Going Further Than an EERS: Danish Lessons on Maximizing Whole Energy System Efficiency

Anna Chittum, American Council for an Energy-Efficient Economy

ABSTRACT

In the United States, energy system planning tends to be done on a utility-specific basis (utility resource planning, natural gas system planning, etc.). To the extent that this planning considers energy efficiency opportunities, they are generally viewed on an individual program- (and measure-) level basis. Rarely are larger systemwide and cross-fuel efficiencies considered as opportunities by electric, natural gas, and larger energy system planners. In contrast, certain European countries have been identifying and pursuing systemwide efficiency opportunities within their national and local energy system planning activities for decades.

In Denmark especially, local municipalities and national energy planners consider resources like industrial and commercial waste heat and transportation energy use concurrently with electric system planning. In Denmark, extensive district heating systems rely on heat produced at combined heat and power stations or municipal waste incineration plants to meet local heat needs, while simultaneously generated electricity meets a large portion of electric needs. And in contrast with the United States, renewable energy goals and policies are developed at the national level in concert with other energy planning efforts.

This paper summarizes the key aspects of Denmark's comprehensive national and local electric and thermal energy planning processes. It discusses how lessons from the Danish experience might be applied to the United States, and how system efficiencies might be considered within existing U.S. energy policy and planning contexts.

The paper provides policymakers and energy efficiency advocates with some suggested paths forward for better incorporating systemwide efficiency opportunities in future energy system plans and efficiency resource assessments. It highlights aspects of the Danish energy planning process that might be translatable to the American policy and regulatory context, and discusses possible technical and policy approaches that might better encourage such systemwide thinking in the United States.

Introduction

Many aspects of the U.S. energy system are highly inefficient. One of the most glaring examples is the U.S. electric system, which is 32% efficient (Laitner 2013). As a country, we throw away two-thirds of the usable energy generated during the electric generation process, usually in the form of heat. Our energy system as a whole is incredibly wasteful. The sectors of the economy that waste the most are electric generation, transportation, and industrial facilities (LLNL 2013). While much of this is waste from thermodynamic processes, which may be difficult to avoid, much of the waste could be harnessed for a useful purpose, or avoided altogether with better planning. For instance, industrial waste heat and heat produced during electricity generation could heat commercial buildings or multifamily residences rather than being vented into the air or dumped into bodies of water; vehicles could reduce their waste by switching to synthetic fuels generated via electrolyzers using excess electricity that is economic to produce but not needed by the grid. These are just two examples of how thinking about more than one subsector within energy planning can yield benefits across sectors. But in order to identify these opportunities for system optimization and maximize system efficiency, we need to understand the full scale and scope of our opportunities.

Unfortunately, there is little work being done to identify systemwide efficiency opportunities. The current manner in which those responsible for planning different aspects of our energy system identify energy efficiency opportunities varies tremendously from utility to utility, state to state, and city to city. It is also very limited to whichever aspects of the energy system each group is legally responsible for.

Each major player in the U.S. energy system has different regulatory and market frameworks in which they operate, which limits their ability to identify and take advantage of systemwide efficiency opportunities. For instance, electricity and natural gas distribution utilities are mainly concerned with ensuring that resources to meet future demand are available and that the acquisition of those resources represents a cost-effective path forward for their customers. They are focused only on that which impacts their service territories and their fuels, and have little need to pay attention to how their resource mixes complement or work at cross-purposes to other local or regional needs. At the same time, cities have a variety of disparate waste heat resources within their city limits, such as heat from municipal solid waste disposal, latent heat in the sewer, waste heat at industrial facilities, and even heat from existing mass transit networks, but they lack a framework to assess or utilize that heat. Cities also may have their own building codes or green building efforts, but usually lack much influence over the energy resources sold to citizens in those buildings. And at the national and state level, climate goals and renewable energy programs delineate specific quantitative benchmarks and binding targets that are to be met within certain time frames, regardless of whether meeting those goals represents the most cost-effective way to reduce harmful emissions for society as a whole.

How can we overcome this compartmentalized consideration of energy resources? This paper's working thesis is that the manner in which we *plan* for our energy resources does us a great disservice. By thinking only about distinct parts of the energy system without looking at it from a more holistic perspective, we fail to see where synergies lie.

The U.S. Approach to Energy Planning

The current U.S. approach to energy planning is dramatically siloed along fuel and resource and geographic lines. The following section describes the parties responsible for critical planning functions within each major energy sector and how such planning fails to consider systemwide efficiencies and optimizations.

Utility System Planning

Electric and natural gas utilities engage in their own system planning, which identifies how future needs are to be met. Electric utilities often develop integrated resource plans (IRPs), and states have certain requirements for these planning documents and processes that vary considerably from state to state (Wilson and Biewald 2013). IRPs usually account for a utility's potential efficiency resources and other demand-side resources, as well as more traditional supply-side ones. IRPs are generally limited to assessments of the intra-utility needs, so synergies that might result from thinking about meeting one utility's needs concurrently with those of another are not considered as part of the IRP process. A state may give general guidance to utilities developing IRPs and other long-term planning documents, but it is ultimately up to the utility to determine which resources to include in the plan.

Looking at a single utility system ignores whether other energy resources could better serve identified needs. But this is what state regulators generally require utilities to do: consider their system only. Oregon, which has been identified as having one of the most thoughtful IRP processes, requires utilities to consider risk and uncertainty, which is to include potential costs associated with greenhouse gas emissions (Wilson and Biewald 2013). PacifiCorp (doing business as Pacific Power, which provides about one-third of Oregon's electricity) develops its Oregon-area plans every two years to meet state IRP requirements. However, its future resource mix does not include any assessment of whether waste heat resources or investments in new heat networks would be cost-effective ways to either provide needed resources or supplement the development of other resources. For instance, in its 2013 IRP, PacifiCorp investigates energy storage options, but does not include any consideration of whether heat networks or waste-heat-to-power opportunities might serve its territories well (Cadmus 2012; HDR 2011). They are not required to look at such options, and neither is any other planning party.

This lack of comprehensive planning at the local utility scale is mirrored at the larger transmission system level, where new federal rules such as Federal Energy Regulatory Commission Order 1000 are just beginning to encourage consideration of how state-level energy goals might be supported within transmission system plans (FERC 2011). Though there are technically many alternatives to new transmission infrastructure pieces, such as nontransmission alternatives found in strategically sited distributed generation, these resources play only a minor role in U.S. transmission planning. Such resources could serve both local on-site heat or power needs as well as larger needs of the grid, but they are not incentivized by state or local policies, which generally do not have any jurisdiction over their relevant transmission system or markets (WGA 2009). Groups like the National Renewable Energy Laboratory have done considerable work to assess how the amounts of renewables in the different interconnections could increase, but these findings must be adopted into the plans of transmission system utilities if they are to have an impact (NREL 2012).

Energy Efficiency Resource Planning

Today 26 states have enacted energy efficiency resource standards (EERS) or other long-term efficiency targets (American Council for an Energy-Efficient Economy 2014). These targets are typically structured as specific annual savings targets for affected electric and natural gas utilities. Utilities meet these targets by implementing programs that save energy among their customers. Programs are usually designed to identify and encourage measures that reduce energy use for a specific building, such as an industrial facility or a single home (ACEEE 2014). While EERS have played a critical role in reducing energy use and increasing nationwide energy efficiency, they continue to focus almost exclusively on efficiency opportunities that are viewed from a single-building perspective.

When developing EERS targets, states or utilities assess the efficiency potential among all relevant customers and develop models that show the efficiency potential in different types of buildings and among different customers. However, these approaches never assess whether systemwide efficiency savings might be achieved by rethinking the manner in which different energy needs are met. For instance, the Pacific Northwest, which arguably has done the most to identify and plan for future energy efficiency resources, relies significantly on the increased efficiency of domestic space heating through electric heat pumps to provide near-term efficiency resources (NWPCC 2010). However, whether long-term economic and emissions benefits could be seen from instead meeting these same heating needs with communal hot-water–based heating networks powered by natural gas or biomass boilers is not assessed. EERS explicitly do not address whether district energy might offer the most efficient and cost-effective energy resource for a given area. In fact, there is no existing energy resource planning framework in the United States in which district energy is considered.

Further, EERS goals are most typically specific to the type of energy sold by each utility. Electric utilities are incentivized to administer programs that improve the efficiency of existing or new electric appliances and operations, while natural gas utilities are incentivized to do the same, but for appliances based on natural gas. Most EERS don't have the capabilities to determine which type of fuel is the most efficient choice for a given customer who might be presented with multiple choices. A customer looking to replace an oil furnace might be offered incentives from one utility for investing in a high-efficiency electric furnace, while another might offer incentives for a high-efficiency natural gas furnace. While one might offer a more cost-effective solution for the individual customer or utility, another might be a more cost-effective and cleaner heating solution for the region at large. There is no framework for choosing and incentivizing the solution that offers the greatest benefits to the city, region, or state. Though the customer in this situation may enjoy multiple options and choose the solution that will directly cost her the least, society at large might suffer the consequences of her choice of a less-efficient option. In the aggregate, this could perhaps mean substantial differences in overall energy savings.

One type of energy efficiency resource that is often eligible within EERS is combined heat and power (CHP), which offers tremendous efficiency benefits over traditional generation. Most of the states view their CHP potential through U.S. DOE-funded assessments conducted by ICF International. These studies look only at existing high-load industrial and commercial buildings, and only at their within-the-fence thermal loads (Chittum and Sullivan 2012). While these studies are important assessments of the existing potential in existing buildings, they fail to assess whether new CHP could meet aggregated heat loads somewhere else, in a manner more efficient than whatever other heat resources are in place. They also fail to assess whether the heat loads of two adjacent buildings could be cost-effectively met with a new or expanded CHP system, and to consider opportunities beyond natural gas–fired CHP systems (Chittum & Sullivan 2012).

Renewable Energy Programs

Similarly to efficiency resources, 29 states currently have a renewable energy portfolio standard (RPS) in place (DESIRE 2014). Like EERS, RPS policies typically delineate a specific amount of energy or electricity that must be provided by qualified renewable energy resources within a certain time frame. Targets for solar power, wind power, and other renewables are developed on a utility-by-utility basis. While these policies have also helped tremendously to strengthen renewable energy markets around the country and incentivize major increases in deployed renewable energy, they limit their scope to individual regulated utility service territories. For instance, while the specific solar-electric target for affected New Hampshire utilities is 0.3% by 2014, there is no assessment of whether these installations are placed in the most cost-effective manner possible. Some facilities that are targeted for new solar electric installations might have their electric or heating needs more cost-effectively met by other types of renewable or efficiency resources. Singling out a certain development or area for a certain type of renewable energy investment may not be the best use of society's energy dollar. But such considerations are broader than the typical scope of an RPS.

One of the resources that is most ill served by failing to take a systemwide planning approach is wind energy. Wind energy potential is very site-specific, and its intermittency has presented a challenge to transmission and distribution system planners around the country (BPA 2013). Much has been written about the need for storage capabilities within heavily wind-based systems, but little attention has been paid to the storage values of heat networks, which could, with CHP systems and thermal storage units, operate as "batteries," then serve other needs when storage capabilities were not needed. Again, though, wind energy targets and wind farm planning are conducted by electric-focused utilities and state agencies. There is no planning framework that considers how investments in district heating or CHP systems (that might concurrently serve identified heat needs) could also allow the deployment of a greater amount of wind capacity.

Local Planning

Cities are fairly limited in their control over the energy infrastructure that serves their citizens, though it is cities that are recognized as playing a more central role in climate change mitigation, absent strong leadership from national governments (Bulkeley 2010; Sperling, Hvelplund, and Mathiesen 2011). Cities, though, generally do little energy planning within their city planning activities. What cities can control is land use and some transportation planning. At the city and regional levels, metropolitan planning organizations typically author and administer components of metropolitan-area comprehensive land use plans. These plans may identify where energy use might be concentrated, and may offer some information about future land developments that could inform strategic energy planning. While cities have input over transportation infrastructure, they do not typically develop renewable fuel standards or fuel economy standards for personal vehicles, but they can do things like implement congestion charges in their cities, invest in bicycle infrastructure, and incentivize electric vehicles. Other ways in which cities can influence energy decisions include heat mapping, which identifies heat needs and in-city heat resources. Some international cities, such as London, have begun to map heat resources, but U.S. cities have yet to follow suit. Even U.S. cities such as Seattle and Portland that have expressed official interest in promoting district heating lack a venue in which to discuss how possible new district heating systems could help alleviate wind-produced strains on the regional electric grid (Chittum 2012; Kane 2013). Additionally, while cities might identify areas that are appropriate for increased energy efficiency or renewable energy deployment, these forecasts and plans are not part of the local utilities' planning processes.

Some cities have taken on the laudable goal of encouraging net-zero buildings, which are buildings that consume only the energy they produce, and, through highly increased efficiency, reduce their on-site needs dramatically in order to be able to meet the demand with on-site resources. These buildings are important efficiency resources and help reduce overall building-related energy consumption. However, the on-site renewable energy production of these buildings may not represent the most efficient or cost-effective use of renewable energy resources.

Net-zero-energy buildings are planned (and often incentivized) on a building-level scale, with very building-specific needs identified and addressed. Whether a more cost-effective renewable energy solution, developed on a community scale, would be a more efficient and effective way to meet the energy needs of multiple net-zero-energy buildings is not typically a part of net-zero-energy programs. To be sure, some organizations, like the Institute for Building

Efficiency and certain cities like Fort Collins, CO, have identified net-zero communities and net-zero cities as a more optimal way to think about reaching the net-zero goal. But states and even the federal government have identified net-zero buildings as important policy goals, especially for public buildings. These efforts encourage net-zero planning on a building-by-building basis and ignore the possibility that neighborhood or city-scale net-zero planning might yield more cost-effective efficiency and renewable deployment.

Critical Aspects of Danish Energy Planning

Denmark ranks very high in its energy efficiency among both European Union and Organization for Economic Co-operation and Development countries. One of the most compelling and telling statistics is that Danish energy consumption has remained essentially unchanged since 1980, while the economy has grown 78% (Energistyrelsen 2009). Denmark's energy intensity of 3,000 BTUs per U.S. dollar (USD) of gross domestic product is much better than the 7,329 BTUs per USD used by the United States (Chittum 2014). Efforts to promote conservation and energy efficiency, especially individual building insulation, were prioritized after the oil shocks of the 1970s, and the country has had nationwide energy efficiency goals in place since the late 1970s. Two efficiency-improving characteristics of the Danish energy system are the marked increase in the use of CHP and district heating in the past several decades. Only about 18% of all electricity was cogenerated with heat in 1980—that is, the electricity generation process produced useful heat that served a heat demand—whereas that figure was 53% in 2007 (Energistyrelsen 2009). Municipalities developed and expanded their district heating systems throughout the country in those same decades, which has greatly reduced the emissions and improved the efficiency of the heating sector. One analysis found that district heating and CHP were responsible for a reduction of 20% of the country's carbon dioxide (CO_2) emissions since 1990 (Dyrelund et al. 2010; Christensen 2009).

Denmark is, to be sure, a much smaller country than the United States. Its primary energy consumption is less than 1% of the 97.469 quads consumed by the United States in 2011 (EIA 2014). It is perhaps more akin to a U.S. state, representing the potential that a smaller state could have in harnessing its in-state energy resources and thinking comprehensively about meeting its in-state needs. Nevertheless, its approach to energy planning is unique and its focus especially on leveraging the power of heat networks could be instructive to many areas of the United States.

The national Danish government has regulatory control over all monopoly utilities. While Danish electric utilities are no longer regulated monopolies, the national government and municipalities still plan for electricity along with other energy sectors. Nationally administered taxes and subsidies applicable to electric generation are a product of these plans, and are tweaked according to identified market needs.

Identifying Resources

In response to the oil shocks of the 1970s, several pieces of legislation prompted Danish cities to undertake heat plans, and prompted the nation as a whole to consider a variety of new energy resources. A national energy plan issued in 1976 called for a system largely based on nuclear power, but when strong public resistance was registered, an alternative plan authored by a group of academics began to gain traction. The alternative plan relied heavily on energy efficiency, CHP, and renewable energy resources (Blegaa et al. 1977; Lund 2000). As Lund (2000) notes, "Historically, one of the most important achievements of making this plan was the mere existence of an alternative one." From that point on, comprehensive energy planning became the normal way to plan for the country's energy future. Heat networks; CHP; renewable resources, especially wind; municipal waste incineration; waste heat from electricity generation; biomass; and other distributed resources were incorporated in all national-level energy plans. These plans included expected efficiency savings from codes, standards, and industry-specific savings goals. In subsequent instances when the official government plan was not widely perceived as in the country's best interest, alternative comprehensive plans proposed by other parties furthered the discussion and changed the course of Danish energy deployment (Lund 2000).

District heating has always been identified as one of the most cost-effective options for heating Danish homes. Over the decades Denmark has identified the most cost-effective way to supply these districts, whether through CHP plants or local solid waste incineration. Cities were empowered in the late 1970s to identify their own heat resources and to plan for their own, typically consumer-owned, district heating systems. By providing the legal framework for this hyperlocal planning, the Danish government could ensure that each city and region was planning for and utilizing its most cost-effective heating solutions. Later, as Denmark worked to increase its capacity of installed wind, the district heating network coupled with CHP proved to be an excellent balancing tool to help regulate the ever-fluctuating output of the country's many wind turbines (Dyrelund and Overbye 2013; DEA 2012b). By concurrently planning for heat and electricity on the local and national levels, the country has continued to allow for a system optimization that makes use of its tremendous wind resources in the most cost-effective manner possible.

Today, Denmark has identified low-temperature heat as the next important untapped resource. The national government funds a research consortium specifically focused on this type of energy resource, and that team is currently identifying how such low-temperature resources could be used by a variety of building types, and how other technologies such as heat pumps could provide even greater flexibility to district heating and electric systems. This is just one example of how the Danish national government continues to encourage cutting-edge energy resource identification and use.

Cost–Benefit Tests

Today Denmark's energy planners speak about energy system optimization, which is when a scenario maximizes cost-effectiveness for all energy sectors, given established parameters. In 1990 Denmark issued an official plan for its energy future. Titled *Energi 2000*, the plan looked forward ten years and envisioned a cleaner, more resilient, and more cost-effective energy system (Energiministeriet 1990). Notably, the plan codified for the first time a concept that had been used to some degree in prior years: "*samfundsøkonomiske*," or socioeconomic, cost-effectiveness. The national government's plan clearly delineated the need to assess every future energy project for its environmental costs and benefits, its economic costs and benefits, and its costs and benefits in terms of actual energy supply. When considering various paths forward to meet identified energy needs, only projects that performed within these three rubrics the best were to be pursued.

This continues today, and the national government has the authority to maintain oversight over the use of the cost-effectiveness test. While this has some parallels with the "societal cost-effectiveness test" used for some energy resource planning the United States, in Denmark this assessment of cost-effectiveness is grounded in annual updates of relevant cost assumptions issued by the Danish Energy Agency. Each year the Danish Energy Agency issues an official forecast of future energy demand curves, fuel prices, prices associated with environmental degradation, and other components that must enter into each cost-effectiveness test (DEA 2011). As a result, every utility, consultant, and investor uses the exact same assumptions to build the cost-effectiveness case (Dyrelund and Overbye 2013). This allows all projects to be viewed along a continuum, and the government to ask: What is the most cost-effective way to meet our energy demand needs and reduce emissions? The question is, given a finite investment in energy resources every year, what is the best use of those kroner? The goal is always *whole system optimization*, rather than setting specific targets for each energy sector.

Applying the Danish Method

While some of the constructs underlying the Danish approach to energy are inherently Danish, such as the long history of political consensus and the penchant for forming cooperative businesses, other aspects could inform energy planning in the United States.

Technical Tools

Both the Danish government and advocates of alternative scenarios use several analytical tools in order to construct models of future energy scenarios for discussion purposes. EnergyPLAN and similar whole-system modeling software packages are critical aspects of the constantly evolving discussion of what the future Danish energy system should look like (Connolly 2010). Figure 1 shows the manner in which a wide variety of courses and uses are integrated in programs like EnergyPLAN.

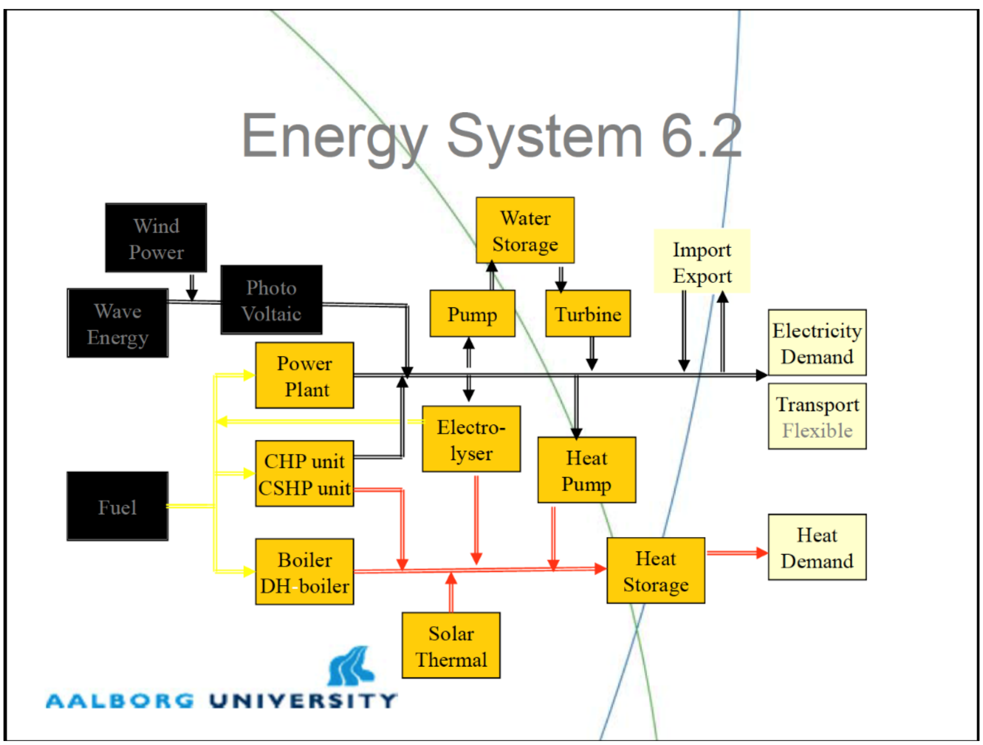

Figure 1. Schematic of EnergyPLAN inputs and outputs. *Source*: Lund 2014.

By always considering the technical realities of the energy system as a whole with many moving parts, the discussion about future energy resources can be more comprehensive by definition. Pieces are not planned for and considered in vacuums, and the impacts of choosing one type of resource over another are felt and modeled throughout the system as a whole.

In addition to university- and private sector–developed modeling tools, the national government issues the aforementioned assumption forecast data each year to help all energy project planners start from the same set of assumptions when assessing the cost-effectiveness of their projects. Making available these yearly assumptions helps maintain confidence among project developers that their projects will be fairly assessed for their costs and benefits, and they perceive less risk in putting forth new project proposals, because they are generally confident that their assessments of the costs and benefits of a project will hold up when considered by local and national decision makers (Dyrelund and Overbye 2013). These types of technical tools and this guidance on cost–benefit assumptions might be appropriately offered by state energy agencies.

Policy Tools

Denmark considers how to most efficiently meet supply needs while reducing emissions and keeping costs down. U.S. efficiency programs tend to, for example, only credit efficiency savings on a utility-by-utility basis, and only for savings of that utility's product. One example of a policy in the United States that aims to counter this is Oregon's recently adopted rule to allow a voluntary emissions reduction program for its natural gas utilities. Natural gas utilities interested in participating may propose programs or projects that reduce CO_2, regardless of whether the project increases on-site natural gas usage. This rule directly addresses the disincentive facing U.S. natural gas utilities that encourages investments like natural gas–fired CHP and natural gas–powered vehicles. Participating utilities will be rewarded based on the cost-effective reduction of CO_2 (Chittum and Farley 2013).

The national government can play an important role in stimulating this planning. The Danish national government provides cities with funding and guidance to undertake broad energy planning, and has for decades supported cities' roles in fully regulating heat-related infrastructure and heat companies. City and regional land use plans influence decisions about natural gas–infrastructure development, and cities are encouraged to support cooperative investments by citizens in locally sited renewable electricity infrastructure. The U.S. DOE could strengthen its direct technical assistance to cities, and help them address policy issues that frequently emerge from jurisdictional battles between state and local authorities.

In addition to providing guidance to cities to help them understand their local energy resources, the U.S. national government could encourage state regulatory commissions to encourage more holistic energy planning, such as through legislative changes to the existing Public Utility Regulatory Policies Act, which has been amended previously in order to require state regulatory commissions to undertake specific regulatory actions. This planning could incorporate and complement existing land use planning efforts, transportation plans, electric system resource plans, and a variety of other planning activities that, taken together, could form a much more robust and comprehensive picture of a given state's or region's true energy options. Additionally, national air-quality rules promulgated by the U.S. Environmental Protection Agency for electric power plants could encourage broader efficiency compliance mechanisms that do not just reduce electricity consumption, but also yield some net reduction in CO_2 emissions.

Finally, the use of a cost-effectiveness framework that is accepted and consistently legitimized by all parties has had an important effect on the Danish energy system. U.S. states and even utilities have their own cost test structures, their own assumptions, and their own ways of applying those tests. Most of those tests focus only on the impact on the utility itself and its ratepayers, rather than looking regionally or nationally at the overall cost-effectiveness of a project or program. They also tend to ignore or minimize environmental and other societal costs, as well as benefits. Encouraging states to promote more comprehensive cost tests would be one way the national government could encourage a more energy-efficient and optimal system.

Conclusion

Determining how the most energy-efficient *system* might look and then determining which energy projects move the system forward, toward that optimized structure, is something that we are failing to do in the United States at the moment. With finite resources and finite investment dollars, the most cost-effective solutions for the country are those that do the "most" with what we have. Environmental goals, economic goals, and energy supply goals are all critical goals to consider, simultaneously, when planning a resilient and effective energy system. By integrating resources such as waste heat and thinking about alternative ways to use existing resources, we could support a flexible energy system much more capable of withstanding unexpected economic and technical challenges.

Denmark offers one compelling example of how to think more holistically about energy planning. By constantly asking the question "What makes sense?" and looking to experts at the local and national levels to help provide answers, Danish energy planners have shown that a cost-effective and highly functional energy system that continues to reduce emissions is possible. Denmark has an official national goal of being 100% reliant on non–fossil fuels by 2050. It is widely recognized within the country that in order to reach this goal, new and creative ways of leveraging the nation's resources will be required. It is also widely recognized that comprehensive systemwide planning is in fact the only way to adequately identify what their energy system of 2050 should look like. Adopting a goal of 100% reliance on renewable fuels is perhaps not a goal the United States will adopt any time soon, but it is important to know and understand how another country is quietly working toward such a future.

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