SECTOR INTEGRATION

Marselisborg, a path to an energy neutral water sector

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 CO2 emissions come from transport

Sector integration

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.

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.

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]

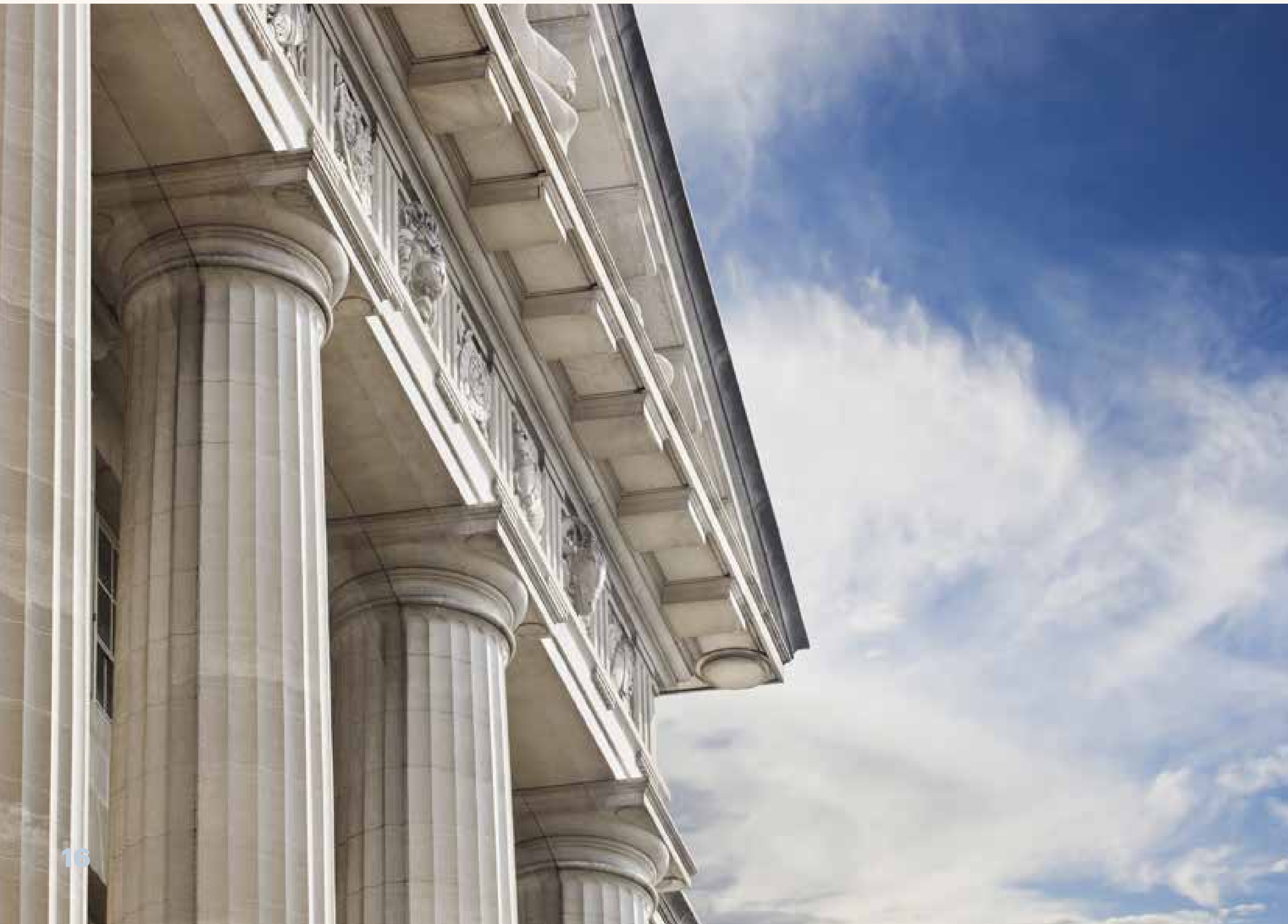
15. UN stats (2020). Ensure availability and sustainable management of water and sanitation for all.
16. International Water Association (2020). How can more water treatment cut CO2 emissions?

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.

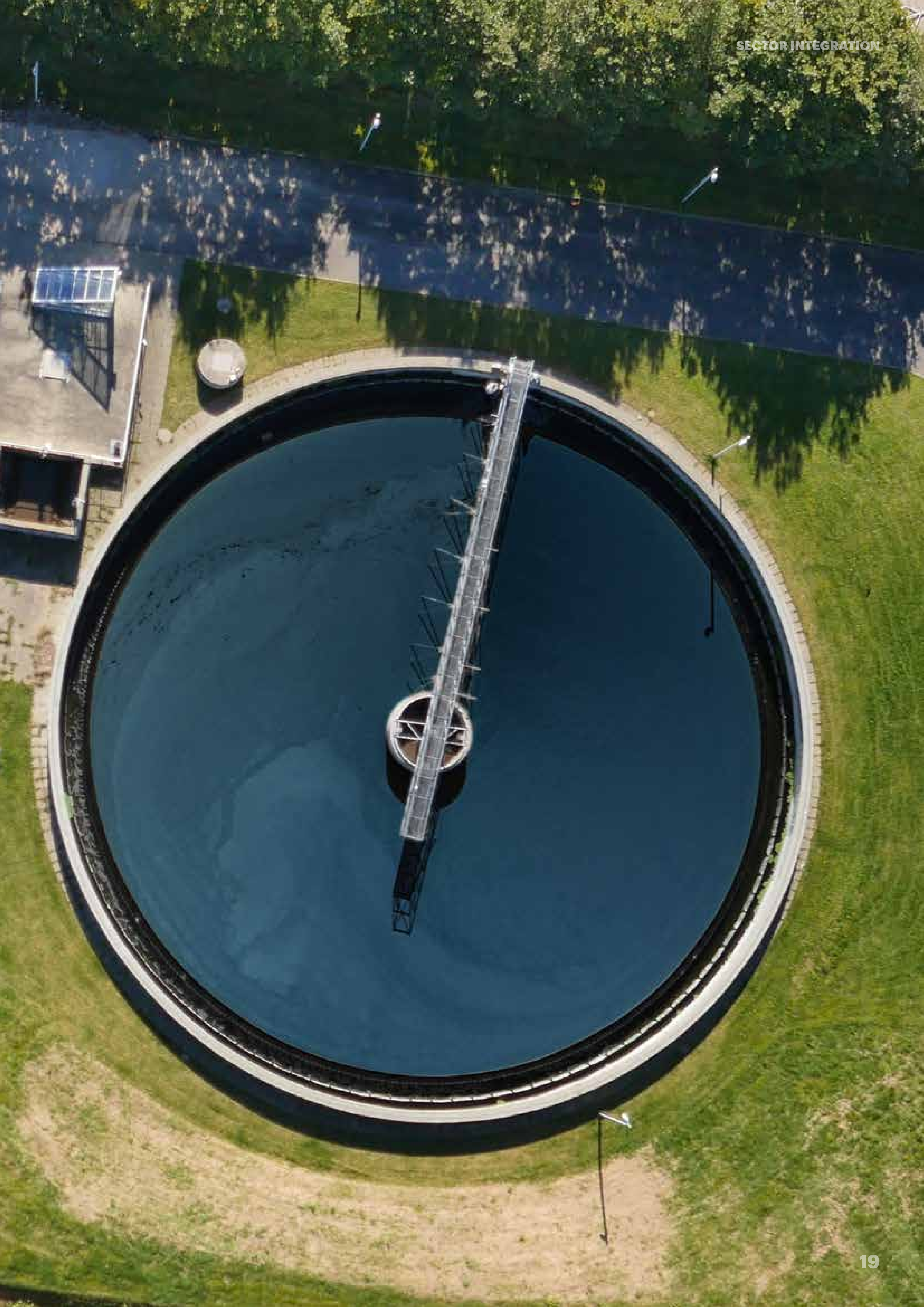
Depending on the existing energy system, energy planning can both reveal small-scale potentials (such as forming the right incentives to heat recovery or the potential of co-generation of heating and electricity) or it can reveal the potential of larger-scale opportunities such as the rollout of district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



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

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