Upscaling from Positive Energy Building to District level

The EXCESS team defines Positive Energy Building as “an energy efficient building that produces more energy than it uses via renewable sources, with high self-consumption rate and high energy flexibility, over a time span of one year. A high-quality indoor environment is an essential element in the PEB, maintaining the comfort and wellbeing of the building occupants. The PEB is also able to integrate the future technologies like electric vehicles with the motivation to maximise the onsite consumption and also share the surplus renewable energy.”[1]

In the case of Viikki, the concept is widened to several buildings, moving on Positive Energy District (PED) level. The focus is on increasing energy resilience and flexibility by improving the stability of energy prices for consumers by PEB energy concepts relying on high energy efficiency in building envelope and HVAC, geothermal energy, multi-source heat pump solutions and local production with PV/PVT solutions.

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[1] PEB as enabler for consumer centred clean energy transition: shared definition and concept (EXCESS D1.1)

EXCESS

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1 Baseline assessment of the implementation environment

1.1 Building (district) description

The replication project in Viikki is widening the PEB solutions on District level, to create a Positive Energy District (PED). Four residential buildings and parking hall are located near a district heating network, enabling the connection to bi-directional District heating/District cooling network. Parking hall includes EV charging. The planned amount of new apartments is 120 for around 300 inhabitants.

1.2 Regulatory aspects and public support schemes

In Finland, the legal system operates under a framework of national law that is the primary source of legal authority. However, local and regional regulations also play important roles, complementing and specifying national laws to address local needs and circumstances. While energy performance and fire safety provisions are regulated at a national level, specific construction provisions and soil drilling fall under the jurisdiction of the City of Helsinki.

Energy Performance

In Finland, energy performance regulations for buildings play a crucial role in ensuring sustainability, minimizing energy consumption, and mitigating environmental impact. This overview presents key regulations governing energy performance in buildings within the Finnish context.

Minimum Requirements for Building Energy Performance: Designers must ensure new buildings comply with stringent energy performance standards. This includes minimizing energy loss and achieving efficiency in room temperature, energy consumption, and ventilation systems.

Calculated Consumption of Delivered Energy of Buildings: Energy consumption encompasses heating, ventilation, cooling systems, auxiliary units, consumer equipment, and lighting, minus any energy from environmental sources used within the building.

Net Heating Energy Demand: The net heating energy demand for building spaces is calculated considering conduction loss, leakage air heat loss, and internal thermal loads.

Various other provisions address specific aspects of building energy performance, including building airtightness, ground frost insulation, calculated room temperature for the summer season, specific fan power of mechanical ventilation systems, and heating capacity and electrical power demand of buildings.

Fire Safety Regulations[2]

Fire safety regulations are critical to ensuring the safety of buildings and their occupants.

Structural Integrity in Fire: A building and the elements therein must not cause danger through collapse due to the effect of fire within a specified period after the start of fire. If necessary for the safety of persons, the building shall sustain the combustion of the entire fire load and the cooling phase without collapse.

Fire-Separating Elements: Along with any attached installations and equipment, fire-separating building elements shall be constructed to prevent the spread of fire from one compartment to another for a specified period. Doors, windows, ducts, pipes, ventilation systems, and similar components must be built with materials and in a manner that does not significantly increase the hazard of fire ignition or the spreading of fire and smoke.

Exits and Evacuation: A building must have an adequate number of appropriately located exits that are sufficiently spacious and easily passable. The time to evacuate the building should not be so long as to cause danger.

Fire Extinguishing and Rescue: The prerequisites for extinguishing fires and rescuing people must be ensured in a building and its vicinity. Adequate access must be provided for fire and rescue service equipment, and water supply facilities must be accessible through designated fire lanes.

Environmental regulations

Deep Geothermal Drilling: All construction projects and changes to them which are likely to have significant environmental impacts must comply with the provisions

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under the Act on the Environmental Impact Assessment Procedure.2

In addition to the latter and to the Land Use and Building Act, the provisions stated in the City of Helsinki building regulations must be complied. While constructing underground, it must be ensured that construction will not impact the safety of the existing above- and underground structures. Drilling a hole for a geothermal heat pump must not damage underground district heating, water, sewage and other tunnels, pipes or cables, nor any rock-covered facilities, such as cable tunnels, air-raid shelters or parking garages.[3]

Construction Regulations[4]

The construction regulations in the City of Helsinki ensure that buildings harmonize with their surroundings, preserve environmental integrity, and adhere to legal requirements.

Harmonizing with Surroundings: The surrounding environment and historical layers of the built environment must be considered to ensure buildings form a harmonious ensemble with the urban image and natural values of the area.

Extensions into Public Spaces: Buildings may extend into public spaces under specified conditions, such as foundations and overhanging elements, without disrupting street use. Internal boundary extensions are also allowed for certain structures without causing significant harm to neighbours or the environment.

Surface Level Maps: Building permits require a surface level map to show existing height relationships. Lighting must enhance safety without disturbing residents.

Yard Soil and Stormwater Management: Yard soil must not be levelled to create excessive height differences, and stormwater must be managed to avoid impacting neighbours. Border plantings or fences are required unless otherwise specified.

Shoreline Regulations: Buildings must be at least 20 meters from shorelines, preserving vegetation, topography, and cultural values, with special attention to external noise mitigation.

Building Permits: According to Section 125 of the Land Use and Building Act, a building permit is required for the construction of a building. This permit ensures compliance with all relevant regulations, including those related to energy performance, fire safety, and construction standards.[5]

EU level

At EU level, new constructions must ensure the building meets high energy performance standards, in accordance with the EPBD. The directive also mandates optimizing health, indoor air quality, and comfort levels in building energy calculations, and highlights the IEQ impacts on health, productivity, and overall well-being of building occupants.

2 Act on the Environmental Impact Assessment Procedure, Section 3.

3 Building regulations in Helsinki, Section 58 <https://www.hel.fi/en/urban-environment-and-traffic/plots-and-building-permits/rakennusluvan-hakeminen/building-regulations-in-helsinki#chapter-9--environmental-and-health-protection>

4 BUILDING ORDER OF THE CITY OF HELSINKI Approved by the city council on May 24, 2023 <https://www.hel.fi/static/rakvv/Rakennusjarjestys.pdf>

5 Land Use and Building Act, Section 125.

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1.3 Social Dimension

The PED in Viikki is part of a European project, in which the needs of the users will be probed throughout the project, to ensure that the developed solutions will create an environment that supports the well-being across the diversity of users living and working in PEDs. This entails the involvement of wide variety of stakeholders, including public authorities, practitioners, citizens and inhabitants, and NGOs through dissemination activities, co-innovation workshops, surveys, and other methods of engagement. In the choice of the PED community members, special attention will be paid to diversity of the group (e.g., gender, age, ethnicity) also seeking co-operation with underrepresented groups, like families with limited financial means or persons with disabilities. Through the diversity of the engaged stakeholders, the viewpoints of e.g., vulnerable groups in deprived neighbourhoods can be taken into account in the development of the solutions. The outlined engagement activities will be designed to advance community building on local level, awareness raising and acceptance raising campaign/events; validation of resilient and affordable PED concepts developed in the project; user requirements towards and experience with PED operation tools and solutions. In Viikki, special attention will be paid to user engagement in operational phase increasing energy consciousness (improved PED community level info, apartment level info).

1.4 Assessing strengths, weaknesses, opportunities and threats in relation to a PED compared to a BAU scenario

The hybrid energy system represents an innovative approach to modern energy challenges, offering numerous strengths and opportunities that set it apart from traditional systems. This system boasts lower energy consumption, reduced life cycle costs, and decreased carbon emissions, while harnessing a variety of energy sources through advanced digital controls. However, its complexity and the necessity for extensive expertise present notable weaknesses, along with potential threats such as unpredictable electricity prices and maintenance availability. The potential and challenges of implementing hybrid energy systems are present in the following SWOT analysis:

Strengths

- Lower yearly energy consumption of hybrid system compared to traditional one
- Lower life cycle total costs
- Lower carbon emissions
- Hybrid system enalbes the use of various sources; excess heat from ventilation cooling, excess heat of PVTs, geothermal heat from energy wells
- Smart control system; digital system enables modifications later when new system version sdeveloped
- Self production by PVs

Weaknesses

- Complex hydronic system; full system requires high expertise
- Huge amount of sensosrs and possibilities of sensor failures
- Lot of initial/basic adjustments of hydronic heating network
- Long hydronic lines causes uncontrolled heat losses

Opportunities

- Good opportunities to use the cheapest possible energy source
- Possibilities for new control strategies implemented later; version management/updates for software
- Service fee for service provider

Threats

- Availability of maintenence and service; Lack of service provider
- Uncontrolled/unpredictable electricity prices

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2 Technical information / design specifications

OVERVIEW OF STRUCTURAL SOLUTIONS

In the buildings, energy efficient solutions are prioritized as far as possible. The load-bearing frame of the buildings consists of reinforced concrete partitions and hollow slabs. The basement structures are watertight, cast-in-place concrete structures. The non-load-bearing partition walls between the apartments are rigid plaster walls. At the destination green concrete is used. The building's concrete structure will serve as flexibility asset for heating and cooling. The load-bearing frame of the parking garage consists of reinforced concrete columns and prestressed reinforced concrete beams. Solar panels will be placed on the roof of the parking hall.

OVERVIEW OF THE ENERGY SYSTEM

The energy concepts will replicate the principles of the two previous projects (EXCESS and HYBGEO) but will be further developed and conceptualized and implemented at a new construction site in Helsinki.

The PED innovation is the integration of energy and building solutions at building and district level and connection to bi-directional DH/DC network, thus utilising the capacity of a central network (energy needed in the PED) and enabling the PED to contribute to energy collection from the district (excess energy in the PED). The district will be used as platform to proof the performance of new geothermal collector types and next generation heat pumps (e.g., new refrigerants) bringing these from TRL 2-4 to TRL 6 at component level. The integration of the components in interoperable systems and towards enhanced PEDs and planning practices increases the TRL up to 8-9.

In the project's energy system, deep boreholes, heat pumps, solar panels, ventilation heat recovery, ventilation cooling and an intelligent hybrid energy control system form one whole that works together. The intelligent system collects data from different parts of the energy system and monitors the building's current and predicted consumption data. It takes into account, among other things, the spot price of electricity and weather forecasts when optimizing the system proactively and as needed. With numerous circulation pumps and valves, heat or coolness can be used and circulated in several different ways in boreholes and ventilation machines. With the help of an intelligent control system, both energy production and consumption are optimized and energy is stored in boreholes, which are used both as long-term energy stores and for short-term storage within a day. Residents can monitor the entire energy system in real time and see how energy is produced, consumed and recycled at any given time. Boreholes are 600-800m deep. The number of boreholes is dimensioned in such a way that the temperature of the bedrock does not decrease even during a long review period. The heat pumps have step-by-step heating of the hot water, which achieves high efficiency. The energy efficiency of heat pumps is improved by the use of low-temperature floor heating in all warm rooms instead of radiators.

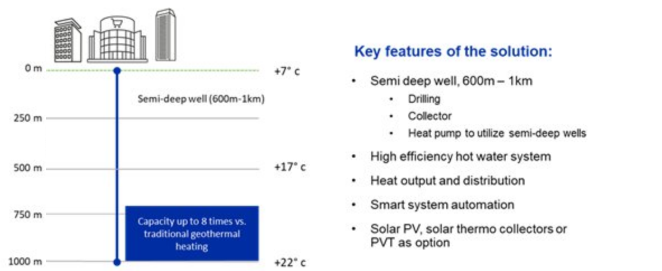

Figure. The key features of semi-deep geothermal system[5]

The ventilation machines are significantly larger than usual and have cooling, which can be used either with the free circulation of heat wells very cheaply, or the cooling can be enhanced by using the system via heat pumps in the summer, especially when solar electricity is available in excess. Ventilation machines have a large heating radiator, which can use low-temperature floor heating water produced by heat pumps with high efficiency.

In addition to ventilation cooling, the ventilation system has a variable air volume (VAV) system that improves indoor air quality and saves energy.

THE PLANNED PERFORMANCE

The buildings in Viikki are still in very early design phase and no detailed information is available about the solutions used for the materials, structures or energy systems. However, the aim is to reach at least the A-class in energy certificate (max 75 kWh/m^2,a), while the demand for new buildings is B-class (max 90 kWh/m^2,a).

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3 Business model details & possible financing arrangements

The EXCESS demonstration and replication case buildings have high insulation and energy efficiency standards combined with renewable energy sources (RES) and a hybrid geothermal energy system with deep boreholes. The high thermal insulation standard and energy efficiency lead to deficient heat energy demand. The building uses high-area heat dissipation systems (floor heating) with a low required temperature level for space heating, enabling low operating temperatures. These low supply temperatures can be provided at high conversion efficiencies from the geothermal energy system, which further reduces the electricity consumption of the heat pump and, therefore, the cost of heating. RES production with PV panels further reduces the building's electricity costs. Surplus PV production could be fed into the grid, leading to an additional revenue stream.

Additionally, the hybrid geothermal energy system, combined with the high insulation standard, a high thermal mass, and a smart building management system, leads to a remarkably high flexibility potential of the building. This adaptability could be an additional revenue stream, reducing payback times and increasing the overall profitability of the replication. It represents an essential aspect of the business model, reassuring stakeholders about the system's adaptability to changing needs. The high complexity of the thermal system requires specialized developers and integrators, which needs to be taken into account when developing the business model.

Furthermore, a high indoor environmental quality is another essential element in the replication case, maintaining the comfort and well-being of the building occupants. Indoor Environmental Quality addresses indoor air quality and thermal, visual, and acoustic comfort. This comfort has been shown to enhance productivity, decrease absenteeism, and improve the building's value.

The demonstration will engage the stakeholders of the earlier PEB projects together with new demo case stakeholders, deepening the lessons learned in earlier cases and facilitating the conceptualisation of the PED solution for different needs (size and user types of the house, connectivity to energy grids, availability of RES, etc.).

The innovative hybrid energy system combined with high comfort and low energy consumption leads to a high property value of the replication which represents a central aspect of the business model. Due to these advantages, the property value is much higher than that of conventional buildings, which could partially compensate for the higher initial investment costs.

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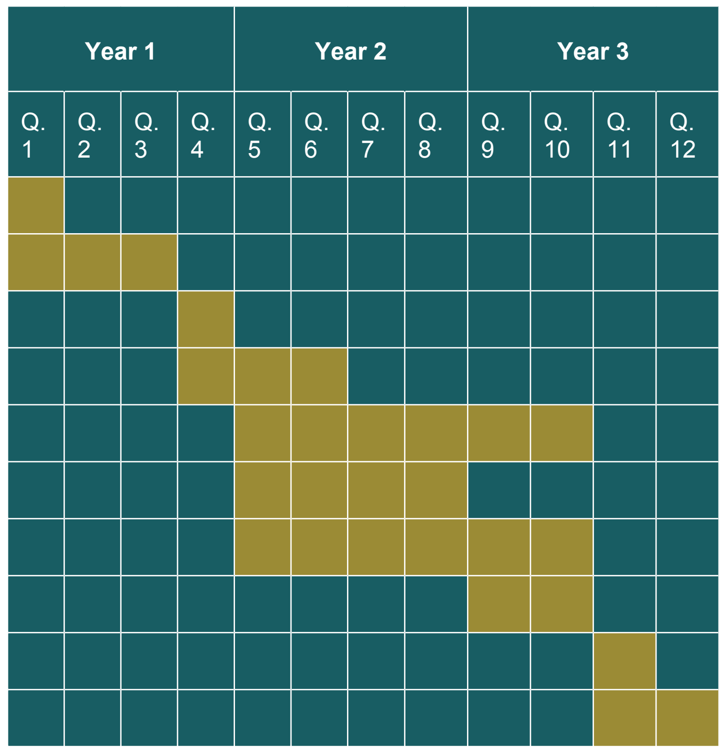
4 Possible PEB timeline

The general timeline for design, construction and operation of PEB building is presented in the table. There is a previous phase to the final decision of construction which can vary depending on the market situation. The latter is formed by the suggestion of the new plot, draft figure of the building(s), draft calculations/market price level, and pre-design and pre-marketing. The energy system installation Q5...Q10 may be shorter, depending on the technical solution. E.g. drilling of boreholes can be done in an earlier phase before construction starts or in a later phase, when the building envelope is constructed.

PEB Activities

- Contract of plot
- Building permit (can take longer)
- Non-appealed permit & setting the guarantees
- Contracts with clients
- Construction
- Detailed designs during the construction
- Energy systems installation
- Commissioning
- Inhabitants moving in
- Operation phase (M30=>...)



5 Local Government Recommendations

In an effort to accelerate energy efficiency, RES-integration and PEB roll-out, as well as financial incentives such as subsidies and grants, local governments could make PEBs/PEDs more attractive in various ways:

Due to the high complexity and lack of expertise that is required, lighthouse projects or programmes should be created for the private sector to develop expertise and gain skills on the practice of complex hydronic systems. Local governments could strengthen those by putting out to tender projects on public buildings, such as libraries and public schools.

In addition, complementing regional and national grant or subsidy schemes, local governments could entertain the establishment of a special fund for PEB support and/or act as a guarantor for banks to offer low-interest loans for PEB projects. Furthermore, LGs could establish support mechanisms to facilitate the access of energy efficiency to the market via energy communities.

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