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Decarbonising heat in buildings – a comparison of policies in Germany and New England

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Introduction[1]

Decarbonising building heat presents both a significant opportunity and challenge to policymakers. Because of the fuel they use and the resulting carbon emissions, buildings are a critical target for energy efficiency. In order to deliver a clean energy system, most buildings will have to be highly energy efficient, providing the remaining energy needs through low-carbon energy technologies.

Buildings are eminently harder to decarbonise than other sectors. In Europe and North America, most of the buildings that will exist in 2050 have already been built. Therefore, it will be essential to retrofit our existing building stock with low-carbon heating technologies and to upgrade their energy performance. This is, by its nature, disruptive for the occupants of a building, subject to high transaction costs and relatively expensive, thus requiring strong policy support.

By contrast, decarbonisation of the power sector is now fully underway. The share of renewable energy has increased far beyond expectations, with prices falling at an unprecedented rate over recent years.[2] In the transport sector, we are beginning to see a substantial shift in the market toward electric vehicles. As the typical turnover period for a vehicle fleet is only 13 years, it is conceivable that, with policy support, a large share of transport could be electric in 10 to 15 years.[3]

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[2] BloombergNEF (2019): Battery Power's Latest Plunge in Costs Threatens Coal, Gas. Retrieved from https://about.bnef.com/blog/battery-powers-latest-plunge-costs-threatens-coal-gas/

[3] RAP (2019): Start with smart: Promising practices for integrating electric vehicles into the grid. Retrieved from https://www.raponline.org/knowledge-center/start-with-smart-promising-practices-integrating-electric-vehicles-grid/

The context in which the building heating transformation will take place is, of course, different across the world. This paper looks at heat decarbonisation and energy efficiency in buildings in Germany and New England,[4] two regions that have established sophisticated policies and set ambitious targets.

Whilst the contexts in the two locations are different, the opportunities and challenges associated with space heating decarbonisation and building energy efficiency are similar. (Energy demand for cooling and appliance use [except heating systems] is excluded from the scope of this paper.) We have analysed the commonalities and key differences between the policies employed and have distilled the important lessons. Those lessons will be valuable not only for policymakers in New England and Germany, but also for those working on policy design and implementation elsewhere.

Different contexts, similar challenges

Germany and New England have historically implemented ambitious energy efficiency and heat policies, which are featured in some shape or form in most international best practice reviews.[5,6] Both regions are global energy efficiency leaders. In the American Council for an Energy-Efficient Economy's (ACEEE) 2018 International Energy Efficiency Scorecard, Germany ranked No. 1, in a tie with Italy.[7] Within the United States, most of the New England states rank high in the 2018 State Energy Efficiency Scorecard.[8]

Before comparing policies and identifying the lessons to be learned, we briefly present the key features in both locations in terms of the importance of heating and buildings, the heating fuels and technologies used, and the climate and energy goals.

Importance of heating and buildings

The buildings sector is important with regard to its contribution to final energy demand. Overall, heat is a significant end use both in Germany (33% of final energy consumption[9]) and in New England (about 33%, but this figure includes a percentage of energy used for cooling[10]). According to Northeast Energy Efficiency Partnerships, these figures are similar for different New England states. For example, Rhode Island estimates that 35% of its energy-related greenhouse gas emissions are related to thermal energy, while Massachusetts estimates that 36% is related to thermal energy consumption in buildings.[11]

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[4] New England comprises the states of Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island and Vermont.

[5] IEA (2017): Market-based Instruments for Energy Efficiency. Retrieved from https://www.iea.org/publications/insights/insightpublications/MarketBased_Instruments_for_Energy_Efficiency.pdf

[6] Ricardo-AEA (2015): A Comparative Review of Housing Energy Efficiency Interventions. Report for ClimateXChange. Retrieved from https://www.climatexchange.org.uk/media/1403/final_report_261015.pdf

[7] ACEEE (2018a): The 2018 International Energy Efficiency Scorecard. Retrieved from https://aceee.org/research-report/i1801

[8] ACEEE (2018b): The 2018 State Energy Efficiency Scorecard. Retrieved from https://aceee.org/research-report/u1808

[9] BDEW (2018): Entwicklung des Wärmeverbrauchs in Deutschland. Basisdaten und Einflussfaktoren. Retrieved from https://www.bdew.de/media/documents/20180925_Waerrmeverbrauchsanalyse_Foliensatz.pdf

[10] NEEP (2017): Northeastern Regional Assessment of Strategic Electrification. Retrieved from http://neep.org/sites/default/files/Strategic%20Electrification%20Regional%20Assessment.pdf

[11] NEEP (2017).

Within the building sector, 70% of the energy use in German homes is for space heating and a further 14% for water heating.[12] In New England, 75% of all direct fossil fuel use in buildings is for space heating and an additional 17% for hot water heating.[13]

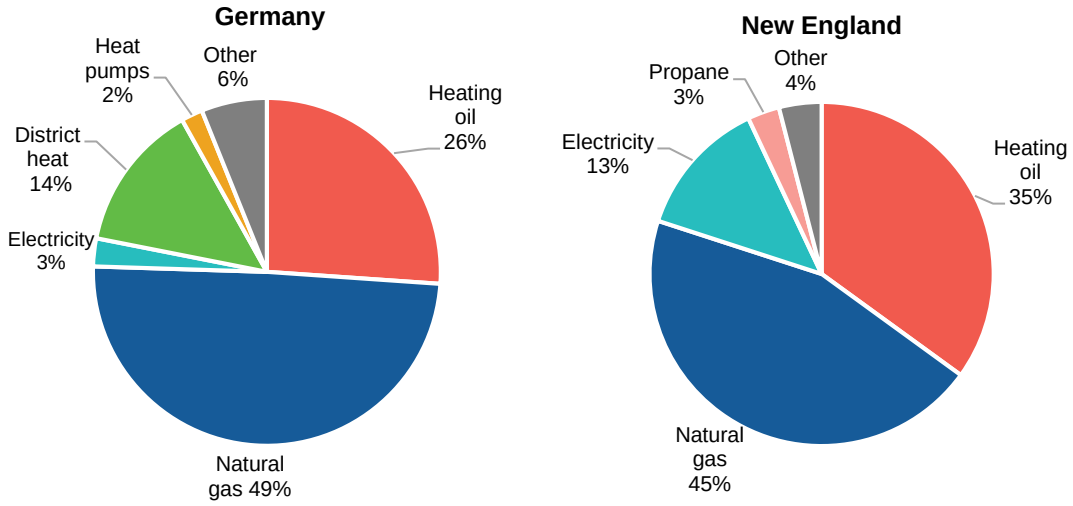
Heating fuels

When considering how to decarbonise heat, it is important to understand current fuel use.

In Germany, more than 75% of energy used for residential heat is based on natural gas or heating oils, as shown in Figure 1.[14] District heating networks, a technology less well known in the United States but an important feature of European heating systems, provide 14% of all heat. Only 4.6% of all energy used for heating is electric, of which 2% is used by heat pumps.

New England also relies primarily on heating oil and natural gas for heating buildings, accounting for about 80%. Electric heating is significantly more important in New England than in Germany, providing more than 10% of heat demand. There is almost no district heating in New England.

Figure 1. Heating fuels used in Germany and New England



Sources: BDEW (2018) and NEEP (2017)

The comparison shows that both places rely heavily on natural gas and heating oil. The key difference is the degree to which heating is electrified. In New England, more than 10% of all heating demand is provided through electric heating systems; in Germany, it makes up less than 5%.

[12] BMWi (2018): Energieeffizienz in Zahlen Entwicklungen und Trends in Deutschland 2018. Retrieved from https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/energieeffizienz-in-zahlen-2018.pdf?__blob=publicationFile&v=12

[13] NEEP (2017).

[14] BDEW (2018) and NEEP (2017).

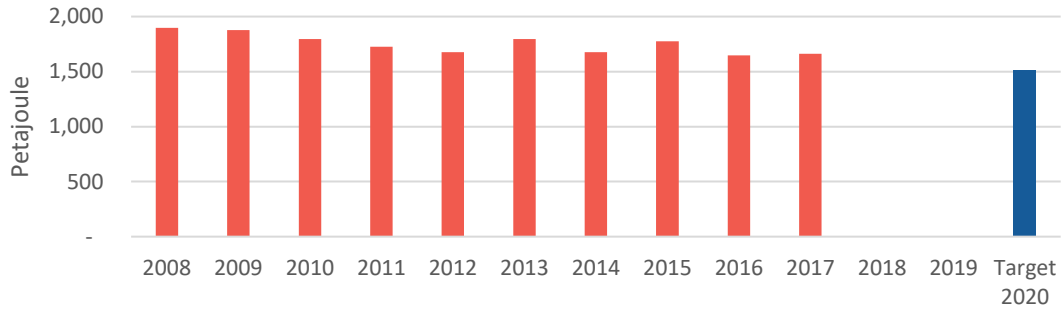
Climate and energy goals

Both Germany and the New England states have adopted ambitious energy and climate goals.

The German government committed to reducing carbon emissions from buildings by 66% to 67% by 2030, compared with 1990 emissions.[15] Achieving this goal will require significant improvements in energy efficiency and the adoption of renewable heating technologies.

In addition to the carbon reduction target, the German government adopted a heat demand reduction target of 20% by 2020, from 2008 levels.[16] In 2017, heat demand from residential buildings was 12% lower than in 2008. Based on the reductions achieved in recent years, Figure 2 illustrates it is possible that Germany will meet the 2020 target for heat demand, although it will be challenging.[17]

Figure 2. Heat demand of residential buildings



Source: Based on data from German Ministry for Energy and Economic Affairs (2017 and 2019)

To complement the targets for heat demand reduction, German legislators also adopted the goal that at least 14% of heating (and cooling) demand in buildings will be provided by renewable energy sources. This target will most likely be reached. With a share of 87.6%, biomass (solid, liquid, biogas and biogenic waste) is the most important source of renewable energy in the heating sector overall. Heat pump systems and solar collectors provided 7.6% and 4.8%, respectively, of total heat derived from renewables.[18]

[15] BMU (2016): Climate Action Plan 2050: Principles and goals of the German government's climate policy. Retrieved from https://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/klimaschutzplan_2050_en_bf.pdf

[16] BMWi (2015): Energy Efficiency Strategy for Buildings. Methods for achieving a virtually climate-neutral building stock. Retrieved from https://www.bmwi.de/Redaktion/EN/Publikationen/energy-efficiency-strategy-buildings.pdf?__blob=publicationFile&v=7

[17] BMWi (2017): Energieeffizienz in Zahlen. Retrieved from https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/energieeffizienz-in-zahlen.pdf; and AG Energiebilanzen (2019): Anwendungsbilanzen für die Endenergiesektoren in Deutschland in den Jahren 2013 bis 2017. Retrieved from https://ag-energiebilanzen.de/#ageb_bericht_anwendungsbilanzen_2013-2017_final__2019-01-03

[18] BMWi (2018): Sixth "Energy Transition" Monitoring Report. Retrieved from https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/sechster-monitoring-bericht-zur-energiewende-langfassung.pdf?__blob=publicationFile&v=6

The New England states have all adopted aggressive and relatively similar greenhouse gas reduction targets, as illustrated in Table 1.[19]

Table 1. State greenhouse gas reduction targets

Connecticut	80% below 2001 levels by 2050
Maine	75%-80% below 2003 levels in the long term
Massachusetts	80% below 1990 levels by 2050
New Hampshire	80% below 1990 levels by 2050
Rhode Island	85% below 1990 levels by 2050
Vermont	75% below 1990 by 2050

Source: Building and Research Information (2016)

Policy approaches

Both Germany and the New England states have deployed a variety of policy approaches to drive the decarbonisation of heat. Some methods have been in place for many decades and have been adapted over time, while others were implemented only recently. The key policies for heat decarbonisation in the two regions include building codes, appliance standards, weatherisation programs and energy efficiency resource standards. In European terms, weatherisation is akin to energy efficiency retrofit programs for buildings, while energy efficiency resource standards are known as energy efficiency obligations. International experience with energy efficiency and heat decarbonisation supports the need to use a mix of policies.[20]

Building codes and appliance standards

Building codes and appliance standards are critical for supporting heat decarbonisation, particularly for new buildings. It is essential that both energy efficiency and clean energy generation technologies can be used in combination to allow homeowners to meet the regulations at least cost.

Germany

In the European Union, all Member States have to establish national building codes following requirements set by the Energy Performance of Buildings Directive. Germany has done so through the Energy Savings Ordinance, which is regularly updated. The focus of the ordinance is mainly on new buildings and requires minimum energy performance levels in terms of primary energy. The ordinance applies to existing buildings in cases of major renovations affecting more than 25% of the building surface or value. In those cases, the whole building needs to be upgraded to meet the requirements in the ordinance. In case of minor renovations, only those parts of the buildings that are new, such as windows, need to comply with the ordinance. Compliance with the law can be achieved through either energy efficiency, on-site renewable energy generation or a combination of the two, given that the performance is measured in terms of primary energy and not final. By definition, this incentivises homeowners to consider heat pumps, which reduce primary energy needs even though they increase the electric load of the building.

[19] State targets presume emissions reductions beyond those solely available from buildings. Center for Climate and Energy Solutions (2019): Greenhouse Gas Emission Targets. Retrieved from www.c2es.org/us-states-regions/policy-maps/emissions-targets

[20] Rosenow, J., Fawcett, T., Eyre, N., Oikonomou, V. (2016): Energy efficiency and the policy mix. Special issue: Building Governance and Climate Change: Regulation and Related Policies. *Building Research & Information* 44(5-6), pp. 562-574. Retrieved from https://www.tandfonline.com/doi/abs/10.1080/09613218.2016.1138803?journalCode=rbri20

European legislation also requires that an energy performance certificate is available for every building sold or rented. The certificate is a convenient way for tenants, leaseholders and buyers to compare the energy requirements and consumption of buildings in Germany. Similar to the energy efficiency label for electrical devices, the energy efficiency of buildings is classified on a sliding bar label with a colour scale ranging from green to red to indicate the energy requirements or consumption. This provides an estimate of costs for heating and hot water. Moreover, the efficiency classes indicate the building's energy efficiency.

Germany also implemented the Renewable Heat Law in 2009. This law requires owners of newly constructed buildings to generate a share of the energy needed for the building through on-site renewable energy technologies. The proportion depends on which technologies are used. For example, with solar thermal, at least 15% of the space heating and cooling energy requirement of the building must be covered by the solar thermal system. For geothermal or biomass, the required contribution is 50%.[21] Heat pumps are also an eligible technology.[22]

Heating systems in Germany are subject to EU regulation under the Ecodesign Directive, which sets minimum performance standards for boilers and heat pumps. These standards will be tightened over time.

New England

New England has taken a similar approach. Building codes require builders to meet certain levels of building energy performance for both new construction and the maintenance and performance of energy systems in existing buildings.[23] The United States Department of Energy requires states to report whether they have adopted the latest version of codes. New Hampshire and Vermont are currently reviewing and considering the 2018 International Energy Conservation Code.[24] Under Massachusetts law, the state is required to adopt the latest version within one year.

A number of states have also moved toward the development of voluntary net-zero standards for new and existing buildings.[25] Planning for this is underway, for example, in Vermont, Rhode Island and Massachusetts.[26]

Ensuring compliance with codes is necessary in order for states — and building owners and bill-payers — to enjoy the benefits of adopting them. The American Council for an Energy-Efficient Economy describes the importance of a "support network" for states that includes various groups and organisations that all help states meet their code compliance goals.[27] For example, in addition to support from federal agencies like the U.S. Department of Energy, there are regional energy efficiency organisations like Northeast Energy Efficiency Partnerships that work closely with states and builders to support code adoption and compliance.

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[21] BMWi (no date): Erneuerbare-Energien-Wärmegesetz. Retrieved from https://www.erneuerbare-energien.de/EE/Navigation/DE/Recht-Politik/Das_EEWaermeG/das_eewaermeg.html

[22] UBA (2018): Umgebungswärme und Wärmepumpen. Retrieved from https://www.umweltbundesamt.de/themen/klima-energie/erneuerbare-energien/umgebungswaerme-waermepumpen

[23] Most U.S. states apply the International Energy Conservation Code (IECC) for residential buildings and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards for commercial building codes.

[24] ACEEE (2018b), Pages 70-71.

[25] A net-zero building produces as much energy as it consumes, typically as measured over one year. ACEEE (2018b), Page 71.

[26] See, for example, Vermont's Comprehensive Energy Plan, Pages 8 and 9. Retrieved from https://legislature.vermont.gov/assets/Legislative-Reports/Executive-summary-for-web.pdf; The Rhode Island Residential Stretch Code. Retrieved from http://www.energy.ri.gov/documents/leadbyexample/stretch-code/RIRSC%20FINAL%2002-15-18.pdf; and the Pathways to Zero Net Energy Program, established by the Massachusetts Department of Energy Resources. Retrieved from https://www.mass.gov/service-details/pathways-to-zero-net-energy-program

[27] ACEEE (2018b), Page 71.

A related approach to promoting the energy-saving features of homes as they are sold is referred to as "home energy labelling." For example, in Maine, a potential building tenant can require the lessor to disclose an energy efficiency checklist, making available audit information on the residential rental property at the time of rental.[28] The rationale of such an approach is similar to that behind the fuel economy standard — i.e., indication of miles per gallon, labels on vehicles — and gives an indication of the energy performance of a building.

Other examples of disclosure include the Residential Energy Services Network, which helps in marketing the energy performance of homes,[29] and the U.S. Department of Energy's Home Energy Score.[30] Connecticut and Massachusetts have adopted this score in their voluntary labelling initiatives.[31] Northeast Energy Efficiency Partnerships has also developed a program called the Home Energy Labeling Information Exchange to help coordinate building energy data across New England states and New York.[32] Finally, it is worth emphasising that not only do states adopt labelling programs, but local jurisdictions within states like Vermont, Massachusetts and Connecticut do as well.[33]

Appliance standards are another form of regulation relevant for heat. The U.S. Department of Energy and the Environmental Protection Agency periodically update appliance standards for furnaces (usually referred to as boilers in Europe) and water heaters, enabling purchasers to capture significant energy savings. The Energy Department's standards require appliances to meet certain efficiency levels, while the Environmental Protection Agency's voluntary Energy Star program encourages even greater efficiency.

Weatherisation programs

Every major study that models pathways for heat decarbonisation demonstrates the need for substantial improvements in building fabric energy performance.[34] This is largely for two reasons. First, the options for energy efficiency improvements are still plentiful, and large reductions in heat demand can be achieved through societally cost-effective energy efficiency measures. Second, it is not practical to decarbonise heat at scale, within the timescales required, without significant energy efficiency upgrades. For example, supplying the additional load resulting from electrified heating will require much higher investments in generation, transmission and distribution if the efficiency of the energy demand remains unaddressed — and legacy fossil fuel emissions will remain higher while those larger renewables fleets are being built.

It is partly for this reason that both Germany and New England have implemented weatherisation programs. We briefly present their key features below.

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[28] State of Maine (2006): Act Regarding Energy Efficiency Standards for Residential Rental Properties. See 14 M.R.S.A. 6030-C, Rental Energy Efficiency Disclosure Statement. Retrieved from https://www.maine.gov/mpuc/online/forms/Chap534finallaw_001.pdf

[29] Residential Energy Services Network (no date). Retrieved from http://www.resnet.us/about/what-is-resnet

[30] Better Buildings (no date): Home Energy Score. Retrieved from https://betterbuildingsinitiative.energy.gov/home-energy-score

[31] Energize Connecticut. Retrieved from https://www.energizect.com/your-home/solutions-list/home-energy-solutions-core-services; and Mass Save. Retrieved from https://www.masssave.com/en/saving/energy-assessments/what-is-a-home-energy-assessment/

[32] Home Energy Labeling Information Exchange. Retrieved from https://neep.org/home-energy-labeling-information-exchange-helix

[33] Faesy, R., Badger, L., Levin, E., Ferington, D., Finlayson, I., and Lano, J.B. (2014): Residential Building Energy Scoring and Labeling: An Update from Leading States. Retrieved from https://aceee.org/files/proceedings/2014/data/papers/2-113.pdf

[34] See, for example, ifeu, Fraunhofer IEE, Consentec (2018): Wert der Effizienz im Gebäudesektor in Zeiten der Sektorenkopplung. Study commissioned by Agora Energiewende. Retrieved from https://www.agora-energiewende.de/fileadmin2/Projekte/2017/Heat_System_Benefit/143_Heat_System_benefits_WEB.pdf

Germany

Germany has a long-standing building energy efficiency finance program that is administered by the public bank Kreditanstalt für Wiederaufbau (KfW). KfW, also known as the German Development Bank, formed in 1948 after World War II as part of the Marshall Plan. The federal government owns 80% of KfW and the German states own 20%. Since its creation, KfW has run several loan and grant programs related to housing refurbishment. The first programs started in 1990, although their primary focus was not energy efficiency but modernising the housing stock in former East Germany after reunification.[35] From 2006 to 2018, 5.4 million dwellings[36] and 1 out of 3 refurbished buildings received KfW funds.[37] The programs are funded through general taxation and currently receive subsidies of about 2 billion euros per year.[38]

While the programs have changed over time, the core idea of providing low-interest loans, and later grants, for energy efficient refurbishment and construction remains. The most innovative feature of the KfW programs is their integration with the building code. The level of finance depends in part on the extent to which the refurbished building exceeds the benchmarks stipulated in the building code requirements for new buildings.[39] In addition, homeowners can also access KfW funds for single measures or for a package of measures.

The other important component of the KfW programs is the integration with and funding for high-quality advice on the types of technologies to install in a building. The program pays 50% of the cost of using an approved energy advisor[40] (up to a maximum of 4,000 euros), in addition to funding for the measures themselves.

There are other finance mechanisms on offer which are often administered at a regional level, but the KfW programs are by far the most important and most prominent mechanism to stimulate investment in building retrofits.

New England

In New England, "weatherisation" is a term that applies to a specific federal program designed to improve the fuel efficiency of low-income housing and also to state efforts generally to refurbish housing to make it more efficient. The Weatherization Assistance Program (WAP) is a federal program that enables low-income families to reduce their energy bills by making their homes more energy efficient.[41] The U.S. Department of Energy provides funding to states that, in turn, fund a network of local community action agencies, nonprofit organisations and local governments that provide these actual weatherisation services.

A number of New England states have developed programs to augment or reinforce WAP funding and expand building refurbishment efforts. In Vermont, for example, the Legislature increased funding for it significantly in 1990 by creating an "all fuels" charge of 0.5% on the gross sales of nontransportation fuels. Those funds, now channelled through a special Home

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[35] Rosenow, J., Eyre, N., Rohde, C., Buerger, V. (2013): Overcoming the upfront investment barrier – comparison of the German CO_2 Building Rehabilitation Programme and the British Green Deal. *Energy & Environment* 24(1&2), pp. 83-103.

[36] BMWi (2019): Energieeffizient Wohnen: 2018 zehn Millionen Tonnen Treibhausgase eingespart. Retrieved from https://www.bmwi-energiewende.de/EWD/Redaktion/Newsletter/2019/02/Meldung/direkt-erfasst_infografik.html

[37] BMWi (no date): Gebäude energieeffizienter machen. Retrieved from https://www.bmwi.de/Redaktion/DE/Dossier/energiewende-im-gebaeudebereich.html

[38] BMWi (2019).

[39] The reference point is a similar building constructed in line with the requirements of the building code from 2009. For refurbished buildings consuming 45% less than the requirements in the 2009 building code, 27.5% of the loan volume is granted as a rebate. This is the maximum amount of rebate on offer. If the refurbished building only consumes 15% less than the 2009 building code requirements, the rebate is capped at 12.5%.

[40] The website https://www.energie-effizienz-experten.de/ lists approved advisors.

[41] Weatherization Assistance Program for Low-Income Persons. Retrieved from https://www.bene.fits.gov/benefit/580

Weatherization Assistance Fund, pay for 80% of the total cost of the low-income weatherisation program. While total funding is far below what is needed even today,[42] the structure of the program is a useful, proven model for the kind of assistance that will inevitably be needed to transform the housing stock for low-income households.[43]

The state of Connecticut developed the Green Bank and the Housing Development Fund to provide loans and technical assistance to owners of affordable multifamily buildings to make energy efficiency improvements.[44] The bank's residential solar program requires all customers receiving an incentive for solar photovoltaics to have an energy efficiency assessment performed. This is done predominantly through the utility-administered Home Energy Solutions program that provides basic weatherisation and other energy saving measures. The bank was funded with a grant from a private foundation as well as with funds from Connecticut's participation in the Regional Greenhouse Gas Initiative (RGGI) carbon allowance market.[45]

The state of Massachusetts administers low-income conservation programs for electricity customers and natural gas customers by placing a conservation charge on energy bills. Through the Green Communities Act, the state mandated additional funding for low-income building weatherisation by requiring that 10% of electric utility program funds and 20% of gas program funds be spent on low-income energy efficiency and education programs. In an effort to encourage standardisation of program implementation among all utilities in the state, the act requires these programs to be implemented through the existing WAP program network.

In addition to the WAP-related programs, Massachusetts utilities fund the Low-Income Multifamily Retrofit Program, which provides cost-effective energy efficiency improvements to multifamily buildings, including those owned by nonprofit and public housing authorities.[46]

Low-carbon and renewable heat programs

International experience has shown that subsidies for replacing fossil fuel-based heating with low-carbon alternatives can also be effective in stimulating demand for both heat pumps and heat networks.[47] Today, the capabilities of electrical end uses like heat pumps make them an effective and low-cost way of integrating higher levels of variable renewable resources. Heat pumps are becoming more efficient and modular but still have the potential to contribute

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[42] RAP (2011): Affordable Heat: Whole-Building Efficiency Services for Vermont Families and Businesses. Retrieved from www.raponline.org/wp-content/uploads/2016/05/rap-affordableheatfullreport-2011-08-01-final.pdf

[43] Vermont Agency of Human Services (2018): Weatherization Assistance Program Overview. Retrieved from https://legislature.vermont.gov/Documents/2020/WorkGroups/Senate%20Economic%20Development/Housing%20and%20Homelessness/W~Geoff%20Wilcox~Weatherization%20Assistance%20Program%20Overview%20~2-7-2019.pdf

[44] Richardson, J. (2018, September 26): More Than $1 Billion Provided by Connecticut Green Bank For Clean Energy Projects. Retrieved from https://cleantechnica.com/2018/09/26/more-than-1-billion-provided-by-connecticut-green-bank-for-clean-energy-projects/

[45] Funds from RGGI auctions are used to fund commercial property assessed clean energy program (C-PACE) loans. State of Connecticut (2018): Auditors' Report Connecticut Green Bank. (for Fiscal Years ended June 30, 2014 and 2015). Retrieved from https://www.ctgreenbank.com/wp-content/uploads/2018/02/Connecticut-Green-Bank_20180215_FY20142015.pdf. For more information see the discussion under the carbon revenue recycling section starting on Page 12.

[46] Action for Boston Community Development Inc. (no date): Massachusetts Low Income Multifamily Energy Retrofit Program. Retrieved from https://www.cityofboston.gov/images_documents/ABCD_Powerpoint_LIMF_tcm3-38494.pdf. ACEEE reports that this program targets one- to four-unit residential buildings where at least 50% of the units are occupied by residents earning at or below 60% of area median income. The program seeks to develop efficiency upgrades for buildings with high energy consumption, specifically for space heating, hot water, air sealing and insulation of building envelopes, lighting and appliances. See ACEEE (2018b), Page 178.

[47] UKERC (2016): Best practice in heat decarbonisation policy: A review of the international experience of policies to promote the uptake of low-carbon heat supply. Retrieved from http://www.ukerc.ac.uk/programmes/technology-and-policy-assessment/best-practice-in-heat-decarbonisation-policy.html

about 4 kWs to a household's peak electricity consumption. Given their flexibility, however, some of this load (especially water heating load) could be moved to different times of the day when power is cheaper and cleaner. Encouraging consumers to shift their usage to more beneficial times of day will require appropriate regulatory, technological and economic support. Yet adding this flexible electric demand to the system and managing it is critical, as it can save consumers money and reduce the total associated power emissions.[48] Heat decarbonisation programs are beginning to recognise these benefits in both Germany and New England.

Germany

The Market Incentive Program, which was established in 1994, is the central funding instrument for expanding the use of renewable energy in the heating and cooling sector. Eligible technologies are heat pumps, biomass and solar thermal. Data from small-scale installations show that in 2017 the program supported around 18,400 heat pumps and 17,800 solar thermal and biomass installations. The program was subsidised with approximately 250 million euros in public funds, of which 210 million were allocated to small-scale installations. According to the last evaluation, these public funds triggered a total investment of 1.1 billion euros.[49]

New England

Three New England states have been focused on promoting electrification by providing incentives for heat pumps and heat pump water heaters with other energy efficiency measures.[50] Maine leads the New England states in displacing residential heating oil with highly efficient electric heat pumps.[51] Heat pump programs in Maine provide residential and commercial customers with rebates to lower the upfront cost. Over 25,000 heat pump units have been installed since the program began in 2011.

Nearly 82% of Massachusetts households use natural gas, fuel oil or propane. The state has two heat pump programs: a collaborative for utilities called Mass Save and the Clean Heating and Cooling program run by a nonprofit, the Massachusetts Clean Energy Center. These two programs have relied on rebates and have incentivised the sale of roughly 18,000 heat pumps in total since 2015.[52]

Vermont has identified heat pumps as a strategy for reducing the state's fossil fuel consumption and supports various programs to incentivise their deployment. State programs administered by the efficiency utility and other utility companies support a midstream rebate program for heat pump distributors. Vermont also has a utility portfolio standard that requires utilities to encourage their customers to reduce fossil fuel usage. One of the categories or "tiers" of the portfolio standard supports greater electrification in homes, including transportation, space heating and water heating. ACEEE reports that "Vermont has the highest [ductless heat pump] installation rate (as a percentage of total homes) of any state in the Northeast. To date, Efficiency Vermont has incentivised more than 8,200 heat pumps through the program. The

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[48] RAP (2018): Beneficial electrification of space heating. Montpelier, VT: Regulatory Assistance Project. Retrieved from https://www.raponline.org/knowledge-center/beneficial-electrification-of-space-heating

[49] Stuible, A., Zech, D., Ullrich, S., Wülbeck, H.F., Wapler, J., Mezer, R., Günther, D., … Schröder, G. (2018): Evaluation des Marktanreizprogramms zur Förderung von Maßnahmen zur Nutzung erneuerbarer Energien im Wärmemarkt im Förderzeitraum 2015 bis 2017. Retrieved from https://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/Berichte/evaluierung-marktanreizprogramm-2017.pdf?__blob=publicationFile&v=3

[50] Nadel, S. (2018, August 1). New programs nudge homeowners to switch to electric heat pumps. Retrieved from https://aceee.org/blog/2018/08/new-programs-nudge-homeowners-switch

[51] Nadel, S. (2018, August 1).

[52] Nadel, S. (2018, August 1).

Vermont Energy Investment Corporation attributes this success largely to the large upstream incentives."[53]

Energy efficiency resource standards

Energy efficiency resource standards (EERS), known as energy efficiency obligations in Europe, set savings targets that retail distributors of electricity or natural gas must meet, and can contribute to significant carbon emissions reductions.[54] They typically require a level of annual percentage reduction or cumulative reduction of energy over a given time period, whether measured in kilowatt-hours for electricity or therms for natural gas. Table 2 illustrates EERS targets for electric and gas utilities in New England.[55]

Table 2. Annual EERS targets by state

	Electricity	Gas
Massachusetts	2.9% (2016-18)	1.2% (2016-18)
Rhode Island	2.5% (2015) 2.55% (2016) 2.6% (2017)	1% (2015) 1.05% (2016) 1.1% (2017)
Maine	2.4% (2014-16)	0.2% (2017-19)
Vermont	2.1% (2015-17)	2% (2015-17)[56]
Connecticut	1.6% (2016-18)	0.61% (2016-18)
New Hampshire	0.8% (2018) 1% (2019) 1.3% (2020)	0.7% (2018) 0.75% (2019) 0.8% (2020)

Source: American Council for an Energy-Efficient Economy (2017)

Because greater adoption of electrification — which obviously *increases* electricity use — may appear to be counterproductive to the achievement of energy efficiency targets, an EERS' metrics may need to be revised or adjusted. Put another way: Because an EERS measures energy savings as reduced or avoided kilowatt-hours or therms, rather than reduced or avoided primary energy like British thermal units (Btu) or joules, the additional kilowatt-hours serving a newly deployed and more efficient electric heat pump, for example, could still mistakenly be accounted for as increased energy use, rather than efficiency. Structured this way, an EERS (or other incentive program) may discourage electrification because efficiency, as typically defined, requires decreases in kilowatt-hour sales, rather than reductions in primary energy consumption.[57]

[53] Nadel, S. (2018, August 1).

[54] Hibbard, P. and Okie, A. (2014): Crediting Greenhouse Gas Emission Reductions from Energy Efficiency Investments, Recommended Framework for Proposed Guidance on Quantifying Energy Savings and Emission Reductions in Section 111(d) State Plans Implementing the Carbon Pollution Standards for Existing Power Plants. Retrieved from https://www.edf.org/sites/default/files/eemv-111d-recommended-framework.pdf

[55] ACEEE (2017): State Energy Efficiency Resource Standards (EERS) Activity. Retrieved from https://aceee.org/policy-brief/state-energy-efficiency-resource-standard-activity

[56] Eileen Simollardes, Vermont Gas Systems, personal communication, 7 May 2019.

[57] Levin, E. (2018, August): Getting from here to there: How efficiency programs can go beyond MWh savings to next-generation goals.

States are beginning to recognise this challenge and address this barrier. [58] As noted recently by ACEEE, Massachusetts' newest Three-Year Energy Efficiency Plan adopts a fuel-neutral savings target (an all-in target of 207 trillion Btu savings), reflecting "a growing trend among northeastern states to take a holistic approach to energy savings, including not only electricity and natural gas but also nonutility heating fuels."[59]

Carbon revenue recycling

Since effective programs are key to decarbonising buildings, ensuring that they are properly funded is also critical. Recycling revenues generated through the auctioning of carbon allowances for energy efficiency and heat decarbonisation programs can make a powerful contribution to achieving decarbonisation targets cost-effectively. Strategically investing carbon revenues in end-use energy efficiency can yield multiple dividends:

- Additional emissions reductions from sectors both covered by and outside of the emissions trading system.
- Lower economic and societal decarbonisation costs, capturing a larger fraction of cost-effective emissions reduction potential and reducing energy bills for end users.
- A wide range of so-called nonenergy benefits to consumers and society. Amongst those are improvements in health, comfort, air quality, public housing and welfare costs, job creation and economic growth.
- Support for the political process to further tighten the cap in an emissions trading system. An increase in the political will and social acceptance, as a result of the previous benefits, can enable more ambitious long-term decarbonisation targets.

Germany

The European Union has long encouraged Member States to dedicate at least half of their carbon revenues to climate purposes, and there is ample experience across Europe on ways to invest receipts from the emissions trading system. Recent research on carbon revenue recycling in Europe reveals that about one-quarter of carbon revenues received in 2016 were reinvested in energy efficiency.[60]

Germany already allocates a significantly higher share (53%) of its carbon revenues to energy efficiency, compared with the average rate in the EU, through the Energy and Climate Fund. Since 2011, the KfW building retrofit programs have been partially funded by the Energy and Climate Fund, a government-owned fund to finance climate policy, energy storage technologies, electric vehicles, energy efficiency measures and renewable energy. The largest portion of financial resources allocated to the Energy and Climate Fund and invested in energy efficiency

Washington, DC: American Council for an Energy-Efficient Economy. Retrieved from https://aceee.org/files/proceedings/2018/node_modules/pdfjs-distviewer-min/build/minified/web/viewer.html?file=../../../../../assets/attachments/0194_0286_000100.pdf

[58] New York has set a target to reduce energy consumption by 185 trillion Btu below forecast energy use by 2025. New York State Energy Research and Development Authority and Department of Public Service. (2018): New Efficiency: New York. Retrieved from https://www.nyserda.ny.gov/-/media/Files/Publications/New-Efficiency-New-York.pdf. In the Wisconsin Quadrennial Review process, the Public Service Commission set energy savings goals for 2019-2022 in terms of kilowatts, kilowatt-hours, therms and million Btu. Additionally, the commission set fuel-specific minimum performance standards. Maine Legislature. Maine Revised Statutes. 35-A MRS §10104, Energy Efficiency, Chapter 97L Efficiency Maine Trust Act. Retrieved from http://www.mainelegislature.org/legis/statutes/35-a/title35-Asec10104.html

[59] ACEEE (2018b), Page 10.

[60] RAP (2018): Carbon leverage: Investing Europe's carbon revenues in energy efficiency. Retrieved from https://www.raponline.org/knowledge-center/carbon-leverage-investing-europes-carbon-revenues-in-european-energy-efficiency/

programs in Germany (approximately 83%) contributes to the KfW program's "Energy Efficient Refurbishment."[61] This means that there is a link between the weatherisation programs run by KfW and carbon revenues.

The revenues generated by auctioning carbon allowances under the European Union's emissions trading system are likely to increase. This growth is driven by recent changes within the trading system framework, especially the implementation of the market stability reserve starting in 2019, which addresses the historic imbalance between supply and demand in the EU carbon market. Given the increase in carbon revenues, it becomes ever more important to assess their use and potential contribution to speeding up decarbonisation efforts.

New England

The New England states have extensive experience using revenues raised through their power sector carbon cap-and-trade program to fund energy efficiency. The Regional Greenhouse Gas Initiative is a cooperative effort among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island and Vermont to cap and reduce power sector carbon dioxide emissions.

In initial discussions leading up to the adoption of the 2005 memorandum of understanding that set out RGGI's initial program design, the states agreed that each would have full discretion in its use of allowance auction proceeds. On the basis of subsequent modelling and recognition that the lowest-cost carbon reduction policy would be increased state energy efficiency investment, the RGGI states, since the inception of the program in 2009, have regularly invested over half of the auction revenue in individual state efficiency programs[62] — including in the most recent three-year compliance period, from 2015 to 2017. [63] Investment in end-use energy efficiency is viewed as a critical program element that keeps consumer economic impacts manageable while reducing carbon emissions at low cost. Energy efficiency's demand reduction and related allowance price suppression effects were also considered an important key to reducing potential emissions leakage in areas bordering the RGGI region.

Lessons learned

As this report shows, there is a wealth of energy efficiency and heat policies in both New England and Germany. Both have shown leadership in this area and are internationally recognised for their achievements. The most important lessons from their experiences are summarised below.

What customers need in order to improve building performance:

- One key lesson from these leading jurisdictions is that retrofitting buildings for energy and carbon reductions is a challenging process because it depends on affirmative decisions made by millions of individuals, most of whom actually live in the buildings needing to be improved. There are many market barriers to be overcome, so well-designed, customer-focused programs are needed. Even the best programs have to address information needs, trust issues, financing and quality assurance needs.

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[61] RAP (2018): Carbon leverage: Investing Europe's carbon revenues in energy efficiency. Retrieved from https://www.raponline.org/knowledge-center/carbon-leverage-investing-europes-carbon-revenues-in-european-energy-efficiency/

[62] New Hampshire is the exception. It rebates any RGGI revenue over $1 per ton raised in the allowance auction. Recently, the New Hampshire Senate voted down a House-passed bill that would have eliminated the rebate and required the state to commit its RGGI funds toward energy efficiency. New Hampshire Public Radio (2018, April 26): N.H. Senate Defeats Bill to Funnel RGGI Funds Into Energy Efficiency. Retrieved from https://www.nhpr.org/post/nh-senate-defeats-bill-funnel-rggi-funds-energy-efficiency#stream/0

[63] Analysis Group (2019): Economic Impacts of the Regional Greenhouse Gas Initiative on Nine Northeast and Mid-Atlantic States: Review of RGGI's Third Three-Year Compliance Period (2015-2017). Retrieved from https://www.analysisgroup.com/globalassets/uploadedfiles/content/insights/publishing/analysis_group_rggi_report_april_2018.pdf

Funding heat decarbonisation and energy efficiency:

- The use of carbon revenues for energy efficiency (weatherisation) programs makes sense, and experience in both areas is positive.
- Low-interest loan programs have been pivotal in Germany for driving forward deep retrofits. The explicit link to building codes is a forward-looking approach to policy integration.
- Energy efficiency resource standards, known as energy efficiency obligations in Europe, are a key policy instrument in New England. Because they accommodate electrification, they will continue to be one of the most effective and economically efficient ways of funding end-use energy efficiency.

Policy continuity and innovation:

- Policy continuity is critical to provide the market for low-carbon heat and energy efficiency with the certainty it needs. Both end-use customers (building owners) and efficiency and heating contractors need continuity in programs and funding in order to learn about, plan for and deliver renovation actions. Both Germany and New England have long-standing policies and long-term targets for decarbonisation in place.
- Policy innovation is required to reap the benefits of efficiency programs as technologies and markets change. The growing capability of low-carbon heat technologies such as heat pumps is a prime example but is by no means the only one. Both Germany and New England have, over time, modified their policies to account for new technologies.

Driving electrification:

- Electrification requires a holistic approach to designing building codes and appliance standards. Germany and New England offer some valuable lessons on how to ensure that the electrification of heating systems is consistent with building code provisions.
- Electrification also requires programmatic assistance to retrofit heating appliances. Experience in both Germany and New England shows that, without this support, the uptake rates remain low.

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