The greenest energy is the energy we don't use

Energy efficiency solutions show the way to accelerate the green transition

The science is clear

The past 20 years, improvements in energy efficiency have kept a lid on emissions. Now we need to break the curve and drive the world towards net zero. Energy efficiency will be critical to success.

Most energy is used in our cities and buildings, in factories, and for transportation. We use much more energy than we need, putting us off track to meet our global climate goals.

If we use our energy smarter, we can break the curve on energy demand. This eases the global transition to clean and green energy sources, since each watt generated from wind and solar stretches further.

The good news is that the solutions are already there. They can be implemented right away. And most have short payback times. We can improve the fuel economy in machines and reduce the demand for diesel. We can electrify trucks and ferries. We can reuse heat from commercial processes to heat homes and industries. We can use both simple and smart technologies to create carbon-zero-ready buildings.

This is not the future. This is now. The solutions are here. They will increase the competitiveness of our industries and improve the livelihoods of citizens. And most importantly, we need them to meet our climate goals.

The Sønderborg Municipality in Denmark is testament to that. Since 2007, energy-related carbon emissions have been reduced by more than 50%. In this booklet, you can learn about eight tangible examples that demonstrate the value of early action on energy efficiency. These have been prepared on the occasion of the International Energy Agency's 7th Annual Global Conference on Energy Efficiency taking place in Sønderborg, Denmark on June 7-9, 2022.

ProjectZero, local solutions to a global challenge

The challenge

Source: IEA (2021). Greenhouse Gas Emissions from Energy

Buildings

28%

of all global energy-related CO_2 emissions come from buildings

Industry

39%

of all global energy-related CO_2 emissions come from industry

Transport

27%

of all global energy-related CO_2 emissions come from transport

Sector integration

196 countries have signed the Paris Agreement that aspires to **limit global warming to 1.5 °C** relative to pre-industrial levels. Many countries, regions and municipalities seek concrete tools that can help them meet this aspiration in an intelligent and cost-effective way.

Source: https://www.iea.org/reports/greenhouse-gas-emissions-from-energy-overview/emissions-by-sector

ProjectZero: Local solutions to a global challenge

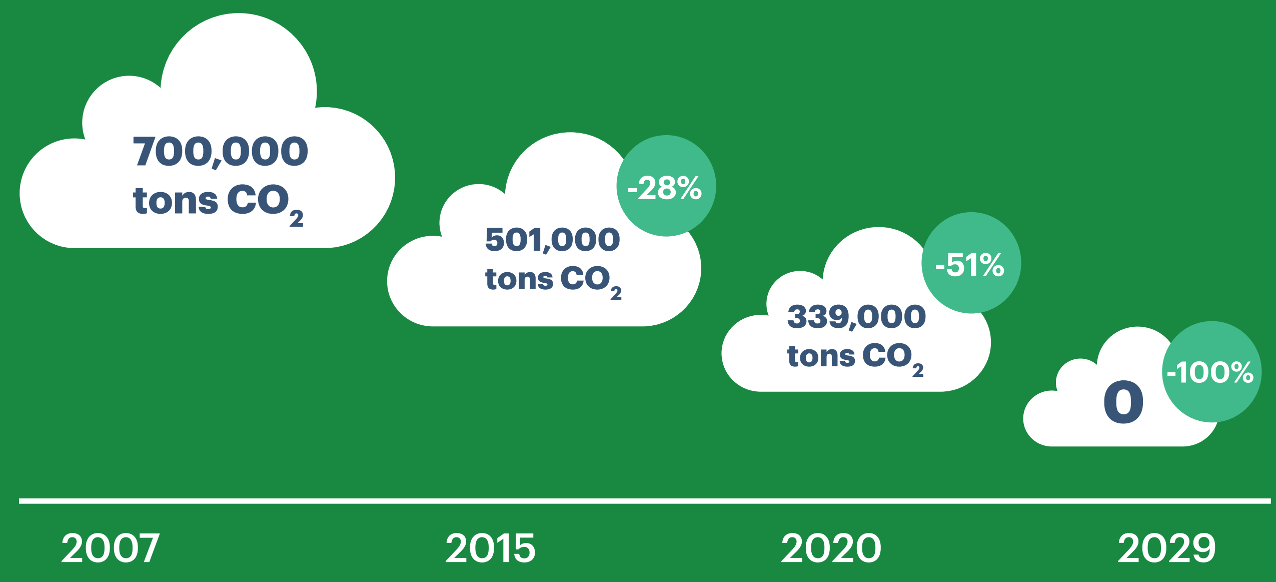
In Denmark, Sønderborg Municipality has worked strategically in a public-private partnership called ProjectZero to find local solutions to a global problem. **Since 2007, energy-related carbon emissions have been reduced by more than 50%** and the municipality is on track to delivering on their 2029 vision for a carbon neutral energy system.

Between 2007 and 2020, Sønderborg Municipality has:

- ✓ Reduced carbon emissions from housing by 63%
- ✓ Reduced carbon emissions from businesses by 60%
- ✓ Reduced carbon emissions from heating by 73%

Source: ProjectZero (2020) Monitoring report

Reductions in Sønderborg's energy-related carbon emissions since 2007



A green turnaround in Sønderborg, Denmark

In the 2000's, Sønderborg Municipality struggled with low-income jobs, unemployment and was projected to have the strongest decrease in population of any region in Denmark. Local politicians, companies, foundations, and citizen's groups joined forces and began a series of initiatives to turn the tide. One of them was ProjectZero.

ProjectZero was established as a public-private partnership in 2007 with a vision of turning Sønderborg Municipality's energy system carbon neutral by 2029, creating jobs and growth on the way.

The ProjectZero office drives the 2029 vision forward. The public-private organizational structure ensures a strict focus on realizing the vision and helps emphasize the positive business potential to local stakeholders.

Sønderborg Municipality

Inhabitants: 73,831

Area: 495 km^2

Density: 150 persons per km^2

Largest city: Sønderborg, 27,000

PROJECTZERO

5 learnings from ProjectZero

The road to a carbon neutral energy system is different from place to place. Unique factors are at play even between neighboring municipalities with very similar profiles. But some things can be replicated.

ProjectZero has extracted 5 universal learnings derived from 15 years of experience that can help most municipalities or regions in their journey to zero.

Toward a carbon neutral energy system

1. Local engagement behind a bold aspiration

ProjectZero has a bold aspiration that sets a clear direction. An aspiration is nothing without support, so its essential that citizens, businesses and organizations back the aspiration.

2. Develop a master plan

A master plan breaks the big challenge down into manageable bites and ensures momentum and engagement. 15 key areas, or 'hot spots,' each have emission and energy reduction targets that show the path to zero.

3. Organize local action

A plan is not enough to drive results. An organization is needed to keep stakeholders such as citizens and businesses engaged and the project on track. Each of the 15 'hot spots' has an owner who takes the overall responsibility as well as a project manager who drives the process and secures input from a working group and experts.

4. Drive performance management

A set of operational KPI's ensures that emission and energy reduction targets are met for each 'hot spot.' A KPI board is reviewed quarterly by the ProjectZero office to ensure an agile and focused approach.

5. Don't wait, the solutions are ready

The succes of ProjectZero relies on existing cost-effective solutions with short payback times – and not future inventions. The municipality has plenty of examples.

Learning 1.

Local engagement behind a bold aspiration

ProjectZero was founded in 2007. Back then, a vision of a carbon neutral energy system in 2029 was way ahead of its time. Much has changed since then. In Denmark, a 70% reduction in carbon emissions before 2030 and climate neutrality before 2050 are now written into law by the government, which has intensified the quest for cost-effective solutions and smart approaches to deliver on ambitions. Sønderborg Municipality had a head start not least because of their early and bold aspiration, which still today is a source of pride that drives engagement and results.

Most human activity depends on energy. Driving an energy system to zero therefore demands participation from everyone in the local community including businesses, politicians, citizens, building owners, utility companies and many more. Climate change is a global problem that will be solved on a local level. Proximity is a green asset. People are more likely to buy into a vision if they can feel the impact and share the commitment. ProjectZero is a testament to that.

A key driver for ProjectZero's results has been to ensure that all stakeholders see the potential and commit to the vision. Stakeholders have rightfully asked, "what's in it for me?" – and ProjectZero has aspired to find honest answers. Most of the time, they have been satisfactory.

Learning 2.

Develop a **master plan**

Many small streams make one big river. Multiple actions are required across the entire local economy to meet ProjectZero's 2029 vision. For that to succeed, planning, KPI's and involvement is needed – just as for any well-run business. A master plan sets the course for ProjectZero and ensures its momentum.

Shifting an energy system to carbon neutrality requires many moving parts. It is important that actions reflect that. Based on a thorough mapping of the energy system, the master plan breaks the big challenge down into 15 focus areas, or 'hot spots,' that require specific attention. Each hot spot has emission and energy reduction targets. Working groups consisting of relevant experts are tasked with finding the most cost-effective solutions that will help them meet their targets.

Cost-effective planning is based on 3 principles:

1. **Energy efficiency:** Use only the energy needed
2. **Sector integration:** Reuse energy already produced
3. **Green energy:** Source demand from renewable sources

15 key focus areas or 'hot spots'

Buildings			Transport			Industry			Energy
Rented housing	Owner-occupied housing	Public	Passenger transport	Heavy transport	Agri-cultural machinery	Large manu-facturers	Brick manu-facturers	SME	District heating

- Biogas
- PtX
- Wind park
- Wastewater plant
- Sector integration

Sønderborg and ProjectZero demonstrate the value of early action on energy efficiency

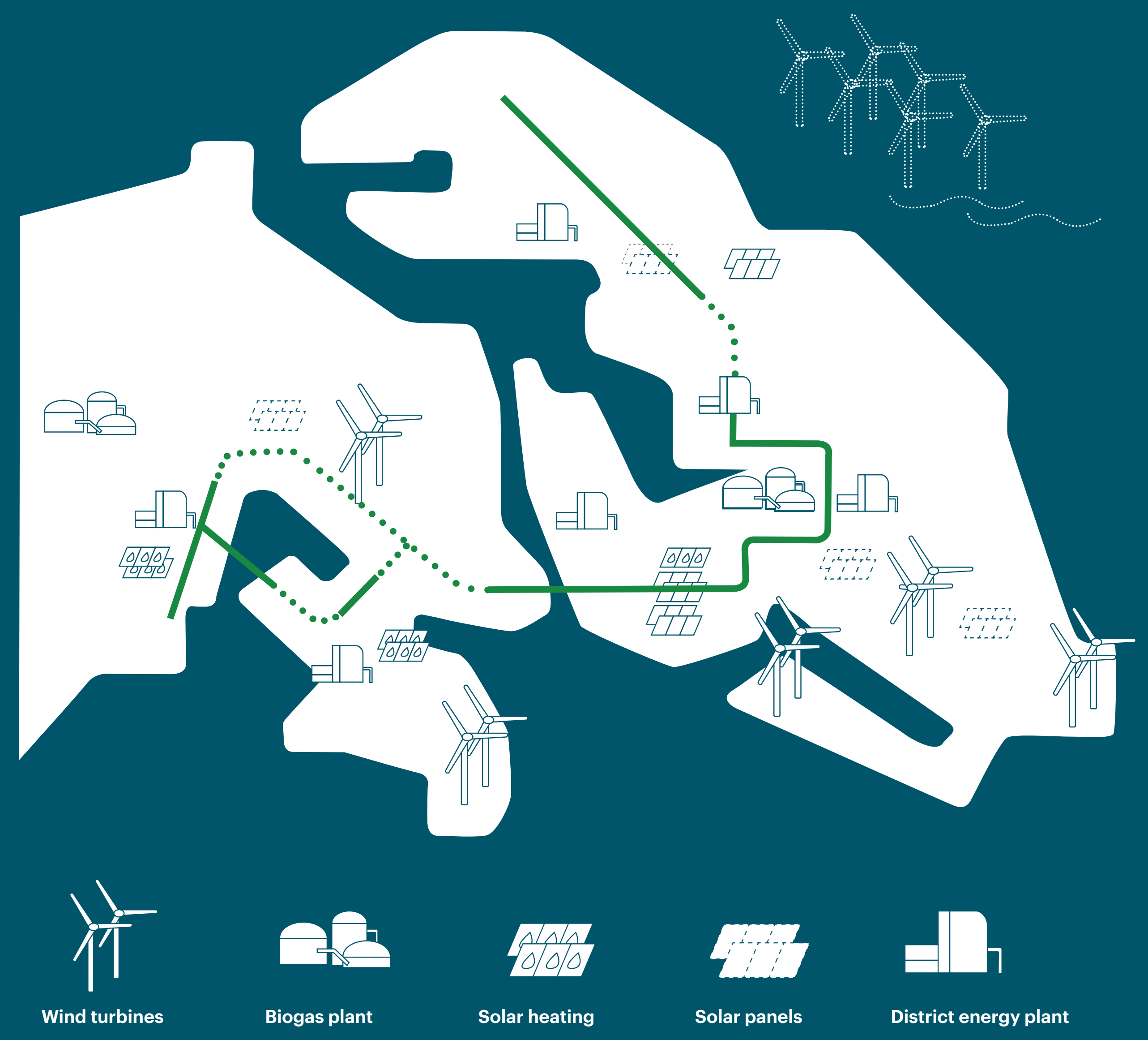
Sønderborg's integrated energy system is central to ensuring the most cost-effective path to the 2029 target.

Carbon reductions in Sønderborg, Denmark, have been driven by three principles for a cost-effective transition: Use only the energy needed, reuse the energy that is already produced and use green energy. Sønderborg's integrated energy system is the backbone that increases the potential in the three principles, since it allows for the most efficient use of energy.

Sønderborg Municipality is supplied with energy from many renewable energy sources, including a planned coastal wind park. The electrification of the economy requires a lot of renewable energy, which in turn requires a balancing of consumption to minimize investments. But not all vehicles and production processes can run on direct electricity. Renewable energy is also used to produce hydrogen or synthetic fuels that can replace fossil fuels where needed.

The primary source of heating buildings and supplying hot water is from the district energy system. One of the main strengths of district energy systems is their capacity to integrate

Sønderborg's integrated energy system



different energy sources that can push fossil fuels out of the energy mix. That includes renewable energy, which can be used not only to keep the lights on but to heat homes and power transport, a concept called sector integration.

And it includes excess heat. A laptop generates heat to operate, and a data center does the same in large scale. Excess heat from data centers can be reused through the district energy system to supply heat to buildings and industries. The same goes for supermarkets, biogas production, wastewater management and many other industrial or commercial processes. And the district energy system is the binding link.

Today, most heat and electricity come from non-fossil waste and biomass. But the journey is not complete. By the end of 2020, there was still 40,000 tons of CO_2 to be eliminated by 2029. To eliminate the remaining CO_2, ProjectZero now focus on electrification combined with utilization of excess heat.

Each of the **15 ‘hot spots’** has an owner who takes the overall responsibility as well as a project manager who drives the process and secures input from a working group and experts.

Learning 3.

Organize local action

Local stakeholders take responsibility by engaging in the work to drive change in the 15 ‘hot spots.’ Collaboration, involvement, and knowledge sharing between stakeholders is central. So is the business case. No stakeholders will play a part if it’s unclear what is in it for them. The ProjectZero office mobilizes stakeholders to engage in the master plan based on a ‘what’s in it for me’ principle which ensures dedication and commitment from all stakeholders.

A plan is not always enough to drive results. An organization is needed to keep the 75 participants engaged and on track. The ProjectZero office mobilizes local stakeholders and motivates them to participate by highlighting potentials and possible solutions. Each of the 15 ‘hot spots’ has an owner who takes the overall responsibility as well as a project manager who drives the process and secures input from a working group and experts.

Learning 4.

Drive performance management

The masterplan is managed with a model that sets operational KPIs, which ensure that emission and energy reduction targets for each hot spot are met.

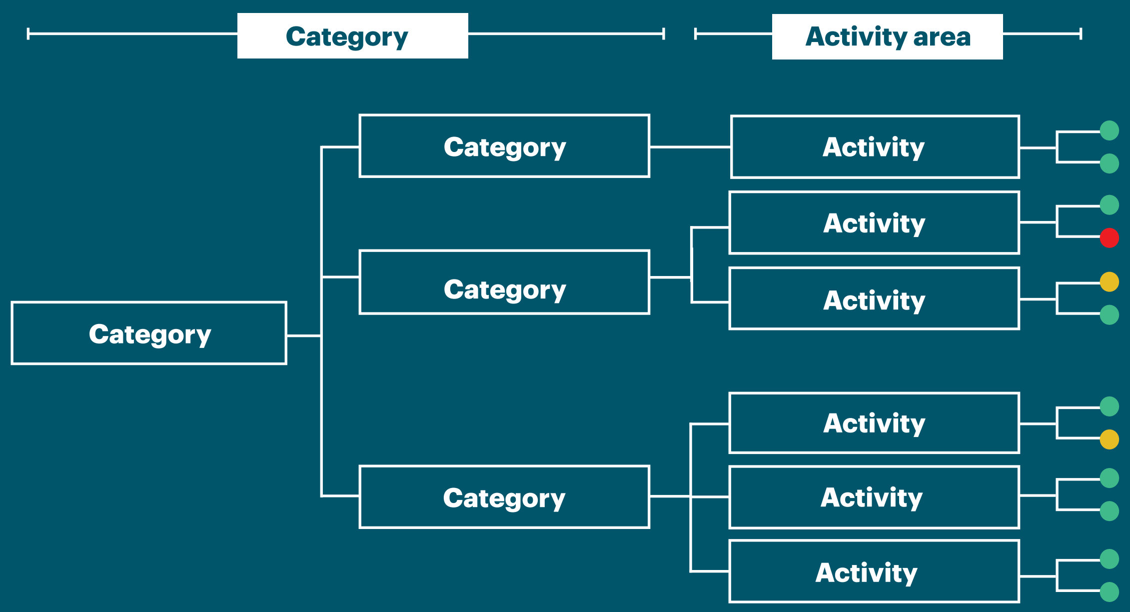
The KPI board is reviewed quarterly by the ProjectZero office to ensure an agile and focused approach. For each KPI, there are a set of actions, which are also evaluated to ensure real progress.

KPI and action plans

KPI

	Yearly Goal	Quarterly Goal	Status	
Category	#	#	#	
Category	#	#	#	
Category	#	#	#	
Category	#	#	#	

Action plan



Learning 5.

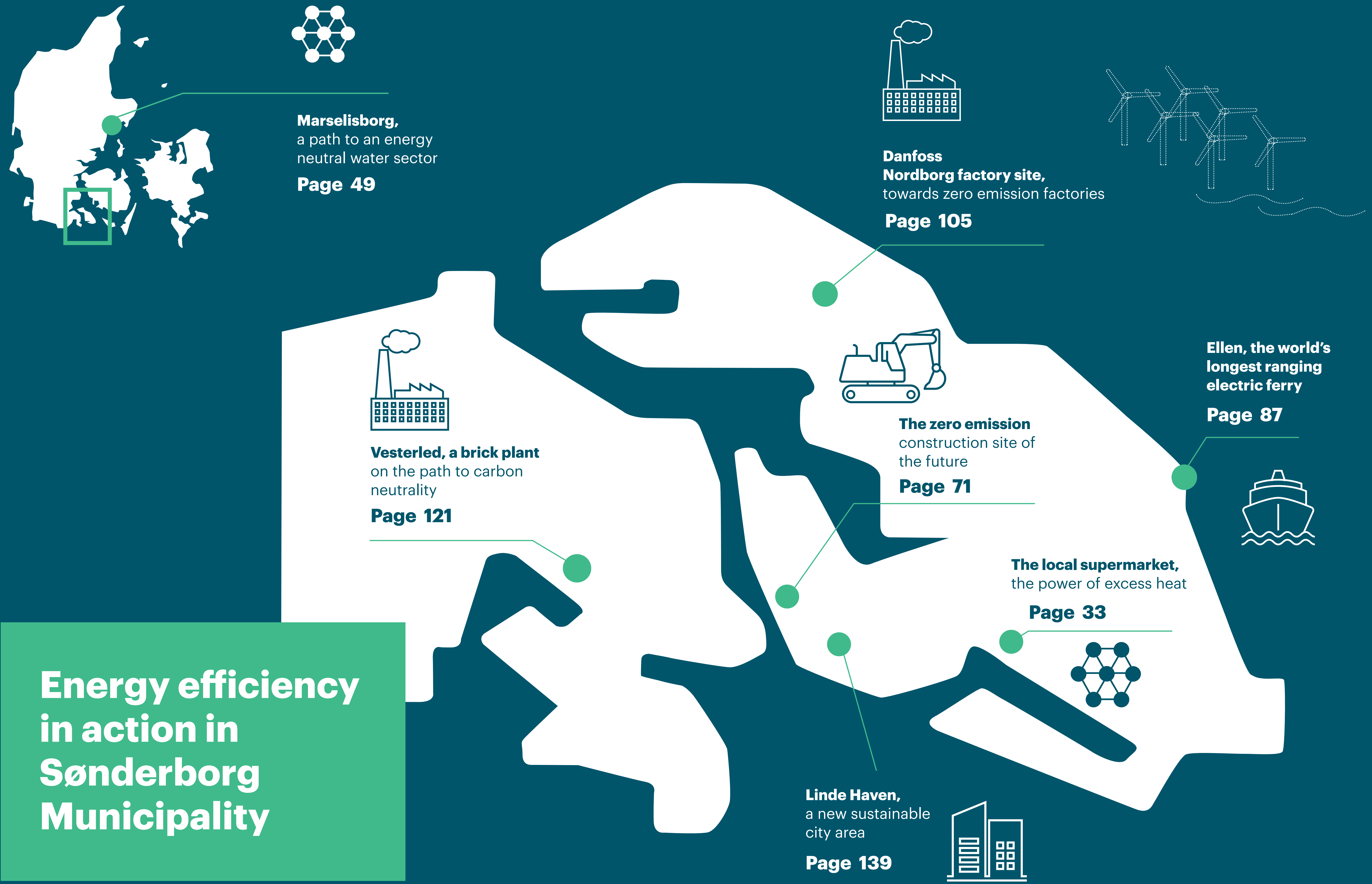
Don't wait, the solutions are ready

A founding principle for ProjectZero has been the belief that many of the solutions that are needed to make Sønderborg's energy system carbon neutral by 2029 are already there – and they are cost-effective with short payback time.

People and businesses should be motivated to act because it is simply a good business case – not because they can get public funding.

Project Zero has delivered extensive campaigns to relay the potential to everyone from homeowners, large factory sites, small business owners and construction sites, all of which can be found in the Municipality of Sønderborg.

Energy efficiency in action in Sønderborg Municipality



Combining multiple energy sectors into an integrated system accelerates the path to zero. The solutions are here.

Sector integration

SECTOR INTEGRATION

The local supermarket, the power of excess heat

The **challenge:**

Buildings

28%

of all global energy-related CO_2 emissions come from buildings

Industry

39%

of all global energy-related CO_2 emissions come from industry

Transport

27%

of all global energy-related CO_2 emissions come from transport

Sector integration

Source: IEA (2021). Greenhouse Gas Emissions from Energy

In 2018, heat accounted for **50%** of global final energy consumption.[1]

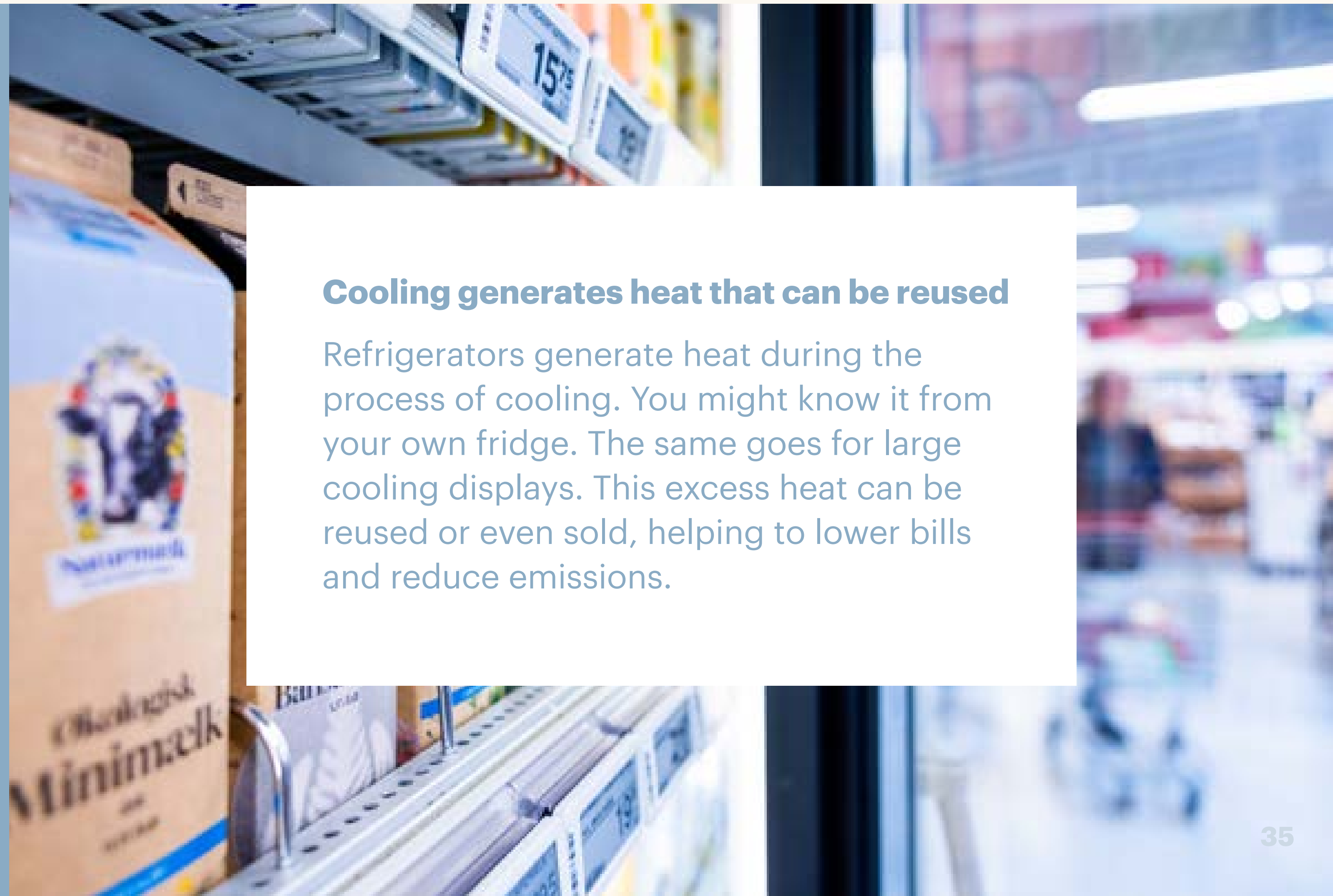
Energy is being wasted everywhere. In the US, 65% of all the energy produced is squandered in the form of waste heat.[2] There is tremendous potential in reusing heat that would otherwise be wasted, also known as "excess heat."

1. IEA (2019). Renewables 2019: Heat.
2. World Economic Forum (2018). Visualizing US energy consumption in one chart.

The **solution:** The power of excess heat

In a small town outside Sønderborg, Denmark, a local supermarket reuses the excess heat that is generated from cooling displays and freezers.

- The local supermarket covers 78% of their heating bill by reusing heat from its cooling displays.
- The supermarket sells green excess heat to nearby homes and companies through the district energy system.



Cooling generates heat that can be reused

Refrigerators generate heat during the process of cooling. You might know it from your own fridge. The same goes for large cooling displays. This excess heat can be reused or even sold, helping to lower bills and reduce emissions.

A local supermarket shows the green potential in excess heat

District heating offers a path for decarbonizing the heating sector

Supermarkets are an integral part of communities around the world. They are also big energy consumers. In the UK for example, supermarkets consume approximately 3% of the nation's electricity production. [3]

Keeping food fresh in cooling displays and freezers accounts for most of the energy consumption in a supermarket. It might sound counter-intuitive, but cooling displays, freezers and fridges produce a significant amount of heat. Anyone who has ever felt the warmth behind their fridge can confirm that. These cooling systems generate significant amounts of excess heat, which is often released directly into the atmosphere and wasted.

In Høruphav, a small Danish town outside Sønderborg, the local supermarket SuperBrugsen has saved a considerable amount of energy by reusing and selling excess heat from the cooling systems.

Since 2019, 78% of SuperBrugsen's heat consumption has been covered by reused heat from cooling processes. And the supermarket has sold 133.7 MWh to other local buildings through the district heating grid, which is equivalent to the energy needed to keep 7 family houses warm over a year.[4]

Three interlinked initiatives have driven the results.

First, like many other supermarkets, SuperBrugsen has converted from chemical refrigerants to a natural refrigerant – namely CO_2 – which is a reliable, environmentally friendly refrigerant.[5] CO_2 is also a highly efficient refrigerant, which requires less energy to perform.[6]

Second, a heat recovery unit is installed at SuperBrugsen, and it is designed to recover the waste heat from CO_2 refrigeration systems. The recovered heat is reused to heat up the store and produce domestic hot water.

Third, SuperBrugsen runs energy efficiency programs. Cooling systems involving high pressures, liquids, and thermodynamics as well as frequent monitoring, adjustments and service have improved energy efficiency and lowered energy consumption at the supermarket even more.

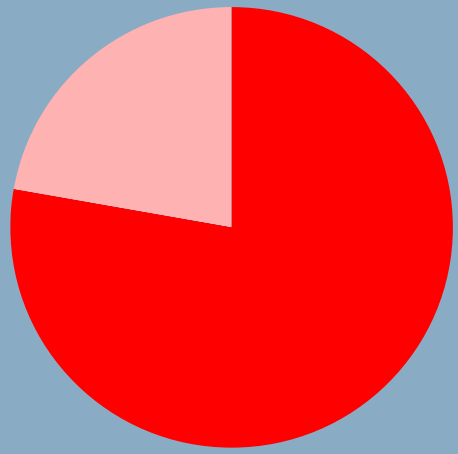
Several supermarkets with different owners are following the example of SuperBrugsen by reusing excess heat to lower their energy bills. And, at times, by selling excess heat to neighboring buildings through the district energy system.

3. Environmental Investigation Agency and Shecco (2018). Technical report on energy efficiency in HFC-free supermarket refrigeration, p. 10.
4. Dansk Fjernvarme (2022). Varmeprisstatistik.

5. Environmental Investigation Agency and Shecco (2018). Technical report on energy efficiency in HFC-free supermarket refrigeration, p. 13.
6. Danish Environmental Protection Agency (2002). Bilag 2 - Kølemiddelgrupper.

Results from SuperBrugsen in Høruphav, Denmark

Since August 2019, when the energy efficiency installations were in place, Superbrugsen Høruphav, Denmark, covered most of its heating demand by reused energy.



78%
of heat demand is covered by reused energy

133.7 MWh has been sold to the district energy system.

Results in the period from August 2019 to April 2022

	Total heat consumption	Reused energy	Sold energy
Super Brugsen Høruphav	**668.1 MWh**	**523.1 MWh**	**133.7 MWh**

District energy provides a path to decarbonizing the heat and cooling supply

In 2018, heat accounted for 50% of global final energy consumption[7]. District energy systems enable a 100% green heat supply today. District energy systems therefore play a vital role in decarbonizing heating supply, which requires nearly half of global final energy consumption.[8] District energy systems offer a simple but effective solution. Heat is a by-product from various processes and can be distributed to nearby buildings and industries. As the district energy technology evolves more and more green heat sources can tap into the system, which will put district energy systems at the center of the green transition.

In many parts of the world, district energy systems supply buildings and industries with heating as well as cooling. District energy systems tap into heat from processes, such as at power plants, and distribute it through pipelines to end users in the form of water. District energy is a collective system that supplies an entire area with heating or cooling. There are vast district energy systems in China and Europe, and more are expected to come.

Today, the majority of global district heat production relies on fossil fuels.[9] According to the International Energy Agency (IEA), the world needs to increase the share of green sources in district heating from 8% today to about 35% in 2030 to reach net zero. If we succeed, this will help to slash carbon emissions from heat generation by more than one third.[10] **The solutions are there to meet that goal and more.**

Denmark is one of the world's most energy-efficient countries, and the widespread use of district heating is one of the primary reasons.[11] In Denmark, 65% of households cover their demand for heating with district heating and more than 70% of the heat is from green sources such as waste, biomass, wind and excess heat from various commercial processes.[12]

7. IEA (2019). Renewables 2019: Heat.
8. EA (2019). Renewables 2019: Heat
9. IEA (2021). District Heating.

Sønderborg Municipality is no exception. Since 2007, carbon emissions from space heating and domestic hot water have dropped by 73% and the local district energy systems have been key drivers. Moreover, the share of natural gas-fired district heating has been reduced from 70% to 8% in the same period.[13]

One of the main strengths of district energy systems is their capacity to integrate different heat sources that can push fossil fuels out of the energy mix. As a result of improved energy efficiency, temperatures in the district energy systems have been lowered over time, which allows for even more green sources to be introduced into the system.[14] Excess heat from commercial process is one of the new heat sources that can tap into the district energy system. A laptop generates heat to operate, and a data center does the same on a large scale. Excess heat from data centers can be reused through the district energy system to supply heat to homes and companies. The same goes for supermarkets. A fridge generates heat when it keeps food and drinks cold, and the cooling displays in supermarkets do the same only on a much bigger scale.

Heat is a waste product from many daily processes, and it can be reused or sold, instead of simply being released into the atmosphere. The binding link is often the district energy system.

10 IEA (2021). District Heating.
11 Danish Energy Agency (2022). Danish Experiences on District Heating.
12 Dansk Fjernvarme (2022). Fakta om Fjernevarme.
13 ProjectZero (2021). Monitoring report 2020 Sonderborg Municipality, p. 38-39 & 41.
14 Thorsen, J. E., et al. (2018). Progression of District Heating – 1st to 4th generation.

Green supermarkets are possible all over the world

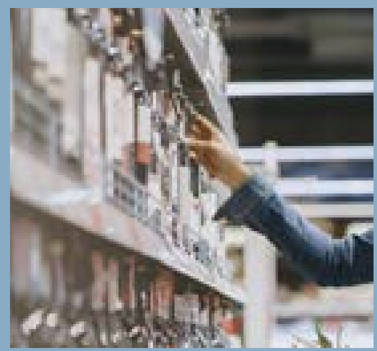
Every time an engine runs, heat is generated. That is true for basically all work processes. But much of the energy is wasted. In the US, **65% of all the energy produced** is estimated to be squandered as waste.[14] There is a great potential in reusing excess heat through existing and well-proven technologies. And there is great potential in selling excess heat through district energy systems. According to a recent estimate, excess heat from accessible sources in urban areas can cover **10% of the European Union's total energy demand.**[15] Supermarkets serve as an example of the potential in excess heat, but the potential is bigger. The cooling displays at supermarkets can also serve as batteries that can store energy that can be used in peak-periods when energy is expensive.

14. World Economic Forum (2018). Visualizing US energy consumption in one chart.
15. European Commission - Cordis (2019). ReUseHeat quantified EU28 urban waste heat potential.

The supermarket Aktiv & Irma in Oldenburg, Germany

The supermarket Aktiv & Irma in Oldenburg, Germany, is at the forefront of 'green supermarkets.' Not only does the supermarket reuse its excess heat from the cooling display cases to keep the store at the right temperature, during peak hours this energy is used to offload the grid and save the supermarket expensive energy peak costs – all without damaging food safety.

During off-peak hours when the weather is windy and sunny, the local power plant typically has plenty of cheap, renewable power. In that situation, the supermarket charges the batteries, drawing extra energy from the grid or photovoltaic system on the roof.



Efficient supermarkets in Portugal and Italy

For supermarkets in warm climates, air conditioning is among the big energy consumers. A project funded by the European Union called MultiPACK recently concluded 5 years of research that aims at building confidence in integrated heating, ventilation, air conditioning and refrigeration (HVAC&R) packages based on CO_2 technology, as an alternative to F-gases, installed in high energy-demanding buildings. Three Supermarkets in Portugal and Italy participated in the project and demonstrated that an integrated CO_2 system for refrigeration, air conditioning and heating can outperform HFC units both in terms of costs and energy efficiency.

Stakeholder toolkit

A more systematic use of wasted energy across all sectors presents a huge, unharnessed energy efficiency potential and constitutes a major opportunity for the industry, governments and citizens to save money, enhance competitiveness and reduce volatility of the energy system. The technologies exist – results depend on a continued and long-term, systematic planning effort supported by the right regulatory framework. Here are some of the key considerations and measures that regulators can use to push for a more energy efficient energy system.

Set minimum requirements

Raise the bar for effort by setting targets and performance standards – an example could be mandatory energy planning. In general, begin to consider waste as an energy resource instead of a problem to be disposed of. Almost all waste can be used for energy production – whether we talk about excess heat, excess cooling, sludge from wastewater systems or household waste. Energy planning begins with a strategic view on excess heat. For instance, in Denmark, municipalities were asked to map the existing heat demand, the existing heat supply method and the amounts of energy used. Furthermore, municipalities can also make an estimate of future demands and supply possibilities. Based on this information, overall energy plans can be prepared that show the priority of heat supply options in any given area and identify locations for future heat supply units and networks. Depending on the existing energy system, energy planning can reveal small-scale potentials (such as forming the right incentives to heat recovery or the potential of co-generation of heating and electricity) or it can reveal the potential of larger-scale opportunities, such as the rollout of district heating.

Address economic incentives

To further improve energy efficiency by using wasted energy, it is essential to remove both financial and legislative barriers. The current design of the energy market is, in many places, a barrier to sector integration technologies, either by hindering the participation of sector integration technologies in specific markets or by not internalizing all positive and negative externalities of respectively low- and carbon-intensive technologies. For instance, power-to-gas facilities may be treated as end consumers and face electricity input costs that include end-user taxes and levies. Therefore, it should be considered to make energy markets reflect positive and negative externalities in order to level the playing field for all technologies and carriers contributing to energy supply. Aspects such as cost-reflective energy price signals, adequate carbon pricing, market accessibility and liquidity, and appropriate network tariff structures should be considered.

Establish partnerships

A more systematic use of excess heat is, at its core, an exercise that spans sectors and stakeholders. Partnerships between local authorities, energy suppliers and energy sources such as supermarkets, data centers, wastewater facilities and industries can help to maximize the full potential of excess heat.

SECTOR INTEGRATION

Marselisborg, a path to an energy neutral water sector

The challenge:

Buildings

28%

of all global energy-related CO_2 emissions come from buildings

Industry

39%

of all global energy-related CO_2 emissions come from industry

Transport

27%

of all global energy-related CO_2 emissions come from transport

Sector integration

Source: IEA (2021). Greenhouse Gas Emissions from Energy

It takes tremendous amounts of energy to provide people with water and sanitation. This challenge will only increase as the world evolves and populations grow. Today, cost-effective and energy efficient solutions can reduce energy consumption in the water sector massively, not least at wastewater treatment plants.

Without action, global water-related energy consumption will increase by 50% by 2030.[1]

1. IEA (2018). World Energy Outlook 2018, p. 123.

The solution: Turning wastewater plants into energy producers

In Aarhus, Denmark, the Marselisborg Wastewater Treatment Plant (WWTP) produces far more energy than it needs for treating wastewater for the 200,00 people it services. In fact, Marselisborg WWTP produces so much energy that it can cover the energy needed for the supply of drinking water as well. Marselisborg WWTP thus offers a pathway to an energy neutral water sector and shows how to decouple energy from water.

- ✓ The Marselisborg WWTP produces enough energy to cover the entire water cycle of a city area of 200,000 people – all with an estimated return on investment of 4.8 years.
- ✓ Excess heat from wastewater treatment plants can heat buildings and industries through district energy systems.

Water is key to climate action

Harvesting the green potential in wastewater management

Water is essential. Most importantly as a precondition to life, but also as a key to combatting climate change. It takes tremendous amounts of energy to provide the public with access to clean drinking water and sanitation – a declared human right.

According to the International Energy Agency (IEA), the global water sector uses roughly 120 Mtoe per year, nearly equivalent to Australia's total energy use.[2] Without action, global water-related energy consumption will increase by 50% by 2030.[3] The world needs more water and fewer carbon emissions. Energy efficiency provides a path to break the curve.

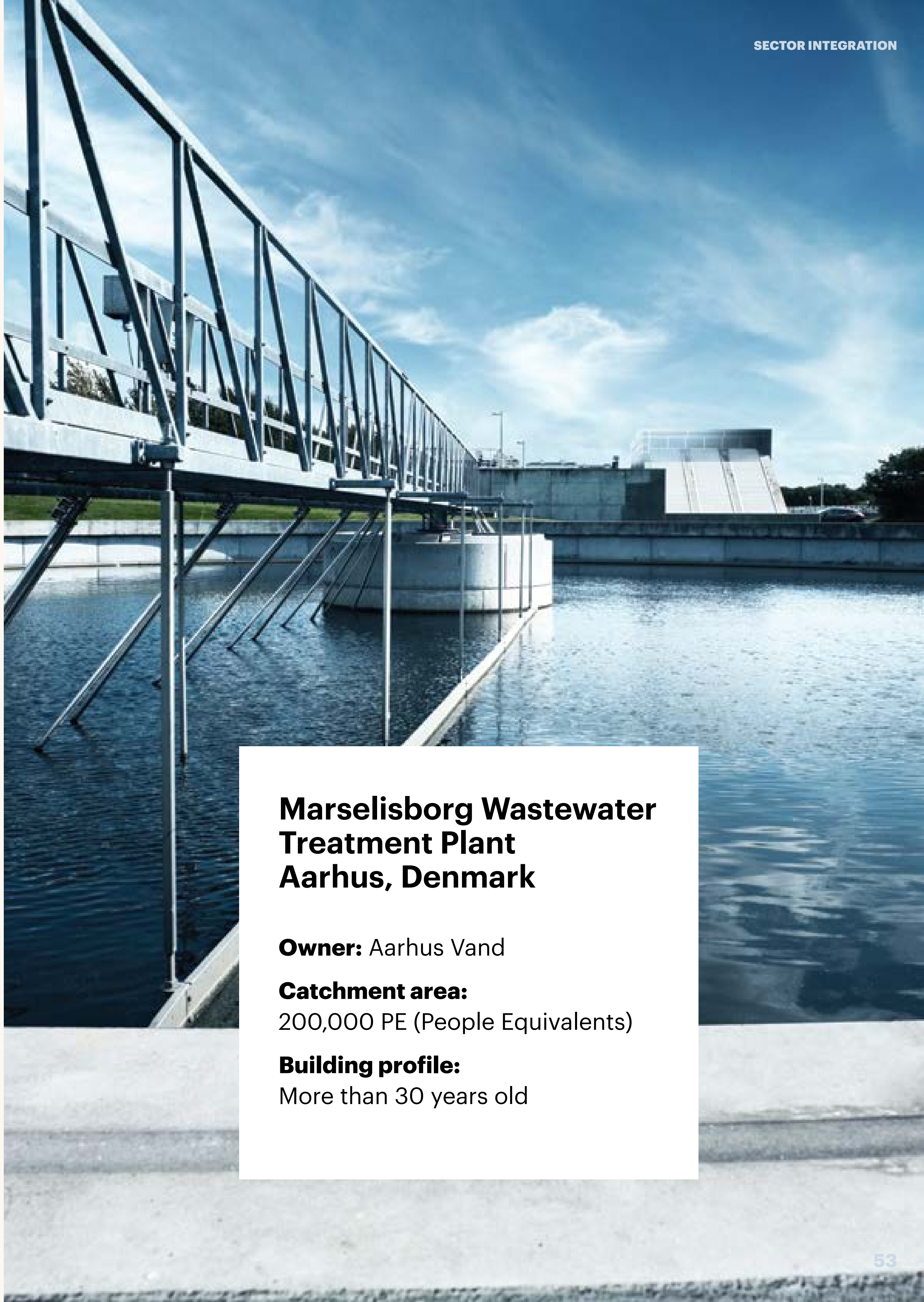
There is a significant potential for energy savings in the water sector if all the economically available energy efficiency and energy recovery potentials are exploited – not least within the water supply and water treatment sector.[3]

An obvious place to start is wastewater treatment plants that are present in most cities around the world. Water treatment plants are often operated by municipalities and eat up between 30-40% of municipal electricity bills.[4] For wastewater companies, the electricity bill constitutes the second largest operational cost behind labor.[5]

Wastewater contains significant amounts of embedded energy that can be harnessed to turn wastewater management energy neutral, thus producing the same amount of energy that it consumes – and with the right approach, even more. Consequently, wastewater treatment plants have the potential to be turned from energy consumers to energy producers.

2. IEA (2018). World Energy Outlook 2018, p. 122.
3. IEA (2018). World Energy Outlook 2018, p. 123.
4. Copeland & Carter (2017). Energy-Water Nexus: The Water Sector's Energy Use, Congressional Research Service, p. 6.
5. Maktabifard, M., Zaborowska, E. & Makinia, J. (2018). Achieving energy neutrality in wastewater treatment plants through energy savings and enhancing renewable energy production, p. 655.

SECTOR INTEGRATION



Marselisborg Wastewater Treatment Plant Aarhus, Denmark

Owner: Aarhus Vand

Catchment area:
200,000 PE (People Equivalents)

Building profile:
More than 30 years old

Energy Neutral Water Management for 200,000 people

Marselisborg Wastewater Treatment Plant

Wastewater treatment requires energy intensive processes that run all hours of the day. Energy is used to pump water through the sewers and down to the treatment plants, where vast amounts of energy is used in the aeration tanks, in the internal pump operation and in sludge treatment.

Wastewater treatment plants have great potential for producing energy, both in the form of electricity and heat. In the city of Aarhus, Denmark, the Marselisborg WWTP, which is operated by Aarhus Vand, has managed to reduce energy consumption while increasing energy production to an extent where they, on average, produce almost enough energy to match the catchment area's total water cycle, meaning both drinking water supply and wastewater treatment, thereby effectively decoupling water from energy.

The foundation of this achievement is a two-tier strategy: Reduce energy consumption while increasing energy production.

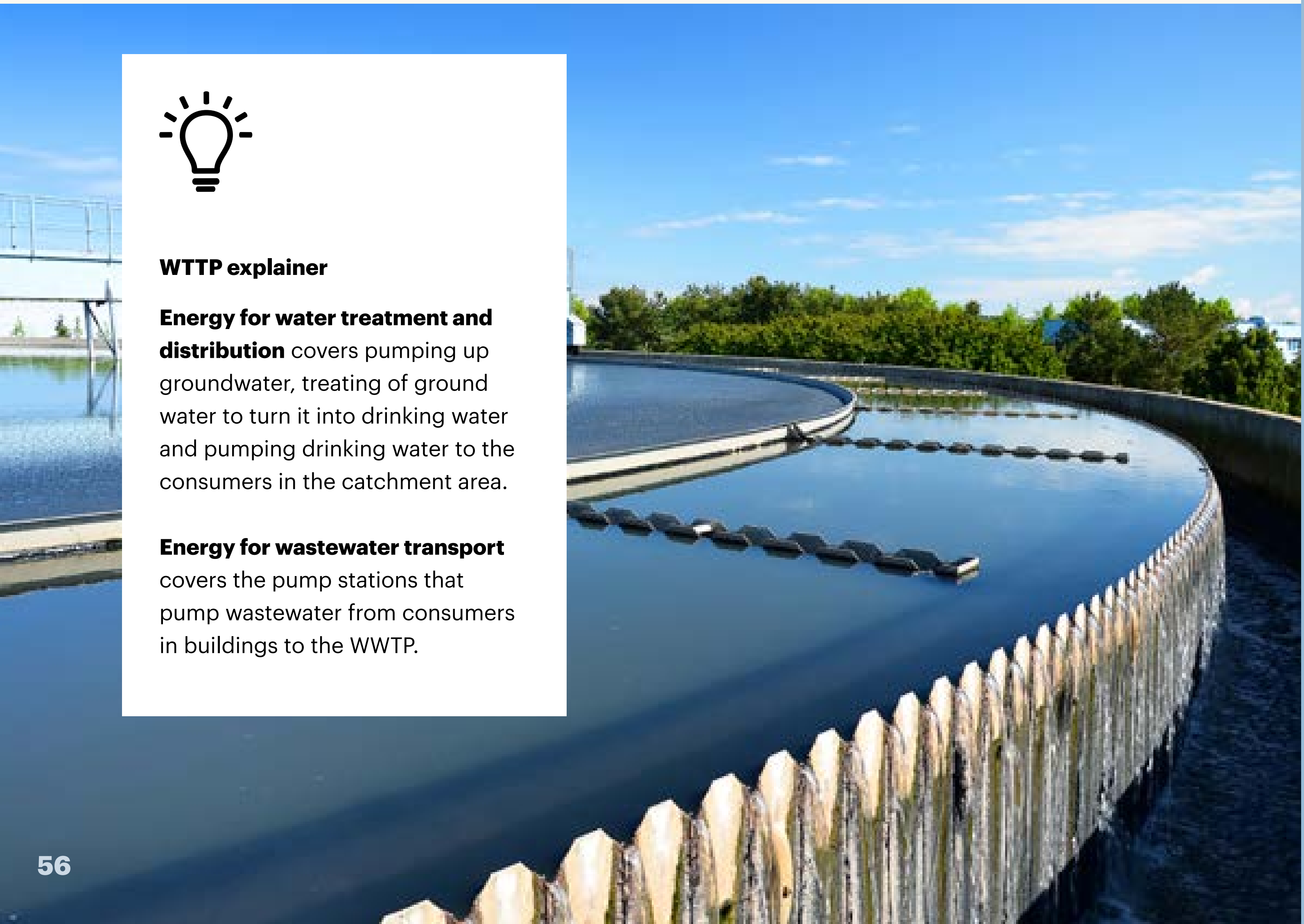
In 2005, Aarhus Vand began to improve energy efficiency at Marselisborg WWTP. Almost all equipment with a motor in the water cycle, 290 in total, were fitted with variable speed drives which offer the controllability that help secure just the right amount of energy needed for optimal performance.

A series of online sensors are mounted throughout the WWTP. They provide critical information in real-time, which allows for automatic calculation of setpoints for the variable speed drives. As a result, the Marselisborg WWTP is a highly energy efficient operation.

But the Marselisborg WWTP is also a biorefinery that produces energy. In 2010, Aarhus Vand began to improve that side of the wastewater equation. The plant generates energy from the biogas it creates out of household wastewater. Sludge is extracted from the wastewater and pumped into digesters. These produce biogas – mostly methane – that is then burned to make heat and electricity.

In the period from 2016 and 2021, Marselisborg WWTP produced close to 100% more energy than needed for treating wastewater. The energy produced can be used to supply the area with drinking water as well. This means that Marselisborg WWTP produces enough energy to match the needs for the full water cycle of the entire catchment area, including both drinking water and wastewater, essentially decoupling water from energy. Process optimization and digitalization is estimated to have contributed to 70% of the improvements.

Decoupling water from energy



WTTP explainer

Energy for water treatment and distribution covers pumping up groundwater, treating of ground water to turn it into drinking water and pumping drinking water to the consumers in the catchment area.

Energy for wastewater transport covers the pump stations that pump wastewater from consumers in buildings to the WWTP.

Energy production from Marselisborg WWTP almost covers the entire water cycle

Energy consumption	**2016-2021** Average
Water treatment, distribution (kWh)	3.3 mill
Wastewater transport (kWh)	0.7 mill
Marselisborg WWTP (kWh)	3.3 mill
Total energy consumption (kWh)	***7.2 mill***
Energy production	
Electrictiy production (kWh)	4.7 mill
Heat production (kWh)	2.1 mill
Total energy production (kWh)	***6.8 mill***
Own energy supply degree	
Wastewater treatment process, electricity and heat (%)	208%
Total water cycle, Marselisborg catchment area	**94%**

Return on investment estimated to be **4.8 years** on average between 2005 and 2016.

From energy consumer to energy producer

A guide to efficient water treatment

The Marselisborg WWTP provides a pathway toward an energy neutral water sector for cities around the world. In simple terms, two steps are required: Refrain from using energy that is not needed and use the energy embedded in the wastewater.

SECTOR INTEGRATION

1. Define the baseline

Measure
Energy meters show how much energy is used both for water supply and wastewater treatment.

Evaluate
Find the most attractive energy saving opportunities.

2. Reduce energy consumption

Local digitalization
Implement local control loops by installing real-time sensors and variable speed drives where there is potential to secure a more efficient use of energy.

Efficient components
Switch to more efficient components, e.g., high-speed turbo blowers.

Holistic digitalization
Combine local control loops in a holistic, automatic, and real-time process based on digital process control of the whole facility.

3. Increase energy production

Holistic digitalization
Selecting the right process control to obtain energy savings creates a double effect. Energy is saved and more sludge is available for gas production, which can be turned into electricity or heat through the process of co-generation (CHP).

Sector integration increases the potential in wastewater

Providing heat and hot water to buildings requires nearly half of global final energy consumption, much of which comes from coal, oil, and natural gas.[7]

In many parts of the world, district energy systems supply homes and companies with heating as well as cooling. District energy systems tap heat from processes, such as at power plants, and distribute it through pipelines to end users in the form of water. District energy is a collective system that supplies an entire area with heating or cooling. There are vast district energy systems in China, Russia and Europe and more are coming.

Today, the majority of global district heat production relies on fossil fuels.[8]

According to the International Energy Agency (IEA), the world needs to increase the share of green sources in district heating from 8% today to about 35% in 2030 to reach net zero. If we succeed, this will help to slash carbon emissions from heat generation by more than one-third.[9]

The solutions are there to meet that goal and more.

Denmark is one of the world's most energy-efficient countries, and the widespread use of district heating is one of the primary reasons.[10] In Denmark, 65% of households cover their demand for heating with district heating and more than 70% of the heat is from green sources such as waste, biomass, wind and excess heat from various commercial processes.[11]

7. IEA (2021). Heating, IEA.
8. IEA (2021). Heating, IEA.
9. IEA (2021). Heating, IEA.
10. Danish Energy Agency (2022). Danish Experiences on District Heating

Taarnby WWTP

In Taarnby Municipality within Greater Copenhagen, a new energy center provides both district cooling and heating to businesses and citizens. Uniquely, the energy central utilizes excess heat from the nearby WWTP to provide heating in the winter and cooling in the summer. The excess heat is extracted by four large heat pumps and results in reduced costs, reduced energy consumption and reduced emissions. The symbioses between excess heat from the WWTP, district heating, district cooling and the electricity grid is the perfect example of sector coupling:

Reusing and recycling energy by linking systems and end-use sectors.

Heat pumps can recover the heat embedded in wastewater outlets. The temperature of the outlet water from the wastewater facility will typically be 7-9 ºC higher than in the receiving water, improving heat pump efficiency and securing shorter payback time. The excess heat can be exported to neighboring buildings or into the local district heating system, an example of sector coupling.

Source: Rambøll (2020). Varmepumper på spildevand giver både fjernkøling og varme i Tårnby.

Sønderborg Municipality in Denmark is no exception. Since 2007 carbon emissions from space heating and domestic hot water have dropped by 73% since 2007 and the local district energy systems have been key drivers. As an added bonus, the share of natural gas-fired district heating has been reduced from 70% to 8% today.[12]

One of the main strengths of district energy systems is their capacity to integrate different heat sources that can push fossil fuels out of the heating and cooling mix. As a result of improved energy efficiency, temperatures in the district energy systems have been lowered over time, which allows for even more green sources to be introduced into the system.[13]

That includes excess heat, not least from WWTPs that have a huge potential. According to the Danish Water and Wastewater Association (DANVA), the potential in excess heat from wastewater treatment plants in Denmark, a country of 5.8 million inhabitants, corresponds to 600-700 MW. That's the equivalent of two fairly large power plants, meaning a potential to heat about 20% of all households with carbon neutral heat.[14]

11. Dansk Fjernvarme (2022). Fakta om Fjernevarme.
12. ProjectZero (2021). Monitoring report 2020 Sonderborg Municipality, p. 38-39 & 41.
13. Thorsen, J. E., Lund, H., & Mathiesen, B. V. (2018). Progression of District Heating – 1st to 4th generation.
14. DANVA (2020). Flere udnytter varmen i Spildevandet.

Reducing energy use for water is possible all over the world

Today, more than 60% of the global population lacks access to safely managed sanitation, and just 20% of wastewater is treated.[15] Meeting the UN's sustainability goal on water and sanitation (SDG 6) to provide clean water and sanitation for all constitutes a serious challenge. Meeting that goal has a significant impact on a municipality's energy expenditure but also on efforts to combat climate change. Carbon emissions from untreated wastewater are about three-times higher than what conventional wastewater treatment plants generate when treating wastewater.[16]

The Marselisborg WWTP provides a blueprint on how to turn a wastewater facility into an energy positive enterprise, thus producing more energy than it needs. If other cities prioritize the new facilities needed to meet the UN's sustainability goals, such as the Marselisborg WWTP example, it will result in energy savings of about 650 TWh globally. That is equivalent to more energy than is produced on all coal power plants in the EU.[16]

15. UN stats (2020). Ensure availability and sustainable management of water and sanitation for all.
16. International Water Association (2020). How can more water treatment cut CO_2 emissions?

Energy efficient desalination in Sarroch, Italy

Large water plants can reduce electricity consumption and carbon emissions with existing technologies. In Sarroch, on the southern coast of Sardinia, lies the largest ultrapure water plant in the Mediterranean. The local Sarlux power plant and Sara refinery required demineralized water for their operations and decided to build a Sea Water Reverse Osmosis Plant (SWRO) to service their needs at lower cost. Through the use of pumps, variable speed drives and pressure transmitters, the SWRO has reduced costs drastically while supplying the power plant and refinery with high-quality demineralized water.

Stakeholder toolkit

A more systematic use of wasted energy across all sectors presents a huge, unharnessed energy efficiency potential and constitutes a major opportunity for the industry, governments and citizens to save money, enhance competitiveness and reduce volatility of the energy system. The technologies exist – results depend on a continued and long-term, systematic planning effort supported by the right regulatory framework. Here are some of the key considerations and measures that regulators can use to push for a more energy efficient energy system.

Set minimum requirements

Raise the bar for effort by setting targets and performance standards – an example could be mandatory energy planning. In general, begin to consider waste as an energy resource instead of a problem to be disposed of. Almost all waste can be used for energy production – whether we talk about excess heat, excess cooling, sludge from wastewater systems or household waste. Energy planning begins with a strategic view on excess heat. For instance, in Denmark, municipalities were asked to map the existing heat demand, the existing heat supply method and the amounts of energy used. Furthermore, municipalities can also make an estimate of future demands and supply possibilities. Based on this information, overall energy plans can be prepared to show the priority of heat supply options in any given area and identify locations for future heat supply units and networks.

Depending on the existing energy system, energy planning can both reveal small-scale potentials (such as forming the right incentives to heat recovery or the potential of co-generation of heating and electricity) or it can reveal the potential of larger-scale opportunities such as the rollout of district heating.

Address economic incentives

To further improve energy efficiency by using wasted energy, it is essential to remove both financial and legislative barriers. The current design of the energy market is, in many places, a barrier to sector integration technologies, either by hindering the participation of sector integration technologies in specific markets or by not internalizing all positive and negative externalities of respectively low- and carbon-intensive technologies. For instance, power-to-gas facilities may be treated as end consumers and face electricity input costs that include end-user taxes and levies. Therefore, it should be considered to make energy markets reflect positive and negative externalities in order to level the playing field for all technologies and carriers contributing to energy supply. Aspects such as cost-reflective energy price signals, adequate carbon pricing, market accessibility and liquidity, and appropriate network tariff structures should be considered.

Establish partnerships

A more systematic use of excess heat is, at its core, an exercise that spans sectors and stakeholders. Partnerships between local authorities, energy suppliers and energy sources such as supermarkets, data centers, wastewater facilities and industries can help to maximize the full potential of excess heat.

Transport accounts for 27% of all global energy-related CO_2 emissions. Electrification and efficient technology enable a more sustainable future.

Transport

The zero emission construction site of the future

The challenge:

Buildings

28%

of all global energy-related CO_2 emissions come from buildings

Industry

39%

of all global energy-related CO_2 emissions come from industry

Transport

27%

of all global energy-related CO_2 emissions come from transport

Sector integration

Source: IEA (2021). Greenhouse Gas Emissions from Energy

Over the next 40 years, the world is expected to build 230 billion square meters in new construction – adding the equivalent of Paris to the planet every single week.[1] **Construction machinery, such as excavators, is notorious for being inefficient, swallowing vast amounts of diesel, very little of which is converted to productive work.** The construction industry accounted for a total of 20% of global energy-related carbon emissions in 2020.[2]

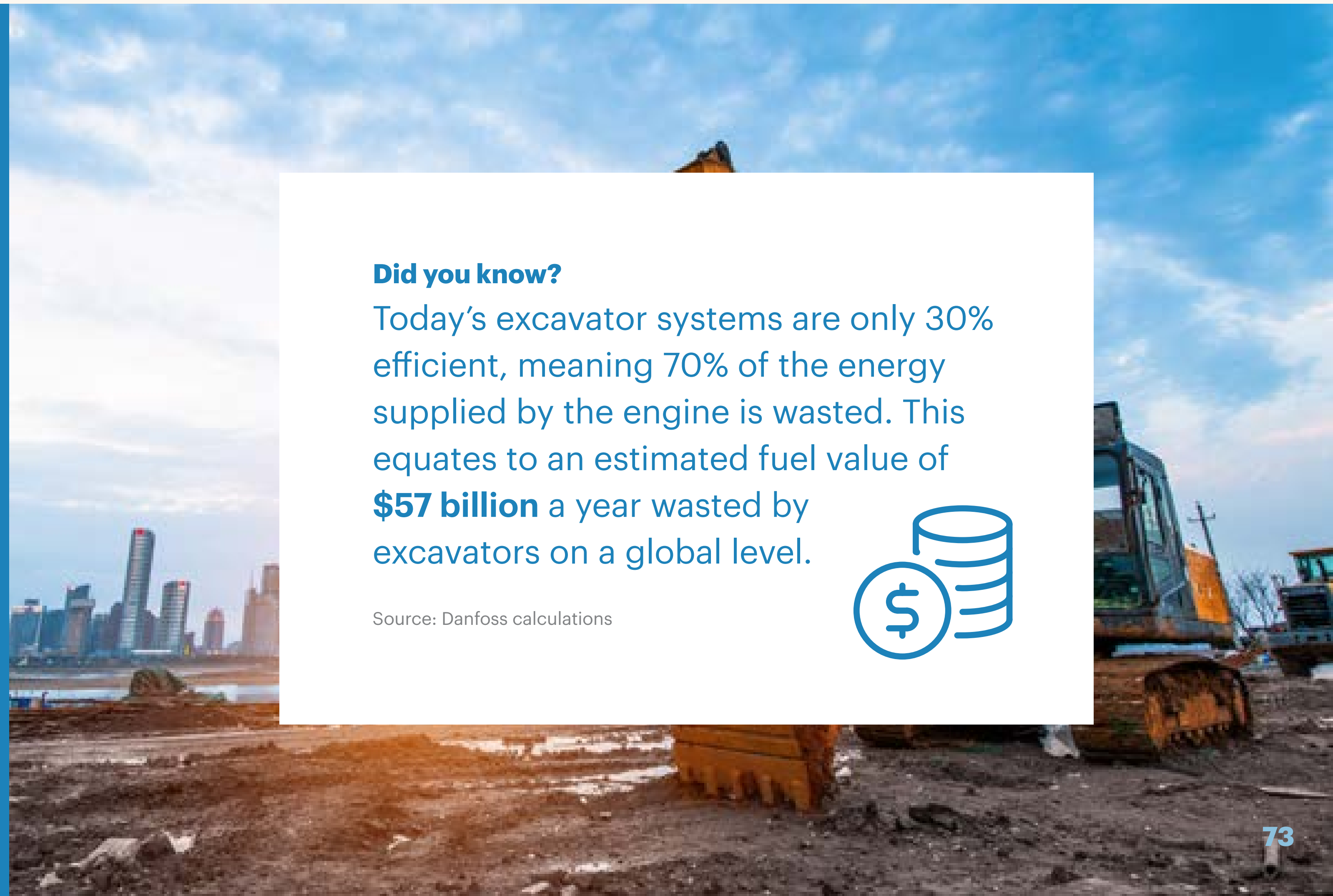
1. UN Environment, GBA & IEA (2017). Global Status Report 2017, p. 2.
2. IEA (2021). Tracking Buildings 2021.

TRANSPORT

The solution: Reduce emissions from construction machinery

Today, the solutions are already there to drastically improve fuel efficiency in heavy construction machines, while more compact machines can be fully electrified. By combining electrification and energy efficient solutions in an excavator, just a quarter of the energy input is needed to shift the same amount of earth. Continued improvements in energy efficiency will pave the way for full electrification of the construction industry.

- An efficient and electrified excavator only needs 25% of the energy to do the same job as an inefficient, diesel-driven excavator.
- Electric construction machines enable zero emission and noiseless construction sites.

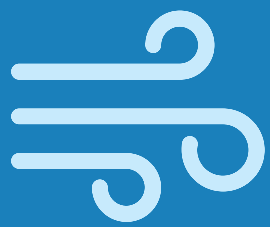


Did you know?

Today's excavator systems are only 30% efficient, meaning 70% of the energy supplied by the engine is wasted. This equates to an estimated fuel value of **$57 billion** a year wasted by excavators on a global level.

Source: Danfoss calculations

The societal **impact of construction** sites and machinery



Emissions

The construction industry accounted for a total of

20%

of global energy-related CO_2 emissions in 2020.[3]

Air pollution

Every year

4.2 mill

people die prematurely due to air pollution.[4]

3. IEA (2021). Tracking Buildings 2021.
4. Bellona (2019). Zero emission construction site, p. 12.

The building mass is growing

Energy efficiency paves the way for zero-emission construction sites

As urbanization continues to grow at pace around the world, the construction of every new building requires materials, machinery and vehicles, all of which emit greenhouse gases.

The construction industry accounted for a total of 20% of global energy-related carbon emissions in 2020[5]. Decarbonizing heavy-duty vehicles such as excavators and wheel loaders used in the construction sector is therefore critical to achieve the Paris Agreement. Moreover, many of these machines are to be found in urban areas, contributing to unhealthy noise and air pollution.

In the construction sector there is a huge, unharnessed energy efficiency potential that represents an opportunity for governments to improve the competitiveness of the construction sector while cutting carbon emissions. Construction machinery is often in the form of vehicles but, compared to regular family cars, they are much more complex and therefore harder to electrify.

Construction machinery is generally designed to complete a specific duty such as digging, lifting or pushing. Different applications require different loads such as hydraulic systems. The construction site environment requires more than range from its vehicles – it requires power, reliability and durability. These requirements mean construction vehicles are often both heavy consumers of diesel and very inefficient in their energy use. Today, this is a barrier for electrification since it means enormous battery capacity is required to power such massive machines.

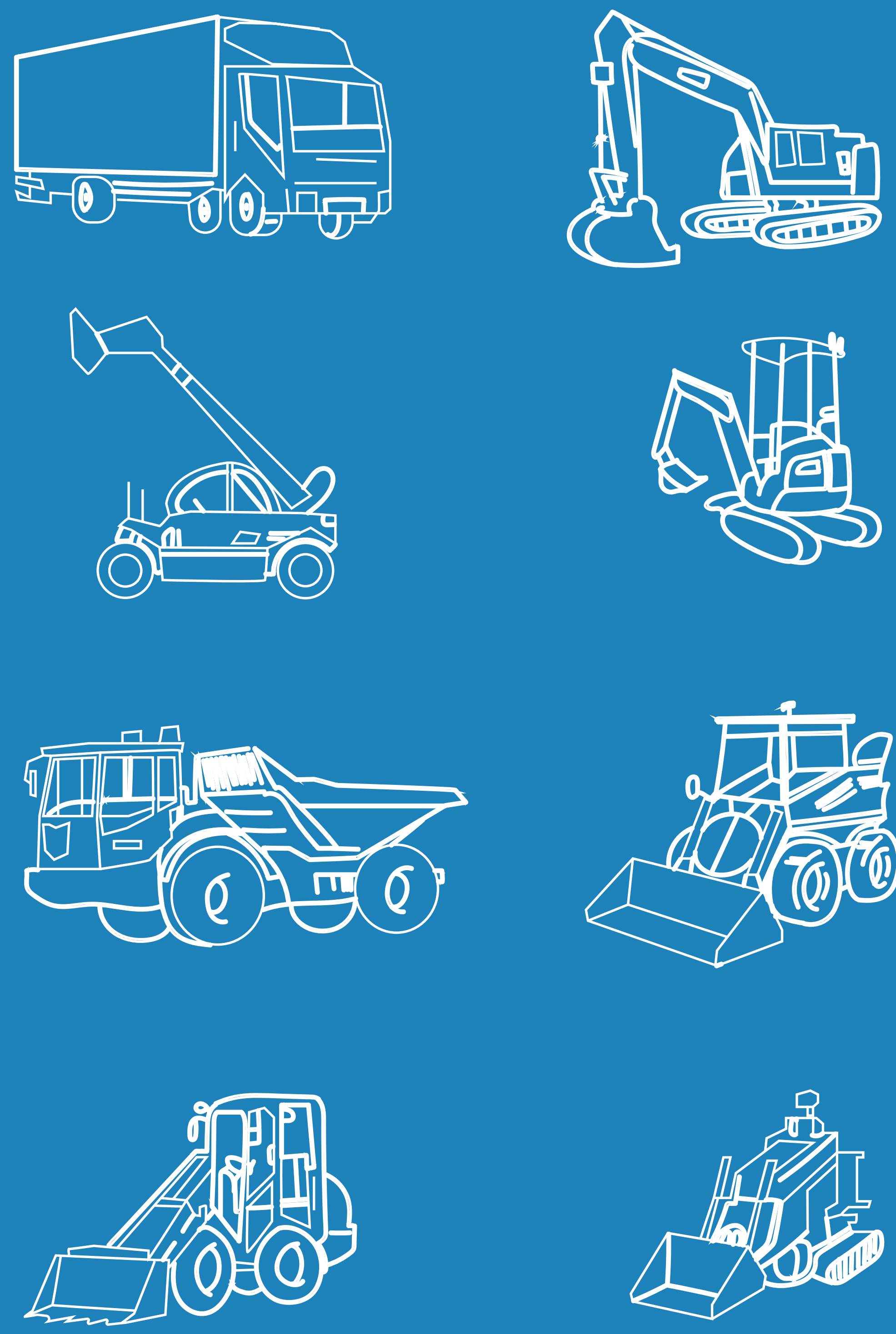
Despite these challenges, a range of fully electric construction vehicles are already on the market. For the mid- to large-scale construction machinery, **the solutions are there to improve energy efficiency substantially, reducing diesel consumption and paving the way for further electrification of the construction industry.**

5. IEA (2021). Tracking Buildings 2021.

The **zero-emission** construction site

Electric off-highway vehicles and machinery

Shanghai, Buenos Aires or Warsaw. No city is without a construction site. This is also true for Sønderborg in Denmark. **There are many models of fully electric construction machines and vehicles available today** which can reduce emissions, noise and air pollution on construction sites in cities all over the world. And as efficiency in bigger construction machines improves, more and more models of vehicles are becoming available.



In Sønderborg, Denmark, **the zero-emission construction site showcases the real-life use of a range of fully electric, compact construction vehicles already on the market.**

The potential in **energy efficiency** and electrification in construction machinery

The excavator as an example

Today's excavator systems are only 30% efficient, meaning 70% of the energy supplied by the engine is wasted before it is used to help the bucket move the earth.[6] The key to reducing emissions from excavators or other heavy vehicles is to improve the energy efficiency of the vehicle's system. This is the first and most important step, and it allows the full potential of electrification to emerge.

Better system efficiency means smaller batteries are required to power electric construction machines. This in turn lowers the capex and opex of electrified construction vehicles and thereby accelerates the market adoption of low emissions construction machinery. Danfoss calculations show that an electrified excavator utilizing Danfoss Digital Displacement® technology will have a better total cost of ownership (TCO) than a standard diesel engine within the near-term five-year horizon. In short, more efficient construction machines are good for people, the planet and profits.

The technologies already exist to improve energy efficiency and electrify excavators.

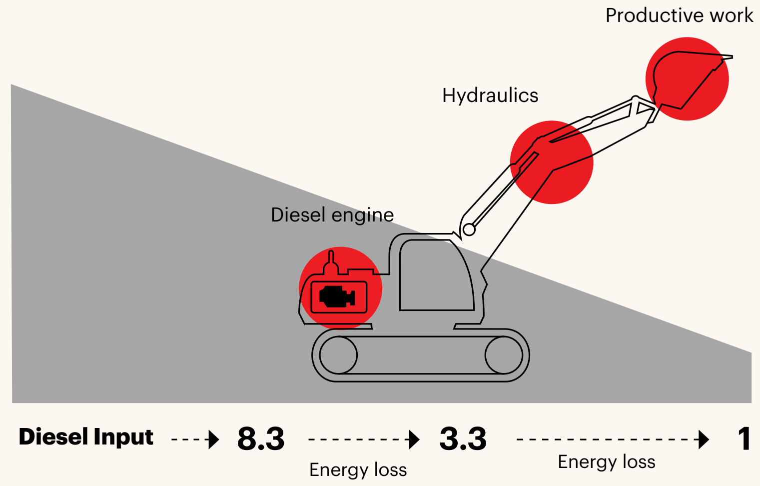
- ☑ **Compared to an inefficient, diesel-driven excavator, it is possible for an efficient and electrified excavator to do the same job with only 25% of the energy.**
- ☑ **Improved efficiency makes the electrification of construction machines easier, since smaller and cheaper batteries are needed.**
- ☑ **Improving energy efficiency and electrifying construction machines also provide a great potential to reduce capital costs and raw material requirements.**

6. Danfoss calculations

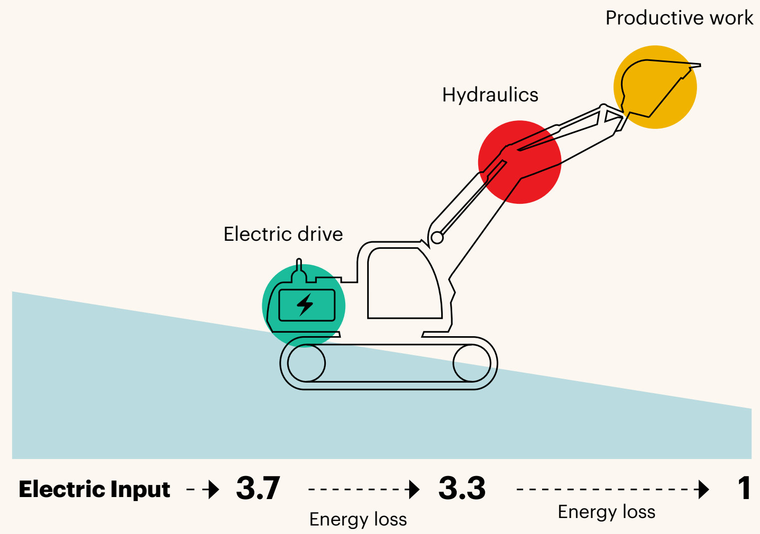
By combining electrification and energy efficient solutions only **25%** of energy input is needed to shift the same amount of earth.

This example highlights the potential in energy efficiency and electrification in a 16 tons conventional excavator

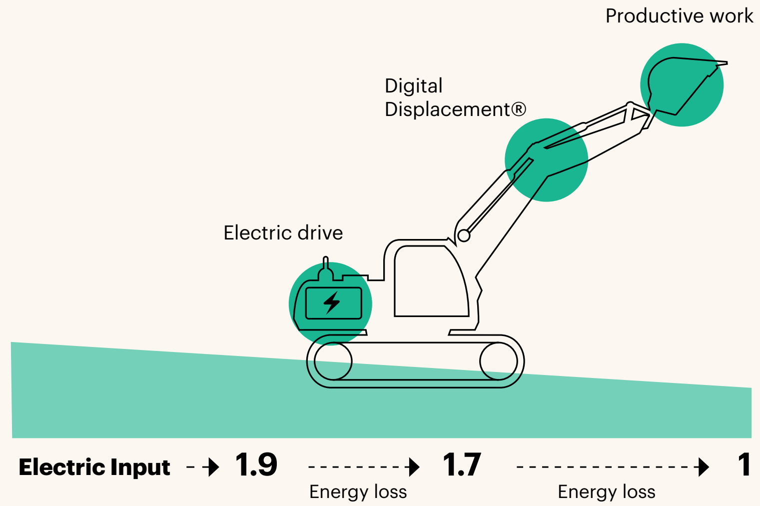
In an inefficient ICE excavator it requires an input of 8.3 units of energy to produce 1 unit of productive work.



In an electrified excavator with a conventional hydraulics system it requires an input of 3.7 units of energy to produce 1 unit of productive work.



In an electrified and energy efficient excavator it requires an input of 1.9 units of energy to produce 1 unit of productive work.



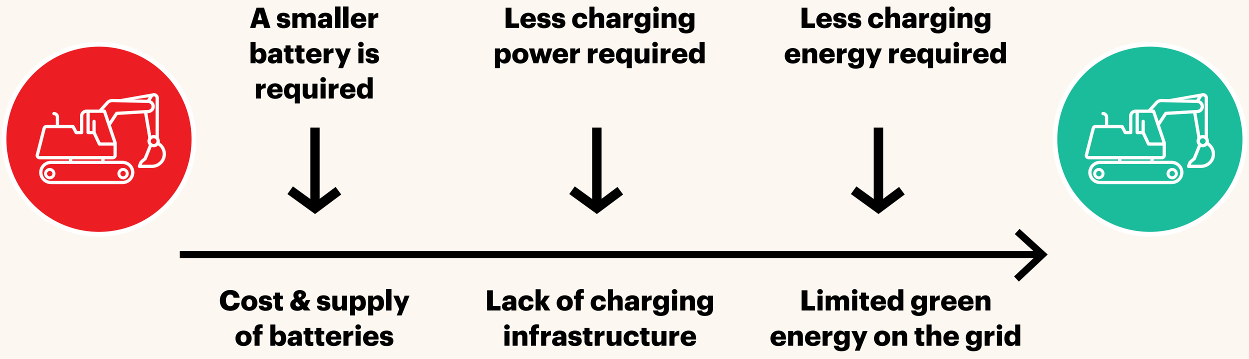
Source: Danfoss calculations

Solutions for reducing carbon emissions in the construction machinery

Clean and cost-effective solutions

Improving energy efficiency reduces carbon emissions in the short and medium term and accelerates electrification for the long term. Energy efficiency solutions available today immediately reduce emissions in diesel and hybrid machines and improve the business case for electric drivetrains. Better system efficiency means smaller batteries – lowering the costs of going electric.

Energy efficiency paves the way for electrification



How to improve energy efficiency in construction machines

1 Reduce idle losses

Reducing energy consumption when the vehicle is not operating is an easy and cost-effective way to save energy. These idle losses can be reduced through solutions such as variable displacement pumps, digital displacement, variable speed pumps and decentralized drives.

2 Reduce hydraulics losses

Hydraulics systems are essential to many off-highway vehicles but are often extremely inefficient. Energy losses can be reduced markedly through solutions such as Individual Metering Control (IMC), direct-driven hydraulics, digital hydraulics or multi-chamber actuators. In an excavator, the Digital Displacement® pump makes it possible to operate multiple actuators simultaneously by setting independent pressures and flows for each of them, allowing for a significant energy reduction.

3 Improve energy recovery systems

Energy recovery systems can recycle energy used during operations e.g., when braking or lowering a boom.

How to electrify construction machines

1 Install an electric motor

Replacing the internal combustion engine with an electric motor in an off-highway vehicle can improve the maximum overall efficiency from 25% to 56%.

2 Fully electric systems

In fully electric off-highway vehicles, all loads are electrically driven. This allows for very energy efficient operations while emissions, as well as noise and air pollution, are effectively eliminated.

Source: Beltrami, Daniele, Paolo Iora, Laura Tribioli, and Stefano Uberti (2021). Electrification of Compact Off-Highway Vehicles, p. 16.

Emissions from construction machinery can be reduced all over the world

As the population nears 10 billion in 2050, new roads, bridges, buildings and public spaces are needed. By some estimates, the global construction sector accounts for just over 20% of global carbon emissions.[6] Of these emissions, around 5.5% is directly attributed to the fossil fuels used in machines and equipment on construction sites.[7]

Until recently, zero emissions construction sites may have seemed unattainable, but market innovations are gathering speed and changing the construction industry. Many cities around the world are now prioritizing different ways to reduce emissions and pollution from the construction sector. And decarbonizing construction sites can be the next big driver in the green transition.

6. IEA (2021). Tracking Buildings 2021.
7. Huang et. Al (2017) Carbon emission of global construction sector.

Electrifying machinery to make ports in Spain and South Africa more sustainable

Ports all over the world are accelerating the introduction of energy efficient technologies to reduce emissions. Shanghai Zhenhua Heavy Industries Co., Ltd. (ZPMC) is one of the largest manufacturers of port machinery in the world. ZPMC has developed a multitude of hybrid and fully electric port machinery that aids ports in meeting their business and climate ambitions. One such product in ZPMC's portfolio is hybrid straddle carriers. A straddle carrier is used in many ports to stack and move containers and for handling boats onshore. ZPMC's straddle carriers are currently operating at Durban Port in South Africa, and the Port of Barcelona in Spain.

Stakeholder toolkit

In the construction sector, there is a huge, unharnessed energy efficiency potential and cutting energy use in heavy vehicles presents an opportunity for governments to reduce air pollution in cities while cutting CO_2 emissions. Here are some of the key considerations and measures that regulators can use to push for a more energy efficient construction industry.

Set minimum requirements

Raise the ambitions for a more energy efficient construction industry by setting new rules for public procurement, including minimum requirements for vehicles and machinery used in construction projects – such as requiring the use of technology that enhances energy efficiency. Furthermore, create a market for emission-free construction machinery by setting higher carbon-intensity standards for new machinery and vehicles built for construction. An example could be to create zero/lower emission zones in cities and set a clear goal that all the municipality construction sites should be emission free as quickly as possible, and no later than 2025. It is essential to ensure that the municipality's plans, guidelines and framework conditions are built on the overall goal of emission-free construction sites.

Address economic incentives

Make sure that present legislation and tax regimes provide incentives to retrofit existing diesel engines to enhance energy efficiency, and make sure not to create short-sighted incentives – for example, to electrify systems that are only 30% efficient. Furthermore, it is essential to provide an enabling technological environment, which could include a buildout and an upgrade of national electricity grids. For instance, subsidizing and dedicating electrical chargers to heavy-duty vehicles and construction machinery can help the construction sites choose a greener alternative.

Establish partnerships

Electric charging infrastructure needs to be planned early and carefully, and preferably in cooperation with different authorities and stakeholders. For instance, involve stakeholders in communicating the reduced local noise and air pollution to build public support for zero-emission construction sites. Utilize existing energy efficient solutions and technology in public procurement. It is essential to have a transparent and predictable municipal process which gives clear, long-term signals on the future direction of construction standards, particularly through the procurement strategy. By doing this, cities can build confidence in the market and potentially lower the risks associated with innovation and investment. Require companies to make their expected construction carbon-footprint and environmental impact available when participating in public tenders.

Ellen, the world's longest ranging electric ferry

The challenge:

Source: IEA (2021). Greenhouse Gas Emissions from Energy

Buildings

28%

of all global energy-related CO_2 emissions come from buildings

Industry

39%

of all global energy-related CO_2 emissions come from industry

Transport

27%

of all global energy-related CO_2 emissions come from transport

Sector integration

With 4.27 billion passengers and 373 million vehicles transported by ferry each year, ferries are significant carbon emitters and often sail close to cities where they add to the already critical air pollution levels.[1]

1. Interferry (2021). Economic impact of the global ferry industry, p. 4.
2. According to 'Detailed Market Study and Business Plan', the E-Ferry Project 2018
3. Eferry (2020). E-ferry project - evaluation of the E-ferry, p. 107-109.

The solution: Electric ferries

The islands of Ærø and Als in Southern Denmark are connected by Ellen – the longest ranging fully electric ferry in the world. This medium-sized ferry does not emit carbon and operates at a low cost. In Europe alone, 696 operating ferries can be replaced by an electric solution similar to Ellen.[2]

- Ellen, the electric ferry, sails without emitting CO_2 and operates at a 24% lower cost compared to a new diesel ferry.
- The payback time for all additional investments on Ellen is 5-8 years.[3]

Ferries rival flights in emissions per kilometer travelled

All around the world, ferries transport passengers, goods and vehicles over short sea and inland routes. They are vital for people to get to work, to study and for tourism. In 2019, an estimated 4.27 billion passengers and 373 million vehicles were transported by ferries worldwide, most of which were in Asia.[4]

The carbon footprint of ferries varies depending on the age of the vehicle and its efficiency. According to a report by the Intergovernmental Panel on Climate Change (IPCC), the average carbon footprint for a passenger travelling by ferry varies from 15 to 150 grams of CO_2 per kilometer, compared to between 90 and 250 grams for a passenger travelling by aircraft.[5] Electrifying maritime transport is a clear-cut way to reduce greenhouse gas emissions.

The solutions are there both to build new electric ferries and to retrofit existing ferries to electrify them with the potential to reduce carbon emissions in lakes, cities and straits all over the world.

4. Interferry (2021). Economic impact of the global ferry industry, p. 4
5. IPCC (2014). Climate Change 2014: Mitigation of Climate Change: IPCC Chapter 8 - Transport, p. 610.

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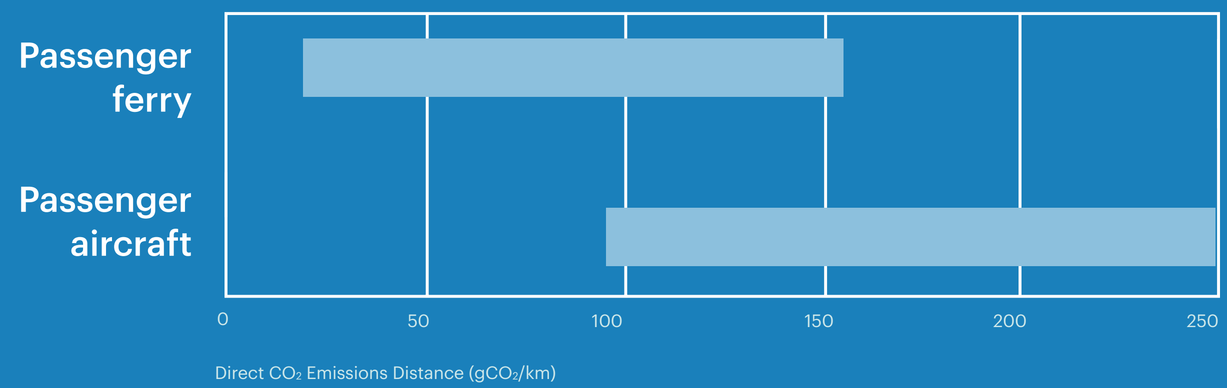
Carbon footprints for ferries and aircrafts



Source: IPCC (2014). Climate Change 2014: Mitigation of Climate Change: IPCC Chapter 8 - Transport, p. 610.

Ellen, the world's longest ranging fully electric ferry

Ellen shows the potential in maritime electrification

Between the islands of Ærø and Als in Southern Denmark, passengers and vehicles are transported by Ellen - a fully electric, medium-sized ferry. The ferry sails without emitting CO_2 and is faster than its diesel-powered predecessor.

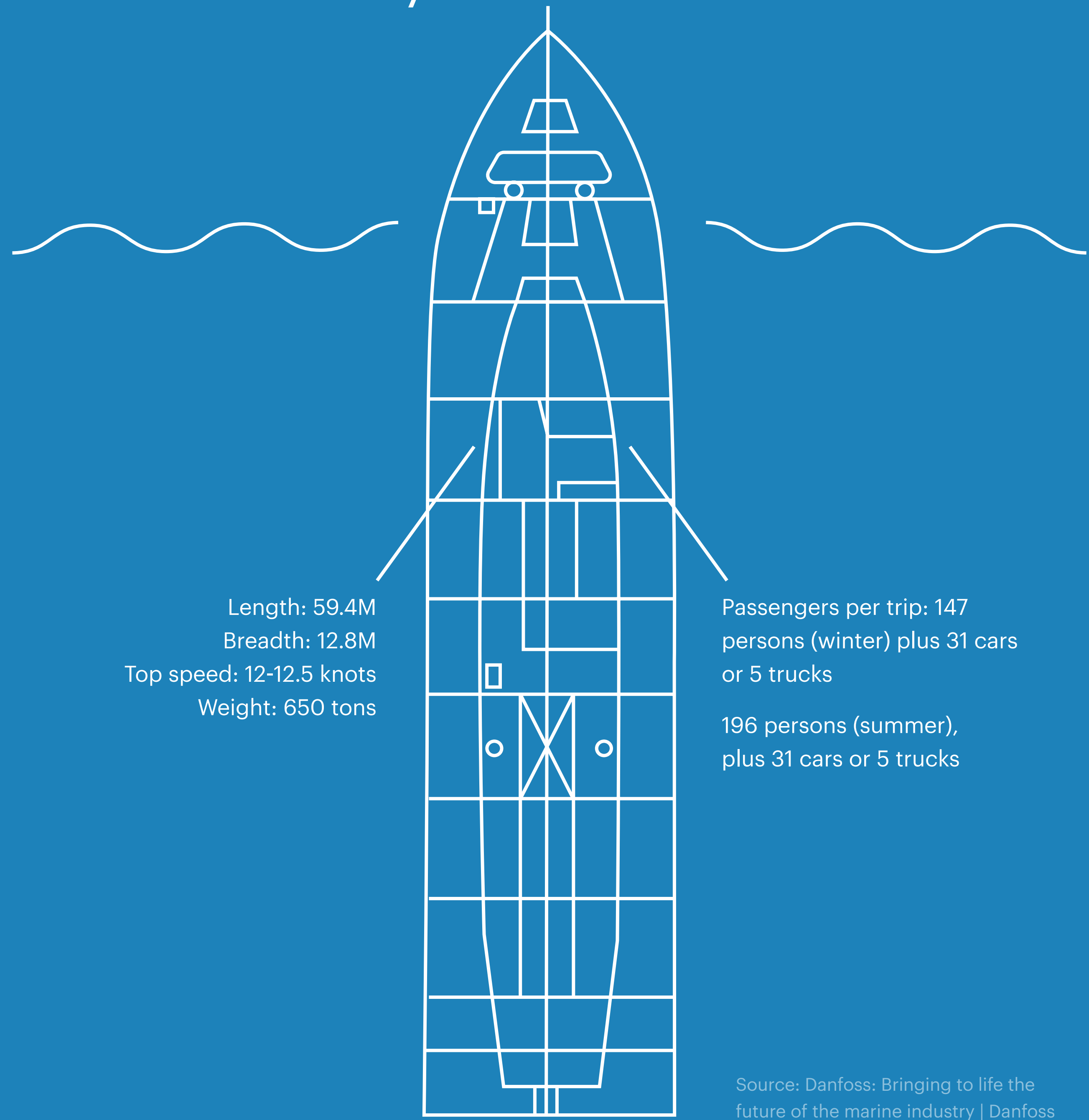
The island of Ærø, which has been a green pioneer since the 1980s, had a vision of using surplus renewable energy to power an electric ferry. That vision became a reality as part of the EU-backed project, "E-Ferry", that addresses the urgent need for reducing European CO_2 emissions and air pollution from waterborne transportation. The project's objective was to build and demonstrate a fully electric ferry with the ability to sail without polluting and without emitting CO_2. A collaboration of European partners, which included local Danish authorities, German and Swiss battery manufacturers, and Danish and Finnish electric engine producers, helped turn vision to reality. Ellen entered into operation in August 2019 and has since been through a thorough evaluation to determine its environmental and economic sustainability.

In operation, Ellen saves 2,520 tons of CO_2 per year compared to the best technological alternative at the time of the evaluation, and close to 4,000 tons when compared to an existing older ferry.[6]

Ellen is charged on the island of Ærø, where electricity demand is fully covered by wind power. Even if Ellen was supplied with an energy mix that mirrors the average Danish grid, it would still reduce carbon emissions by around 2,010 tons per year compared to the best technological alternative.[7]

6. Eferry (2020). E-ferry project - evaluation of the E-ferry, p. 139-140.
7. Eferry (2020). E-ferry project - evaluation of the E-ferry, p. 119.

The Ellen E-ferry



Length: 59.4M
Breadth: 12.8M
Top speed: 12-12.5 knots
Weight: 650 tons

Passengers per trip: 147 persons (winter) plus 31 cars or 5 trucks

196 persons (summer), plus 31 cars or 5 trucks

Source: Danfoss: Bringing to life the future of the marine industry | Danfoss

Ellen also provides a valid commercial alternative. Even though construction costs are higher than conventional ferries, the operational costs are significantly lower, which ensures a payback time for the additional investment of 5-8 years of operation.[8] That payback time is expected to improve as costs decrease – such as for batteries – and as innovation improves and demand increases.

Since its launch, Ellen has also won praise from passengers. Alongside its environmental benefits, passengers have shown appreciation for the reduced noise levels and smog-free operations, and rated Ellen either "extremely satisfying" or "very satisfying" in terms of safety, comfort and reduced travel time.[9]

8. Eferry (2020). E-ferry project - evaluation of the E-ferry, p. 108-109.
9. Eferry (2020). E-ferry project - evaluation of the E-ferry, p. 127.

Results from Ellen

Ellen lowers emissions and operates at lower costs

2,520 tons of CO_2

saved per year compared to the best technological alternative[10]

87.4%

energy efficiency in the electric system – more than twice as much as that of the propulsion system of a classic diesel ferry[11]

24%

lower operational costs compared to a new diesel ferry[12]

Payback time 5-8 years

for the additional investment, lifetime savings of 2 million euros[13]

10. Eferry (2020). E-ferry project - evaluation of the E-ferry, p. 119.
11. Kortsari et al. (2020). Evaluation report of the E-ferry, p. 67.
12. Eferry (2020). E-ferry project - evaluation of the E-ferry, p. 107.
13. Eferry (2020). E-ferry project - evaluation of the E-ferry, p. 108-109.v

Solutions for the birth of the electric ferry

A blueprint for the maritime industry

Most ferries run on diesel and others operate as hybrid ferries that are rebuilt diesel ferries with an emergency generator on board. In contrast, Ellen was designed and constructed from scratch according to the needs and particularities of a medium-range, fully electric ferry.

TRANSPORT

1. Design

Ellen is long and narrow, and shaped more like a classic sailing ship than a traditional ferry. To reduce weight and to avoid the use of elevators, the car deck is open and the passenger deck is on the ground floor close to the waterline. A significant part of the design was to use lightweight materials and the use of steel was restricted to just the specially designed hull, with the bridge constructed of aluminum instead.

2. Battery

Ellen has one of the largest battery packs installed for maritime use with a capacity of 4.3MWh. Ellen has no emergency back-up generator on board, whereas hybrid ferries typically do because they cannot rely on the electric drivetrain.

3. Drivetrain

A fully-electric 'EDITRON' drivetrain powers Ellen. A drivetrain includes all of the components necessary to transfer energy from the engine to the propellers. The system comprises two 750kW propulsion motors and two 250kW thruster motors, both of which are driven by synchronous reluctance assisted permanent magnet technology and are controlled by DC/AC inverters. As well as the electric drivetrain, the system also provides the vessel's power management system for complete onboard automated power and load control.

Electrifying ferries is possible all over the world

According to some estimates, the global ferry fleet comprises more than 15,000 vessels that transport 4.27 billion passengers and 373 vehicles a year.[14] The average ferry is over 20 years old and very, very few are electric, which makes the potential for turning ferries into a green driver massive.

14. Interferry (2021). Economic impact of the global ferry industry, p. 4.

TRANSPORT

Cleaner air with Asia's first E-ferry

The Taiwanese port city of Kaohsiung relies on marine ferries to move goods through its busy port. Emissions from energy-intensive ferries and heavy industry contribute heavily to local air pollution. To improve air quality, the Kaohsiung city government mandated that Taiwanese shipping company Ship reduce emissions from its ferry fleet. This included the popular Cijian Island passenger ferry route.

The 100-ton, 23-meter-long ferry Happiness – which carries 8 million passengers every year – thus became Asia's first hybrid electric ferry. The ferry's new system ensures pure electric cruising for half the ferry's operation time, significantly reducing diesel fuel consumption. Lowering diesel consumption reduces both carbon emissions and the release of other harmful emissions, which helps improve air quality in the region. Other benefits of the hybrid system include reduced operational noise and lower maintenance costs. Following the success of this project, the Kaohsiung City Government plans to retrofit the rest of its diesel fleet.

Clean transportation across Norway's fjords

Ferries are an essential part of infrastructure in Norway, where locals and tourists alike rely on them to make their way across the scenic fjords, and between islands and peninsulas. On the west coast of Norway, three ferries serving the Hareid-Sulesund crossing – Suloey, and its sister ferries Hadaroey and Giskoey – make an important contribution to reducing emissions and pollution. The conversion of the three ferries from diesel propulsion to all-electric ferries has led to a significant annual reduction in CO_2 emissions from the service. Powerful onshore support is essential when converting the ferries from diesel to all-electric propulsion. To successfully carry out the conversion, the existing power grid needed additional power to meet the required charging capacity. Norwegian Electric Systems (NES), a supplier of energy design and smart control solutions for vessels, reinforced the power grid on both sides and retrofitted the Norwegian vessels with batteries and the latest inverter and power control technology to create an optimal solution for electric propulsion. With the introduction of electric vessels, the Hareid-Sulesund ferry operations have reduced CO_2 emissions by thousands of tons annually. By actively controlling, monitoring and supporting the grid from local batteries on shore side, the system supplies the high peak power crucial to rapid charging, with no need to scale up the grid infrastructure. Instead of extra capital investment, the system relies on peak shaving functionality, which means it uses energy when supply is plentiful and stores energy for times of short supply.

Stakeholder toolkit

Decarbonizing local ferries presents an opportunity for governments to cut operational costs and reduce air pollution while cutting CO_2 emissions. In general, the ferry industry is more flexible towards the introduction of alternative fuels, such as electricity, compared to the ocean-going sector. This applies especially to ferries operating on local routes.[15] However, energy efficiency is still not a strategic focus area in the domestic shipping industry and achieving results depends on a continued and long-term, systematic effort supported by the right regulatory framework. Here are some of the key considerations and measures that regulators can use to push for a more energy efficient domestic shipping industry:

15.Gagatsi et al. (2016). Exploring the potentials of electrical waterborne transport in Europe, p. 1573.

Set minimum requirements

Raise the ambition for electrifying domestic shipping (ferries), for example by setting targets and performance standards. National governments should set an end date for building new vessels with fossil fuel propulsion and strengthen the carbon intensity standards. Furthermore, prepare a strategy for electrifying ports as ferry operators themselves are not used to ordering and building transformer stations on land. Without available electricity, operators could be more hesitant to electrify their ferries. Norway offers a great example of how decarbonizing ferries can be politically accelerated, even in what is widely deemed a hard-to-decarbonize sector. The Norwegian state has acted entrepreneurially by playing an active role in market creation and transformation through public agencies and support schemes.

Address economic incentives

Make sure that taxes and fiscal policy support the electrification of maritime transport and address or alleviate barriers. In many places current regulations on energy taxes do not support a shift to electrical propulsion. For example, hydrocarbon fuels for ships are exempted from all taxes in many EU countries while at the same time a greener alternative – namely electricity – is heavily taxed. Furthermore, present legislation and tax regimes mean that traditional ferry operators lack exposure to the socio-economic cost of emissions and other environmental impacts, and result in existing conventional propulsion solutions being favored.

Establish partnerships

Ellen was made possible through a partnership with 9 partners, and voluntary cooperation between different authorities and stakeholders. A partnership approach that for example involves local authorities, the port and green electricity producers can drive initiatives in collaboration. These may include the provision of onshore power supply (preferably from renewable sources); safe and efficient bunkering of alternative low-carbon and zero-carbon fuels; and support for the optimization of port calls including facilitation of just-in-time arrival of ships.

Factories are the beating heart of industry, a sector that accounts for 39% of all global energy-related CO_2 emissions. The solutions are there to meet growing demands for production while curbing emissions.

Industry

Danfoss Nordborg factory site, towards zero emission factories

The challenge:

Source: IEA (2021). Greenhouse Gas Emissions from Energy

Buildings

28%

of all global energy-related CO_2 emissions come from buildings

Industry

39%

of all global energy-related CO_2 emissions come from industry

Transport

27%

of all global energy-related CO_2 emissions come from transport

Sector integration

Factories are the beating heart of the industry, a sector that accounts for 39% of all global energy-related carbon emissions. The challenge for factories all over the world is to meet growing demands for production while curbing emissions.

The solution: Decarbonizing factory sites

Danfoss is Denmark's largest industrial company. Danfoss' solutions are unique, but their Nordborg factory in Denmark is not. With 250,000 m^2 of production, administration and testing facilities, the Danfoss Nordborg factory site mirrors factory sites around the world.

- In 2022, the Danfoss Nordborg factory will become carbon neutral.[1] By implementing available solutions, all with an estimated payback time of less than 3 years, the energy used has been reduced significantly.
- The Nordborg factory shows how factory sites can become part of the local energy grid, providing lower energy prices for the local community and at the same time reducing consumption of natural gas significantly.

1. in scope 1 and 2, that are emissions from purchased energy and from sources owned or controlled by Danfoss.

Kim Fausing,
CEO of Danfoss

“Carbon neutral factories benefit the climate and the bottomline. The solutions are there to make it happen.”

Towards carbon neutrality in industry

The Danfoss Nordborg factory site, Denmark

Numerous companies across the world have committed to reducing their carbon footprint. Danfoss is one of them. Danfoss is one of the largest industrial companies in Denmark, engineering solutions that increase machine productivity, reduce emissions, lower energy consumption and enable electrification. In 2022, the Nordborg factory site will become carbon neutral (in scope 1 and 2, that are emissions from purchased energy and from sources owned or controlled by Danfoss) and provides a roadmap for decarbonization of factory sites all over the world. As part of an ambitious climate strategy, Danfoss has a stated goal of making its global operations carbon neutral by 2030 – that includes 40,000 employees working in 95 factories in more than 20 countries[2]. And all within the framework of the Science Based Targets initiative that sets targets in line with climate science.

Danfoss' factory in Nordborg is set to be the frontrunner, paving the way for the rest of the global organization. Massive improvements in energy efficiency – generating more output while using less heat and electricity – have put the goal to be carbon neutral in 2022 within reach. Danfoss has estimated that since 2007, when the initiative began, energy consumption for heating and manufacturing has been reduced by 70%, while electricity demand has been reduced by 43%. The amount of heat and electricity needed to provide hot water, comfort and to support manufacturing processes on the factory site has been reduced markedly as the result of energy efficient solutions and energy recovery coupled to an integrated energy system.

The significant reductions in emissions at the factory site in Nordborg has been made possible by focusing on three key initiatives.

Firstly, energy is only used in the amounts needed. A number of technical projects and improvements have been made to deliver the significant savings in energy consumption.

2. Danfoss (2022). About Danfoss.

Secondly, energy savings have helped lower temperatures in the factory site's heating network significantly from 145°C to 67°C. In addition to fewer transmission losses, lower temperatures in the heating grid make it possible to recover and reuse a significant amount of excess heat from manufacturing processes, such as ventilation, cooling and compressed air.

Thirdly, the remaining heat demand is sourced by reusing excess heat, green district heating and natural gas, the demand for which has been reduced significantly. The remaining emissions from natural gas will be covered by biogas certificates from a local biogas plant until it is phased out. Electricity demand is mostly covered by solar panels and through corporate power purchase agreements with suppliers of carbon neutral energy.

However, the journey is not yet complete. There are plans for the Danfoss factory to further reduce carbon emissions, which will make certificates redundant. An on-campus data center will produce excess heat of an estimated 1MW that will be recycled through the local heating grid, but also supplied to the entire region. When the Danfoss factory produces more heat than needed, the heat will be sold to the city-wide district energy system to the benefit of local citizens and companies.

This also works in reverse; when the Danfoss factory needs heating, the city's biomass plant can deliver heat in return. Inspired by the success at the Danfoss factory in Nordborg, Danfoss has reduced the carbon intensity of its global operations by applying energy-saving and cost-effective solutions since 2007.

The Danfoss Nordborg factory site, Denmark

Employees
3,000
Approx.

Buildings
53
buildings constructed between 1951 and 2008

Employee profile
Production, administration and testing facilities

Size
250,000 m2

Source: Danfoss

Results from the Nordborg factory site

Towards carbon neutrality in 2022

Estimated progress from 2007 to 2021 at the Danfoss Nordborg factory site

Heat consumption for manufacturing processes and buildings.

-70% ↓

Electricity consumption

-43% ↓

The estimated payback time for all investments related to reaching carbon neutrality is

3 years

or less

Towards carbon neutrality at the Danfoss Nordborg factory site

Steps to reduce factory emissions

The Danfoss factory site in Nordborg provides a path towards carbon neutrality for factories based on three overall steps.

1. Improve energy efficiency

Refrain from using energy that is not needed.

Energy saving solutions
Whether you are heating, cooling or refrigerating, ensure that temperatures match your production or storage needs. Adjusting temperatures to reach proper comfort levels saves energy.

Lower temperatures (from 145 °C to 67 °C)
Over time, the Danfoss Nordborg factory site has lowered temperatures in the internal district heat network from 145°C to 67°C. Lower temperatures reduce transmission loss and allow for new heat sources, such as surplus heat from industrial processes or from data center operations.

2. Sector integration

Reuse the energy that is already being produced.

Improve efficiency and reuse heat from ventilation
Waste from industrial processes is extracted directly from the source and fed into the ventilation system instead of into the air. This allows for recovery and reuse of 50% of the heat. Reducing the number of ventilation ducts systems from 18 to 4 in each building allows for bigger volumes of air to move slower, which reduces energy consumption by 80%.

Improve efficiency and reuse heat from compressed air processes
Similarly, excess heat from compressed air processes can be recovered and reused.

Centralized cooling systems
5 cooling systems allow for more energy efficient cooling as well as recovery and reuse of heat.

3. Source green energy

Use renewable energy sources when possible.

The remaining heat demand is supplied from green district heating, excess heat and natural gas. Any further electricity demand is supplied from solar PV and from offshore wind farms.

Decarbonizing factory sites is possible all over the world

In China, Danfoss has reduced energy consumption and emissions in their factories.

The world's 500 largest companies employ 70 million people, generate USD 33 trillion in revenue and account for a large share of global emissions. In 2019, 163 Fortune Global 500 companies had set formal climate targets – and more are expected to have set climate targets since.[3] Some companies are making progress, like the German multinational chemical company BASF, which has reduced carbon emissions from their factories significantly through energy efficency measures. Others have not begun their journey yet. What is common for almost all companies is that existing and cost-effective solutions enable them to produce more while emitting less.

That is also true for companies in all global regions. No factories are alike. They differ in several ways depending on what they manufacture, where they are located, the size and nature of the building stock and the available local energy infrastructure. Despite the differences, Danfoss has tackled the challenge head on by undertaking substantial energy savings projects at 27 factories in 11 countries by improving energy efficiency, reusing energy through sector integration and by sourcing green energy.

3. Visual Capitalist (2021). Visualizing the Climate Targets of Fortune 500 Companies.

Reducing costs and emissions at Danfoss factories in China

At the Danfoss Haiyan Factory, smart monitoring technologies improve energy efficiency. Heating and cooling technology turns waste heat from the factory production processes back into the plant, delivering 50% energy savings compared to normal air conditioning systems.

In the Danfoss Zhenjiang Factory, the temperature of the production environment is regulated by energy efficient inverter technology, which enables the factory to achieve a stable production environment under any climate conditions using the lowest amount of energy possible.

In the Danfoss Wuqing Factory, a central heating station recovers waste heat from air compressors using software to adjust the heat supply according to the outdoor and indoor temperature to lower carbon emissions.

In addition, Danfoss will build the first Zero Carbon Industrial Park in Haiyan.

Stakeholder toolkit

The industrial sector has huge, unharnessed energy efficiency potential. This presents an opportunity for governments to improve the economy and the competitiveness of industry while cutting CO_2 emissions. However, energy efficiency is still not a strategic focus area in most industries and achieving results depends on a continued and long-term, systematic working effort supported by the right regulatory framework. Here are some of the key considerations and measures that regulators can use to push for a more energy efficient industry.

Set minimum requirements

Raise the bar for effort by setting targets and performance standards and requiring information to be publicly available. For instance, in Australia the government requires large companies to assess their energy efficiency potential and disclose the results to both the public and company shareholders. Voluntary agreements like this have been applied in countries such as Denmark, Sweden, the US and the Netherlands, and each country administers rewards or penalties in case of non-compliance.

Address economic incentives

To speed up carbon reductions in industries across the globe, make sure that taxes and fiscal policy push the industries towards becoming more energy efficient, such as utilizing carrot-and-stick policies that encourage action and address or alleviate barriers. For instance, voluntary agreements between companies and authorities can get you a long way. The agreements should be based on a principle where companies entering the scheme will have economic incentives ("carrot") for the extra work necessary ("stick"). Under Danish legislation, the immediate economic benefit selected is energy tax relief. Keep the rules simple and build the system step by step.

Establish partnerships

Initiatives to become more energy efficient are possible through partnerships and voluntary cooperation between different authorities and actors. Provide guidelines, tools and templates to help the industry create their own programs and measures to improve energy performance and learn from their peers.

INDUSTRY

Vesterled, a brick plant on the path to carbon neutrality

The challenge:

Buildings

28%

of all global energy-related CO_2 emissions come from buildings

Industry

39%

of all global energy-related CO_2 emissions come from industry

Transport

27%

of all global energy-related CO_2 emissions come from transport

Sector integration

Source: IEA (2021). Greenhouse Gas Emissions from Energy

Producing materials in the heavy industry sector is an extremely energy intensive process - requiring around 2,300 Mtoe in 2019, roughly equivalent to the total primary energy demand of the United States.[1]

Reducing energy consumption in the heavy industry is central to a sustainable transition of the energy sector.

1. IEA (2020). The challenge of reaching zero emissions in heavy industry.

The solution: Reduce emissions from heavy industry factories

The Vesterled brick factory has reduced their energy consumption for heating by an estimated 29% in 20 years by improving energy efficiency, reusing heat and by designing a new brick. And they have cut carbon emissions in production by an estimated 36%.

The Vesterled Brick Plant

Denmark's most energy efficient brick production

For the past 30 years, Vesterled has been Denmark's most energy efficient brick plant. Vesterled is part of the Wienerberger Group, the world's largest producer of bricks, and has worked strategically to improve sustainability in their entire value chain from product design, to sourcing and production.

Vesterled thereby provides a blueprint to brick makers and industry, not only inside the Wienerberger Group, but the entire heavy industry sector, showcasing how to reduce energy consumption and carbon emissions through technological innovation, process optimization and proper investments.

By applying the ISO 50001 certified Energy Management System (EMS) for effective energy management, Vesterled Brick has reduced their energy consumption for heating by 29% since 2002.

The ISO standard has been a key driver of the results. It enables a structural approach to all parts of the production cycle.

After bricks are formed and dried, they are fired in kilns, a type of oven, at temperatures of up to 1000 °C. A lot of heat is created in that process. Heat recovery units enable the collection of excess heat, so that it can be reused in other heat demanding processes, such as drying the bricks. **At Vesterled, outdated machinery has been replaced and new installations allow for reusing heat from the burning process.**

Vesterled is further exploring whether excess heat from brick production can be recovered and distributed through the local district heating grid for the benefit of local consumers.

Wienerberger Group

As part of their ESG program, Wienerberger aims to reduce CO_2 emissions by 15% by 2023 compared to 2020. This covers scope 1 and 2 emissions from purchased energy and sources owned or controlled by Wienerberger.

Vesterled Brick Plant, Denmark

Employees	Production Size	Energy Consumption
Approx 37	40,000m²	57 GWh (2020)

Vesterled has been frontrunners in developing innovative products with a smaller carbon footprint. Firing bricks is energy intensive and the inner core of the brick is the last part to dry. **A brick product with three holes has been designed to reduce the amount of clay needed for one brick** and to allow for a faster firing and drying process, all of which reduces energy consumption and emissions.

Moreover, 65% of the energy source at Vesterled has been converted from natural gas into certified biogas from the local biomass plant, reducing emissions by 30% as of 2022. Lastly, the electricity used at the Vesterled plant was changed in 2021 to be sourced solely from wind power with a shift to certified green energy. All in all, Vesterled is on track to become carbon neutral in 2050.

Wienerberger's global operations are focused intensively on reducing their carbon footprint and, in many respects, Vesterled shows the way. By tracking energy consumption rigorously, Wienerberger has identified areas where other factories could benefit from implementing a similar process. In 2020, a one-to-one implementation of the Vesterled process at another Danish factory resulted in a 25% reduction in energy consumption.

Results from Vesterled

Estimated development from
2002 - 2020

Vesterled Brick Plant

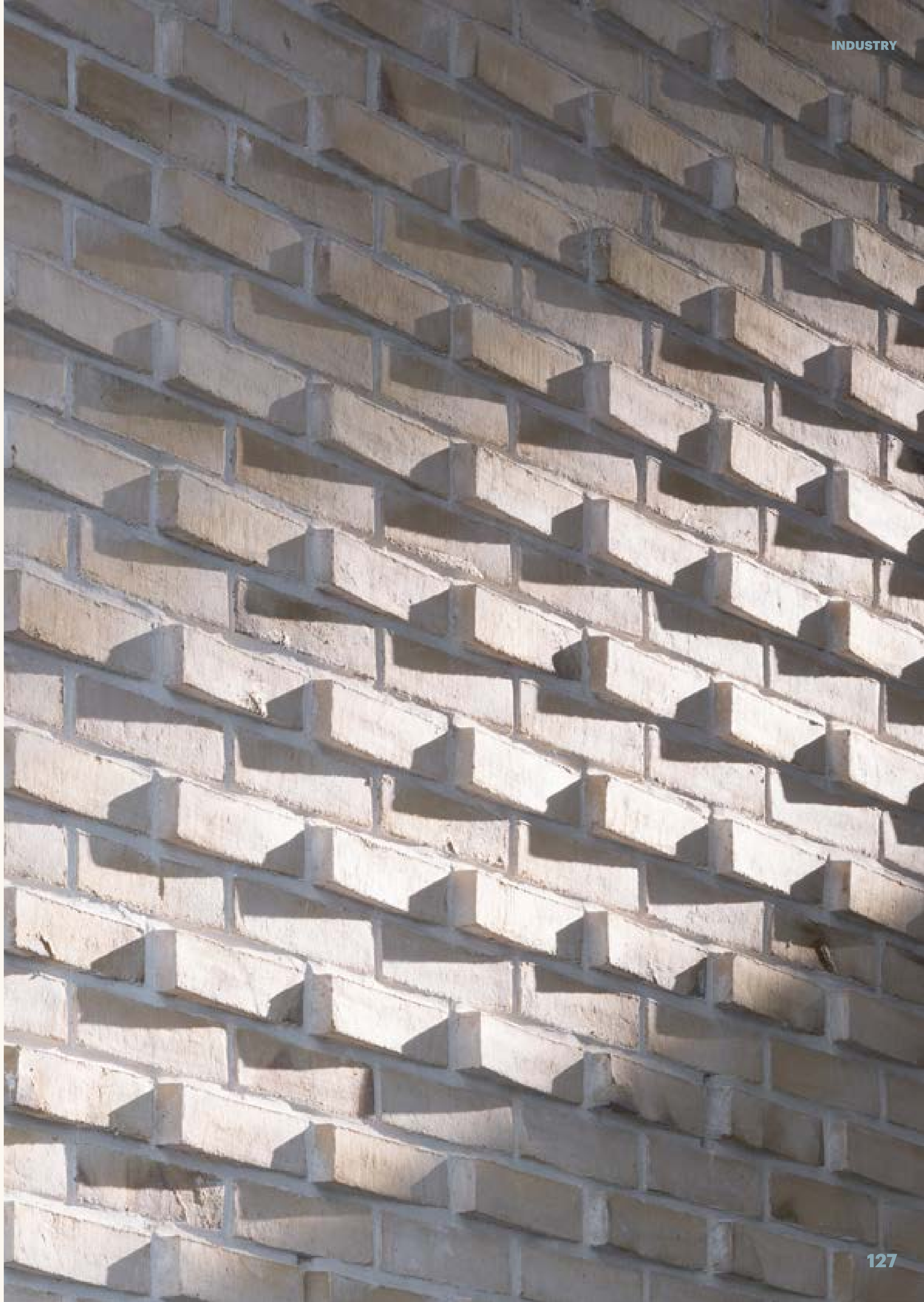
29%

Reduction in energy consumption for heating by transferring heat to other areas of production, implementing new kilns and rigidly working with energy management.

36%

CO_2 reduction in production
by switching to certified biogas and reducing raw material in production.

INDUSTRY



A three-step approach to reducing emissions in brick production

The path to carbon neutrality

At Vesterled brick plant, the path to carbon neutrality has been divided into 3 phases. This methodology is not necessarily specific or unique to brick production but can also be applied in many other heavy industries.

Are being implemented at the Vesterled brick plant →

To be implemented →

1 Improve energy efficiency

- Implement ISO 50001
- Define best practice
- Upgrade equipment & processes

2 Improve design and source green

- Switch to biogas and wind power
- Reuse excess heat
- Rethink the brick design

3 New technologies and electrification

- New technologies for producing bricks
- Electric kilns
- Heat pumps
- Carbon capture

Carbon neutrality in **2050**

Heavy industry can reduce emissions all over the world

No sector can escape the need to dramatically reduce emissions. The heavy industry sector is an area where emissions are particularly "hard to abate". Factories in the heavy industry typically have lifetimes of around 30 - 40 years, which makes retrofitting existing systems central to their transition. The manufacturing processes require very high temperatures, which today are almost exclusively provided by fossil fuels. And several industrial processes result in emissions from chemical reactions that are inherent to today's production processes. All these factors highlight the importance of energy efficiency in reducing emissions from the global heavy industry sector, where significant gains can be made with existing and cost-effective solutions.

At Wienerberger, factories vary in size, age, set-up and infrastructure. As a result, no road to carbon neutrality is the same and initiatives are adjusted to the local environment and legal framework in place at each factory. Some countries have more established legal frameworks that encourage decarbonization, thus helping companies in the process. Knowledge-sharing is therefore key to reaching Weinerberger ambitious decarbonization goals.

Kortemark, Belgium

A new, CO_2-neutral production line for brick slips with an electric kiln at the Kortemark site in Belgium has just been launched. Both the dryer and the kiln operate entirely on electricity. An on-site photovoltaic installation generates 25% of the required electricity, supplemented by 100% renewable electricity. Hence, the use of energy from fossil sources has been reduced to zero.

Pannerden, Netherlands

Extensive research and testing has been done in the production of pavers to public roads to implement a slimmer version of pavers without compromising on the mechanical properties. This new slim version has been implemented thus yielding a 5.9% dematerialization of raw material and an equal reduction of 5.9% CO_2 emission/m².

Stenstrup, Denmark

A new facing brick with 3 holes was launched in 2020. It took one year to develop the right production method for a brick with three holes, 10% less material and the same properties as a regular brick. Combined with biogas as the energy source, CO_2 emissions in production are reduced by up to 60-80% compared to production of a regular facing brick.

Stakeholder toolkit

Industry has huge, unharnessed energy efficiency potential. This presents an opportunity for governments to improve the competitiveness of industry while cutting CO_2 emissions. However, energy efficiency is still not a strategic focus area in most industries and achieving results depends on a continued and long-term, systematic working effort supported by the right regulatory framework. Here are some of the key considerations and measures that regulators can use to push for a more energy efficient industry.

Set minimum requirements

Raise the bar for effort, for example by setting targets and performance standards and requiring information is made publicly available. For instance, in Australia, the government requires large companies to assess their energy efficiency potential and disclose the results to both the public and company shareholders. Voluntary agreements on this have been applied in countries such as Denmark, Sweden, the US and the Netherlands, and each country administers rewards or penalties in case of non-compliance.

Address economic incentives

To speed up carbon reductions in industries across the globe, make sure that taxes and fiscal policy push industries towards becoming more energy efficient, such as by utilizing carrot-and-stick policies that encourage action and address or alleviate barriers. For instance, voluntary agreements between companies and authorities can get you a long way. The agreements should be based on a principle where companies entering the scheme will have economic incentives ("carrot") for the extra work necessary ("stick"). Under Danish legislation, the immediate economic benefit selected is energy tax relief. Keep the rules simple and build the system step by step.

Establish partnerships

Initiatives to become more energy efficient are possible through partnerships, and voluntary cooperation between different authorities and actors. Provide guidelines, tools and templates to help the industry create their own programs and measures to improve energy performance and learn from their peers.

Buildings account for 28% of all global energy-related emissions. We need to ramp up improvements in the energy efficiency of buildings.

Buildings

Linde Haven, a new sustainable city area

The challenge:

Source: IEA (2021). Greenhouse Gas Emissions from Energy

Buildings

28%
of all global energy-related CO_2 emissions come from buildings

Industry

39%
of all global energy-related CO_2 emissions come from industry

Transport

27%
of all global energy-related CO_2 emissions come from transport

Sector integration

Over the next 40 years, the world is expected to build 230 billion square meters in new construction – adding the equivalent of Paris to the planet every single week.[1]

It is therefore vital that new city areas are built to be highly energy efficient and with an energy supply that can be decarbonized.

1. UN Environment, GBA & IEA (2017). Global Status Report 2017, p. 2.

The solution: Zero-carbon-ready city areas

As the world grows, new city areas are added all over the world. How they are constructed is an important factor in the green transition. The new city area of Linde Haven in Sønderborg is built to meet the highest sustainability standards, not least regarding energy efficiency. Energy efficient design of the buildings allows Linde Haven to be supplied by low-temperature district heating.

Linde Haven will operate at low temperature, which has the potential to reduce distribution heat loss by an estimated 31% compared to similar buildings operating at normal temperatures.

Towards zero-carbon-ready buildings

Most of the world's building stock must be zero-carbon-ready by 2050. Zero-carbon-ready buildings are highly energy efficient and supplied with energy directly from renewable sources or from energy sources with the potential to be fully decarbonized, such as district heating.[2] This means that a zero-carbon-ready building will become a zero-carbon building by 2050, without any further changes to the building or its equipment.

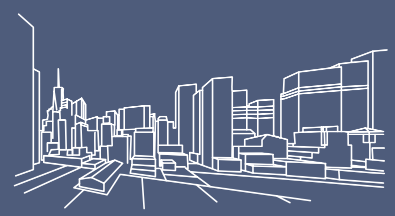
According to the International Energy Agency's (IEA) Net Zero Emissions by 2050 Scenario, all new buildings must be zero-carbon-ready by 2030. And 20% of all existing buildings must be retrofitted to be zero-carbon ready by 2030.[3]

Both passive and active energy efficiency measures are central to meet the net zero scenario. Passive measures aim at reducing energy demand by increasing the use of natural heating and cooling, and by reducing energy losses through the building envelope. Passive measures include wall insulation, loft space insulation, skylights, roof windows, and designs that account for sunshine, shading and ventilation.

Active measures aim at reducing energy demand by measuring, monitoring, and controlling energy usage in both new and existing buildings. Active measures include everything from simple thermostats to artificial intelligence. At both a room, building and local level there is a large potential to reduce emission and to save energy and money.

2. IEA (2021). Net Zero by 2050, p. 148
3. IEA (2021). Net Zero by 2050, p. 147

Examples of the potential in active energy efficiency measures



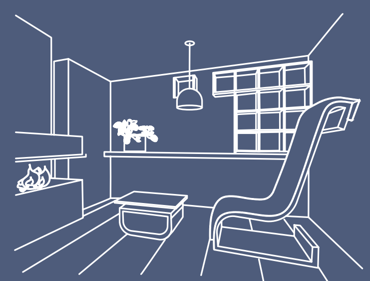
Heat supply at local level

Lower temperature heat supply through a district energy system: Every 1 EUR spent in buildings for obtaining lower temperatures will reduce future supply costs with approx. 4 EUR.[4]

Heat control of buildings

Control heating systems with **model-predictive control systems** that combine artificial intelligence and building, weather and user data to adjust temperatures.

In an apartment building, model-predictive control systems can **reduce heating consumption by 11%.**[5]



Heat distribution and room control

Electronic thermostatic radiator valves retain a specific room temperature digitally and enable lower temperatures at night or over a holiday period for further energy savings. In a multi-family building, electronic thermostatic radiator valves **save 11% on final energy with a payback time of 1 year.**[6]

Manual thermostatic radiator valves automatically retain a specific room temperature level. In a multi-family building, thermostatic radiator valves **save 7% on final energy with a payback time of 1 year.**[6]

Automatic hydronic balancing can optimize the water distribution in a building's waterbased heating or cooling system. In a multi-family building, an automated hydronic balancing system can **save 10% on final energy with a payback time of 1 year.**[6]

4. Lund et al. (2018). The Status of 4th Generation District Heating: Research and Results, p. 157.
5. EA Energianalyse (2021). ACTIVE ENERGY EFFICIENCY, p. 18.
6. Ecofys (2017). Optimising the energy use of technical building systems – unleashing the power of the EPBD's Article 8, p. 55 & 60.

A new **sustainable** city

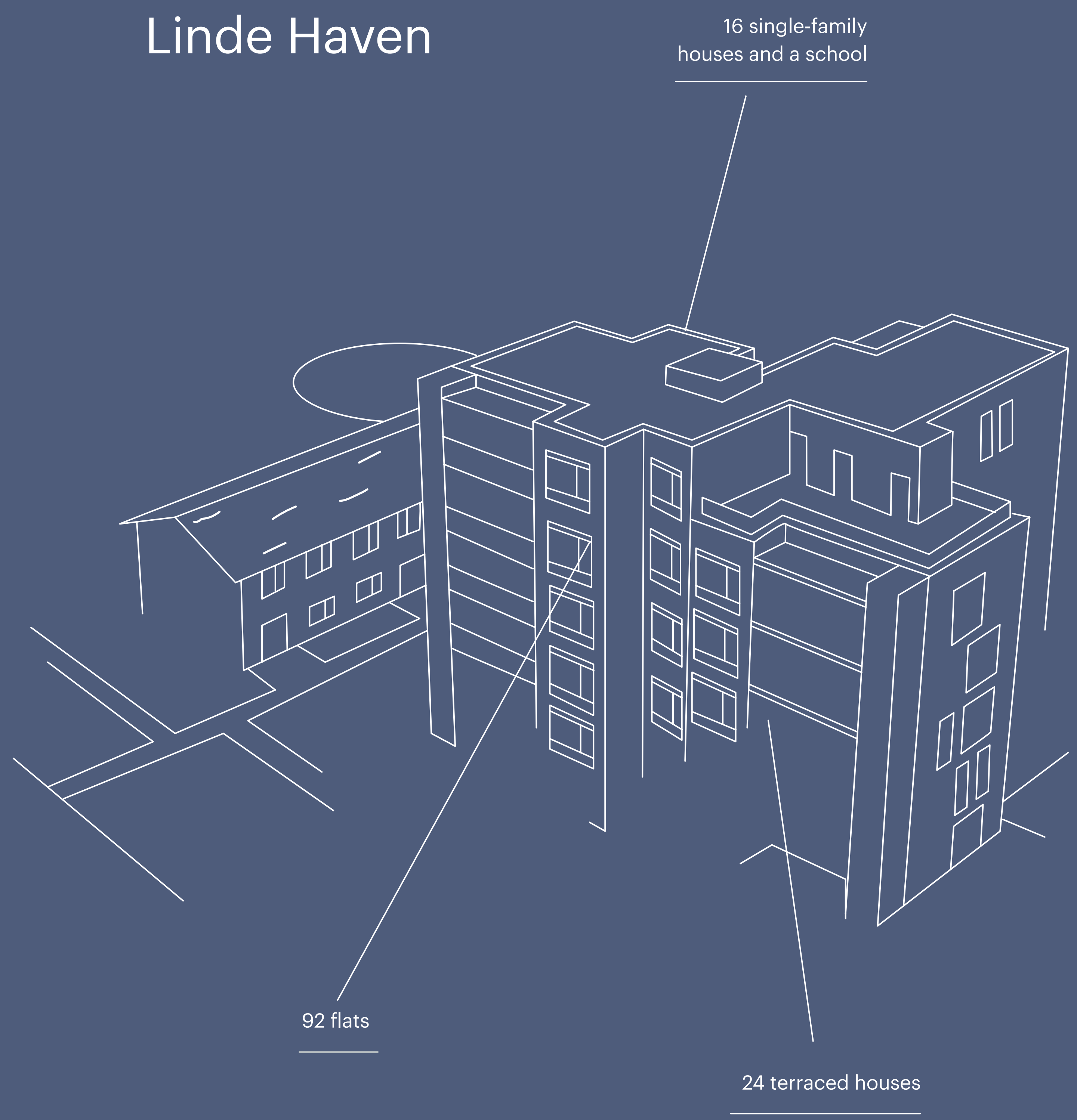
Linde Haven is an entire new area in the city of Sønderborg complete with 92 flats, 34 terraced houses, 16 single-family houses and a school.

When the housing association 'B42' was tasked with constructing Linde Haven, they decided to make an extra effort to tap into the municipality's ambition to have a carbon neutral energy system in 2029 by adopting a sustainable approach both in the construction phase and in operations.

'B42' has prioritized sustainable materials and proximity of contractors in the tender process. Bricks, concrete elements, floors and other materials were chosen based on sustainability criteria and supplied by local manufacturers to reduce emissions from transport.

Energy efficiency has been a central focus in all aspects of the building's design and to provide comfortable living conditions inside the dwelling with the least possible amount of energy consumption. The building enclosure is designed with a series of passive energy efficiency measures such as insulation, energy efficient windows, doors and ventilation systems that reduce energy needs. Similarly, active energy efficiency measures add to the overall efficiency. Smart systems allow tenants to control everything from lighting, heating, air conditioning, underfloor heating and other forms of energy use as efficiently as possible.

Hot water is produced at an apartment level instead of in the basement, which minimizes the waste of heat and, together with highly efficient heat exchangers, allows the buildings to operate at lower temperatures. Lower temperatures offer great potential for lowering energy bills and reducing emissions.



District energy provides a path to decarbonizing the heating and cooling sector

When buildings operate at lower temperatures, it supports a more efficient use of heat from heat pumps or district energy systems. Linde Haven will serve as a great example of that once the city area is complete.

In many parts of the world, district energy systems supply homes and companies with heating as well as cooling. District energy systems tap heat from processes, such as at power plants, and distribute it through pipelines to end users in the form of water.

Today, the majority of global district heat production relies on fossil fuels.[7] According to the International Energy Agency (IEA), the world needs to increase the share of green sources in district heating from 8% today to about 35% in 2030 to reach net zero. If we succeed, this will help to slash carbon emissions from heat generation by more than one-third.[8] The solutions are there to meet that goal and more.

In Sønderborg Municipality, Denmark, carbon emissions from space heating and domestic hot water have dropped by 73% since 2007 and the local district energy systems have been key drivers.[9]

7. IEA (2021). District Heating.
8. IEA (2021). District Heating.
9. ProjectZero (2021), Monitoring report 2020 Sonderborg Municipality, p. 38-39.

One of the main strengths of district energy systems is their capacity to integrate different heat sources that can push fossil fuels out of the heating and cooling mix. As a result of improved energy efficiency, temperatures in the district energy systems have been lowered over time, which allows for even more green sources to be introduced into the system.[10]

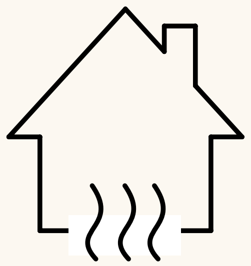
That includes excess heat. A laptop generates heat to operate, and a data center does the same in large scale. Excess heat from data centers can be reused through the district energy system to supply heat to buildings and industries. The same goes for supermarkets, biogas production, wastewater management and many other daily processes. Heat is generated as a waste product, and it can be reused or sold, instead of being simply released into the atmosphere. The binding link is the district energy system.

Linde Haven is at the forefront of low-temperature green district heating and aims at operating at a temperature of 57°C when installations are complete, compared to the typical supply temperature of 70°C. When complete, Linde Haven will demonstrate the full potential of the link between modern, low energy buildings and energy efficient district heating.

10. Thorsen, J. E., Lund, H., & Mathiesen, B. V. (2018). Progression of District Heating – 1st to 4th generation.

The potential in energy efficient buildings and green district heating

The energy efficiency of buildings defines their operational temperatures. Operational temperatures at Linde Haven are low, and therefore the district heating temperatures can be lowered as well. Low district heating temperatures result in lower distribution heat losses. And better insulated distribution pipes reduces the heat loss further. It is estimated that the lower temperatures in the network have the potential to save 81 MWh a year – equal to a reduction of distribution heat loss of 31% compared to a similar building operating at normal temperatures.



31%

reduction in heat distribution loss compared to similar buildings operating on normal temperatures.

Energy savings can be found in buildings all over the world

Active energy measures can drive energy consumption down in both new and existing buildings all over the world.

The efficient airport in Istanbul, Turkey

Once complete, Istanbul's new airport will have an annual passenger capacity of up to 200 million, making it the world's busiest airport. The vast airport is built with energy efficiency in mind. The main terminal building of Istanbul Airport, its state guest house, mosque and ATC tower were designed according to LEED (Leadership in Energy and Environmental Design) certification, which promotes energy efficiency in design and operations. With the help of control valves, the indoor climate is kept comfortable using the lowest amount of energy, while heating installations prevent snow and ice from gathering on the enormous roof of the terminal building.

Keppel Bay Tower in Singapore

Keppel Bay Tower in Singapore is an exceptional commercial building with an unparalleled location. The 18-story building, owned by Keppel REIT and managed by Keppel Land, has been certified as a Green Mark Platinum Zero Energy building by the Building and Construction Authority (BCA), making it the first commercial building in Singapore to achieve this distinction.

Retrofitting the tower with energy efficiency solutions has been key to Keppel Bay Tower's certification achievement. This includes retrofitting existing air handling units with new and emerging energy efficiency technologies to improve the energy efficiency of air ventilation in the building, which significantly reduced energy consumption in the Keppel Bay Tower.

Denmark's energy lab in Nordhavn, Denmark

Nordhavn, Scandinavia's largest urban development project, is underway in Copenhagen. The project EnergyLab Nordhavn showcases the latest energy solutions and is a living laboratory that shows how electricity and heating, energy efficient buildings and electric transport can be integrated into an intelligent, flexible, and optimized energy system, supplied by a large share of renewable energy as well as reused excess energy.

Affordable heating in Brooklyn, USA

In recent years, the average rent for a one-bedroom apartment in Brooklyn's Bushwick neighborhood has skyrocketed to more than $3,000 a month, excluding utilities. That is why New York City's Department of Housing Preservation and Development (HPD) and Ridgewood Bushwick Senior Citizens Council (RBSCC) came together to develop Knickerbocker Commons, a six-story, 24-unit, affordable multifamily building.

RBSCC wanted to cut tenant utility costs radically without compromising comfort, so they asked architects and engineers to design an ultra-low-energy building. Knickerbocker Commons features continuous exterior insulation, energy recovery ventilators, sealed combustion boilers, and individual room thermostat controls. It was the first mid-sized apartment building in the US to be certified to the Passive House Standard and was recognized in former New York City Mayor Bill de Blasio's One City: Built to Last program as an innovative approach to reducing the city's carbon footprint.

Stakeholder toolkit

Buildings have a long lifetime. Poor energy efficiency in new buildings locks consumption and operating costs in at a needlessly high level for decades to come. Even today, most new buildings are still being built with no effective mandatory efficiency codes. According to the IEA Net Zero Scenario, all new buildings must be zero-carbon ready in 2030. To meet this milestone, the following measures can be considered.

BUILDINGS

Set minimum requirements

Improve energy efficiency in new buildings by setting minimum requirements for specific areas, i.e., energy efficient cooling (in warm climates), energy efficient ventilation, energy efficient pumps and fans, and energy efficient appliances (IT equipment, fridges, freezers, washing machines, etc.). Furthermore, set building energy codes with minimum requirements for overall building energy performance, low-carbon materials and integration of onsite renewables or waste heat sources. If the new buildings are to become more energy efficient, it is essential to develop requirements for all new buildings, both residential and non-residential, public and private, and make sure to update the requirements regularly.

Address economic incentives

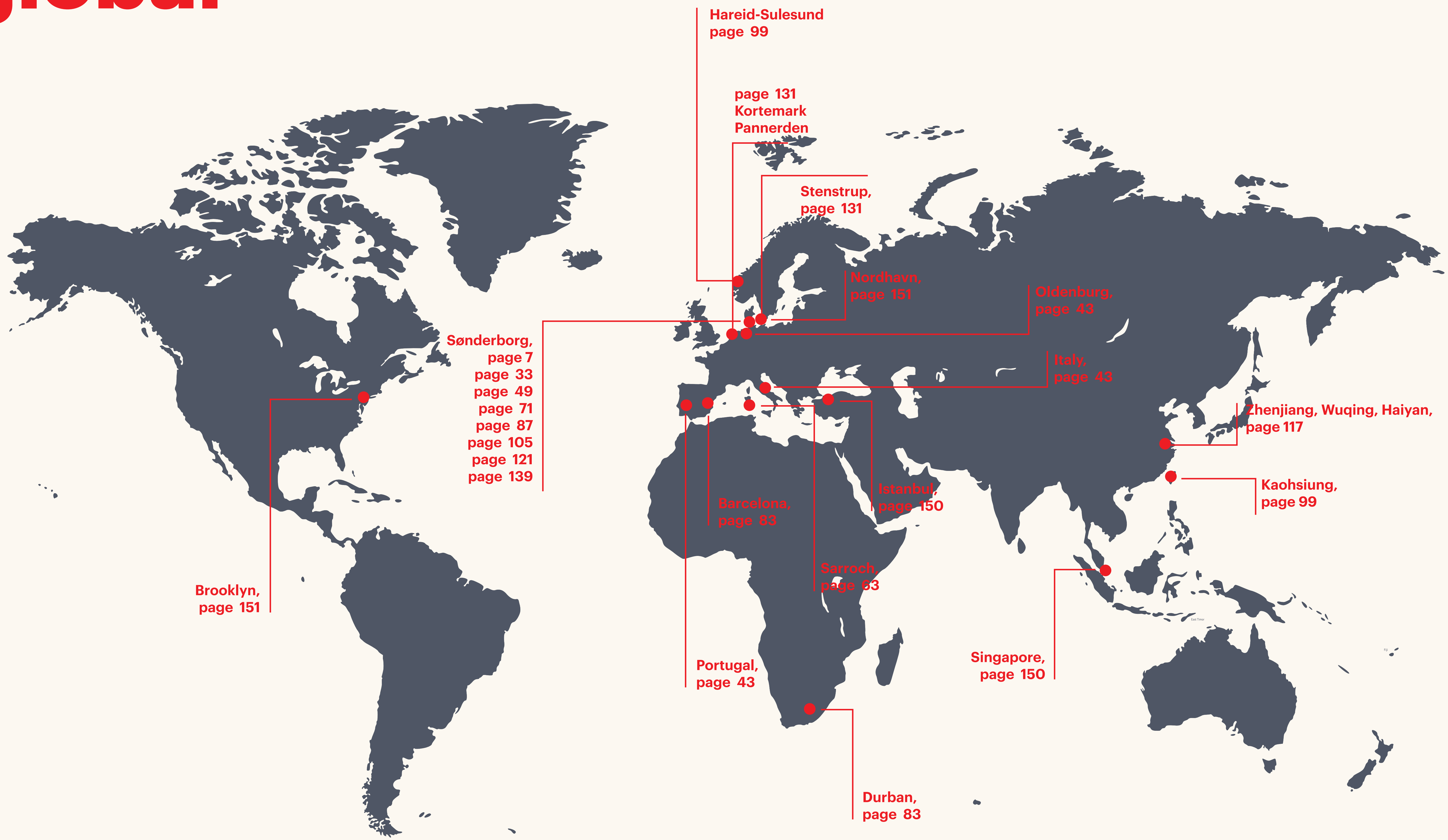
Make sure that taxes and fiscal policy support the construction of zero-emission buildings and address or alleviate barriers. Federal and local governments can reward green building construction and provide incentives to the different phases of green building construction, all the way from the planning phase throughout the operation of the building. For instance, governments can address the taxes on energy to make sure that there is an incentive to integrate heat sources such as excess heat. Furthermore, consider providing rebate incentives to stakeholders to offset the cost of procuring energy efficiency building features, and promote green mortgages and performance-based preferential loans to lessen the financial burden for stakeholders to construct and operate green buildings.

Establish partnerships

Initiatives like Linde Haven are possible through partnerships, and voluntary cooperation between different authorities and stakeholders is essential in any case. In order to promote energy performance certificates, passports and energy performance disclosure should be provided at the point of sale or lease. Meanwhile, partnerships and voluntary cooperation between different authorities are crucial for the provision of technical, financial and legal guides for the construction industry and other stakeholders. Furthermore, partnerships are also needed to provide training and education for craftsmen, architects, and engineers.

The potential is global

Energy efficiency solutions are applicable all over the world



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Learn more about how energy efficiency solutions can accelerate the green transition.

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