

ENGINEERING
TOMORROW



How to future-proof **HVAC systems** to meet **efficiency** and **carbon emission goals**

Part II: Major factors that are related to the trends or the drive to future-proof HVAC systems

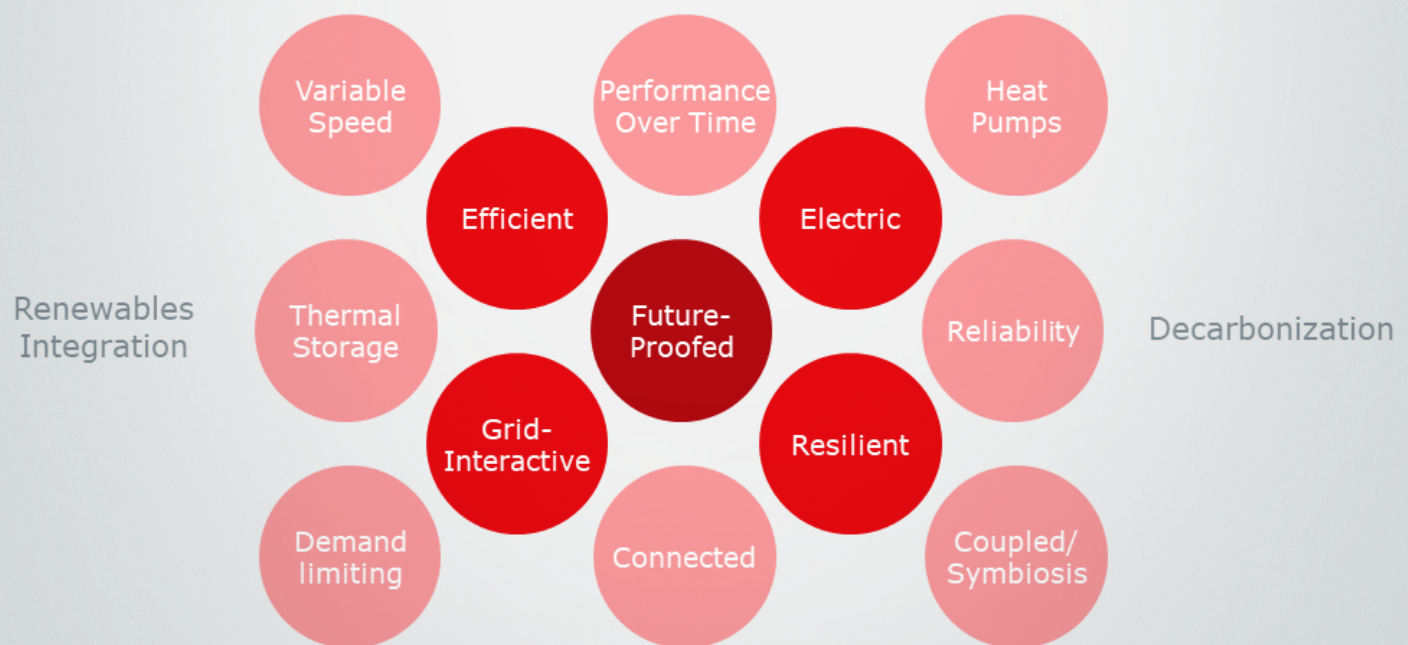
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The major drivers of future-proofed HVAC systems are efficiency, resiliency, electrification, and grid-interactivity. Efficiency has been around as long as HVAC systems have. A more recent trend has been pushing the industry more towards electrification, including heating and the move to heat pumps. While a major focus of the past was reliability, today the focus has evolved to include resiliency. The latest driver is grid-interactivity. This article will touch on all of these points and the components that tie into them.

Future-Proofed HVAC Systems Characteristics



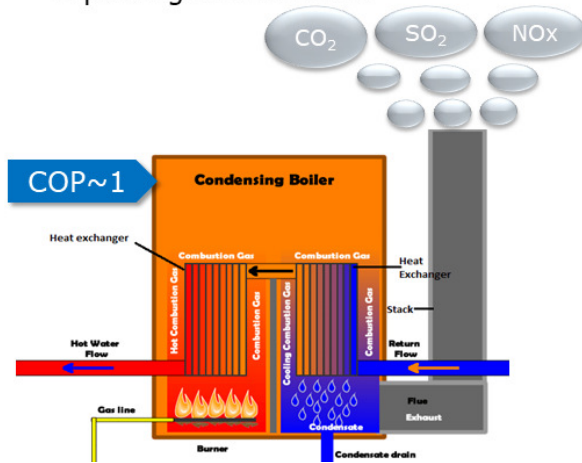
Efficiency

While variable-speed technology is not new, it is becoming more critical than ever. And with variable-speed comes drives, the latter enabling the former to improve performance.

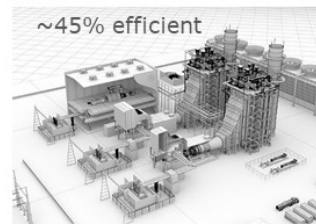
Fossil fuels vs. **heat pumps** for heating

Fossil fuels

- Inefficient
- Drive CO₂ & other gas emissions impacting environment



Heat pumps



Transmission & Distribution

-10%



- More efficient
- Efficiency increases (especially oil-free) at part-load

~35% operating cost reduction
~60% emissions reduction



As HVAC systems become more connected and more tracking of performance of equipment is done as a result of that connectivity, the realization of performance over time becomes much more critical and maintaining that performance becomes much more critical. As I mentioned before, electrification and specifically electrification of heating is becoming a major factor, and the major factor for HVAC systems related to that is the trend to heat pumps—both air-to-water heat pumps and water-to-water heat pumps.

Resiliency

In the past, resiliency was mostly defined as reliability, especially for mission-critical systems. What has added to that factor more recently is the coupling of cooling and heating systems to renewable-based power generation and their corresponding inconsistent availability. More critical for HVAC systems is designing a system that can react to those periods of low or no renewable generation.

Grid-interactivity

Having a more resilient system that incorporates the systems of multiple buildings for a micro-thermal grid, it is very critical that all components and systems are connected and that you understand the real-time operating costs and the operation of each one of those components in the systems. Tied to that grid-interactive factor, as well, is demand limiting. In these grid-interactive, efficient buildings, the number one factor that comes into play for HVAC systems is the ability to respond to the utility's signal to demand-limit those components. That, in turn, ties to variable-speed and the ability of a variable-speed HVAC system to respond exactly to that demand-limiting signal and closely match the thermal load at the same time.

Electrification

The most significant factor that we see changing with HVAC systems in the future is the change from fossil fuel source electric. More specifically, the move to renewables and heat pumps. This move is based on the fact that fossil fuel sourced heating is inefficient—with the COP of approximately one—and it also drives the emissions of CO₂ and other gases, which are harmful to the environment.

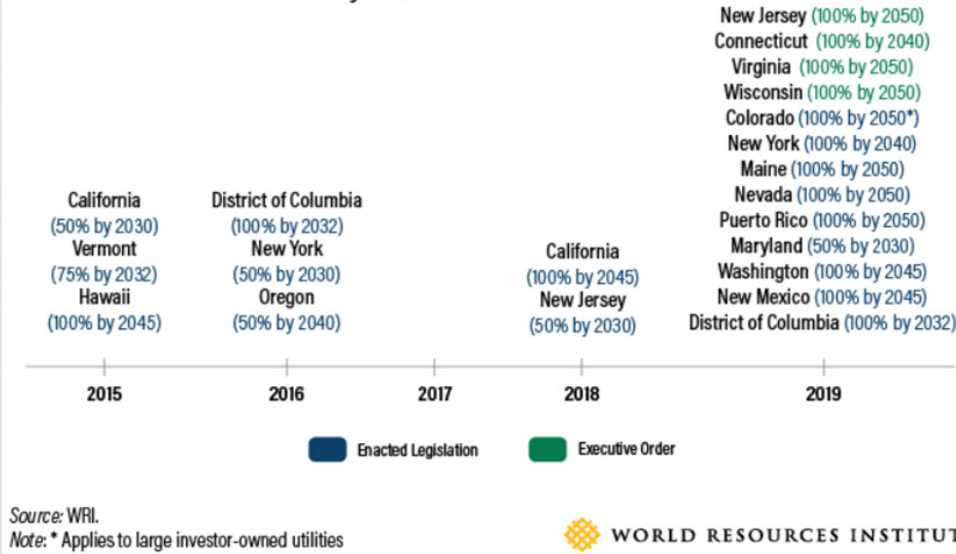
Emissions reduction



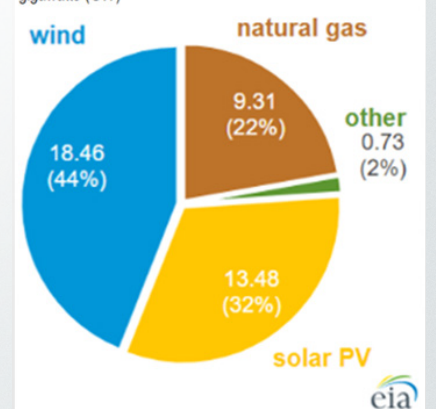
Even accounting for losses from generation to usage, electric systems are significantly more efficient. Based on modelling that Danfoss has done, changing from a fossil fuel-based to an electric system can reduce operating costs at least 35% and reduce corresponding

emissions by 60%. What drives decarbonization is a reduction in energy consumption, as well as the decarbonization of the energy consumed. To put it another way, using an energy efficient electric system on a grid that uses renewable resources.

U.S. States' Clean Electricity Commitments



Planned U.S. electric generating capacity additions (2020) gigawatts (GW)

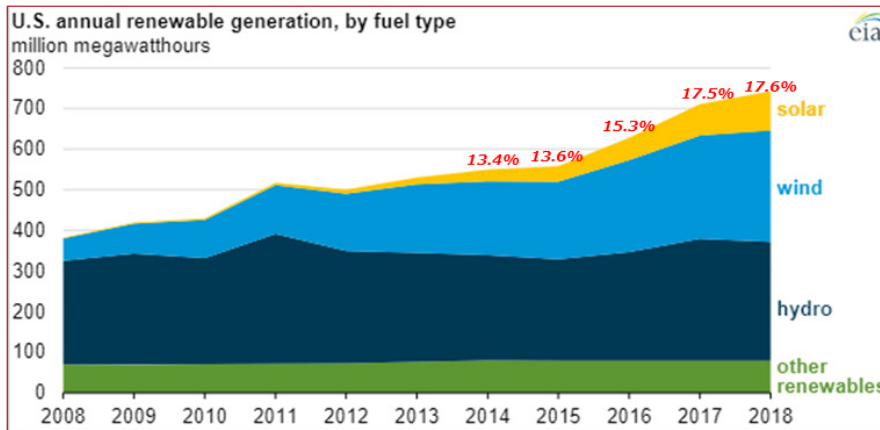


Renewables = 76% of 2020 new US power generation capacity

In the last few years, we have seen a significant change in the commitments of individual states to integrate renewables into their power grid. Just last year, we had a number of states commit to have

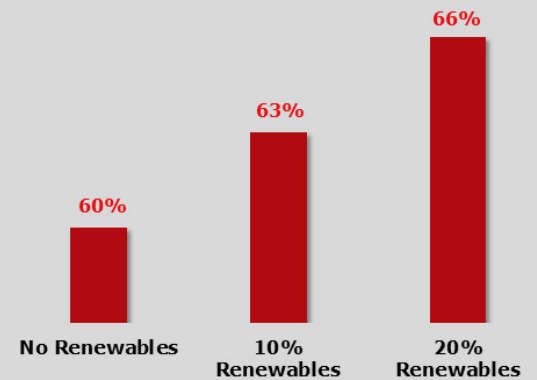
around 100% of their energy come from renewable sources as early as 2030. That only matters if the reality of what is being implemented reflects the policy of what is being planned.

Emissions reduction



As grid integration of renewable energy grows,
so does heat pump resulting
greenhouse gas emissions reductions

Danfoss Oil-Free Heat Pump CO₂ Emissions Reduction: Renewables integration impact

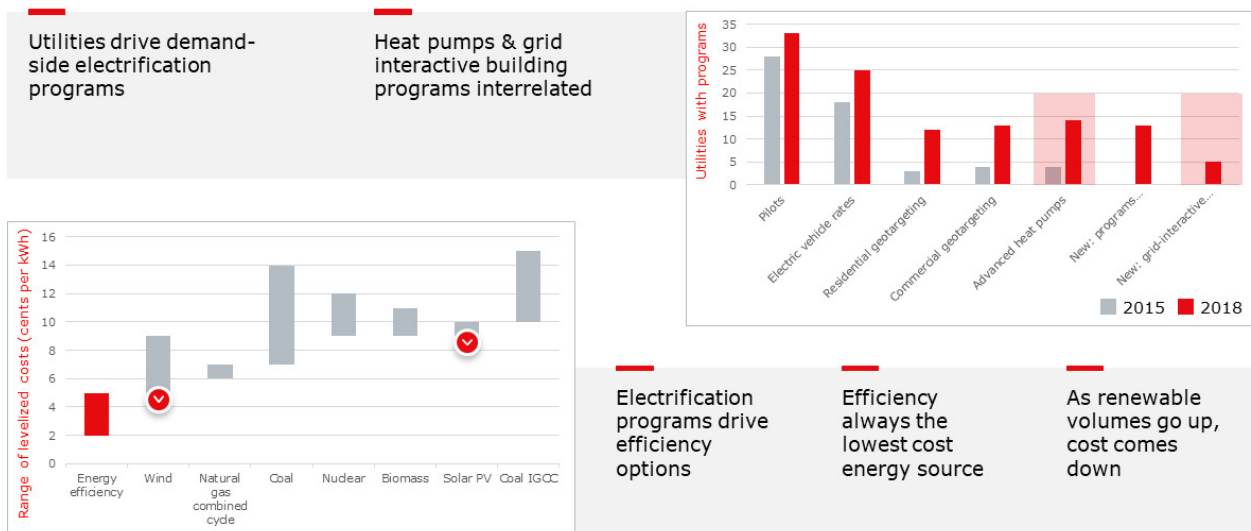


Based on oil-free AHP applied in 'warm' climate

The Energy Information Agency (EIA) has reported that 76% of new US power generation capacity is renewable. Additionally, November 2020, the IEA in reported that globally, renewables constituted 90% of the year's newly installed power generation. To accomplish this plan, the need continues for some level of what are called peaking plants to address gaps with a renewable grid on the supply side.

Previously, we had peaks and valleys mainly driven by the demand side, but moving forward, we expect to see them also driven by the supply side. Which is where peaking plants as well as energy storage come in, to address those gaps, as well as on the demand side, which we will address below.

Energy Costs & Utility programs



In the past several years, we have seen a significant growth in the use of renewable energy and integration in power grids. That, in turn, drives a significant reduction in CO₂ emissions from implemented electrification equipment. As discussed previously, we have the potential for around 60% CO₂ emissions reduction based on a near

100% fossil fuel source electric grid. As renewables are integrated into a grid, the resulting CO₂ emissions reduction from the implementation of heat pumps, as opposed to fossil fuel-based boilers, also goes up.

Significant increase in electrification program number and funding
Potential demand-side emissions reduction credits / potentially addressing higher capex demand-side investments

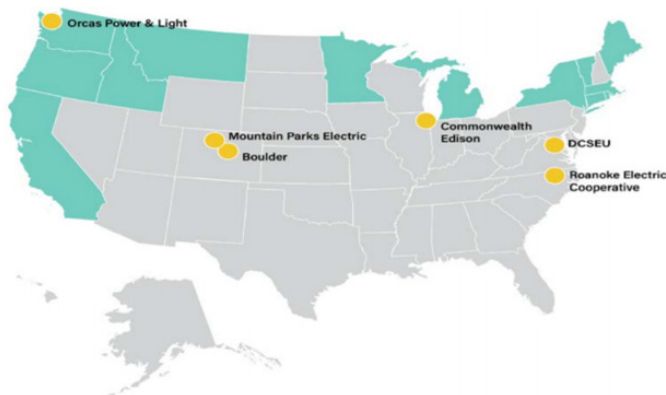


Figure 1. States and programs profiled in this brief. States that are shaded green have multiple programs that are discussed in this paper. Yellow dots indicate programs operated by individual program administrators that are not discussed in the sections on the shaded states and regions.

https://www.aee.org/sites/default/files/pdfs/programs_to_electrify_space_heating_brief_final_6-23-20.pdf

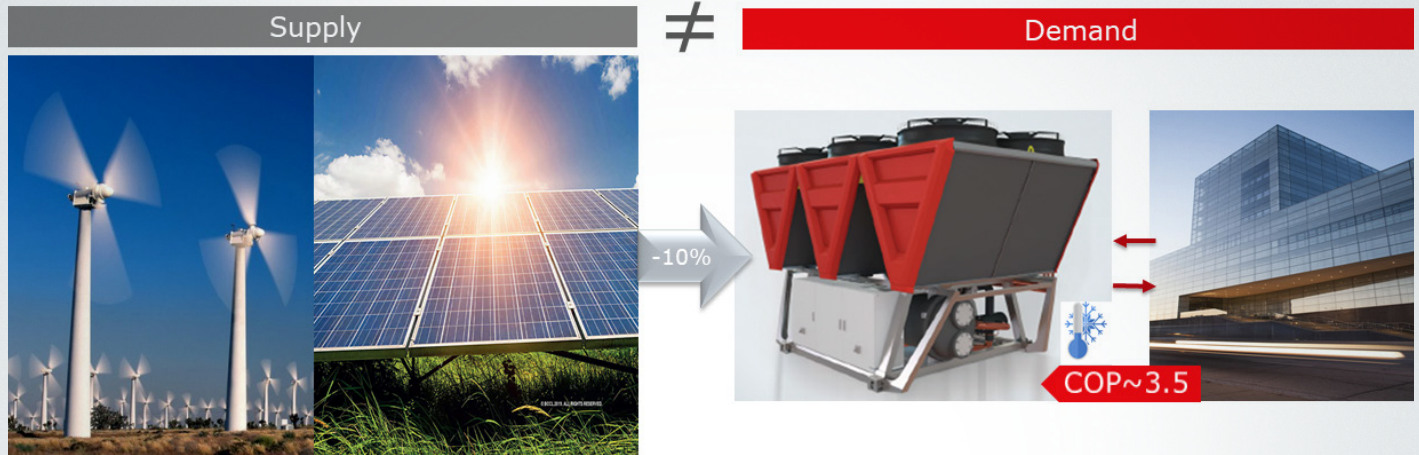
Utilities are driving the demand side of electrification programs. Specifically, they are creating electrification programs that include advanced heat pumps and grid-interactive efficient buildings. These demand-side changes can allow utilities to put off the more capital-intensive changes of additional switching from fossil fuels

to renewables. Electrification programs also drive the efficiency option, as efficiency is always the lowest cost option. To put it another way, not using energy in one location is always the lowest cost source for another.

Table 1. Budgets and participation by program

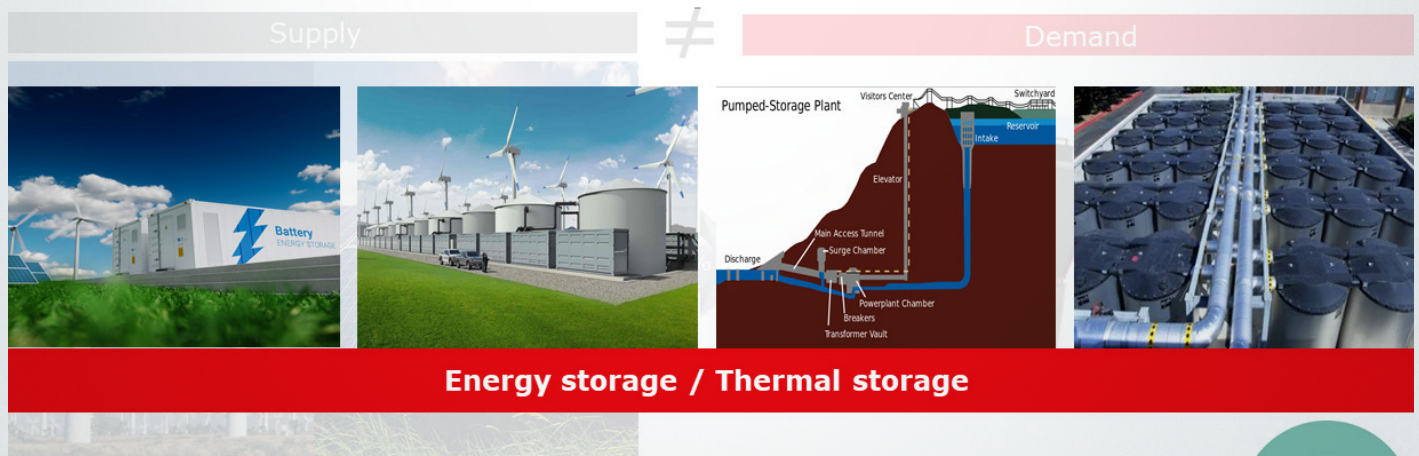
Program implementer	Annual budget	
	Prior year	Current year
Total	\$63,875,169	\$108,886,374
Program	Incentive	
Ground-source heat pumps		
NYSERDA 2019	\$1,500/ton	
NY utilities 2020	\$1,500–2,850/ton	
Massachusetts MVP	\$6,000–20,000 per home	
Ducted heat pump (sometimes cold climate)		
SMUD	\$4,500 per system	
SCE	\$300–600/ton	
NYSERDA 2019	\$1,000/ton	
NY utilities 2020	\$1,000–2,000/ton	
Energize CT	\$500 per system	
Mass Save	\$1,250/ton	
MassCEC	\$2,500 (convert from NG)	
Massachusetts MVP	\$2,000–12,000 per system	
Vermont Tier III	\$500–800 per system	
Efficiency Vermont	\$800/ton	
Vermont ZEN	\$15,000 per home	
National Grid Rhode Island	\$1,000/ton	
EWEB	\$800 per system	
Boulder	\$1,450 per system	

Reconnecting **Supply** & **Demand**



As the renewable volume goes up on electricity grids, the cost comes down. And that can be seen with wind and solar, which have significantly come down in cost and will continue to go down. In the meantime, energy efficiency is by far the lowest cost generation source. We have also seen a significant change in the number and the content of electrification programs. The American Council for an

Energy-Efficient Economy (ACEEE) is a great resource for what electrification programs are available, both locally and across the nation. Today, a lot of these programs are centered especially around the northwest and northeast, but they are expanding to other localities.



As previously mentioned, another factor that comes into play is reconnecting supply to demand. In addition to peaking plants, we will need to address the additional disconnect created from supply and demand by integrating energy storage on the supply and demand side.



Grid Interactive Efficient Buildings (GEB)



"GEB is about enabling buildings to provide flexibility in energy use and grid operation"



Prioritizing HVAC solutions which provide flexibility/resiliency for variable electrical supply



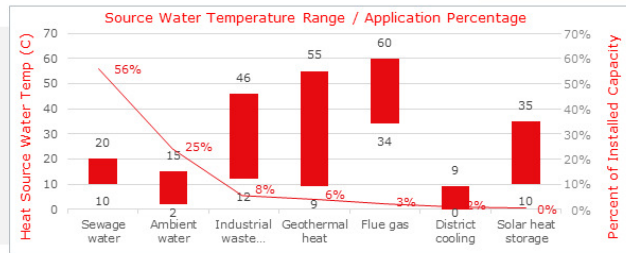
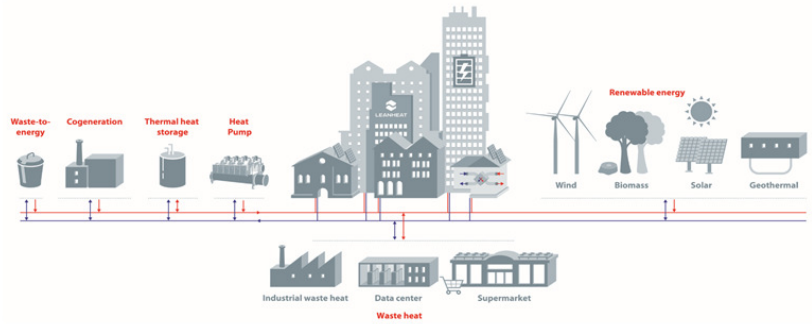
Critical factors with GEB
1. Efficiency
2. Load shift/shed
3. Modulate

	Technologies	Capability Legend: NA Low Med High	Efficiency	Load Shed	Load Shift	Modulate	Overall Potential
HVAC	HVAC#1: Smart Thermostats						High
	HVAC#2: Separate Sensible and Latent Space Conditioning						High
	HVAC#3: Liquid Desiccant Thermal Energy Storage						High
	HVAC#4: Controls for HVAC Equipment w/ Embedded T-stats						Med
	HVAC#5: Hybrid Evaporative Precooling						Low
	HVAC#6: Dual-Fuel HVAC						Low
Cross Cutting	CC#1. Thermal Energy Storage (TES)						High
	CC#2. Modulating Capacity Vapor Compression						Med
	CC#3. Non-vapor Compression (NVC) Systems and Materials						High

Energy storage takes various forms, including batteries, pumped hydro, and thermal storage. The most cost-effective form of energy storage today is thermal storage. While the energy storage cost of batteries will continue to come down, thermal storages is still in the range of about 1%–10% of the applied cost of battery storage, and we expect that difference will continue for a while.

Missing from the conversations thus far on grid-interactive efficient buildings and future-proof HVAC systems has been the potential of district energy systems to address all these goals. District energy systems have built-in redundancy, storage, and resiliency. A district energy system takes advantage of the built-in thermal flywheel effect, creates the option for recovering heat from different sources in the system, and turns down generation sources that are built into the system as needed based on demand.

- Conspicuously missing from most US electrification discussions
- Built-in redundancy/storage/resiliency
- Enable multiple heat recovery heat pump heat sources / storage opportunities
- Efficiency, loading and scale flexibility



District cooling prevalent in US / district heating less so

Europe evolution provides great benchmark

Historic water-water heat pumps & associated heat sources

Multiple heat sources with a few most prevalent

Evolving to new and more distributed sources today

We have seen significant evolution of district energy—especially district heating—systems, particularly in integrating in and planning out heat recovery and electrification of those systems. Adding heat pumps, and specifically water-to-water heat pumps using heat recovery, is a fantastic solution for both electrification and the ultimate goal of decarbonization. Examining the different

district energy solutions available today, we see that smaller-capacity heat recovery sources are becoming much more prevalent as opposed to more of the centralized utility-driven generation. With the move from macro thermal grids to micro thermal grid with these district energy systems, the energy source is moving to the outer reaches of newer systems.

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