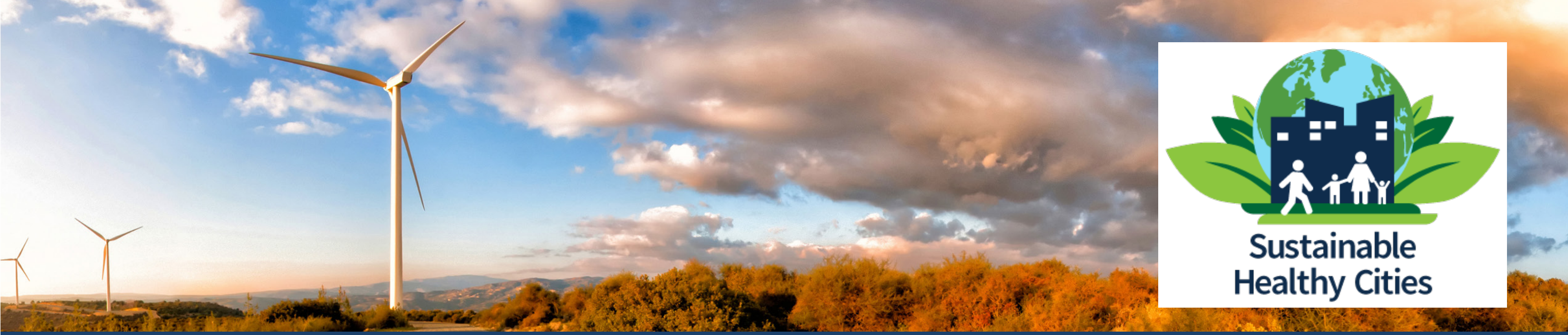


JOURNAL BRIEF: Distributed Electricity-Based Heating Systems and Renewable Energy Scenario Planning

Sustainable Healthy Cities Journal Brief - 2019, No. 11 - Distributed Electric Heating and Renewable Planning

This brief is adapted from the following peer-reviewed journal article: Yuan, S., Stainsby, W., Li, M., Xu, K., Waite, M., Zimmerle, D., Feiock, R., Ramaswami, A., & V. Modi. (2019). Future energy scenarios with distributed technology options for residential city blocks in three climate regions of the United States. Applied Energy, 237(2019), 60-69.

Study Intent and Research Question

As residential heating converts from natural gas-based to distributed electricity-based systems, can enough renewable energy be generated locally to meet most, if not all, of increased electricity demand? This study uses real consumption data to model the optimal renewable generation mix to meet increased demand due to the electrification of residential heating systems. The scenarios modeled include battery and thermal energy storage options, an option that assumes no storage, and an option that overbuilds renewable supply by 150% of demand. The scenarios consider three representative residential block types per model and are run in four US cities—Fort Collins (CO), Minneapolis (MN), New York (NY), and Tallahassee (FL)—which are located in three different climate zones.

Key Background Information

As of 2017, 48% of US homes were heated by natural-gas, while 37% were heated with electricity (EIA, 2017).

Shifting from natural gas based heating systems to distributed electric heating and cooling systems in buildings—using electric heat pumps—has been identified as a way to improve energy efficiency and reduce emissions in the residential sector (Bertsch & Groll, 2006).

Heat pump systems move heat rather than generate heat. They supply homes with warm air during heating days, and remove heat from homes during cooling days. They can be up to 50% more energy efficient than furnace or baseboard heaters powered by electricity (DOE, n.d.).

Two common types of heat pumps include air source pumps (aggregate heat from the air) and ground source pumps (aggregate heat from the ground). Ground source pumps are more expensive but more efficient. (DOE, n.d.). As more homes use electric heat pumps, overall electricity demand is expected to increase (Waite & Modi, 2016).

Because a region is generating enough renewable energy to theoretically meet all electricity demand in that region does not mean renewable penetration (percent of demand that is actually met using renewable supply) will be 100%. This is due to time-based misalignments in when renewable supply is generated and when there is demand.

Solar typically reaches peak generation during midday and wind generation is strongest at night, neither of which align ideally with afternoon/evening peak load times for electricity that are typical in the U.S.

Energy storage increases penetration by helping to match supply and demand, storing excess renewable supply so that it can be used to meet demand when renewable supply cannot be generated.

Comparative analysis for renewable energy planning across city types and climate regions is important due to geographically variable weather patterns, demand profiles, and local renewable supply options.

Key Findings

For residential heating supply based on both air source and ground source heat pump technology, the scenarios in this study respectively consider renewable energy scenarios that assume: 1) no storage capacity, 2) 12-hour battery storage capacity, 3) 36-hour thermal storage capacity, and 4) overbuilt renewable supply at 150% of demand.

On a per home basis, investment in 12-hour battery storage is the most cost effective strategy to meet a greater load proportion supplied by renewable generation.

For the scenario without storage, wind based supply dominates the optimal mix for Minneapolis and New York City, while the optimal mix in Fort Collins and Tallahassee is more even between solar and wind.

When 12-hour storage is available, the optimal supply mix in New York becomes more even between solar and wind, skewing toward solar in Fort Collins and Tallahassee.

When 12-hour storage is available, renewable penetration (actual demand met by renewable supply) increases: from 62 to 80% (New York City), 54 to 70% (Minneapolis), 54 to 83% (Tallahassee), and 49 to 69% (Fort Collins).

In all scenarios, some fossil fuel generation is needed to meet peak demand in cold climates (Fort Collins & Minneapolis) where renewable supply/demand are not aligned in the coldest months, even when storage is considered. Ground source pumps become cost competitive in cold climates in the winter as they reduce the need for fossil-fuel based peak generation.

Policy and Practice Implications

Incentives to switch to electric heating supply could have adverse GHG consequences if electricity supply is not also shifted to renewable generation.

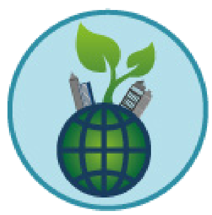
Policymakers should be cognizant of geographic and climactic variability in the optimal mix of wind versus solar generation because of interacting weather, supply, and demand considerations.

Incentives to invest in battery storage systems will increase the overall amount of demand that can be met with renewables.

Under scenarios in this study, renewable generation cannot meet 100% of demand, even when supply is overbuilt to 150% of demand. Low-carbon energy system planners should be counting on a smaller, but nonetheless important, role for fossil-fuel plants in meeting peak demand.

Incentives to switch home heating to electric heat pumps should consider the efficiency of new systems. In cold climates, a focus on ground source pumps (more expensive, but more efficient in the cold), may be warranted.

Energy



Environmental Sustainability

Integrative Scenarios

Further Reading and References

-Bertsch, S., & E. Groll. (2006). Air Source Heat Pump for Northern Climates Part I: Simulation of Different Heat Pump Cycles. International Refrigeration and Air Conditioning Conference, Paper 783. http://docs.lib.purdue.edu/iracc/783 [Open Access]
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The Sustainable Healthy Cities Network is a U.S. National Science Foundation supported sustainability research network focused on the scientific advancement of integrated urban infrastructure solutions for environmentally sustainable, healthy, and livable cities. We are a network of scientists, industry leaders, and policy partners, committed to building better cities through innovations in infrastructure design, technology and policy. Our network connects across nine research universities, major metropolitan cities in the U.S. and India, as well as infrastructure firms and policy groups to bridge research and education with concrete action in cities.