Electrification of U.S. Industry: Applying Lessons from Denmark

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December 2024
White Paper

ACEEE

About ACEEE

The **American Council for an Energy-Efficient Economy** (ACEEE), a nonprofit research organization, develops policies to reduce energy waste and combat climate change. Its independent analysis advances investments, programs, and behaviors that use energy more effectively and help build an equitable clean energy future.

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Acknowledgments

The authors gratefully acknowledge external reviewers, internal reviewers, colleagues, and sponsors who supported this report. External expert reviewers included Danielle Sass Byrnett from the National Association of Regulatory Utility Commissioners, Claus Krog Ekman from the Consulate General of Denmark in Silicon Valley, and Claus Andreasson from the Danish Energy Agency. Internal reviewers included Archie Fraser, Steve Nadel, Nora Esram, and Neal Elliott. External review and support do not imply affiliation or endorsement. Last, we would like to thank the following members of ACEEE's editorial and communications team: Ben Somberg, Camron Assadi, Kate Doughty, Keri Schreiner, Mariel Wolfson, Mark Rodeffer, Mary Robert Carter, Nick Roper, Rob Kerns, and Roxanna Usher for their help in launching this report.

Suggested citation

Hoffmeister, Andrew, Richard Hart, and Hellen Chen. *Electrification of U.S. Industry: Applying Lessons from Denmark*. Washington, DC: ACEEE. www.aceee.org/white-paper/2024/12/electrification-us-industry-applying-lessons-denmark.

Data and licensing information

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Executive summary

This white paper presents findings and how to apply lessons learned from a June 2024 study trip to industrial electrification sites in Denmark.

Key findings

- Strong, clear national policy (and international standards and collaboration) drives industrial electrification in Denmark.
- Electrification is widely understood as a winning strategy for national competitiveness.
- Demonstrations of the successful use of electric technologies and energy efficiency in industrial plants are critical. They provide guidance and reassurance for future decarbonization projects.
- A centralized, independent testing facility supports industry through the energy transition. Companies rely on their results for performance and financial returns.
- Dynamic electricity pricing, a national energy data hub, and regional interconnections have been other important drivers of Danish electrification.
- Public–private partnerships between manufacturers and government are critical for accountability, government understanding of industry needs, and engagement.
- The United States can accelerate into a new era of industrial resilience by applying lessons learned from our allies, such as Denmark. We can build on existing collaboration between stakeholders, including policymakers, utilities, industrial firms, technology vendors, and others.

Electric technologies are critical for reducing industrial energy costs, improving modularity of heating to meet specific temperature requirements, and boosting the competitiveness of domestic manufacturers. They are also essential for decarbonizing industrial process heat, which is a major source of emissions in the United States (Rightor et al. 2022; Hoffmeister, Chen, and Eisen 2024).

This white paper looks toward electrification-enabling strategies that are in place or being pursued internationally, where there is more experience. It describes the political, economic, and energy landscapes that have allowed the uptake of electric technologies in the industrial sector, and the suite of policies and approaches that can be appropriated for the United States to the same effect. The lessons described in this white paper are based on a study trip to Denmark in June 2024 that was led by the American Council for an Energy-Efficient Economy (ACEEE) and sponsored by the Consulate General of Denmark in Silicon Valley.

National policy and regulation are essential for creating an environment conducive to industrial electrification

Danish policies, political goals, funding pools, and data transparency have been critical in establishing a manufacturing landscape ready for electrification. Policies such as carbon taxes and subsidy programs have created market incentives for decarbonization through electrification. Political goals have enabled market certainty, public funding pools have created the capital necessary for industrial CapEx investments, and greater data transparency has allowed for the dissemination of success stories and the reduction of perceived risks.

In the United States, we can replicate this landscape through long-term federal and state commitments to electrify the industrial sector, effective state and federal policies in support of efficiency and electrification, public-facing case studies of electric technologies, and public funding pools that can make electrification of industrial processes affordable at scale.

Utilities and grid operators can improve the affordability of industrial electrification

The Danish dynamic electricity-pricing model for commercial and industrial customers has allowed for economical electrification and the associated load increases and for these same customers to anticipate rates and plan energy consumption accordingly.

In the United States, we should apply these lessons in industrial rate design and demand side programs, accommodating electricity demand through infrastructure buildout and additional resiliency measures. As well, data-sharing and real-time energy models similar to the Danish approach would allow utility customers to make more informed energy purchasing decisions.

Collaborations between government agencies and industry can minimize risks and build coalitions in decarbonization efforts

In Denmark, public–private partnerships and other joint ventures between industrial companies and the Danish government have helped minimize risks for industry while the government can ensure progress is made toward decarbonization goals. Additionally, collaboration has helped consolidate industry behind a holistic and cohesive action plan.

U.S. industry and government agencies can adopt a similar model, building sector alignment and coalitions around strategies. Through this approach, industrial companies can share concerns to help government agencies know which barriers need to be mitigated with the most urgency, and to deliver funding to the most critical parts of the electrification supply chain.

Electric technologies must be ready and available to meet demand

Denmark and other European countries have invested heavily in the manufacturing of electric technologies. They have also promoted public demonstrations and case studies of those technologies in international publications. Despite that, there are still supply chain issues to overcome and a need for additional investment in the manufacturing of electric technologies and their components to meet growing demand.

To avoid stoking demand and faith in technologies that cannot be expeditiously delivered to end users, the United States needs to make similar investments in the manufacturing of electric technologies, research and development into new applications, and increased capacities of such technologies.

Introduction

Industry accounts for over 30% of U.S. energy use and over a quarter of energy-related carbon dioxide (CO_2) emissions (DOE 2022). Some 51% of onsite industrial energy is used in producing and consuming process heat, of which only about 5% comes from electricity (DOE 2022). The vast majority of process heat needs are met through the combustion of fossil fuels, even for relatively low temperature applications.

Producing heat with electricity, rather than the combustion of fossil fuels, will be necessary to reach decarbonization targets and mitigate the worst impacts of climate change. To learn more about the status of the domestic industrial sector's use of electricity for process heat and the need to accelerate industrial electrification, please read ACEEE's industrial electrification brief (Esram, Johnson, and Elliott 2024) and visit ACEEE's industrial heat pump landing page (ACEEE 2023).

A U.S. delegation to Denmark spent five days in June 2024 learning about Danish progress in industrial electrification; successful applications of technologies like industrial heat pumps (IHPs), district heating, and electric boilers; the economic and policy factors that have enabled their adoption; and the anticipated future of decarbonization in Denmark. The delegation was composed of representatives of industry, utilities, regulators, federal agencies, state energy offices, NGOs, foundations, and more. Denmark was chosen as the delegation's destination because of its ambitious climate goals, diverse industry, and advanced progress in electrifying industry. For more information on the trip, please see the appendix.

In this paper, we summarize the essential learnings from Denmark's own industrial electrification strategy that are needed to enable a similar transformation at scale in the United States. Our focus areas are

- National policy and emissions regulation
- Grid operator programs and energy regulation
- Industry and corporate responsibilities
- Technology status and availability

National Policy and Regulation

What is the landscape of Danish policy and regulation?

Danish national policy and international regulation have created an environment conducive to widespread industrial electrification. These measures include the European Emission Trading system that covers more than 75% of emissions from industry and a CO_2 tax (currently $28.10 USD per metric ton of CO2e, updated yearly), as well as support for district heating and energy efficiency (Tax Foundation 2024).

The industrial transformation is supported by Denmark's established political goals, vision, and plan for a climate neutral society by 2045. A major upcoming milestone is a 70% reduction in GHG emissions by 2030 (Ministry of Foreign Affairs of Denmark 2024). These targets have set the stage for investment in electrification, by ensuring both an adequate supply of electric technologies and long-term policy that supports deployment of that technology. Approximately 15% of Danish emissions are due to industrial

processes (not including the emissions from the generation of energy consumed by industry). For comparison, approximately 23% of U.S. emissions are due directly to industrial processes (EPA 2024). Displacement of fossil fuels, and especially natural gas, in the generation and use of process heat, space heating, and district heating, is a primary pathway toward these targets. Figure 1 below (Buhler 2023) depicts Denmark's climate status and outlook from 2022–2035 for gas use by sector.

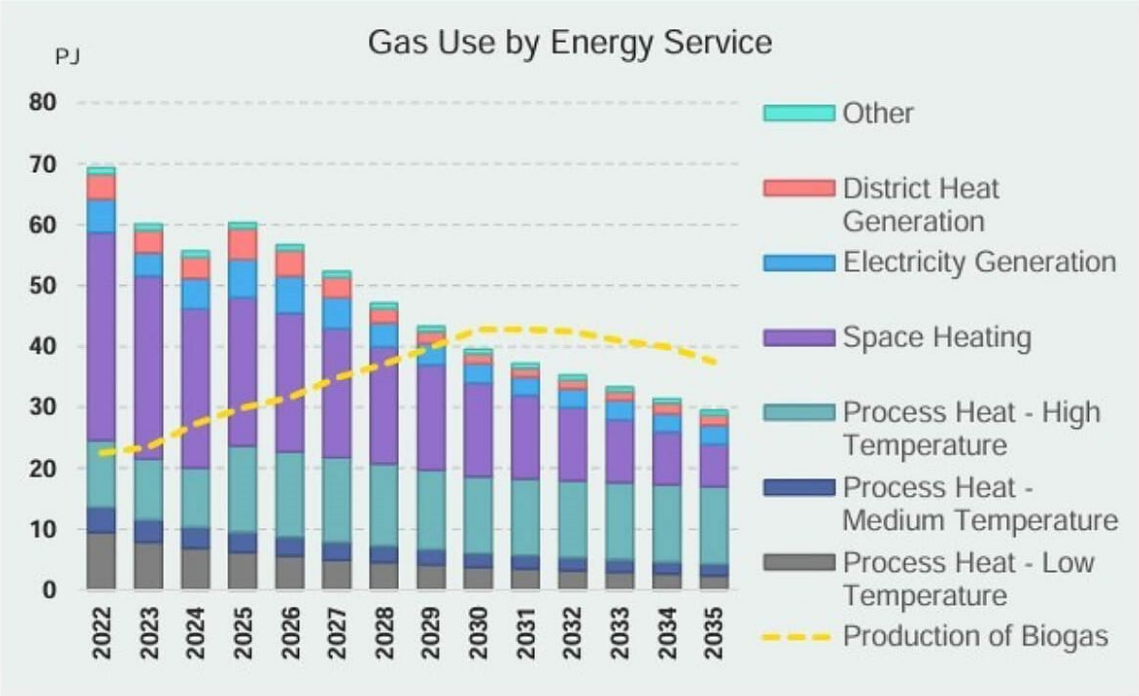

Figure 1. Danish gas use in petajoules (PJ) by end use. Source: *Buhler 2023*.

To reduce economic barriers for the industrial transition, Denmark has created a funding pool of more than $500 million USD through federal legislation for acquiring and installing decarbonization technologies, including electric technologies for industrial process heat generation. This support scheme enabled over 560 emissions saving projects at industrial facilities in 2022. Of those projects, 50% included electrification, while 30% included heat pumps (Krog Ekman 2024).

Other policy drivers (in no particular order) have contributed to this landscape for electrification of industry at scale, including

- Mechanisms to support data transparency: for example, over 700 Danish firms are required to report on emissions and energy use for tax filing purposes (Krog Ekman 2024)
- A focus on public–private partnerships to drive impactful investment beyond public transition funding (further details in "Industry and Corporate Responsibilities" section)
- Information and knowledge gap bridging, such as mandatory energy audits and energy management, which are recognized as two of the most effective pathways for improving efficiency (Buhler 2023)
- Regulatory measures such as emissions limits on compounds including NOx, SOx, and CH_4 (Buhler 2023)

- In 2021, the European Union's (EU) Energy Efficiency Directive introduced mandatory energy audits every four years for large companies (EC 2023a). The United States has no equivalent audit requirement.

How can these policies be applied to the United States?

Denmark and the United States are very different in their politics and energy landscapes. Industry in Denmark is responsible for just over 95 trillion British thermal units (Btus) of final energy consumption (IEA 2024a). This is approximately equivalent to industry in Maryland, which is responsible for about 87 trillion Btus of final energy consumption (EIA 2024).

Robust district heating networks, which are often used as a sink for industrial waste heat in Denmark, are not widely deployed in the United States and likely cannot be replicated on any large scale (beyond the city level—note that reuse of industrial waste heat in district heating offsets emissions for district heating networks rather than industry if fossil fuels are still being used at the industrial plant level). Additionally, the lack of a carbon price in the United States makes the value proposition for electric technologies more challenging. The costs associated with retrofitting, new equipment, retraining the workforce, and other activities must be offset by efficiency gains, public financing mechanisms, and co-benefits.

Despite these differences, however, there are several key learnings applicable to the U.S. context:

- Federal commitments toward long-term electrification and policy consistency, independent of government change, are key for investment decision making. These commitments can take the shape of national targets and international agreements. This strategy is difficult to replicate at the national level in the United States but is becoming more widespread at the state level. Policymakers and stakeholders can emphasize the technology-agnostic cost savings and the job-creating potential of electric technologies to build bipartisan support for electrification and continue to advocate for effective state-level policy.
- Energy and emissions data transparency, peer exchange, published case studies, and success stories of applications of electric technologies across subsectors of industry and various applications are essential in amplifying learnings and reducing perceived risk.
- Public funding pools, such as funding opportunities allocated by the U.S. Department of Energy, can motivate dozens of projects under the right circumstances.
- Energy efficiency enables electrification by right-sizing energy needs, and by adding cash to the bottom line of businesses. The Danish requirement for regular energy efficiency audits is paying off.

These key learnings (in no particular order) also align directly with the Danish Energy Agency's list of most important factors for enabling electrification and a transition away from industrial fossil fuel use:

- Political agreement to ensure continuity
- Incentives (both carrots and sticks) that focus on cost effectiveness
- Information sharing to establish a culture of saving energy
- Public–private accountability/collaboration across society
- Financing, transition funding pool, taxation

Grid Operator Programs and Regulation

What is the current Danish grid mix?

Utilities and grid operators in Denmark have been a key part of electrifying industry and enabling the circumstances for even greater uptake of electric technologies. However, a significant amount of work is still needed to reach Denmark's ambitious climate goals. Energinet, the independent, public enterprise that owns, operates, and develops Danish gas and electric transmission systems indicated an energy trilemma among

- National goals to increase use of renewable energy (solar and wind)
- Need to maintain security of supply
- Need to maintain affordability

Figure 2 depicts the Danish electricity and generation mix from 2022 (IEA 2024a). Denmark's plan for 2050 is to increase the share of electricity generated by solar and wind. The decarbonizing grid will deepen the decarbonizing impacts of electrification and ensure that the investments enabled by Danish and EU policy maximize the impact on GHG emissions.

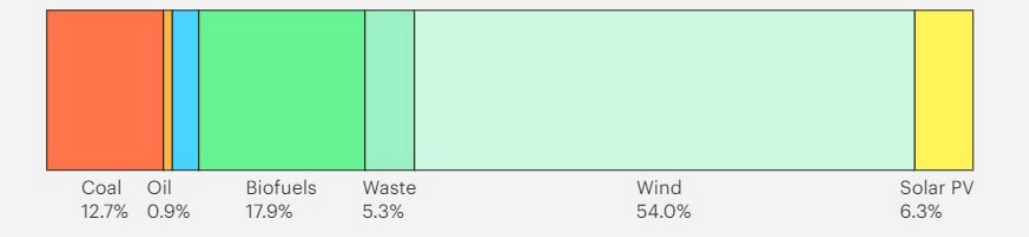

Figure 2. Danish energy (electricity) mix in 2022 by source, percentage. Light blue refers to natural gas. Source: IEA 2024a.

One of the most significant differences in grid operations between the United States and Denmark is the **dynamic pricing model** available to all commercial and industrial customers in Denmark. Prices vary by the hour, with day-ahead notice of the hourly price.

Energinet, the Danish national transmission system operator, provides a national database of energy meter data (Energinet 2024). Utilities and service providers have controlled access to the database so they can help customers anticipate costs and energy use ahead of time. The database also enables end users to more affordably access energy storage in various forms to provide demand flexibility.

Denmark is also fully connected into other European grids (Germany, Norway, Sweden, the Netherlands, United Kingdom) to interchange electricity. This allows for more flexible pricing and limits curtailment of renewable energy generators.

Energinet indicated that the Danish grid of the future will include

- More market participants
- More data
- More prosumers (entities that both produce and consume energy)
- More storage

What lessons can we apply to the United States?

Denmark's ambitious and economy-wide approach to electrification provides a roadmap that can be used by U.S. policymakers. Many of the issues related to electricity adequacy, grid planning, and affordability that Denmark is working to solve are being faced presently by state agencies, utilities, and businesses across the United States. Many of the lessons learned from Denmark's electricity grid can be applied to regions across the country. In particular, dynamic pricing and flexibility incentives allow industry to more economically electrify by strategically storing energy and minimizing spark-gaps—the difference in price between electricity and natural gas. Those lessons are summarized below:

- Energy prices often determine whether industrial electrification projects can proceed. Industrial rate design and demand-side programs that support cheaper and cleaner electricity, as compared to natural gas, can be impactful drivers to that end.
- Flexible industrial operations and distributed energy resources (DERs) can minimize the operational expenses of electrifying, especially in the United States where spark-gaps are typically greater.
- Data sharing and real-time energy grid models permit grid users to make more informed energy purchasing decisions.

Industry and Corporate Responsibilities

What is the relationship between industry and government in Denmark?

Danish industry has been engaged in energy efficiency since the oil crisis of the 1970s, through a mix of self-directed activities and engagement with policy from the Energy Ministry. Some examples over the past 30 years include

- In the 1990s, a voluntary program offered tax relief in return for a commitment to deep energy efficiency: for example, an obligation to implement energy efficiency investments with payback of less than four years and mandatory "energy efficient design" for CapEx projects[1] (Larsen, Karup, and Pipi 1998). The United States does have voluntary agreements with manufacturers to improve energy efficiency projects; however, funding is competitive and limited.
- From 2006–2020, Energy Efficiency Obligations were placed on energy providers, including escalating targets for annual energy savings. The industrial sector responded well to outreach from their providers, contributing 30–50% of overall savings, depending on the year (Danish Energy Agency 2010). The United States has no federal obligations on energy providers for annual energy savings, although about half of U.S. states do have such obligations (Subramanian et al. 2022).

Overall, Danish industrial firms have adopted these measures enthusiastically, seeing financial benefits in terms of cost reductions and competitive benefits in terms of exceeding supply chain requirements. The result has been a **47% reduction of energy intensity** from 1975 to 2021 (Bach 2024).

Recently, the drive to decarbonize and electrify has required buy-in from across the hierarchy and value chain of large industrials, from C-suite to plant-level managers. Even in the EU and Denmark, where district heating, energy prices, and carbon prices make the economics of purchasing electric

[1] CapEx, or capital expenditure, projects are large-scale investments; in this case for energy efficiency upgrades.

technologies more favorable than in the United States, perceived financial risk limits the agility and willingness of manufacturers to make long-term investments in electric technologies and the infrastructure required to sustain them. Additionally, electrification involves inherent risks, including grid reliability concerns and vendor continuity concerns. Public–private partnerships and joint ventures help minimize risks for industry while government can ensure electrification progress. For example, Danish Business Pool Subsidies can be used to reduce the costs of energy-saving projects by as much as 50%, further solidifying partnerships between government and private companies in decarbonization efforts (IEA 2023).

In Denmark, the government has made a concerted effort to consolidate industry behind a cohesive set of decarbonization actions. These recommended actions, called climate partnerships, are essentially roadmaps toward decarbonization for 14 different sectors of the economy and include the best entry points for how government can support and enable the initiatives of each sector (State of Green 2023).

Each sector came together in 2020 to create its own sector-wide goal and an action plan. For example, the plan for one of those sectors, energy-intensive industry, includes recommendations for (a) facility level redundancy in electric systems, (b) electrification, (c) biogas, and (d) removing taxes on the use and sale of excess heat (State of Green 2023). There have been over 400 recommendations made across the sectors. Figure 3 depicts the flow from climate partnerships to implemented recommendations in Denmark.

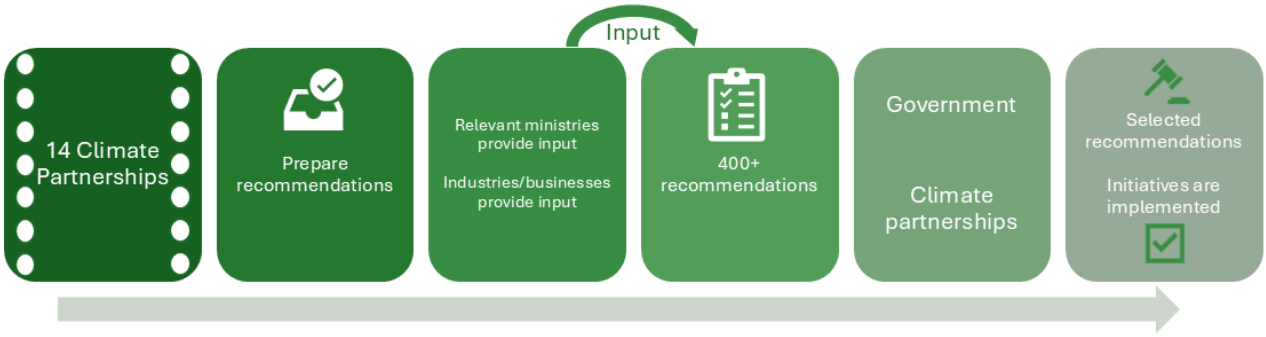

Figure 3. Danish public–private partnership formation. Source: Adapted from State of Green 2024.

What lessons can we apply to the United States?

- Public–private partnerships can build sectoral alignment and coalitions around decarbonization strategies, ensuring buy-in from industry.
- Partnerships have the potential to shape policy and funding, helping to incentivize risk-averse industrial firms, especially those with similar processes concerned about competition, to share perspectives.
- Long-term energy strategies are important for stability in both the energy market and manufacturing.
- Incentives should exist along with regulation: both sticks and carrots, with a focus on cost effectiveness.

- It is imperative to build on early progress enabled by DOE programs (including the 48C Manufacturing Tax Credit[2] and the Industrial Demonstrations Program[3]) to provide manufacturers with more funding to accelerate electrification projects and to deepen the connections between government agencies and the needs of the industrial sector.

Technology Status and Availability

What is the status of electric technology availability in Denmark?

The availability of electric technologies, and especially those that can reach higher temperatures and capacities, varies between Denmark, the rest of the EU, and North America. Because of a variety of factors already introduced—including energy prices, the prevalence of district heating, and decarbonization targets—electrification, and the technologies that enable it, are better ingrained in the EU market, with supply chains more clearly defined. Products that can reach sink temperatures of over 120 °C are advancing in commercialization and market stability in both Denmark and the rest of the EU, whereas in the United States they are just now approaching precommercial demonstrations. Table 1 depicts temperature ranges of process heating sinks in European industry, the technology readiness level of IHPs to provide that heat (where 1 is lowest and 11 is highest), and example processes for which those temperatures are required.

Table 1. IHP technology status by TRL[4] and applications. *Source*: IEA 2022.

Temperature range	Technology readiness level (TRL)	Example process
<80 °C	TRL 11: Proof of market stability	Paper: De-inking Food: Concentration Chemical: Bioreactions
80 °C to 100 °C	TRL 10: Commercial and competitive, but large-scale deployment not yet achieved	Paper: Bleaching Food: Pasteurization Chemical: Boiling
100 °C to 140 °C	TRL 8–9: First-of-a-kind commercial applications in relevant environment	Paper: Drying Food: Evaporation Chemical: Concentration
140 °C to 160 °C	TRL 6–7: Precommercial demonstration	Paper: Pulp boiling Food: Drying Chemical: Distillation Various industries: Steam production

[2] The Inflation Reduction Act (2022) expanded 48C to provide $10 billion in tax credits for industrials to construct clean energy projects, which include the manufacturing or installation of electrified heat technologies. The tax credit was 30% of the amount invested.

[3] The Bipartisan Infrastructure Law provided over $6 billion under the Office of Clean Energy Demonstrations for the Industrial Demonstrations Program (IDP). The IDP was intended to fund decarbonization projects in energy intensive industries, including those that enable the decarbonization of process heat. Almost $200 million were provided to major, multinational companies to that end.

[4] TRL refers to technology readiness level, or a measurement that assesses the maturity level of technology from low to high.

Temperature range	Technology readiness level (TRL)	Example process
160 °C to 200 °C	TRL 8–9 First-of-a-kind commercial applications for small-scale MVR systems and heat transformers TRL 4–5: Early to large prototype	Various industries: High-temperature steam production
>200 °C	TRL 4: Early prototype	Various industries: High-temperature processes

Despite the relative market stability of many electric technologies in Denmark, there are still significant lead times (estimated five months or more[5]) in Denmark and elsewhere in the EU. Additionally, intermittent supply chain issues have arisen due to geopolitical factors such as the Russian invasion of Ukraine, and a sharp increase in demand over the past five years. To ameliorate this, the Danish government is prioritizing investment in building up capacity to manufacture electric technologies and components, research and development of new technologies to reach higher heats and capacities, and the sharing of data and information in peer-based exchanges, like the International Energy Agency's (IEA) high-temperature heat pump annexes.

The IEA's Annex 48 includes 22 Danish case studies of IHPs, totaling 19 MW in capacity (IEA 2018). Figure 4 depicts IEA's anticipated timeline for IHP rollout and commercialization, leading to IHPs being established as the preferred technology by 2026–2030 depending on the temperatures reached and the capacity of application. The Danish perception of the market and supply chain mirrors this estimated timeline.

[5] As of August 2024.

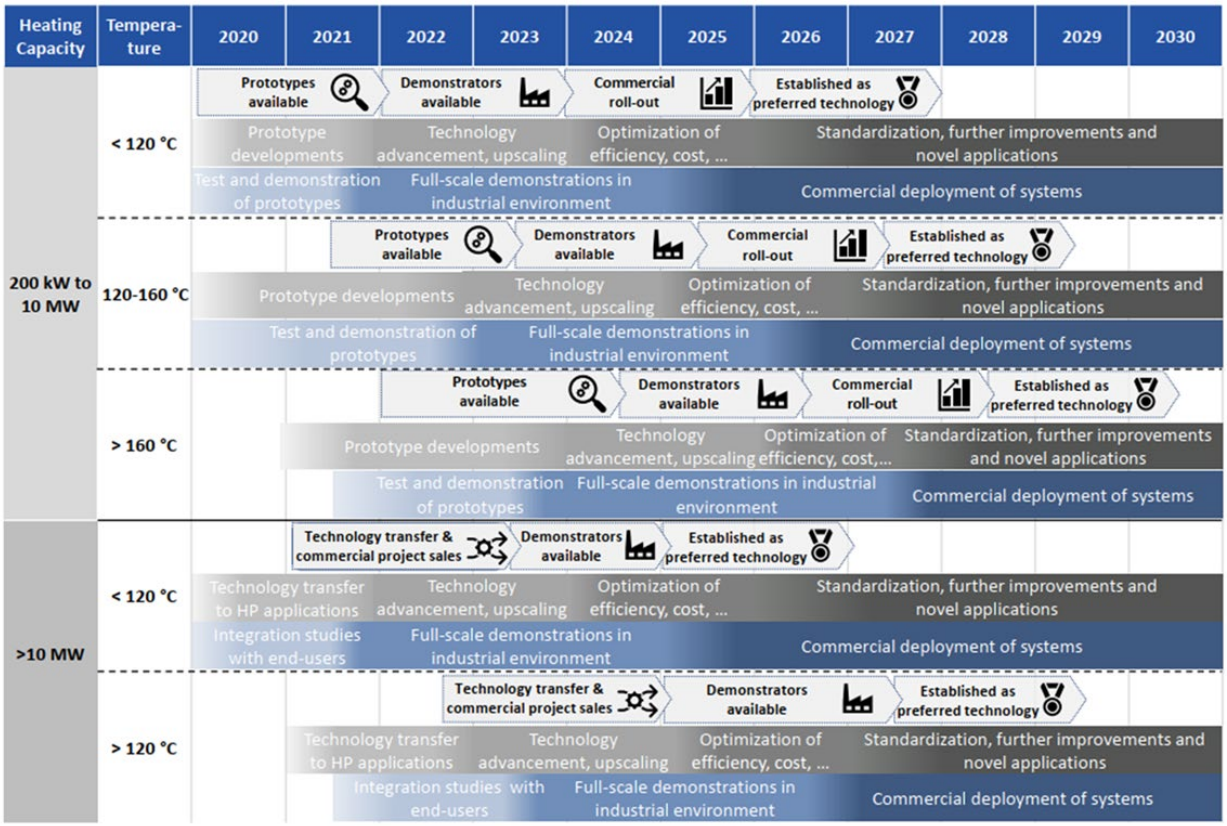

Figure 4. IEA IHP commercialization timeline. Source: *IEA 2024b.*

In addition to these efforts, the Danish Technological Institute (DTI), which is an independent nonprofit focused on research and technology, provides a critical service in advancing the Danish heat pump market. DTI contributes:

- Validation, such as rigorous testing of IHPs at scale.
- Integration services, including process integration assistance, on-site testing, and education.
- Development, including experimental testing of new technologies and simulation.

What lessons can we apply to the United States?

It is critical that the domestic supply and manufacturing of electric technologies and their components continue to develop so that U.S. industry has access to the same level of capacity as exists in the EU and elsewhere. Significant progress has been made to that end in recent years. Six global manufacturers of IHPs were selected for awards to scale up manufacturing in the United States in 2023 and 2024 (DOE 2023). Over 10 other large multinational corporations have begun to import their products to the United States and are investigating other funding pathways to U.S. manufacturing (IHPA 2024). There may be opportunities to leverage North American free trade to deepen IHP and IHP component manufacturing potential more quickly.

To capitalize on this momentum, it is essential that the federal and state government(s) dedicate additional funds to domestic manufacturing of electric technologies as well as research and

development (R&D) of new applications and advancements at national laboratories. This will ensure that supply meets a growing network of demand across industry and manufacturing subsectors.

Finally, an independent testing facility (like DTI's) at a site like the Electrified Processes for Industries Without Carbon Center (EPIXC) at Arizona State University, or a national laboratory, could serve as a test bed for the entire market, allowing potential end users to see various technologies in action across myriad applications and demonstrating energy savings.

Conclusions

Despite the fact that Denmark and many other countries in the EU are ahead of the United States in industrial electrification, we are not aware of any large facilities in Denmark that are yet fully electrified. Significant work is still required to align industrials, government, utilities, and other entities around the full decarbonization potential of electrification. Specifically, stakeholders in Denmark are working to

- Make supply chains more efficient and reduce lead times as much as possible.
- Continue to strengthen public–private partnerships to ensure that industry's concerns are being considered by government.
- Continue to make available pools of funding for mitigating initial capital costs.
- Develop paths to full electrification for industrial facilities, including other technologies such as thermal energy storage and onsite renewable energy generation.

Although the landscape in Denmark is different from that of the United States—in terms of politics, the district heating network, and the ubiquity of dynamic energy pricing—there are essential lessons to glean from the Danish, and EU, experience that U.S. stakeholders can use to further motivate the domestic electrification transition. Those high-level learnings include the following (in no particular order):

- Public demonstrations of electric technologies are essential. Participation in international case study collaborations, like IEA's High Temperature Heat Pump Annexes, can disseminate success stories and further progress.
- Strong, clear policies drive industrial electrification, allowing for informed investment decisions.
- Public–private partnerships are critical for accountability, understanding of needs, and engagement.
- Robust data collection and industrial rate design are important pathways to making electrification affordable.

Next Steps

From these learnings, ACEEE suggests the following priority actions for different stakeholders, in no particular order:

Table 2. Priority actions for stakeholders

Stakeholder	Recommended actions
Industrial firms	• Show leadership - Set high-level targets for GHGs - Communicate to government audiences (federal/state/regulators) - Market GHG reduction plans to the layperson - Ensure that the target and commitment inform long-term planning - Review job descriptions to make sure the right people are in the right roles • Expand relationships - Partner across the supply chain and sectors - Collaborate internally and externally to reduce silos - Engage with stakeholders to expand workforce pipeline and development • Improve planning - Develop integrated technical assessments across the portfolio to (a) better allocate CapEx in an aggressive way and (b) better align with incentives - Use sustainability infrastructure as headroom for continued growth
Federal and state governments	• Improve processes for incentives, including structure, feedback process, consistency of funding, assistance with applications, and reduced bureaucracy • Communicate the vision of polices with clear goals and a timeline • Boldly implement policies necessary to achieve goals • Signal the priority of a just transition and workforce support and make these priorities implementable • Use incentives for new-build manufacturing to support excellent demonstration projects • Fund and support deep decarbonization projects as exemplars • Develop industrial partnerships linked to clear topline goals
Utilities	• Offer more rate structure options to industrial customers, including time-of-use • Deepen engagement with industrial and other large customers • Provide more creative programs and funding to drive energy efficiency for industrial and other large customers

Stakeholder	Recommended actions
	• Publish energy use data transparently with appropriate anonymization, aggregation, and cybersecurity • Educate policymakers on the utility perspective • Partner with regulators on pilot projects • Expand district heating and/or district cooling in their service territories
Utility regulators	• Consider engaging stakeholders and utilities to develop creative programs that expand efficiency and other demand-side options to avoid new infrastructure • Integrate planning for electric and gas utilities • Expand education of state legislatures, utilities, stakeholders, and customers alike
Environmental regulators (federal and state agencies)	• Get better cost data on possible solutions to reduce air emissions (full costs and associated benefits that reduce cost) • Identify pollution trade-offs of different decarbonization pathways and then optimize response • Include consideration of a just energy transition

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Appendix: Sites Visited

The U.S. delegation to Denmark spent five days learning about Danish progress in industrial electrification, successful applications of technologies like industrial heat pumps (IHPs), district heating, and electric boilers; the economic and policy factors that have enabled their adoption; and the anticipated future of decarbonization in Denmark. The group toured facilities and heard presentations at

Policy and Technology:

- **Danish Technological Institute** – This leading center for innovation and research in Denmark is known specifically for its work to advance emerging technologies. The Danish Energy Agency presented on the energy landscape and decarbonization targets in Denmark.
- **Danish District Heating Association** – Founded with the aim of organizing Danish district heating companies and fostering cooperation, the Association has over 350 member companies today. The presentation at the Association focused on district heating applications in Denmark and innovations with the technology.
- **State of Green** – The State of Green is a nonprofit, public–private partnership created between the Danish government and high-profile business associations including Danish Industry, Green Power Denmark, the Danish Agriculture and Food Council, and others. The presentation focused on the role of the private sector, public–private partnerships, and invigorating local economies through decarbonization.

Industrial Sites and Supply Chain:

- **Johnson Controls Denmark** – Johnson Controls Denmark is a heat pump manufacturer committed to facilitating electrification and sustainability of industrial processes. The facility visit was intended to explore how Johnson Controls products are applied in real world settings, and for participants to learn about optimizing systems for electrification to reduce energy consumption and enhance efficiency.
- **Hamlet Protein and Horsens District Heating** – Hamlet Protein produces soy-based ingredients for animal feed. The facility prioritizes mitigating their environmental impact by investing in efficiency. In 2019, Hamlet Protein partnered with District Heating Horsens to allow waste heat from their processes to be used to heat residential houses in Horsens. The visit investigated this unique district heating application.
- **Danfoss A/S** – Denmark's largest industrial company leads research, development, and manufacturing of mechanical and electronic components. Danfoss' Nordborg campus presented their efforts towards carbon neutrality (globally neutral by 2030), which includes significant efforts in electrification.
- **Carlsberg Danmark A/S** – Carlsberg manufactures prominent brands of beer, water, and soft drinks. Carlsburg's managers of sustainability, technology expense, and energy presented on energy optimization, including renewables integration, water savings, and electrification of process heat.
- **Energinet** – An independent public enterprise owned by the Danish Ministry of Climate, Energy, and Utilities, Energinet owns, operates, and develops Danish gas and electric transmissions systems. Energinet's presentation focused on the Danish green transition, electricity adequacy needs, work on data hubs, and business development.

- **S.C. Nordic** – S.C. Nordic is a service provider in Denmark that specializes in managing electricity usage to economically reduce grid strain. S.C. Nordic presented on energy storage, integrating storage with efficiency, and industrial demand response.

- **Royal Unibrew** – Royal Unibrew is a leading Danish multi-beverage company with an international brand portfolio. The presentation at this facility focused on industrial electrification efforts, including an industrial heat pump that provides 10% of the facility's hot water needs.