Location opportunities for green transition energy systems in Raseborg - Finland

Exploratory analysis

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NOVIA
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This exploratory analysis has been mandated by Raseborg Stad and has been prepared by researchers Ruslan Gunko and Jorge Gómez-Paredes, and environmental scientist and geomatics expert Aurelie Noel from Novia University of Applied Sciences, Raseborg, Finland ©2026

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Introduction

Background

Climate goals and the green transition are creating both pressure and opportunities for the land use and energy sectors. Land use solutions broadly support sustainable development and coordinate the needs of different sectors such as the regional needs of energy. Land use planning has then a direct impact on the potential for green energy systems since it also addresses the challenges posed by their space needs, properties or availability (Sweco, 2025).

Several major development projects related to land use and energy systems are currently underway in Raseborg and there is a need to draw a clear picture of the boundary conditions and suitability of energy systems land use.

Yrkeshögskolan Novia University of Applied Sciences has been mandated by Raseborg Stad, in the context of their close cooperation (Kompetenscentret för Hållbara lösningar och energiomställning), to support their municipal planning. Indeed, a new comprehensive master plan covering the entire city is being prepared, which will set the guidelines for land use and zoning in the city and create prevailing planning. It is then critical to include energy systems to also prepare for possible future investment projects and guide consequent local plans (Lohja, 2025).

Goal

To create a clearer overall picture for the municipality, an exploratory analysis is being conducted to assess the potential for green transition energy systems in Raseborg. This analysis might be used as guidance by the decision-maker, the municipality of Raseborg, to welcome potential energy projects and investments.

The goal is to identify potential areas that are suitable for energy systems: available land, meeting land use and energy system requirements and accounting for risks, impacts, legal framework, and development priorities.

The focus is set on *emission-free* renewable energy systems: production (promotion of green energy), transfer infrastructure, conversion, storage, and usage; divided into two categories:

- Traditional: Solar park, geothermal energy, hydrogen/biogas, battery storage and data centre.
- Potential/seasonal: Bioenergy plant, floating solar panel, wind energy, heat storage system, and seawater heat.

Methodology

To start answering this question: “what kind of energy systems would be possible or not, and where”, the analysis has been divided into three parts.

Part 1 – Energy portrayal: This part offers an overview of the energy systems under consideration and some additional suggestions, and their requirements – what the systems need, their potential risks and impacts.

Part 2 – Context map: This part defines where the available land to be developed is, featuring little to no constraint (limiting factor) and/or permissive element (enabling factor) in the municipality.

Part 3 – Cross analysis: This part supports the municipality to define suitable areas. It allows to cross check availability of land, proximity distances and energy requirements with additional considerations.

Disclaimer

This analysis has been conducted based on available data. This report and associated maps have been created to provide guidance and are purely informative. The resulting map provides a reasoned view of the total area and location opportunities.

The storymaps of this project has been published: https://arcg.is/1SaKrq3

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Part 1 – Energy portrayal

Energy systems under consideration

Solar parks

Overview and key requirements

Utility-scale photovoltaic (PV) installations, commonly referred to as solar farms or solar parks, represent large-scale renewable energy installations that use ground-mounted PV systems to generate electricity from solar radiation. These installations are typically designed for utility-scale energy and are connected either directly to the electrical power grid or integrated with energy storage systems, which allow for improved management of electricity supply and demand.

The operational principle of solar panel parks is based on the large-scale deployment of PV arrays of solar modules that convert solar radiation into electrical energy through the PV effect. In addition to the panels themselves, solar farms incorporate various supporting components and infrastructure, including mounting structures, inverters, transformers, electrical cabling, monitoring systems, and grid-connection facilities (Figure 1.1). These elements collectively enable efficient conversion, management, and transmission of electricity to regional or national power networks.

PV technology has been implemented internationally for several decades and has undergone significant technological and economic development. Early applications of solar energy systems were small-scale and decentralized, often installed on building rooftops or other suitable surfaces. Such distributed PV systems are typically designed to supply electricity for local consumption within residential, commercial, or institutional buildings, with the possibility of exporting excess electricity to the grid.

In contrast, solar parks represent a utility-scale approach to solar energy generation. These installations are designed to produce substantial quantities of electricity and contribute directly to the broader energy system by supplying power to the grid. As a result, solar parks play an increasingly important role in national and regional energy transitions, particularly in the context of decarbonization policies, climate mitigation strategies, and efforts to increase the share of renewable energy in electricity production.

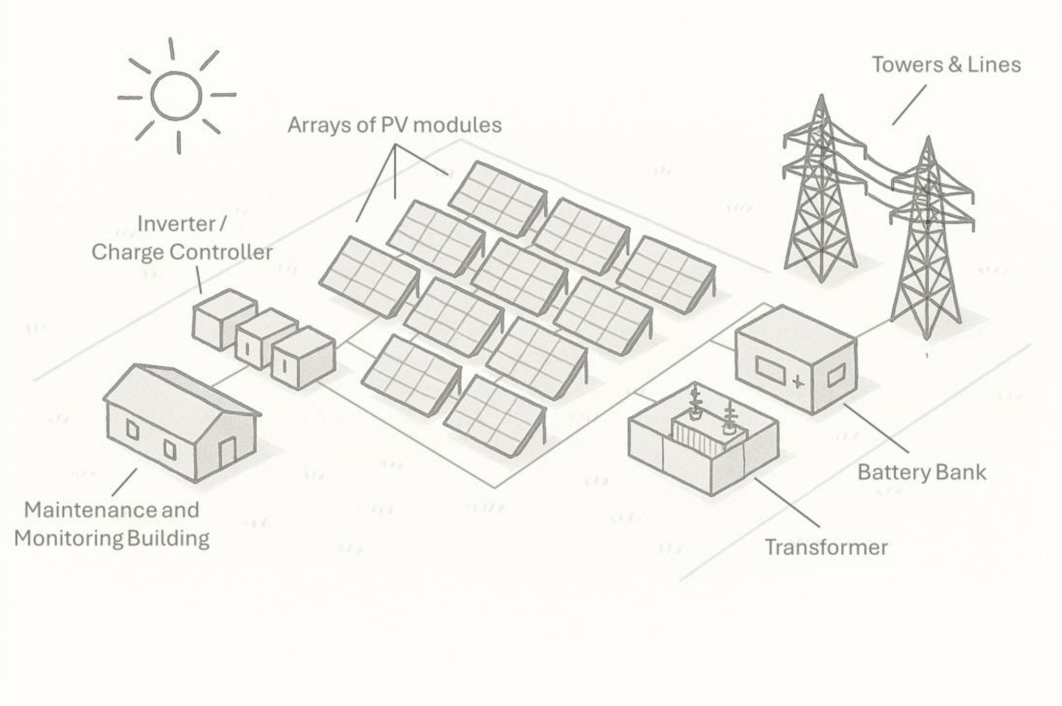

Figure 1.1. Solar parks (AI-generated with prompts by Copilot, J. Gómez-Paredes)

Although Finland is located at high latitudes, the country's solar energy potential is comparable to that of many Central European regions. For example, annual solar irradiation in southern Finland is approximately 900–1000 kWh/m^2, which is similar to northern Germany and Denmark, but lower than levels observed in southern Europe (Jokiniemi, 2019). Finland's industrial-scale power (>1 MW installations) has grown rapidly in recent years, with a record 227 MW added in 2025, and an expected larger increase in 2026 (Suomen uusiutuvat ry, 2026). The current total power capacity of the existing 34 solar parks is 352 MW (Figure 1.2). For a detailed list of the parks and their locations, see Annex 1.

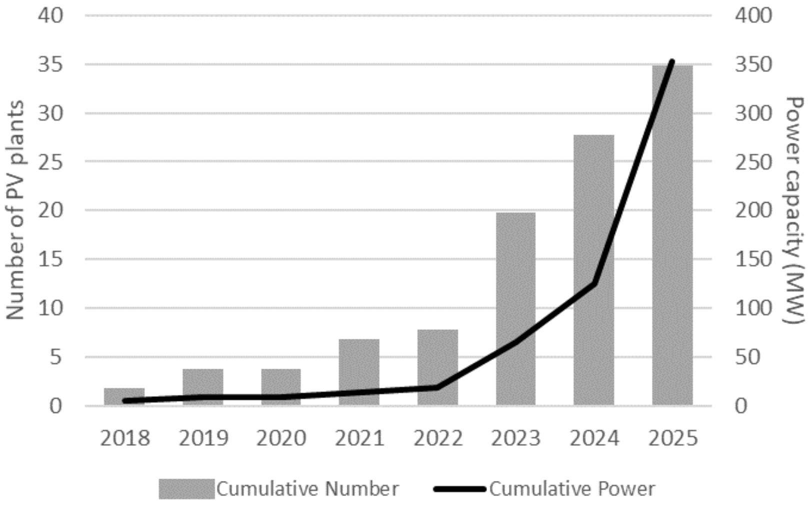

Figure 1.2. Installed industrial-scale PV power in Finland
(Data from Suomen uusiutuvat ry, 2026)

Spatial extent: The efficient and reliable operation of solar panel farms requires the fulfilment of several specific requirements already at the planning and construction stages. From a construction perspective, solar panel farms consist of rows of PV panels mounted on metal frames and securely attached to the ground. These panels cannot be installed too closely together due to shading effects and the need for maintenance access. Therefore, these rows are typically separated by approximately 2,5-3,0 meters to prevent shading and ensure unobstructed access to sunlight, and service roads and access paths between panel arrays must also be included in the design. An important factor in this construction is the appropriate positioning angle of the panels, which is usually about 25–30 degrees and oriented toward the southwest to capture the maximum amount of solar radiation (BayWa r.e., 2026). In addition to transformer stations and inverters, modern solar panel parks increasingly incorporate energy storage solutions, such as battery energy storage systems, to improve energy management and grid stability (U.S. Department of Energy, 2024).

Thus, the development of solar panel fields generally requires relatively large land areas that can accommodate the arrays of PV panels. Suitable sites are typically characterised by open, relatively flat terrain with minimal shading and high levels of solar exposure. In general, a solar farm with a capacity of 1 MW typically requires approximately 1,5-2,0 hectares (ha) of land (Ilmatar, n.d.; EPV Energy, n.d.). A relevant reference for new projects in Raseborg is the Kirkniemi solar project in Lohja, which, based on its reported peak capacity (7,4 MWp; Eltel, 2025) and estimated total area (10 ha.; Surmunen, 2023), has a gross capacity density of 0,74 MWp/ha (equation 1). This value reflects the spacing required in Finnish ground-mounted solar installations, where layout design must account for snow loads and low solar elevation angles. More precise land-use estimates for a specific project would require additional information on site characteristics.

$$\text{(1)} \qquad Gross\ capacity\ density = \frac{Peak\ capacity\ (MWp)}{Total\ land\ area\ (ha)}$$

Site characteristics: The location of a solar park requires careful selection and planning. Site selection processes also must consider additional factors such as proximity to existing grid infrastructure, land availability, environmental and landscape considerations, and accessibility for installation and maintenance activities (Sweco, 2026).

In addition to the area for the installation, it is also recommended to consider the fencing and other security measures to ensure stable and uninterrupted operation of the solar farm (Kurowska et al., 2022). Furthermore, it is important to ensure that the selected site is not exposed to potential seasonal flooding. In cases where such risks exist, preventive infrastructure should be implemented, such as stormwater management systems and the placement of critical equipment in elevated areas. Another crucial factor affecting the efficiency and feasibility of solar farms is easy access to the electrical grid and proximity to existing energy infrastructure (U.S. Department of Energy, 2024).

Potential environmental and social impacts

As with any economic activity, the implementation of a solar park entails both positive and negative environmental and social impacts. Some of the most relevant impacts are summarised in Table 1.1 and explained in the following text.

Table 1.1. Main impacts of solar parks with environmental and social implications

Positive	**Negative**
Reduction in CO_2 emissions	Land-use change
Energy security	Habitat loss
Employment and local economic effects	Landscape impact

Reduction in CO_2 emissions (positive impact): In principle, solar parks contribute to reducing CO_2 emissions by providing a low-carbon alternative to electricity generation. CO_2 emissions associated with PV systems arise primarily during the manufacturing, construction, installation, and end-of-life (EoL) phases, particularly from the production of solar panels, materials used (e.g., silicon, aluminium, glass), and EoL (Parascanu et al., 2025). In contrast, the operational phase —electricity generation—is largely emissions-free. As a result, the lifecycle emissions of solar parks are significantly lower than those of comparable fossil fuel-based energy sources. Hence, solar PV may play an important role in achieving Finland's national target of carbon neutrality by 2035 (Schroderus et al., 2025). However, the actual magnitude of this climate benefit depends on several system-level conditions:

1) <u>Displacement of higher-emission electricity sources.</u> Emission reductions materialise only if solar PV electricity replaces fossil-based or otherwise carbon-intensive generation within the energy system. If solar generation merely adds to overall energy supply without displacing higher-emission electricity sources, the resulting CO_2 emission reductions are largely potential rather than fully realised.

2) <u>Accounting for full lifecycle emissions</u>. All CO_2 emissions across the value chain, particularly manufacturing, transport, installation, and EoL management (decommissioning and recycling), must be rigorously assessed and minimised during the project planning and development, to ensure that the overall carbon footprint remains low.

3) <u>Impacts on carbon sinks</u>. The conversion of land for solar parks can reduce carbon sequestration capacity while simultaneously releasing stored carbon, particularly in cases involving deforestation or disturbance of carbon-rich soils (see Land Use Change below). Therefore, these effects can offset emissions savings.

Consequently, strategic site selection is the most important factor to ensure net climate benefits.

Energy security (positive impact): Solar PV enhances Finland's energy security by increasing domestic electricity production and diversifying the energy mix. By reducing dependence on imported fuels, solar power strengthens the country’s resilience against external energy shocks, as it is largely independent of global energy prices or geopolitical conditions that affect fossil fuels. These objectives align with the Energy and Climate Plan (Ministry of Economic Affairs and Employment of Finland, 2024), which identifies the expansion of renewable energy as a central strategy for ensuring a secure and reliable energy future.

Employment and local economic effects (positive impact): The development of solar parks generates direct employment primarily during the construction and installation phases, encompassing a range of fields such as engineering, earthworks, and electrical contracting. Operational employment is more limited, focused only on monitoring, maintenance, and occasional technical support. Solar parks may also provide land-lease income for landowners and additional municipal tax revenues, supporting the local economy. However, the net economic effect—both in terms of jobs and taxes—should account for any reductions in employment or tax revenue in existing sectors, such as agriculture, forestry, or other land-based uses (see Land use-change and Landscape impacts, below), to assess the overall local economic impact accurately.

Land use-change (negative impact): Changes in land use are the main cause of the most significant negative impacts associated with the development of solar parks. As previously mentioned, a key requirement for solar energy generation is the availability of a sufficiently large area that can be leased or converted for a long-term period, typically 25-30 years (Sweco, 2026). The land must be properly prepared for the installation of solar panels, which often involves clearing, levelling, and ensuring accessibility, including adequate road connections for construction and maintenance. Depending on where solar parks are built, these requirements may alter existing land uses, including forests and agricultural areas, with different ecological and social consequences.

Forest-clearing (deforestation) generates CO_2 through several pathways. If the wood is burned for fuel, the carbon stored in tree biomass is released immediately as CO_2, adding directly to atmospheric concentrations. Even when wood is not burned, the natural decomposition of logging residues, like branches, roots, stumps, and leftover slash, releases CO_2 gradually. Depending on oxygen availability and microbial activity, the decomposition process may also produce CH_4 (methane), a greenhouse gas with a warming potential about 25 times higher than CO_2 over a 100-year period (United Nations Framework Convention on Climate Change [UNFCCC], n.d.). These emissions are particularly significant in primary (“virgin”) forests, which store substantially more carbon than secondary (previously logged) forests (Pascual et al., 2026). If forests are not allowed to regrow (e.g., due to conversion to solar infrastructure), the landscape’s capacity to sequester atmospheric CO_2 is reduced, eliminating an important carbon sink.

In wetlands or peat-rich soils, land disturbance from clearing, trenching, and soil compaction can expose previously waterlogged peat to oxygen, accelerating soil-carbon oxidation and releasing large quantities of CO_2. At the same time, patches of disturbed, waterlogged soils can become anaerobic hotspots, generating CH_4 until the soils dry and oxygen returns (Yang et al., 2025).

Converting agricultural land into solar parks can reduce the availability of productive farmland, which is a limited resource in Finland, with potential implications for food security and rural livelihoods. In regions such as Western Finland, the installation of ground-mounted solar parks on arable land may decrease the area available for crop cultivation, thereby lowering regional agricultural output and increasing reliance on food imports, particularly where dual-use practices are not implemented. Furthermore, construction activities associated with solar park development—such as soil compaction, grading, and vegetation removal—may lead to soil degradation, potentially reducing long-term soil fertility and limiting the feasibility of restoring the land to agricultural use after decommissioning. Over time, large-scale deployment on fertile land may weaken the resilience of local food systems and increase dependence on external food supplies. This land-use change can also affect rural economies and cultural landscapes, especially in areas where agriculture plays a central economic and social role.

Habitat loss (negative impact): Connected to the previously discussed impacts of land-use change, constructing solar parks on natural or semi-natural land can lead to direct habitat loss and fragmentation, negatively affecting multiple species (Lafitte et al., 2023). Boreal forests, wetlands, and species-rich grasslands—common in Finland—harbour specialised ecological communities that are particularly sensitive to permanent land conversion. When solar parks replace these habitats, they reduce available living space, alter vegetation structure and local microclimates, and can disrupt ecological connectivity at the landscape scale. Although these effects have not yet been extensively documented in peer-reviewed studies specific to Finland, recent academic theses consistently identify terrestrial biodiversity loss driven by land occupation as a key environmental impact of utility-scale solar electricity production (see, for example, Paananen, 2025; Leviskä, 2024).

Landscape impact (negative impact): Beyond their physical footprint, solar parks can affect landscapes through how they are perceived and experienced. These perceptions vary among individuals and are shaped by cultural values, sense of place, and expectations of what a landscape should look like. In Finland, where outdoor recreation, scenic and aesthetic appreciation, and nature-based tourism are closely linked to rural and semi-natural landscapes, solar parks may alter the visual character of recreational areas, potentially affecting such activities and tourism appeal. In Raseborg, the coastal setting, forested countryside, archipelago environments, and historic rural landscapes support outdoor recreation, second-home living, and nature-based tourism, making visual landscape quality a key cultural ecosystem service.

Concluding remarks: It is important to note that all of the impacts discussed above are highly context specific. The relative significance of positive and negative effects depends largely on the transformation from the baseline land-use condition to the project's implementation, rather than on the technology alone. In other words, the sustainability of a solar park will be determined less by the fact that it produces renewable energy and more by where and how it is developed. For instance, solar parks can be located on land with limited alternative uses, such as brownfield sites, former industrial areas, or low-productivity agricultural land. Siting projects on such low-conflict landscapes will significantly reduce the negative impacts previously discussed. Also, emerging land-use concepts such as agrivoltaics—combining solar production with agriculture—may maintain productive land use while enhancing rural income streams and energy generation (University of Turku, 2025).

By contrast, a project that reduces forested area or replaces managed agricultural areas, thereby lowering carbon sequestration capacity, releasing carbon, and potentially affecting biodiversity, in order to generate electricity that does not meaningfully displace fossil-based energy would be difficult to characterise as sustainable, despite producing renewable electricity.

Ultimately, the sustainability of a solar park depends on the consideration of positive and negative impacts assessed in relation to local environmental, social, and economic conditions. Consequently, their development requires careful spatial planning, an independent and site-specific environmental impact assessment, and early stakeholder engagement to ensure that renewable energy expansion is balanced with environmental protection, biodiversity conservation, and sustainable land-use management (Puustinen et al., 2025).

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Geothermal energy

Overview and key requirements

Geothermal energy is a renewable energy source derived from the Earth's internal heat, stored in underground rocks and fluids (see Figure 1.3). It is extracted and utilised through heat exchange processes, typically involving circulating fluids to transfer heat to the surface for practical use. The process requires preparatory measures, including the drilling of wells at varying depths depending on the scale and type of the geothermal energy project. Although this renewable energy system is less prevalent across the EU, it demonstrates considerable potential and is already being implemented in Finland. Its current level of adoption remains limited compared to more established renewable technologies such as wind and solar power; however, Finland's geological conditions and energy demands create favourable circumstances for its further development (European Commission, n.d.; Dulian, 2023; GTK, 2025).

Figure 1.3. Geothermal Energy System
(Source: European Union)

The most commonly used geothermal solution in Finland is the ground-source heat pump, which extracts heat from the upper ground layers (typically 100–300 m) using boreholes and a heat pump system. This is primarily a local-scale approach and is widely applied in residential buildings, as well as in schools, hospitals, and office buildings. The system requires boreholes drilled into bedrock. The number and depth of boreholes depend on the size of the building and its heating demand (for example, approximately one borehole per 100-150 m^2 of heated floor area, with depths typically ranging from 50 to 200 m, depending on local geological conditions). There are also specific requirements regarding distances: boreholes should generally be spaced approximately 10-15 m apart, located at least 3 m from building foundations, and at least 4 m from public infrastructure. In addition, installation may be restricted or prohibited in designated groundwater protection areas (City of Helsinki, n.d.; City of Riihimäki, n.d.; GTK, 2019; Majuri et al., 2021).

Medium-depth geothermal systems operate at greater depths, where higher temperatures allow for more efficient heat production (typically at depths of 1-2 km). However, the construction and infrastructure requirements in this case are significantly more demanding, and the suitability and efficiency of such systems depend on the local thermal gradient. Consequently, detailed investigation of bedrock conditions and the development of subsurface temperature profiles are required. These systems are generally more suitable for larger buildings or facilities with continuous heat demand.

Deep Enhanced Geothermal Systems (EGS) are intended for large-scale heat production, particularly in urban areas with district heating networks. These systems require very deep drilling, typically at depths of 4-7 km, making them both costly and technically complex. They also require sufficiently high temperatures at depth and stable geological conditions. In Finland, EGS technology is still considered largely experimental and, due to its complexity and cost, is not suitable for smaller municipalities (Kukkonen and Pentti, 2021; Arola, 2022).

Steam-based geothermal systems are not suitable for Raseborg or Southern Finland due to insufficient underground temperatures and unfavourable geological conditions. Such systems require high-temperature geothermal resources, typically exceeding 150 °C, in order to generate steam for electricity production. However, Finland is located in a geologically stable Precambrian shield area characterised by a low geothermal gradient (app. 8–17 °C/km) and low heat flow. As a result, temperatures in the subsurface increase very slowly with depth (Piipponen et al., 2022).

Potential environmental and social impacts

Geothermal energy systems encompass a diverse set of technologies that differ substantially in scale, depth, and risk profile. In the Finnish context, however, it is essential to distinguish clearly between a) ground-source heat pump–based systems, which are widely deployed and primarily used for heating, and b) geothermal electricity generation, which relies on deep, high-temperature sources and is absent in Finland. Each of these technologies entails distinct environmental and social impacts. As geothermal electricity generation is not considered a viable emissions-reduction pathway, largely due to the low geothermal gradient associated with the country's thick Precambrian crust and lithosphere (Kukkonen, 2000), this chapter focuses exclusively on the impacts of heat pump-based systems. The most relevant impacts are summarised in Table 1.2 and elaborated below.

Table 1.2. Main impacts of geothermal energy with environmental and social implications

Positive	**Negative**
Reduction in CO_2 emissions	Groundwater impacts
Energy security and reliability	Construction-phase disturbances
Local employment and economic effects	

Reduction in CO_2 emissions (positive impact): Geothermal energy contributes to reducing greenhouse gas emissions by providing low-carbon heat and, in specific geological contexts, electricity. In Finland, the dominant climate benefit arises from geothermal heat pump systems, which supply space heating and domestic hot water for buildings and district heating networks, resulting in emission reductions. On the other hand, lifecycle emissions from geothermal heating systems are primarily associated with the electricity consumed during operation (to run the heat pump), while emissions from drilling and construction (manufacturing and installation of ground heat exchangers) are smaller contributors (Aresti et al., 2022). This, however, depends on the carbon intensity of the electricity mix. When heat pumps are powered by low-carbon electricity, they can contribute significantly to reducing greenhouse gas emissions and support progress toward carbon neutrality.

Energy security and reliability (positive impact): Geothermal heat pump systems provide stable baseload heating throughout the year, largely independent of weather conditions and seasonal variability. This characteristic distinguishes geothermal energy from variable renewable energy sources such as wind and solar power, making it particularly well suited to Finland's climatic conditions. From an energy system perspective, geothermal heating can reduce dependence on imported fuels and enhance the resilience and security of municipal energy systems.

Local employment and economic effects (positive impact): Heat pump–based geothermal projects support local drilling contractors, designers, and maintenance services and are often implemented across multiple small sites, distributing economic benefits locally. Operational employment is limited, focusing on system maintenance.

Groundwater impacts (negative impact): Potential impacts on groundwater constitute the most important environmental risk associated with heat-pump-based geothermal systems. Borehole drilling and operation can affect groundwater flow, temperature and, in rare cases, quality, particularly if boreholes are improperly sealed or intersect sensitive aquifers (Casasso & Sethi ,2019). Hence, geothermal installations require prior hydrological assessments and are prohibited in Finland's groundwater protection areas.

Construction-phase disturbances (negative impact): Geothermal heat pump projects can cause temporary local disturbances during drilling and installation. These impacts include noise, vibration, and short-term air emissions from drilling equipment (Casasso & Sethi, 2019). Such disturbances are most relevant in densely populated urban areas and near sensitive land uses such as schools or healthcare facilities. These impacts are generally short-lived and can be mitigated through time restrictions, noise control measures, and clear communication with residents.

Concluding remarks: In the Finnish context, geothermal energy is used predominantly for heating purposes, particularly residential and building-scale applications, rather than broader electricity generation or large-scale energy production. Heat-pump-based geothermal systems constitute a low-impact, reliable, and effective renewable heating solution with climate-mitigation and energy-security benefits. When implemented in appropriate locations and supported by sound engineering and regulatory frameworks, geothermal heat pumps can play an important role in Finland's energy transition.

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Hydrogen/biogas pipeline

Overview and key requirements

The hydrogen pipeline and its infrastructure represent a national-scale approach to energy production and distribution, rather than a local-scale initiative. While the interest and cooperation of municipalities are important for the successful construction and operation of the pipeline, it is crucial to recognize that many aspects of building the pipeline within a municipality fall under government authority due to security considerations, strategic importance, and the scale of investment required.

Hydrogen is categorized by production method, commonly represented by colour (IEA, 2019):

- Brown hydrogen is produced from lignite (soft coal) through a process called coal gasification, where the coal is heated to high temperatures to release hydrogen. This process simultaneously produces large amounts of CO_2, which is released into the atmosphere. Despite its historical use in industry, this method has a very high carbon footprint.
- Black hydrogen is produced from hard coal using a similar gasification process, where the coal is heated to extract hydrogen. Like brown hydrogen, it generates significant CO_2 emissions, which are released into the atmosphere, making it highly carbon intensive.
- Grey hydrogen is produced from natural gas using Steam Methane Reforming (SMR), where natural gas is heated with steam to release hydrogen. This process simultaneously generates CO_2, which is released into the atmosphere. Despite the popularity of this method due to its cost-efficiency, it has a large carbon footprint.
- Blue hydrogen is produced using a similar method as grey hydrogen, with the key difference that CO_2 is captured and stored during the process, often underground. While blue hydrogen results in lower emissions compared to grey hydrogen, it still relies on fossil fuels, introducing concerns related to energy security and continued dependence on natural gas.
- Green hydrogen is produced using renewable energy sources, primarily water and electricity generated from wind, solar, or hydropower. Through electrolysis, electricity splits water into hydrogen and oxygen. Because the process uses clean energy, green hydrogen has lower emissions comparing to other types and is considered the cleanest type of hydrogen. The planned hydrogen pipeline passing through Raseborg is intended to transport green hydrogen (Gasgrid, n.d.). However, the overall sustainability of green hydrogen is debated due to significant energy losses, infrastructure demands, and the fact that it often diverts renewable energy from more efficient direct uses (Pashchenko, 2024; Shahzad et al., 2026).

A critical feature of hydrogen is its ability to act as an efficient storage medium for electricity generated from wind or solar power. Excess electricity can be converted into hydrogen and stored in large tanks, underground storage facilities, or other storage systems. Later, the hydrogen can be converted back into electricity using power plants or fuel cells, or it can be used directly as fuel in industrial processes, shipping, or steel production (Gado, 2026). Access to hydrogen could stimulate the development of various industries, including steel production, chemical manufacturing, oil refining, the production of synthetic fuels and fertilizers, transport applications from buses to ships, and energy supply for data centres (IEA, 2019).

Efficient transport and use of hydrogen require the development of supporting infrastructure. Compressor stations, typically located every 100 to 200 kilometres depending on the pipeline design, are essential for maintaining pressure and regulating flow within the pipeline (Wang et al., 2021). Regulation and metering stations, often located close to local users, monitor hydrogen flow and reduce pressure before distribution. Branch pipelines are necessary to connect local users, such as industrial facilities or refuelling stations, to the main pipeline, particularly when distances are significant (OECD, 2023). Hydrogen storage facilities may also be installed to ensure a stable supply for local users and provide backup in case of emergencies. Because hydrogen is very light and highly flammable, comprehensive safety measures are essential. These include leak detection systems, emergency shutdown valves, communication, and education for residents in potentially affected areas, and local emergency alarm systems with training on potential incident scenarios (UNE). Proper planning and investment in infrastructure, safety, and community awareness are therefore essential to ensure the safe, efficient, and reliable operation of a hydrogen pipeline within a municipality.

Considering that the hydrogen pipeline planned to pass through Raseborg will transport green hydrogen, its primary value for the municipality lies in enabling the decarbonization of existing industrial activities while also attracting new low-emission industries to the area. Potential sectors that could benefit from such a connection include metal processing, chemical manufacturing, and the production of synthetic fuels or fertilizers, as these rely on a stable hydrogen supply, particularly for high-temperature heat or as a feedstock. To support local hydrogen use, infrastructure such as connection points, distribution pipelines, and storage facilities would need to be developed in coordination with industrial actors. Land requirements for hydrogen-related infrastructure vary significantly depending on scale and function. Small connection and regulation stations typically require only limited space, often within the range of approximately 0.1–1 hectare, reflecting their role as compact pressure regulation and monitoring points integrated into existing infrastructure layouts (IEA, 2019). Hydrogen refuelling stations and local storage facilities generally require larger plots, approximately 1–5 hectares, due to safety buffers, compression equipment, and storage systems (IRENA, 2020; Hydrogen Council & McKinsey & Company, 2021; Wang et al., 2026). Electrolysis plants used for hydrogen production typically require around 5–20 hectares depending on capacity, as they include electrolyzer units, power conditioning equipment, water treatment, and storage systems, along with mandatory safety spacing (IRENA, 2020). At the largest scale, integrated industrial facilities such as hydrogen-based steel production, chemical plants, or synthetic fuel production hubs can occupy tens to hundreds of hectares, reflecting the combination of production units, storage, logistics infrastructure, and associated industrial processes (European Commission, 2020; Hydrogen Council & McKinsey & Company, 2021).

Potential environmental and social impacts

The development of hydrogen pipeline infrastructure entails a mix of potential environmental and social benefits and risks. Given its national scale, a hydrogen pipeline entails impacts arising from its physical footprint and their role in enabling broader energy-system transformation. Considering that the pipeline planned through Raseborg is intended to transport green hydrogen, the most relevant impacts are summarised in Table 1.3 and discussed below.

Table 1.3. Main environmental and social impacts of a hydrogen pipeline

Positive	Negative
Support for decarbonization	Land-use and construction-related impacts
Energy-system flexibility and reliability	Risks related to hydrogen leakage and safety
Regional economic effects	Local disturbance and social acceptance

Support for decarbonization (positive impact): At the energy-system level, hydrogen pipelines may contribute to climate mitigation by enabling the use of green hydrogen in sectors that are difficult to electrify, such as steel production, chemical manufacturing, and heavy transport (IEA, 2019). If green hydrogen effectively replaces fossil fuels in these applications, substantial CO_2 emission reductions may be achieved. In this sense, a hydrogen pipeline infrastructure may form an important component of Finland's broader national decarbonisation strategy.

Energy-system flexibility and reliability (positive impact): Hydrogen infrastructure can enhance energy security by increasing system flexibility and enabling large-scale storage of renewable energy. Hydrogen offers the possibility to store excess wind or solar power over longer periods and transport it to industrial users or energy hubs, potentially improving resilience against seasonal variability and supply disruptions (Gado, 2026). For Finland, this could support national energy-security objectives.

Regional economic effects (positive impact): The construction and installation of a hydrogen pipeline generate temporary employment in engineering, construction, and logistics, while long-term operation creates limited but specialised technical jobs. Furthermore, the availability of hydrogen as an energy source can stimulate industrial development by supporting emerging clean-technology sectors and energy-intensive industries (IEA, 2019). In regions such as Raseborg, potential economic benefits depend on whether local or nearby industrial users connect to the pipeline. Without such local connections, economic impacts may remain modest and primarily associated with short-term construction activities.

Land-use and construction-related impacts (negative impact): The most direct environmental impacts of a hydrogen pipeline occur during the construction phase, with the nature and extent of impacts differing depending on whether the pipeline is installed below or above ground. For buried pipelines, trenching, excavation, and backfilling can disturb habitats, vegetation, and soils, particularly along linear corridors crossing forest areas, agricultural land, or sensitive ecosystems. These activities may disrupt soil structure, drainage patterns, and root systems, and can lead to temporary habitat fragmentation, although these detrimental effects may be significantly reduced with remediation measures after construction (Brehm & Culman, 2022). Above-ground pipeline sections, while typically requiring less extensive excavation than buried infrastructure, can result in more persistent surface-level impacts. Construction activities may lead to immediate vegetation loss, including plant mortality and alterations in the diversity and arrangement of plant communities. In the longer term, pipelines create linear corridors that are often maintained with grasses or low ground cover to facilitate inspection and prevent soil erosion, resulting in a sustained alteration of landscape structure and ecological conditions. These corridors require ongoing vegetation clearance and access for maintenance, which can contribute to the fragmentation and modification of habitats across diverse ecosystems. In addition, above-ground pipelines may act as physical or visual barriers to wildlife movement, particularly for larger mammals, unless mitigation measures—such as elevating pipelines to allow passage—are implemented (Richardson et al., 2017). From a human perspective, the presence of visible pipeline infrastructure and cleared corridors can also alter landscape aesthetics, potentially reducing visual amenity and affecting the perceived quality of natural and rural environments. Consequently, the choice between above- and below-ground routing has important implications for both short-term construction impacts and long-term environmental and land-use considerations. In addition, above-ground facilities such as compressor stations, metering stations, and safety installations may further intensify landscape impacts by introducing permanent structures that alter the character of rural or semi-natural areas and compete with existing land uses, particularly near residential or recreational landscapes.

Risks related to hydrogen leakage and safety (negative impact): Hydrogen is a colourless, odourless, and tasteless gas that is highly flammable and can ignite at concentrations as low as 4% in air (Calabrese et al., 2024). Consequently, the transport of hydrogen involves inherent risks of fire and explosion in the event of pipeline damage, material degradation, or equipment failure, leading to leakages. These risks are significantly mitigated in modern hydrogen pipeline systems through the application of high engineering standards, including advanced monitoring and leak-detection technologies, pressure-management systems, and emergency shutdown mechanisms (Calabrese et al., 2024). Effective risk management further requires comprehensive emergency preparedness and close cooperation with local authorities and nearby residents.

Local disturbance and social acceptance (negative impact): Aligned with the negative impacts discussed above, particularly those related to safety risks, a hydrogen pipeline may give rise to social-acceptance challenges. Even where technical risks are well managed, public perceptions of danger can contribute to risk amplification and to so-called non-in-my-backyard (NIMBY) responses, especially among residents living close to pipeline routes or associated infrastructure. Such perceptions may, in turn, affect the desirability and perceived value of nearby land or property. Accordingly, early and proactive stakeholder engagement is essential. Clear and transparent communication regarding hydrogen safety standards, emergency procedures, and the long-term objectives of the infrastructure project can help build public understanding and trust (Schönauer & Glanz, 2022). In the absence of meaningful engagement and effective information sharing, local opposition may emerge even in situations where objective technical risks remain relatively low.

Concluding remarks: While pipelines transporting green hydrogen may enable substantial emissions reductions at the national and industrial scale, their local impacts are primarily shaped by construction disturbance, land-use interactions, safety considerations, and social-acceptance challenges. Importantly, the associated climate benefits are conditional rather than inherent. The pipeline itself does not reduce emissions; its effectiveness depends on the extent to which green hydrogen use displaces fossil-based or otherwise carbon-intensive energy sources. For example, climate benefits may materialise if the pipeline enables the utilisation of surplus renewable electricity by converting it into hydrogen that can later be used as low-carbon, dispatchable energy. In contrast, if renewable electricity used for hydrogen production could have been directly applied to displace fossil energy, and hydrogen use merely adds energy to the system without significant substitution effects, the net climate benefit may be limited. Beyond these considerations, the sustainability of a green hydrogen pipeline depends significantly on routing choices, engineering standards, safety management, and stakeholder engagement. Careful spatial planning, transparent risk communication, and alignment with well-defined national decarbonisation objectives are therefore essential to ensure that potential long-term benefits outweigh local environmental and social costs.

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Battery storage facilities

Overview and key requirements

It is common for battery storage facilities to be referred to as Battery Energy Storage Systems (BESS). These systems consist of large batteries that store electricity for later use. The electricity stored in BESS can serve multiple purposes, such as utilising electricity when prices are low for later efficient use, providing backup power for critical infrastructure, or supporting other facilities. BESS also plays an important role in balancing the grid and can be particularly useful for storing electricity generated from renewable sources during periods of low demand, allowing it to be saved for future use (e.g., storing excess electricity produced by a solar park in summer; World Bank, 2020; Feng et al., 2022; Garttan et al., 2025).

There are commonly used technologies for BESS:

- Lithium-ion batteries: Lithium-ion is the most widely used technology due to its high energy density, efficiency, and fast response time. However, these batteries are sensitive to degradation from repeated charge cycles and require thermal management systems to prevent overheating (Gutsch and Leker, 2022).
- Sodium-sulphur batteries: These batteries operate at high temperatures (300–350 °C) and offer high energy capacity, making them suitable for large-scale grid storage. Their longer life cycle is an advantage, but they require excellent insulation and continuous safety monitoring due to the high operating temperature (Liang et al., 2023).
- Flow batteries: These batteries store energy in liquid electrolytes contained in external tanks. Their capacity can be increased by enlarging the tanks, and they are not sensitive to high numbers of charge/discharge cycles. While their lifetime is long, they have lower energy density and require much more space for installation compared to lithium-ion systems (Reber et al., 2023).
- Lead-acid batteries: These batteries consist of lead plates immersed in sulfuric acid. This older technology is low-cost and reliable, but it has lower energy density, shorter lifespan, and higher maintenance requirements compared to modern systems. Therefore, lead-acid batteries are no longer recommended for new BESS installations (May et al., 2018).

There are several unified requirements for BESS that apply regardless of the battery technology used. These include a reliable connection to the power grid and the necessary infrastructure to ensure stable operation and efficient interaction between the BESS and the grid. Key components include transformers, inverters, protection and monitoring systems, and efficient cooling systems, as well as planned battery replacement management, typically occurring every 10-20 years. Equally critical to the efficient operation of BESS are adequate safety measures, due to the high operational risks associated with large-scale energy storage. Safety requirements typically include fire detection systems, regular fire safety inspections, thermal monitoring, flood prevention management, efficient ventilation, emergency shutdown systems, and the designation of hazard containment zones. These zones must be continuously managed and maintained, often incorporating fire protection barriers, blast zones, restricted access areas, and other safety measures as needed, depending on the facility's design and risk profile (European Parliament and Council, 2023; EASE, 2025).

Altogether, these requirements mean that BESS installations occupy significant land areas, which vary depending on the scale of the system (Table 3.3).

Potential environmental and social impacts

While BESS provide important systemic benefits, their environmental and social impacts depend on system scale, battery technology, siting, and operational design. The most relevant general impacts are summarised in Table 1.4 and discussed below.

Table 1.4. Main environmental and social impacts of BESS

Positive	Negative
Support for decarbonization	Land-use change
Energy security and grid resilience	Resource-use and lifecycle impacts
	Fire and safety risks
	Local disturbance and social acceptance

Support for decarbonization (positive impact): BESS support climate-mitigation efforts by enabling higher shares of variable renewable energy, such as wind and solar power, within the electricity system. By storing electricity during periods of excess generation and releasing it during peak demand or low-generation periods, BESS facilitate more efficient use of low-carbon electricity. However, BESS contribute to emission reductions only if the stored electricity replaces fossil-based generation or avoids the need for carbon-intensive peak power. In addition, lifecycle greenhouse-gas emissions associated with battery manufacturing, transportation, replacement, and EoL management must be taken into account, as these factors reduce the overall climate benefits of BESS.

Energy security and grid resilience (positive impact): BESS enhance energy security by improving grid reliability, frequency regulation, and resilience to short-term disturbances. At the utility scale, they allow for a wider mix of energy sources by enabling higher shares of renewable energy in the electricity system and supporting the stable operation of networks with increasing levels of variable generation. For Raseborg, which is not a major electricity-generation hub but hosts industrial activity, infrastructure, and ports, BESS could contribute to energy system resilience.

Land-use change (negative impact): As noted above, depending on their type and scale, BESS may require infrastructure that occupies several hectares. In Raseborg, where land is used for forestry, agriculture, housing, and recreation, the siting of BESS may therefore give rise to land-use impacts similar to those associated with solar parks. For instance, if BESS are developed in forested areas, they may result in deforestation-related greenhouse gas emissions as well as the long-term loss of carbon sequestration capacity (Pascual et al., 2026). Where BESS are sited on wetlands or peat-rich soils, site preparation activities such as excavation, grading, and soil compaction may disturb carbon-rich substrates, reduce local carbon-storage capacity, and lead to greenhouse-gas emissions

(Yang et al., 2025). Although spatially more localised, BESS installations on natural or semi-natural land may still cause direct habitat disturbance, particularly in sensitive ecosystems. Similarly, the installation of BESS on agricultural land may lead to the loss of productive farmland.

Resource-use and lifecycle impacts (negative impact): BESS require substantial material and energy inputs during manufacturing, particularly in the case of lithium-ion technologies, which rely on critical raw materials such as lithium, cobalt, nickel, and manganese (Peters et al., 2017). The extraction and processing of these materials are frequently associated with significant environmental impacts in mining regions, including habitat degradation and pollution, with adverse effects on biodiversity (Sonter et al., 2020). In some regions, these activities are also linked to social and governance challenges. Additional life-cycle impacts arise from the periodic replacement of batteries and from EoL management. Although recycling technologies are advancing rapidly, current recycling rates and material recovery efficiencies remain variable. Improper handling or disposal of EoL batteries can result in the leaching of hazardous substances—including cobalt, nickel, and electrolyte compounds—into soil and groundwater, thereby posing risks to ecosystems and human health.

Fire and safety risks (negative impact): Safety risks constitute a critical environmental and socio-technical concern associated with BESS, particularly those based on lithium-ion chemistries. Lithium-ion batteries are susceptible to thermal runaway—a self-reinforcing exothermic reaction triggered by mechanical, electrical, or thermal abuse—which can result in high-intensity fires, explosions, and the release of hazardous gases such as hydrogen fluoride and other toxic decomposition products (Larsson et al., 2017; Wang et al., 2012). These incidents are notably challenging to control and extinguish due to the potential for cell-to-cell propagation and re-ignition. Sodium–sulphur batteries, by contrast, operate at elevated temperatures (typically 300–350 °C) and present distinct safety hazards, including the risk of molten sodium combustion and violent reactions if containment is compromised (Liang et al., 2023). Flow batteries, such as vanadium redox systems, generally exhibit lower fire and explosion risks due to their aqueous electrolytes and decoupled energy storage architecture; however, they introduce alternative hazards related to the handling, leakage, and disposal of large volumes of corrosive or toxic electrolyte solutions (Alotto et al., 2014). These risks can be substantially mitigated through comprehensive system design and engineering controls, including advanced thermal management, fire detection and suppression systems, physical separation and containment measures, and emergency shutdown mechanisms. Nevertheless, residual risks remain due to factors such as component degradation, external impacts, control system failures, or inadequate maintenance, highlighting the importance of robust safety standards and operational oversight.

Local disturbance and social acceptance (negative impact): BESS installations may raise public concerns related to fire safety, chemical hazards, and the long-term environmental risks discussed above, as well as to moderate operational noise generated by cooling systems, inverters, and transformers. These impacts are generally manageable through appropriate system design, the establishment of adequate buffer distances, and transparent stakeholder engagement, including clear communication of safety measures and risk-mitigation strategies.

Concluding remarks: BESS can deliver significant system-level benefits—such as grid stability and renewable energy integration—while generating relatively limited local impacts. However, poorly located installations may result in substantial adverse effects primarily associated with land-use change. Avoiding undeveloped, forested, carbon-rich, or otherwise ecologically valuable areas and productive lands would minimise environmental impacts. Priority should instead be given to siting BESS within existing energy infrastructure corridors or other industrialised zones. The utilisation of brownfield sites, former industrial areas, or low-productivity agricultural land can further reduce pressure on natural ecosystems and prevent negative impacts. Beyond spatial considerations, critical factors are robust safety management practices and effective stakeholder engagement.

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Data centres

Overview and key requirements

A data centre is a physical facility that houses infrastructure related to information technology (IT) systems, including servers, data storage, network infrastructure, and power distribution equipment. These facilities are critical for the efficient and secure management, storage, processing, and sharing of digital data and services, supporting cloud platforms, digital applications, and advanced technologies such as artificial intelligence (AI). In an era of rapid digitalisation, growth in cloud computing, and increasing reliance on AI, the development and availability of data centres have become strategically important for national digital infrastructure and network security. Continuous and reliable 24/7 operations are essential for data centres, requiring robust infrastructure that ensures uninterrupted service delivery (European Commission, 2024; McKinsey & Company, 2025; Kumar and Pindoriya, 2026).

The Nordic countries have become a region of rapid data centre development due to a combination of factors. Colder climate conditions reduce the need for energy-intensive cooling, improving overall operational and cost efficiency. In addition, there is a strong regional focus on powering data centres with renewable energy sources, including hydropower, wind and solar, which supports low-carbon operations and aligns with broader sustainability goals. The strategic location of the Nordic region, with extensive subsea and terrestrial fibre networks, is also crucial for connectivity between local infrastructure and the wider European digital network (Dybdal Christensen et al., 2018; Mattila, 2025).

Efficient operation of a data centre requires access to critical infrastructure, particularly a reliable electricity connection with high power capacity (>0.5 MW). A stable connection must also include backup systems such as generators and uninterruptible power supplies (UPS) to maintain continuous operations in the event of grid disruptions. Data centres commonly deploy redundant power feeds and backup capacity to maintain uptime and avoid service interruptions (Takci et al., 2025; Yu et al., 2025).

In the Nordic and Finnish context, the relatively cool climate reduces the energy demand for cooling compared with warmer regions, but modern facilities still often use liquid-based cooling systems and dedicated cooling infrastructure to manage high-density workloads. These requirements contribute to the large land footprint demanded by data centre developments. Typical land demand for data centres varies by size and purpose. Smaller enterprise or standard facilities generally require approximately 10 ha of land or more to house buildings, support infrastructure, and allow for future expansion, while larger hyperscale and AI-focused campuses may need several tens to hundreds of hectares (e.g., 80–200 ha or more) to accommodate extensive power, backup systems, cooling equipment, and redundancy infrastructure (Dybdal Christensen et al., 2018; Koronen et al., 2020).

In addition to land size, site accessibility near major energy infrastructure such as substations or high-capacity grid connections is necessary for fast and cost-effective development. Proximity to fibre networks and low-latency communication corridors is equally important to ensure high-quality data transport between sites, cloud service providers, and end users.

The energy consumption of data centres results in the production of significant waste heat, which, in many Nordic cities and regions, is increasingly reused to support local district heating networks. By feeding excess thermal energy into these networks, data centres can reduce overall emissions and contribute to local energy efficiency and sustainability goals. This approach is also supported at the EU level, where current directives encourage waste heat reuse when technically and economically feasible, as part of mandatory sustainability reporting and energy performance frameworks (Koronen et al., 2020; European Commission, 2024).

Potential environmental and social impacts

The development of data centres entails a range of environmental and social impacts that differ in nature and scale from those associated with energy-generation infrastructure. While data centres do not produce energy or emissions directly through combustion, their very high electricity demand, extensive land requirements, and continuous operation create substantial indirect and local impacts. The significance of these impacts depends on facility scale, location, energy sourcing, and integration with surrounding infrastructure. The most relevant impacts are summarised in Table 1.5 and outlined below.

Table 1.5. Main environmental and social impacts of data centres

Positive	Negative
Employment and direct economic effects	Energy consumption and indirect climate impacts
Support for digitalisation and socio-economic development (conditional impact)	Land-use change, habitat loss, and landscape impacts
Waste heat utilisation	Water use, thermal effects, and other lifecycle impacts

Employment and direct local economic effects (positive impact): Data centres can generate economic benefits through employment and municipal tax revenues; however, the scale and distribution of these benefits vary substantially over the project lifecycle and according to facility size. During the construction phase, a data centre may create hundreds to thousands of jobs in construction, engineering, electrical installation, and related support services. These employment effects are, however, temporary and typically persist only for the duration of the construction phase. Once a facility becomes operational, direct permanent employment is considerably lower. Operational data centres generally employ a relatively small workforce, with typical staffing levels ranging from approximately 8–15 employees in small facilities (1–5 MW), 15–35 employees in medium-sized facilities (5–20 MW), and 35 or more employees in large facilities (>20 MW), depending on the level of automation and operational complexity (Broadstaff Global, 2025). Operational roles are mainly concentrated in technical maintenance, IT operations, security, and facility management. Consequently, expectations regarding long-term job creation should remain realistic, particularly in smaller municipalities.

In contrast, data centres may provide relatively stable fiscal benefits during the operational phase, primarily through property taxes, business taxes, and fees related to land leases, grid connections, and infrastructure use. These revenues can contribute to municipal finances but must be evaluated in relation to potential public costs, including infrastructure upgrades, increased electricity demand, and the loss of economic activity from alternative land uses (e.g. agriculture or forestry). In municipalities such as Raseborg, the net local economic contribution of a data centre will therefore depend on local tax structures and on whether generated revenues offset the opportunity costs of land use, additional infrastructure demand, alongside other adverse environmental and social effects.

Support for digitalisation and socio-economic development (conditional positive impact): Data centres are a core component of modern digital infrastructure, supporting cloud computing, AI, data analytics, digital public services, industrial automation, research and development, and digital platforms used across sectors such as healthcare, education, transport, finance, communication and entertainment. As such, they can act as enabling infrastructure for productivity gains, service innovation, and digital resilience at national and regional scales. However, the benefits of this digitalisation are conditional rather than inherent. The societal value generated by a data centre depends strongly on how its digital capacity is used and the types of services it supports. Facilities that enable essential public services, scientific research, education, or industrial efficiency can yield substantial positive social value. In contrast, data centres primarily dedicated to low-value or socially problematic digital activities may deliver little, if any, societal benefit. For example, certain digital services, particularly some forms of social media use, have been linked to adverse mental health outcomes, including anxiety, depression, eating disorders, and self-harm among younger populations, girls in particular (Wellbeing Research Centre et al., 2026). Additional concerns include the facilitation of mass automated surveillance, increasingly intrusive data-driven advertising practices (Goldfarb & Tucker, 2011), and the generation and spread of disinformation and misinformation (Vosoughi et al., 2018), which exacerbate social polarisation (Azzimonti & Fernandes, 2023), erode institutional trust, and heighten societal conflict. This issue is particularly relevant as data centres increasingly support computation-intensive AI development and applications, which, while enabling societal benefits, can also scale up and amplify these detrimental effects (e.g., Park & Nan, 2025; Bommasani et al., 2021). In such cases, energy- and land-intensive data-centres may impose environmental costs without delivering commensurate social benefits and may even contribute indirectly to societal harm. Consequently, the contribution of data centres to socio-economic development should not be evaluated solely on the basis of digital capacity or technological advancement, but in relation to the function and societal purpose of the services they support. From a sustainability perspective, positive digitalisation impacts are most likely to materialise when data centre developments are aligned with clear public-interest objectives, coherent national or international digital-policy goals, critical infrastructure needs, and a transparent oversight mechanism.

Waste heat utilisation (positive impact): Data centres generate substantial quantities of low-temperature heat, which can be captured and supplied to heating networks where infrastructure exists. When effectively integrated, waste-heat recovery can improve overall energy efficiency, reduce fuel demand for heating, and lower system-level greenhouse emissions. Waste heat from data centres can be utilised in several ways: it can be directly used for heating nearby offices or apartment blocks; small-scale distributed servers can serve as heat sources in individual apartments; on a larger scale, waste heat can be integrated into district heating systems; and it can also be used for industrial processes such as drying biomass, preheating in thermal power plants, or low-temperature applications like heating greenhouses and aquaculture facilities. The extent to which waste heat can be utilised depends on factors such as the availability of heating infrastructure, legislation, market conditions, and the location of data centres (Koronen et al., 2020). Consequently, waste-heat integration can represent a significant local benefit. However, the feasibility requires proximity to heat networks, sufficient year-round heat demand, and economic viability. Where these conditions are not met, waste heat is typically dissipated without recovery, limiting local benefits.

Energy consumption and indirect climate impacts (negative impact): Data centres are among the most electricity-intensive forms of modern infrastructure, operating continuously and requiring a highly reliable, high-capacity power supply (Oxford Economics, 2026). Consequently, depending on their scale, data centres can significantly increase regional electricity demand, potentially necessitating additional generation capacity and/or grid reinforcement. If this additional demand is met by fossil fuel-based electricity generation, it will lead to more greenhouse gas emissions, thereby undermining Raseborg's (and Finland's) decarbonisation efforts and contributing to climate change. Supplying data centres with renewable electricity can mitigate these direct emissions. However, from a system-level perspective, allocating limited low-carbon electricity to data centres may entail opportunity costs when it diverts renewable energy from other uses that could otherwise displace fossil fuel-based generation, also slowing overall decarbonisation. A comprehensive carbon footprint analysis of data centres should also account for life-cycle greenhouse gas emissions arising during the construction phase, where embodied carbon from building materials, infrastructure, and on-site activities can represent a substantial and effectively irreversible share of total emissions (Alissa et al., 2025). Conversely, data centre facilities that integrate waste heat recovery systems (see above) can partially offset these negative climate impacts.

Land-use change, habitat loss, and landscape impacts (negative impact): As previously mentioned, data centres may require extensive, secure land areas to accommodate buildings, cooling infrastructure, backup power systems, grid connections, access roads, safety buffers, and even space for future expansion (Alissa et al., 2025). This can lead to long-term changes in land use and landscape structure and may compete with alternative land uses such as forestry, agriculture, recreation, or other economic activities, especially in municipalities such as Raseborg. In forested areas, land conversion for a data centre may involve tree removal and soil disturbance, leading to the release of carbon stored in biomass and soils and a diminished capacity for future carbon sequestration. These impacts are most pronounced when primary forests are cleared (Pascual et al., 2026). In wetlands or peat-rich soils, land disturbance may also release greenhouse gases (Yang et al., 2025). Alternatively, the use of agricultural land may reduce the availability of productive farmland, with implications for food production. Depending on the location, land-use change can lead to the loss and fragmentation of natural habitats, with negative consequences for biodiversity. In addition, visual impacts may be particularly relevant in rural or semi-natural environments if large, industrial-scale buildings contrast with existing landscape character. This is particularly relevant in

Raseborg, where scenic landscapes support outdoor recreation, second-home living, and tourism. The inclusion of vegetated buffers may mitigate these visual impacts.

Water use, thermal effects, and other lifecycle impacts (negative impact): Modern data centres employ a range of cooling technologies, including advanced liquid-based systems such as direct-to-chip and immersion cooling. These technologies do not inherently require high freshwater consumption and can, when implemented in closed-loop configurations, reduce direct water use relative to conventional evaporative air-cooling systems (Alissa et al., 2025). However, overall water demand remains strongly dependent on system design, particularly the method of heat rejection, the use of cooling towers, and indirect water consumption associated with electricity generation across the full lifecycle (Mytton, 2021). Where freshwater abstraction is required, cooling-related water use may place pressure on local water resources, while evaporative losses and thermal discharges to surface waters can alter local water balances and ecological conditions (Rajeev et al., 2021). Although Finland generally has high freshwater availability, additional abstraction or inadequately managed thermal discharges may contribute to cumulative pressures on local water systems, particularly during dry periods and under future climate variability. These considerations are especially relevant in sensitive catchment areas and groundwater-dependent ecosystems, which rely on stable groundwater levels and groundwater–surface water interactions to maintain ecological function. In Raseborg, where several groundwater abstraction areas and protection zones are present, increases in water demand or changes in groundwater–surface water interactions may have local negative impacts. Consequently, site-specific assessments of water sourcing and careful consideration of cooling technology selection, heat-rejection pathways, waste-heat recovery (see above), and cumulative lifecycle impacts must be required to ensure that a data centre does not adversely affect local hydrology or associated ecosystems.

Beyond water use and thermal effects, impacts may arise from the generation of electronic waste, the use of hazardous materials in cooling and energy-storage systems, and the eventual decommissioning of buildings and infrastructure. While Finland has robust waste-management and recycling systems, the volume and turnover rate of ICT equipment underscore the importance of circular-economy practices and responsible EoL management.

Concluding remarks: Overall, the environmental and social impacts of data centres are highly context-dependent and closely linked to facility scale, location, and operational design. In the Finnish context, favourable climatic conditions can reduce cooling demand, yet data centres are still likely to require a significant amount of electricity, with potential system-level climate implications even when supplied with low-carbon power. Large-scale developments also pose challenges related to land-use change, landscape transformation, water use, and cumulative ecological pressures. For municipalities such as Raseborg, these risks underscore the importance of prioritising already industrialised sites, degraded land, or brownfields, thereby minimising conflicts with high-value landscapes, ecosystems, agriculture, and recreation. The integration of waste-heat recovery into local or regional heating systems represents a key opportunity to improve overall energy efficiency and partially offset negative climate impacts. While construction activities may generate short-term employment and operational phases can provide stable fiscal revenues, long-term job creation is limited, and economic benefits are contingent on local tax structures and opportunity costs. From a sustainability perspective, it is therefore essential that data-centre developments are not evaluated solely on the basis of technological capacity or economic activity, but on whether the digital services they support deliver clear public-interest value and whether the societal benefits of digitalisation meaningfully outweigh local environmental and social costs.

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Additional opportunities

Bioenergy plants

Overview and key requirements

Bioenergy plants are energy systems that convert organic materials into energy that can be transmitted, stored, or used. This type of energy infrastructure is highly dependent on a constant biomass supply. Common sources include wood and forestry residues, agricultural waste (e.g., straw), animal manure, energy crops (e.g., willow), and organic municipal waste. Due to the nature of these sources and their renewability, bioenergy plants are generally considered part of renewable energy production (Chum et al., 2011).

There are different types of bioenergy plants based on the energy production process:

- Combustion plants: The process of energy production is based on the burning of biomass to produce heat, which is then used to generate steam for driving turbines and producing electricity. This type of bioenergy plant is often integrated into municipal heating systems.
- Biogas plants: This process is based on anaerobic digestion, where microorganisms break down organic material in the absence of oxygen, resulting in the production of biogas. The output of this process can be used for municipal heating or converted into biomethane for use as a transport fuel.
- Biofuel production plants: The aim of these plants is to convert biomass, through a series of chemical and biological processes, into liquid fuels such as ethanol or biodiesel.
- Gasification and pyrolysis plants: These technologies use thermochemical processes to convert biomass into synthetic gas or bio-oil (intermediate products), which can then be processed into fuels or used to generate electricity, for example by combustion or in turbines (IEA Bioenergy, 2023).

Bioenergy plants are highly sensitive to resource supply, which should preferably be locally sourced and consistent in quantity. Storage infrastructure for biomass is therefore crucial. This requires that plants are located close to biomass production sources and relatively near to energy users (e.g., towns or industry). The infrastructure of well-functioning bioenergy plants also requires relatively large areas for conversion technologies (e.g., boilers, digesters, or reactors), as well as turbines, generators, and control systems (Merfort et al., 2023; Blay-Roger et al., 2024).

Despite being considered a renewable energy source, bioenergy can still contribute to air pollution and may lead to resource competition, particularly due to land use for energy crops instead of food production. It is also important to note that bioenergy plants are generally less efficient in energy production compared to other renewable energy systems such as solar or wind power (Prananta and Kubiszewski, 2021; Schlemminger et al., 2024; Singh and Clough, 2024; Morese, 2025).

Potential environmental and social impacts

Bioenergy plants can contribute to energy production and thereby support energy diversification towards renewable sources. In Finland, bioenergy already plays an important role in the national energy system, particularly for heat production and combined heat and power (CHP) and is an established component of municipal energy supply (IEA Bioenergy, 2024). Finnish bioenergy is dominated by combustion-based plants, primarily fuelled by solid biomass such as forest residues, wood chips, bark, and by-products from the forest industry, as well as biodegradable waste fractions, and these plants are typically integrated into district-heating and CHP systems (Finnish Energy, 2024). The environmental and social impacts of these, and other forms of bioenergy, remain highly context-specific and depend on feedstock sourcing, combustion technology, plant scale, and integration with local energy systems. The most relevant general potential impacts are summarised in Table 1.6 and discussed below.

Table 1.6. Main environmental and social impacts of bioenergy plants

Positive	Negative
Energy diversification and security	Air pollution and climate effects
Support for a circular economy (conditional impact)	Land-use change and resource competition
Employment and local economic effects	Water, soil, and biodiversity impacts

Energy diversification and energy security (positive impact): Bioenergy plants support energy diversification by providing dispatchable and storable renewable energy, particularly for heat and CHP. In Finland, this function is especially important during winter peak demand, when variable renewable sources such as solar cannot reliably meet heating needs. Combustion-based biomass plants and biogas facilities can therefore enhance energy security and reduce dependence on imported fossil fuels.

Support for a circular economy (conditional positive impact): Certain bioenergy plants can contribute to circular economy objectives by using agricultural residues, manure, forestry byproducts, sewage sludge, and other biodegradable waste streams that would otherwise be discarded. From a circular economy perspective, such systems help turn unavoidable organic side streams into useful energy and materials, rather than treating them as waste (European Commission, 2025). Biogas systems are particularly well aligned with circular economy principles, as they allow wet and mixed organic materials—such as manure and food waste—to be treated in a controlled way, while capturing methane that would otherwise be released into the atmosphere during uncontrolled decomposition (IEA Bioenergy, 2024). In addition to producing renewable energy, anaerobic digestion generates digestate, which can be returned to agricultural land. This supports the recycling of key nutrients, especially nitrogen and phosphorus, and reduces the need for mineral fertilisers. Alternatively, thermochemical pathways, such as biomass combustion and gasification, can also support circular economy objectives when they use sustainably sourced forestry residues and agricultural by-products that have few alternative material uses. In these cases, energy recovery can improve overall resource efficiency. However, unlike biogas systems, thermochemical conversion usually does not return nutrients to productive use, because most nutrients remain in ash fractions whose application is restricted by technical and regulatory requirements (IEA Bioenergy, 2024).

On the other hand, bioenergy plants do not support circular economy principles when they rely on purpose-grown energy crops that compete with food production, when biomass extraction exceeds sustainable residue availability, or when systems focus solely on energy generation without considering material recovery, nutrient cycling, or environmental impacts. Such approaches may increase pressure on land, soils, and ecosystems and conflict with the circular economy goal of keeping resources in use at their highest value (Ellen MacArthur Foundation, 2024).

In municipalities such as Raseborg, where agriculture and forestry coexist with residential and coastal land uses, bioenergy systems based on local residues may therefore provide environmental benefits, as long as they are appropriately scaled and designed in line with circular economy principles and that potential negative impacts (see below) are carefully managed.

Employment and local economy effects (positive impact): Bioenergy plants can generate positive economic effects, particularly at the local and regional level. Residue-based bioenergy systems tend to create employment across the supply chain, including feedstock collection, transport, plant operation, and maintenance, which is especially relevant in rural and semi-rural areas (Deloitte & Bioenergy Europe, 2022). Because bioenergy relies largely on domestic resources, a greater share of energy-related expenditures remains within the local and national economy, supporting regional value creation (IEA Bioenergy, 2024). For agriculture and forestry, bioenergy can provide additional income streams by valorising residues and side streams that would otherwise have limited economic value, thereby strengthening the economic resilience of these sectors.

Air pollution and climate effects (negative impact): Bioenergy plants are not emission-free and may have negative impacts on air quality and climate if not carefully designed, operated, and regulated. Thermochemical bioenergy plants (e.g., biomass combustion and gasification) can negatively affect local air quality by emitting particulate matter (PM), nitrogen oxides (NO_x), and carbon monoxide (CO), with emission levels depending on fuel quality, operating conditions, and emission-control equipment (IEA Bioenergy, 2024). These pollutants are associated with adverse human-health effects, for example, PM2,5 and PM10 are widely used indicators in air-quality regulation due to their established health relevance (World Health Organization [WHO], n.d.). Biogas plants generally exhibit lower direct stack emissions than solid-biomass combustion systems; however, they present specific emission related to methane (CH_4) losses along the process chain, including emissions from open or non-gas-tight digestate storage and CH_4 in CHP exhaust due to incomplete combustion (Liebetrau et al., 2017). CH_4 losses are also relevant in biogas upgrading, where “methane slip” can occur depending on the upgrading technology and operating conditions, and such losses can reduce the overall climate benefits of biomethane systems. Digestate management can additionally be associated with ammonia (NH_3) emissions during storage and application, with implications for environmental impacts and local air-quality pressures (Romio et al., 2024). Finally, where biogas is used in gas engines for CHP, exhaust emissions can include NO_x, CO, CH_4 (as unburned hydrocarbons), and—in some contexts—PM, based on field measurements and emission-factor studies for gas-fired engines operating on biogas (Kristensen et al., n.d.).

Furthermore, bioenergy is often described as carbon-neutral because the CO_2 released when biomass is burned, or when biogas is used, comes from plants that previously absorbed CO_2 from the atmosphere as they grew. However, this does not automatically mean that all bioenergy is climate-neutral. For bioenergy to be considered carbon-neutral in practice, all emissions over its entire life cycle must be taken into account, including emissions from growing or collecting biomass, processing it, transporting it, building and operating energy plants, and converting biomass into energy (Liu et al., 2017). Bioenergy can become carbon-positive—meaning it adds more CO_2 to the atmosphere than it removes—when total emissions over the life cycle are higher than the amount of carbon absorbed during biomass growth. This can happen, for example, if bioenergy production leads to deforestation or the conversion of grasslands or carbon-rich soils for energy-crop cultivation (see Land-use change, below). Such land-use changes can release large amounts of stored carbon and may take many decades to offset through regrowth, a delay often referred to as a long carbon payback time (Berndes et al., 2011). Bioenergy systems can also become carbon-positive when emissions along the supply chain are high. This may occur if conversion technologies are inefficient, if energy plants require emission-intensive construction, if biomass is transported over long distances using fossil fuels, or if CH_4 leaks occur in biogas systems. CH_4 is a particularly strong greenhouse gas, and even relatively small leaks can significantly reduce or eliminate the climate benefits of biogas (Buivydas et al., 2024; UNFCCC, n.d.).

Land-use change and resource competition (negative impact): Bioenergy plants can exert negative impacts through land-use pressures and competition for natural resources, particularly when biomass demand increases beyond locally available residues and side streams. Since bioenergy systems require continuous and reliable biomass flows, at larger scales, this demand may displace existing agricultural or forestry activities. Such displacement can result in indirect land-use change, whereby land previously used for food production or forestry is diverted to energy purposes, prompting land conversion elsewhere through market-mediated responses (IEA Bioenergy, 2022). Converting agricultural land from food or feed production to energy-crop cultivation can increase competition for land and raise concerns about indirect land-use change, particularly when energy crops are grown on productive agricultural land rather than marginal areas (Abreu et al., 2022). Similarly, increased demand for forestry residues or wood-based biomass may intensify pressure on forest ecosystems. Excessive extraction of forest biomass can reduce above- and below-ground carbon stocks by removing woody material that would otherwise contribute to long-term carbon storage in tree biomass, deadwood, and forest soils (Brockerhoff et al., 2017). Where harvesting intensity increases or residue removal becomes systematic, this may weaken the forest carbon sink over time and alter soil carbon dynamics. If bioenergy production leads to deforestation, greenhouse gas emissions may increase due to the release of carbon stored in tree biomass and forest soils. These emissions occur through the combustion and decomposition of harvested biomass, as well as through soil disturbance during harvesting operations. Disturbance of forest soils can accelerate the decomposition of organic matter, resulting in additional CO_2 emissions and a weakening of the forest carbon sink, at least in the short to medium term (Berndes et al., 2011).

Water, soil, and biodiversity impacts (negative impact): Bioenergy plants can affect water quality, particularly biogas and biofuel production facilities that generate nutrient-rich digestate and wastewater. If these are not properly managed, nutrients such as nitrogen and phosphorus may leach into surface waters or groundwater, increasing the risk of eutrophication, which is especially relevant in Finland, where nutrient runoff is already affecting Finnish inland and coastal waters (Finnish Environment Institute [SYKE], n.d.). On the other hand, combustion and gasification plants may generate ash and air-pollution-control residues that require appropriate handling and, in some cases, controlled disposal to avoid potential negative effects in soil quality and, through leaching processes, pose a potential risk to water resources (Zhai et al., 2021). Lastly, increased biomass harvesting to supply bioenergy plants can also negatively affect biodiversity, particularly in boreal forest ecosystems. More intensive harvesting may reduce deadwood, simplify forest structure, and disturb habitats that many species depend on, including insects, fungi, birds, and small mammals. The removal of biomass residues, such as branches, tops, and deadwood, can further reduce habitat availability and disrupt nutrient cycling, weakening forest ecosystem functioning over time (Brockerhoff et al., 2017).

Overall, the environmental performance of bioenergy plants depends strongly on feedstock choice, land-use effects, plant scale, technology selection, and operational practices. Bioenergy can contribute to climate-mitigation objectives only when air-pollutant emissions are effectively controlled and when full life-cycle greenhouse gas emissions are demonstrably lower than those of the fossil energy systems they replace (Osman et al., 2024; IEA Bioenergy, 2024).

Concluding remarks: Bioenergy plants can deliver system-level benefits for renewable energy supply, energy security, and circular resource use, particularly in the Finnish context of district heating and CHP. However, their environmental and social impacts are highly dependent on technology choice, feedstock sourcing, and scale. Bioenergy can deliver clear climate benefits when biomass is sourced sustainably and emissions from harvesting, processing, transport, and energy conversion are kept low. This is especially the case for bioenergy systems based on residues and waste streams, which avoid land-use change and can replace fossil fuels while making use of existing materials (Osman et al., 2024). Under these conditions, the CO_2 released during energy production is largely balanced by new biomass growth or by avoided emissions from alternative waste-management practices. For Raseborg, bioenergy options based on residual and waste-based feedstocks, integration with existing infrastructure, and careful siting away from ecologically sensitive or multifunctional land are more likely to align with local sustainability objectives. As with other infrastructure projects, site-specific assessments are essential to ensure that potential benefits materialize and local environmental and social risks are avoided.

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Floating solar panels

Overview and key requirements

Floating solar panels (PV) are sometimes also called floatovoltaics. The principle of working floating solar plants is similar to the above-described solar panel parks, as their main goal is to convert sunlight into electricity. The main difference is that these panels are floating on open water, using durable buoyant structures made from UV-resistant materials (e.g., plastic bases), which are anchored for stability (Figure 1.4). There should be space not only for panels but also for the inverters and monitoring systems required (in some cases this infrastructure is located on land if distances allow it). The electricity produced is transmitted to shore via underwater power cables to the local grid (Gökmener et al., 2023; Planète Énergies, 2024).

Floating solar panels require careful water body selection, with calm waters (e.g., lakes and reservoirs) that have stable and predictable water levels, including minimal wave activity or active wave protection structures. It is vital for the operation of such panels that they are exposed to sunlight, minimising the effect of shading. Floating solar panels should also be located in accessible places, ensuring safety for their cleaning and repair (World Bank Group, 2019; Forester et al., 2025).

Floating solar panel systems are usually more efficient in comparison with land-based solar parks due to the cooling effect of the surrounding water, which allows them to operate at lower temperatures and improves efficiency. It has been indicated that this cooling effect can result in approximately 5–15% higher energy production compared to similar land-based systems. However, despite the advantages for cooling due to climate conditions and higher wind speeds, floating PVs in Nordic regions demonstrate lower relative gains, typically suggesting up to 5% increased efficiency. In addition, floating systems usually experience lower dust accumulation, which minimizes efficiency losses over time (Pimentel Da Silva & Branco, 2018; Sukarso & Kim, 2020; Pouran et al., 2022; Hayibo et al., 2025).

On the downside, floating photovoltaic systems generally require more complex operation and maintenance than land-based PV installations due to the presence of floating structures, anchoring systems, and sustained exposure to humid or marine environments. In freshwater settings, this typically results in additional inspection and monitoring requirements but not necessarily substantially higher maintenance effort. In contrast, offshore or coastal floating PV systems usually face higher maintenance demands due to corrosion, biofouling, and access constraints associated with seawater exposure, necessitating the use of corrosion-resistant materials and more intensive inspection regimes (Selj et al., 2025).

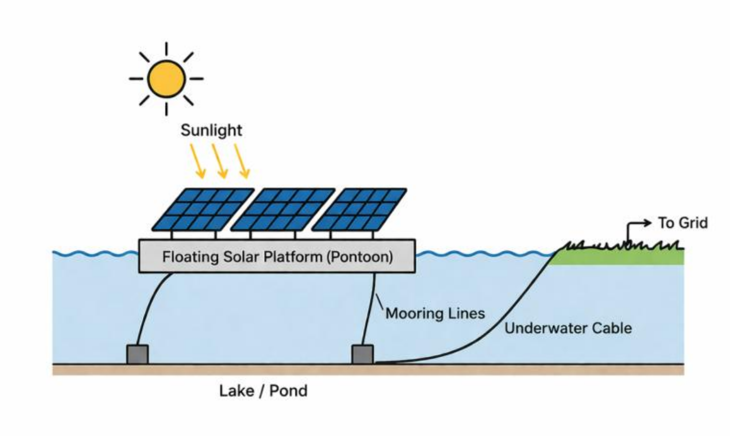

Figure 1.4. Floating Solar Panels (AI-generated with prompts by ChatGPT, R. Gunko)

Potential environmental and social impacts

Floating solar panel systems can provide renewable electricity while reducing competition for land resources. By using existing water bodies, they offer a distinct spatial alternative to land-based solar parks. However, their environmental and social impacts differ from ground-mounted systems and are closely linked to the characteristics of the water body, system scale, and local uses. The most relevant potential impacts are summarised in Table 1.7 and discussed below.

Table 1.7. Main environmental and social impacts of floating solar panels

Positive	Negative
Reduction in CO_2 emissions	Effects on aquatic ecosystems
Energy security	Landscape impact and alternative uses
Spatial land-use impacts	
Water conservation and quality	
Employment	

Reduction in CO_2 emissions (positive impact): In principle, floating PV systems contribute to climate-change mitigation by generating low-carbon electricity. However, like land-based solar installations, lifecycle greenhouse-gas emissions arise primarily from manufacturing, transport, installation, and EoL management, whereas emissions during the operational phase are minimal (NREL, 2013). Consequently, assessments of the climate benefits of floating PV systems must be based on full life-cycle greenhouse-gas emissions rather than operational performance alone. Importantly, depending on specific conditions, floating solar panels may also influence greenhouse gas emissions from the water bodies on which they are installed. Lakes and reservoirs naturally emit methane due to anaerobic biological decomposition in their sediments. In small, shallow, and nutrient-rich ponds, very high floating PV surface coverage can reduce water mixing and oxygen availability, leading to increased methane emissions. However, these effects are highly site-specific and are much less likely in larger, deeper, and well-mixed water bodies. Even where local methane emissions increase, floating PV electricity typically remains low-carbon on a per-kilowatt-hour basis compared with many energy alternatives (Ray et al., 2024; Nobre et al., 2024).

Floating solar panels are particularly compatible with hydropower because both technologies use the same water reservoirs and can support each other operationally when deployed on existing reservoirs. Hydropower infrastructure provides grid connections and managed water surfaces that allow floating PV deployment. Moreover, solar and hydropower generation profiles are complementary: solar generation can meet daytime demand while conserving reservoir water for flexible hydropower production at other times. Thus, floating solar panels can add low-carbon generation without expanding reservoir area (Almeida et al., 2024).

Lastly, however, as with other renewable energy technologies, net emission reductions are realised only as far as floating solar panels' generated electricity displaces more carbon-intensive generation (mainly fossil fuel-based electricity) at the power-system level.

Energy security (positive impact): Alike ground-mounted-solar panels, floating PV systems can contribute to strengthening Finland's energy security by expanding domestic electricity generation, diversifying the national energy portfolio, and lowering reliance on imported fuels. These aims are consistent with the Energy and Climate Plan (Ministry of Economic Affairs and Employment of Finland, 2024).

Spatial land-use impacts (positive impact): A principal advantage of floating solar panel installations is the avoidance of direct land-use conversion. By occupying existing water surfaces such as lakes, reservoirs, and ponds, these systems reduce pressure on agricultural land, forests, and other terrestrially constrained land uses, thereby avoiding land-use impacts commonly associated with ground-mounted solar parks (see Solar Parks, above), including deforestation, habitat loss, soil sealing, erosion, and agriculture displacement.

Water conservation and quality (positive impact): Floating solar panels can provide co-benefits for water resource management by reducing evaporation losses from reservoirs and lakes. By shading the water surface and limiting direct solar radiation and wind exposure, floating PV installations can significantly decrease evaporation rates (Pouran et al., 2022), thereby enhancing water security under increasing climatic stress. In addition, by reducing sunlight penetration and, consequently, surface-water temperatures, floating solar panels can suppress phytoplankton growth and, in eutrophication-prone systems, mitigate harmful algal blooms, with potential improvements in water quality (Pouran et al., 2022). However, these effects are highly site-specific and depend on factors such as reservoir depth, nutrient status, and the proportion of surface area covered by solar panels. Moreover, floating solar panels may also generate negative impacts on aquatic ecosystems (see below), underscoring the need for careful design, site selection, and monitoring to balance water-quality benefits with ecological integrity (Pimentel Da Silva & Branco, 2018).

Employment (positive impact): Similarly to ground-mounted solar installations, floating solar panels can generate employment opportunities, particularly temporary jobs during the construction and decommissioning phases, and both direct and indirect employment across the value chain, including manufacturing of components, installation, operation and maintenance, and associated services. As with terrestrial solar technologies, the number of jobs created per megawatt of installed capacity varies substantially depending on national context, but estimates range from 7 to 70 full-time jobs per MWp (Pouran et al., 2022).

Effects on aquatic ecosystems (negative impact): By reducing solar radiation reaching the water surface, floating PV systems can influence physical, chemical, and biological processes in aquatic environments. Shading may affect phytoplankton growth, thermal stratification and nutrient cycling, as well as dissolved oxygen concentrations by restricting air–water gas exchanges and limiting photosynthesis, thereby negatively affecting aquatic organisms and ecosystems' conditions (Pimentel Da Silva & Branco, 2018). Furthermore, floating PV installations may also pose risks of chemical and material pollution from the degradation or corrosion of floating structures, anchoring systems, and protective coatings, as well as the release of microplastics. Lastly, construction activities such as anchoring and mooring can disturb lake or reservoir sediments, increasing turbidity and potentially affecting benthic habitats and bottom-dwelling organisms (Pouran et al., 2022; Pimentel Da Silva & Branco, 2018).

Landscape impact and alternative uses (negative impact): Floating photovoltaic installations may occupy substantial areas of the water surface, altering the spatial character of coastal areas, lakes, and reservoirs and potentially constraining other uses such as fishing, recreation, or navigation. These impacts are particularly relevant in contexts where water bodies provide important cultural ecosystem services or support tourism and leisure activities.

Concluding remarks: Overall, floating solar panels remain a low-carbon energy option, but their net benefits depend on fossil fuel displacement, careful site selection of water bodies, and consideration of impacts throughout their lifecycle. Their deployment on managed water bodies, including drinking-water reservoirs, and places within brownfields and abandoned industrial sites, further will reduce competition with other activities and limit their negative impacts on ecosystems.

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Wind energy

Overview and key requirements

Wind energy is generated by converting the kinetic energy of the wind into electricity, typically using wind turbines. A crucial requirement for this system is the presence of consistent and strong wind, preferably with speeds of at least 5–6 m/s. This ensures the blades can rotate effectively and generate electricity.

Large-scale wind energy projects are typically organised as wind farms, which may be located onshore or offshore, while small-scale systems are used for local power supply. Offshore wind farms require areas free from restrictions, such as environmental protection zones or regions actively used by the military. Therefore, offshore wind farms are not suitable for Raseborg (European Commission, 2024).

Onshore wind farms require flat areas with minimal obstructions. The site must be relatively large due to the necessary spacing between turbines, which should be 5-10 times the rotor diameter in the direction of the prevailing wind and 3-5 times the rotor diameter perpendicular to it. For example, a turbine with a 100 m rotor diameter should be positioned 500–1000 m apart in line with the wind and 300-500 m side by side. For a 4×4 turbine wind farm, the area required for efficient operation is approximately 1,4-4,5 km^2. Additionally, it is recommended to maintain a minimum distance of at least 1250 m from nearby buildings in Southern Finland (Gupta, 2016; Yang et al., 2024; Suomen uusiutuvat ry, 2025).

Potential environmental and social impacts

Onshore wind energy is a mature and widely deployed renewable-energy technology that can contribute significantly to climate-change mitigation and energy security. However, wind farms also generate a distinct set of environmental and social impacts. The magnitude and significance of these impacts are highly site-specific and depend on turbine size, layout, surrounding land uses, and local environmental conditions. The most relevant potential impacts are summarised in Table 1.8 and discussed below.

Table 1.8. Main environmental and social impacts of onshore wind energy

Positive	Negative
Reduction in CO_2 emissions	Land use and habitat fragmentation
Energy security	Effect on wildlife
Complementarity with PV generation	Landscape impact and public acceptance
Co-existence with other land uses	
Employment	

Reduction in CO_2 emissions (positive impact): In principle, wind energy contributes to greenhouse-gas emission reductions by generating electricity without fuel combustion or direct operational emissions. Therefore, in Finland, wind power has become an increasingly important component of the national electricity system (Suomen uusiutuvat ry, 2026). As with other low-carbon energy technologies, however, wind power is not emission-free when assessed over its full life cycle. The majority of wind-energy-related greenhouse-gas emissions occur upstream and downstream of operation, primarily during turbine manufacturing, transport, construction, maintenance, and decommissioning (Heath & Dolan, 2012). Nevertheless, lifecycle assessment studies consistently show that wind power has markedly lower greenhouse-gas emissions per kilowatt-hour than fossil-fuel-based electricity generation (NREL, 2021), and therefore a strong capacity to reduce carbon dioxide emissions when it displaces more carbon-intensive electricity sources, particularly coal-, oil- and gas-fired power generation.

Energy security (positive impact): Similar to other domestic renewable energy technologies, wind energy strengthens Finland's energy security by increasing national electricity production, diversifying the power-generation mix, and reducing dependence on imported fuels. These contributions are closely aligned with Finland's Energy and Climate Plan, which emphasises the expansion of domestic renewable electricity as a key component of decarbonisation and energy-security strategies (Ministry of Economic Affairs and Employment of Finland, 2024).

Complementarity with PV generation (positive impact): In Finland, wind power and solar (PV) generation exhibit complementary production profiles at seasonal and, to a lesser extent, daily timescales. Solar PV output is highest during the summer months, when long daylight hours enable substantial electricity generation, whereas wind power production tends to be higher during winter, when solar generation is limited by short daylight hours and low solar irradiance (Gardemeister et al., 2025). This seasonal complementarity contributes to smoothing aggregate renewable electricity production over the year. While simultaneous high production can occur during transitional seasons, the combined wind–solar portfolio improves system resilience and reduces reliance on single-source variability.

Co-existence with other land uses (positive impact): Although wind farms require relatively large areas for turbine spacing, only a small proportion of the total site is permanently occupied by wind energy infrastructure. In Finland, this is about 1,4–6,0% of the total project area (Balotari-Chiebáo & Byholm, 2026). As a result, most of the land within wind farm project areas remains physically unaffected, allowing for the potential coexistence of wind energy with other land uses (such as agriculture, forestry, or recreation). Thus, wind energy is often characterised by relatively high land-use efficiency compared to other forms of energy infrastructure.

In addition, wind farms are generally regarded as largely reversible land uses, as infrastructure can be removed after decommissioning; however, residual impacts such as habitat fragmentation, soil disturbance, and remaining infrastructure may limit full ecological restoration (see below).

Employment and local economic effects (positive impact): Wind-energy developments can also generate local economic benefits, particularly in rural areas. These include employment (although mostly temporary and linked to the construction and decommissioning phases), land-lease payments to landowners, municipal tax revenues, and increased demand for local services during construction, operation, and maintenance phases.

Land-use change and habitat fragmentation (negative impact): Despite their relatively small physical footprint, onshore wind farms can have significant spatial and ecological impacts. The need for turbine structures, access roads, crane pads, and grid connections means that several areas are affected, even if only a fraction is permanently occupied. This fragmentation reduces the availability of large, unbroken habitat patches, posing particular risks to species that depend on extensive, contiguous forest areas, and potentially leading to changes in ecosystem structure and function. When wind farms cause deforestation, there is further habitat loss, combined with the release of stored carbon and the loss of carbon sequestration capacity (Balotari-Chiebáo & Byholm, 2026).

Effect on wildlife (negative impact): Wind energy can have significant effects on wildlife, particularly on birds and bats, through both direct and indirect mechanisms. In Finland, collision mortality is identified as a main concern, particularly for local populations of raptors, geese, gulls, and terns, with species that have long generation times and low reproductive output being especially vulnerable. For example, white-tailed eagles have been shown to experience high collision rates and displacement near wind turbines, leading to reduced breeding success. Additionally, the disturbance from wind farms can cause birds to avoid areas around turbines, resulting in functional habitat loss as these areas are used less frequently compared to control sites or pre-construction scenarios. These impacts underscore the importance of careful spatial planning (Balotari-Chiebáo & Byholm, 2026). In addition, wind turbines generate aerodynamic noise, which can affect wildlife by contributing to behavioural disturbance, including avoidance of areas near turbines and potential interference with acoustic communication. However, such effects are generally considered secondary to habitat modification and collision risk, and their magnitude varies across species and environmental contexts.

Landscape impact and public acceptance (negative impact): Landscape change is one of the most prominent and widely perceived impacts of wind energy. Modern turbines are tall structures that can dominate views over long distances, altering landscape character and visual identity. These effects are strongly influenced by turbine height, layout, topography, and visibility from settlements and recreational areas. Visual impacts may significantly influence public acceptance. Also, as previously mentioned, wind turbines generate noise, which, although typically moderate in absolute terms, may contribute to annoyance among nearby residents, particularly in quiet rural environments.

Concluding remarks: Wind power plays a central role in Finland’s transition to a low-carbon energy system, contributing to climate mitigation, energy security, and domestic electricity production. At the same time, the sustainability of wind power depends less on the careful spatial planning and site selection, informed by the extensive body of scientific evidence, environmental data, and practical experience already available. A systematic and context-sensitive approach is therefore essential to ensure that the long-term benefits of wind energy are realised while minimising local negative impacts.

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Heat storage systems

Overview and key requirements

Heat storage systems are often called thermal energy storage (TES) systems and refer to technologies that store heat for later use in order to ensure balance between energy supply and demand. This could include, for example, storing solar heat collected during the daytime and using it at night, storing heat produced by industry for reuse in later processes, or storing excess electricity by converting it into heat. Thus, it improves energy use efficiency, supports renewable energy systems (e.g., solar or wind), and reduces heat waste (Sarbu and Sebarchievici, 2018; Sifnaios et al., 2023).

There are a few of the most popular types of TES systems used worldwide:

- Sensible heat storage: This approach involves storing energy by increasing the temperature of materials such as water, rock, or molten salts. The stored heat is usually used for municipal heating.
- Latent heat storage: The materials used in latent heat storage are called phase change materials, which absorb, store, and release heat during phase transitions. They can store a large amount of energy at a constant temperature. They can also store cold for future use. An example of such a system are paraffin wax systems.
- Thermochemical storage: This approach uses reversible chemical reactions and can achieve high energy density for storage (Li, 2016; Reddy et al., 2018; Abdullah et al., 2024).

The efficient use of TES systems requires relatively large areas for construction, particularly for storing materials and enabling the processes involved in heat storage. For example, large-scale systems based on the use of hot water tanks, peat thermal storage or underground storage require significant space for construction. These constructions must have proper insulation to minimise heat losses, ensure economic benefits, and enable efficient long-term application. A good connection to the consumers of the stored energy is crucial to ensure efficiency and to avoid heat losses during the transportation stage (IEA, 2018; Sarbu and Sebarchievici, 2018; IEA DHC, 2020).

Potential environmental and social impacts

TES systems can play an important role in supporting broader renewable energy systems. Compared to many other energy infrastructures, TES systems often have more spatially contained and less visually prominent impacts. However, their overall environmental and social implications vary depending on the specific storage technology, scale of deployment, and local context. In general, the most relevant potential impacts are summarised in Table 1.9 and discussed in the following sections.

Table 1.9. Main environmental and social impacts of TES systems

Positive	**Negative**
Support for decarbonization	Land-use change and visual impacts
Energy security and grid resilience	Safety and environmental risks

Support for decarbonization (positive impact): TES systems support climate mitigation efforts by enabling the more efficient use of low carbon and renewable heat sources within district heating and local energy systems. By storing heat produced from renewable electricity (via power to heat) during periods of surplus, TES allows this heat to be utilised later when demand is high. This reduces the need for fossil fuel based peak heat production and improves the overall efficiency of heat supply (Sornek et al., 2025). However, the decarbonization benefits of TES are dependent on the effective displacement of heat that would otherwise be generated from carbon intensive sources such as coal, peat, oil, or natural gas, or when it enables the use of renewable electricity that would otherwise be curtailed.

Energy security and grid resilience (positive impact): While TES does not directly enhance electricity grid reliability in the same way as electrochemical battery storage, it can indirectly support overall energy system resilience. Through power-to-heat applications, TES can alleviate stress on both electricity and heat supply systems during peak demand conditions. In this way, TES contributes to improved system flexibility by acting as a buffer between energy supply and demand, a key feature of smart energy systems (Lund et al., 2014). TES also enhances energy security by increasing the flexibility, reliability, and resilience of heat supply systems, particularly in regions with high heating demand and well-developed district heating networks. At the system level, TES supports sector coupling by linking electricity and heat systems, thereby enabling greater integration of variable renewable electricity, and contributing to overall energy system stability in low-carbon energy transitions (Lund et al., 2017).

Land-use change and visual impacts (negative impact): Large-scale installations, such as hot-water tanks, pit thermal energy storage, or solid-material storage, may require significant land areas, potentially leading to tree-removal, soil disturbance, and habitat disruption. Although generally less visually intrusive than wind or solar installations, large TES facilities may still affect landscape character, contributing to perceptions of industrialisation.

Safety and environmental risks (negative impact): TES systems generally exhibit lower safety risks compared to many chemical and electrochemical energy storage technologies, particularly in configurations based on water, rock, or sand. This is mainly due to the absence of flammable fuels, electrochemical reactions, or high-pressure gaseous storage (Sarbu & Sebarchievici, 2018). However, safety considerations vary significantly depending on the storage medium and system design. High-temperature systems such as molten-salt and hot-water storage operate under elevated thermal conditions and, in some cases, pressure, requiring robust containment, thermal insulation, and continuous monitoring to prevent overheating, material degradation, or structural failure. In molten-salt systems, corrosion and thermal cycling can further increase engineering and operational risks, particularly in large-scale applications (Prieto et al., 2024). Thermochemical storage systems may involve reactive materials and reversible chemical processes, which require controlled operating conditions and secure containment to avoid unintended reactions or material degradation. Across TES technologies, failures or leaks could potentially result in thermal hazards or localised environmental impacts, particularly in underground or large-scale installations, although such risks are typically manageable through appropriate engineering design and safety standards (Sarbu & Sebarchievici, 2018).

Concluding remarks: TES systems are most suitable where large, predictable heat demand coincides with surplus or low-cost heat sources and sufficient space is available—often underground—to minimize thermal losses. Accordingly, optimal locations are typically within designated areas for energy infrastructure, situated along the corridor between heat sources and end users, and in close proximity to urban or peri-urban areas where heat demand is concentrated.

TES systems are important enabling infrastructure rather than primary energy generation technologies. Finland has emerged as a frontrunner in this field, notably through the development of the world's largest operational *sand* battery in Pornainen by Polar Night Energy, which has received international recognition, including being highlighted by *Time* magazine as one of the best inventions of 2025 (TIME, 2025). While the environmental and social impacts of TES systems are generally context-dependent, well-designed and appropriately sited installations (such as those located on brownfield or industrial sites) can provide system-level benefits, including improved energy efficiency, reduced renewable energy curtailment, and enhanced energy security, with limited local environmental and social impacts compared to many large-scale energy infrastructures.

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Seawater heat

Overview and key requirements

A seawater heat system is a system in which a heat pump is used to extract thermal energy from seawater and use it for the heating of residential buildings. It is important to note that this is a hybrid system, where around 60% of the heat supplied to the district or residential heating network comes from seawater, while the remaining share is produced using electricity from the grid. In this process, seawater is pumped through tunnels or pipes to a heat pump plant, where the stored thermal energy from the seawater, together with electricity, is used to produce high-temperature heat for use.

This system is very demanding in terms of requirements, such as year-round access to seawater with a minimum temperature of around 2 °C. This results in the need for long intake and discharge pipes or tunnels, which can be 15-30 km in length. Due to the temperature and stability requirements, access to deep seawater at depths of 50-70 m is essential. As a result, this energy system is not well suited to the depth conditions of Raseborg, where the number of suitable areas is limited, and their locations are relatively far from the coastline, with additional complications related to the archipelago (Figure 1.5) (Helen, 2021a; Helen, 2021b; Ali et al., 2024).

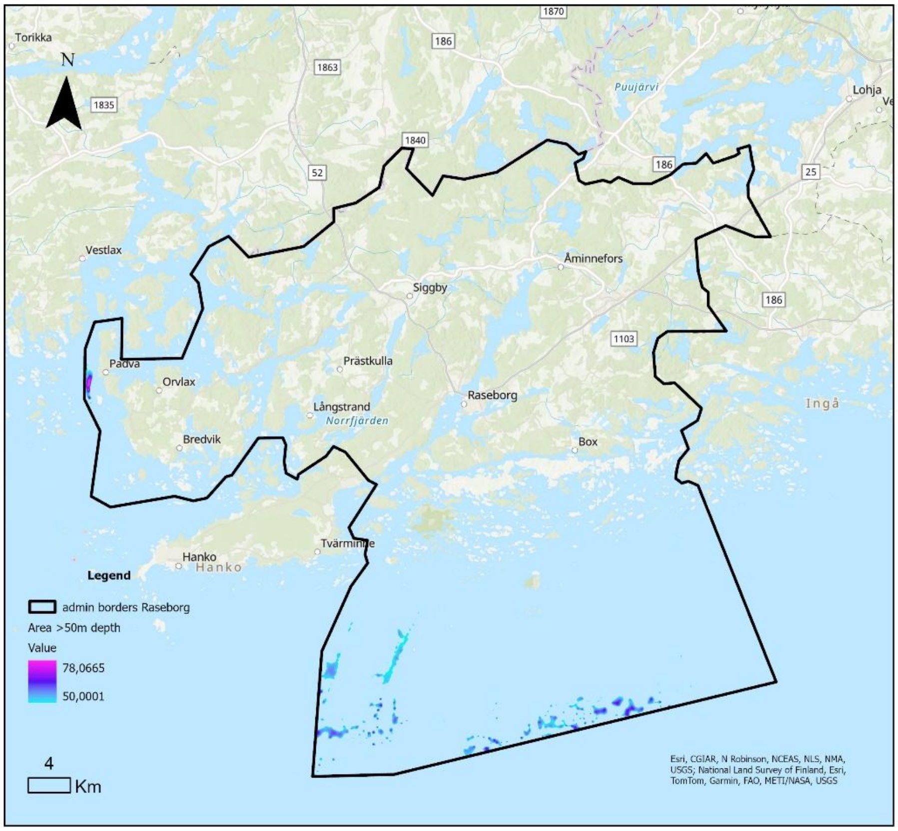

Figure 1.5. The suitable area within Raseborg administrative borders (R. Gunko)

Potential environmental and social impacts

Seawater-based heat pump systems can contribute to low-carbon heat production by utilising seawater as a stable and renewable thermal resource, particularly when integrated into district-heating systems. These systems' environmental and social impacts are highly site-specific and closely linked to marine conditions and infrastructure requirements. The most relevant potential impacts are summarised in Table 1.10 and elaborated below.

Table 1.10. Main environmental and social impacts of seawater-based heat systems

Positive	Negative
Support for decarbonization	Marine and coastal disruptions, thermal and pollution effects
Energy security and grid resilience	

Support for decarbonization (positive impact): Seawater heat systems can significantly reduce greenhouse gas emissions by replacing fossil-fuel-based heating in district or residential heating networks. By using a renewable and relatively stable marine heat source, these systems can support the transition toward decarbonization.

Energy security and system resilience (positive impact): Seawater heat systems can contribute to diversifying heat-supply sources, enhancing local energy security. Their continuous availability, independent of weather variability, provides stable baseload heat production, improving overall system resilience.

Marine and coastal disruptions, thermal and pollution effects (negative impact): Seawater heat systems require extensive intake and discharge infrastructure, typically involving long pipelines or tunnels installed on or beneath the seabed. Construction and installation of this infrastructure may disturb marine sediments, benthic habitats, and coastal ecosystems, particularly in shallow waters and archipelago environments (Ali et al., 2024). During operation, the discharge of slightly cooled or warmed seawater may cause localised thermal changes near outflow points which, if inadequately dispersed, could affect sensitive marine organisms (Leng et al., 2024). In addition, environmental pollution risks may arise from leaks or structural failures in high-pressure intake and discharge pipelines, corrosion of marine infrastructure, or malfunctions associated with large-scale electrical and heat-pump installations (Bordbar et al., 2023). While these impacts are generally considered manageable, they require robust engineering design and detailed marine environmental assessments.

Concluding remarks: Seawater heat systems can deliver substantial benefits where physical and spatial conditions allow effective implementation. As with other energy technologies, their environmental and social impacts are highly location-dependent and closely linked to marine ecosystems and engineering design. Unfortunately, these systems seem unfit for Raseborg.

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Part 2 – Context map

Introduction

The location opportunities for energy systems are assessed as a result of classification of the land into categories featuring level of constraints. This classification clarifies where are the areas to be developed featuring little to no constraint (limiting factor) and/or permissive element (enabling factor) in the municipality.

The purpose of the classification is to support land use planning and zoning. The classification of the areas are recommendations and guidelines for planning support (Uudenmaan liitto, 2024, p. 50).

Material: Layer sources and pre-processing

The layers that have been used and classified are openly available from official platforms and repositories (see References), available in local CRS EPSG 3067 and pre-processed (Table 2.1).

Table 2.1. List of layer source and processing on those layers

Source	**Processing**
Uudenmaanliitto - VISIO	Manually digitized from visio webmap
Uudenmaanliitto – Uusimaa kavaa 2050	Download and clip to AOI
Uudenmaanliitto - Kulttuuriympäristöt	Download and clip to AOI
Uudenmaanliitto - Ekologiset verkostot	Download and clip to AOI
Uudenmaanliitto - Peltoalueet	Download and clip to AOI
Raseborg Stad	Gpkg from City
Delgeneralplan	
Generalplanens	
HULEVET	
Raseborg Stad Louhi - KRAV	Download
Finnish Environment Institute (SYKE)	Download and clip to AOI
National Land survey (MML)	Download topographic database
Finnish Heritage Agency (FHA)	Download and clip to AOI
Västra Nylands Museum	Manually digitized from MIP webmap*
Birdlife - Important Bird and Biodiversity Areas	Download and clip to AOI
Finnish Food authorities (FFA)	Download and clip to AOI
Fingrid	Manually digitized from webmap
Gasgrid	Manually digitized from webmap

* Privileged access

Methods

Land classification

Features to consider

- Natural value
- Cultural value (environment, landscape, buildings, archaeological) of national, regional and local importance

- Man-made
- Critical infrastructure

Guiding principles

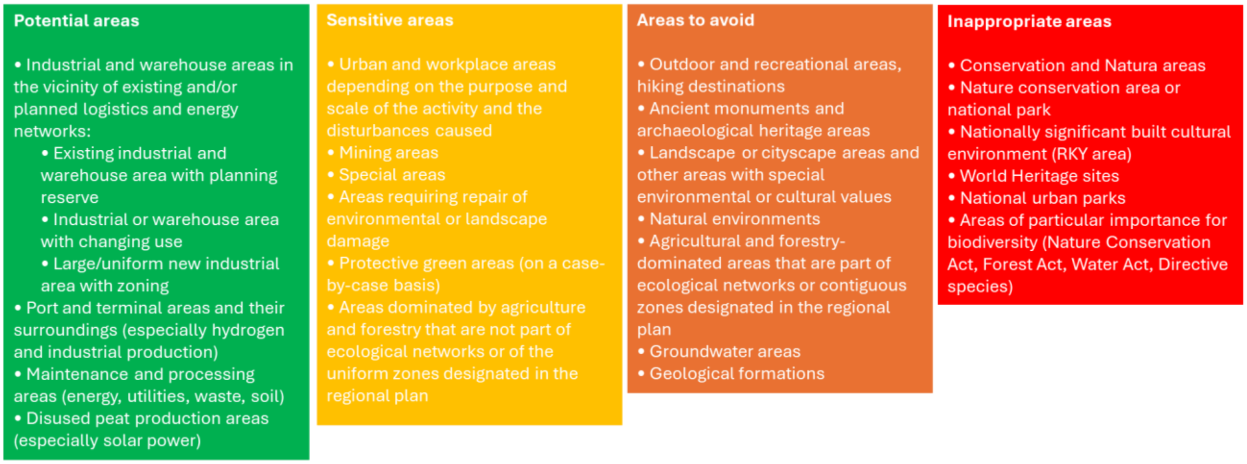
The municipal land has been categorized following regional and local guiding principles. Firstly, areas have been categorized according to governing documentation. Then, expert guidance steered the remaining areas to be categorized.

Governing documentation

- Uusimaa green transition plan: A study of land use needs for green transition projects in Uusimaa (translated from Uudenmaan liitto, 2024) (Figure 2.1).
- Hulevet project: Implementation of the stormwater management operating model in Uusimaa and Päijät-Häme (translated from VHVSY ry, 2025). This document assesses sensitivity of receiving areas to stormwater load. For details about how the sensitivity has been assessed per area, and which datasets have been considered, please refer to the document. Those areas have been assumed to preserve the same status for land use development/changes since those sensitive areas remain of greatest significance, nevertheless.

Expert guidance

- Cultural and historical values were assessed with arkeolog Tanja Ranta and byggnadsforskare Tellervo Saukoniemi from Västra Nylands museum (Figure 2.2).
- Plan markings (and related planning regulations) are letter, number, line, and colour codes used on the local plan map that define in a legally binding manner how a specific area may be used and built. Together with the zoning map and regulations, they form a legal document that guides land use and the granting of building permits. Plan markings were interpreted and assessed with planning architect Planläggningsarkitekt Pontus Högström (Figure 2.3).
    - Regional provisions: An unofficial combination of the valid regional plans of Uusimaa – markings and regulations (translated from Uudenmaan liitto, 2023) (Annex 2).
    - City provisions (byggnadsordning, gällande planer – generalplaner, detailed planning): Land use and building act formula markings (translated from the Decree of the Ministry of the Environment on markings used in plans in accordance with the Land Use and Building Act, 2020).



Potential areas

- Industrial and warehouse areas in the vicinity of existing and/or planned logistics and energy networks:
  - Existing industrial and warehouse area with planning reserve
  - Industrial or warehouse area with changing use
  - Large/uniform new industrial area with zoning
- Port and terminal areas and their surroundings (especially hydrogen and industrial production)
- Maintenance and processing areas (energy, utilities, waste, soil)
- Disused peat production areas (especially solar power)

Sensitive areas

- Urban and workplace areas depending on the purpose and scale of the activity and the disturbances caused
- Mining areas
- Special areas
- Areas requiring repair of environmental or landscape damage
- Protective green areas (on a case-by-case basis)
- Areas dominated by agriculture and forestry that are not part of ecological networks or of the uniform zones designated in the regional plan

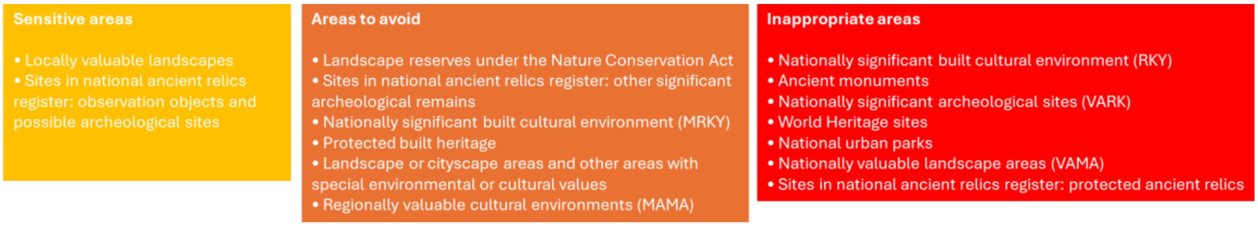
Areas to avoid

- Outdoor and recreational areas, hiking destinations
- Ancient monuments and archaeological heritage areas
- Landscape or cityscape areas and other areas with special environmental or cultural values
- Natural environments
- Agricultural and forestry-dominated areas that are part of ecological networks or contiguous zones designated in the regional plan
- Groundwater areas
- Geological formations

Inappropriate areas

- Conservation and Natura areas
- Nature conservation area or national park
- Nationally significant built cultural environment (RKY area)
- World Heritage sites
- National urban parks
- Areas of particular importance for biodiversity (Nature Conservation Act, Forest Act, Water Act, Directive species)

Figure 2.1: Classes from Uusimaa green transition plan



Sensitive areas

- Locally valuable landscapes
- Sites in national ancient relics register: observation objects and possible archeological sites

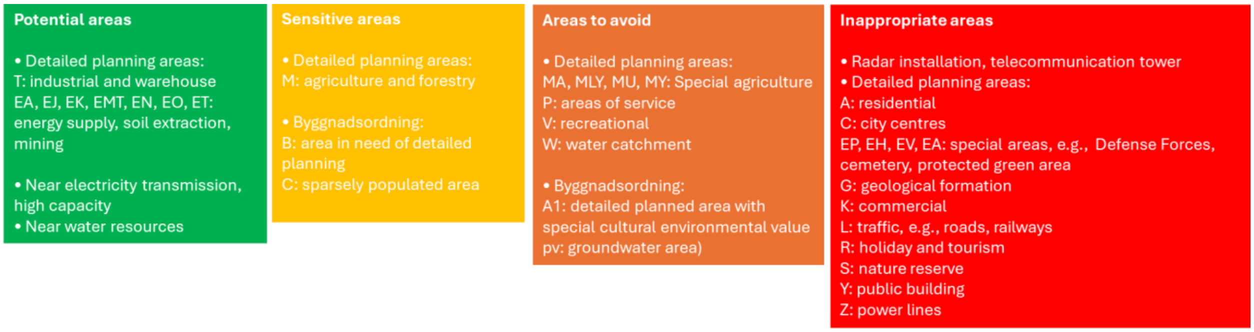
Areas to avoid

- Landscape reserves under the Nature Conservation Act
- Sites in national ancient relics register: other significant archeological remains
- Nationally significant built cultural environment (MRKY)
- Protected built heritage
- Landscape or cityscape areas and other areas with special environmental or cultural values
- Regionally valuable cultural environments (MAMA)

Inappropriate areas

- Nationally significant built cultural environment (RKY)
- Ancient monuments
- Nationally significant archeological sites (VARK)
- World Heritage sites
- National urban parks
- Nationally valuable landscape areas (VAMA)
- Sites in national ancient relics register: protected ancient relics

Figure 2.2: Classes recommended for Regional and local cultural and historical items



Potential areas

- Detailed planning areas:
T: industrial and warehouse
EA, EJ, EK, EMT, EN, EO, ET: energy supply, soil extraction, mining

- Near electricity transmission, high capacity
- Near water resources

Sensitive areas

- Detailed planning areas:
M: agriculture and forestry

- Byggnadsordning:
B: area in need of detailed planning
C: sparsely populated area

Areas to avoid

- Detailed planning areas:
MA, MLY, MU, MY: Special agriculture
P: areas of service
V: recreational
W: water catchment

- Byggnadsordning:
A1: detailed planned area with special cultural environmental value
pv: groundwater area)

Inappropriate areas

- Radar installation, telecommunication tower
- Detailed planning areas:
A: residential
C: city centres
EP, EH, EV, EA: special areas, e.g., Defense Forces, cemetery, protected green area
G: geological formation
K: commercial
L: traffic, e.g., roads, railways
R: holiday and tourism
S: nature reserve
Y: public building
Z: power lines

Figure 2.3: Classes according to plan markings

Classes

The level of constraint (class) has been set according to the guiding principles:

Potential areas do not, at best, have land pressure or natural and cultural values. They might also be undeveloped or exempt of legal effects. Finally, they might be already industrialized and supporting a coherent industrial development (Table 2.2).

Table 2.2. Type of potential areas

Potential
Industrial and warehouse areas in the vicinity of existing and/or planned logistics and energy networks: • Existing industrial and warehouse area with planning reserve • Industrial or warehouse area with changing use • Large/uniform new industrial area with zoning
Port and terminal areas and their surroundings (especially hydrogen and industrial production)
Maintenance and processing areas (energy, utilities, waste, soil)

Disused/former peat production areas (especially solar power)
Specific provisions (EJ, EK, EMT, EN, EO, ET)
Proximity to a power station and to power line
Moderately flat or gentle slope
Field that is not cultivated or low yield*
Geologically reasonable buildable (sand, sandy moraine, coarse sand)

**This is debatable since Metsähallitus considers some of those sites as traditional biotope (but the layer was not available) e.g., meadow, pasture created by traditional agriculture and potentially rich in species.*

Sensitive areas are locations where more care is required and are more dependent on case-specific planning and assessment (Table 2.3).

Table 2.3. Type of sensitive areas

Sensitive
Urban and workplace areas depending on the purpose and scale of the activity and the disturbances caused
Active or former mining/rock/soil extraction areas
Locally valuable landscapes, sites in national ancient relics register
Ecological networks in Uusimaa
Special areas
Areas requiring repair of environmental or landscape damage
Protective green areas (on a case-by-case basis)
Areas dominated by agriculture and forestry that are not part of ecological networks or of the uniform zones designated in the regional plan
Specific byggnadsordning: B
Specific provisions (M)

Areas to be avoided require special justification and exhibit reasonable level of constraint, e.g., extensive impact assessment. Those areas have special cultural and natural values potentially conflicting with green transition infrastructures (Table 2.4).

Table 2.4. Type of areas to be avoided

Avoid
Outdoor and recreational areas, hiking destinations
Landscape or cityscape areas and other areas with special environmental or cultural values (Nature conservation act)
Natural environments, conservation program areas
Agricultural and forestry-dominated areas that are part of ecological networks or contiguous zones designated in the regional plan
Groundwater areas
Geological formations
Cultural and historical value: protected built heritage, archaeological sites and remains
Regionally significant built cultural environment (MRKY area)
Regionally valuable landscape areas (MAMA)
Specific byggnadsordning: A1
Specific provisions (MA, MLY, MU, MY, P, V, W)

Inappropriate areas are highly regulated or/and legally protected under current legislation, exhibiting heavy constraints (Table 2.5).

Table 2.5. Type of inappropriate areas

Inappropriate
Conservation and Natura areas – SAC, SPA, Birdlife
Nature conservation area or national park
Nationally significant built cultural environment (RKY area)
World Heritage sites
National urban parks
Areas of particular importance for biodiversity (Nature Conservation Act, Forest Act, Water Act, Directive species)
Ancient monuments, archaeological heritage areas (VARK) and protected ancient relics
Nationally Valuable Landscape Areas (arvoalueet) (VAMA)
Specific provisions (A, C, EH, EV, EA, G, K, L, R, S, Y)

Forbidden areas are areas where land development is not possible (Table 2.6).

Table 2.6. Type of forbidden areas

Forbidden
Defence reservations
Traffic infrastructure
Specific provisions (EP, EMT, EH, Z)

Spatial analysis

A simple spatial analysis has been conducted to highlight the areas available for development. Using the basic municipal polygon as starting point (NLS, 2026), all the layers belonging to one class have been merged together then subtracted incrementally from the general polygon using QGIS 3.40 (QGIS, 2026). The final difference represents available areas (limiting) then has then been clipped with the potential class to obtain available areas already enabling development (enabling). It is to be noted that vector points and lines **have not been** included in this analysis since their actual coverage is not accurately depicted by the usage of simple vector. To be perfectly accurate, one should manually digitize the actual coverage of line and point elements into aerial polygons and include them in the analysis then (Annex 3).

To estimate which land cover lays within those areas, land cover data from SCALGO at 2-m resolution was used using its WMS (SCALGO, 2025). This layer displays pixels classified according to 10 land cover classes based on data from the National land survey (aerial photos, 2022 and topographic database, 2025) and Väylävirasto (transportation, 2023). The WMS content was exported in TIFF, then a mask was applied using the available areas resulting polygon to only extract land cover from those areas. Finally, the number of pixels from each class was counted to estimate the area each land cover class represents.

Results

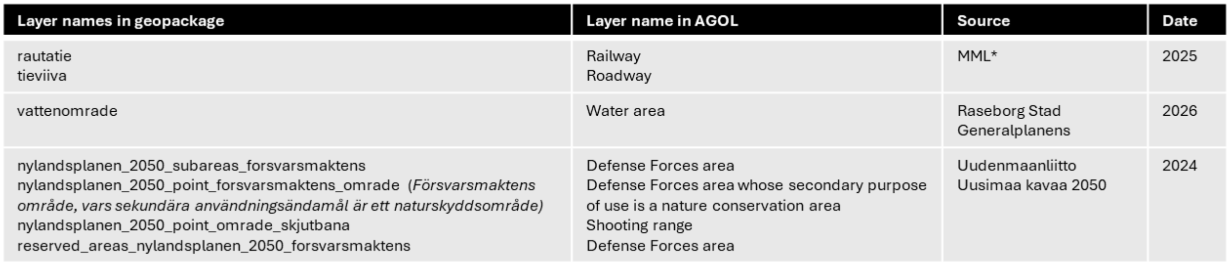
Classification

The resulting features have been classified and saved in separate geopackages in WGS84 EPSG 4326 (Table 2.7 and Figures 2.4-2.8), a total of 79 layers have been classified in 5 categories.

Table 2.7. Resulting features colour and storage

Class	Map colour	Geopackage
Potential	Green	EMP_p_20260424.gpkg
Sensitive	Yellow	EMP_s_20260408.gpkg
To avoid	Orange	EMP_a_20260408.gpkg
Inappropriate	Red	EMP_i_20260408.gpkg
Forbidden	Black/grey	EMP_f_20260408.gpkg

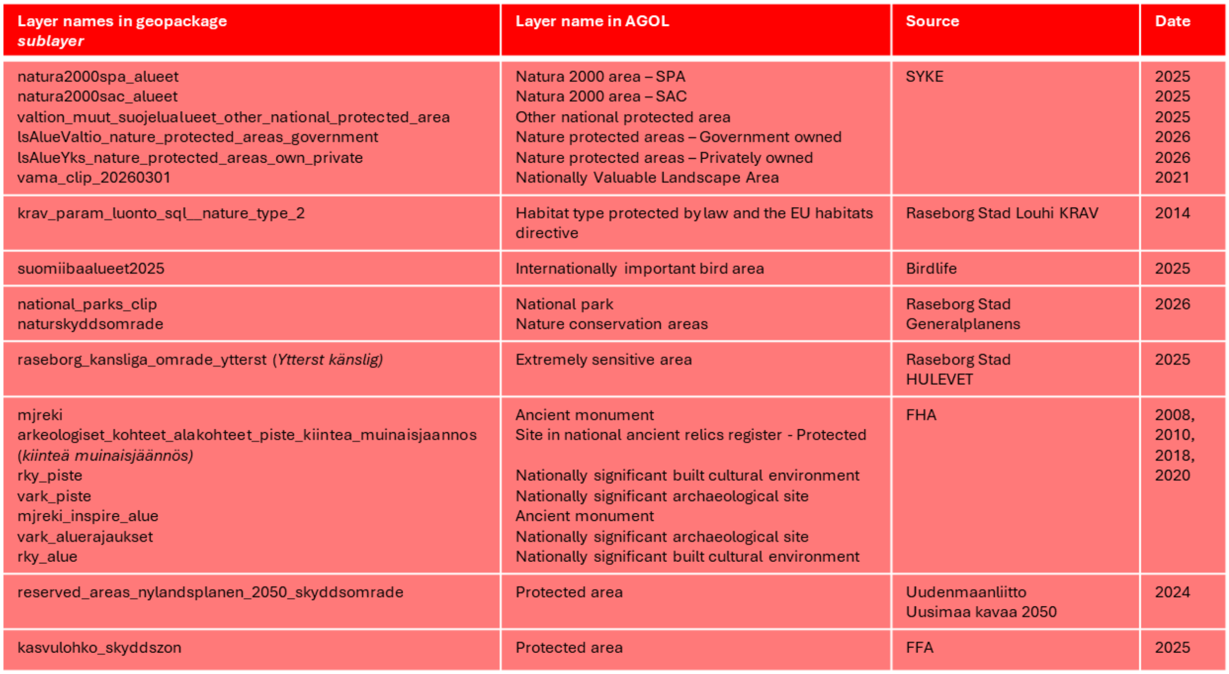
Forbidden area



Layer names in geopackage	Layer name in AGOL	Source	Date
rautatie tieviiva	Railway Roadway	MML*	2025
vattenomrade	Water area	Raseborg Stad Generalplanens	2026
nylandsplanen_2050_subareas_forsvarsmaktens nylandsplanen_2050_point_forsvarsmaktens_omrade (*Försvarsmaktens område, vars sekundära användningsändamål är ett naturskyddsområde)* nylandsplanen_2050_point_omrade_skjutbana reserved_areas_nylandsplanen_2050_forsvarsmaktens	Defense Forces area Defense Forces area whose secondary purpose of use is a nature conservation area Shooting range Defense Forces area	Uudenmaanliitto Uusimaa kavaa 2050	2024

Figure 2.4. Seven forbidden area layers

Inappropriate area



Layer names in geopackage ***sublayer***	Layer name in AGOL	Source	Date
natura2000spa_alueet natura2000sac_alueet valtion_muut_suojelualueet_other_national_protected_area lsAlueValtio_nature_protected_areas_government lsAlueYks_nature_protected_areas_own_private vama_clip_20260301	Natura 2000 area – SPA Natura 2000 area – SAC Other national protected area Nature protected areas – Government owned Nature protected areas – Privately owned Nationally Valuable Landscape Area	SYKE	2025 2025 2025 2026 2026 2021
krav_param_luonto_sql__nature_type_2	Habitat type protected by law and the EU habitats directive	Raseborg Stad Louhi KRAV	2014
suomiibaalueet2025	Internationally important bird area	Birdlife	2025
national_parks_clip naturskyddsomrade	National park Nature conservation areas	Raseborg Stad Generalplanens	2026
raseborg_kansliga_omrade_ytterst (*Ytterst känslig)*	Extremely sensitive area	Raseborg Stad HULEVET	2025
mjreki arkeologiset_kohteet_alakohteet_piste_kiintea_muinaisjaannos (*kiinteä muinaisjäännös)* rky_piste vark_piste mjreki_inspire_alue vark_aluerajaukset rky_alue	Ancient monument Site in national ancient relics register - Protected Nationally significant built cultural environment Nationally significant archaeological site Ancient monument Nationally significant archaeological site Nationally significant built cultural environment	FHA	2008, 2010, 2018, 2020
reserved_areas_nylandsplanen_2050_skyddsomrade	Protected area	Uudenmaanliitto Uusimaa kavaa 2050	2024
kasvulohko_skyddszon	Protected area	FFA	2025

Figure 2.5. Twenty inappropriate area layers

Area to be avoided

Layer names in geopackage ***sublayer***	**Layer name in AGOL**	**Source**	**Date**
nylandsplanen_2050_subareas_utvecklingszon_tatortsfunktioner nylandsplanen_2050_subareas_vardefull_geologisk_formation nylandsplanen_2050_subareas_viktig_kulturmiljon (*viktigt med tanke på kulturmiljön eller landskapsvården)* nylandsplanen_2050_subareas_grundvatten nylandsplanen_2050_subareas_vattenforsorjning (*vattenförsörjning viktigt ytvattenområde)* reserved_areas_nylandsplanen_2050_areas_rekreationomrade reserved_areas_nylandsplanen_2050_areas_skogsbruksdominerat (*som är vidsträckt, sammanhängande och betydande för det ekologiska nätverket)* nylandsplanen_2050_point_avoid: *Målområde för rekreationsbruk / Område för centrumfunktioner, centrum / Område för handel / Område som är viktigt med tanke på kulturmiljön eller landskapsvården / Servicekoncentration / Värdefull geologisk formation* nylandsplanen_2050_lines_kulturmiljo (*Område som är viktigt med tanke på kulturmiljön eller landskapsvården)*	Area of development Valuable geological formation Valuable landscapes and cultural environments Groundwater area Important water surface area for water supply Recreational area Forested area important ecologically Purposed area Special cultural value	Uudenmaanliitto Uusimaa kavaa 2050	2024
Uudenmaanliitto_MaakKulttuuriymparistot	Regionally significant cultural environment	Uudenmaanliitto - kulttuuriympäristöt	2022
arvokkaatmoreenimuodostumat arvkallioalue maisemanhoitoalueet lsoalue luonnonmuistomerkit	Nationally valuable moraine formation Nationally valuable rocky area Landscape management area Nature conservation program area Natural monuments	SYKE	2018 2025 2022 2021 2025
suojellut_rakennukset_alue suojellut_rakennukset_piste arkeologiset_kohteet_alue_muu_kulttuuriperintokohde arkeologiset_kohteet_piste_muu_kulttuuriperintokohde arkeologiset_kohteet_alakohteet_piste_muu_kulttuuriperintokohde	Protected built heritage Protected built heritage Site in national ancient relics register - other significant archeological remains Site in national ancient relics register - other significant archeological remains Site in national ancient relics register - other significant archeological remains	FHA	2008, 2010, 2018, 2020
raseborg_kansliga_omrade_mycket (*Mycket känslig)*	Very sensitive area	Raseborg Stad HULEVET	2025
krav_param_luonto_sql__nature_type_1	Valuable natural area	Raseborg Stad – Louhi KRAV	2014
kasvulohko_naturvard (*plantskola, frukt, naturvardsvall, miljoavtalsareal, vatmark, permanent vall, pollinerare,..)*	Natural interest area	FFA	2025
Urheilujavirkistysalue Merkittavaluontokohde Rauhoitettukohde Muistomerkki	Sports and recreation area Significant natural site Protected area Memorial	MML	2025
raseborg_kansliga_omrade_mycket (*Mycket känslig)*		Raseborg Stad HULEVET	2025
important_bird_areas_in_finland__finiba important_bird_areas_in_uusimaa_maali	Important bird area in Finland (FINIBA) Important bird areas in Uusimaa (MAALI)	Birdlife	2002 2018
byaomraden bostadsomrade omrade_for_centrumfunktioner	Town area Residential area Area for central functions	Raseborg Stad Generalplanens	2018, 2019

Figure 2.6. Thirty-two areas to be avoided layers

Sensitive area

Layer names in geopackage ***sublayer***	**Layer name in AGOL**	**Source**	**Date**
Soidensuojtaydehdalueet	Peatland protection area	SYKE	2020
kayrava_alueet	Ecological network corridor	Uudenmaanliitto ekologiset verkostot	2018
raseborg_kansliga_omrade_kanslig	Sensitive area	Rasborg Stad HULEVET	2025
arkeologiset_kohteet_alakohteet_piste_havaintokohde *mahdollinen muinaisjäännös*	Site in national ancient relics register – Observation site	FHA	2008, 2013, 2015, 2025
arvoalueet _mpi	Locally valuable landscape	Västra Nylands Museum	1992, 1993, 2003, 2006, 2010, 2019
kasvulohko_clip_cropland	Cropland (active parcel)	FFA	2025
hyvatjayhtenaisetpeltoalueet	Good and uniform field	Uudenmaanliitto eltoalueet	2017

Figure 2.7. Seven sensitive area layers

Potential area

Layer names in geopackage ***sublayer***	**Layer name in AGOL**	**Source**	**Date**
Varastoalue Louhos Kaatopaikka Maaaineksenottoalue Muuntoasema Taytemaa Satamaalue Niitty	Storage area Quarry Landfill Soil extraction area Electric transformation point Filled area Port area Meadow	MML	2025
prod_indus_visio *Koncentration av industriell produktion, logistik, marksubstansförsörjning och/eller cirkulär ekonomi* *Område för energiförsörjning EN/h* *Område för energiproduktion EN/t*	Concentration of industrial production, logistics, area of energy production or supply	Uudenmaanliitto VISIO	2026
detailed_plan_t_e* *Areas TY, T: Industrial and warehouse buildings, industrial area where the environment places special demands on the quality of operations* *Areas EJ: waste treatment area*	Industrial (TY, T) and special (EJ) area	Raseborg Stad Delgeneralplan	1996-2006
nylandsplanen_2050_point_industry *Utvecklingsområde för marksubstanshantering* *Utvecklingsområde för produktion och logistikverksamhet*	Development area for soil substance management, production or logistics	Uudenmaanliitto Uusimaa kavaa 2050	2024
kasvulohko_pasture_meadow *Pasture, fodder and meadows*	Pasture, fodder and meadow	FFA	2025
Metsasuunnitelma	Forest plan	Raseborg Stad Louhi	2025

Figure 2.8. Thirteen potential area layers

Spatial analysis

About 15% of the total area of the municipality, 356 km^2, is available for development, without any identified constraint. Potential areas represent 6,5% of the available areas, about 23 km^2. And only 23% of the potential areas are on available areas (77% have a certain level of constraints). The results of the spatial analysis are in EMP_20260408.gpkg. The merged layers are named with the prefix as_ and suffix _merged, the difference layers are named with the prefix as_ and suffix_diff (Table 2.8). The resulting layers: **area available for development** free of constraint is raseborg_available, and the area **areas available already enabling development** is raseborg_available_potential.

Table 2.8. Class areas

Area	Area in km^2	Remaining area in km^2	Name
Municipality	2354		/
Water	1206	1148	/
Forbidden - f	7	1141	as_for_diff as_forbidden_areas_merged
Inappropriate - i	2757*	899	as_inapp_diff as_inappropriate_areas_merged
To avoid - a	3784*	493	as_avoid_diff as_areas_to_avoid_merged
Sensitive - s	998*	356	as_sens_diff as_sensitive_areas_merged
AVAILABLE	356		raseborg_available
Potential - p	100	23	raseborg_available_potential

*since areas overlap

In the available areas, 78% of the pixels are classified as dense vegetation, usually representing areas covered by trees and high-density shrubbery, and 15% are shallow vegetation, usually representing areas such as shrubs, meadow, pasture, grassland (Table 2.9 and Figure 2.12).

Table 2.9. Land cover class areas in available land

Class	Area in km^2	Area in %
Dense vegetation	278,92	78,3
Shallow vegetation	54,39	15,3
Fields	9,55	2,7
Bare land	6	1,68
Impervious (building, roads)	4,2	1,17
Water	1,35	0,4
Other	1,59	0,45
Total	356	100

Mapping

The resulting interactive map is available on ArcGIS online (AGOL - ESRI, 2026) at: Energy master plan web and a light version is Figure 2.11. Additionally to class-coloured layers (annex 3), the area available for development, free of constraint is in pink and the area available already enabling development is in purple.

The user is able to navigate and explore the map by activating and deactivating features classes through the legend menu. It allows the user to have an overview of areas of certain classes. The features are named in English, with a Swedish description when possible then Finnish, and the source is in parenthesis. Some features overflow municipal boundaries. No label was added to not crowd the map; however most features are explorable with hovering or selecting. The metadata presented in this report are also available in AGOL.

Raster layers pertaining to green transition have been provided but not added to the webmap (incompatible CRS) (Figure 2.9).

General guidance for opportunities	**Layer names in EMP raster folder** ***sublayer***	**Source**
Energy possibilities for Uusimaa	Geoenergy Wind power potential Carbon sequestration	Uudenmaanliitto – Geoenergia, 2020 Uudenmaanliitto – Tuulivoimaselvitys, 2013 Uudenmaanliitto – Hiilensidonta, 2023
Forest layer with indication of canopy height and density	Puustoisuusluokat_forest_classification	SYKE, 2022
Condition of peatland and mineral soil drainage	Ojitustilanne_peatland and mineral soil drainage	SYKE, 2025

Figure 2.9. Raster layers relevant for guidance

Additional layers have been added for background and general guidance and saved in EMP_20260424.gpkg (Figure 2.10). Topographic features such as mast, building have been added since specific distances apply to development around those elements (Part 3). Soil information and urban areas are also part of the package since their respective locations also facilitate or impede development.

General guidance for opportunities	**Layer names in geopackage** ***sublayer***	**Layer name in AGOL**	**Source**
Legal rules applying to the land	cadastral_boundaries general_plan_and_legal_effects rakennusjarjestys_sql – byggnadsördning (some areas already have provisions, detailed areas)	Cadastral boundaries General plan and legal effects City provision area	Raseborg Stad, 2026
Future development areas	detailed_plan_for_future_urban_development detailed_plan_for_future_urban_development__under_preparation raseborg_utvecklingszon	Detailed plan for future urban development Detailed plan for future urban development under preparation Development area	Raseborg Stad, 2026 Uudenmaanliitto - Uusimaa kavaa 2050
Ownership of nature reserves	lsaluevaltio_nature_protected_areas_government lsalueyks_nature_protected_areas_own_private	Nature protected area owned by the government Nature protected area owned by the private owner	SYKE, 2026
Soil	soil	Soil Mining info: https://gtkdata.gtk.fi/mdae/index.html	Geological survey of Finland (GTK) and Natural Resource Institute, 2016***
Background	Rakennus* Masto Rautatieliikennepaikka Taajaanrakennettualue Raseborg_20260105	Building (residential and holidays) Mast** Railway station Urban area Raseborg	MML, 2025
Existing energy elements			
Electricity	electricity_component nylandsplanen_2050_lines *Riktgivande sträckning för kraftledning* Sahkolinja (with voltage)	Electricity related project and infrastructure Additional line Electric transmission line	Fingrid, 2026 Uudenmaanliitto – Uusimaa kavaa 2050 MML, 2025
Gaz	guiding_layout_for_hydrogen_pipeline current_gas_route_20260119	Guiding layout for hydrogen pipeline Current gas distribution line	Gasgrid, 2025

Date for MML: https://hkp.maanmittauslaitos.fi/hkp/published/fi/de4d45c1-1ec0-427d-b9dc-11365562d962

**Description for MML: https://www.maanmittauslaitos.fi/sites/maanmittauslaitos.fi/files/old/maastotietokohteet.pdf*

*** Topographic features such as mast, building have been added since you can only develop the areas around those at specific distances*

**** Only the southern part of Raseborg is covered by this layer.*

Figure 2.10. Additional layers relevant for guidance

It would be recommended to add supplementary layers for a more comprehensive overview such as digital elevation model (DEM), or district heating network. It is to be noted that vectorial isolated and linear layers do not represent the actual coverage and footprint of the feature they represent. It is also to be noted that the analysis stops at the municipal boundaries and it is recommended for a global overview to also include neighbouring municipalities features (edge effect and boundaries conditions).

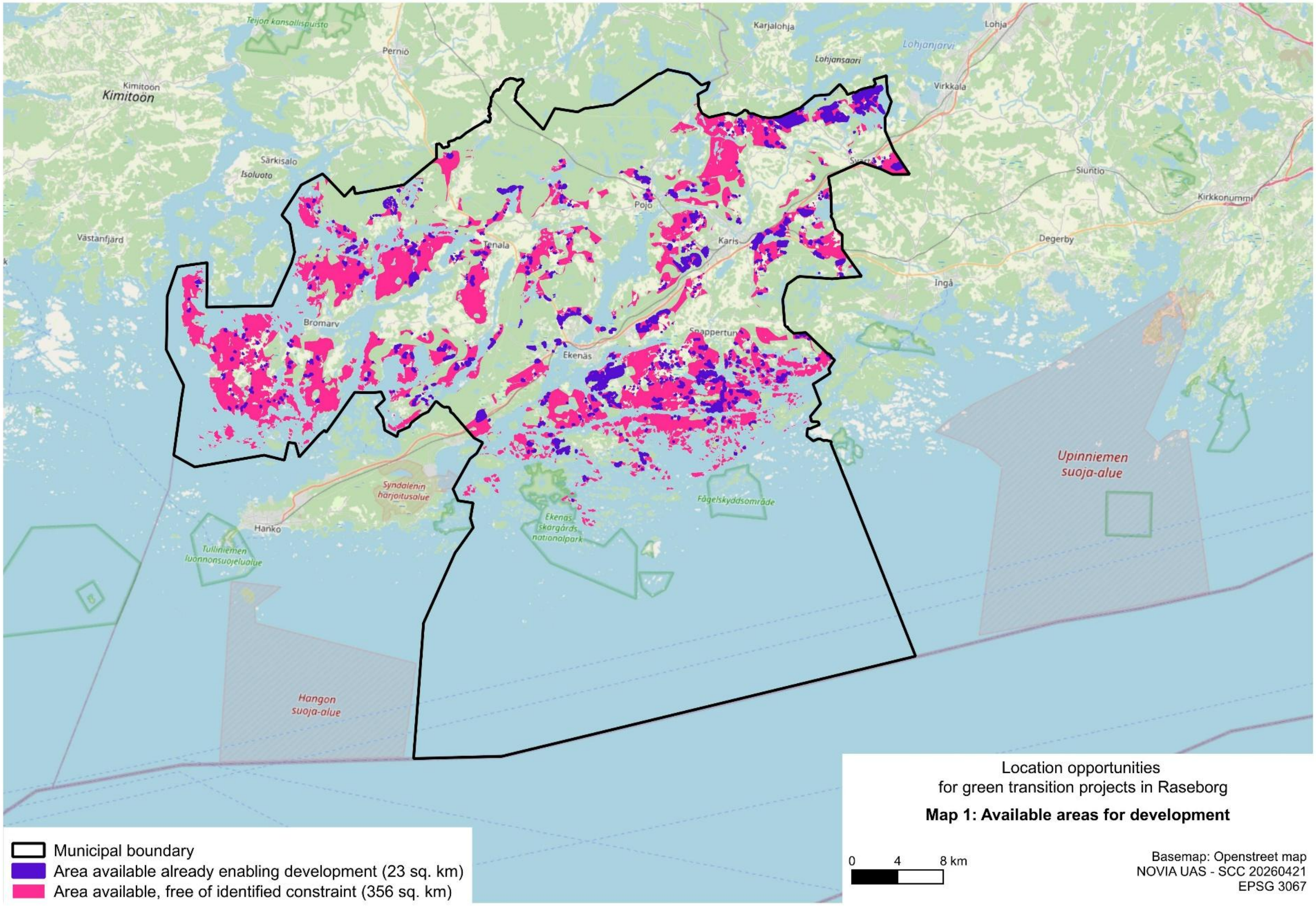


Figure 2.11 Synthesis map (A. Noel)

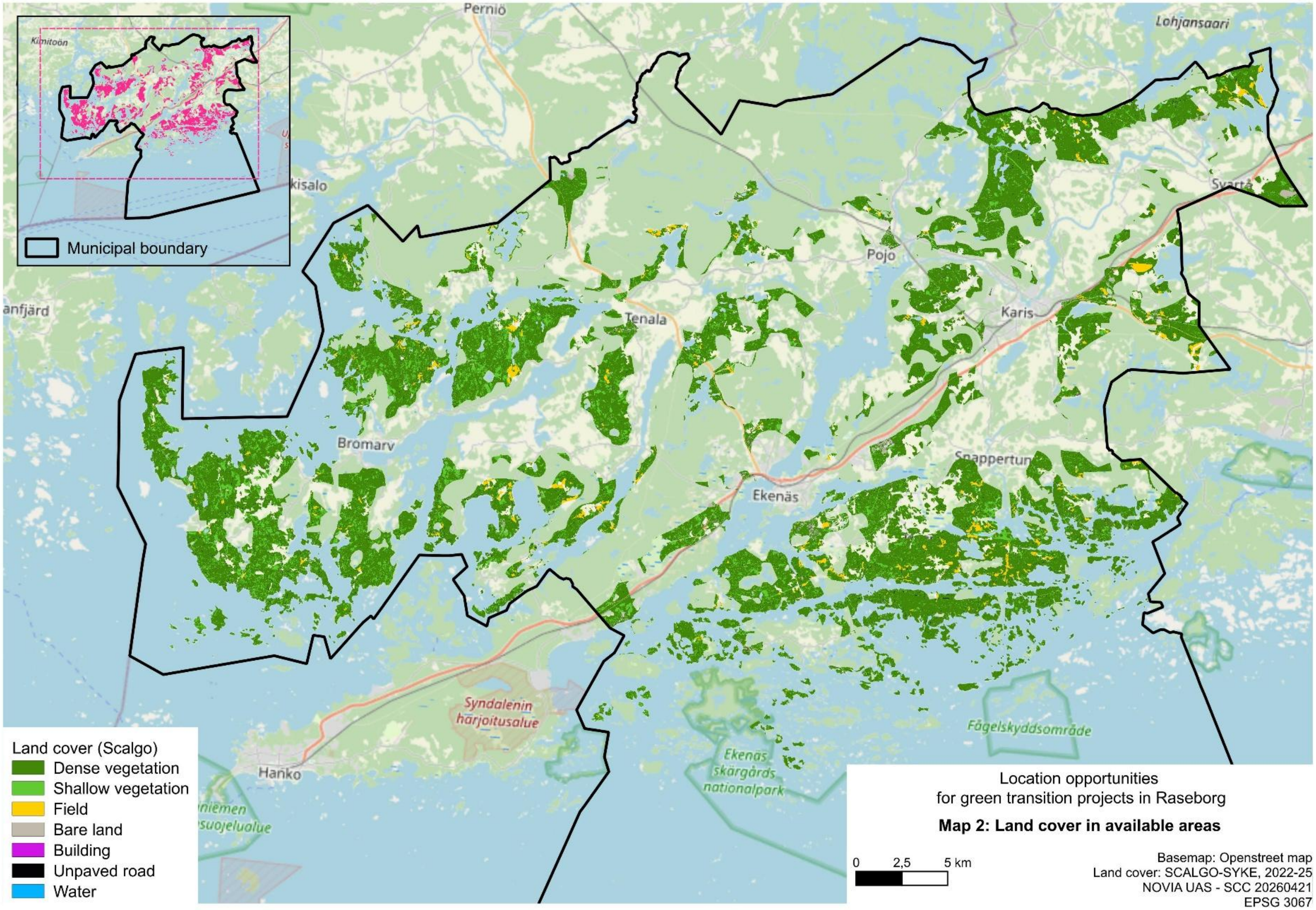


Figure 2.12 Land cover in available areas (A. Noel)

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SYKE, 2018-2025: https://www.syke.fi/en/environmental-data/downloadable-spatial-datasets

Uudenmaanliitto – VISIO, 2026: https://uudenmaanliitto.fi/kaavoitus-ja-liikenne/maakuntakaavat/visiokaava/

Uudenmaan liitto, 2023: https://uudenmaanliitto.fi/wp-content/uploads/2022/01/Uudenmaan-voimassa-olevien-maakuntakaavojen-epavirallinen-yhdistelma-merkinnat-ja-maaraykset-13.3.2023-1.pdf

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Part 3 – Cross analysis

Setback distance

The tables below (Table 3.1, 3.2, 3.3) contain guiding distance found in the literature and are not regulatory. The purpose of those tables is to guide the creation of buffer zones along and around land feature and energy system to consider actual footprint and minimize potential impact. Those buffer zones complete the land availability assessment related to energy system requirements, risks and impacts (parts 1 and 2). Indeed, while the part 2 assesses potential development **inside** area (inclusion), this part complements it with distance to and from those areas (proximity).

While solar park and geothermal energy seem to be more commonly regulated, there is currently no specific distance provisions dedicated solely to hydrogen pipeline nor data centre. As a result, installation distances are determined case-by-case by a combination of regulations, assessments, standards and specific permitting (Enico, 2026; Tukes, 2026; DLA Piper, 2025).

Table 3.1. Recommended setback distance from land feature for development

Topographic feature	Distance in m	Detail	Source
Natural value			
River, stream, wetland, lake	10-50	Around water area and along linear feature	VHVSY ry, 2025
Critical infrastructure			
Highway and main road	100	Along the feature - corridor	Raseborg Stad
Regional and connecting road	50	Along the feature - corridor	Raseborg Stad
Defense Forces area	2000	Around the feature	Raseborg Stad
Railway	100	Along the feature - corridor	Raseborg Stad
Powerline	100	Along the feature - corridor	Raseborg Stad

Table 3.2. Recommended setback distance from energy system under consideration

	Solar park	Geothermal energy	Hydrogen/biogas pipeline	Battery storage facility	Data center
Range in meters	1,2-2 ha/MW		> 10 ha[1]		50-300 ha[1]
Min perimeter				25 around[8]	
Min area			5-10 right of way		
Distance from in meters (around or along the feature)			300[2]		
Natural value					
Conservation and nature area and site	100[1]				
River, stream, wetland, lake					
Groundwater					
Area of scenic values					
Cultural value					
Culturally and historically valuable area, line and site	20-50[1,*]				
Man-made			72[4]		
Residential settlement and holiday settlement	50[6]-100[1]-200[2]	3[9]	40[3]		100[5]
Recreational trail and area	50[1]				
Critical infrastructure					15[7]
Highway and main road	30[1]		40[4]		
Regional and connecting road	20[1]				
Terminal and other traffic area					
Defense Forces area					
Railway	30[1]		40[4]		
Powerline					
Communication tower					
Other	Prohibited on high-productivity land	Prohibited on drinkable water area			Preferred industrial, commercial zones
Energy needs			50-300 MW[1]		100-250 MW[1]

1. Päijät-Hämeenliito, 2025; 2. Raseborg Stad, 2026; 3. Gasgrid, 2026; 4. OECD, 2023; 5. Datacenters.com, 2026; 6. BayWa.re, 2026; 7. Salgrom, 2026; 8. Pelastusopisto, 2026; 9. Riihimäki, 2026

* Depending on type: ancient remain/protected building

Table 3.3. Typical land requirements of BESS installations

Scale	Capacity	Power rating	Usual location	Main applications	Approx. land area needed
Residential	5–20 kWh	3–10 kW	individual houses, apartments, small buildings	solar energy storage, backup power, self-consumption	<0.01 ha (installed indoors or outdoors)
Commercial / Industrial	100 kWh – 10 MWh	50 kW–5 MW	offices, factories, hospitals, infrastructure objects, data centres	peak demand reduction, backup power, solar integration	0.05 – 0.5 ha (depending on size)
Utility-scale (Grid-scale)	10 MWh – 500+ MWh (some >1 GWh)	5 MW – 500+ MW	power plants, substations, renewable energy sites	grid stabilization, frequency regulation, renewable storage, peak load support	5 – 50 ha (depending on total MWh and container spacing for fire safety)

Additional considerations

Additionally to land use enabling and limiting factors (Table 3.4) and energy requirements (Table 3.1, 3.2 and 3.3), risks and impacts (Table 3.5), energy projects are also typically subject to a variety of regulations to comply to, priorities to consider and cost to quantify (Bergmann, 2026).

Table 3.4. Examples of general limiting and enabling factors

Enabling	Limiting
Electricity transmission main and distribution network	Waterways, roads, railways
Grid development plan 2024–2033	Settlements and growth areas
Proximity to the railway network	Groundwater area
Proximity to the highway network	Sports and recreation areas
Proximity to water resources	Natura 2000 zones
Secondary land-use areas; disused peat production areas, wastelands	Nationally significant bird areas and migratory routes
Planning situation, projects in neighbouring municipalities	Nationally, regionally and locally significant landscape
Multipurpose areas (like solar panels near windfarms)	Old forest

Table 3.5. Examples of positive and negative impacts

Positive impact	Negative impact
Reduction in CO_2 emissions	Land-use change
Energy-system flexibility and reliability	Habitat loss, biodiversity impact, effects on terrestrial and aquatic ecosystems and wildlife
Employment	Landscape impact
Regional and local economic effects	Groundwater impacts
Support for decarbonization	Construction-phase disturbances
Grid resilience	Local disturbance and social acceptance

Support for digitalisation	Resource-use and lifecycle impacts
Socio-economic development	Fire and safety risks
Support for a circular economy	Water use, thermal effects, and other lifecycle impacts
Energy diversification	Energy consumption and indirect climate impacts
Complementarity with other energy systems	Air and water pollution (dust, odour)
Co-existence with other land uses	Visual and noise impact
	Disruption

Examples of regulations and legal permitting involved in energy project:

- Environmental Impact Assessment
- Environmental permit
- Chemical permit
- Building permit
- Fire safety assessment

Examples of priorities to consider in energy project following Do No Significant Harm (Euro-Lex, 2021)

- Climate change mitigation
- Adaptation
- Decarbonization
- Sustainable use and protection of water and marine resources
- Transition to a circular economy
- Pollution prevention and control
- Protection and restoration of biodiversity and ecosystems

Examples of quantification of energy project cost:

- Euro
- Carbon budget
- SDGs (sustainable development goal)
- Biodiversity budget

While this report highlights areas available for development, this part 3 is essential to determine if those are indeed suitable by balancing all the above considerations.

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Annexes

Annex 1: Existing PV Parks in Finland

Name	Region	Municipality	Owner / Owner of SPV	Nominal power (MW)	Installation year
Boliden	Satakunta	Harjavalta	Boliden	3.8	2023
Callio	Pohjois-Pohjanmaa	Pyhäjärvi	Solarigo Oy	13	2025
Flakanasa Solpark	Pohjanmaa	Pedersöre	Esse Elektro-Kraft Ab	2	2024
Hietakangas	Keski-Pohjanmaa	Kannus	Puhuri Oy	5	2024
Hirvensalmi	Etelä-Savo	Hirvensalmi	Suur-Savon Sähkö	4	2024
Högbergin haara	Uusimaa	Tuusula	Stockmann	2	2024
Isku SOL	Päijät-Häme	Lahti	Isku	2.8	2021
Isosuo	Pohjois-Pohjanmaa	Utajärvi	Skarta Energy	106.8	2025
Joroisten lentokenttä	Pohjois-Savo	Joroinen	Ilmatar	5	2023
Juurakon aurinkopuisto	Pohjois-Pohjanmaa	Kalajoki	Solarigo Oy	13	2023
Järvelä	Päijät-Häme	Kärkölä	Koskisen Oy	2	2023
Kirkniemi	Uusimaa	Lohja	Helen	7	2024
Lakari	Satakunta	Rauma	CPC Finland	32	2024
LEMENE PV01	Pirkanmaa	Lempäälä	Lempäälän Energia Oy	2	2019
LEMENE PV02	Pirkanmaa	Lempäälä	Lempäälän Energia Oy	2	2019
Liesoja	Pohjois-Pohjanmaa	Ii	OK Aurinkovoima oy	5.84	2025
Lindö solpark	Uusimaa	Hanko	Chaps Invest Oy	1.98	2023
Loukkaanaro	Pohjois-Pohjanmaa	Utajärvi	OSS	17.6	2025
Nokian renkaat	Pirkanmaa	Nokia	Nokian Renkaat	1.1	2021
Nurmijärvi aurinkopuisto	Uusimaa	Nurmijärvi	Helen	1.5	2023
Nurmo, Atria aurinkovoima	Etelä-Pohjanmaa	Seinäjoki	Atria	5	2018
Nurmo, Atria aurinkovoima laajennus	Etelä-Pohjanmaa	Seinäjoki	Atria	4.3	2023
Paarmala	Pohjois-Pohjanmaa	Raahe	Oulun Energia Oy	4.4	2025
Raasepori	Uusimaa	Raasepori	Raaseporin Energia	1	2021
Ruda Solpark	Varsinais-Suomi	Kemiönsaari	Ruda Solpark Oy	1.98	2023
Ruotsinoja	Pohjois-Pohjanmaa	Liminka	OSS	9.5	2025
Seepsulan aurinkovoimala	Uusimaa	Tuusula	Seepsula Oy	2.8	2023
Simo Aurinko	Lappi	Simo	Exilion	70	2025
Soljuva	Etelä-Savo	Juva	Solarigo Oy	5.2	2024
SunSulkava	Etelä-Savo	Sulkava	Solarigo Oy	3.8	2023
Taalintehdas	Varsinais-Suomi	Kemiönsaari	Dalsbruks fabrik oy	2	2024

Tokmanni	Uusimaa	Mäntsälä	Tokmanni	1.7	2023
Vihreäsaari aurinkopuisto 1	Pohjois-Pohjanmaa	Oulu	Oomi Solar Oy	4.9	2022
Vihreäsaari aurinkopuisto 2	Pohjois-Pohjanmaa	Oulu	Oomi Solar Oy	5.1	2023

Annex 2: Examples of provision texts

Recreation area

🟩

Description

The area reservation designation refers to areas of more than 50 hectares that are intended for public recreation and outdoor activities and are mainly located in areas owned or managed by the state, municipalities or the Uusimaa Outdoor Areas Association.

The designation includes paths and structures that exist in the area and are necessary to unify the social structure.

The designation is subject to building restrictions according to Section 33 of the Building and Land Use Act.

Planning provision

The area is reserved for public recreation and outdoor activities. The more detailed planning of a recreation area shall ensure the preservation of the conditions for using the area for recreation, the accessibility of the area, an adequate level of equipment and environmental values. In the planning of the area, special attention shall be paid to the quality of the environment, the location of the area in the ecological network and its importance for natural diversity.

Buildings and structures serving public recreation may be constructed on the area.

In the area, more detailed planning may designate local trails as well as facilities and structures for community services that, based on studies, are necessary to unify the community structure. Trail planning shall ensure the unhindered and safe continuation of recreational connections.

Armed Forces area

EP

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Description

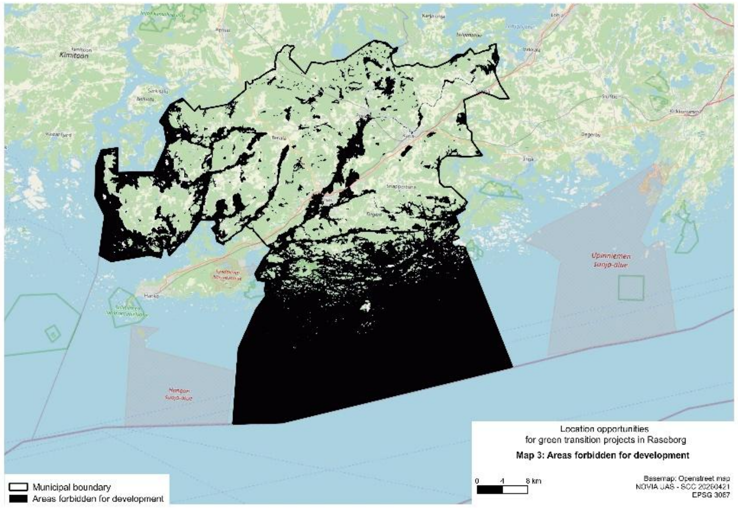
The area reservation designation designates areas that are permanently used by the Armed Forces and to which public access is restricted.

Small areas have been designated with an object designation.

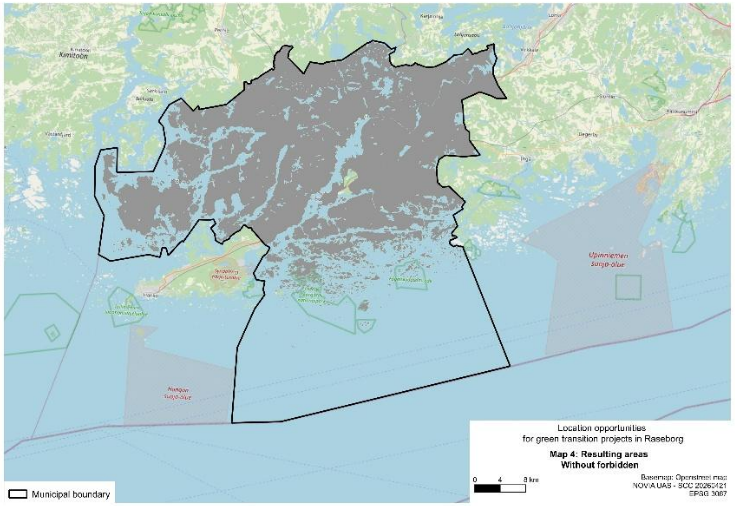
Planning provision

The area or object is reserved for the use of the Armed Forces.

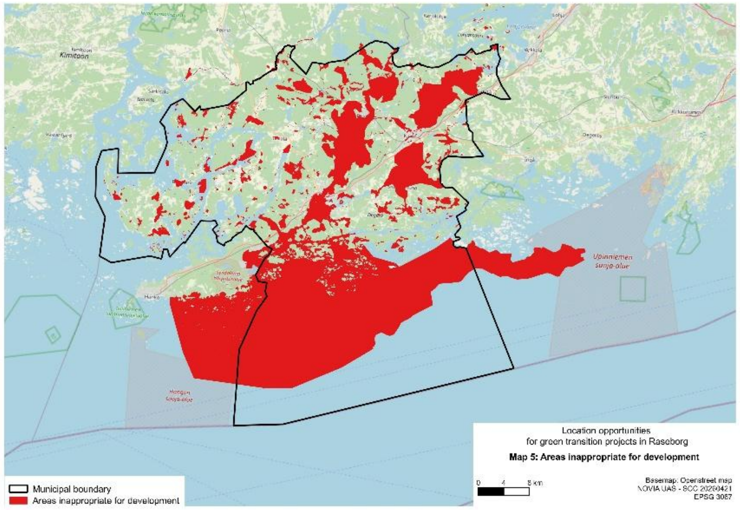
Annex 3: Intermediate maps



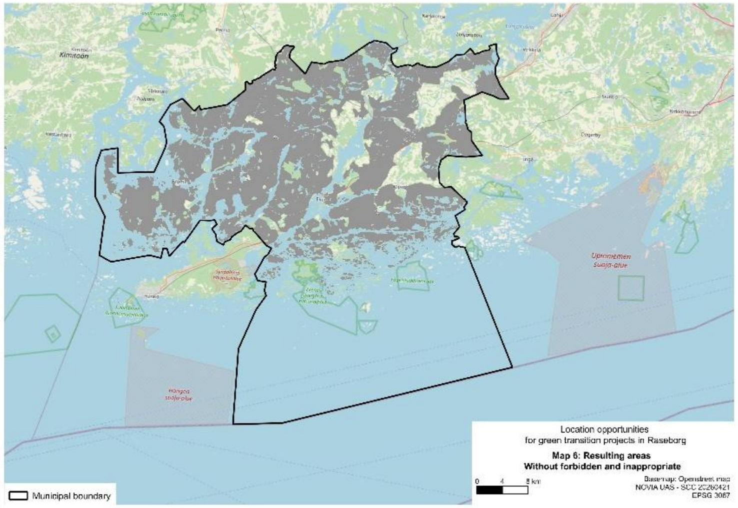
Forbidden areas



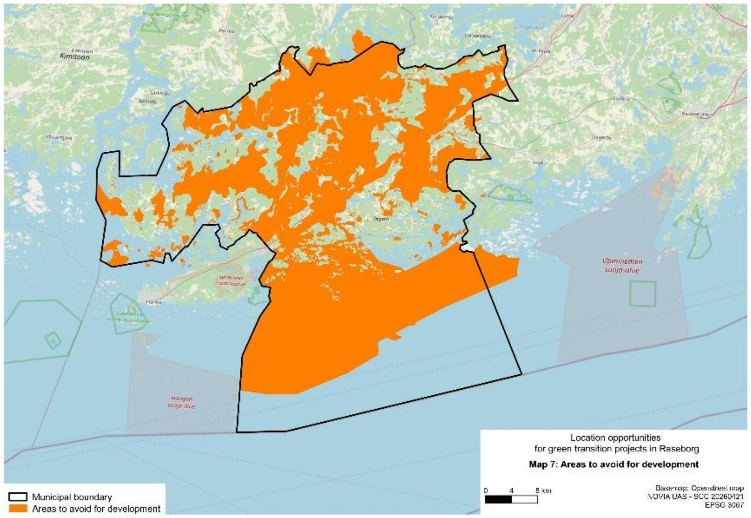
Resulting map without forbidden areas



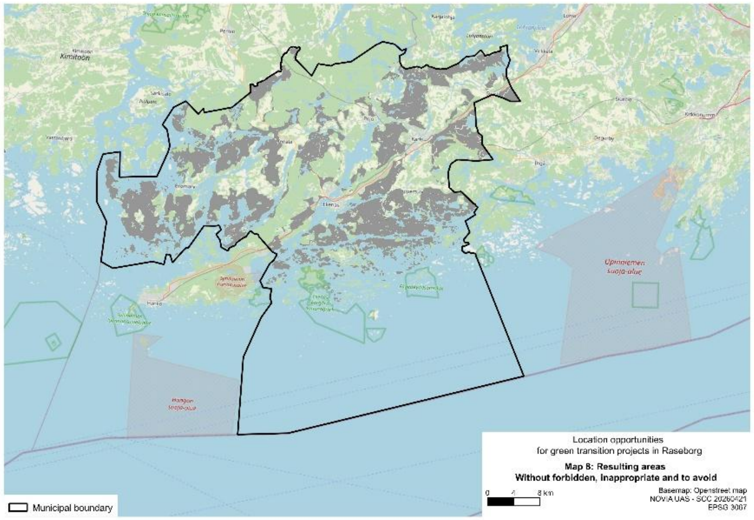
Inappropriate areas



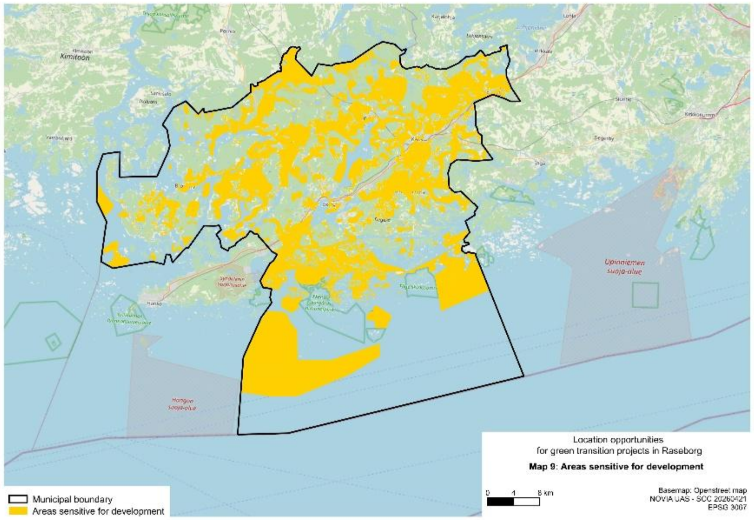
Resulting map without forbidden and inappropriate areas



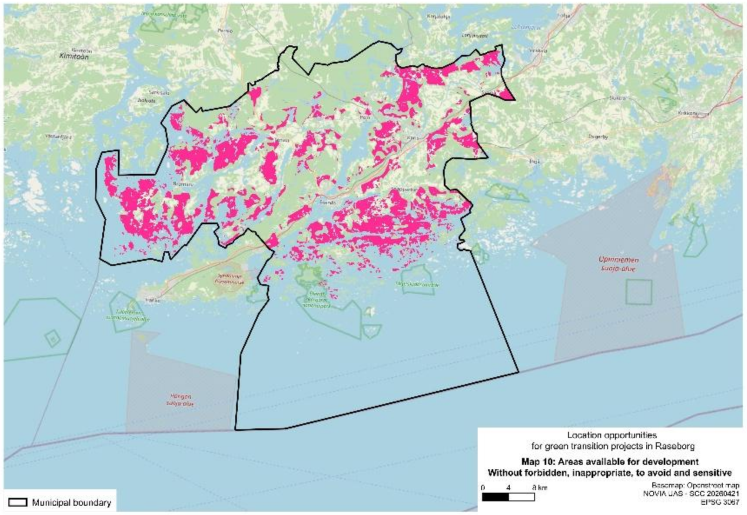
Areas to avoid



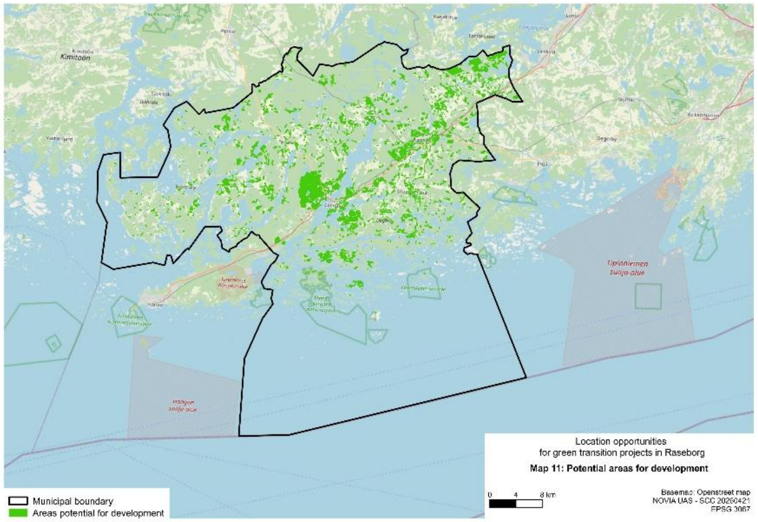
Resulting map without forbidden, inappropriate and areas to avoid



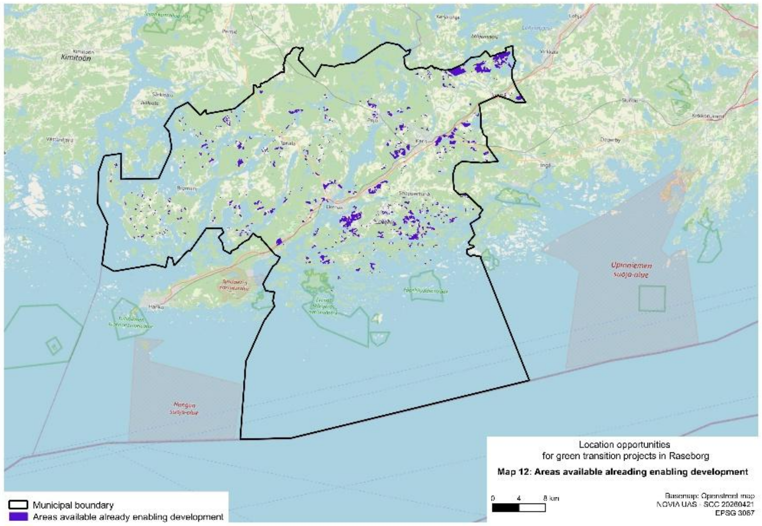
Sensitive areas



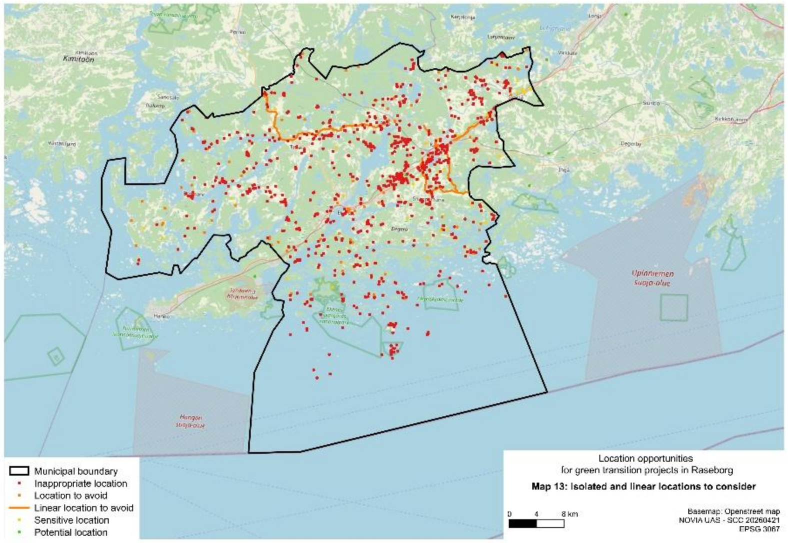
Resulting map without forbidden, inappropriate, to avoid and sensitive a.k.a Areas available for development (no limiting factors)



Areas with potential for development



Areas available already enabling development



Additional locations to consider (points and lines)