Decarbonizing the Gas Grid: Lessons from Denmark/Sweden

Final Agenda

Sept 10 – Sept 15, 2023

Welcome to Denmark! We are so excited to have you with us, and we hope that you become equally excited about the Danish way of building sustainability into almost every aspect of daily life.

Our only two rules for the trip:

1. We leave exactly on time! We have a lot of ground to cover and want to be respectful of both our hosts and the other participants. This means if you miss a departure you will need to find your way to where we will be on your own. All departure times and addresses of our destinations are included in this itinerary.
2. We provide preselected wines for all group meals. If you would like to drink something different, such as a cocktail or an alternative wine, please let the wait staff know that you will be paying for that on your own.

We encourage you to read I-SUSTAIN's report, Decarbonizing the Gas Grid: The Role of Renewable Fuels in Denmark's Path to Carbon Neutrality, in advance of our meetings. This report, available on the i-SUSTAIN web site at https://www.i-sustain.com/decarbonizing-gas-2023background, will provide valuable background and context.

SUNDAY (10 Sept) - Copenhagen

Directions to our hotel: With a station right at the CPH airport, it's easy to catch the Metro. Buy a 3-zone ticket to center city at the self-serve DSB vending machines in the main terminal. Then take the elevator up to the Metro station, where you will catch the M2 toward Vanløse Station. Trains depart every 3 minutes, so there's no need to run! Go eight stops (13 min.) to Kongens Nytorv Station. Once you're at Kongens Nytorv go up the two banks of escalators and keep walking in that direction until you see the Gade Street / Strøget exit. Take the stairs (or the elevator) up to street level, and with the Rolex sign behind you walk around the square toward the building with the Huawei sign. Nyhavn, a busy pedestrian-filled street, will then be to your right. From Kongens Nytorv, it is a 9-minute walk (1/2 mile) to Hotel 71 Nyhavn.

Afternoon – check into our hotel in Copenhagen, 71 Nyhavn

King Christian IV founded the Nyhavn area to support the flourishing trade in the 1600s. The harbor was completed in 1673 as an alternative to the old port (the name Nyhavn was derived from "Den Nye Havn", the New Harbor) and for many years Nyhavn was a busy commercial port where ships from all

over the world docked. The 1,500-foot-long canal in Nyhavn was constructed to make Denmark more competitive in the trade business by creating a waterway that led straight into Kongens Nytorv – the new upcoming city center of Copenhagen. The warehouse was built in 1805 and became a hotel in 1971. It's a great example of urban reuse.

5.00p – leave our hotel lobby for an eight-minute walk to the Phoenix Hotel (Bredgade 37)

5.15p to 6.45p – introductions, review the itinerary and then a welcome toast over Aquavit

6.45p – leave the Phoenix Hotel to walk a short distance to Hummer (Nyhavn 63A)

7.00p – welcome dinner at Hummer

MONDAY (11 Sept) - Copenhagen

Please note that long pants and closed flat shoes (no high heels) are required for our afternoon visit to the Copenhill plant.

8.30a to 9.00a – take our bus to the Danish Energy Agency for our morning meetings (Carsten Niebuhrs Gade 43, 1577)

9.00a to 11.30a – series of meetings at Danish Energy Agency

9.00a to 9.30a – State of Green: Denmark's Green Transition

State of Green is a not-for-profit, public-private partnership that seeks to foster relations with international stakeholders. This presentation will provide an introduction to Danish perspectives on the role of renewable energy and renewable fuels, with an emphasis on how Danish companies and solutions are allowing the nation to decarbonize the energy sector while achieving economic growth.

9.30a to 10.15a – The Confederation of Danish Industry: Biogas in Denmark

The Confederation of Danish Industry (DI) is Denmark's largest and most influential business and employers' organization. DI believes that a strong society needs strong companies – just as strong companies benefit from a strong society. We will hear about the goals of industry in Denmark, how the government's policies have accelerated the growing biogas economy, and how the shift to a green economy has impacted labor and training needs.

10.15a to 11.30a –Danish Energy Agency: PtX and Green Hydrogen Initiatives

The Danish Energy Agency, established in 1975, is an agency of the Danish Ministry of Energy, Utilities and Climate and Energy and is responsible for activities related to energy production, supply and consumption, as well as Danish efforts to reduce carbon emissions. This includes responsibility for the regulations regarding government subsidies and other support for sustainable biogas and hydrogen production. The Agency will provide an overview of Danish climate goals and government policies related to green hydrogen production through Power-to-X.


11.30a to noon – take our bus to lunch at Reffen-Copenhagen Street Food (Refshalevej 167A, 1432 København)

Noon to 1.30p – no host lunch at Reffen-Copenhagen Street Food

Reffen is an organic street food market and urban area for start-ups, innovation and creativity in Refshaleøen in Copenhagen. You'll find more than 50 start-ups in the form of food stalls, bars and creative workshops. The ambition is to create a melting pot of cultural experiences and innovative projects that attract and inspire both locals and tourists.

Contact info: Patricia Chase: +1.206.349.4904 | Jayson Antonoff: +1.206.354.2278

1.30p to 2.00p – take our bus to Copenhill Waste to Energy Plant (Amager Resource Center, Vindmoellevej 6, DK-2300 Copenhagen S)



2.00p to 4.00p – series of meetings at Copenhill Waste to Energy Plant

2.00p to 2.45p – Ørsted's Carbon Capture Initiatives

Ørsted is establishing carbon capture at the Avedøre Power Plant and at its wood chip fired Asnæs Power Station in Kalundborg. The plants will begin capturing and storing approximately 430,000 tons of biogenic CO2 annually, starting in 2025. The Asnæs Power Station will not only serve as hub for the capture and shipping of Ørsted's own biogenic CO2, but potentially also for shipping CO2 produced by other emitters. This project will be the first step in establishing a large-scale CO2 infrastructure across Denmark, as Denmark hopes to not only remove domestic carbon, but also transport CO2 from surrounding nations for storage under Danish soil, becoming a regional leader. In direct support of this project, Microsoft signed an agreement with Ørsted to purchase 2.76 million tons of high-quality, durable carbon removal over 11 years from the capture and storage of biogenic carbon from the Asnæs Power Station. This represents one of the world's largest carbon removal offtake agreements by volume, to date.

2.45p to 4.00p – Presentation and Tour of Carbon Capture at Copenhill Plant

Amager Bakke (Amager Hill), also known Copenhill, is a combined heat and power, waste-to-energy plant and recreational facility within view of the city's downtown. The facility opened in 2017 and was designed to play a major role in Copenhagen's ambitions of meeting zero carbon requirements by 2025. This is the world's cleanest and most advanced waste processing plant, comfortably outperforming the EU's standards for best practice. The plant is currently working toward achieving carbon neutrality, with a new carbon capture demonstration plant, inaugurated in August 2023, expected to capture up to 4 tons of CO2/day. The goal is to commission a full-scale carbon capture unit that will capture up to 500,000 tons of CO2 annually.

In addition to the waste management and energy production aspects of the plant, the building demonstrates how an industrial facility, typically designed to be hidden from public view, can be sited close to an urban center and provide important public amenities. The recreational components of the facility, which include a dry ski run, hiking trail and climbing wall, are used by an estimated 40 to 60 thousand visitors annually.

4.00p – enjoy the view for a few minutes at the top of Copenhill

We'll take our group bus back to our hotel, or you can stay to enjoy a no host beer and meet us at the hotel or the BrewPub for dinner. For those that don't want to take the group bus it's a pleasant two-mile walk back to the hotel.

6.00p – we will be leaving the hotel lobby with those that want to walk together to dinner, or you can just meet us at the restaurant

6.30p – casual group dinner at BrewPub Copenhagen (Vestergade 29)

TUESDAY (12 Sept) – Copenhagen to Aarhus

8.15a – make sure you are checked out of your room and your bags are on the group bus

8.30a to 9.00a – take our group bus to Dansk Metal (Molestien 7, 2450 København SV)

9.00a to 10.00a – meeting with Dansk Metal

Dansk Metal is the union that represents the metal workers in Denmark, with workers in automotive, IT, telecommunications, construction, aviation,. and other industries. Dansk Metal is also building new homes – including student and dormitory housing, as well as apartments – at the Sydporten in Copenhagen, where members of Dansk Metal have the first right to rent. The union represents many of the workers who are key to the growth of the green economy in Denmark. We will be hearing about their initiatives to provide training and workforce development for these critical skills.

10.00a to 10.45a – take group bus to EnergiNet (Pederstrupvej 76, 2750 Ballerup)

11.00a to 12.30p – series of meetings at EnergiNet

11.00a to 12.00p – meeting with EnergiNet

Energinet is an independent public enterprise owned by the Danish Ministry of Climate, Energy and Utilities. As the Danish national transmission system operator it owns, operates and develops the transmission systems for both electricity and natural gas in Denmark. Energinet

also oversees the green certificates issued for carbon credits for biofuels, and established the quality guidelines for RNG that is injected into the national distribution system. The presentation will cover:

- An introduction to Energinet
- Danish biomethane experiences
- Future Danish hydrogen backbone
- EU developments and regulation

12.00p to 12.30p – meeting with Green Hydrogen Hub

Green Hydrogen Hub (GHH) aims to be the world's first project to combine green hydrogen production with two large-scale energy storage solutions – underground storage of hydrogen and compressed air energy storage (CAES). GHH is located in an area where large caverns suitable for storage of hydrogen are created in salt deposits. It's also close to existing energy infrastructure, including the high-voltage electricity transmission grid, the gas transmission network, and wind resources. We will visit the proposed GHH site the following day.

The presentation will describe how existing natural gas infrastructure can be repurposed as needs change, and will demonstrate the role that an underground storage facility such as this can play in decarbonizing energy systems.

12.30p to 1.30p – group lunch at the Energinet cafeteria

1.30p to 2.45p – take group bus to Odden Ferry Harbor

3.30p to 4.50p – ferry to Aarhus (MOLSLINJEN A/S, Færgevej 7A, 8000 Aarhus)

5.00p – arrive by our group bus at Hotel Royal in Aarhus (Store Torv 4, 8000 Aarhus)

Evening – stroll through lovely Aarhus and enjoy dinner on your own

WEDNESDAY (13 Sept) – Aarhus to Esbjerg, via Skive

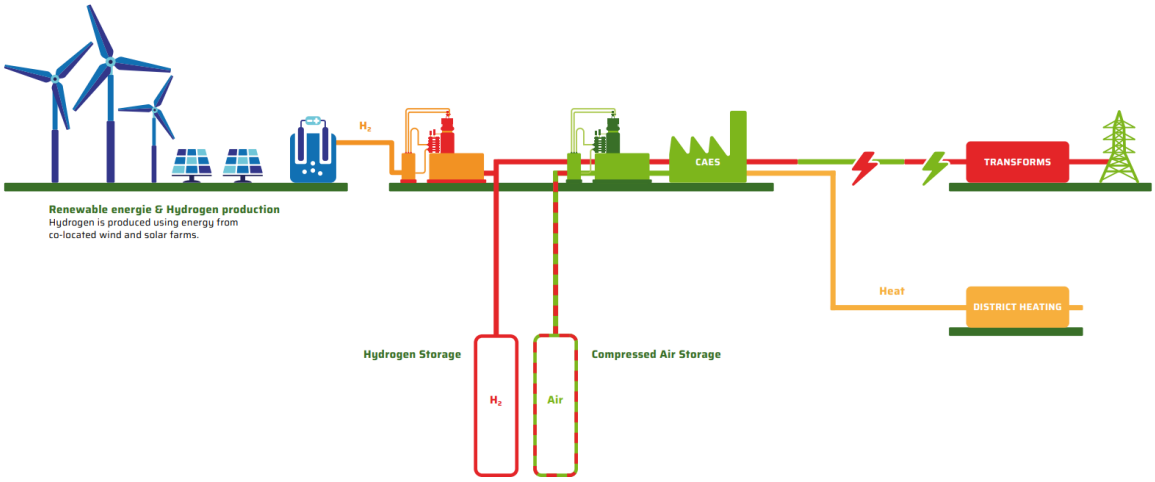
8.45a – make sure you are checked out of your room and your bags are on the group bus

9.00a to 10.30a – take group bus to the Green Hydrogen Hub, Lille Torup (Rækkeborgvej 4, 9620 Aalestrup)

10.30a to 12.00p – tour of Gas Storage Denmark facility

The existing Gas Storage Denmark facility at Lille Torup is proposed to be converted into the Green Hydrogen Hub (GHH), a facility for storing and using green hydrogen. This project will take three of the seven salt caverns currently used to store natural gas and repurpose them for green hydrogen storage and compressed air energy storage (CAES). When the weather allows for generation of more wind energy than what is demanded, this excess energy will be used for electrolysis to generate green hydrogen. Part of the hydrogen will be used to fuel the CAES facility, where air from the atmosphere is compressed and then stored. When renewable energy sources do not produce enough electricity to satisfy the demand, the compressed air can be released from the storage and through turbines in the CAES facility to generate green energy once again. The other part of the hydrogen that is produced by electrolysis is stored in another cavern. This hydrogen can either be used in its pure form as fuel or combined with carbon or nitrogen to produce sustainable e-fuels. The green hydrogen can be stored for as long as six months, which will enable GHH to provide green energy all year round, regardless of the weather.

We will break into two smaller groups to tour the facility and learn about the current operations as a natural gas storage facility, as well as how things would change if the facility is repurposed for green hydrogen and compressed air storage.



12.00p to 12.30p – take group bus to Restaurant Hjarbæk Fjord for lunch (Stavildvej 2A, 8832 Skals)

12.30p to 1.30p – lunch at Restaurant Hjarbæk Fjord

1.30p to 2.15p – take group bus to GreenLab Skive (Næstildvej 10A, DK-7860 Spøttrup)

2.15p to 3.45p – visit GreenLab Skive

GreenLab is a unique, green and circular industrial park, established in 2019 to test, demonstrate and accelerate the green transition by improving the way renewable energy is produced, converted, stored

and utilized. It generates sustainable energy, supplies it to the businesses located there, and transforms it into heat, electrofuels, and other green products. The GreenLab Biogas plant produces 21M m3 of biogas per year, and handles both manure and industrial waste from nearby production facilities.

With its projects, GreenLab is also a frontrunner in green hydrogen and has helped to solve the knots that arise when a whole new market is created, and value chains are assembled. GreenLab's unique SymbiosisNet™ enables the park's companies to share surplus energy - in all its forms - with each other, ensuring an efficient and higher utilization of renewable energy and a meaningful conversion from electricity to e-fuels.

3.45p to 4.15p – visit Green Hydrogen Systems' PtX facility at GreenLab Skive

GreenLab is a frontrunner in PtX and expects to launch the world's first full-scale PtX production facility, projected to reach 12MW, by 2023. That will enable the production of green hydrogen, scalable hydrogen storage and distribution, as well as PtX symbiosis activities such as methanol production. In 2024 GreenLab plans to begin construction of a 100 MW electrolysis plant involving several national and international partners. The GreenHyScale plant will employ pressurized alkaline electrolysis to enable large-scale production of green hydrogen, enabling the establishment of a commercially viable hydrogen infrastructure. Alkaline electrolysis is the most cost-efficient type of electrolysis, and a technology that efficiently works with the variable load from renewable electricity sources.

4.30p to 7.00p – take group bus to our hotel, Hjerting Badehotel (Strandpromenaden 1, 6710 Esbjerg)

7.30p – group dinner at the Brasserie Ship Inn restaurant at our hotel

THURSDAY (14 Sept) – Esbjerg to Malmö

9.30a – make sure you are checked out of your room and your bags are on the group bus

9.45a – leave hotel on our group bus to go to the Esbjerg Business Park (John Tranums Vej 23, 6705 Esbjerg Ø)



10.00a to 11.45a – bus/walking tour of Esbjerg, the center of green energy in Denmark

Esbjerg is a case study in the energy transition in action, having evolved from Europe's biggest fishing port, to Denmark's oil and gas hub, to being the world's leading offshore wind port, and now transitioning to become a future hub of power-to-X. The city of 72,000 people has more than 250 companies working in the energy sector.

The Port of Esbjerg has entered a cooperation agreement with Danish labor market pension fund PensionDanmark to invest up to $1B in the port's green transition. While much of the investment is expected to go towards the construction of offshore wind turbine production facilities, more than $100m will be used to build terminals for handling Power-to-X and the capture and storage of CO2 by 2028. In addition, the Danish fund management company Copenhagen Infrastructure Partners (CIP) has unveiled plans for the establishment of Europe's largest production facility of CO2-free green ammonia. The Power-to-X-facility will turn power from offshore wind turbines into green ammonia for use by the shipping industry as a CO2-free green fuel. The facility, which is expected to be built by 2028/29, will use a 1GW electrolysis facility to produce up to 900,000 tons of green ammonia annually. This is expected to reduce CO2-emissions by about 1.5 million tons yearly – equivalent to removing 730,000 cars from the roads.

H2 Energy has plans to establish a 1.2 GW electrolysis plant in Esbjerg, which will annually produce between 90,000 and 100,000 tons of green hydrogen for heavy transport and industrial purposes. Evida is currently conducting a feasibility study of constructing a 90 km hydrogen pipeline to transport this green hydrogen between Esbjerg and Fredericia. This would be an important step towards the realization of a hydrogen pipeline infrastructure. Market players expect that 87 percent of hydrogen produced In Denmark from 2030 onward will be transported via pipes.

11.45a to noon – take group bus to Nature Energy Korskro Plant (NE Korskro, Lunde Hovedvej 51, 6705 Esbjerg Ø)

We will provide you with box lunches and snacks to eat now or later in the day.

Noon to 2.00p – Nature Energy Korskro Plant, presentation and site visit

Noon to 1.00p – presentation on Nature Energy and the Korskro Plant

Nature Energy began in 1979 as Naturgas Fyn, a natural gas distribution company. It established its first biogas plant in 2015, and today is Denmark's largest producer of biogas, and one of the leading producers of biogas in the world. Nature Energy currently has 11 operational biogas plants throughout Denmark, consuming manure and food waste, with several more under development. The Korskro plant receives manure from cattle and pigs, organic waste from industry and retail, and a small amount of energy crops (corn silage). The plant produces about 780M cf of biogas that is upgraded to RNG, and then injected and distributed via the natural gas network. They also capture carbon dioxide for use in the food and beverage industry. Nature Energy Korskro is a joint ownership between Nature Energy and the farmer-owned supplier association Sydvestjysk Biogas AMBA, which consists of approximately 100 suppliers.

1.00p to 2.00p – tour of the Korskro Plant

2.00p to 6.00p – take group bus to our hotel in Malmö (a 3.5-hour drive with a 30-minute rest stop)

We will use our time on the bus for a rolling meeting to discuss what we saw during the week, its significance, and its relevance to our own region.

6.30p – arrive at Clarion Hotel Malmö Live (Dag Hammarskjölds torg 2, 211 18 Malmö)

7.45p – Leave hotel to walk to our restaurant, Buccan (Norra Vallgatan 78, 211 22 Malmö)

8.00p – Farewell dinner at Buccan

FRIDAY (15 Sept) - Malmö

8.45a – make sure you are checked out of your room and your bags are on the group bus

9.00a – leave hotel to take group bus to our site visit (location tbd)

9.30a to 11.00a – site visit of a geothermal system (tbd) in Malmö

Ground source heating and cooling systems (geothermal systems) take advantage of the relatively constant temperatures beneath the earth's surface - this constant earth temperature is higher than

average winter temperatures, and lower than average summer temperatures. Heat pumps can operate efficiently by transferring heat between a building and the earth. These systems can use either shallow ground loops or deep bore wells that are hundreds or even thousands of feet deep. ATES (aquifer thermal energy storage) systems improve the efficiency of heat pump operations even more. A typical ATES system uses pairs of deep wells to draw groundwater from underground limestone layers. Each pair contains one well for heat storage, and one for cold storage. During summer the water is pumped up from the cold wells and passes through a heat exchanger, which is connected to the building's cooling system. This heated water is then reinjected into the aquifer through the hot storage wells. In winter the process is reversed. Water is pumped from the hot storage wells and, after heat is extracted by running it through the heat exchanger, the water is reinjected into the aquifer through the cold wells.

11.30a to 12.00p – Go to the airport on our group bus (optional)

Our bus will take whoever wants to get to Copenhagen Airport (CPH) by noon, for an early afternoon flight. For those opting to go to CPH from Malmö on their own, the most efficient and cost-effective way is by train. The train station is an 8-minute walk from the hotel. The 803 or 804 train will take you to the international terminal of the airport. Total time, door to door, is 30 min, and the train runs every 20 minutes.

Figure 1 - Trip Overview

Click on this map to go to an interactive, on-line view with labels for all the places we will be visiting.

Additional Information for guests:

Guests are welcome to come with us on the group bus as we travel between different sites, and join us for all group dinners. However, guests are not allowed to participate in meetings or site visits, which means there could be a lot of waiting around. To minimize this, we would like to suggest an alternative program for the days when we have long bus rides and meetings in the countryside without a lot for guests to do.

Sept. 10 - Same as group

Sept. 11 - Hang out on your own in Copenhagen while the group attends meetings and site visits.

Sept. 12 - While the group travels on the bus with several stops for meetings guests can take the non-stop train to Aarhus, where we will all be spending the night. The train is very easy to use in Denmark and will take just under three hours from the Copenhagen central station. i-SUSTAIN will reimburse you for your train fare but you are responsible for getting to the train station, buying your tickets, and getting to the hotel in Aarhus.

Sept. 13 - While the group travels on the bus in the hinterlands with several stops for meetings, i-SUSTAIN will hire a private taxi for the guests to take you to Legoland, in Billund. All guests must travel at the same time. We will pay for the taxi but you are responsible for paying for Legoland. We will then have another private taxi take you from Legoland to our hotel in Esberg. Again, you must all agree to leave at the same time.

Sept. 14 – The bus will pick you up at our hotel at 1.30p and then you will travel with us on the bus to Copenhagen.

Sept. 15 - You can enjoy yourself in Malmö, which is a lovely city, while the participants are in the program.