FINE TUNING POLICY FOR ENERGY EFFICIENCY: A DATA-DRIVEN APPROACH TO SUPPORT TARGETTED POLICY-MAKING FOR RESIDENTIAL HEATING

[Muhammad Bilal Siddique, Technical University of Denmark (DTU), +45 22 22 43 06, bsikh@dtu.dk]
[Claire Bergaentzlé, Technical University of Denmark (DTU), +45 46 77 53 61, clberg@dtu.dk]
[Philipp Andreas Gunkel, Technical University of Denmark (DTU), +45 46 77 52 81 phgu@dtu.dk]

Overview

At the European level, the building stock represents 40% of total energy consumption along with 36% of total Green House Gas (GHG) emissions. These emissions are primarily driven by thermal energy needs which make building renovations and energy equipment upgrades critical leverages to heat decarbonisation. Denmark with a cold climate is no stranger to high heat consumption. The residential buildings stock accounted for about 25% of total energy consumption in Denmark in 2018 (IEA, 2021), resulting in 14% of total national carbon footprint.

The decarbonization of the heat sector is a political priority in Denmark, as expressed in the Climate Agreement of 2020 (Finansministeret and Klima- Energi og Forsyningsministeriet, 2020). The Agreement tackles carbon emissions reduction in the heat sector in multiple ways, including through building renovation programs and conversion programs for gas and oil boilers. In total, a budget of 60 Mil. Eur (456 Mill Dkr.) is adopted to support energy efficiency in buildings and another 11 Mil Eur. (85Mil. Dkr.) for the conversion of individual oil and gas boilers until 2030. The main economic incentive implemented by the authorities is a fixed subsidy scheme.

Currently, information about the spatial and temporal distribution of heat demand is based on estimation tables, heat maps, and other tools constructed using either top-down or bottom-up methodologies. These tools serve several purposes, such as informing consumers or supporting future planning of district heating. They are also the main source of information used by policymakers in their energy efficiency policies in buildings and serve as basis to design current economic incentives.

One such example of a state-of-the-art heat consumption estimation tool is (Nielsen et al., 2017) with a stated purpose that danish home-owners can compare their heat consumption with similar buildings and take informed decisions for energy efficiency investment. However, the accuracy of such estimation tools has not been adequately addressed in the literature nor have they by policymakers.

This study addresses this gap in comparing current state-of-the-art estimation tools for energy efficiency policy in Denmark to observed metered data for energy consumption in the different building types. Building on this comparison, the article assesses the impact in terms of CO_2 emissions saving resulting from the use of current estimation data compared to observed consumption data. This gives insights into what is ‘assumed’ to be a building with important energy needs and the one with ‘observed’ heat demand and pinpoint discrepancies that could lead to making subsidy scheme more effective. Ultimately, we provide a finer identification of the building types that policies should target for a maximum CO_2 reduction impact at the least cost in Denmark. For the validation of state-of-the-art estimation tools and subsequent optimization of the subsidy scheme, Lyngby commune in Denmark is used as a case study. Our results serve to inform policymakers on better design for future energy efficiency policies, specifically, targeting subsidy scheme for home energy renovations in Denmark.

Methods

The heat consumption estimations, in kWh/m2/year, in buildings based on their year of construction and use type are given in (Nielsen et al., 2017) for the whole of Denmark. This classification of buildings based on their year of construction and use type is referred to as building archetypes. These estimations are used as the baseline in this study. They are validated by actual data of the yearly heat consumption in individual buildings using a bottom-up approach.

For such analysis, Lyngby municipality, located in the northern suburbs of Copenhagen, Denmark, is chosen as a case study. The selection of building types considered in the study (only residential buildings of selected characteristics) is motivated by the fact that residential buildings compose the large majority of buildings in Lyngby and because of anonymization constraints associated with demand data in the other types of buildings in the city.

We compare the data for heat demand per building type such as utilised by policy makers (baseline estimations) to observed, metered heat data in the same building types. The actual or observed consumption data is provided by the

municipality administration. The heat consumption is recorded from 2009 till 2017. This data is used to calculate average heat consumption in a year, in kWh/m2/year, to compare it with baseline estimations.
The CO_2 emissions are calculated for both cases using the heat supply mix of Lyngby commune -which is predominantly based on natural gas and using carbon coefficient of different fuels (Gómez et al., 2006).
Since most of the subsidy schemes for energy renovation investment are constrained by the total maximum state budget, we propose an optimization model that maximizes the CO_2 savings taking into account the total budget allocated to building renovation subsidy scheme. Based on our assessment on the actual heat consumption, an optimization model is used to maximize the impact in terms of energy savings under the condition of limited resources i.e. total subsidy budget. The optimization model considers the exponential relationship between energy renovation cost and resulting energy savings.
We model three scenarios of subsidy redistribution : (a) optimal redistribution of subsidy budget based on baseline heat consumption estimations for the selected building archetypes (baseline consumption scenario), (b) optimal redistribution of subsidy budget based on actual heat consumptions using the observed data (actual consumption scenario), and (c) a present Danish subsidy scheme scenario (SparEnergi, 2021)– where each household is eligible to get an almost same subsidy, thus, in this scenario the subsidy is equally distributed among all the buildings (present scheme scenario).

Results

- The preliminary results show that at the aggregated municipality level, there is an overall overestimate of the heat consumption in the baseline in buildings constructed before 1973. An opposite trend is observed for newer buildings, constructed after 1973, where the baseline estimates a lower heat consumption than the actual consumption. The estimation accuracy of the baseline for the detached and semi-detached family houses is relatively better, mostly within a 30% error margin. However, for multistorey buildings and apartments, the estimation accuracy is very low and usually overestimating the heat consumption.
- The calculation of CO_2 emissions resulting from heat consumption shows that the baseline estimation yields 19% higher total emissions than actual consumption.
- According to the baseline, the buildings constructed after 1973 are responsible for 27% of total CO_2 emissions while actual consumption data show that this share is 39%. Thus, the heat consumption of these buildings and resulting emissions seem to be under-represented. This inability of baseline to capture the higher actual consumption in newer buildings results in about 3000 tons of CO_2 annually being unaccounted for.
- Under the baseline consumption scenario, most of the subsidy is distributed to older buildings, about 92% of the subsidy is distributed to buildings constructed before 1973. However, under the actual consumption scenario, the distribution is less concentrated to older buildings constructed before 1973 (about 66%) and about 12% is allocated to buildings constructed after 1999 as compared to none in the baseline scenario. The present scheme also tends to allocate resources similar to that of actual consumption scenarios but with different magnitudes.
- Relative energy savings have been calculated by benchmarking the saving resulting from the subsidy distribution for three scenarios against the actual consumption. The actual consumption scenarios lead to about 9% and 12% more savings as compared to baseline and present scheme scenarios, respectively.

Conclusions & Policy Recommendations

The state-or-the-art-tool studied in this paper, represents the average yearly heat consumption for different building archetypes in Denmark. While this tool gives a good presentation of the overall consumption pattern, its specific use for local policy design should be cautioned. This study demonstrates that policy-makers should pay particular attention to the building types with the largest gaps between estimated and observed heat demand as this could provide them with the basis to redesign targeted incentives and support schemes to reach a higher CO_2 reduction impact. This is particularly true for the present Danish subsidy scheme for energy efficiency in buildings which is found to be allocating about the same subsidy amount in the form of grants to buildings belonging to different archetypes. This results t in inefficient outcomes for decarbonisation and in terms of state budget allocation.

Essentially, it can be concluded that for Lyngby commune, any energy efficiency improvement scheme, i.e. subsidy, should target detached and semi-detached family houses along with allocating some resources to newly constructed buildings in addition to older buildings to maximize the impact in terms of energy savings and carbon emissions reduction.

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