, Net energy need in kWh/m2BRA/a; Gross energy need in kWh/m2BRA) Energy carrier (Energy use in kWh/a; Energy generation in kWh/a; Delivered energy in kWh/a; Exported energy in kWh/a; Self-consumption in %; Self-generation in %; Colour coded carpet plot in kWh/a)
Power/Load	Power/load performance (Net load early profile in kW; Net load duration curve in kW; Peak load in kW; Peak export in kW; Utilisation factor in %); Power/load flexibility (Daily net load profile in kW)
Mobility	Mode of transport (% share); Access to public transportation (Meters; Frequency)
Economy	Life cycle cost (LCC) (NOK; NOK/m2BRA/a; NOK/m2BAU/a; NOK/capita)
Spatial qualities	Demographic needs and consultation plan (Qualitative); Delivery and proximity to amenities (Number of amenities, Meters (distance from buildings); Public space (Qualitative)
innovation	Under development

Table 1: Evaluation criteria of the ZEN demo sites (Wiik et al, 2019)

5.1.2 Implementation

Until now, there is no national programme towards PED development and initiatives are scattered around different initiatives, such as research projects that incorporate several real life demo sites, e.g. the H2020 founded +CxC project or the Research Centre on Zero Emission Neighbourhoods in Smart Cities (ZEN Centre) . As the ZEN Centre presents nine demo sites in Norway and with that a broad range of experiences, we build our paper on this project to study Norwegian PED approaches.

The Research Centre on Zero Emission Neighbourhoods in Smart Cities (ZEN Centre) will last eight years (2016-2024), with user partners from the private and public sector in Norway. NTNU is the host and leads the Centre together with SINTEF. The goal is to develop solutions for future buildings and neighbourhoods with no greenhouse gas emissions and thereby contribute to a low carbon society. The ZEN Centre has 11 public partners, including the Trondheim municipality, 21 industry partners and 2 research partners (NTNU and SINTEF). The partners of FME ZEN cover the entire value chain of the built environment development on neighbourhood scale in the framework of smart cities and include representatives from municipal and regional governments, property owners, developers, consultants and architects, ICT companies, contractors, energy companies, manufacturers of materials and products and governmental organisations.

The ZEN Centre will contribute to and manage a series of neighbourhood-scale demo sites, which will act as innovation hubs and a testing ground for the solutions developed in the ZEN Centre. They are geographically limited – primarily urban – areas in Norway in which the Centre's researchers, together with the user partners test new solutions for the construction, operation and use of neighbourhoods to reduce the greenhouse gas emissions on a neighbourhood scale towards zero.

Demo site	location	Type of area	Area size (m^2)	Project owner	further information
Ydalir	Elverum	Brownfield	430 000	Public	Residential area with a school and kindergarten
Furuset	Oslo	Mixed-use neighbourhood with local centre	870 000	Public	Retrofitting/upgrading and new construction: 1 700 – 2 300 dwellings and 2 000 – 3 400 workplaces (up to 160000 m^2)
ZVB	Bergen	Greenfield	378 000	Private	Residential area with 720 dwellings (92 000 m^2), a kindergarten and additional service functions
NTNU Campus	Trondheim	University Campus	339 031	Public	Retrofitting and new construction (ca. 136 000 m^2)
Sluppen, Trondheim	ZEN/ +CxC	Mixed use area, mainly commercial	275 000	Private/ Public	Multifunctional local centre with a mobility hub, residential area, offices, warehouses; incl. retrofitting and new construction
Evenstad Campus	Evenstad	University Campus	61 000	Public	Optimisation of energy system
New City – New Airport	Bodø	Former airport	3 400 000	Public	Multifunctional city quarter with residential and business areas; 2 800 dwellings in first construction stage
Fornebu	Bærum	Former airport	3 400 000	Public	Multifunctional city quarter, ca. 265 000 m^2 existing building stock with ca. 3 700 new dwellings
Mære	Steinkjer	Agricultural school	18 000	Public	Optimisation of energy system and control

Table 2: Demo sites for Zero emission neighbourhoods in Norway

5.2 Switzerland

In Switzerland, a certification scheme is in place which is based on the SIA (Swiss Society of Engineers and Architects) Energy Path of Efficiency and the certification scheme "European Energy Award" for municipalities, which labels settlement areas with sustainable use of resources and efforts aimed at climate protection. The 2000-Watt Site certificate was developed as part of the «EnergieSchweiz» programme, whereby the Swiss Federal Office of Energy (SFOE) promotes the implementation of the national energy policy on energy efficiency and renewable energies. Certificates for '2000-Watt Sites' are awarded to housing developments that use resources sustainably in the construction, operation and renovation of their buildings, and in the traffic they generate. The Swiss Federal Office of Energy (SFOE) and the 'Energiestadt' (energy city) association award this certificate in two stages, the first being for 'Sites under development'. The next stage is reached when construction has progressed to the point that at least half of the total living space is in use. The development is then considered a 'Site in operation' and can apply for a new '2,000-Watt Site' certificate.

Actual operating values are then measured to determine whether the Site fulfils the necessary criteria for certification. This certification was developed as part of the SwissEnergy programme, with which the SFOE promotes national energy policy implementation, specifically in the areas of energy efficiency and renewable energy. Through a sub-program called SwissEnergy for municipalities, the SFOE systematically supports projects on a communal level.

5.2.1 Concept and approach (2000-Watt-Society)

The 2000-Watt Society is a concept for a liveable future. It focuses on ensuring a high quality of life that meets the goals of sustainability. The concept incorporates the notion of the resources the earth provides, to use them sensibly and share them equally around the globe. In that sense, the 2000-Watt Society vision represents a sustainable and socially just society. The basis forms the calculation that for every person on earth, 2000 Watts of continuous power (primary energy) are available. This provides enough energy to ensure prosperity and a high quality of life. The CO2 emissions caused by this level of energy consumption must not exceed 1 tonne per person per year. Today, the primary energy consumption per capita worldwide is on average 2500 watts – with enormous country-specific differences.

At present, each Swiss inhabitant uses about 4700 watts. Thus, drastic reductions have to achieved. The goals of the 2000-Watt Society are scheduled to be met between the years 2050-2100. This is under revision since the Paris agreement is focusing on "climate neutrality" to be achieved already by 2050.

Basically, three strategies exist to meet the goals of the 2000-Watt Society:

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- efficiency: use less energy for the same purpose
- consistency: use renewable instead of non-renewable energy resources; use of environmentally friendly technologies; reuse and recycle
- sufficiency: use less, for a better quality of life

Individuals, private companies and the public sector have to combine all these strategies in order to achieve the objectives of the 2000-Watt Society.

5.2.2 Implementation (2000-Watt-Sites)

A 2000-Watt Site is more than the sum of its houses. The «2000-Watt Site» certificate allows to evaluate large site developments in terms of building quality, density, mixed usage and mobility. The total energy consumption of a certified site is optimised to the targets of the 2000-Watt Society. The aim for low resource consumption is achieved by energy-optimised buildings in a well-functioning urban development context.

The development of districts requires a distinct understanding of the situation now as well as a vision of the future district to be able to develop suitable pathways for this transition. In order to be able to do that a district needs to be modelled that consists of several buildings, described in sufficient detail so that the future district can actively manage its energy consumption and the energy flow between them and the wider energy system. The energy master planning process requires an analysis of different scenarios, which include new construction to different levels of energy efficiency, major renovation of all or some buildings comprising building stock under consideration with Deep Energy Retrofit of these buildings, minor renovations with energy-related scope of work, or demolition of some old buildings. Such analysis requires building energy modelling.

A 2000-Watt-Site (200WS) is a new form of settlement. It has achieved a reputation for energy efficiency, renewable energies and climate friendliness and reflects the values of a responsible society. The core idea of the 2000-Watt Site is an ongoing evaluation process of a site's sustainability in terms of energy in development, planning, implementation and operation. Certificates are issued for a limited time period and must be renewed periodically. They are awarded in two stages: As a «site under development» until at least half of the total living space is in use, and after that as a «site in operation».

The concept of a 2000WS takes an integrative view of the entire site rather than individual buildings. It opens up the perspective by depicting the whole living environment. The subject areas of the criteria for evaluation of 2000WS are shown in Table 3.

Subject area	Max. pts.
1. Management system	110
2. Communication, cooperation, participation	70
3. Site utilisation and urban planning	100
4. Supply and waste disposal	70
5. Buildings	90
6. Mobility	90
Site total	530

Table 3: Evaluation criteria of the 2000WS certification scheme

5.2.3 Functional issues

The recent focus was put on recertification of sites that are a couple of years old, as well as sites in transition. For sites in transition, a separate certificate was developed that is used to certify plans, implementation and operation of existing sites that want to transform themselves into 2000WS. This requires setting up a transformation plan and continuous certification (every 4 years) where it has to be shown that the GHG emission reduction is followed according to a reference path (ref.). This ensures a medium timeframe planning and implementation (as many district transformations can take 20 years and more). Here, the goal is derived from the Swiss path towards a zero carbon society (ref. SIA Absenkpfad, etc.).

While features such as comfort and energy efficiency are inherent in MINERGIE buildings, buildings certified according to MINERGIE-P-ECO also meet the requirements of a healthy and ecological construction method and require the disclosure of the built-in "grey energy". Structurally, all the prerequisites for this have been created, but the building can only achieve optimum energy savings during operation. It depends on how much the apartments are heated, how the users ventilate them, whether they leave the lights on unnecessarily, how much hot water they need, and much more. In “Kalkbreite” e.g. the cooperative largely dispenses with regulations to reduce resource consumption and focuses primarily on self-management and awareness-raising. The resource consumption can be calculated with various instruments, e. g. with the ECO2 calculator from Novatlantis or the footprint calculator from WWF. In this way, users receive clues about consumption in the following areas: living, mobility, consumption and nutrition. Every consumption contains a proportion of "grey energy" that can only be influenced to a limited extent, but should nevertheless be included in consumer behaviour. Conscious shopping, avoiding unnecessary purchases and economical use of consumer devices can improve the consumption of “grey energy”.

Site	Location	Certification	Area size (m2)	Achieved	Further information
«Erlenmatt West»	Basel	2017 (re)	25 600	66%	http://erlenmatt-west.ch/
«Stöckacker Süd»	Bern	2020 (re)	1 750 000	74%	http://www.stoeckackersued.ch/
«Burgunder»	Bern-Bümpliz	2017 (op)	7 660	61%	https://www.npg-ag.ch/projekte/siedlung-burgunder/
«Im Lenz»	Lenzburg	2018 (re)	61 400	63%	https://www.imlenz.ch/de/home
«Freilager»	Zürich	2018 (re)	7 050 000	74%	https://freilager-zuerich.ch/
«Hunziker Areal»	Zürich	2017 (op)	41 000	75%	https://www.mehralswohnen.ch/
«Kalkbreite»	Zürich	2021 (re)	6 393	89%	https://www.kalkbreite.net/
«Sihlbogen»	Zürich	2017 (re)	2 100 000	64%	https://www.bgzurlinden.ch/home
«City West»	Chur	2020 (tr)	26 500	57%	https://www.citywest-chur.ch/
«AXA»	Winterthur	2019 (tr)	32 000	63%	https://www.rwpa.ch/axa-gebaeude-g
«Campus Sursee»	Oberkirch LU	2019 (tr)	142 065	67%	https://www.campus-sursee.ch/2000-watt-areal/
«UNIL Dorigny»	Lausanne	2019 (tr)	90 000 000	65%	https://www.unil.ch/index.html
«Campus Mythenquai»	Zürich	2019 (tr)	22 908	68%	https://www.swissre.com/about-us/our-global-presence/campus-mythenquai.html

(op) in operation
(re) in operation, re-certifiied
(tr) in transformation

Table 4: Analyzed 2000-Watt-Sites in Switzerland

Dimension	ZEN	2000 Watt Areal
A. Concept and approach		
Integrated approach	Value chain integration approach of the construction sector	Measurable contribution to resource conservation and climate protection
PED Definition	Development of own ZEN definition during lifetime of ZEN centre, including challenge to apply ZEN in demo sites as long as definition is not finalized	Own definition and certification criteria.
System boundaries	Static geographical system boundary	Static geographical system boundary
Guidelines and tools	Own definition of PED including KPIs as guiding principles for planning and design, Toolbox development of relevant tools	Own definition and certification criteria. A planning tool is available
Energy flexibility	Intra-district energy flexibility	Intra-district energy flexibility
B. Implementation (learnings from pilots)		
Integrative urban transformation process	Urban transformation process based on experimental approach and stakeholder involvement	The quality characteristics are useful for marketing and image-building.
PED competencies	Professional competencies	Professional competencies
Steering and process leadership	(Mainly) public steered demo sites	Private steered process. users enjoy a high standard of housing and living
Holistic process of developing and deploying PEDs	Planning and design phase focused	Planning and design phase focus, but additional new programme focusing on transformation of existing sites
Approach to open innovation and stakeholder interaction	Open innovation is driven by public sector as main project owner (8 of 9 projects are public owned)	Implementation of proven technology
C. Functionality		
Functional sub-divisions in district	Diverse functions, ranging from residential areas with social infrastructure, mixed-used neighbourhoods, university campus areas	Often mixed use, with residential, office, and other functions
Stakeholders involved on site	Diverse, dependant on the context (phase of development and function)	creates added value for all stakeholders – for investors, planners, users, law enforcement agencies and authorities:

Table 5: Summary of findings

Next to living, mobility is the largest consumer of energy in our society. The need for mobility is very individual and therefore an area of sustainability that is difficult to influence. The 2000WS take various measures to make it easier for users to use their mobility more consciously.

In order to approach the goal of the 2000 Watt society, it is essential that all users minimise their energy consumption for mobility. This includes, in particular, avoiding frequent air travel.

2000WS aim at reducing area use; e.g. in Kalkbreite, the average individual space consumption per person, including the share of shared space, is 33.5 m². This is significantly lower than the usual space consumption of 45 m² (41 m² in the city of Zurich) per capita in today's new buildings. Depending on the situation (large building depth of 16.5 m and complicated corner situations), the Kalkbreite has apartments that are too large, which makes it difficult to achieve this objective. This is compensated by the relatively large proportion of apartments with 5 or more individual rooms, in which the space consumption is lower than in apartments with 1 to 4 rooms. In addition to the residential and commercial spaces, the shared rooms help reduce individual space consumption.

6 RESULTS

In this chapter we introduce the two concepts for PED development in Norway and Switzerland and present our findings within the three dimensions Concept and approach, Implementation (Pilots) and Functionality. We present the findings for each dimension and in relation to the Norwegian and Swiss Case. Table 3 gives an overview of the results, which will be further developed in the text beneath.

6.1 Concept and approach

6.1.1 Norway

The centre develops a definition and KPIs to assess zero emission neighbourhoods during its lifetime, which is combining the concept of Positive Energy Districts with climate neutrality. According the current definition, a zero emission neighbourhood aims to reduce its direct and indirect greenhouse gas (GHG) emissions towards zero over its life time. With help of life cycle assessment in all phases of neighbourhood development- including planning, implementation, operation and demolition phase – the total number of emissions are accounted for [Wiik et al., 2019; Wiik et al., 2021]. These emissions are compensated through renewable energy production on site during the operation phase of the neighbourhood, and what makes the neighbourhood become positive in its annual energy balance.

The ZEN centre has developed KPIs within seven categories: GHG; energy, load, mobility, economy, spatial qualities and innovation, both to assess the status towards carbon neutrality and to help stakeholders to guide them to identify the right solutions.

6.1.2 Switzerland

The concept of a 2000-Watt Site takes an integrative view of the entire site rather than individual buildings. It opens up the perspective by depicting the whole living environment. The definition of 2000-Watt-Sites is based on a set of KPIs which are all measured and evaluated for the certificate. These are divided into six themes: management system; communication, cooperation, participation; site utilisation and urban planning; supply and waste disposal; buildings; and mobility. In each theme there are 3 – 4 KPIs that are evaluated and points given (see Table 1 for details).

Most 2000WS provide a Minergie-P-Eco-Bau standard for its buildings which uses approx. 30 kWh/m²/year. That is around five times less than an average house or ten times less than an unrenovated house built between 1960 and 1980. The heating is designed for a comfort temperature of 20 ° C in the living rooms and bedrooms and 21 ° C in the bathrooms with an outside temperature of - 8 ° C. It only needs a little added heat, which is generated by other means (different technical solutions are in use, ranging from district (waste) heating to ground source heat pump). Considerable amounts of electricity are produced from PV systems on the roof.

6.2 Implementation

6.2.1 Norway

The ZEN Centre will contribute to and manage a series of 9 neighbourhood-scale demo sites, which will act as innovation hubs and a testing ground for the solutions developed in the ZEN Centre, moreover the ZEN definition and KPIs are tested and adapted [Wiik et al. 2019]. Learnings identified so far from implementation are:

- Public sector/municipalities as driver for PED development
- Difficulties to put ambitions higher than existing laws
- Land development agencies and public procurement as tools.

6.2.2 Switzerland

So far, 39 2000WS are in operation, implementation and transition in Switzerland (Haase 2021). The implementation was done by various stakeholders.

Interesting is the fact that 2000WS require a single point of contact to be certified. In that sense, a development company or cooperative is formed that plays the official partner in the certification. They pay the fees and receive the certificate (not the site itself). This ensures that a stable ownership is created as a prerequite to form the goal of becoming a 2000WS. If this goal is not agreed upon, it is often not possible to achieve ambitious goals (proof?).

6.3 Functionality

6.3.1 Norway

In the ZEN research centre, a neighbourhood is defined as a group of interconnected buildings with associated infrastructure, located within a confined geographical area. However, the system boundary for analysis of energy facilities serving the neighbourhood is not necessarily the same as the geographical area. Infrastructure includes grids and technologies for exchange, generation and storage of electricity and heat. Infrastructure may also include grids and technologies for water, sewage, waste, mobility and ICT.

6.3.2 Switzerland

User behaviour is decisive for achieving the savings potential. In the event of carelessness such as incorrect ventilation, letting the premise cool down, etc., deviations of several 100% are possible. In summer as in winter, there is a risk that the apartments will overheat if the sun is shining and the sun protection is not used properly. The sun can heat the rooms very quickly and because of good insulation it is difficult to dissipate excess heat. Disciplined shading is therefore necessary in summer.

The residential and commercial buildings have comfort ventilation, which ensures a constant, low exchange of air with filtered outside air. Heat exchangers remove the heat from the exhaust air and thus preheat the supply air. This enables sleeping with the window closed, although all windows can still be opened. In summer as in winter there is a risk of overheating if the sun protection is not used correctly. Excess solar radiation can heat the rooms very quickly. Because of good insulation, it is difficult to dissipate excess heat. In summer, disciplined shading is therefore necessary during the day.

7 DISCUSSION

The differences between the two concepts, what is specific for each of them with respect to certification, social and functional differences is an important analysis.

7.1 Concepts and approaches

The 2000-Watt Site certificate creates added value for all stakeholders – for investors, planners, users, law enforcement agencies and authorities: users enjoy a high standard of housing and living. They can live with the assurance that they are contributing to resource conservation and climate protection. Investors and owners are interested in value-preserving sites offering a high quality of living and working. The quality characteristics are useful for marketing and image-building. Due to the high level of acceptance, cooperation with authorities is much easier. For local municipalities it helps them to bring their concerns to bear at an early stage. The certificate is a guarantee of successful commercial implementation of their energy and climate-policy goals. The certificate was designed as part of the federal programme EnergieSchweiz (SwissEnergy). The Swiss Federal Office of Energy (SFOE) is thus promoting the implementation of national energy policy in the areas of energy efficiency and renewable energy. With the SwissEnergy programme, the SFOE supports specific projects at municipal level.

7.2 Implementation

The ZEN demo sites are all part of a larger research initiative and thus a progressive academic environment. Previous research projects with ambitions goals have shown that on the technical side it is relatively easy to get new technology used, especially when their economic benefits are communicated. It is more complicated to ensure that social practice is implemented. This implies a societal acceptance of the goals and that individuals follow those goals.

In Switzerland, the discussions of the 2000-Watt Society have formed the basis for a large support of the ideas connected to it. Several companies have identified business models around it, such as the 2000WS certification scheme. This scheme forms the structure and the social character of the district. People creating 200WS or moving to them are convinced that what they are doing is good in the sense of "good for society and good for the planet" (quote from one interview). In some 2000WS there are groups of active inhabitants which promote a "sufficient" lifestyle, offer sharing options and promote an alternative way of living (relying less on fossil fuel, vegetarian food, etc.). Car sharing options are available in many sites, together with strict rules for owning cars (and restricted parking space). These are rules in place that inhabitants have to agree to before moving onsite. So there is a possibility for segregation implemented in the system. Further work is needed to identify further implications.

7.3 Functional issues

In a typical district, there will exist several heating, or cooling loops and many electrical subdivisions (distribution boards) on top of various end uses of energy. The different concepts are explained in more detail in Haase (2020).

The energy related operation processes are usually in the control of facility managers and technical staff of each building. Multi-owned districts often lack professional skilled workers. A multitude of performance indicators can be related to this structure. Some performance indicators are important in the design and commissioning of the systems, others are of use in the day-to-day running of the buildings. Energy can be considered to follow function because energy in the end is used to meet requirements defined by the activities that take place in a district. In each district, requirements are diversified by the type of activities/functions (residences, commercial (shops, retail), service (schools, restaurants, cafes, etc.), by the sizes of tenants' rental spaces, or by the type of spaces (public areas, offices, parking etc.). The different activities can be characterised by functional patterns for various groups; – opening hours for commercial buildings will differ from operational hours for technical services and lighting. Facility operation has to meet the requirements of staff in commercial and cultural or service buildings before they open to the public. In districts, many tasks are performed outside of opening hours which require maintaining health and safety for the workers. Examples are maintenance and cleaning, sanitation and supply infrastructures, mobility and transport.

8 CONCLUSION

Concepts and approaches

When we look at the system for implementation, it becomes obvious that with the 2000WS certification scheme developed and applied exclusively in Switzerland, the implementation of ambitious districts has become more explicit than in Norway, where certification is so far done by international certification systems, such as BREEAM..

Implementation

In terms of acceptance and information dissemination the 2000WS have gained some public interest. Many different stakeholder groups have engaged in implementing 2000WS. There are construction companies totally specialising solely in the construction of 2000WS .

Functionality

However, when it comes to the criteria that need to be fulfilled, it seems that 2000WS do not aim for a "net zero emission" balance. The goal is to reduce energy use to (constant?) 2000W power per person. With 8760h/a this corresponds to 17500 kWh/a. The amount of GHG emissions that this energy use corresponds to depends on the GHG emission factor of the energy used and varies for the different purposes. Grey energy is not automatically accounted for in these calculations (only indirectly through the use of certain standards (Minergie). However, the goals of the 2000WS are currently under revision in order to become completely compatible with the energy policy goals of Switzerland (Bundesrat). This means that stricter rules are needed but it remains to be seen if these comprise a rigorous accounting of GHG emissions throughout the lifetime and certain amount of requested renewable energy production on-site as it does in the ZEN/PED approach.

On the other hand, 2000WS have a system in place to account for energy use of mobility and it even explores potential to induce a behaviour change to use less transport systems (by offering car-sharing services and by not allowing to own a private car) and more fossil free transport systems. For example, parking area within the 2000WS are normally restricted and are exemptions rare.

Further research

What could be next research questions? National transition pathway towards PEDS. How many PEDs does a city need? How are the PEDs embedded in the city network? Where do they deliver energy to? How is the mobility connected to the city transport system? How are parking areas managed?

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