How to best design subsidies for home energy retrofits? A literature review*

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Abstract

This paper reviews the evidence on the effectiveness of subsidy programs for home energy retrofits, looking in particular at which design features yield the greatest benefits. It draws heavily on the French subsidy portfolio, which is of unparalleled size and diversity, thus perfectly lending itself to comparative analysis. Subsidy programs are found to be effective at increasing household investment, saving them energy, and creating jobs in the renovation industry, but not as much as predicted, partly due to inframarginal participation. Effectiveness tends to be higher with per-unit subsidies, as opposed to *ad valorem* ones; when lower-income households are entitled greater benefits; when subsidies are publicly-funded, as opposed to utility-funded; and when they are deployed at the local, as opposed to national, level.

Keywords: Energy efficiency, subsidies, home retrofit.

1. INTRODUCTION

Subsidy programs for home energy retrofits are a widespread policy tool in rich economies (Kerr and Winskel, 2020). As of 2025, the International Energy Agency (IEA) has recorded 143 national government spending programs on energy-efficient building[1]. On allocative grounds, such programs are considered an adequate tool to address at once several market and behavioral frictions hindering energy efficiency investment. While reducing CO_2 emissions is usually their primary motivation, they are increasingly recognized to generate a number of co-benefits – health improvements through reduced exposure to cold-related illness, mostly prevalent among low-income households (Dervaux and Rochaix, 2022; Roberdel *et al.,* 2025); easier access to credit, which is essential to cover upfront costs in the thousands or even tens of thousands of euros; or increased attention to the long-term benefits of retrofit investments (Allcott and Greenstone, 2024). In addition, from a political economy perspective, subsidies tend to receive stronger support from both consumers and the renovation industry than

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1 Source : IEA's Policies Database (https://www.iea.org/policies), as of February 6, 2025.

does pricing CO_2, the textbook remedy to the climate change externality (Douenne and Fabre, 2020; van der Ploeg, 2025).

Existing subsidy programs exhibit widely differing designs. First, they can be *ad valorem*, when subsidy rates are proportional to the investment cost, and per unit when amounts are proportional to the energy savings generated. Second, they can more or less finely target different household groups, based on income level or other relevant characteristics (*e.g.,* urban versus rural). Third, while most programs are funded by public bodies, some are funded by private bodies. The IEA (2020) has recorded 49 utility-funded energy efficiency programs in 24 countries, usually implemented to comply with a government-imposed energy efficiency obligation. Fourth, public programs can be funded by the national government or more local jurisdictions.

Empirical evaluations of subsidy programs have focused on assessing their impact along several dimensions – take-up, looking at both the extensive and intensive margins of investment; induced energy savings and how well they match engineering predictions; and, since more recently, job creation in the retrofit industry. This literature is by now rich enough so general conclusions can be drawn about subsidy effectiveness. Moreover, while existing evaluations have focused on individual programs and therefore are limited in assessing how design affects performance, this gap can now be filled by comparing evaluations of different programs. In this paper, I seize this opportunity to review the literature and examine which subsidy design features yield the greatest benefits. In doing so, I bridge the – mostly empirical – literature on impact evaluation with the – largely theoretical – one on policy design. I draw heavily on the French subsidy portfolio, which is of unparalleled size and diversity, thus perfectly lending itself to comparative analysis within a given institutional context. This portfolio includes four flagship national programs with various designs – a uniform reduction of value-added tax, a public per-unit subsidy program differentiated by income level, a similar program funded by energy utilities, and a zero-interest loan program – alongside 560 sub-national programs. In 2023, the national programs alone involved €6 billion, half of which was provided by utilities (Hainaut *et al.,* 2023; PLF, 2024). This is the most generous and comprehensive portfolio of subsidy programs for home energy retrofits I am aware of.

The rest of the paper is organized as follows. Section 2 describes the French subsidy portfolio. Section 3 reviews the literature on the effectiveness of subsidy programs along several margins. Section 4 reviews which design components are most effective. Section 5 concludes.

2. THE FRENCH POLICY PORTFOLIO

In this section, I provide some background on the subsidy programs implemented in France, with a strong emphasis on national programs. I introduce them in chronological order and highlight the design features that have been most extensively studied. Further details can be found in Giraudet *et al.* (2021) and Chlond *et al.* (2023). These programs largely overlap, and they can all be claimed to cover the same investment.

2.1. VAT reduction

Since 1999, a reduced value-added tax (VAT) rate applies to home energy retrofit works, down to 5.5% from 20%. This VAT reduction at first applied to all types of retrofit works – energy-related or not. It was de facto restricted to energy-related works in 2014 when the rate was raised to 10% for non-energy-related works. This benefit is available to all households without income restriction. Assessed against the 20% default rate, as the government typically does, the implied public cost was about €1-1.5 billion per year over the 2015-2017 period (IGF, 2020). When assessed against the 10% rate applying to the closest type of investment, which arguably provides a more relevant benchmark, it is only one third of that. Overall, the VAT reduction can be considered a uniform ad valorem subsidy with a 14.5% rate when assessed against the regular 20% VAT rate or 4.5% when assessed against the 10% VAT rate.

2.2. White certificates (CEE)

In 2006, the government imposed an energy efficiency obligation on energy suppliers. Known as *Certificats d'économies d'énergie* (CEE), the program applies to suppliers of all types of fuels electricity, natural gas, fuel oil and, since 2010, gasoline – in proportion to their retail sales. Energy savings can in turn be achieved in all sectors –- residential buildings, commercial buildings, agriculture, industry, and transport. To meet their obligation, energy suppliers must actively promote investment in energy saving equipment, typically by granting subsidies. I prefer to keep as it was in the original draft: They are entitled energy savings certificates in return to each action, based on ex-ante engineering calculations expressed in lifetime-discounted kilowatthour savings (hereafter kWh_{LD}). The so-called "white certificates" are tradable, allowing a party short of their target to purchase savings from one with excess supply.

The overall obligation has been tightened every three or four years, from 54 TWh_{LD} in the first phase (2006-2009) to 850 TWh_{LD} in the third phase (2015-2018) and 3,100 TWh_{LD} in the ongoing fifth phase (2022-2025). Meanwhile, the white certificate price has varied within a narrow range of €2-4/MWh_{LD} during the first ten years of the program, before rising sharply at the outset of Phase IV in 2018 and remaining within the €6-8/MWh_{LD} range since then. Over the years, residential buildings have consistently been the main delivery sector, contributing as much as 83% savings in Phase I and as little as 50% in Phase III. These figures together imply €75 million annual spending in the residential sector in Phase I, €425 million in Phase III and a tentative €2.7 billion in Phase V.

In 2016, a sub-obligation was introduced targeting low-income households, with a separate market. Eligible households are identified as belonging to the first two quintiles of the income distribution. White certificates are doubled for households of the first quintile, with subsidies expected to be doubled as well. Three regimes therefore prevail – the top 60% of the income distribution get subsidies based on the baseline price, the 20%-40% group gets subsidies based on the low-income price and the first quintile gets twice the latter amount. Since then, however, prices in the two separate markets have not significantly differed, suggesting the sub-obligation has not yet been binding. Lastly, since 2014, the program is subject to an eco-condition – to get subsidies, households must hire contractors certified with a good-practice label called *Reconnu garant de l'environnement* (RGE).

Taking all these features together, CEE subsidies can be considered per-unit, with an amount that depends on the expected performance and that is differentiated by income level.

2.3. Zero-interest green loans (EPTZ)

In 2009, the government introduced a zero-interest loan program called *Eco-prêt à taux zéro* (EPTZ). The program allows households to borrow money for free to invest in a selection of energy-related works. Accessible without income restrictions, loans are capped at €30,000, to be repaid over a maximum period of 15 years. Banks are compensated by the government for forgone revenue on each loan. Since 2014, the EPTZ program is subject to the same eco-conditionality as CEE. After an encouraging start, the program benefited 80,000 households in 2010 before plummeting to 40,000 in 2011 and reaching a historical low of 19,000 in 2018. Accordingly, the public cost has varied widely, from €200 million in 2010 to €22 million in 2019.

By giving back interests that would otherwise be proportional to the amount borrowed, the program can be interpreted as an ad valorem subsidy, however with important qualifications. First, the implied subsidy rate varies across time – due to fluctuations of the market interest rate – and individuals – since different borrowers would typically be charged different interest rates. Second, the rate is non-linear, as several measures need to be combined for the project to be eligible.

2.4. Direct subsidies (CITE, HM, MPR)

In 2020, the government introduced its flagship program called *MaPrimeRénov'* (MPR). It was in fact the merging and rebranding of two existing programs, a tax credit program called *Crédit d'Impôt pour la Transition Energétique* (CITE) implemented in 2005, and a low-income subsidy program called *Habiter Mieux* (HM) implemented in 2010. The CITE program was available to all households without income restrictions. The tax refund was proportional to the cost of the underlying measure, making it an *ad valorem* subsidy. While the rate was initially differentiated across measures – from 10% for window replacement to 50% for heat pump installation – it became fixed at 30% for all measures in 2014. Over the 2015-2018 period, the CITE program benefited on average 1.3 million households per year, for a total public cost of €1.9 billion per year. Meanwhile, the low-income program targeted households from the bottom 30 % of the income distribution. The subsidies were primarily granted on *ad valorem* with a 50% rate, to which smaller per-unit bonuses could be added. Over the 2015-2018 period, the program benefited between 40,000 and 50,000 households per year, for an annual cost of about €240 million (Cour des Comptes, 2018).

Since the two programs were merged, the MPR subsidies have been technically quite similar to their CEE counterparts – per-unit, performance-based and income-based, however with different amounts and thresholds. Just like CEE and EPTZ, the MPR program is subject to RGE conditionality, which was already the case with CITE since 2014.

2.5. Sub-national programs

Alongside public national programs, myriad local programs exist in France. As of today, 560 local programs have been identified (Eryzhenskiy and Giraudet, 2025). 2% are implemented at the regional level – the highest tier jurisdiction – 8% are implemented at the departmental level – the second-highest tier – and 84% are implemented at the sub-departmental level, including 14% at the municipal level. Their total cost is unknown. The best documented program is operating in Essonne, a department of 1.3 million people that is part of the Ile-de-France region which also includes the city of Paris and its metropolitan area. Implemented in 2020, the *Prime Eco-logis 91* (PEL) program benefited 30,339 households between 2019 and 2022, for a total public cost of €54.3 million.

3. ARE SUBSIDY PROGRAMS EFFECTIVE?

3.1. Do subsidies foster investment?

The question of whether energy efficiency subsidies increase investment is that which has received the most attention. Specifically, researchers have been concerned with estimating the degree of inframarginal participation, that is, the number of participants that would have invested even in the absence of any incentive (Boomhower and Davis, 2014). The inability of the regulator to screen out these participants can indeed be a source of resource waste (Giraudet, 2020). That said, the deadweight loss will be limited if inframarginal participants take advantage of this opportunity to increase their spending. With varying geographical scope and methodology, existing studies point to inframarginal participants typically accounting for 50%, and not infrequently up to 90%, of total participants (Grösche and Vance, 2009; Boomhower and Davis, 2014; Alberini *et al.,* 2016; Rivers and Shiell, 2016; Houde and Aldy, 2017). This low impact on the extensive margin of investment does not seem to be compensated by a strong impact on the intensive margin, which has only been examined in a handful studies (Rivers and Shiell, 2016; Houde and Aldy, 2017).

The results are qualitatively similar in France. The policy with the longest track record, the CITE has consequently been the most studied. Using panel data on household renovation investment, Nauleau (2014) found inframarginal participation in the program to be in the 60% to 80% range between 2007 and 2010. This result was confirmed by Mauroux et al. (2014) in a difference-in-differences framework using fiscal data and by Risch (2020) in a temporal regression discontinuity framework using the same dataset as Nauleau. Risch (2020) additionally finds a significant 22% effect on the intensive margin of investment. By combining the effects on the extensive and intensive margins, the leverage effect of subsidies is typically close to 1 – one euro of public support inducing an increase in private investment of one euro, or even more (Giraudet *et al.,* 2021; Chlond *et al.,* 2023). Turning to the CEE program, using geographic cutoffs in subsidy amounts in a regression discontinuity design, Aja and Giraudet (2025) find that the program had hardly any effect on investment take-up. This lack of effect can be explained by the low white certificate price that prevailed at the time, generating subsidies that only covered 5% of the upfront cost on average. Lastly, the EPTZ program has been evaluated by Eryzhenskiy *et al.* (2023). Using panel data on household renovation investment and an eligibility restriction to newer buildings, the authors find that eligibility to the program significantly increased the number of investments by 22%, especially for low-income households, and spending by 3%. These effects however vanished after two years into the program. The pattern of effects – strong on the extensive margin, weak on the intensive one – suggests that this policy is effective at alleviating credit constraints that can be critical for low-income households. Taking these estimates together, EPTZ had a leverage effect of 1.7 in the early days of the instrument, meaning that €1 given to banks by the government for issuing loans increased household spending by €1.7.

3.2. Do subsidies deliver energy savings?

A related question is whether subsidy programs effectively save energy. From a methodological perspective, the answer to this question is conditional on the previous one – whether the subsidy triggered investment in the first place. Accordingly, the ideal evaluation setting is to proceed in two steps – first estimating the policy effect on take-up and then use it as an instrument to estimate energy savings. Unfortunately, existing datasets are rarely comprehensive enough to provide all the data and restrictions needed for causal analysis.

Notwithstanding these methodological difficulties, the induced energy savings question has been extensively studied. The results have been quite disappointing, most studies showing that effective savings significantly underperformed engineering predictions. The issue was identified in the early age of energy efficiency economics (Joskow and Marron, 1992; Hassett and Metcalf, 1995). It was revisited and confirmed recently with more modern techniques. To cite only the most frequently cited one, in a randomized control trial involving 30,000 households in Michigan, Fowlie *et al.* (2018) identify a 70% gap between predicted and realized savings. A similar order of magnitude was found in related studies (Davis *et al.,* 2014; Graff Zivin and Novan, 2016; Giraudet *et al.,* 2018).

Three main reasons have been invoked to explain the so-called performance gap. The most commented one is the rebound effect, according to which household use energy-consuming durables more intensively after having improved their energy efficiency. Impact estimates here vary from limited (Fowlie *et al.,* 2018) to strong (Davis *et al.,* 2014). Another frequently invoked reason is the pre-bound effect – the notion that engineering models overestimate energy use before investment (Sunikka-Blank and Galvin, 2012). The effect is particularly prevalent in the least-performing dwellings, which are more likely to be occupied by low-income households (Aydin *et al.,* 2019; Charlier, 2021). The third explanation, which is less studied, is quality defects, due to the information asymmetries inherent in-home energy retrofits (Giraudet *et al.,* 2018). While these problems have been studied separately, a recent study for the first time assesses their respective influence. Exploiting data from 9,800 renovations in Illinois using machine learning techniques, Christensen *et al.* (2021) identify a 51% gap between predicted and realized savings, of which they attribute 42% to quality issues, 40% to modeling errors and 6% to the rebound effect (with 14% remaining unexplained).

In France, this outcome has been studied in relation to the CEE program and the Essonnian PEL program, both using energy data made available by the energy network operator. Wald and Glachant (2024) find that the CEE program reduced energy consumption by less than 1% between 2017 and 2021. Importantly, they find that actual savings were only 49% of predicted ones, thus uncovering a performance gap in line with that of other studies. In the case of the PEL program, Eryzhenskiy and Giraudet (2025) find that eligibility to the program reduced natural gas consumption by 8% compared to neighboring municipalities from other departments.

3.3. Do subsidies create jobs?

Besides fighting climate change externalities and providing co-benefits to households, energy efficiency subsidies are also meant to provide a stimulus to the renovation industry. This goal has been little studied. Interestingly, the few studies we are aware of on the issue both focus on France. Using regulatory changes that significantly expanded the subsidy amounts awarded to households under the CEE program, Cohen *et al.* (2024) find that €1 million of spending from utilities created 1.4 jobs in the renovation industry. Using similar industry data and comparing Essonnian municipalities and non-Essonnian ones, Eryzhenskiy and Giraudet (2025) find a higher estimate of 20 jobs created per million euro spent. This could be explained by the more intense publicity made by the local program administrator – a point we will return to.

3.4. Do existing programs close the energy efficiency gap?

The impacts reviewed so far have been estimated in reduced form. While they provide useful guidance as to what outcome can be expected from subsidy programs, they are not necessarily informative about their full welfare effects, which in turn depend on the different goals assigned to them (Allcott and Greenstone, 2024). Indeed, as said earlier, energy efficiency subsidies have the ability to address at once multiple market and behavioral failures that add up to discourage investment in energy efficiency – a phenomenon known as the energy efficiency gap (Jaffe and Stavins, 1994). These market failures chiefly include the CO_2 externality, but also credit constraints, cold-related illness, present bias, the landlord-tenant dilemma and coordination problems in multi-family housing. Whenever one of these problems is corrected, it is expected that energy efficiency and economic efficiency increase hand in hand.

Hahn *et al.* (2024) have developed a Marginal Value of Public Funds (MVPF) indicator that translates the welfare effects of climate policies into a single metric, thus allowing for comparison between them. Applying it to over 90 policies implemented in the United States, they find that subsidies to home energy retrofits (also called weatherization) have MVPF values around 1 – slightly below or slightly above. While this implies that every dollar of public money induces about one dollar of welfare gains, they note that subsidies for other climate change mitigation measures – such as wind power and solar panels – entail much higher MVPFs. These works, however, focus on the climate change externality as the main market failure to address.

France provides an interesting case study to take a broader perspective, owing to the empirical estimates available there to quantify ancillary market failures. In microsimulation work incorporating the frictions listed above and factoring in the behavioral responses estimated in empirical works, Vivier and Giraudet (2024) find that existing national programs – VAT reduction, MPR, CEE and EPTZ – together help close half of the energy efficiency gap in the French residential sector. Specifically, they close about two thirds of gap along the energy efficiency dimension but only one third of it along the economic efficiency dimension. Importantly, they find that total spending (from both the government and utilities) is commensurate with that needed to fully close the gap. This implies that existing programs are not designed in the best possible way. Let us review now what design features yield the greatest benefits.

4. WHAT DESIGN FEATURES ARE MOST EFFECTIVE?

We review theoretical works and compare the results of different empirical evaluations to discuss the relative merits of four design features – *ad valorem versus* per-unit regime, targeting of certain household groups, public versus utility funding and national versus local administration.

4.1. Should subsidies be *ad valorem* or per-unit?

Generally speaking, both *ad valorem* and per-unit subsidies can be found. In France, the subsidy portfolio was initially dominated by the *ad valorem* regime, owing to the central role played by the CITE program. As the CEE program grew bigger and the CITE program was replaced by MPR, the per-unit regime became the dominant one. Which one is best? The answer is trivial under perfect competition – for a given per-unit subsidy, it is always possible to find an *ad valorem* rate that generates the same effect, such that the two regimes are equivalent. It is more ambiguous under imperfect competition, which is an important characteristic of energy efficiency markets (Fischer, 2005). In France, there is indeed evidence that market concentration is substantially higher in the appliance and energy retrofit industries than in other industries (Carbonnier, 2007). In this context, the French Anti-trust authority has raised suspicion of collusive practices in the heating, air conditioning and hot water industries, at both the manufacturing and retail levels (Conseil de la Concurrence, 2006).

Theoretical research into the relative merits of *ad valorem* and per-unit subsidies under imperfect competition points to a clear superiority of the latter, for different reasons (Nauleau *et al.,* 2015). In the simplest framework where a monopolist is selling a single energy efficient product, ad valorem subsidies entail higher public spending since, compared to per-unit subsidies, they need to make up for the lower product price to which the subsidy rate applies. In the richer framework of a multi-product monopolist selling two goods, a high-end product of high energy efficiency and a low-end product of low energy efficiency, the inability of the monopolist to observe the preference of the buyer for the high- or low-end product induces it to restrict the quality of the low-end product to make sure the high-end consumer buys the high-end product. Through their action on prices again, *ad valorem* subsidies only exacerbate this problem, which is not the case with per-unit subsidies.

4.2. The more finely targeted the better?

Existing subsidy programs increasingly target low-income households. In France, this was the case when the low-income sub-obligation was introduced in the CEE program in 2016 and the MPR program superseded the non-targeted CITE program in 2020. This regulatory change was driven by and large out of necessity, as imposing income restrictions is an easy way to reduce overall spending in tense economic times. But this can also be seen as a win-win intervention reducing fuel poverty while increasing allocative efficiency. This is due to the correlation that is often observed between energy efficient housing and household income (Chan and Globus-Harris, 2025). In this context, renovating the least efficient homes mostly benefits low-income households while making the most out of public spending.

This insight has been confirmed in France, where both microsimulation works (Giraudet *et al.,* 2021) and the joint evaluation of multiple programs (Chlond *et al.,* 2023) have showed that low-income targeting increased the leverage of subsidies. Looking at the low-income sub-obligation in the CEE program, Darmais *et al.* (2024) find that it effectively reduced the households' vulnerability to energy price increase – a side effect of the CEE program we will return to. Against this background, it should be reminded that Eryzhenskiy *et al.* (2023) find that the EPTZ mostly benefited low-income homeowners despite the fact that it was open to all. This goes to suggest that imposing specific provisions is not a necessary condition for subsidies to benefit low-income households.

4.3. Do utility-sponsored programs perform better than publicly-funded ones?

While most energy efficiency subsidy programs are publicly funded, they coexist in many countries with utility-sponsored programs. The latter are usually implemented to comply with an energy efficiency obligation, known in North America as Demand-Side Management (Berry, 1984; Joskow and Marron, 1992; Wirl, 2000; Auffhammer *et al.,* 2008) and in Europe as White Certificate programs (Bertoldi *et al.,* 2010; Giraudet *et al.,* 2012; Rosenow *et al.,* 2019). Implemented in 2006, the French CEE program has grown to become the most important utility-funded program. Its interaction with several other publicly funded programs makes it an ideal case study to compare the merits of the two systems.

Just like the targeting discussed in the previous section is motivated by reducing public spending, so too is the case with delegating part of the energy saving effort to utilities. This is only a money transfer from tax payers (who pay for publicly funded programs) to rate payers, however, since utilities are allowed to pass-through compliance costs onto their retail prices. This mechanism makes utility-sponsored programs a hybrid instrument between an energy efficiency subsidy and an energy tax. On the one hand, this allows the same amount of energy to be saved with lower price variations than under a pure tax or a pure subsidy, thus making the instrument politically more palatable (Giraudet and Quirion, 2008). On the other hand, it raises equity issues, as subsidies are only granted to a few beneficiaries while being paid by all energy end-users. Such a regressive effect can however be overcome by adding provisions for low-income households (Darmais *et al.,* 2024).

Alongside these practical considerations, as is again the case with targeting, the delegation of energy savings can also be motivated by allocative considerations. Energy utilities are indeed thought to possess private information about end-use patterns, which puts them in an ideal position to identify the best energy saving opportunities. Imposing an energy efficiency obligation on them is thus expected to leverage this informational advantage and deliver energy savings more cost-effectively than would the government. While free competition among obligated parties might encourage them to promote energy savings by their competitor's customers, thereby discarding the intended mechanism, this threat is mitigated by the trading provision, which restores incentives to target the most cost-effective options (Giraudet *et al.,* 2020).

Does this work in practice? In their assessment of the third phase of the program, Aja and Giraudet (2025) find that the impact of the program, despite being low overall due to a low white certificate price, was nevertheless concentrated on a handful measures that rank pretty high in the cost-effectiveness merit order – attic, wall and floor insulation – and more so than what the publicly-funded CITE program produced. The authors interpret this outcome as evidence that the program was at least qualitatively effective at identifying the best renovation opportunities. One could expect that the subsequent tightening of the target would increase the white certificate price, hence subsidy amounts, thereby making the program fully additional, both quantitatively and qualitatively. The fourth phase of the program that started in 2018 fulfills the first part of the expectation but casts doubt on the second. The tightening of the target did cause prices to soar. Prompted to act by energy suppliers, the government responded by introducing a bonus system boosting earned certificates. This intervention had the expected effect of containing the price increase. Meanwhile, it changed the pattern of actions in a way that closely matched the pattern of bonuses designed by the government. This indicates that the role of the government was more important in steering actions than that of energy suppliers. This does not mean that the program was quantitatively ineffective – it was, in particular when it comes to job creation (Cohen *et al.,* 2024). But this essentially resulted from a government impetus, rather than from energy suppliers leveraging private information. Taken together, these results seriously challenge the information leverage hypothesis and hence the added value of utility-sponsored programs compared to publicly funded ones.

4.4. Do local programs perform better than national programs?

Subsidy programs are typically implemented at the national or state level – *e.g.,* Italy, France, Denmark, Germany, the UK, Massachusetts, Connecticut – and, to a lesser extent, at local or municipal levels – *e.g.,* Baltimore, Chicago, Detroit, Portland (Kerr, 2020). This raises the question of which level is the most appropriate – national or local? One could argue that industry stimuli, which are integral part of the motivation of subsidy programs, are most effective the wider they are, thus enabling economies of scale. On the other hand, home renovation essentially relies on local contractors. It is moreover a tailored technology akin to a credence good (Giraudet, 2020). Identifying the most cost-effective opportunities thus requires a good understanding of the housing stock, which is arguably best achieved by local agencies. The answer to the scale question is therefore ambiguous. France could be a good candidate to study it, owing to a plethora of local programs (560). However, these are much less well documented than their national counterparts. We thus provide hints based on the Essonnian PEL program. As discussed previously in various sections, the program had a significant effect on both natural gas consumption – an 8% reduction – and employment – 20 jobs created in the renovation industry per million euro spent. These results compare quite favorably to national programs – the CEE in particular. Interestingly, we find that, compared to the MPR subsidies granted in the same department, the PEL program had a stronger effect on hiring Essonnian firms. This indicates that its benefits are mostly retained locally. This could be due to a stronger involvement of local agencies in advertising for the program, in turn due to a closer alignment of incentives between public spending and the revenue from corporate taxes, which accrues locally.

5. CONCLUSION

This review of subsidy programs for home energy retrofits, focused on the French context, delivers the following insights. Overall, they are effective at increasing investment, however with a large number of infra-marginal participants, which probably is the reason for their relatively low marginal value of public funds. It should however be noted that energy efficiency subsidies can address several market and behavioral frictions at the same time, and failure to recognize this may lead to an underestimation of their benefits. In terms of energy savings, with a performance gap of about 50%, subsidies do just as well as non-subsidized energy efficiency investment.

Beyond these general conclusions, the comparison of different programs has shed light on which design features perform best. Per-unit subsidies should be preferred to ad valorem ones, due to the lower price distortions they generate under imperfect competition. Targeting subsidies to low-income households is a win-win approach that reduces fuel poverty while increasing the efficiency of public spending. While evidence needs to be further corroborated, local programs exhibit good properties, which is consistent with the essentially local nature of energy efficiency markets. This calls for a stronger involvement of local agencies in administrating subsidy programs. Lastly, utility-sponsored programs do not seem to add much value to public spending. This calls for merging the two systems, such as into the sort of "one-stop shop" promoted by the European Commission (Pardalis *et al.,* 2025). In this case, the same amount of private funding would be requested, but instead of having energy suppliers granting subsidies themselves, they would contribute the same amount to a public-private fund which would redistribute subsidies.

Some important questions inherent in subsidy programs remain unanswered, thus providing promising avenues for further research. One is to what degree subsidies increase the price of home energy retrofits in the field. Another one is whether energy efficiency subsidies encourage technological change, which in turn determines whether they should be temporary or permanent. Preliminary evidence suggests this is not the case (Hahn *et al.,* 2024), thus calling for rather permanent subsidies. Lastly, energy efficiency subsidy programs are known to entail administrative complexities. The extent to which this affects participation is an open question. Preliminary research suggests it can be a big hurdle, which however can be easily overcome with careful policy changes (Chlond *et al.,* 2025).

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