INTEGRATING DEMAND-SUPPLY DECARBONIZATION EFFORTS IN THE BUILDINGS SECTOR: A MODELING ASSESSMENT FOR FRANCE

Célia Escribe, CIRED-CNRS, 45 bis, Avenue de la Belle Gabrielle, Nogent sur Marne, 94736, France
Phone: +33 1 43 94 73 73, email: celia.escribe@polytechnique.edu
Lucas Vivier, CIRED-CNRS, 45 bis, Avenue de la Belle Gabrielle, Nogent sur Marne, 94736, France
Phone: +33 1 43 94 73 73, email: vivier@centre-cired.com
Louis-Gaëtan Giraudet, CIRED-CNRS, 45 bis, Avenue de la Belle Gabrielle, Nogent sur Marne, 94736, France
Phone: +33 1 43 94 73 73, email: louis-gaetan.giraudet@enpc.fr
Philippe Quirion, CIRED-CNRS, 45 bis, Avenue de la Belle Gabrielle, Nogent sur Marne, 94736, France
Phone: +33 1 43 94 73 73, email: philippe.quirion@cnrs.fr

Overview

The building sector is the second largest source of energy consumption and GHG emissions in temperate, high-income countries. Two-third of it comes from housing, a diffuse sector of energy consumption characterized by strong inertia and important barriers to investment. The pursuit of decarbonization necessitates the implementation of measures from both demand-side and supply-side, which mutually interact. In this context, how should decarbonization efforts be allocated between energy efficiency improvements, fuel switch and energy system decarbonization ?

Most modeling studies only focus on one sector. On the one hand, building stock models are usually based on exogenous prices and carbon content of energy, and therefore do not consider the feedback of building energy demand on energy price and content (Giraudet et al., 2021). On the other hand, bottom-up energy optimization models often consider exogenous assumptions about renovation rate and allocation between heating systems (Brown et al., 2018; Shirizadeh and Quirion, 2022).

Two recent works explicitly model the competition between investments in heating electrification, switching space heating fuels, building renovation, and power mix decarbonization (Mandel et al., 2023; Zeyen et al., 2021). Their approaches rely on the optimization of bottom-up energy models to find optimal trade-off between demand- and supply-side options. However, they model retrofitting as a supply option, and therefore fail to consider that investments in retrofitting are decentralized and that homeowners may not invest in the socially optimal decision. Empirical studies have long shown that homeowners do not systematically invest in energy efficiency measures that pay off in the long run (Hausman, 1979), a phenomenon known as the energy efficiency gap (Gerarden et al., 2017). Neglecting the particularities and diversity within the building sector can result in a technical optimum which may mislead policymakers when formulating energy efficiency measures.

Method

Our approach aims to explicitly capture the frictions inherent in energy efficiency investment when evaluating the trade-off between demand-side and supply-side options in an overall decarbonization strategy. We develop an original integrated framework hard-linking a highly detailed building stock model with a highly detailed energy system model for France. The building stock model, Res-IRF, provides a joint description of building and household characteristics. Agents' investment decisions are based on investment costs, energy cost savings, and subsidies of retrofitting options. This specification allows for explicit consideration of heterogeneity of preferences, key market failures (landlord-tenant dilemma, credit constraint for low-income households, and inherent frictions due to collective decisions in multifamily housing) and non-monetary costs. The estimate of preferences for heater and insulation model comes from discrete choice experiments (Stolyarova, 2016). The energy system model, EOLES, optimizes investment and dispatch with a multi-sectoral perspective and in an hourly timescale (Shirizadeh and Quirion, 2022). Annualized cost includes operating and maintenance costs and

annualized capital costs. The annuity takes into account the discount rate, overnight construction costs, life, and lead time of the investment.

Our model takes the perspective of a social planner seeking to minimize costs by controlling housing sector policies, under three constraints: net-zero emissions must be achieved by 2050, energy efficiency markets are plagued by market failures, and energy markets are perfectly competitive. Co-benefits from energy efficiency investments such as reducing energy poverty are included in the objective function. We capture dynamics of heating replacement investments and building insulation through a multi-stage myopic optimization.

To our knowledge, we are the first to propose a holistic approach taking into account the interplay between demand-side and supply-side alternatives, while recognizing that energy efficiency investments are undertaken by individual property owners.

Results

Our study first highlights that failure to achieve any of the dimensions studied (building efficiency, performance of heating solutions, switching to low-carbon heating solutions including electricity) would lead to an increase in total costs to achieve emission reductions targets. We compare the optimal decarbonization trajectory under different energy efficiency subsidy programs targeting different housing groups and insulation measures. The role played by demand-side and supply-side options in the global decarbonization strategy differ based on the public policy scheme available in each scenario. Subsidies that target global renovation and heat pumps and that address the main market failures in the residential sector lead to a decrease of total welfare costs of 4% compared to a scenario with uniform ad valorem subsidies. We demonstrate that targeting subsidies to housing segments with the highest energy poverty greatly increases the role played by insulation investment and allows to reduce both health costs and total welfare costs. This highlights the importance of including energy efficiency investments co-benefits in the assessment of the trade-off between supply-side and demand-side decarbonization options.

We also quantify the increase in total costs due to the existing market barriers and failures in the residential sector. A thought experiment techno-economic scenario where energy efficiency investments are allowed to be tapped in increasing cost-efficient order leads to a decrease in total costs of 8% compared to a uniform subsidy scenario where energy efficiency investments are made by individual agents under market failures.

Conclusions

Insulation, fuel switch and development of low-carbon supply options are cost-optimal to reach net-zero target. Reaching this target at lower cost requires subsidizing both heat pumps and insulation measures. Relative role of each option depends on the subsidy design available to the social planner. More targeted insulation subsidies at cost-efficient potential lead to lower total system costs and increased insulation role in decarbonization strategy.

References

Brown, T., Schlachtberger, D., Kies, A., Schramm, S., Greiner, M., 2018. Synergies of sector coupling and transmission reinforcement in a cost-optimised, highly renewable European energy system. Energy 160, 720–739. https://doi.org/10.1016/j.energy.2018.06.222

Gerarden, T.D., Newell, R.G., Stavins, R.N., 2017. Assessing the energy-efficiency gap. J. Econ. Lit. 55, 1486–1525.

Giraudet, L.-G., Bourgeois, C., Quirion, P., 2021. Policies for low-carbon and affordable home heating: A French outlook. Energy Policy 151, 112140. https://doi.org/10.1016/j.enpol.2021.112140

Hausman, J.A., 1979. Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables. Bell J. Econ. 10, 33–54. https://doi.org/10.2307/3003318

Mandel, T., Kranzl, L., Popovski, E., Sensfuß, F., Müller, A., Eichhammer, W., 2023. Investigating pathways to a net-zero emissions building sector in the European Union: what role for the energy efficiency first principle? Energy Effic. 16, 22. https://doi.org/10.1007/s12053-023-10100-0

Shirizadeh, B., Quirion, P., 2022. The importance of renewable gas in achieving carbon-neutrality: Insights from an energy system optimization model. Energy 255, 124503. https://doi.org/10.1016/j.energy.2022.124503

Stolyarova, E., 2016. Rénovation énergétique de l'habitat en France : analyse microéconométrique du choix des ménages. (These de doctorat). Paris Sciences et Lettres (ComUE).

Zeyen, E., Hagenmeyer, V., Brown, T., 2021. Mitigating heat demand peaks in buildings in a highly renewable European energy system. Energy 231, 120784. https://doi.org/10.1016/j.energy.2021.120784