Toolbox

for industrial areas to become smart and climate-neutral

Mecklenburg-Vorpommern
Ministry of Economics,
Infrastructure, Tourism
and Labour

GRÜNE GEWERBEGEBIETE
natürlich erfolgreich

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ENERGY TRANSITION
GreenIndustrialAreas

Abstract

This report presents a comprehensive toolkit designed to facilitate the certification of industrial areas as „Green Industrial Areas." The toolkit compiles a range of innovative technologies and best practices aimed at enhancing sustainability, resource efficiency, and environmental compliance in industrial zones. By integrating these solutions, industries can streamline their transition toward greener operations, reduce environmental impact, and align with global sustainability standards.

The toolkit encompasses key technological solutions, including renewable energy integration, circular economy approaches, smart resource management, and digital monitoring systems. These technologies enable industries to optimize energy consumption, minimize waste, and improve overall environmental performance. Additionally, the report outlines certification frameworks, regulatory requirements, and practical implementation strategies to support industries in achieving green certification.

A key feature of the toolkit is its adaptability across different industrial sectors, ensuring that businesses can tailor sustainability measures to their specific needs. Case studies and best-practice examples illustrate successful implementations, demonstrating the tangible benefits of adopting green industrial strategies.

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Abbreviations and Their Meanings

CAPEX:	Capital Expenditures
OPEX:	Operational Expenditures
LTDH:	Low Temperature District Heating
PV:	Photovoltaic
PVT:	Photovoltaic-Thermal Hybrid
BESS:	Battery Energy Storage System
VAWT:	Vertical Axis Wind Turbine
ROI:	Return on Investment
COP:	Coefficient of Performance
SCOP:	Seasonal Coefficient of Performance
NZEB:	Nearly Zero Emission Buildings
RCCF:	Regional Council for Circular Finland
ERDF:	European Regional Development Fund
JTF:	Just Transition Fund

Introduction to Toolbox

This toolbox has been developed based on a previously compiled compendium that gathers existing experiences from industrial areas around the Baltic Sea, as well as insights collected through a series of peer reviews with project participants and businesses. The purpose of the toolbox is to support the green transition in industrial areas by presenting concrete examples of technologies, procedures, and the organization of local collaborations.

Industrial areas face significant challenges and opportunities in relation to energy transition and resource efficiency. Collaboration between companies within an industrial area can help optimize resource utilization and reduce environmental impact through the sharing of energy, materials, and knowledge. The toolbox compiles a range of solutions designed to inspire businesses and stakeholders to implement sustainable initiatives.

The foundation of the toolbox is the collection of a wide array of Good Practice examples, technologies, procedures, and collaboration models. The toolbox should be seen as a dynamic document that can be continuously adjusted and expanded as new experiences and solutions become available.

To ensure effective use, the toolbox also includes a description of its structure, applications, limitations, and considerations. The goal is to make it easier for users to navigate the material and identify the most relevant solutions for their specific context.

The toolbox is intended as a resource for businesses, municipalities, and other stakeholders who wish to contribute to the green transition in industrial areas.

User Guide for the Green Toolbox
For Industrial Areas in the Baltic Sea Region

Purpose of the Toolbox

This toolbox has been developed to support industrial areas—especially those with mixed industries—in promoting sustainability through green initiatives. The goal is to inspire and guide decision-makers, business leaders, and planners in implementing effective green solutions tailored to their local context.

The toolbox is based on multiple concrete examples from industrial areas in the Baltic Sea Region that have implemented green initiatives. These examples cover a wide range of topics such as resource efficiency, circular economy, renewable energy, collaboration, and governance.

How to Use the Toolbox

The toolbox is structured as a collection of tools in the form of case-based examples. These examples are divided into five parts:

1. **Energy**
2. **Reduction of land consumption**
3. **Sustainable mobility and transport**
4. **Biodiversity and water management**
5. **Industrial cooperation and circular economy**

Each part consists of descriptions of concepts and technologies, as well as links to more detailed information.

At the beginning of each main section (part), there is a process diagram that supports the user's application of the relevant part of the toolbox.

Step-by-Step Guide

1. **Identify needs and opportunities in your area**
   Begin by analyzing the current level of sustainability in your industrial area and identifying potential areas for improvement. Consider collaboration formats and existing resources.
2. **Map current processes and resource use**
   - Sort by themes (e.g., waste management, energy supply, symbiosis, etc.)
   - Sort by type of stakeholder involved (public, private, or partnerships)
   - Sort by maturity level (pilot project, scaled solution, policy)
3. **Explore relevant examples**
   Use case studies as inspiration to see how similar areas have approached sustainability. Note what works and how it could be adapted to your local context.
4. **Select and adapt tools**
   Choose the most relevant initiatives and evaluate how they can be tailored to local conditions. Engage local stakeholders early to ensure ownership.
5. **Plan implementation**
   Use case studies as input when developing project descriptions. You may also seek additional insights from the featured projects.
6. **Evaluate and share experiences**
   Follow up with data collection and evaluation. Share your experiences in networks—and contribute your own tools to future versions of the toolbox.

Target Groups

The toolbox is intended for:

- Local authorities and urban planners
- Industrial Park administrators
- Business leaders and CSR managers
- Development consultants
- Regional networks and industry clusters

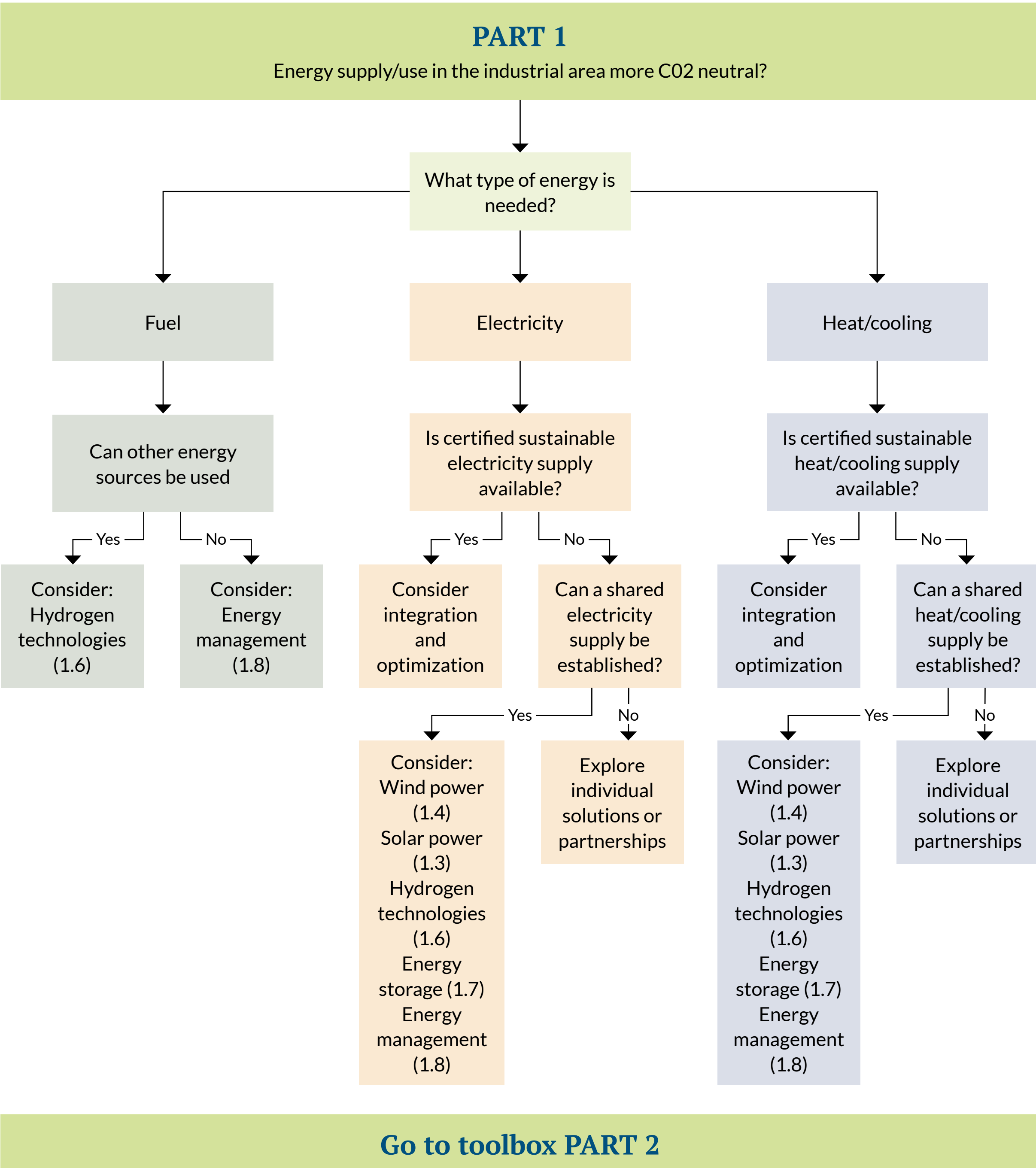
Tips for Successful Use

- Think systemically and collaborate across sectors.
- Start small, but with a scaleable outlook.
- Use the toolbox as a dialogue tool in workshops.
- Rethink waste as a resource—and your neighbor as a partner.
- Continuously evaluate and don't be afraid to adjust your course.

Part 1 - Energy

This part of the toolbox contains technologies and examples focusing on the energy consumption of companies and industrial areas, as well as their share of low-carbon energy.

Below is a diagram that supports the user in analyzing which energy choices can be implemented.



1.1 District heating and cooling

District heating and cooling systems provide thermal energy to multiple buildings from central source, which is efficient, especially in urban areas. These systems are designed to maximize energy efficiency by utilizing waste heat from industrial processes, power plants, or renewable sources, thereby reducing overall energy consumption and environmental impact. They can use various energy sources, including fossil fuels, biomass, geothermal, and solar energy, allowing for adaptation to local energy availability and sustainability goals. Modern systems often operate on a closed loop principle, where energy is reused within the network. Heated buildings can deliver excess cold from the heating process to the system, while cooled buildings can deliver excess heat, from the cooling process optimizing the energy use. Additionally, the latest generation of systems operates at lower temperatures, reducing energy losses and increasing efficiency, which also allows for the integration of low-grade energy sources. These systems incorporate energy storage solutions to manage temporal imbalances between supply and demand, ensuring a reliable energy supply. By utilizing waste heat and renewable energy sources, district heating and cooling systems contribute to reducing greenhouse gas emissions and achieving environmental targets. Overall, district heating and cooling systems are a promising solution for sustainable urban energy management, offering efficiency, flexibility, and environmental benefits.

Below, we refer to four selected good practice examples.

District heating and cooling systems connect multiple buildings through a network of pipes to provide heating and cooling, using zero-carbon energy sources like geothermal and solar thermal heat

District heating by heat pumps is a key component, where large scale heat pumps utilize waste heat sources of low temperatures to minimize heat losses and facilitate the integration of renewable power.

Low Temperature District Heating operates at lower temperatures, reducing energy losses and increasing efficiency, which also allows for the integration of low-grade energy sources

Heat capture from district cooling involves reclaiming heat that would otherwise be lost during the cooling process, improving overall system efficiency

1.1.1. District heating and cooling

Location:	Jyväskylä, Finland
Business:	Textile

The new factory making textile from cellulose was built to Jyväskylä. The Woodspin factory produces Spinnova fibre from Suzano cellulose in a modern factory. The factory was built to Eteläportti industrial area, which is connected to city's district heating system. This offered Woodspin an excellent opportunity to build waste heat recovery system in their process which now produces heating for Jyväskylä. With the waste heat recovery power of 5MW it is estimated to save 2,4kg of district heating CO2 emissions per kg of produced fibre.

When implementing a shared heating system, there are several important considerations to take into account. One is the need for adequate space for the piping system, which is typically installed underground and requires careful planning and coordination, especially in built-up areas. Another key factor is the availability of a common heat production facility or a sufficient and stable supply of waste heat, which serves as the energy source for the system and determines its overall efficiency and feasibility.

Links to further information:

210331_THS_D3.9_CREARA_THERMOS_Case_Studies_V2_FINAL-komprimiert.pdf (thermos-project.eu)

Good practice link:

Woodspin ramps up production of sustainable, wood-based SPINNOVA® fibre at new zero-emission factory - Spinnovagroup

Economic indicators

Payback time	under 10 years
CAPEX (Capital expenditures)	250 - 600 EUR /m
OPEX (Operational expenditures)	2 EUR /kW/year

1.1.2. District heating by heat pumps

Location:	Hajnówka, Poland
Business:	Public buildings – "Power to heat" Podlaska Regional Development Foundation

The idea is to develop an energy concept where electricity from regional wind and solar power plants can be used for large heat pumps to replace coal in the existing district heating system in Hajnówka (county and city). The heat supply is based on the analysis, selection, and optimization of local sources of electricity from renewable energy sources, as well as the selection and optimization of ground and water heat pumps and energy storage. The heating system is currently based in a central coal-fired power plant and operates at a high temperature level (130°C). The main heat source is operated by a regional company specializing in coal, oil, and biomass heating.

The technology substitutes heating is provided by coal-based technology, air pollution is much higher what influences health of local society.

The technology allows to replace coal based technologies by cleaner ones, which improves e.g. quality of the air and provide energetical independence for local society.

Links to further information:
Renewable Power-to-Heat Hajnówka - EUKI

The introduction of district heating supplied by large heat pumps reduces CO2 emissions by 54%	
Payback time	3,82 years
CAPEX (Capital expenditures)	25 million EUR
ROI % (Return of investment)	27,69%

1.1.3. Low Temperature District Heating (LTDH)

Location:	Lund, Sweden
Business:	Research Facility Max IV

In Lund there is a high activity to demonstrate the latest solutions in many fields. One such field is to construct the largest LTDH network based on fossil fuel free surplus energy. Kraftringen Energi (Lund's energy and utility company) and its partners develop concepts for energy, mobility and lighting for the infrastructure. The construction was started in 2018 in the district of Brunnshög with the goal to become Europe's largest LTDH facility and test field for LTDH solutions. The total development will cover 100 ha over time. This way, the city can keep growing without increasing the GHG emissions. The biomass presently used in the DH system can be used elsewhere to replace fossil fuels.

Besides developing, demonstrating, and evaluating optimized heat production and distribution technologies, the Brunnshög LTDH project offers the opportunity to develop new business models and test exciting new applications. In addition to heating homes, the surplus heat and the low-temperature network can be used for things that don't normally use this kind of heat source. For example, is it used to heat the ground at a number Brunnshög's tram stops in the winter to prevent the build-up of snow and ice. Other applications and technologies are being investigated by the EU-funded COOL DH innovation project.

The Research Facility Max IV outside of Lund produces waste heat

Links to further information:
https://www.cooldh.eu/demosites-and-innovations-in-cool-dh/brunnshog-in-lund/

that is distributed in low temperature distribution networks (65 degrees Celsius) to buildings in the nearby residential area. The system temperature of 65 °C was chosen to eliminate the need for extra equipment to handle growth of legionella bacteria. The lower temperature also means plastic pipes, specially developed for the Cool DH project, could be used. These can be laid closer to the surface, meaning shallower digging and thereby narrower working area and less intrusion on the surrounding area. The new pipes are delivered on 100-meter rolls which can be rolled out very effectively compared to previous technology where 16-meter sections needed to be lifted into the ground. This also means that the LTDH grid needs far fewer joints, leading to further reduction in costs. An economic side-effect is that Brunnshög's district heating customers can have a lower district heating tariff than with traditional solutions. The return temperature is quite low, at 35°, which is a measure of the system's efficiency in making most of the heat 'stay' in the buildings. The system will be further expanded as the Brunnshög area develops. The total available source of low-grade heat including ESS will grow to 250 GWh/year by 2027 with a maximum capacity of 40 MW. Fully developed in 2050, up to 40 000 people will live and work in Brunnshög.

When planning for the implementation of low-temperature district heating (LTDH), several important considerations must be considered. One key factor is the availability of surplus heat, which can serve as an efficient and sustainable energy source for the network. Equally important are the relationships between the district heating company and its customers; strong, trust-based connections can significantly influence the success of the system.

Whether or not property owners choose to connect to the LTDH network often depends on a range of factors. These include their previous experiences with district heating, which may shape their expectations and trust in the system, as well as their environmental concerns, with many viewing LTDH as a greener alternative. Additionally, an ambition toward innovation can motivate property owners to adopt new, forward-thinking energy solutions.

Good practice link:

Smart City Sweden – A platform for smart sustainable city solutions:

https://smartcitysweden.com/best-practice/358/developingcutting-edge-fossil-free-districtheating-at-a-lower-temperature/

https://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=9108545&fileOId=9108550

1.1.4. Heat capture from district cooling

Location:	Kalundborg, Denmark
Business:	Kalundborg Symbiosis

The maximum cooling effect will be 166 MW. Technology: from an intake located in Kalundborg harbor, the district cooling plant draws in 18,000 m3 of seawater per hour at maximum load, but it is expected that the average cooling requirement is approximately half that. The size of the intake and its location under the water means that the water, even at high load, almost seeps in by itself and there will be no large currents at sea level. From there, the water is filtered in two stages in the part of the plant that is located underground. The seawater is pumped by pumps where the impeller and the shaft are made of super-duplex to avoid corrosion from the seawater. The seawater is pumped on to the exchange station. The water from the closed cooling circuit, which comes back warm from the industry, is cooled down over the heat exchangers with the lower temperature of the seawater. The exchangers are made of titanium, so they are more resistant to corrosion. The water is circulated to industry with a maximum temperature of 22.5 degrees and preferably lower in the periods where it is possible. The closed cooling circuit is connected from Kalundborg Forsyning (Utility) to the Novo Nordisk and Novozymes sites with an almost one-kilometer underground pipe, which is two meters in diameter inside. In this pipe, the cooled water is circulated to industry, while there is a similar pipe that takes it back. When the water is circulated back to the district cooling system from the industry, it has a temperature of a maximum of 31.5 degrees. In the project, it has been taken into account the seawater temperature may be too high during the summer period, so that it is not possible to cool the water down to the desired maximum temperature of 22.5 degrees. Therefore, the district cooling system is equipped with so-called chillers, a cooling system of 10 megawatts which in particularly hot periods can supplement the cooling after the exchanger and bring the temperature down. The now heated seawater is then discharged into the harbor somewhere other than the intake. They are located far enough apart so that the discharged water does not affect the intake.

In the second phase of the project the excess heat will be utilized either in Kalundborg or for district heating in other cities. In the Industrial Symbiosis context, the cooling and excess heat centrally produced can be utilized all industries in the area, reducing overall energy consumption and waste.

Surplus heat from cooling industrial production in Kalundborg can be converted into sustainable district heating in the future. Enough surplus heat from industry is generated to potentially heat more than

40,000 households. With the right infrastructure in place, the new district cooling system alone will generate enough surplus heat to potentially replace natural gas in Holbæk and heat the city of Kalundborg. Now, there are 17,500 households in Holbæk municipality that are heated with natural gas.

Good practice links

https://www.symbiosis.dk/en/2022/10/21/ (District cooling holds great potential for utilization of excess heat from Kalundborg Symbiosis)

When planning a district heating and cooling system, several key considerations must be taken into account to ensure its success and sustainability. First and foremost, there must be a substantial and consistent demand for both heating and cooling in the area. The system also relies on access to diverse and sustainable energy sources, which are crucial for long-term operation and environmental performance.

In addition, the presence of supportive policies and regulations at both local and national levels plays a vital role in enabling development and securing funding or incentives. Public awareness and acceptance of the system are equally important, as community support can influence both implementation and long-term use. The local climate must also be suitable, offering conditions where both heating and cooling are needed throughout the year.

Collaboration is another key factor, requiring strong cooperation between local government, energy providers, businesses, and community stakeholders to ensure integrated planning and shared benefits. Finally, a comprehensive environmental impact assessment should be conducted to evaluate the system’s footprint and ensure that it aligns with sustainability goals and environmental standards.

1.2 Heat pump technologies

Heat pump technology is an energy-efficient solution for heating and cooling by transferring thermal energy from one location to another. Unlike traditional heating systems that generate heat through combustion, heat pumps use existing heat sources, such as ambient air, ground, water, or industrial waste heat, making them a sustainable and cost-effective option. This technology significantly reduces carbon emissions and dependence on fossil fuels, aligning with global energy efficiency goals.

The efficiency of a heat pump is measured by its Coefficient of Performance (COP), which indicates the ratio of useful heat output to the energy input. Depending on the type of heat pump, COP values can range from 1.5 to 4 or higher, ensuring a substantial reduction in primary energy consumption. Additionally, heat pumps can be integrated into district heating networks or industrial processes, optimizing heat recovery and reuse.

Below we refer to five good practice examples of heat pump applications, demonstrating their effectiveness in different settings:

Waste Heat Recovery – AB Lifosa & AB Panevėžio Stiklas (Lithuania)
A phosphate fertilizer producer reuses process heat from sulfuric acid production to heat its facilities and supply 100,000 MWh to the Kėdainiai district heating system, reducing CO2 emissions by 150,000 tons annually. Additionally, a glass manufacturer captures waste heat from compressor cooling, covering 18% of the facility's heating needs in winter. The investment paid off in just 5 months, with CO2 reductions of 301 tons per year.

Sewage Heat Recovery – Kalundborg Utility (Denmark)
A high-efficiency heat pump extracts thermal energy from wastewater, contributing 80,000 MWh annually to the district heating network, covering 30% of the local heating demand and cutting CO2 emissions by 1,000 tons per year.

Absorption Heat Pump – Rīgas Siltums (Latvia)
Installed in a biomass-based district heating plant, this absorption heat pump maximizes heat recovery from flue gases, reducing CO2 emissions by 1,402 tons per year and lowering energy costs.

Air-Water Heat Pump – Aalto University (Finland)
A block-scale heating and cooling system utilizes air-water heat pumps to supply 8,000 MWh of heat annually, covering 70-90% of the area's heating demand while maintaining zero emissions.

Geothermal Heat Pump – Mikkeli (Finland)
A real estate rental company transitioned from district heating to a geothermal heat pump system, cutting operational costs and ensuring energy independence with an expected payback time of 6-10 years.

These examples highlight the versatility of heat pump technology in improving energy efficiency and sustainability across industries and municipalities.

1.2.1. Waste Heat recovery

Location:	Kėdainiai, Lithuania
Business:	AB „Lycosa“

AB "Lifosa" is a phosphate fertilizer producer, covering an area of 292 hectares in Kėdainiai industrial area. Since 2000, AB Lifosa has been using the process heat generated by sulphuric acid production to heat the company's facilities and Kėdainiai town. Using special steel tubular heat exchangers, the sulphuric acid heat is used to heat the water to 90° C and fed to the Kėdainiai boiler house for heating residential buildings. In 2007, the company installed the HRS (Heat Recovery System), which uses waste heat sources to generate around 250 million kWh of electricity, of which around 50 million kWh are fed into the national grid. The city is supplied with around 100,000 MWh of heat. To produce this amount of energy, Lithuanian power plants and boiler houses would need to burn over 70 million cubic meters of natural gas. This would result in the release of 150 000 tons of greenhouse carbon dioxide into the atmosphere.

When planning for the use of waste heat, several important considerations must be addressed. The waste heat source should be as constant as possible, with stable parameters to ensure efficient and predictable energy recovery. A heat exchange unit is essential to capture or accumulate the thermal energy from the waste heat stream. Equally important is the utilization of the recovered heat, which requires identifying a suitable consumer—either within the same facility, such as other process units, or externally, such as a nearby heat network or industrial partner.

Links to further information

https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Waste_Heat_to_Power_Fact_Sheet.pdf

Good practice links

lifosa.com/en

https://www.alva.fi/in-english/

Economic indicators:

Payback time	< 3 years
CAPEX (Capital expenditures)	3 000 – 100 000 EUR (small-large scale systems)
OPEX (Operational expenditures)	https://ior.org.uk/public/downloads/HD2mP/Dr-Joel-Hamilton-June-22.pdf, 3,5€/MWh

Location:	Panevėžys, Lithuania
Business:	AB Panevėžio stiklas

AB Panevėžio stiklas is one of the largest companies in the Baltic States producing and processing glass products. Industrial glass production line runs continuously throughout the year as uses natural gas to produce high levels of heat. High-performance combustion products are exhausted through a chimney, while high-power electrical or mechanical equipment that runs continuously must normally be cooled. The resulting cooling heat can be used as waste heat.

In 2017 AB Panevėžio stiklas installed heat recovery from compressor cooling technology that covers about 18% of the heat needs of buildings during the cold season.

Example of technology investment calculation:
Considering the electricity consumption of the compressors and their typical operating efficiency (0.65-0.75 for screw compressors), the heat removed with the cooling air accounts for about 30% of the electricity used. Based on the electricity consumption for compressed air production, the heat recovery can be up to 1482 MWh/year.

The heat production in the heat exchanger will result in a heat price equal to the price of the additional gas used (in 2017 prices) of EUR 18,91/MWh, and an energy saving of EUR 28 037. Heat exchanger at market prices for heat exchangers on the market, the cost of a heat exchanger with a capacity of around 200 kW is equal to EUR 5 200. Installation costs are estimated at EUR 5,000 and design and other costs are assumed at 15% of the total investment of EUR 1,530. The normal payback time for the investment is 5 months. CO_2 emission reduction 301 t/year (2018 data).

Good practice links
AB Panevezio stiklas

1.2.2. Sewage heat recovery

Location:	Kalundborg, Denmark
Business:	Kalundborg Utility

In 2017, Kalundborg Utility implemented an innovative solution to harness excess heat from wastewater. By installing a high-efficiency heat pump, the utility tapped into this underutilized resource. The system boasts an impressive, combined heat capacity of 10 MWt (34mmBTU/hr). Leveraging the excess heat and energy present in wastewater, which maintains a consistent temperature of 30°C (86°F), the heat pump plays a pivotal role in heating the supply water distributed through the district heating network to customers.

One of the notable advantages of this system is its ability to replace traditional materials such as biomass (wood chips) in the production of district heating. This shift translates into a substantial environmental benefit, lowering the carbon footprint associated with district heating operations.

In practical terms, the heat pump has a remarkable impact on the community. It contributes a substantial 80,000 MWh per year, meeting an impressive 30% of the citizens' total demand for district heating.

Links to further information

https://www.niras.com/projects/waste-water-turned-into-district-heating, district heating from waste water

Economic indicators:

The usage of sewage heat pump in Kalundborg utility CO2 emission lowered in Kalundborg Symbiosis by 1000 tons /year.	
CAPEX (Capital expenditures)	appr. 8.1 million EUR
ROI % (Return of investment)	appr. 5 years

When considering the implementation of a sewage heat recovery system for district heating, several key factors must be addressed to ensure success. Firstly, the sewage treatment plant should be located close to the area where the district heating is needed, as this minimizes heat loss during the transportation of wastewater. To extract heat effectively, the installation of heat exchangers is required, and their performance depends heavily on the quality of the wastewater, which must be suitable to avoid corrosion or fouling.

A well-established district heating network in the distribution area is also essential to make use of the recovered heat. In addition, the project must comply with local regulations and environmental standards, particularly those concerning wastewater management and heat production.

Beyond the technical and regulatory aspects, it is important to assess the financial feasibility of the project, ensuring it is economically viable in the long term. Engaging with the local community and relevant stakeholders plays a vital role in gaining public acceptance and support. Furthermore, the project must have access to technical expertise for the design, installation, and ongoing maintenance of the system. Finally, establishing a robust monitoring and maintenance plan is critical to ensure that the system operates efficiently and reliably over time.

1.2.3. Absorption heat pump

Location:	Riga, Latvia
Business:	Joint Stock Company "Rīgas Siltums"

Their applications are restricted to those cases when electricity is extremely expensive or a large amount of unutilized heat at suitable temperatures is available and when the cooling or heating output has a greater value than heat input consumed. The heat pump allows for the production of more thermal energy without the need for additional fuel, thus maximizing the utilization of the input fuel. This, in turn, enables a reduction in the thermal energy tariffs for residents.

Links to further information

https://broadusa.com/broad/products-2/

AS „Rigas Siltums" is located in Riga, Latvia and operates since 1995, it is the main supplier of heat energy in Riga. It performs heat energy production, transmission and sale, as well as provides technical maintenance of heat energy users' internal heat supply systems. The total length of the heating networks that belong to "Rīgas Siltums" is approximately 689 km. „Rigas Siltums" produces more than 30% of the required thermal energy in its heat sources - 5 thermal power plants, as well as several dozen small and medium-sized boiler houses, while about 70% is purchased.

To maximise the recovery of thermal energy from flue gases after a biomass boiler with a wet-type flue gas condenser, the „Zasulauks" heat plant is equipped with an absorption-type heat pump with a total capacity of 4.7 MW. In addition to the flue gas condenser, the heat pump cools down the outgoing flue gases from approximately 45°C to as low as 25°C, extracting low-grade thermal energy from them In 2022, the implementation of the absorption-type heat pump project with a capacity of 4.7 MW began at the „Zasulauks" heat plant, located at 16 Kandavas Street. The heat pump was put into operation in January 2023. The heat pump has been operating in line with the manufacturer's BROAD specifications so far. On hot summer days, the flue gas

Good practice links

www.rigassiltums.lv

Rīgas siltums: Pioneering sustainable district heating - Nordic Investment Bank temperature after the heat pump reaches as low as 25°C, effectively cooling the atmosphere. Lessons learned: Absorption heat pumps require large units. Therefore, if they are to be integrated into an existing technology system, it may necessitate rebuilding and adaptation to accommodate the heat pump.

KPI/Economic indicators:

CO2 reduction of	1402 tons /year
Payback time:	5 years

One important consideration when working with this type of heat pump technology is that it requires larger units compared to compression heat pumps. This means that more space must be allocated for installation, which can influence both design and placement decisions in a project.

1.2.4. Air/water heat pump

Location:	Espoo, Finland
Business:	Aalto University

Air-water Heat pumps have COP of 1.5-4 (average 3), meaning that primary energy consumption needed to produce heat is low. Also, if renewable energy is used the heat production causes no emissions. Another benefit of heat pumps is the scalability: they can be installed as units, so the investment can be done only for the current need → no need for early investments, although causes slightly higher total costs.

An area in the Aalto University campus was completely renovated and an innovative block heating and cooling system was installed there. The air-water heat pumps produce approximately 8000 MWh heat per year, which is 70-90% of the area's needs, rest comes from district heating. The system also has 2 MW cooling capability, and it recovers waste heat from many places. The system is economically viable and has worked well.

When considering the use of industrial-scale heat pumps, there are a few important factors to keep in mind. These systems perform poorly at air temperatures below -15°C, unless special heat pumps designed for colder climates are used. Additionally, sufficient space is required to accommodate the larger size of industrial-scale units, which can influence site selection and system design.

Links to further information

Air source heat pump - Wikipedia

Good practice links

https://www.sweco.fi/en/projects/a-zero-emission-local-energy-solution-developed-for-aalto-university-at-block-level/

Indicators:

CO2 reduction 1168 kg/year; current system is zero emission and normal district heating produces around 146 kg/MWh of CO" emissions.

COP 3; With COP 3 this means that for every unit of energy input into the system, the heat pump produces 3 units of useful heating or cooling output. This value represents the system's effectiveness in transferring thermal energy and is a measure of its efficiency. A COP should always be over 1 in heat pumps for them to be viable.

1.2.5. Geothermal heat pumps

Location:	Mikkeli, Finland
Business:	Rental of real estate

Geothermal heat can be used e.g. to heat buildings utilizing HVAC or water heating systems.

Geothermal heat is local and renewable, the only energy purchased is electricity for the pumping system. The efficiency coefficient is about 2,5-3,5 in Finland. Geothermal heat pumps can replace the connection to district heating system. A medium-sized machine shop with 6100 m2 heated space and consumption of about 836 MWh of purchased district heat. The real estate owner conducted a profitability study on moving from district heating to geothermal energy.

When considering the use of surface-installed pipes for real estate heating in Finland, it is important to note that these systems typically require around 1.5 times the surface area of the building they are intended to heat. This means that sufficient land must be available to install the necessary infrastructure. Additionally, geothermal energy collectors cannot be installed in certain locations, such as groundwater protection areas, regions with unstable soil conditions, or areas containing underground structures, as these factors can compromise both the efficiency and safety of the system.

Links to further information

Ground source heat pump - Wikipedia

Economic indicators

Payback time:	6-10 years depending on loan and interest rate
CAPEX (Capital expenditures):	300-400 kEUR
OPEX (Operation expenditures):	1000 EUR/a

1.3 Solar Power

In The sun is an abundant and renewable energy source that can be harnessed in various ways to produce electricity and heat. Two of the most widely used technologies for utilizing solar energy are photovoltaic (PV) systems and solar thermal systems. PV systems convert sunlight directly into electricity using semiconductor materials, making them ideal for a wide range of applications, from small-scale residential installations to large solar farms. In contrast, solar thermal systems capture and store heat from the sun, which can be used for heating buildings, generating steam for industrial processes, or even producing electricity through concentrated solar power (CSP) plants.

Below are five different examples of how these technologies are applied in practice, showcasing their potential for sustainable energy production and efficient solar energy utilization.

Photovoltaic cells (PV) is an energy harvesting technology that converts solar energy into useful electricity through a process called the photovoltaic effect.

Solar Thermal technology utilizes sunlight to produce heat. It works by using collectors to capture and concentrate sunlight, transferring heat to a fluid, and then utilizing a heat exchanger to provide heating.

PV-Solar Thermal -hybrid (PVT) generates electricity with the photovoltaic panels and heat with integrated collector system.

PV, solar thermal and heat pump technologies with energy management systems. A combination of three technologies for heating buildings involves installing photovoltaic panels on the walls and roofs of public buildings along with ground heat pumps and solar collectors.

Agrivoltaics, also known as solar farming or solar agriculture, is a sustainable land use practice that combines the cultivation of crops or vegetation with the installation of photovoltaic solar panels on the same land.

1.3.1. Photovoltaic (PV) cells

Electricity from solar cells has become cost competitive in many regions and photovoltaic systems are being deployed at large scales to help power the electric grid. Without the use of PV, electricity would have to be drawn from the general power grid, which is primarily generated from fossil fuel sources (e.g. carbon, petroleum, nuclear energy).

The successful implementation of solar panels depends on several key preconditions. First, the terrain profile should be suitable, ensuring that panels can be installed at an optimal angle for maximum sunlight exposure. Additionally, the location must receive sufficient sunlight throughout the year to ensure efficient energy generation. Compliance with local planning regulations is also essential to meet legal requirements and avoid restrictions on installation. Lastly, a well-developed energy infrastructure is necessary to integrate the generated electricity into the grid or support on-site energy consumption effectively.

There are several different types of PV cells which all use semiconductors to interact with incoming photons from the sun to generate an electric current. The electricity generated by the solar system can be largely used to cover your own electricity needs. This means, for example, that you must draw less electricity from the public power grid. At the same time, this enables financial advantages. As a rule, the self-produced electricity from your own system is more cost-effective than if the electricity must be purchased from an energy supplier. In this way energy costs can be saved.

Links to further information

www.energy.gov/eere/solar/solar-photovoltaic-cell-basics

www.nrel.gov/research/re-photovoltaics

Good practice example

Location:	Parchim, Germany
Business:	Manufacturing industry (44 companies from the trade (18), commercial (13), service (12) sectors and one company from the industrial sector

In Parchim-West, a variety of measures are being implemented to promote sustainable management and the use of renewable energies in the industrial area. The majority of the energy is generated by combined heat and power and photovoltaic systems, covering about 87 per cent of the electricity demand. This local energy production has significantly reduced dependence on external sources and stabilised the volatile cost of electricity at a good level.

Thanks in part to these measures, this business park is one of the first to receive the „ Grünes Gewerbegebiet in MV“ (Green Business Park in MV) award.

Good practice links

www.gruene-gewerbegebiete.de/parchim (in German)

www.parchim.de/de/buergerservice-1/buergerservice/umwelt-klima-und-natur/klima-und-umwelt/gruene-gewerbegebiete (in German)

Economic indicators:

CAPEX:	(> 1 MWp) = 800 [EUR/kWp]
OPEX:	Ab 1.000 kWp : 13,3

1.3.2. Solar Thermal

Solar thermal technology utilizes sunlight to produce heat for large-scale heating systems in communities and urban areas. It works by using collectors to capture and concentrate sunlight, transferring the heat to a fluid, and then utilizing a heat exchanger to provide heating for applications such as space and water heating, industrial processes, and district heating. The technology is renewable, reduces carbon emissions, and offers long-term cost savings while promoting localized energy production.

By supplementing heat production with heat from thermal solar collectors, cheaper heat and a reduced environmental impact are achieved.

In this technology, solar collectors, often consisting of flat-plate or concentrating solar panels, capture solar radiation and convert it into thermal energy. This thermal energy is then used to heat a heat transfer fluid, such as water or a specialized heat transfer fluid like glycol.

The heated fluid is circulated through a network of pipes and heat exchangers, transferring the collected thermal energy to a centralized district heating system. This district heating system can serve multiple buildings, including residential, commercial, and industrial facilities, providing them with a reliable source of hot water or space heating.

Solar thermal technology for district heating offers several benefits, including reducing greenhouse gas emissions, decreasing reliance on fossil fuels, and increasing energy resilience. It's particularly valuable in regions with high heating demands, where it can contribute to sustainable and efficient heating solutions for entire communities.

The successful implementation of a solar thermal system depends on several key factors. First, a suitable area must be available for setting up the installation, ensuring optimal exposure to sunlight. Additionally, there should be an existing energy demand that the solar thermal system can supplement, improving overall efficiency. To maximize the benefits, sufficient storage capacity must be in place or planned to store excess heat for later use. Finally, compliance with planning regulations and legal requirements is essential to ensure a smooth and lawful installation process.

Links to further information

https://ens.dk/media/6378/download

Good practice example

Location:	Svebølle, Denmark
Business:	district heating

Svebølle Viskinge District Heating Company is a small district heating company. The heating plant provides warmth to 535 households.

In 2011, the district heating company inaugurated a solar heating system with 7000 m2 of solar panels. In 2024, the system was expanded with an additional 3000 m2 of solar panels and an extra heat accumulation tank of 2000 m3.

To optimize the supply temperature and heat production, which occurs through a combination of burning wood chips and solar heating, sensors have been installed in the district heating network. These sensors provide real-time data back to the heating plant 's control system. The control, along with the implementation of solar heating, has resulted in a significant improvement in efficiency and enhanced financial performance for the district heating plant. "

The solar heating system is situated next to a new industrial area in Svebølle. The local district heating company has now installed 11000 m2 of solar thermal collectors to supplement their heat production based on wood chips.

The solar thermal collector facility in Svebølle produces 5000 – 5500 MWh/year. In connection with the facility, thermal storage tanks have been constructed, allowing for the storage of 170 MW.

Just north of the district heating plant, there is an allocated area of 15 hectares for a new industrial zone. The district heating plant will be able to supply heat to this area, but there is also the possibility of receiving surplus heat in the future if it becomes relevant.

Good practice links

www.svf.dk (in Danish)

Economic indicators:

CAPEX (Capital expenditures)	2,03 mio EUR
Heat production pr. day	50 MWh/day (best case)
Heat production pr. year	5500 MWh/year

1.3.3. Solar PV-Thermal -hybrid (PVT)

The technology Solar PV-thermal -hybrid collector (PVT) generates electricity with the photovoltaic panels and heat with integrated collector system. Solar PVT is often used as part of the heating system combined with heat pumps. It raises the efficiency of the heat pump drastically thus lowering the need for primary energy. Solar PVT also saves space needed for heat pumps since their efficiency is improved. The difference between regular solar heat is that PVT also produces electricity. Electricity is also produced in with efficiency compared to regular PV, since the thermal system cools down the panel. This heat collector system also cools down the panels and increases the PV production.

Good practice links

https://www.kraftringen.se/brf/energitjanster/nojda-kunder-brf/magnolia/ (in Swedish)

Good Practice example:

Location:	Lund, Sweden
Business:	Apartment block

New apartment blocks in Lund utilize solar PVT -panels to produce energy for the houses. To generate usable heat with PVT in the Nordics, it needs to be combined with heat pumps, but the efficiency of the heat pumps in this combination is very high. In this case the heat production SCOP is 4,2 and if the electricity produced is included in the calculations, it is 8,5. The example energy system also includes two accumulator tanks and a battery for energy storage, improving self-consumption efficiency even more. The block provides 40% of water heating, 62% of space heating and 50% of electricity consumption from its own energy system. The rest is bought from the grid and district heating network. It is also studied that the PVT panels produce 6% more electricity than the PV panels per sqm, because of the cooling of the panels.

Good practice links:

Economic indicators:

CAPEX (Capital expenditures)	1000 EUR + installation (350Wp ePower)
Increased PV production	6%

1.3.4. PV, solar thermal and heat pump technologies with energy management systems

A combination of three technologies for heating buildings involves installing photovoltaic panels on the walls and roofs of public buildings along with ground heat pumps and solar collectors. This technology combines both photovoltaic (PV) and heat pump systems. It involves installing PV panels on the facades and roofs of public buildings alongside heat pumps. Additionally, traditional coal-fired boilers have been largely replaced by ground-source heat pumps

Good Practice example:

Location: Turośń Kościelna, Poland
Business: Public and private buildings

The heat source replacement project in the Turośń Kościelna Commune covered over 400 households and over 10 commune buildings. In addition, over 70 photovoltaic installations were built. Old coal-fired boilers were replaced, almost 50 ground-source heat pump installations were built, and over 270 solar collector installations were installed to produce heat for heating and domestic hot water. In terms of electricity generation from the PV installation, energy management devices have been installed in buildings, e.g. programmable power sockets for selected receivers, in order to optimize energy consumption generated directly from the sun. Unconventional methods of installing PV installations were also used: on vertical building facades or on the roofs, in order to optimize production of electricity to meet the energy needs of the facility. As a result of the project, CO_2 emissions were reduced by over 1,000 tons and more than 300 kWp of new electricity generation capacity was installed. As a result of implementation, most municipal buildings in the commune became Nearly Zero Emission Buildings (NZEB), through the installation of heat pumps, which are fully powered by energy generated by photovoltaic installations.

Good practice links

https://www.turosnkoscielna.pl/pl/inwestycje/inwestycje-2019-r/ (in Polish)

Public utility building installation supporting the system in Turośń Kościelna

Environmental indicators:

CO_2-e emission reduction: 107 tons CO_2/year
Additional renewable energy capacity (MW) 0,097 Mwe + 0,080 MWt

1.3.5. PV, Agrivoltaics

Agrivoltaics represents the dual use of farmland for crop growing activities and renewable energy production via photovoltaic (PV) cells in solar panels. This innovative approach allows for the simultaneous generation of renewable energy and agricultural production, optimizing land use efficiency and promoting both food and energy security. Agrivoltaics can help mitigate land scarcity issues and contribute to the transition towards more environmentally friendly and economically viable farming practices.

Good practice example:

Location:	EU Horizon 2020 project HyPErFarm (Denmark, Germany, Belgium)
Business:	Farming

HyPErFarm has one main goal: to sharply reduce the use of fossil fuel in farming. To achieve this goal of decarbonization, the project actively looks for business cases farmers might adopt that help them reduce their use of fossil fuels and find economic gain. The key to this question is energy production. Using agrivoltaics, the agricultural sector not only has the potential to greatly defossilize, but also to produce energy that can be used on-farm.

The developed concepts are demonstrated in 3 different pilot setups in 3 different European countries, with diverse climate conditions. Crop and energy production are thoroughly assessed and compared between regions, as well as social, environmental and legal aspects of these systems on a national and European level.

Good practice links
https://hyperfarm.eu/

1.4. Wind Power

Wind energy is a clean, renewable source of power that harnesses the natural movement of air to generate electricity. Wind energy is the process of converting the kinetic energy of atmospheric air currents into mechanical energy, and subsequently into electrical energy, typically using aerodynamically designed wind turbines. Large wind turbines, often placed in windy areas or offshore, capture the wind's kinetic energy with their rotating blades. This mechanical energy is then converted into electrical energy using a generator. Wind energy is environmentally friendly, as it produces no greenhouse gas emissions and reduces dependence on fossil fuels. It's one of the fastest-growing sources of sustainable power worldwide.

Below, we refer to two selected good practice examples.

Hybrid of solar and wind energy PV systems use space under or next to a wind turbine to take use of different times of generation to create savings and synergies when using shared energy infrastructures.

Vertical axis wind turbines (VAWTs) Vertical axis wind turbines (VAWTs) are wind turbines for electricity generation with vertical axis instead of horizontal ones.

Good practice examples:

1.4.1. Hybrids of solar and wind energy

Location:	Parchim, Germany
Business:	manufacturing industry (44 companies from the trade (18), commercial (13), service (12) sectors and one company from the industrial sector

Güterverkehr Zentrum (GVZ; freight transport centre) is a location that serves to transfer goods from one mode of transport to another. A moderate amount of electricity is needed relatively evenly throughout the day. Several energy generation plants were gradually installed on the GVZ site.

With the realization of the wind-PV hybrid project in the GVZ, the project developer (WIND-project) pursues the goal of a land-saving supply of renewable energy and the co-use of the already existing infrastructure by operating a wind turbine. The Nordex N117 wind turbine, which was realized in 2014, was extended by a 750 kWp PV system in recent months. For a high surface efficiency, the modules of the PV system were installed both in the immediate vicinity and below the rotor blades of the wind turbine. The wind energy plant and the photovoltaic plant have a common grid connection point and a common grid infrastructure in the Stadtwerke grid.

Today, electricity from solar cells and Wind turbines has become cost competitive in many regions and these systems are being deployed at large scales to help power the electric grid. Without the use of PV and Wind turbines, electricity would have to be drawn from the general power grid, which is primarily generated from fossil fuel sources (e.g. carbon, petroleum, nuclear energy).

A photovoltaic (PV) cell is an energy harvesting technology that converts solar energy into useful electricity through a process called the photovoltaic effect. Wind turbines convert the available wind into mechanically usable energy and then mostly into electricity. This is done with the aid of a generator. Today's large turbines are predominantly three-bladed lift rotors with a horizontal axis and rotor on the windward side.

Generating electricity from wind and PV plants in a joint system has several advantages. On the one hand, there are space savings. Depending on technical, organizational and regulatory conditions, PV can be built up to the foundation of the wind turbine, but certainly up to the rotor radius.

Another advantage is that the systems produce different amounts of electricity at different times. This means that lines, electricity storage, transformers and other systems can be dimensioned smaller than if both systems were operated separately.

Links to further information

www.energy.gov/eere/solar/solar-photovoltaic-cell-basics

www.nrel.gov/research/re-photovoltaics

PV systems can use space under or next to a wind turbine to take use of different times of generation to create savings and synergies when using shared energy infrastructures.

Economic indicators:

CAPEX:	PV (> 1 MWp) = 800 [EUR/kWp], Wind = 800-1.400 [EUR/kWp]
OPEX	~2 % of Capex

1.4.2. Vertical axis wind turbines (VAWTs)

Location:	Raisio, Finland
Business:	Wind turbines

Vertical axis wind turbines (VAWTs) are wind turbines for electricity generation with vertical axis instead of horizontal ones.

Because of the vertical axis they can produce electricity with wind from any direction, but their swept area is smaller than in horizontal turbines. Because of the smaller swept area, they don't produce as much power than horizontal ones, but they can produce power with lower and higher wind speeds. VAWTs also cause less noise, hazards, and vibration, so they can be installed closer to other infrastructure and people. They're also more robust and require less maintenance.

Windside OY has installed vertical turbines to Mylly shopping center to provide local energy production and a special landmark for the building. There's two WS-12 wind turbines, producing about 500 kWh of energy per year. Lessons learned was that even though the turbines could still produce energy with high wind speeds, they start to wobble too much in over 15 m/s wind speeds to be used. Also, the maintenance costs are apparently so high that they're not economically feasible investment.

Windside references:
Gallery | Oy Windside Production Ltd

Good practice links
https://windside.com/

1.5. Gasification and Fermentation

Gasification and anaerobic digestion are two processes used for converting organic materials into energy, but they operate differently.

Gasification is a thermochemical process that involves heating organic materials (like biomass or waste) at high temperatures with limited oxygen. This converts the material into a combustible gas (syngas), which can be used to generate electricity or produce fuels. Gasification is often used for materials like wood, agricultural residues, and waste.

Anaerobic digestion, on the other hand, is a biological process where microorganisms break down organic matter in the absence of oxygen. This process produces biogas, primarily methane, which can be used for energy. Anaerobic digestion is commonly used for food waste, sewage sludge, and agricultural waste.

Both technologies contribute to waste management and renewable energy production but differ in their methods—gasification relies on heat and oxygen control, while anaerobic digestion relies on biological processes.

Below are 5 cases referring to these technologies:

Gasification: Carbonaceous materials are converted to gases (hydrogene, nitrogene and others) without combustion to extract valuable materials for energy production and other products.

Bioethanol (second generation): Bioethanol technology refers to the production of bioethanol from bioconversion of biocarbon from various organic sources. Unlike first-generation bioethanol, which primarily uses food crops like corn and sugarcane, second-generation bioethanol offers a more sustainable and environmentally friendly alternative for biofuel production.

Biomethane (second generation): Biomethane, also known as renewable natural gas, is a nearly pure methane source derived from biogas by removing impurities like CO and CO2. It‘s produced through biogas upgrading (making up 90% of global production) or thermal gasification of biomass followed by methanation.

Biogas – second generation: Biogas technology involves the production of biogas, a renewable energy source, through the anaerobic digestion of organic materials; a process through which bacteria break down organic matter such as agricultural residues, animal manure, sewage, and food wastes in the absence of oxygen.

Anaerobic fermentation/digestion: Anaerobic digestion is a sequence of processes by which microorganisms break down biodegradable material in the absence of oxygen. The process is used for industrial or domestic purposes to manage waste and/or to produce biogas (fuels). As a by-product the digestate represents a nutrient rich fertilizer.

1.5.1. Gasification

In gasification carbonaceous materials are converted to gases (hydrogene, nitrogene and others) without combustion to extract valuable materials for energy production and other products.

The successful implementation of this solution requires certain preconditions. Firstly, there must be a sufficient supply of input material, such as wastewater. Additionally, adequate space is necessary to accommodate the required infrastructure. Lastly, the location should ideally be within a commercial or industrial area, as emissions from the process could potentially disturb residential communities.

The energy locked in biomass and municipal solid waste can be retrieved through gasification, transforming those materials into valuable products and removing the need for landfilling or burning. CO2 is saved. Biomass is a renewable organic material from plants and animals. It is used to produce electricity and other valuable products like chemicals, fertilizers, and fuels. Using biomass fuels for electricity and transportation generation is increasing in several developed countries to avoid carbon dioxide emissions from fossil fuel use. It allows more technologies to be used and synergies in the network.

Links to further information

www.energy.gov/eere/fuelcells/hydrogen-production-biomass-gasification

www.carboncollective.co/sustainable-investing/gasification

Good practice examples

Wastewater treatment plant provides Heat and electrical power

Location:	Grevesmühlen, Germany
Business:	Wastewatertreatment Plant provides Heat and electrical power for manufacturing industries.

- Garnelen Farm Grevesmühlen GmbH & Co. KG,
- HanseGarnelen Grevesmühlen GmbH,
- Sägewerkstechnik Harmut Lingk

Since 2014, the local wastewater treatment plant has been the first energy-plus wastewater treatment plant in Germany. The wastewater treatment plant produces more renewable electricity than it consumes and has an even greater heat surplus. It also uses a photovoltaic system for solar sewage sludge drying.

The industrial park had an energy consumption of 4.125 MW/h in 2019. It covers almost 100 percent of its heat demand from waste heat from the wastewater treatment plant. Three local heating networks have now been developed from the cooperation between the local companies and the sewage treatment plant. The shrimp farm is supplied by heat network 1 and has its wastewater treated at the sewage plant. Heat network 2 is the area network of the sewage treatment plant. The municipal utilities operate the 3rd heat network, this supplies the company Enosys Recycling.

The Grevesmühlen Nordwest industrial area covers 81 percent of its electricity requirements from renewable energies. One company operates a photovoltaic system to use its own electricity. Two solar parks supply the entire area with electricity and feed the surplus into the public grid. The citizen solar park supported by the „Stadt ohne Watt – Verein für nachhaltige Stadt- und Regionalentwicklung“ registered association is one of them.

Good practice links

www.gruene-gewerbegebiete.de/grevesmuehlen (in German)

Economic indicators:

CAPEX:	5.000 EUR/kW
OPEX:	4% from CAPEX

1.5.2. Bioethanol – second generation

Bioethanol technology refers to the production of bioethanol from bioconversion of biocarbon from various organic sources. Unlike first-generation bioethanol, which primarily uses food crops like corn and sugarcane, second-generation bioethanol offers a more sustainable and environmentally friendly alternative for biofuel production. Second-generation bioethanol is produced from lignocellulosic biomass, which includes plant materials like crop residues (stalks, leaves), wood chips, straw, grasses, and non-edible parts of plants. These feedstocks are abundant and do not compete with food production, reducing concerns about food security and deforestation.

Second-generation bioethanol production generates valuable co-products. For instance, lignin, a by-product of the pretreatment process, can be used for the production of chemicals and materials. Additionally, the leftover biomass after ethanol extraction can be used for various purposes, such as animal feed or further processing for biogas production.

The successful production of bioethanol depends on several key preconditions. A stable and growing market demand is essential to ensure long-term viability and attract investment. Equally important is the availability of lignocellulosic feedstocks, such as agricultural and forest residues or organic waste, to maintain a steady production flow. An efficient infrastructure for collecting, storing, and transporting large quantities of biomass must also be in place to support operations. Additionally, scalable and cost-effective production processes are necessary, optimizing every stage from pretreatment to fermentation and purification to maximize ethanol yield while minimizing costs.

Government policies and incentives, such as subsidies and tax benefits, can further drive investment and expansion in second-generation bioethanol production. At the same time, ensuring that the process is

Links to further information

Second Generation Bioethanol – An Overview - Global Waste Cleaning Network (gwcnweb.org) environmentally and socially sustainable is crucial for long-term success. Lastly, public awareness and acceptance of bioethanol technology play a vital role in fostering a favorable market and policy environment, helping to secure its place in the renewable energy landscape.

Without second-generation bioethanol technology, the biofuel industry would face severe environmental, social, and economic challenges. The shift toward non-food feedstocks and the development of more sustainable and efficient production methods are essential to mitigating these challenges and creating a more environmentally friendly and socially responsible biofuel industry. Research and investment in advanced biofuel technologies are crucial to achieving these goals and reducing the negative impacts associated with traditional biofuel production.

As for Kalundborg Symbiosis, without this technology, industries within the symbiosis might need to explore alternative bioethanol, lignin or hemicellulose sources.

Good practice example:

Location:	Kalundborg, Denmark
Business:	Meliora

Meliora, located in Kalundborg, stands as a groundbreaking example of sustainable bioethanol production. Using straw from local farmers as its primary feedstock, Meliora has pioneered the world's first full-scale second-generation bioethanol plant. Unlike traditional bioethanol facilities, Meliora focuses on utilizing agricultural residues, specifically straw, to produce bioethanol, thereby addressing environmental concerns associated with first-generation bioethanol production.

Meliora's production process begins with the collection of straw from local farms, which would otherwise be treated as waste or burned, causing environmental pollution. The straw undergoes efficient pretreatment processes to break down cellulose and hemicellulose into fermentable sugars. Innovative enzymatic hydrolysis and fermentation techniques are employed to convert these sugars into high-quality bioethanol, ensuring maximum yield and efficiency.

Meliora has established a symbiotic relationship with Comet Bio, a leading biotechnology company specializing in the extraction of valuable compounds from biomass. In this partnership, Comet Bio utilizes the hemicellulose by-products generated during Meliora's bioethanol production process to produce prebiotics, which are essential for promoting gut health in humans and animals. This utilization of hemicellulose not only reduces waste but also creates an additional revenue stream for both Meliora and Comet Bio.

Furthermore, Meliora generates lignin, another by-product of the bioethanol production process. Lignin, a complex organic polymer, is a valuable resource that can be used in various industries, such as the

Good practice links

Meliora Bio - Energy Solutions (meliora-bio.com) production of bioplastics, adhesives, and carbon fiber. Meliora explores partnerships with companies involved in these sectors, ensuring that lignin does not go to waste and contributes to the development of eco-friendly products.

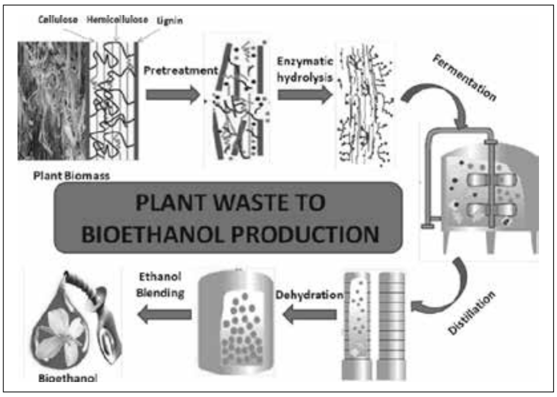
Meliora produces approximately 4.5 million liters of 2G bioethanol (equivalent to ethanol):

Input materials: About 35,000 tons of residual wheat straw (maximum 18% moisture) from local/regional agriculture are used and fermented for the process replacing food/sugar sources.

Industrial Symbiosis perspective on the technology:

In the context of Industrial Symbiosis, 2nd generation bioethanol production generates several by-products, which can be utilized by other symbiosis partners, for example, hemicellulose and water (C5 sugars in aqueous solution) for food ingredients at Comet, residual biomass from fermentation for biogas production at Kalundborg Bioenergy, and lignin for asphalt production at Avista Green.

The 2nd generation bioethanol production in Kalundborg benefits from being part of the symbiosis by utilizing green stream from Asnæs Power Station and surface water from the lake Tissø.



Second Generation Bioethanol Production: The State of Art: From Current Status to Practical Implementation - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Schematic-illustration-of-second-generation-bioethanol-production-process_fig2_326520090 [accessed 23 Oct, 2023]

Environmental indicator:

CO2 emission reduction:	ca 85%

1.5.3. Biomethane – second generation

Biomethane, also known as renewable natural gas, is a nearly pure methane source derived from biogas by removing impurities like CO and CO2. It's produced through biogas upgrading (making up 90% of global production) or thermal gasification of biomass followed by methanation. Biomethane is chemically identical to natural gas, requiring no infrastructure changes, and is suitable for various applications, including natural gas vehicles. Biomethane has an LHV (lower heat value) of around 36 MJ/m3

The successful production of biomethane relies on several important preconditions. A continuous and reliable supply of organic waste, such as agricultural residues, food waste, sewage, and biomass, is essential to maintain steady production. Access to anaerobic digestion facilities is also crucial, as these are the sites where organic materials are broken down in the absence of oxygen to produce biogas—the raw material for biomethane. To ensure the gas is suitable for use, investment in upgrading technologies and infrastructure is needed to purify the biogas into high-quality biomethane.

Furthermore, supportive government policies, regulations, and financial incentives can drive innovation and encourage investment in the sector. A strong market demand for biomethane—as a fuel for natural gas vehicles, for heating, or for electricity generation—is another key factor for commercial success. Public awareness of its environmental benefits, such as reduced greenhouse gas emissions and sustainable waste management, also plays a role in gaining societal support. Finally, the presence of existing natural gas infrastructure that is compatible with biomethane makes it easier to integrate this renewable fuel into current energy systems.

Without biomethane technology, organic waste would pollute the environment, and we'd rely more on fossil fuels, increasing pollution and hindering climate goals. Energy costs might rise, and opportunities for sustainable practices and economic growth through recycling would be missed.

As for Kalundborg Symbiosis, without this technology, industries within the symbiosis might need to explore alternative organic waste management solutions and alternative sources of biomethane.

Biomethane technology enhances the energy situation by providing a sustainable, low-carbon energy source, reducing environmental harm, and contributing to a more diverse and environmentally friendly energy landscape.

Links to further information

An introduction to biogas and biomethane – Outlook for biogas and biomethane: Prospects for organic growth – Analysis - IEA

Good practice example:

Location:	Kalundborg, Denmark
Business:	Kalundborg Bioenergy

Kalundborg Bioenergy plays a vital role in sustainability by upgrading residues from insulin and enzyme production at Novo Nordisk and Novozymes to biomethane, equivalent to natural gas quality. This biomethane is distributed through the natural gas grid to Kalundborg Refinery and other consumers. The upgrading process, while producing high-quality biomethane, also removes hydrogen sulfide and carbon dioxide. Moreover, it ingeniously returns sulfur from hydrogen sulfide to the residual biomass, enriching the biogas plant's fertilizer products. This innovative approach not only provides clean energy but also contributes to a circular economy by recycling resources efficiently.

Kalundborg Bioenergy produces approximately 46 million cubic meters of biogas, which is upgraded to approximately 30 million cubic meters of biomethane per year (equivalent to approximately 27 million cubic meters of natural gas) after removing CO2/CO, hydrogen sulfide, and water.

Input materials: About 450,000 tons of wet residual biomass primarily from local industries are used annually in the process (bio-gassed) – replacing food/sugar sources.

Output products: CO_2 (22,000 cubic meters) is currently not utilized but is planned to be integrated into the Kalundborg CO_2 Hub (by Ørsted and the symbiosis consortium) – can replace fossil carbon for fuel and bioplastics. Mineralized liquid fertilizer is returned to agriculture – replacing other fossil-based fertilizer production.

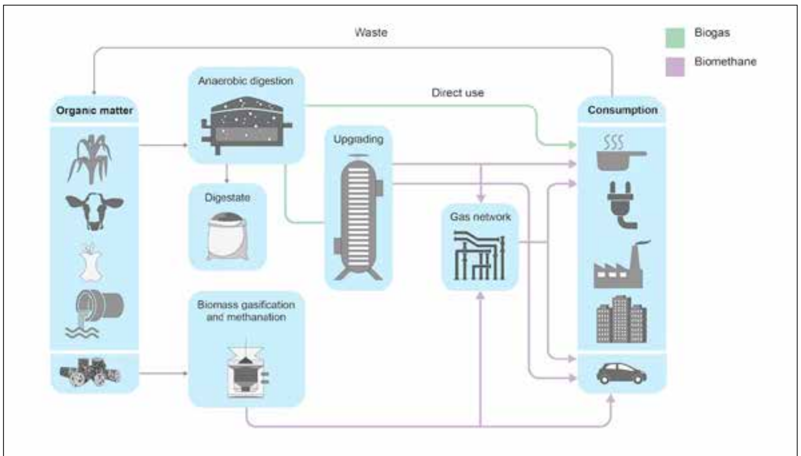
Industrial Symbiosis perspective on the technology

In the context of Industrial Symbiosis, bio-methane production can be employed to treat organic waste generated by several companies in the area. In Kalundborg Symbiosis, Kalundborg Bioenergy uses biomass from Novo Nordisk and Novozymes to produce biogas and organic fertilize. By sharing resources and collaboration on waste management, industries in the symbiotic network can achieve economic savings. In an Industrial Symbiosis, multiple companies can share the initial investment costs for establishing a biogas plant. This can make the financial burden more manageable for each partner.

Kalundborg Bioenergy supplies biomethane both to the local natural gas grid (4 bar) and the national natural gas grid (19 bar). The lower pressure requirement for the local natural gas grid in the context of industrial symbiosis has sustainable advantages for delivering biomethane to neighboring companies; lower pressure requires less energy for compression and transportation.

Good practice links

Kalundborg Bioenergi A/S - Bigadan



Economic indicators

CAPEX (Capital expenditures):	three-digit million (DKK). Investment in doubling the tank capacity = 4,1 million euro

Environmental indicator

CO2 emission reduction:	17.000 ton/year

1.5.4. Biogas – second generation

Biogas technology involves the production of biogas, a renewable energy source, through the anaerobic digestion of organic materials; a process through which bacteria break down organic matter such as agricultural residues, animal manure, sewage, and food wastes in the absence of oxygen.

Biogas is a mixture of methane (CH4) and carbon dioxide (CO2), with methane being the primary component (typically around 50 – 70%). Methane is the valuable component used as a clean energy source.

Biogas can be stored and used as a source of renewable energy for various application, including electricity generation, heating, and transportation.

Biogas technology is environmentally friendly, as it helps in waste management by converting organic waste into energy and valuable by-products, reducing greenhouse gas emissions , and contributing to sustainable agriculture practices. It is a versatile and sustainable source of renewable energy with various applications in different sectors.

The successful production of biogas depends on a range of key preconditions. First and foremost, there must be a consistent supply of organic waste, as this serves as the primary feedstock for biogas generation. The suitability of the feedstock—in terms of its composition and biodegradability—is also critical, as it directly influences gas yield. To design, build, and operate biogas plants efficiently, technical knowledge and expertise are essential, supported by adequate investment and funding to cover infrastructure, equipment, and ongoing operational costs.

Access to necessary utilities and infrastructure, including water, electricity, and transportation networks, is vital for smooth operation. Equally important is public awareness and community support, which help foster local acceptance and long-term viability. Supportive policies and regulations at all governmental levels can further encourage the development and scaling of biogas technologies. Additionally, the availability of a skilled workforce ensures proper plant operation and maintenance. Lastly, conducting thorough environmental impact assessments is crucial to prevent harm to ecosystems and nearby communities, ensuring that waste management, odour control, and emission monitoring are handled responsibly.

The absence of biogas technology would result in environmental challenges, increased greenhouse gas emissions, missed opportunities for renewable energy production, and hindered agricultural and rural development. Embracing biogas technology helps address these issues by providing a sustainable solution for organic waste management and clean energy generation.

Links to further information

How biogas is made - Bigadan ,
How is biogas produced? | Gasum

As for Kalundborg Symbiosis, without this technology, industries within the symbiosis might need to explore alternative organic waste management solutions and biogas sources.

How does this technology improve the situation energy-wise?

Biogas is a renewable energy source produce from organic materials. By harnessing the methane content in biogas, it can be used for electricity generation, replacing the need for non-renewable sources such as coal or natural gas. Biogas technology allows for decentralized energy production which reduces the need for extensive energy transportation infrastructure, making energy production more efficient and cost-effective.

Biogas plants can provide a stable and consistent energy supply unlike some other renewable sources like wind and solar.

Good practice example

Location:	Kalundborg, Denmark
Business:	Kalundborg Bioenergy (belonging to Bigadan)

Biogas and fertilizer potentials from residual biomass from Novozymes (Novogro®) and Novo Nordisk (yeast slurry - nutritional mixture) are exploited and realized at a biogas plant Kalundborg Bioenergy with in the Kalundborg Symbiosis. At the biogas plant, biogas is produced and upgraded to natural gas quality (biomethane) through a refining process where carbon dioxide and hydrogen sulfide are removed from the product. Biomethane is send to local companies (Gyproc, Unibio and Kalundborg Refinery) and to end consumers via the national gas grid.

Sulphur from the hydrogen sulfide fraction is collected and reused in fertilizer products together with the gasified biomass residual. Kalundborg Bioenergy produces approximately 46 million cubic meters of biogas, which is upgraded to approximately 30 million cubic meters of biomethane per year (equivalent to approximately 27 million cubic meters of natural gas) after removing CO2/CO, hydrogen sulfide, and water.

Input materials:About 450,000 tons of wet residual biomass primarily from local industries are used annually in the process (bio-gassed) – replacing food/sugar sources.

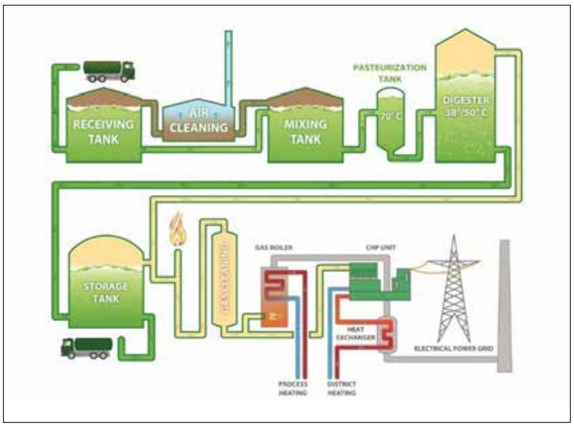
Output products: CO2 (22,000 cubic meters) is currently not utilized but is planned to be integrated into the Kalundborg CO2 Hub (by Ørsted and the symbiosis consortium) – can replace fossil carbon for fuel and bioplastics. Mineralized liquid fertilizer is returned to agriculture – replacing other fossil-based fertilizer production."

Industrial Symbiosis perspective on technology

In the context of Industrial Symbiosis, biogas production can be employed to treat organic waste generated by several companies in the area. In Kalundborg Symbiosis, Kalundborg Bioenergy uses biomass from Novo Nordisk and Novozymes to produce biogas and organic fertilizer. By sharing resources and collaboration on waste management, industries in the symbiotic network can achieve economic savings. In an Industrial Symbiosis, multiple companies can share the initial investment costs for establishing a biogas plant. This can make the financial burden more manageable for each partner.

Good practice links

Kalundborg Bioenergi A/S - Bigadan



Economic indicators:

Payback time:	Confidential information
CAPEX (Capital expenditures):	three-digit million (DKK). Investment in doubling the tank capacity = 4,1 million euro
OPEX (Operational expenditures):	Confidential information
ROI % (Return of investment):	Confidential information

Environmental indicator:

CO2 emission reduction:	17.000 ton/year

1.5.5. Anaerobic fermentation/digestion

Anaerobic digestion is a sequence of processes by which microorganisms break down biodegradable material in the absence of oxygen. The process is used for industrial or domestic purposes to manage waste and/or to produce biogas (fuels). As a byproduct the digestate represents a nutrient rich fertilizer.

The successful production of bioethanol depends on several important preconditions. A key requirement is the availability of digestible biomass, such as manure or organic residues from urban, industrial, or agricultural sources, in sufficient and stable quantities. This ensures a continuous feedstock supply for efficient production. Additionally, locating production facilities in rural areas is often more suitable, as these environments are more accustomed to the natural odors associated with materials like manure. If facilities are placed closer to urban or residential zones, effective odor control measures must be implemented to minimize potential nuisance and maintain public support.

Manure/biomass would be kept at closed storage facilities (extra consumption of space and finances). Potential release of methane (climate gas) to the atmosphere. There would not be an opportunity to produce electricity and thermal energy on the next stage of anaerobic digestion. Manure and biomass would be a waste of by-products (carbon nutrients and water).

Manure/biomass as a by-product is used to create biogas that decreases the cost of production of thermal energy. Electricity is produced as a by-product that decreases the need to buy electricity from the grid. Reduces the need for non-renewables and related emissions.

Good practice example

Location:	Kroņauce, Latvia
Business:	JSC „Agrofirma Tērvete“

AS „Agrofirma Tērvete“ is a diversified agricultural production company that started in 1947. It is located in Kroņauce, Tērvetes parish, Dobeles municipality, Latvia.

Today it operates in 4 sectors: crop production, dairy farming, energy and biogas production. The company employs on average 190 employees, keeps a herd of 2600 cows on average, has 3200 ha of farmed land and produces 3200 MWh of electricity annually. Company's self-consumption is 100% based on renewable energy sources.

The company's current energy production is mainly based on the complete biochemical recycling of dairy waste products (manure, agricultural biomass) through the process of anaerobic fermentation whereby biogas – a renewable energy resource – is obtained. The current processed volume of manure exceeds 110 000 tons per year, providing more than 3 million m3 of biogas annually, which was burnt in internal combustion engines producing green electricity and heat for sale and the company's consumption.

Anaerobic digestion system was built in 2 phases, in 2013 first phase when 0.5 MW capacity was built, in 2014 during the second phase 1.5 MW was built. During the anaerobic process biogas is produced in order to get electricity and thermal energy on the next stage in the cogeneration plant. Before, manure had been a waste product.

Experience from biogas production in cooler regions, such as Latvia, has highlighted several important lessons. One key consideration is the need for thermal insulation of fermenters, with particular attention to the roof, as this is where the majority of heat loss occurs. Proper insulation helps maintain optimal temperatures inside the digester, which is crucial for efficient biogas production.

Another important lesson is the careful preparation and filtration of the substrate before it enters the anaerobic digester. This step helps protect sensitive components such as pumps from damage and improves the overall efficiency of the process.

When selecting technology, it is essential to ensure that both the heat sources and the equipment can operate reliably at the lowest ambient temperatures expected in the area, rather than relying on average temperature figures provided by manufacturers. This helps prevent freezing and ensures uninterrupted operation during cold periods.

Lastly, in chemically aggressive environments, it is advisable to avoid black metal and instead opt for stainless steel components, which offer greater resistance to rust and corrosion, thus ensuring a longer lifespan and more reliable performance of the system.

Good practice links

https://tervete.lv/en/energy-and-biogas-production/

Economic indicators:

Payback time:	7-8 years (depends on the prices of electricity and resources)
Environmental indicator:	Avoided non-renewable natural gas = 3.000.000 m3 biogas per year

1.6. Hydrogen technologies

Hydrogen technologies play a pivotal role in the global transition toward sustainable energy systems. As an energy carrier, hydrogen offers significant potential to decarbonize hard-to-electrify industrial sectors, especially when produced through renewable-powered electrolysis. Green hydrogen—created by splitting water using electricity from wind, solar, or other renewable sources—can replace fossil fuels in energy-intensive industries such as chemical manufacturing, steel production, and heavy transport. Its ability to store and transport renewable energy over long distances also helps to address the intermittent nature of renewable power sources.

The significance of green hydrogen lies in its capacity to store and transport renewable energy over long distances and periods, addressing the intermittency of renewable power sources. For industrial areas, adopting hydrogen technologies can reduce reliance on fossil fuels, lower carbon footprints, and create new economic opportunities. Furthermore, integrating green hydrogen into industrial processes enhances energy security and supports the circular economy by utilizing by-products such as oxygen and heat.

The technologies for the production and utilisation of hydrogen are presented below. Electrolysis in various scenarios and the fuel cell will be discussed.

Green hydrogen production via electrolysis involves splitting water or steam into hydrogen and oxygen using renewable electricity. This process enables the conversion of surplus energy into hydrogen, which can be stored or utilized in industrial processes, as a fuel, or for producing derivatives. During periods of excess renewable energy production, electrolysis provides a sustainable means of energy storage while facilitating the replacement of fossil-based fuels, chemicals, and materials.

Considerations for electrolysis include the need for a reliable supply of electricity and water, as well as the efficient use of by-products. Heat generated during electrolysis can be repurposed for industrial processes or district heating systems, enhancing overall efficiency. Oxygen, another by-product, can be utilized in industrial applications, oxygen-enhanced incineration, or aquaculture. Due to hydrogen‘s flammability, safe transportation, storage, and conversion to more stable derivatives are essential. To produce synthetic methane or other carbon-based derivatives, proximity to biological CO2 sources is advantageous.

Links to further information

Iea on electrolysers

1.6.1. Fuel Cell

Fuel cells convert hydrogen into electricity through an electrochemical reaction, offering an efficient and emission-free energy solution. They play a crucial role in industrial areas by providing decentralized power generation and backup energy supply. Fuel cells require a reliable supply of hydrogen or methane as a fuel source, which can be delivered through pipelines stored on-site, or transported by specialized vehicles. This flexibility allows them to support a variety of industrial applications, from primary power to emergency backup systems.

Links to further information

Convion Successfully Delivers and Commissions the First SOEC System for Testing

Good practice example #1

Location:	Espoo, Finland
Business:	VTT Research Centrum

High temperature electrolysis test system at a VTT R&D site with solid oxide electrolysis technology. The technology enables hydrogen production at 25-30% lower electricity consumption, when waste heat is utilized for steam generation. The demo plant will be utilized to create e-fuels.

The system will test the whole value chain from production of hydrogen from steam and electricity to transfer and storage, and further processing to electronic fuels with carbon dioxide. In case the technology works, it can be utilized either as an energy storage at wind farms to balance the grid or to create off-grid areas, or to create a system of distributed e-fuel capacity.

Economic indicators

Payback time:	Pilot, not profitable
CAPEX:	Industrial scale investment 2700-2800 EUR /kWh
OPEX:	Gasification 2,21 kWh/kg, Liquification 15,2 kWh/kg

Good practice example #2
Electrolysis in Power-to-Gas and storage application

Location:	Grapzow, Germany
Business:	WIND-projek Ingenieur- und Projektentwicklungsgesellschaft mbH

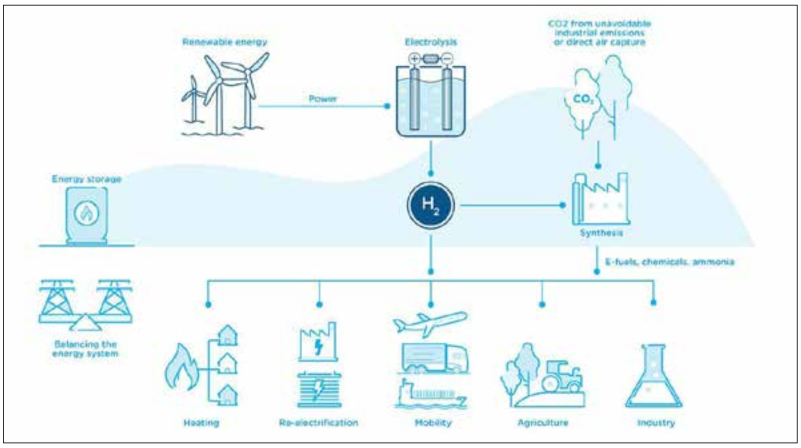
Power-to-Gas (PtG) technologies convert electricity into gaseous energy carriers like renewable hydrogen, enabling long-term storage and flexible utilization of renewable energy. This process supports industrial decarbonization by transforming electricity into storable and transportable chemical potential, enhancing energy system synergies and energy security. Successful PtG implementation requires access to renewable energy and water resources (approximately 9 kg of water per kg of hydrogen) and efficient transport infrastructure, including pipelines and trucks.

The RH2-WKA project in Mecklenburg-Vorpommern exemplifies PtG in practice by integrating renewable hydrogen production with a wind farm and establishing a CO2-free, sustainable energy system. It features a Power-to-Gas plant for renewable hydrogen feed-in and involves municipal participation at the inter-communal level. Key components include 28 wind turbines (up to 7.5 MW each), two combined heat and power plants (160 kWel, 90 kWel, 400 kWth) for hydrogen reconversion with 33.2% electrical efficiency, a 1 MW alkaline electrolysis system producing 210 Nm3/h of hydrogen at 60.7% electrical efficiency, and hydrogen pressure storage at 310 bar with a capacity of approximately 3,300 Nm3 (300 kg). This project demonstrates the feasibility of integrating PtG with renewable energy to create a sustainable and regionally cooperative energy system.

Good practice links

How Power-to-X works

Demonstration and innovation project RH2-WKA



Economic indicators:

Payback time:	Pilot, not profitable
CAPEX:	Electrolysis 1.000 EUR / kW power, Plus, costs for storage (for e.g. low pressure tank 40 bar: 150.000 EUR per tank ~22,5 MWh) and power generation (see PV or wind power)
OPEX:	~4% of CAPEX

Good practice example#3
Methanol-based fuel cell

Location:	Espoo, Finland
Business:	R&D Site

In a test a methanol-based fuel cell is utilized as a backup electricity source in a 5-10 kW system including camera surveillance system and lighting of an industrial area. The system consisted of a battery which was charged by the fuel cell as required. The system ran as a stand-alone system without a need for external power. A similar system can be utilized to back up other critical functions, like critical IT-infrastructure during absence of network electricity. The system could run on hydrogen as well. Benefits of methanol-based fuel cell are easier storage of methanol in comparison to hydrogen, and longer life of the fuel cell.

Links to further information

https://www.theseus.fi/bitstream/handle/10024/753048/Salminen_Pinja.pdf?sequence=2
(in Finnish, abstract in english)

Economic indicators:

CAPEX:	About 10.000 €/kWh
OPEX:	Methanol 0,495 €/kg, consumption 0,9 l/kWh

1.7. Energy storage

Energy storage technologies play a vital role in ensuring a stable and sustainable energy system by balancing supply and demand, maintaining grid stability, and facilitating the integration of renewable energy. Different storage methods offer unique advantages depending on their application, duration, and efficiency.

Below, we refer to four selected good practice examples.

Battery Energy Storage Systems (BESS) store electrical energy for future use, providing grid stability, back-up power, and enabling participation in energy markets.

Sand Batteries (Thermal energy storage)

Smart Energy Storage

Short-Term Thermal Energy Storage

1.7.1. Battery Energy Storage System (BESS)

These systems are crucial for managing peak loads and integrating renewable energy sources by storing surplus energy during low-demand periods and releasing it during peak times. This improves energy efficiency and reduces reliance on fossil fuels. However, BESS require careful management to ensure battery longevity, safe operation, and to mitigate environmental impacts related to raw material extraction and battery disposal. Efficient energy management systems and cooling mechanisms are essential for maintaining performance and safety.

Links to further information

Economic Analysis of Battery Energy Storage Systems

Good practice example
BESS in Brewery Operations

Location:	Kerava, Finland
Business:	Brewery

A major brewery in Kerava, Finland, implemented a 20 MW & 20 MWh BESS system built by Siemens and MW Storage AG. This system stabilizes the grid and provides a 20 MW demand response capacity, allowing participation in frequency markets for additional revenue. The BESS enhances operational flexibility and reduces energy costs by optimizing electricity consumption during off-peak hours.

Links to further information

The large-scale battery in Kerava

Economic indicators

Payback time:	5 years
CAPEX:	200-400 €/kWh
OPEX:	3-4,5% of CAPEX

1.7.2. Sand Batteries (Thermal energy storage)

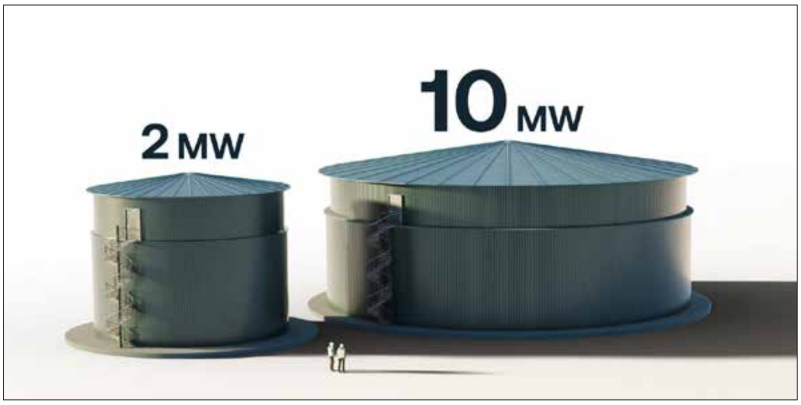
Sand batteries store energy as heat by heating sand to temperatures of up to 1000°C. This heat can be used for district heating or converted back into electricity, providing long-duration energy storage. Sand is an abundant, low-cost, and environmentally sustainable medium. However, effective implementation requires extensive insulation to minimize heat loss and infrastructure to connect the stored energy to existing heating and power systems. This technology is particularly useful for industrial applications requiring large-scale heat storage.

Good practice example
Sand Battery for District Heating

Location:	Kankaanpää, Finland
Business:	Energy company

Polar Night Energy installed an 8 MWh sand battery in Kankaanpää, Finland. This system stabilizes the district heating system and utilizes waste heat from data centers. The sand battery provides a reliable and sustainable heat source, reducing fossil fuel dependency.

Links to further information
Sand Battery



Economic indicators:

Payback time:	~20 years (subject to uncertainty)
CAPEX:	~2.2M EUR for a larger system (2MW/200MWh)
OPEX:	5,000-10,000 EUR

1.7.3. Smart energy storage

Smart Energy Storage systems convert excess electricity into heat, which is stored in e.g. crushed basalt rock and later transformed back into electricity through a turbine during periods of high demand. This technology is a safe, scalable, and cost-effective alternative to conventional battery storage. It uses abundant, non-scarce materials and poses no explosion risk. With no geological or geographical constraints, PtP systems can be implemented globally and maintained using standard equipment. These systems achieve high round-trip efficiency through heat pump technology and can support the integration of larger shares of renewable energy. Successful deployment requires advanced control systems for grid compatibility and compliance with regulatory standards.

Links to further information

https://www.stiesdal.com/storage/the-gridscale-technology-explained/

Good practice links

https://www.stiesdal.com/storage/the-gridscale-technology-explained/

https://andel.dk/en/news/andel-and-stiesdal-join-forces-on-large-scale-energy-storage/

1.7.4. Thermal energy storage (short term)

Short-term thermal energy storage captures and stores excess thermal energy for later use, typically over hours or days. This technology improves energy efficiency by reducing peak-load demand and enabling more consistent operation of thermal systems. It is especially effective for integrating renewable thermal sources, such as solar collectors and biomass boilers. During high-demand periods, stored thermal energy is released to meet consumption needs, reducing reliance on less sustainable systems like gas boilers. Maintaining efficiency requires adequate insulation and monitoring systems to prevent heat loss and ensure reliable energy delivery.

Links to further information

https://online.flippingbook.com/view/175118845/10/

https://bankwatch.org/blog/first-large-scale-solar-district-heating-plant-in-the-baltics-opens-in-latvia

https://www.euroheat.org/resource/latvian-city-invests-in-solar-district-heating.html

Good practice example
Thermal energy storage

Location:	Salaspils, Latvija
Business:	Ltd. Salaspils Siltums

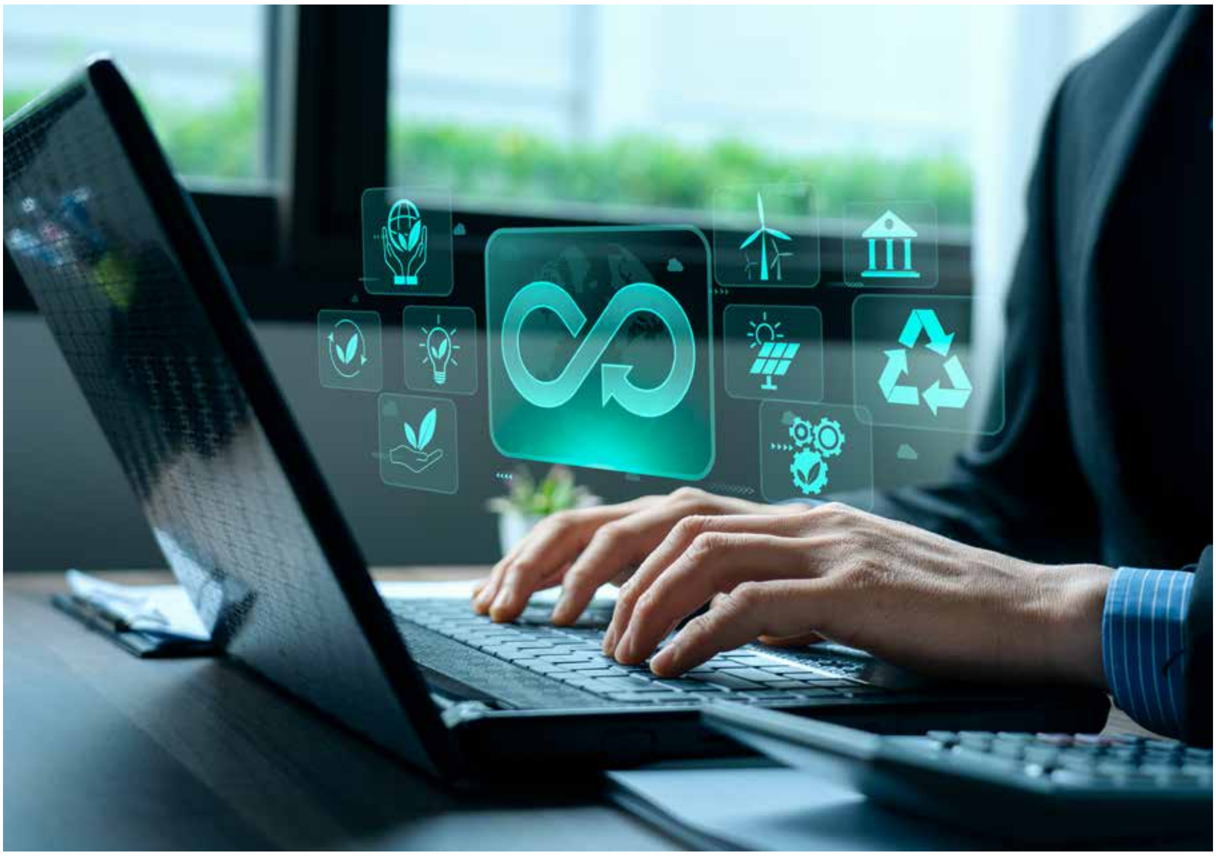
Ltd.Salaspils Siltums is a modern district heating company providing heat to Salaspils and Saulkalne, delivering 60,000 MWh of thermal energy annually with a maximum heat load of 27 MW. To increase the use of renewable energy, the company implemented a large-scale project between 2018 and 2019, which includes a solar collector field, an 8000 m^3 accumulation reservoir, and a 3 MW wood chip boiler house.

The solar collector field consists of 1720 collectors spread over 6.5 hectares, supplying approximately 20% of the city's annual thermal energy consumption. During the summer months, 90-95% of the thermal energy needed is sourced from solar power. This high efficiency is made possible by the accumulation reservoir, which stores thermal energy for several days, allowing the heat generated during the day to be used when demand is higher. The reservoir is large enough to meet the city's thermal energy needs for five days during summer, particularly for hot water supply.

Diversifying thermal energy sources and integrating thermal energy storage has proven to be an effective strategy for reducing production costs and improving system efficiency. Throughout the project, the involvement of local specialists and experts has been essential for the successful implementation and long-term maintenance of the system.

Indicators:

Payback time:	5 years
CAPEX:	200-400 €/kWh
OPEX:	3-4,5% of CAPEX
CO2 emission reduction:	135.9 metric tons, equivalent to 88.4% (when comparing the year 2022 to 2018).
Share of renewable energy in final consumption:	90% - 95% (before project implementation in 2018 - 56%).



1.8. Energy management

Effective energy management helps ensure that energy is used efficiently—avoiding unnecessary consumption and, when possible, shifting usage to times of day when energy is cheaper. At its core, energy management is about monitoring, analyzing, and optimizing energy use in buildings and businesses to support more sustainable and cost-effective operations. Without a proper system in place, energy consumption can be difficult to track, often leading to hidden costs and wasted resources.

1.8.1. Building Energy Management Systems

Building Energy Management System (BEMS) or Building Management System (BMS), is the integration of IT and various sensor-based indoor climate solutions and devices within the building to automate and control its operations for increased energy and operational efficiency (foremost heating, ventilation and air conditioning), reduced energy consumption and the negative impact of buildings on nature. The active control of energy usage ensures an optimal distribution and consumption of energy in the building and leads to a more efficient use of the generated energy.

Without building automation technology, different building's systems are managed manually and separately, resulting in lower accuracy and efficiency, as well as in higher energy use. This technology provides a control system that allows more precise control of building's energy consumption, at the same time ensuring more flexible operation of energy networks. Among several, key benefits of building automation are reduced energy consumption and infrastructure maintenance costs.

Below are two examples showcasing that the energy consumption can be reduced by between 10 and 88% with the installation systems that monitor and automatically adjust the energy using technologies in buildings.

For the successful installation of a building's ventilation system, certain preconditions must be met. The ventilation system piping must be installed using separate branches for each room, considering both the volume and the specific function of each space. This ensures effective air distribution and indoor climate control tailored to the needs of individual rooms.

In addition, the room where the system is to be installed must be equipped with an electrical supply, water supply, and a drainage system to support proper operation and maintenance. Furthermore, the building should already have piping for the space heating system, as this may be integrated with or influenced by the ventilation setup.

Links to further information

European Building Automation and Controls Association https://eubac.org/about/what-are-bacs/

Good practise example # 1

Location	Klaipėda, Lithuania
Business	Inno Line - furniture manufacturing

Inno Line, a furniture manufacturing company belonging to the SBA Home group, launched its production of foil-wrapped cabinet furniture in 2022. The robotic and automated production complex, located in the SBA Industrial Innovation Valley near Klaipėda, employs over 600 specialists. The Inno Line factory building, which is the size of 7 football fields, has an A++ energy rating and the highest sustainability standards, and incorporates environmentally friendly technologies. Thanks

Inno Line building

to the information system, various parameters (heating, cooling intensity, etc.) can be changed on demand from any point, thus saving energy. The intelligent control system regulates the lighting and saves energy depending on the amount of natural light and the presence of people in the room.

Indicators:

Payback time:	2-6 years
CAPEX:	EUR 2-7 per square metre
Savings in energy consumption	10-30%

Good practice links

https://sba.lt/en/news/%E2%80%9Enotus-developers-uzbaige-%E2%80%9Einno-line-pastato-statyba

https://sa.lt/tvari-baldu-gamybos-milzine(in Latvian-inno-line/ (in Latvian)

Good practice links

https://info.midatlanticcontrols.com/blog/how-much-does-a-building-automation-system-cost

Good practise example # 2

Location	Malmö, Sweden
Business	Offices

The block Abbedissan 2 in Malmö, Sweden, is the Real Estate Company Vasakronan's most energy-efficient property. With a geo-installation in the basement, solar cells on the roof and with solutions for demand-controlled ventilation with active devices, DALI-controlled (Digital Adressable Lighting Interface) lighting and smart sun shading, the energy consumption is only 18 kWh/sqm per year - even though there are business running around the clock in the property.

According to the Swedish Energy Agency's latest energy statistics reported in 2022-05-11, the average office is at 108 kWh/m2, year for heat and hot water and 50 kWh/m2, year for electricity. 18 instead of 158 => 88% lower!

The use of sensors and advanced control systems plays a vital role in optimizing energy efficiency and indoor comfort in modern buildings. Technologies such as DALI systems, battery-less switches with dimming functions, and sensors for presence detection and daylight compensation allow for intelligent management of lighting and energy use. Additionally, the choice of windows with optimized G and U values contributes to better thermal performance, while features like sun shielding and automated solar shading help regulate indoor temperatures and reduce the need for artificial cooling or heating. Together, these elements create a more sustainable and responsive building environment.

Source: www.lindinvent.se

Links to further information

https://noda.se/en/offerings/buildings/

https://noda.se/en/offerings/energy-systems/

https://www.lindinvent.com/solutions/offices/#fndtn-tab-0

https://www.lindinvent.com/proven-values/our-folders/

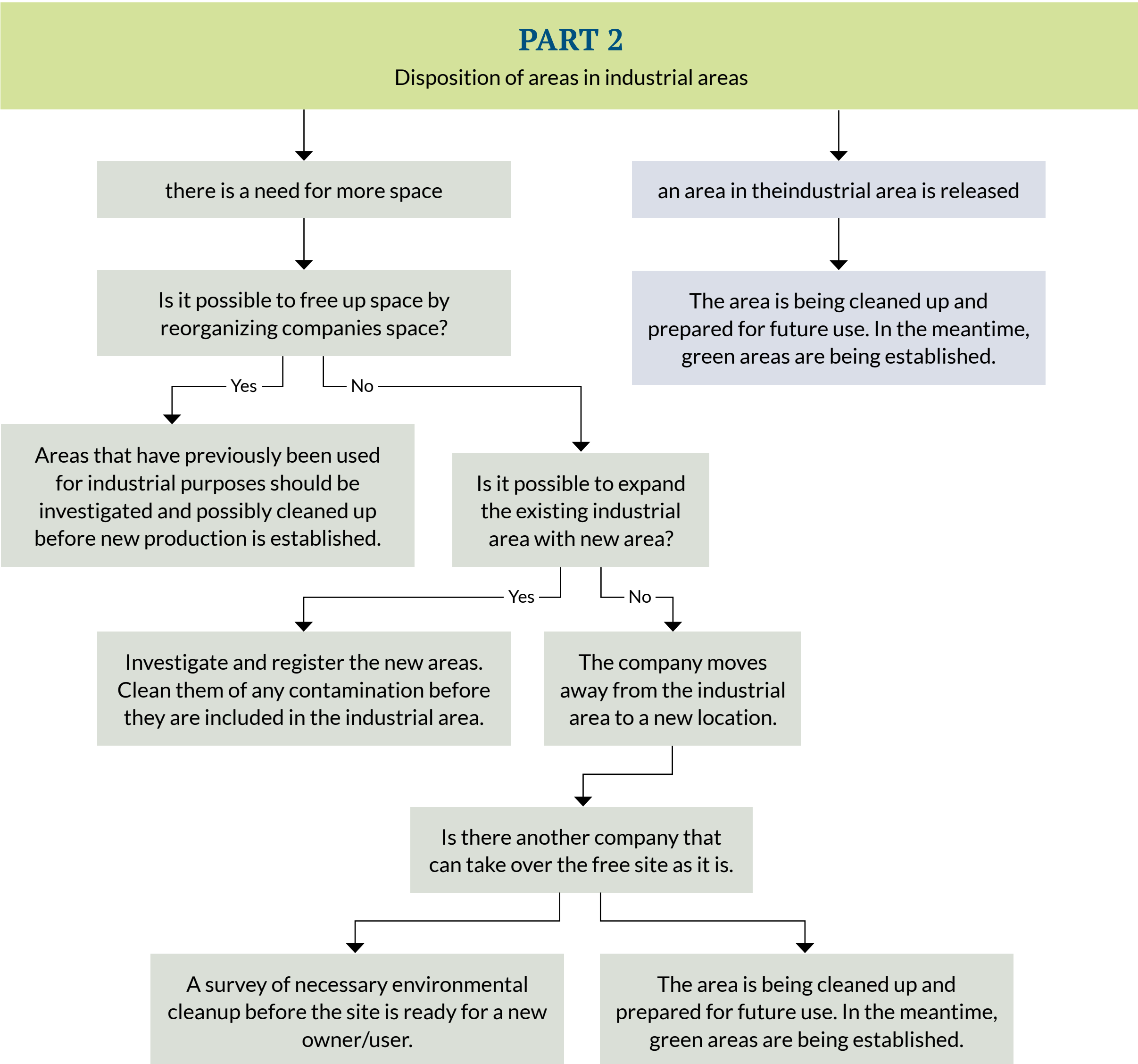
Good practice links

https://www.lindinvent.se/referensobjekt/case-studies/abbedissan-malmo-vasakronans-mest-energieffektiva-fastighet/

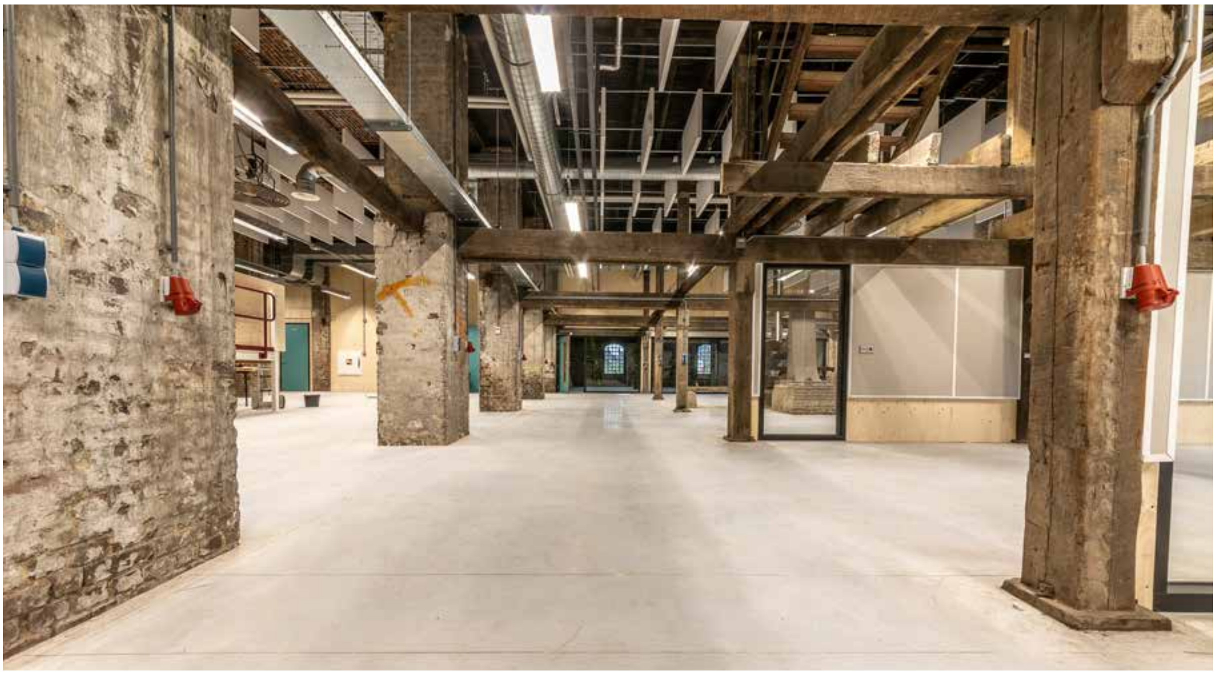
Part 2 - Reduction of land consumption

This part of the toolbox contains examples focusing on reduction of land consumption of companies and industrial areas, as well as their share of low-carbon energy.

Below is a diagram that supports the analysis of opportunities to reduce land consumption for companies and industrial areas that are relevant in the work.



Go to toolbox PART 3



2.1. Reduction of land consumption and promotion of biodiversity

The rapid expansion of urban areas, agricultural activities, and particularly industrial zones has led to significant land consumption, posing a threat to natural ecosystems and biodiversity. The reduction of land consumption is a critical issue that addresses the need to balance human development with environmental sustainability. This concept involves implementing strategies to minimize the amount of land used for urbanization, agriculture, and industrial activities, thereby preserving natural habitats and promoting more efficient land use.

Industrial areas are a major contributor to land consumption, especially when new sites are developed without considering the potential for reusing old, unused industrial areas. The development of new industrial zones often leads to the destruction of forests, wetlands, and other natural areas, resulting in habitat loss and fragmentation. Additionally, the conversion of agricultural land for industrial development reduces the availability of fertile soil for food production, which can have long-term implications for food security.

To combat these challenges, various approaches can be adopted to reduce land consumption in industrial areas. One effective strategy is the re-establishment of old, unused industrial sites, also known as brownfield redevelopment. This involves the cleanup and reuse of contaminated industrial sites, which can revitalize communities and reduce the need for new land development. By prioritizing the redevelopment of existing industrial areas, it is possible to minimize the environmental impact of new industrial projects and make better use of available land resources.

Smart growth principles can also be applied to industrial development. These principles advocate higher-density development, mixed-use zoning, and the preservation of open spaces. By promoting compact and efficient industrial forms, smart growth can help reduce the need for new land development and protect natural areas. Additionally, the implementation of green infrastructure in industrial zones can enhance urban resilience while minimizing land consumption. Green roofs, urban forests, and permeable pavements are examples of green infrastructure that can be integrated into industrial areas.

Below, we refer to the selected case:

Laflora manages peatlands and extracts peat for potting soil. Given the long time it takes for peat to form, Laflora is transitioning from peat extraction to recultivation projects to promote sustainability. These projects include agricultural production like berries, beekeeping, ornamental plantings, sphagnum restoration, afforestation, and biomass production.

The recultivation efforts are carried out in collaboration with business partners, scientists, government agencies, and local communities. At the Kaigi peat extraction site, planned measures include renaturalization, establishing floodplain and forest plantations, and creating renewable energy production areas. The goal is to reduce land consumption and enhance biodiversity while ensuring the land's future use.

Good practice example: KAIGU PILOT

Laflora is originally engaged in managing peatlands and extracting peat substrate for potting soil. Peat, however, takes thousands of years to grow into a layer thick enough for extraction. This means that after the peat is extracted, that piece of land can no longer be used for that purpose. And companies like Laflora will have to find new ways of land use.

Laflora's goal is foster local social and economic wellbeing while transitioning from peatland extraction to peatland recultivation projects.

With respect to a sustainable future and European climate regulations, the company has been focusing for years on sustainable management of peatlands, efficient use of peat resources and modernisation of peat extraction and production.

Through so-called peatland recultivation projects, they experiment for example with the introduction of agricultural production like berries, beekeeping, commercial plantings of ornamental plants, restoration of the bog's flora through sphagnum plantings, afforestation and biomass production.

These recultivation projects are being implemented in collaboration with business partners, scientists, regional government, ministries and state agencies and in consultation with local communities.

Planned recultivation measures and timetable for Kaigu peat extraction site with the goal of land consumption reduction and promotion of biodiversity

In accordance with the requirements of regulatory enactments, the recultivation of developed peat extraction fields shall be initiated no later than 1 year after the completion of extraction in the relevant peat extraction field.

In accordance with the provisions of regulatory enactments (Cabinet of Ministers Regulation No. 570 "Procedures for the Extraction of Minerals"), peat extraction sites may be recultivated - by performing renaturalization (restoration of the environment characteristic of a bog); by preparing for use in forestry, by preparing for use in agriculture, for example, by creating berry or mint growing fields, by creating water bodies, by preparing for recreation or by preparing for use in another way.

The purpose of recultivation is to ensure the full-fledged further use of the extraction site after the completion of the extraction of minerals, to prevent threats to human health and life and the environment, as well as to promote the integration of the extraction site into the landscape. Reclamation measures must be initiated within a year after the completion of mineral extraction in the entire site or in a compact developed area where recultivation works can already be carried out without interfering with extraction.

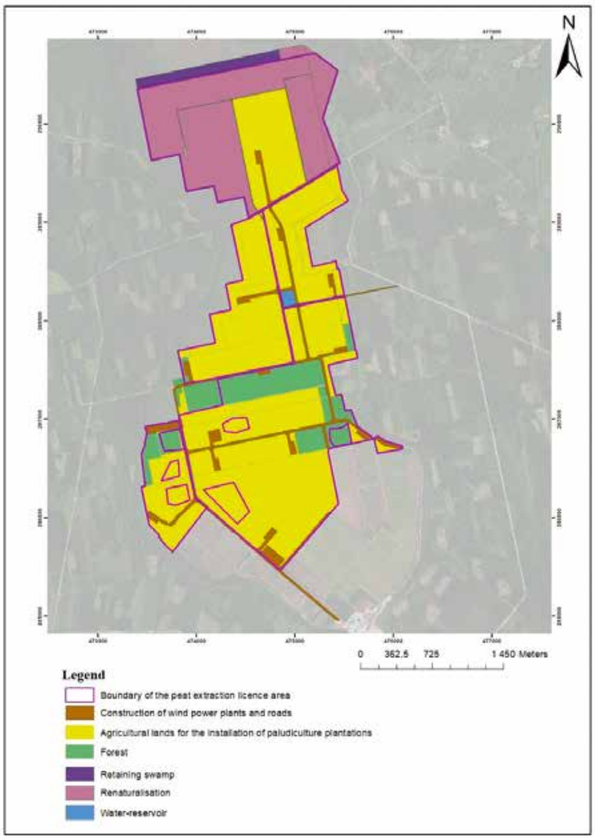
The type of recultivation of the territory is selected in accordance with the planned type of land use upon completion of mineral extraction, in accordance with the requirements set by the landowner or legal possessor and the local government.

The type of peat extraction in Kaigi Bog after the completion of peat extraction is planned - restoration of the environment characteristic of the bog, establishment of floodplain plantations, establishment of forest plantations and preservation of existing forest stands, establishment of renewable energy production areas (Figure 1).

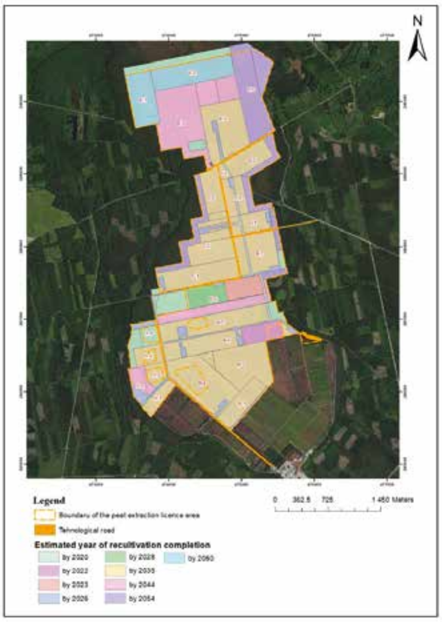
The total area of subsoil uses licenses where peat extraction is possible is 763.32 ha.

24 peat extraction fields have been established at the Kaigu Bog peat extraction site. The gross area of peat extraction fields is 740.26 ha. According to the planned technological extraction scheme for the peat extraction site of the Kaigu bog peat extraction site, it is predicted that the reclamation measures of the peat extraction site will be implemented gradually, in parallel with the extraction of minerals. In general, considering the depth of the peat deposit in the peat extraction fields, the reclamation measures of the territory will be implemented throughout the duration of the subsoil license.

When planning the course of recultivation of a peat extraction area in accordance with the set goal, existing conditions are assessed, such as - the values of the elevation marks of the ground surface in the areas of the planned peat extraction fields, the direction of water runoff, the depth of the peat deposit and possible technological solutions resulting from the types of peat production to be obtained. The implementation of this type of approach allows achieving the main set goals, namely, to carry out the necessary recultivation measures in accordance with the set goal, based on the hydrological conditions and terrain of the territory, as well as to obtain a predictable sequence of measures to be implemented in time.



Predicted types of recultivations of the Kaigu bog peat extraction site

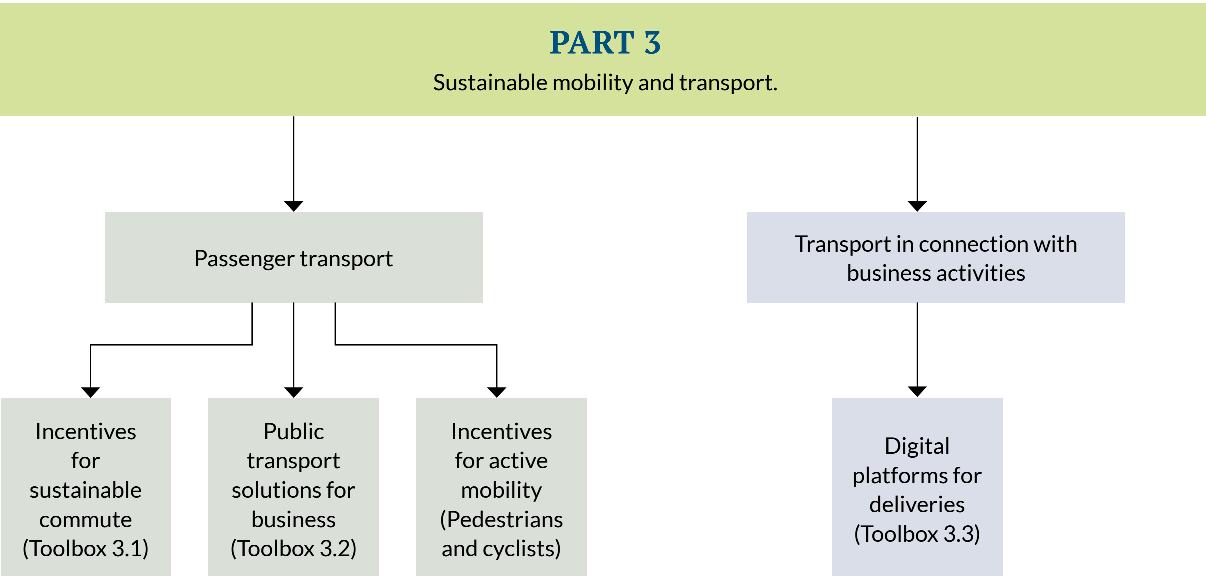


Recultivation stages of the Kaigu bog peat extraction area

Part 3 - Sustainable mobility and transport

This part of the toolbox focuses on the decisions to be made when aiming for more sustainable transport to and from industrial areas, as well as between the companies within the area

Below is a diagram that supports the analysis of opportunities to improve sustainable transport in connection with your industrial area.



Go to toolbox PART 4

To be a Green industrial Area it is important to lower the emissions of transport as well. Joint logistics, traffic management, and sustainable commute are good ways to achieve this.

Promoting sustainable commuting methods is good for the company and has societal benefits. It lowers the need for parking lots, lowers sick leaves due to incidental exercise, and lowers the emissions. Promoting is easiest via financial incentives; it is easier to try public transport if it is very cheap or free, and switching to biking is more likely if you can get a good bike cheaply. Other noted incentives are better parking- and charging facilities for (e-)bikes, better employee facilities (i.e. enough lockers and showers), and possibility for bike maintenance for example. Also, putting a cost for parking space puts a negative incentive for driving and that money can be used to subsidize other commuting methods. Other ways to promote sustainable commuting can be various public transport initiatives, like flexible bus routes, demand-responsive transport, and carpooling services are modern ways to enhance accessibility, reduce travel costs, and support greener transportation options for businesses and their workforce.

To achieve sustainable logistics there's many ways the companies can utilize. Co-operation and joint logistics are a great way to optimize the logistics of the whole area. Digital solutions that foster the joint logistics, and support to sustainable vehicles are examples on how to switch to more sustainable logistics. Sustainable vehicles (i.e. EVs, biogas or H2) can be promoted by offering fuelling for them, or by making it more convenient like automating the charging procedure to a place where they're stopped anyway. Also, applying and optimizing multimodal transport solutions and digital solutions like IoT powered logistics can reduce the emissions of transport even drastically.

Below, we refer to four selected good practice examples.

Incentives for sustainable commute describes an example with paid parking to fund subsidies for public transport tickets and e-bikes, alongside free bike maintenance events, successfully promoting sustainable commuting and reducing parking demand.

Public transport solutions for businesses offered in cooperation between municipality and traffic/bus operators.

The City of Helsingborg and the Swedish Transport Administration have developed a transparent **digital platform for deliveries** to promote sustainable transport, reduce climate impact, and streamline goods deliveries—particularly in industrial areas—through shared shipments, open data sharing, and the use of the Sam app.

Automated EV charging. Elonroad provides an innovative automatic conductive charging system—via ground-embedded rails—for electric vehicles, enabling seamless charging while parked or in motion, thereby reducing CO_2 emissions, minimizing downtime, lowering energy costs, and optimizing fleet operations for greater sustainability and efficiency

3.1. Incentives for sustainable commute

Good practice example:

Location:	Jyväskylä, Finland
Business:	Manufacturing industry

Valmet decided to put a payment for the parking lot and use that money to subsidise public transport ticket or e-bike. They subsidise roughly half of the public transport ticket price and organize free bike maintenance events.

They get 220k€ from the parking payments per year of which 90k€ goes to taxes and payment system. Then they subsidise public transport with 100k€ and bike maintenance with 130k€ per year (data from 2017). This has lowered the need for parking spaces and raised the use of sustainable commuting methods. E-bikes have been very popular.

Links to further information

Public-Transport-Benefits-Mobility-for-YEU-Benefits-for-all

Good practice links

Fiksusti töihin Valmet Jyväskylä - Rautpohja (only in Finnish)

3.2. Public transport solutions for businesses

Good practice example

Location:	Kalundborg, Denmark
Business:	Companies in Kalundborg

Businesses in Kalundborg Municipality require efficient and reliable transportation solutions to ensure smooth commutes for their employees. To address this need, Kalundborg Municipality offers various mobility and in collaboration with Movia and Nabogo. These initiatives aim to enhance accessibility, reduce commuting challenges, and promote sustainable transportation options:

Buses on fixed routes

Kalundborg Municipality, in partnership with Movia, allows businesses to order and finance additional bus routes or departures on existing routes. This initiative enables companies to support their employees' transportation needs effectively.

By collaborating with Movia, businesses can customize routes to align with employees' commuting patterns, ensuring better accessibility to workplaces.

Flextur and Plustur services

These flexible transport schemes are offered by various Danish bus operators and provide tailored mobility solutions:

- Flextur: A demand-responsive service allowing transportation between two specific addresses, catering to the unique travel needs of individuals.
- Plustur: A service integrated with Rejseplanen, connecting users from their chosen address to nearby bus or train stations, facilitating seamless multimodal journeys.

These services benefit employees by offering reliable last-mile connectivity and reducing travel barriers, particularly for those without direct access to fixed-route bus services.

Good practice links

https://www.midttrafik.dk/english/plan-your-journey/plustur-dial-a-ride-service/?utm_source=chatgpt.com

https://sydtrafik.dk/en/flextur/?utm_source=chatgpt.com

Nabogo carpooling service

Kalundborg Municipality has partnered with Nabogo to offer a convenient and cost-effective carpooling solution. Users can access the service through a free app, with the Municipality covering operational costs. Payments between passengers and drivers are automated via the Nabogo app at standard rates, making shared commuting simple and efficient. This initiative promotes sustainable mobility by reducing the number of single-occupancy vehicles, lowering traffic congestion, and decreasing carbon footprints.

Good practice links

https://nabogo.com/en/

3.3. Digital platform for deliveries

Good practice example

Location:	Helsingborg, Sweden
Business:	Skånemejerier, Grönsakshallen, Rönnowska school

The Swedish City of Helsingborg, together with the Swedish Transport Administration, has investigated the possibilities of a transparent digital platform for transport. The aim was to create conditions for actors to take the initiative for joint loading by making data about deliveries visible. The overall aim was to increase the share of sustainable transport and reduce the climate impact through joint loading.

This good practice example includes a school, but the application is most applicable for industrial areas. Two suppliers to Rönnowska School among others, Skånemejerier and Grönsakshallen, have a collaboration in which the two companies' goods, i.e. dairy products and vegetables, are distributed jointly. For several recipients, the collaboration has resulted in a halving of the number of delivery occasions, which means fewer interruptions in regular operations. According to the suppliers, key factors for the joint loading have been similar delivery requirements and the same delivery locations. The transports are carried out by a third party (a haulage company) that has been contracted out by the two suppliers. All three actors exchange data with each other, which means recipient information, shipping weights and schedules.

To be able to follow up on transports and deliveries made for the city of Helsingborg, the city has developed an app called Sam (open source). Sam collects transport data so that employees within the city of Helsingborg can understand how they can become better in placing orders. This can, for example, involve deliveries of food or other goods that the city orders for the city's operations.

The Sam service consists of a mobile app that is used by drivers, and a website where all tracked deliveries are collected. Data about the transports is made available and compiled on the website so that suppliers, transporters, purchasers/customers and any other interested parties can see which transports are made and understand when there is room for collaboration or changing order patterns.

The service is currently so developed that we can describe transports that go to and from different businesses in the city, via geofencing*. This means that only deliveries to geofenced addresses are registered; other stops on the way will not be registered on the website. Your company joins by creating an account and downloading the app. The driver is then responsible for starting and ending tracking while driving. If they miss to end tracking, this will happen automatically eight hours after the app is started.

A crucial aspect of Digital platforms for deliveries is the need for transparency in freight pricing. Knowing the cost of transport in advance is vital for both businesses and consumers, ensuring that the transport component is seamlessly integrated into the overall deal. While open transport data may be perceived as uncertain, this concern is primarily relevant to the private market. For city transports, open data is generally less sensitive and can facilitate better planning and execution.

Moreover, the integration of systems for collecting empty goods on return trips is essential for maximizing efficiency. Effective data sharing plays a pivotal role in ensuring these systems function smoothly. A key piece of advice in this context is to adopt a gradual approach: taking several small steps in the right direction is preferable to attempting a single, large leap that may not succeed. Participation in a data sharing service can be beneficial in the long run, but it requires careful implementation through incremental steps.

*Geofence is an international technical term. It is a geographically delimited or defined area that has been determined and "fenced" with software.

Good practice links

https://www.youtube.com/watch?v=Dj8fjpjYUgc

https://www.youtube.com/watch?v=dUthw4vyUe4

Instruktion/förtydligande om användning – ta bort denna sida (in Swedish)

Instruktion/förtydligande om användning – ta bort denna sida (in Swedish)

https://media.helsingborg.se/uploads/networks/1/2023/01/transparenta-transporter-fas-3-sbf.pdf (in Swedish)

Environmental indicators

Assumption:	a normal distribution vehicle consumes 2.5 liters of diesel in city driving and with an impact of approximately 2.8 kg CO2/liter. This gives a reduction of 3.5 tons CO2 per year just for the Rönnowska school, which is one of the city's all units.

3.4. Automated EV charging

Location:	Stockholm, Sweden
Business:	Elis Textil Sverige AB

The mission of Elonroad is to revolutionize how we move, reducing emissions and optimizing transportation networks for a more sustainable and accessible world. Elonroad's automatic conductive charging solutions for any electrical vehicle significantly decrease CO2 impact and lower the total cost of ownership, offering the flexibility to charge electric vehicles whether on the move, "in motion charging" (while travelling or while circling, enhancing operation in ports and terminals) or parked via rails in the road. Elonroad's innovative solution features a charging rail embedded in the ground. When a driver parks a truck over the rail an energy collector lowers from the truck's underside and charging begins automatically. This means seamless, efficient charging, no cables, no manual plug-ins. The same technology can be applied for in motion charging, i.e. charging while driving.

Elis Textil Sverige AB (former Berendsen Textil Service AB), a circular services leader, has partnered up with Elonroad to transform how their electric vehicle fleet operates. By installing Elonroad's automatic charging solution at Elis Textileservice AB's Stockholm location, the partnership has solved the challenges of mid-shift charging and space limitations that previously hindered the efficiency of Elis' fleet. No disruptions, just productivity with seamless operations and cost savings for their electric vehicle (EV) fleet. This partnership is helping Elis take another step towards their goal of achieving a fossil-free vehicle fleet by 2030.

Elis Textil Sverige AB a leader in circular services, empowers businesses to achieve optimal hygiene and protection for its employees and clients, promoting sustainable well-being enrichment. Elis incorporated electric vehicles into its fleet early on but faced efficiency challenges as drivers had to stop for mid-shift charging at public stations or at home. To streamline its operations, Elis sought a charging solution at its fleet hub. Space limitations and wanting to avoid driver downtime during charging made a conventional DC charging pole impractical.

Elonroad equipped the Elis Veddesta, Stockholm location with two charge rails at the loading docks and retrofitted eight VW eCrafter Light Commercial Vehicle (LCV) vans with CCS-compatible (Combines Charging System) auto charge kits. Utilizing the 50kW charger cabinets placed inside the facility, these vehicles could charge automatically, eliminating the need for cables and poles. The retrofitting process for each vehicle took approximately 4 hours, followed by thorough testing before being commissioned for operations. The transition wrapped up with comprehensive driver training and a testing period, bolstered by additional support to ensure drivers were fully equipped and confident in using the new system.

Eight of Elis' LCV drivers now concentrate solely on delivering goods, thanks to Elonroad's solution that charges its vehicles' batteries during loading and unloading. This solution not only saves time and boosts driver morale but also cuts energy costs by 80% by using the facility grid connection instead of public charging stations. Looking ahead, Elis can increase EV utilization and reduce transport costs per ton by adding another shift and rolling out this solution to its other major Swedish hubs

Good practice links

https://www.elonroad.com/

https://www.elonroad.com/partners/elis

https://www.linkedin.com/posts/elonroad_innovation-partnership-estonia-activity-7216064707835662337-ofrl

Part 4 – Biodiversity and water management

This part of the toolbox focuses on the decisions to be made when aiming for biodiversity and water management in green industrial areas.

Below is a diagram that supports the analysis of opportunities to improve issues in connection to biodiversity and water management in green industrial areas.

PART 4
Biodiversity and water management

Water management	Biodiversity
Does the company have a significant water consumption?	Does the company have outdoor lighting?
"Water management in the Kalundborg Symbiosis" (Toolbox 4.1)	"Sustainable lighting in industrial areas" (Toolbox 4.2)

Go to toolbox PART 5

Below, we refer to two selected good practice examples.

Water management in the Kalundborg Symbiosis is a pioneering example of industrial symbiosis, where treated surface water, steam, heat, and wastewater are reused across industries to maximize resource efficiency and minimize environmental impact.

Sustainable lighting in industrial areas. Outdoor lighting has been carefully planned to minimize light pollution by using low installation heights, warm color temperatures, and low brightness levels, protecting wildlife and saving energy. The project involves collaboration between the city, builders, and residents to ensure sustainable and nature-friendly lighting solutions.

4.1. Sustainable lighting in industrial areas

Location:	Kangas, City of Jyväskylä
Technology:	Sustainable outdoor lighting

Outdoor lighting is needed for safety and convenience in many areas. These areas have spread during urbanization and the habit of lighting the whole yard has become more popular. This, added to the technological change from incandescent lamps to LEDs has increased the light pollution drastically in the world. The cheap, bright, and white LEDs cause more light pollution than the older lights; they're often overly bright and white colors are more harmful for insects.

To change to more environmentally friendly lighting, the brightness and time-of-use should be adjusted to the need and the color temperature should be lower (shifted towards red). Also, the height of lighting poles should be lowered, and their shading should be designed to reduce the unwanted glare.

Cheaply built outdoor lighting often causes a lot of light pollution and is bad for wildlife.

Outdoor lighting is designed to be comfortable for people and wildlife as well as used only when needed. By dimming or turning the lights off when they're not needed, also energy is saved!

This leads to the simple instruction of better outdoor lighting, "3 Lows":

- Low installation height,
- Low color temperature
- Low lux levels.

The Kangas area is an area which has been developed with a new kind of planning. Nature, art, and sustainability have driven the development of the area, and it has included the city, the construction companies and the residents of the area to the planning and construction. This has also led to outdoor lighting being planned better, causing less light pollution and being more friendly for the wildlife.

Guiding lines have been established for the design of outdoor lighting in Kangas and have mandated it to be planned well. Lights are dimmed and shut down during the night, they're downwards aiming and only light the areas the need illuminating. Also, the color temperature is set to 3000k in most lights.

Links to further information

GIA_lighting_guideline_ENG

More info of the area (not relevant to lighting):
Kangas in Jyväskylä | Jyväskylä.fi

Kangas planning instructions (in Finnish only):
Laatuaapinen.pdf

Article on Kangas and lighting:
Smart Outdoor Lighting Reduces Light Pollution

City of Jyväskylä

The picture is from Kangas, which is a mixed residential and office area, but it shows well the importance of nature-friendly outdoor lighting. At the back of the picture is seen a regular industrial or commercial area, which produces much more light pollution.

4.2. Water management in Kalundborg Symbiosis

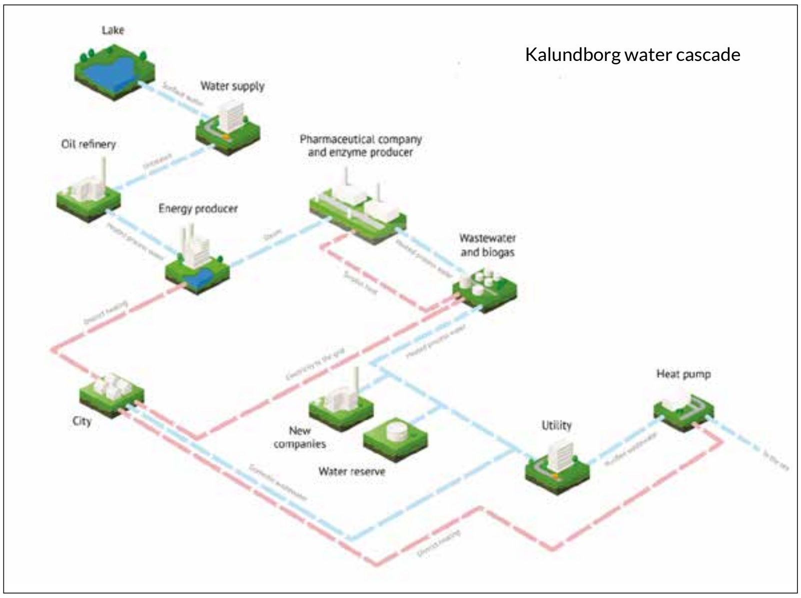
Location:	Kalundborg
Business:	Utility – water

Water plays a vital role in the industrial symbiosis cooperation within the Kalundborg Symbiosis. Kalundborg Utility, a 100% publicly owned utility company, serves as the partner responsible for all water supply and final wastewater treatment within the symbiosis. As the utility company of Kalundborg Municipality, it oversees the water management for the larger geographical and legal area that the municipality represents. Currently, the water sources used in the Kalundborg Symbiosis are derived from groundwater and surface water, with the latter originating from a large lake located 13 kilometers from Kalundborg. However, increasing growth, driven by the expansion of existing partners and the addition of new ones—has placed significant pressure on the water supply in the Kalundborg area. Simultaneously, climate change has introduced new challenges, such as more frequent droughts and floods. Additionally, legislative changes have created opportunities to utilize new types of water.

To address these challenges and opportunities, the Kalundborg Symbiosis has established a dedicated Water Group, led by Kalundborg Utility and comprising the largest water consumers within the symbiosis. The Water Group's mandate is to discuss and identify potential scenarios to improve or rethink the water cycle. The objectives include developing proposals for substituting water streams, exploring options for reusing different water qualities, and ensuring that water supply for production is managed responsibly. By working together, the partners aim to tackle complex water management challenges—issues that individual companies cannot solve alone but can address collaboratively.

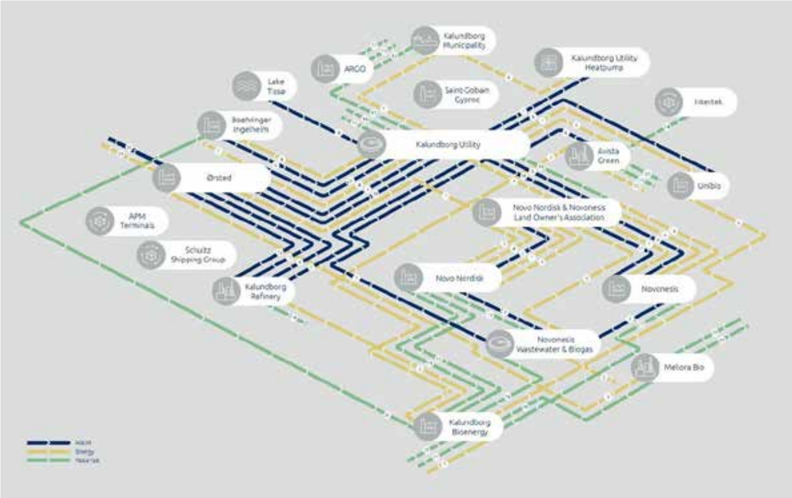
Rainwater, like other fractions of stormwater from the companies' sites, is typically collected by each company's internal water system and mixed with wastewater on-site. Depending on the company's setup, the stormwater is either treated on-site—if the company has its own pre-treatment facility—or sent directly to Kalundborg Utility's wastewater treatment plant. As previously mentioned, Kalundborg Utility manages the final treatment and polishing of all wastewater before the cleansed water is discharged into the sea.

Turning water into synergy: the Kalundborg water cascade



The Kalundborg water cascade is a pioneering example of industrial symbiosis, where water flows through multiple industries, transforming and being reused to maximize efficiency and minimize environmental impact. At the heart of this system lies a circular approach, ensuring that water and energy are shared and repurposed across partners in the Kalundborg Symbiosis.

The journey begins with surface water drawn from Lake Tissø, approximately 3.5 million cubic meters annually. This water



Streams mentioned regarding water cascade:
1 – steam,
6 – wastewater,
7 – treated wastewater,
8 - surface water,
9 – used cooling water,
10 – deionat,
11 – treated surface water,
12 – flue gas condensate,
30 – hot water

travels through a 13-kilometer pipeline to Kalundborg Utility, where it undergoes treatment. A significant portion of the treated surface water—over 1.5 million cubic meters—is upgraded to drinking water quality and supplied to industries like Novonesis, which use it in enzyme production. By using surface water instead of drinking water, this system helps preserve valuable groundwater resources.

At Kalundborg Refinery, the treated surface water is used as cooling water in closed systems. Once heated, the water is sent to Ørsted, where its elevated temperature reduces energy consumption during steam production at Asnæs Power Station. Steam, now the primary product of the power station after transitioning from coal to biomass, is distributed to various industrial partners through the iconic green pipes that have become a symbol of Kalundborg Symbiosis. These pipes deliver steam to companies like Novonesis and Novo Nordisk, where it is used for critical processes such as cleaning, sterilization, and distillation.

The use of steam does not end there. Through vapor traps, steam condensate is captured and reused. This process not only recovers valuable heat and water but also helps regulate the temperature and pressure of steam for specific industrial applications. The excess heat extracted from the condensate is used to produce district heating, while the cooled condensate is repurposed for tasks like mixing lye and acid at Novonesis or supplementing cooling towers, thereby reducing the need for additional surface water.

District heating plays a vital role in this cascade. Produced at Asnæs Power Station, it provides heat for approximately 24,000 households and local industries. During colder months or periods of low electricity prices, Kalundborg Utility's heat pump enhances district heating capacity, powered by treated wastewater.

Water treatment is an integral part of the system. Wastewater from industrial partners is pre-treated by each company before undergoing final treatment at Kalundborg Utility. Treated wastewater is then channeled through a heat pump, producing 80,000 MWh of energy annually—enough to meet more than 30% of the utility's district heating needs.

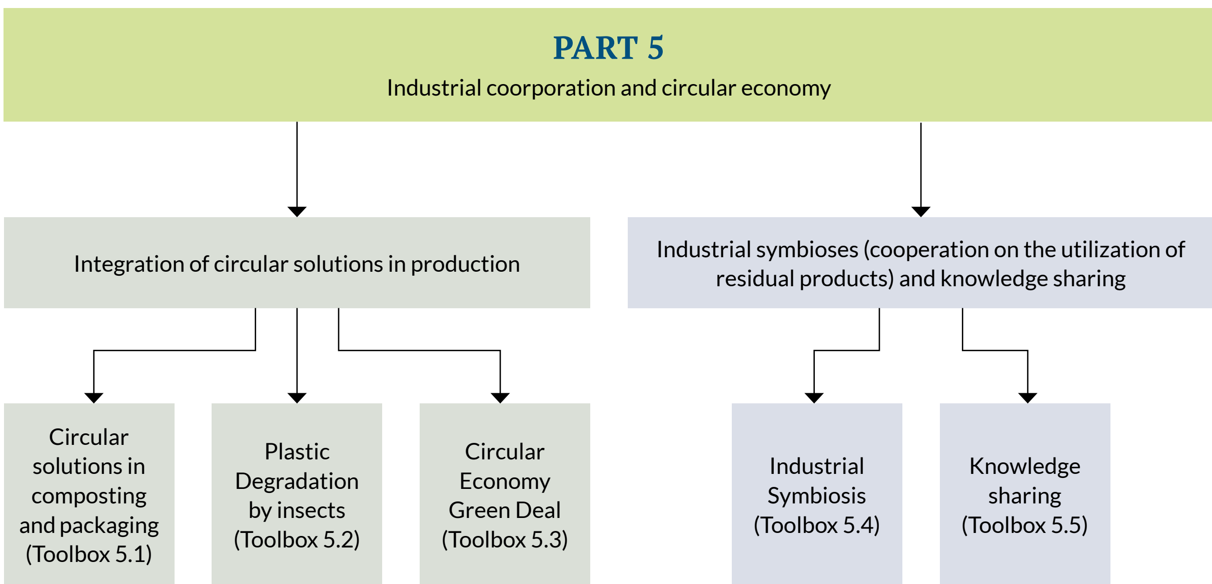
Even the byproducts of energy production are not wasted. At Asnæs Power Station, burning biomass generates flue gas condensate, which is treated and supplied to Kalundborg Refinery. The refinery uses this purified condensate as boiler water, covering a third of its requirements and further reducing its reliance on surface water.

The Kalundborg water cascade is a testament to the power of collaboration and innovation. By reusing and repurposing water and energy at every step, this system exemplifies sustainable industrial practices. It is a model of circular resource management, proving that efficiency and environmental responsibility can go hand in hand.

Part 5 –Industrial cooperation and circular economy

The circular economy is an economic model designed to minimize waste and make the most of resources. Instead of the traditional linear economy model — take, make, dispose — the circular economy is based on a more sustainable loop: make, use, reuse, remake, recycle. Industrial symbiosis acts as a local or industrial-scale strategy for implementing circular economy principles, leading to greater environmental sustainability and economic efficiency.

Industrial symbiosis is a concept where different industries or companies collaborate to use each other’s by-products, waste, or excess resources to create a more sustainable and efficient system. The goal is to reduce waste, lower costs, and minimize the environmental impact of industrial activities. Essentially, it’s about creating a “circular economy” within a region or industrial park, where one company’s waste becomes another company’s raw material.



For example, a factory might produce heat as a by-product, which could be used by a neighbouring factory that requires heat for its processes. Similarly, waste materials like metals, chemicals, or organic matter might be repurposed or recycled into new products by other companies in the area.

Industrial symbiosis fosters resource efficiency, reduces environmental impact, and can help businesses save money by finding new uses for materials or energy that would otherwise go to waste. It often involves collaboration between businesses, governments, and other stakeholders to establish shared infrastructure and logistical systems. Industrial symbiosis relies on a variety of technologies to make the efficient exchange of materials, energy, and resources possible. These technologies facilitate the reuse of by-products, recycling, and energy recovery, promoting sustainability and cost savings.

Below, we refer to five selected good practice examples.

Circular solutions in composting and packaging is an example where composting machines transform food waste and biodegradable packaging into nutrient-rich compost within 24 hours, supporting circular and local nutrient recovery. Their solutions reduce waste volume, minimize emissions, and create high-quality soil product.

Plastic degradation by insects is an example of insect-based biorefinery that transforms over 90% of common plastics into proteins, lipids, and biofertilizers using Greater Wax Moth larvae. Their modular solution enables decentralized, sustainable plastic upcycling, integrating easily into existing recycling processes.

Circular Economy Green Deal is a Finnish initiative supporting companies, regions, and municipalities in halving the use of non-renewable resources and doubling circular material use by 2035.

Industrial symbiosis is a collaborative approach where companies exchange materials, energy, and resources to reduce waste, lower carbon footprints, and boost competitiveness. Through local partnerships and shared infrastructure, businesses achieve both environmental and economic benefits by turning waste into valuable inputs.

Knowledge sharing as seen in the Kalundborg Symbiosis, enables companies to exchange insights, technologies, and best practices to drive innovation, improve energy efficiency, and promote sustainable energy use. Through structured networks, seminars, and collaborative platforms, stakeholders gain critical knowledge to enhance operations and form new partnerships.

5.1. Circular solutions in composting and packaging

Location:	Sweden
Business:	Restaurant

Solserv is a company based in the south of Sweden, offering a product range including composting solutions to recover nutrients from both food waste and biodegradable packaging, food packaging machines and food packaging materials1 .

Solserv's composting machines offer closed-loop and circular solutions for the extraction of nutrients from food waste, grass clippings, residues from the food industry, warehouses for storage of fruit and vegetables etc. The composting machines, with capacities ranging from 5-1,500 kilos per day (facilities with pre-treatment: 5-500 tons/day) convert organic residual materials within approximately 24 hours into easy-to-handle compost. After another 2-3 weeks of post-stabilization, the compost is ready to be used as fertilizer, or after adding sand, sawdust or similar substrates also as a growing medium.

Specially adapted microorganisms quickly break down the organic material under continuous stirring in the machine. An optimal moisture content for the microorganisms is maintained throughout the time in the substrate. The process is continuously controlled by a computer system.

Tissue paper, napkins and cellulose-based food packaging and disposable plates, etc. can also be advantageously mixed with the food waste in the machine to obtain a well-balanced ratio between organic carbon and nitrogen.

The pH value of the Solserv compost is mostly about 5.5-6.5 and is optimal for most garden plants. It also has a well-balanced nutrient composition with mainly nitrogen bound as ammonium or in an organic form. The quota between carbon and nitrogen promotes favorable conditions for soil micro-organisms and creates a vital and healthy soil.

The added residual material to some extent determines the biological and chemical properties of the compost, and the final product can thus partly be adapted to the types of plants intended to be grown. The pH value of the Solserv compost is mostly about 5.5-6.5 and is optimal for most garden plants. It also has a well-balanced nutrient composition with mainly nitrogen bound as ammonium or in organic form. The ratio between carbon and nitrogen promotes favorable conditions for soil microorganisms and creates a vital and healthy soil. The added residual material determines to some extent the biological and chemical properties of the compost, and the final product can thus be partially adapted to the types of plants intended to be grown.

Links to further information

https://solserv.se/

The range of different sizes of composting machines offers the opportunity for collaboration between nearby businesses in, for example, an industrial area, supermarket areas, market halls or similar business constellations.

Among the customers are e.g. Volvo, Fazer Food, Swedish food retail actors like ICA and AXFOOD, H&M, NOMA, Sheraton and chefs like e.g. Jamie Oliver, Titti Qvarnström, Paul Svensson and Tareq Taylor.

Good practice links

From food waste to soil in 24 hours | Mitsubishi Electric x Solserv x Radisson Blu

Environmental indicators:

The benefits of composting machines:

- No more odor or mess from the waste, as the composting machine converts food waste directly into nutrient-rich soil.
- Reduced emissions and transportation costs as the food waste does not have to be transported to an external facility.
- Reduced emissions and transportation costs as the need for imported commercial fertilizer is reduced.
- Less waste in smaller kitchens as the composting machine minimizes the volume of the waste and in addition keeps it clean and hygienic.
- Nutrient-rich compost soil perfect for growing or as a soil improver.
- Hygienic and odorless with minimal maintenance. The composting machine stays free of vermin and pests.

5.2. Plastic Degradation by insects

Location:	Sweden
Business:	Plastic up-cycling

The Swedish company NBTech AB/Norbite tackles the problems of plastic waste and the upcycling of plastic waste into sustainable solutions. The company offers plastic degradation by biological means, a novel insect-based biorefinery solution.

The solutions may be integrated into the existing recycling processes and/or be added as separate units providing module decentralized recycling to valorize plastic waste.

More than 90% of commonly used plastic materials can be transformed into sustainable products by one specific insect, Greater Wax Moth (Galleria mellonella).

The larvae of the insect digest and transform plastics into proteins, lipids and biofertilizers. Instead of disposal or incineration, which is the typical end-of-life approach in a linear plastic value chain, Norbite is developing the technological and commercial foundations to transform residual polymeric materials, such as packaging, textiles, furniture, etc., into a food source for the larvae of Galleria mellonella. A cheaper and more sustainable alternative to waste incineration. By refining the larvae of the insect for multiple high-value products, aimed at food and feed, organic farming, technical applications etc. plastic waste is given the opportunity to re-enter the economy. The insect's transformation capabilities mean the elimination of residual products in the plastic industry through their conversion into resource materials for another value-creating i.e. industry symbiosis. The uniqueness of this technology is confirmed and protected by 4 patents.

Links to further information

https://norbite.eu/

Good practice links

Larverna äter plastavfall och blir mat på rymdresor | IT-Hållbarhet

Environmental indicators:

The Norbit-technology is saving 67% of CO_2 emissions compared with incineration.

5.3. Circular Economy Green Deal

Location:	Finland
Business:	Circular Economy

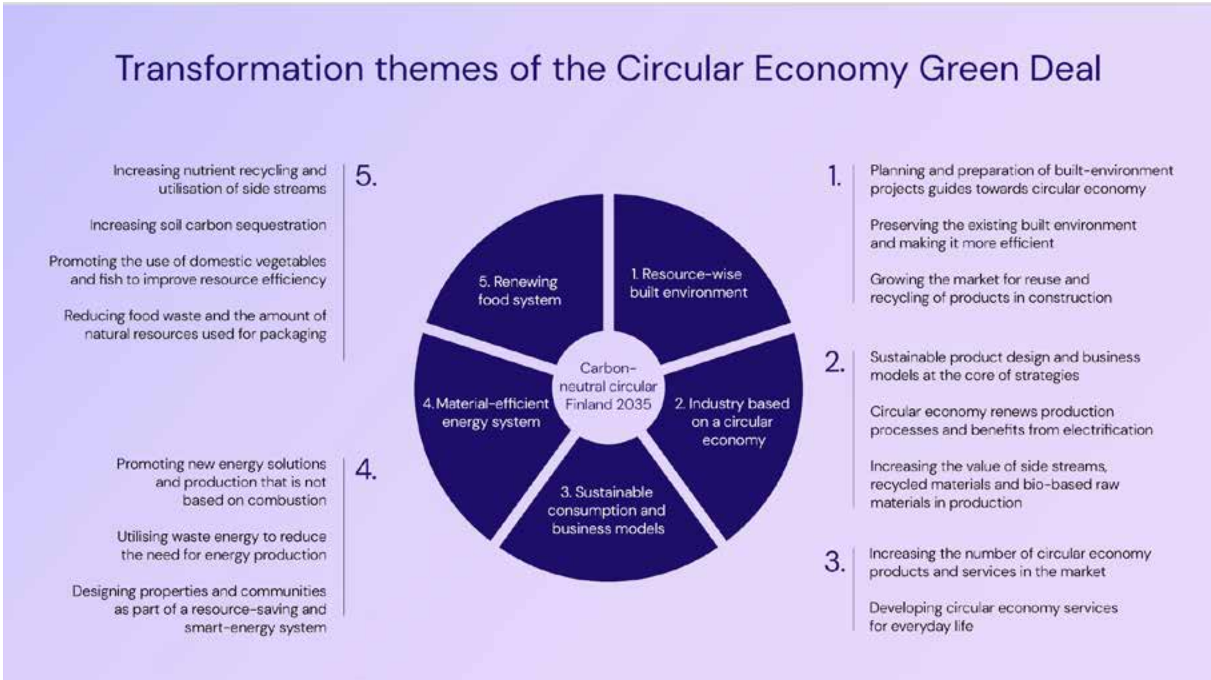
The Circular Economy Green Deal is a voluntary strategic commitment for companies, municipalities, regions, organizations, and the state. It aims to achieve the goals set by the government, which come from the Circular Economy Strategic Program. The goal is to halve the consumption of non-renewable natural resources and double the circular economy rate of resources and materials by 2035. The Circular Economy Green Deal has been prepared on behalf of the state by the Ministry of the Environment and the Ministry of Employment and the Economy.

The Regional Council of Central Finland aims to support regional actors in promoting the circular economy and encourages them to make their own commitments. The goal is 22 commitments in the region by 2035. The regional council also intends to increase the EU funding channels to regional actors in the circular economy. In addition, the Regional Council of Central Finland sets guiding targets for regional actors to increase non-combustion-based energy production and to promote the circular economy of underused and sold-out publicly owned properties.

The circular economy will be more strongly integrated into regional development and land use planning. The KiSu circular economy thinking toolkit will be utilized in operations, for example. The circular economy will be made more visible in the regional strategy and regional

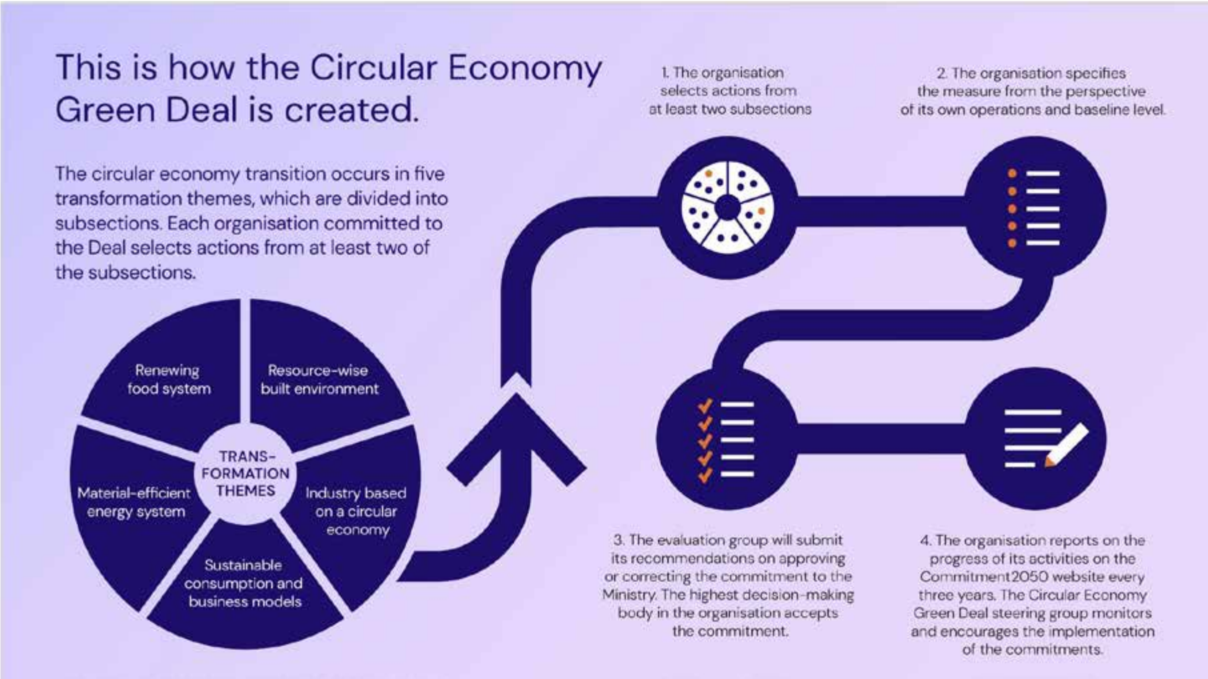
Links to further information

Circular Economy Green Deal - Ministry of the Environment



plan (target 2030) and more broadly in regional strategies and planning (including municipalities) (target 2035). The circular economy will be raised as one of the themes to be assessed in the assessment of the timeliness of the regional plan. The assessment of timeliness includes negotiations with municipalities, in which, for example, what kind of projects and ideas are underway in municipal planning. The circular economy will also be included as one of the themes in the negotiations. The regional strategy will be updated every four years in cooperation with stakeholders in the region, including municipalities. In workshops and meetings related to the strategy update, municipalities will be encouraged to consider the opportunities of the circular economy in their own operations.

Good practice links
https://demoshelsinki.fi/projects/circular-economy-green-deal-towards-circularity/



Key performance indicators:

Non-combustion-based energy solution:	Initial phase 13,1 -%, 17-% in 2030, 25 -% in 2035.
Defined funds %-amount from total of ERDF / JTF- funds:	Initial phase 4 -%, 10-% in 2030, 15 -% in 2035.
Amount of green deal commitment from Central Finland:	Initial phase 0, 15 deals in 2030, 22 deals in 2035.
Unused public buildings, based on region planning report 2027:	based on planning report 2030, based on planning report 2035.

1 A large number of the packaging materials produced by Solserv are produced from decomposable raw materials such as paper fibers, bagasse and similar biodegradable substances. Together with food residues they can be a raw material for compost production.

5.4. Industrial symbiosis

Location:	Kalundborg, Denmark
Business:	Industries

Industrial Symbiosis is both a strategic and practical approach to production, where diverse companies collaborate to enhance resource efficiency, reduce carbon footprint, reuse materials, establish shared infra-structure, and achieve competitive advantage.

By promoting synergies between companies and across different sectors, industrial symbiosis leads to minimizing environmental impact while maximizing economic benefits.

As these sustainable synergies mature, they will be led and facilitated within a network of companies forming a partnership on industrial symbiosis collaboration.

The fundamental concept behind Industrial Symbiosis involves the exchange of materials, energy, and water among two or more companies, effectively transforming waste into valuable resources. This approach brings about a decrease in the use of new materials, costs, and the need for transportation. Embracing a circular approach proves advantageous for both environmental initiatives and the financial performance of businesses. Industrial symbiotic relationships are commonly established in close geographical proximity and may manifest as larger collaborative projects with shared funding.

Below are five different examples of how these technologies are applied in practice, showcasing their potential for sustainable energy production and efficient solar energy utilization.

Good practice links
https://www.symbiosis.dk/en/

Indicators:

CO2 emission reduction:	586,000 tons
Ground water saved:	4 billion m3
Recycled materials:	62,000 tons

5.5. Knowledge sharing

Location:	Kalundborg, Denmark
Business:	Kalundborg Symbiosis/network organization

Knowledge sharing is a supporting activity which is important for promoting innovation, driving improvements in energy efficiency, and fostering other sustainable energy use practices.

As a result of knowledge sharing activities, a company can learn more about the opportunities to improve energy efficiency in its operations, to switch to more sustainable energy sources, and to get the information it needs, both in terms of the specific technologies to be applied and the need for investment, possible partners, suppliers etc. It involves sharing insights, data, research findings, and lessons learned among various stakeholders such as businesses, researchers, policy-makers, and practitioners. Most common forms of knowledge sharing within the energy topic are through seminars, conferences, knowledge platforms, networks, and energy audits.

The Kalundborg Symbiosis is a partnership between 18 local companies. The partnership is formed as a non-profit organization. The partnership is organized with a board of directors formed by the CEOs of the companies/plants, a secretariat (with 4 employees), an advisory board (covering specialist on managerial level from the companies).

Besides the partnership has an innovation board, and working groups, some are formal (for instance water), others are" ad hoc". The members pay a member fee variating from 4.000 to 15.000 EUR. This sum covers 1 employee at the secretariat. The rest of the salaries are covered by project participation, consultancy, and a visitor service. In 2019 an LCI was conducted on the benefits of the symbiosis.

Links to further information

Copenhagen center on energy efficiency: https://c2e2.unepccc.org/knowledge-management-system/

Horizon project Enefirst: https://enefirst.eu/knowledge-sharing/

Synergy Analysis of Knowledge Transfer for the Energy Sector within the Framework of Sustainable Development of the European Countries: https://www.mdpi.com/1996-1073/15/1/276

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