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# WORKING PAPER

## Improving the Energy Efficiency of the French Residential Sector: The Role of the Middlemen

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Increasing prices and the growing scarcity of resources call for an urgent reduction of energy use. The residential sector has become a major policy target in that regard, as it accounts for a non-negligible part of final consumption. Part of this consumption has been attributed to the "energy efficiency gap", meaning the difference between the energy consumption that could be achieved if every building were made with state-of-the-art materials and the actual energy consumption. Ambitious reduction targets have been set in developed countries, relying on a mix of awareness, regulatory and financial instruments. This paper exploits the originality of the French context to explore the efficiency of these policies, for which there are very few \textit{ex post} reviews. More specifically, the caveats this paper aims to address are (1) the role of construction contractors as middlemen between policymakers and households while (2) controlling for factors affecting energy consumption, especially spatial ones. A comprehensive dataset was built at the neighborhood level by compiling information from various sources. Results are estimated through spatial panel regressions and suggest areas of improvement for French financial aid schemes.

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KEYWORDS

Energy efficiency | Energy retrofits | Policy evaluation | Spatial econometrics

# Executive summary

In France, the residential sector accounts for roughly a third of total energy consumption. The current 50% consumption reduction target set for 2050 implies that 2% of the existing buildings needs to be efficiently retrofitted every year. This paper provides insights on the impact of the 5 national-scale policies implemented to achieve this goal, while controlling for access to skilled companies. Dwelling refurbishment are in most cases undertaken by small construction companies, which are very heterogeneous in their skill levels, experience and training. Do financial aid schemes for households stimulate the implantation of higher-quality firms? Does access to these skilled companies lead to energy savings over time? These questions are tackled by taking advantage of the specificities of the French policy mix. A broad range of fiscal incentives for households has been established, including lowering the V.A.T. to 5.5\% for retrofit projects in 1999, zero-interest loans in 2009 and tax credits for all households since 2005 and additional rebates for low-income ones since 2010. Regarding companies, the "R*econnu Garant de l'Environnement*" (RGE) certification was implemented in 2011. It is a costly label for firms, based on a few days of training and an audit of several work sites. Labeled firms are committed to use better materials and are certified to have the skills required to perform efficient energy retrofits. The explicit goal of the RGE label is to reduce fraud in the construction sector and ensure a minimal quality of the retrofits. Most importantly, if a household wants to benefit from three out of the current five current financial aid schemes, they have to hire a RGE contractor.

A comprehensive panel dataset was built using information on RGE firms' precise location in metropolitan France, household aid spendings by the State and household consumption of gas and electricity over the 2011-2018 period. Results show that the number of RGE firms is driven by both the number of competing firms and financial aid to households. This supports the idea that the label is used as a differentiation strategy on the quality of service in a competitive context. This is further reinforced by the fact that there are less RGE firms when spending for reduced VAT rates increase. The heterogeneous distribution of RGE firms is a concerning result in itself, since it has had a direct consequence in terms of access to public aid schemes for households since 2014. Further results show that, with the exception of tax credits, all policies seem to contribute to a decrease of electricity consumption, but with different magnitudes. Results on gas consumption however suggest that part of the decrease in electricity consumption induced by eco-loans is compensated by a shift to gas heating. This is likely due to a bias induced in the computation of energy etiquette and further analysis would be needed to see the total impact on households' overall energy consumption. A more alarming result is the significantly positive coefficient associated with tax credits across all specifications, which signals a design issue with this scheme. Our data does not allow to differentiate between a rebound effect and phony installations, but recent audit of the systems have revealed severe flaws in the way retrofits were handled. Our results further support the need to improve the oversight of this policy.

These policies come with a non-negligible cost, and their effect has to be more clearly measured and monitored. There is room for improvement when it comes to including firms in the implementation of these programs. They are key actors of the retrofitting process, yet the RGE label is the only measure directly involving them. This paper also raises questions around the multiplicity of aid schemes, and suggests a more unified approach could be more impactful given the heterogeneity of their impact. Overall, the French policy mix seem to foster energy savings, but these key points should be more carefully looked at, especially considering the cost of these programs and the future ban on renting out dwellings with an etiquette F and G.

# 1. INTRODUCTION

Increasing prices, growing scarcity of resources and, more generally, climate issues call for an urgent reduction of energy use. The residential sector has become a major policy target in that regard, as it accounts for a non-negligible part of final energy consumption - reaching 26% among European Union countries (Eurostat 2020). At the individual level, energy expenses are also an important part of households' yearly budgets, accounting on average for 25.7 % of their expenses in the EU. Part of this consumption has been attributed to the "energy efficiency gap", which was first defined by Hirst and Brown (1990). In the residential sector, it refers to the difference between the energy consumption that could be achieved if every building were made with state-of-the-art materials, and the actual energy consumption of buildings. In other words, a significant decrease could be achieved by bridging this gap through the retrofit of existing dwellings. Ambitious reduction targets have been set at the European level since the adoption of the "Energy Performance of Buildings Directive" by the European Commission in 2010, and have yet to be reached (Eurostat 2019), promoting three policy tools. First, awareness campaigns aim to spread good practices and information about the need to lower the energy consumption and the potential individual gains, relying on individual willingness. Second, financial instruments are meant to further incentivize agents to retrofit existing buildings, through grants or loans, in order to diminish the cost borne by companies and households. Third, regulatory instruments are to be put in place to constrain new builds and professional practices - materials used, access and implantation. Optimally, a combination of these policies should boost household investments in the energy efficiency of their dwellings, as the current levels remain too low. Such investments typically involve high upfront costs and become profitable only over a long period of time. Despite the large impact they would have overall on energy usage, a number of households are thus reluctant to commit.

The actual impact of these policy mixes on the energy consumption of the residential sector remains somewhat unclear. Most of the evaluations conducted to this day were based on simulations with *ex-ante* data. They exploited information on dwellings' technical characteristics, which are the main focus of such policies. Better insulation, double glazing and more recent heating systems do in theory favor energy savings, but these simulations usually lack a number of controls. Individual characteristics, such as income and family structure, also shape households' needs and capacity to pay. An increasing number of *ex-post* surveys have for instance shown that low-income households are often unable to afford their desired level of comfort, especially with respect to heating. In these cases, improving the energy-efficiency of the dwelling will not necessarily lead to a decrease of consumption, as households may prioritize increasing their comfort. Using real-world data rather than consumption projections will in most cases produce lower estimates of the potential for energy savings. These evaluations are however usually based on one-off regional policies, not long-term national programs. Their evaluation requires controls for location, local climate and housing density, which all impact individual energy demand but are usually not included. Typically, less energy is required to maintain an indoor temperature of 21°C in denser areas (Combes and Gobillon 2015). Finally, the quality of installation is almost never accounted for, despite being central to the actual performance of the materials and appliances installed during a retrofit (Hamilton and Huessy 2010). Dwelling refurbishment are in most cases undertaken by small construction companies, which are very heterogeneous in their skill levels, experience and training. The majority of households have little to no knowledge of what they need and how it should be installed. Hiring contractors hence poses typical procurement issues, as refurbishment activity is not as regulated as new construction. The only widespread policies targeting professionals are labels assessing the quality of their work, which are not mandatory. As there are virtually no quality controls by parties other than the contractors, poor workmanship and/or dishonesty on the professional's part can seriously hinder the energy savings.

The caveats this paper aims to address are (1) the role of construction contractors as middlemen between policymakers and households while (2) controlling for factors affecting energy consumption, especially spatial ones. Do financial aid schemes for households stimulate the implantation of higher-quality firms? Does access to these companies lead to energy savings over time? These questions are tackled by taking advantage of the specificities of the French policy mix. A broad range of fiscal incentives for households has been established, including lowering the V.A.T. to 5.5% for retrofit projects in 1999, zero-interest loans in 2009 and tax credits for all households since 2005, and additional rebates for low-income ones since 2010 (Robinet, Hainaut, and Postic 2018). Regarding companies, the "*Reconnu Garant de l'Environnement*" (RGE)[1] certification was implemented in 2011. It is a costly label for firms, based on a few days of training and an audit of several work sites. Labeled firms are committed to use better materials and are certified to have the skills required to perform efficient energy retrofits. The explicit goal of the RGE label is to reduce fraud in the construction sector and ensure a minimal quality of the retrofits. Most importantly, if a household wants to benefit from three out of the current five current financial aid schemes, they have to hire a RGE contractor. Overall, these policies benefited roughly 2.1 million dwellings from 2016 to 2019, which represents 7% of French metropolitan dwellings[2] (ONRE 2020). A comprehensive panel dataset was built using information on RGE firms' precise location in metropolitan France, household aid spendings by the State and household consumption of gas and electricity over the 2011-2018 period. It contains information on technical, socioeconomic and location-specific characteristics. The objective is to exploit spatial and temporal disparities in both the distribution of RGE firms and fiscal aid to estimate the impact of these policies while controlling for household determinants. If tax credits for households favor the undertaking of energy retrofits, then higher levels of spending should lead to a higher number of RGE-certified companies locally. Additionally, if having access to a certified firm favors the undertaking of energy retrofit, there should be a decrease of energy consumption per capita in areas where there are relatively more of them, everything else equal.

This paper is organized as follows. First, a literature review will examine the main contributions in the fields of energy and urban economics, which are both relevant to this work. Second, the various data sources will be presented, with specific attention given to the construction of some key variables. Regression results and robustness tests will then be presented, followed by a discussion of their implications in terms of policy design.

## 2. Literature review

A large number of papers have explored the optimal policy mix to incentivize households to make their homes more energy-efficient. Following Sebi et al. (2019), two types of policy tools can be distinguished: regulatory instruments, which establish the minimum standards imposed on new construction, and financial instruments, which are meant to boost homeowners' will to undertake projects. The former imposes

[1] "*Reconnu Garant de l'Environnement*" can be translated to "Recognized Environmental Guarantor".
[2] Metropolitan France refers to the European territory of France, which excludes overseas regions.

restrictions on people's behaviors while the latter focuses on their incentives to reduce barriers. Voluntary-based instruments, such as incentive-based schemes for households and eco-labeling of buildings can be more efficient than regulatory instruments as they offer more flexibility, even if their outcomes may be more unpredictable (Tambach, Hasselaar, and Itard 2010; Lee and Yik 2004). High upfront costs, perceived or real, have indeed been identified as the primary obstacle deterring the undertaking of energy retrofits by households, as shown in the UK (Caird, Roy, and Herring 2008), in Ireland (Aravena, Riquelme, and Denny 2016), in Germany (Achtnicht and Madlener 2014), and in Switzerland (Alberini, Banfi, and Ramseier 2013). The level of grant also significantly increased the probability of undertaking a renovation projects, while households' uncertainty about future energy prices had a negative effect. Financial aid schemes should in that regard be efficient to boost the number of retrofits. Additionally, Fischbacher, Schudy, and Teyssier (2021) found that less risk-averse decision-makers were more likely to retrofit, and that less present-biased individuals were likely to live in more efficient houses. Comfort and concerns for the environment were also often cited as motivations to undertake a renovation project, but appeared less important - even though they can impact the nature of the investment. Households whose primary issue is comfort were found to invest in insulation, while drought proofing and solar panels were more likely to be installed by cost-driven households (Collins and J. A. Curtis 2017). Detailed surveys in Ireland have highlighted more precise factors when it comes to household decision-making, such as the proximity to the gas-network when choosing a heating system (J. Curtis, McCoy, and Aravena 2018). Rural households tend to undertake more energy retrofits than their urban counterparts, but they are less comprehensive on average (Collins and J. Curtis 2016). These findings overall highlight the need to design policies that account for household's characteristics and location.

Early evaluations of financial aid schemes for households focused on cost-efficiency: is it viable for states or local institutions to finance large-scale retrofit programs? A major source of inefficiency is the potential for a rebound effect. After a retrofit, households may change their behaviors and consume more energy, as its efficiency becomes relatively higher. It has been a long-standing topic in the economic and engineering literature[3], and was more recently studied in the context of energy retrofit programs. The impact of any type of financial aid has been found to be impaired by the rebound effect, which was even larger for low-income households (eg. Jin 2020). Further, from a total surplus perspective, grant programs can have a negative social impact and differentiated policy instruments should target households in situation of fuel-poverty (Dresner and Ekins 2006). Financial aid programs can also be subject to free riding. In this context, it refers to households using state subsidies to finance a retrofit project they would have taken on either way using their private founds. D'Alpaos (2021) found that the Italian tax credit scheme led to an over-investment that was not socially optimal, given current energy prices. Based on a survey on beneficiaries of State grants in Switzerland, Studer and Rieder (2019) found that 49.5% of households were free riders, meaning the subsidy did not increase the quality nor the scope of the retrofit. In France, Nauleau (2014) found that grants always had a significant and positive effect on households' propensity to retrofit, but that the share of free riders rose to 40% for low-income households after 2006, and up to 85% for high-income ones. Overall, European and North-American surveys found large shares of free riders among state program beneficiaries. Grants were found to induce more retrofits than loans but at a much higher cost for the state in that regard (Kerr and Winskel 2020). Even though financial schemes are efficient tools in theory, they have to lead to substantial improvements and not deter private investments to be cost-efficient in practice. The type of

[3] See Greening, Greene, and Difiglio (2000) for a literature review on different methods to characterize the rebound effect.

policy implemented - zero interest, tax credits, grants, etc. - also seems to impact the effectiveness of public investments.

Theses estimations of policies' cost-effectiveness however assume savings will be achieved through the policy. A more recent strand of literature explored whether fiscal aid programs actually induced energy savings in practice. European countries were found to differ significantly in their overall energy consumption, and in how it evolved after these policies were established (Filippini, Hunt, and Zorić 2014). The type of policy was identified as one of the main source of variation. Studying the transformation of a grant scheme to a low-interest loan program in the US, Gillich (2013) also found that the former reached more households, while the latter seemed to encourage larger-scale projects. The grant came out as more effective, both from the perspective of the cost-effectiveness of the public investment and regarding the overall energy savings achieved. The type of buildings targeted can impact the outcome as well. Exploiting another local subsidy program in the US, Liang et al. (2018) measured a 12% energy consumption reduction for commercial buildings and only a 8% one for the residential sector. Their results further indicated that the latter were subject to a rebound effect, with no significant savings for low-income households. Regarding the optimal scale of regulations, Bonifaci and Copiello (2017) found that programs facilitating partial renovations were sub-optimal, as they were more expensive and did not have a great-enough impact on consumption. More generally, specific areas of work could have more of an impact than others. In Ireland, Clinch and Healy (2000) found a significant effect of retrofits on consumption, particularly when drought-proofing and roof insulation were undertaken. Insulation proved to be effective to reduce consumption of electricity and gas in New Zealand, while results were mixed for heat pump installation (Grimes et al. 2011). Webber, Gouldson, and Kerr (2015) analyzed the Kirklees Warm Zones program in New-Zealand and found higher effective savings than predicted, despite a significant rebound effect for households. Galvin and Sunikka-Blank (2013) however concluded to the contrary for German households. A more recent randomized-encouragement design conducted by Fowlie, Greenstone, and Wolfram (2018) in the context of the Michigan Weatherization Assistance Program also led to relatively low estimates of energy savings. A 10% to 20% energy consumption reduction was achieved on average, which made up for roughly half the mean cost of retrofits. Similar conclusions were drawn by Blaise and Glachant (2019) regarding French households over the 2010-2013 period. Again, the outcome of these aid schemes seems very dependent on the policy design and local contexts. the lack of consensus on the impact of these policies reinforces the importance of global *ex-post* evaluations.

A common blind spot of these papers is the lack of information regarding the quality of the retrofit. The structure of the supply side could have a non-negligible impact. It is mainly composed of micro-firms, which tend to be risk-averse and to not have the resources to face the higher bureaucracy cost induced by eco-certifications (Owen, Mitchell, and Andrew Gouldson 2014) - and it is especially the case in France. As these firms are key to both the diffusion of retrofit policies and the actual undertaking of these retrofits, their skill level has to be accounted for. The multiplicity of stakeholders on a renovation project, from the household to the various contractors and potential state institutions involved, does make policy implementation relatively harder in the construction sector (Zhang et al. 2021). In particular, bad advice from contractors, due to a lack of skills or incentives, can deter energy retrofit investments (Risholt and Berker 2013). Fuller (2010) went as far as describing contractors as a "primary sales force for home energy improvements"[4], insisting that

[4]Fuller (2010), p59.

quality control should be at the heart of any program. Contractors' costs and incentives are yet almost always overlooked, both in economic evaluations and by policymakers. They directly impact the cost-effectiveness of financial schemes: "Supply side policy can generate additional retrofit activity via an installer recommending a policy measure [...] or in terms of improved training for installers"[5]. Poor installation and/or choices by contractors can drastically hinder the performance of a retrofit, as was already pointed out by Goldman (1985) after finding "systematic variations in the choice of retrofit options – for example, caulking and weatherstripping were installed in almost all low-income homes; energy savings from these measures are likely to be small and are directly related to the quality of workmanship"[6]. Smaller-scale ethnographic surveys have also highlighted the key role of installers. They were found to be instrumental in convincing households to switch to a heat pump (Wade, Shipworth, and Hitchings 2016), and it has been shown that repeated interactions are needed for individuals to trust their contractors (De Wilde 2019). Firms have also been shown to act as intermediaries facilitating or hindering the adoption of energy-efficient technologies when households plan on simpler refurbishment projects (Decuypere et al. 2022; Zaunbrecher et al. 2021). This aspect has to be addressed in the economic field, and there has not been a proper evaluation of the link between quality labels for firms and energy efficiency policy diffusion thus far.

## 3. Data

### 3.1. Overview

This paper focuses specifically on the role played by high-quality professionals in the outcome of energy-efficiency programs targeting households. In France, households have to hire a RGE contractor to apply for several tax credits and grants, hence financial programs may encourage certifications. Controls include aggregated census information on household, dwelling and climate-related characteristics, which have been found to drive residential energy demand in France (Risch and Salmon 2017). Another contribution of this work is the examination of the impact of both the improvement of existing dwellings and the change in local density due to new builds on energy consumption. The panel dataset contains information the evolution of the number of dwellings and their occupancy status. A well-established result in urban economics is that higher-density areas tend to have lower consumption per capita due to agglomeration externalities (Combes and Gobillon 2015). A prime example is the "urban heat island" phenomenon: local temperatures are significantly higher in cities than in rural areas, mostly due to a more intense human activity. Urban households may thus have lower needs in terms of heating (Santamouris et al. 2001) but higher air conditioning needs (Wong et al. 2011). Dense city centers are also typically composed of shared living spaces. They were found to be more energy-efficient since there are less exposed walls, hence the energy needed to heat up one square-meter is lower (Madlener and Sunak 2011). Overall, a negative relationship between residential energy demand and population density has been corroborated by surveys in France (Lampin 2013), Québec (Larivière and Lafrance 1999), China (Liu, Song, and Arp 2012; Chen, Jia, and Lau 2008), Norway (Holden and Norland 2005) and the USA (Erwing and Rong 2008).

Administrative data from the French census was combined with income declarations, energy consumption information published by two distributors (ENEDIS and GRDF), and local climate information. The final

[5] Kerr and Winskel (2020),p.7.
[6] Goldman (1985), p144.

sample is based on "tax households", meaning the grouped tax households listed in the same dwelling, which *de facto* excludes collective housing such as hospitals, retirement homes, etc., and homeless individuals. Accessibility to RGE firms was computed using the list of RGE firms provided by the French Agency for the Environment and Energy Management (ADEME). Their addresses were turned into GPS coordinates through the application programming interface of the "National Address Database" (BAN) produced by the French National Institute of Statistics and Economic Studies (Insee). The data is restricted to metropolitan France and covers the 2011-2018 period. For the sake of clarity only the year 2018 was used for the figures in this section. Observations are provided at the "aggregated unit for statistical information" (IRIS)[7] level. It is a spatial unit defined by the Insee in order to publish infra-municipal data while protecting anonymity. They can be one of four types :

- Activity IRIS, or A-type IRIS, which gather roughly 1 000 employees and has at least twice more workers than residents.
- Habitat IRIS, or H-type IRIS, the population of which lies between 1 800 and 5 000 inhabitants. The habitat is homogeneous and the borders are based on the main dividers of the urban space (eg. main roads, train tracks, rivers, ...).
- Non-subdivided IRIS, or Z-type IRIS, which are cities that are too small to be subdivided into infra-communal area. Their population has to be under 5 000 inhabitants.
- Miscellaneous IRIS, or D-type IRIS, which are specific zones with few inhabitants, covering large surface areas (eg. leisure parks, harbors, forests, ...).

The final dataset regroups 48 619 IRIS-level observations for each year, established following the 2020 update of the mapping, which comprises 820 A-types, 14 428 H-types, 33 049 Z-types and 322 D-types.

### 3.2. RGE Firms

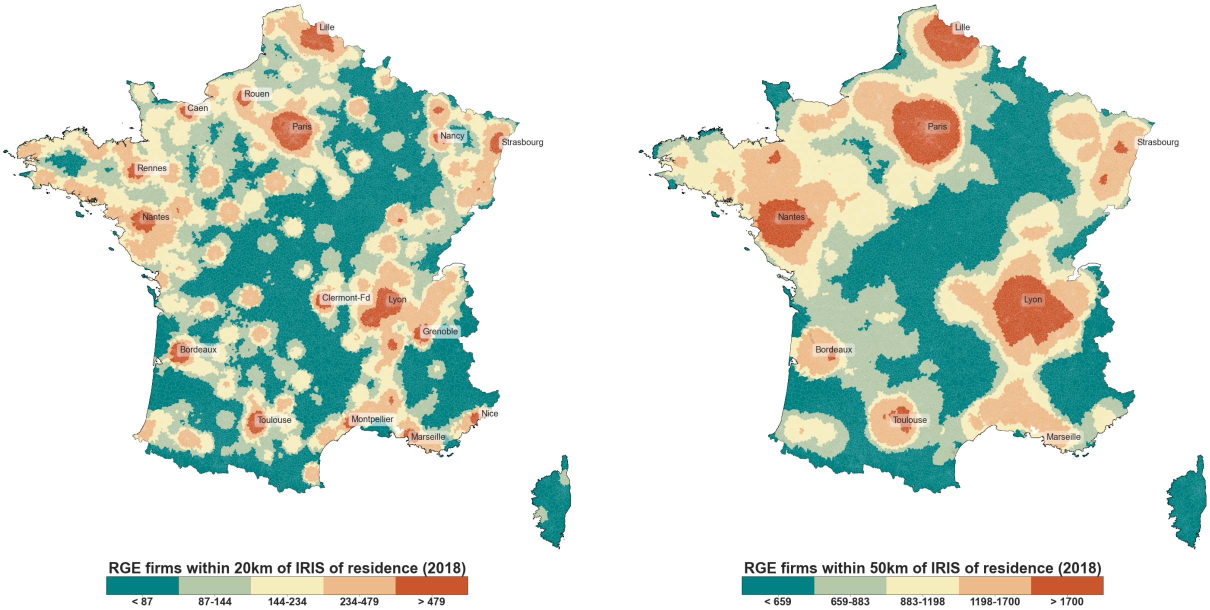
The RGE label was created following previous quality certifications established by professional organizations (CGEDD 2017). The Construction Sector Artisan Federation CAPEB created the *Eco-artisan* brand in 2008, while the French Building Federation (FFB) launched the *Pros de la performance énergétique*[8] in 2009. The CAPEB label relied on offering clients an energy efficiency diagnosis, while the FFB one was granted after the audit of at least one worksite. In 2010, both organizations signed a professional training convention with the French state and other institutional actors to improve construction firms' skills regarding energy-efficiency-specific tasks. The RGE label followed, formally introduced in 2011. The objective was both to strengthen and consolidate preexisting labels, and to set the ground for the cross-compliance of financial aid schemes. The RGE label became regulatory in 2014, as amendments were voted to make financial aid dependent on hiring a certified company for three policy initiatives - namely the tax credit, zero-interest eco-loans and white certificates, which will be detailed in the next section.

The ADEME historical dataset provides the exhaustive list of RGE firms, with the time period during which they were certified and their precise addresses. GPS coordinates were then interacted with buffer zones around IRIS zones' centroids. Figure 1 displays the number of RGE firms within a 20km (left) and 50km (right)

[7] "*Ilots Regroupés pour l'Information Statistique.*

[8] "Professionals of energy performance".

euclidean distance of each zone's centroid, per quintile. Their spatial distribution is far from homogeneous. The 50-km buffers hint at the existence of four main hubs around the cities of Nantes, Lille, Lyon and Paris. Two smaller hubs appear around Bordeaux and Toulouse in the South-West. At first glance, the presence of RGE firms does not seem to be directly related to city size, as Marseille is the third French city in terms of population and is merely in the fourth quintile in these graphs. The last quintile threshold is 5.5 times higher than the first one's for the 20km buffer, and 2.6 times higher for the 50km buffer. Such disparities in the access to RGE firms should raise concerns in itself, since several aid schemes for households are conditional on hiring these contractors. The same method was applied to the entire stock of active French firms using the SIRENE database provided by the Insee in order to obtain the total number of firms in each buffer. The share of RGE companies is relatively low everywhere, reaching a maximum of 32.3% in 20km buffers and 26.4% in 50km buffers.




Source: Author's computations from ADEME data.
Note: Data is represented by quintiles from the whole sample. For instance, only 20% of IRIS zones had more than 479 RGE firms within 20km of their centroids in 2018.

Figure 1: Access to RGE firms per IRIS

### 3.3. Financial aid policies

This paper focuses on the five national-scale policies for the retrofit of private housing in France. The smallest spatial aggregation available is used in the regressions. Policies targeting State-owned buildings and social housing were left out. Additional policies may also exist at the department or region level. They usually take the form of a grant or a property tax reduction attributed to owner-occupiers undertaking a renovation. They are excluded from the analysis due to lack of data and will be captured by fixed effects. This section aims to clarify the purpose and application of each policy, as well as indicate how the data was retrieved[9].

- White certificates are the most widespread policy in Europe and have been implemented in France since 2006. The general principle is to set energy-saving targets for key economic actors, mainly energy

[9] I would like to thank L. Gouiffes and M. Ledez from the Institute for Climate Economics (I4CE) for their helpful pointers when I was compiling information on public spending.

suppliers. They can either achieve the reductions themselves, in particular by financing retrofits, buy certificates from other actors or pay a penalty to the State. National-level spendings were computing using the Emmy database, which is the institution in charge of overlooking the policy.

- The *Agence Nationale de l'Habitat* (ANAH)[10] has delivered financial aid on behalf of the Environment and Economy ministries since 2010. Its specific goal is the elimination of energy poverty, hence the grants are delivered to low-income households only. National and regional-level amounts were compiled from the agency's yearly activity reports (eg. ANAH (2018) for the year 2018). As region borders officially changed in 2015, amounts were projected to keep the previous borders for the 2016-2018 period.

- Zero-interest eco-loans have been established in 2009. They are monitored by the public financial institution *Caisse des Dépôts et des Obligation*[11], but they are are granted by private banks. Households can borrow up to 30 000 €, depending on the targeted area of work (roof insulation, double glazing, etc.), and the state compensates the banks for the loss of interest profits. National and department-level information were found in the statistical reports produced every quarter by the *Société de Gestion des Financements et de la Garantie de l'Accession Sociale à la propriété* (SGDAS).

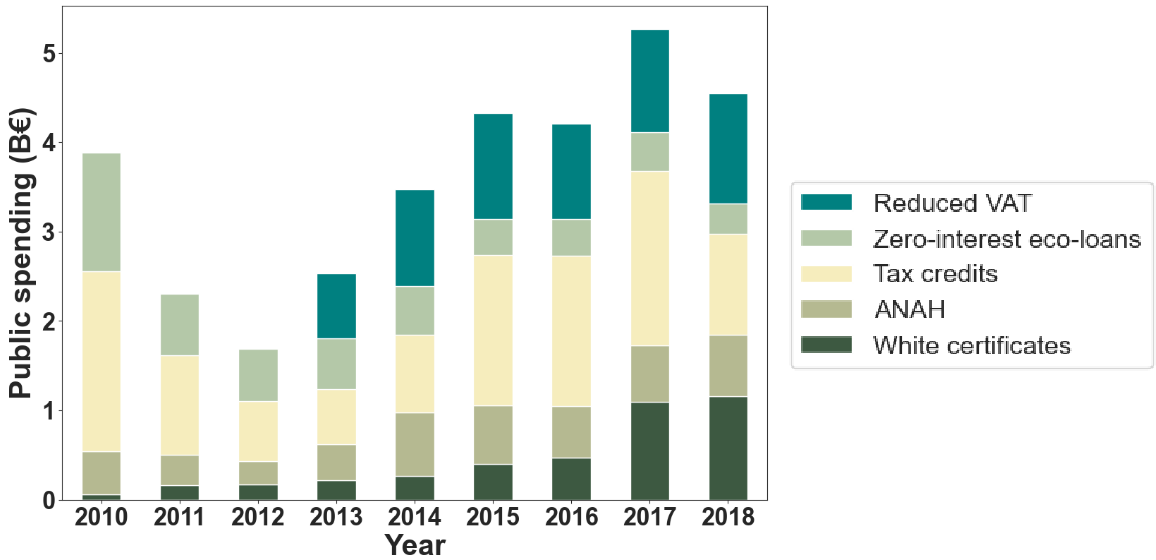
- Tax credits were first introduced in 2005 with the *Crédit d'Impôt Développement Durable* (CIDD)[12]. It also relied on a list of areas of work, for which households could get tax deductions as a percentage of their cost. This percentage has varied over the years and depending on the area of work. It became the *Crédit d'Impôt pour la Transition Energétique* (CITE)[13] in 2015, with two major changes. First, the rebate rates were all set at a unique rate of 30%. Second, they dropped the bunch of work requirement. National level amounts were compiled from financial expenses appendices to yearly Finance Acts. For instance, the precise amount received by households in 2018 can be found in the appendix to the 2021 Act (PLF 2021) as the 2019 public spending, since there used to be a one-year fiscal delay in France. Regional-level amounts were deduced using the shares received by each region, found in the official report by the *Inspection Générale des finances* (IGF 2017) for the 2010-2015 period, which were used to get projected shares for the remaining years.

- VAT reduction measures have been implemented since 1999 in order to boost economic activity and employment in the construction sector. The normal VAT rate is set at 20%, and the reduced rate has varied between 5.5% and 10% over the years. A 2013 modification created two different VAT regimes, distinguishing energy retrofit work from the rest of construction activities. Current rates are set at 5.5% and 10% respectively. Given the general nature of the measure prior to 2013, only the spending related to energy retrofit were kept in the main analysis[14]. National level amounts were also compiled from financial expenses annexes to yearly Finance Acts.

Figure 2 displays the evolution of these policies over time. For clarity, "public spending" refers to the amounts *perceived* by households and firms for each year, not *spent* by the State - the firms in the case of white

[10] "National Housing Agency".
[11] "Deposits and Consignments Fund".
[12] "Tax Credit to support Sustainable Development".
[13] "Tax Credit to support the Energy Transition ".
[14] See Appendix A for the evolution of public spending related to VAT reduction measures. Given the differences in amounts between the energy-efficiency improving work and general renovation activity, including the policy prior to 2013 appeared mistake-inducing

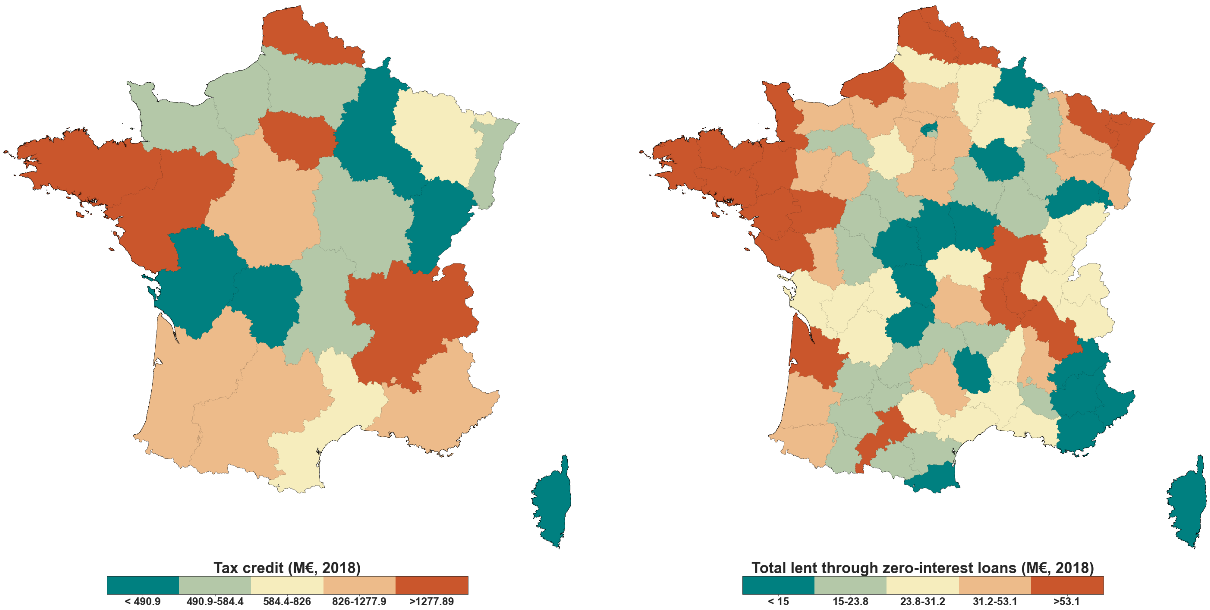
certificates, or the banks for the eco-loans. There was an overall steep decrease from 2010 to 2012, mostly driven by the reduction of the amounts spent on tax credits. Overall amounts increased rather steadily afterwards. ANAH grants have not increased significantly, despite efforts to boost demand. The application conditions were loosened in 2013, extending beyond owner-occupiers and increasing the maximum revenue condition. Investments induced by white certificates were also increasing, which is in line with the higher energy reduction targets set by the state over time. Zero-interest eco-loans represent a decreasing share of the overall amounts, which can in part be explained by the overall low interest rates offered by commercial banks which made them less attractive (IGF 2017). Another important factor was the change of regulation regarding the cumulation of aids. Households were not allowed to apply for a tax credit and a loan for the same project after 2011. Cumulation was allowed again in 2012 for low-income households, and in 2016 for all households, but it did not seem to affect the trend. Spending related to reduced VAT has been stable since 2014, and has contributed significantly to the general increase.




Sources: Official documents from various public institutions.
Note: Public spending refers to what households actually received during each given year.

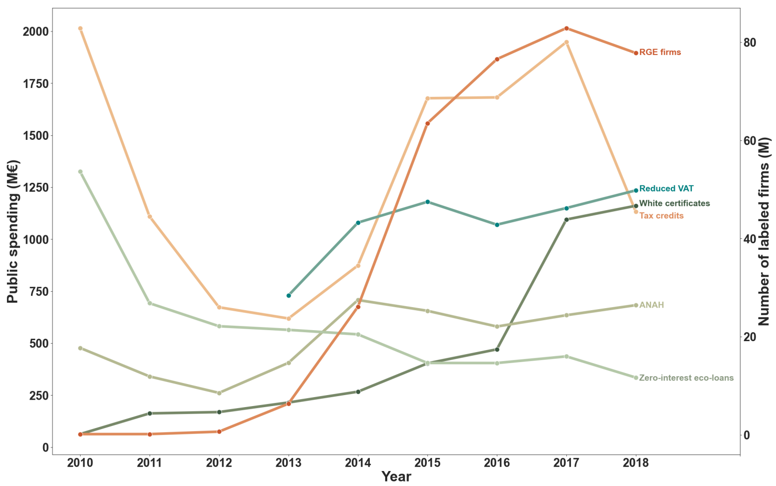
Figure 2: Evolution of French public policies since 2010

Hiring a RGE contractor has become a condition for households to be able to apply for white certificates, tax credits and zero-interest eco-loans since 2014. The financial aid received locally should hence be directly linked to the access to RGE firms. There seems to be a positive correlation between the four main clusters visible on Figure 1 and tax credit spending at the regional level (Figure 3, left). The areas around Bordeaux, Toulouse and Strasbourg also seemed to have received more zero-interest loans in in 2018 (Figure 3, right), which is consistent with the spatial distribution of RGE firms. The number of labeled firms follows a similar overall trend to the total amount of aid distributed through white certificates and tax credits (Figure 4). ANAH grants and reduced VAT spending seem to follow an independent trend, and the link with zero-interest loans is not clear before 2016.




Sources: Official documents from various public institutions.
Note: Public spending refers to what households actually received. Data is represented by quintiles. For instance, in 20% of the departments, households received less than 490.9 M€ overall in 2018.

Figure 3: Public spending at the local level

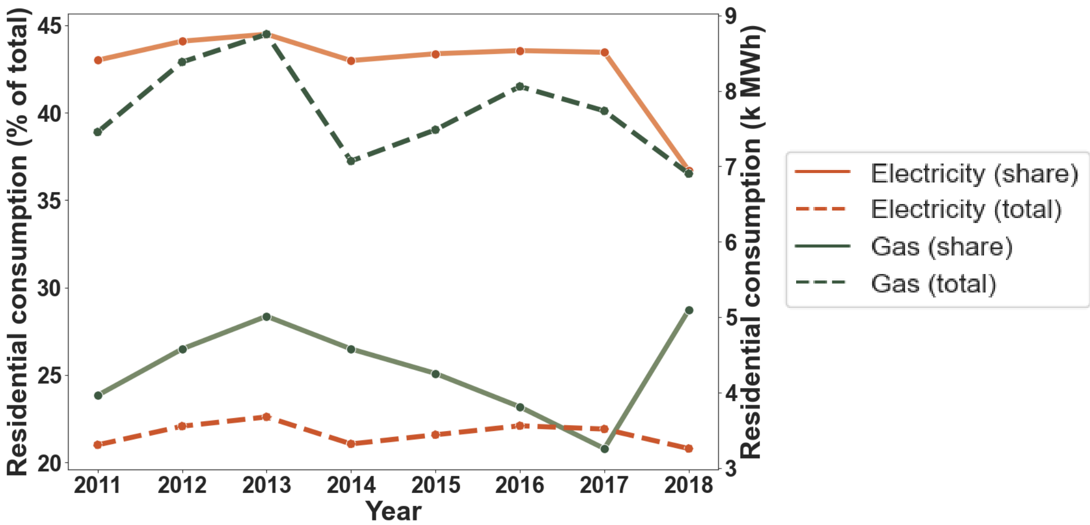



Sources: Official documents from various public institutions; author's computations from ADEME data.
Note: Public spending refers to what households actually received during each given year.

Figure 4: Public spending and RGE firms over time

## 3.4. Energy consumption data

Electricity consumption data has been made available at the IRIS level by the firm ENEDIS, which is in charge of the management and the maintenance of 95% of the electricity network in metropolitan France (1 324 045 km of power lines). Following the French data protection laws, areas where there are less than 11 distribution points are systematically anonymized. The main advantage of working with producer data is that, contrary to previous studies, the analysis can be conducted using actual consumption in physical units rather than household expenses, which are less reliable. A few drawbacks should be noted. The annual information is provided using the IRIS mapping that year, which changes every year. As a result, 1 300 IRIS could not be matched because of border modifications over the years and were excluded from the final dataset. Finally, the region of Corsica is missing in the data, and will be removed from the final sample. The share of the residential sector among total consumption has remained around 40% since 2011, peaking around 45% in 2013 and dropping to 37% in 2018 (Figure 5).




Sources: ENEDIS; GRDF.
Note: Average shares are derived from IRIS-level consumption data for each year.

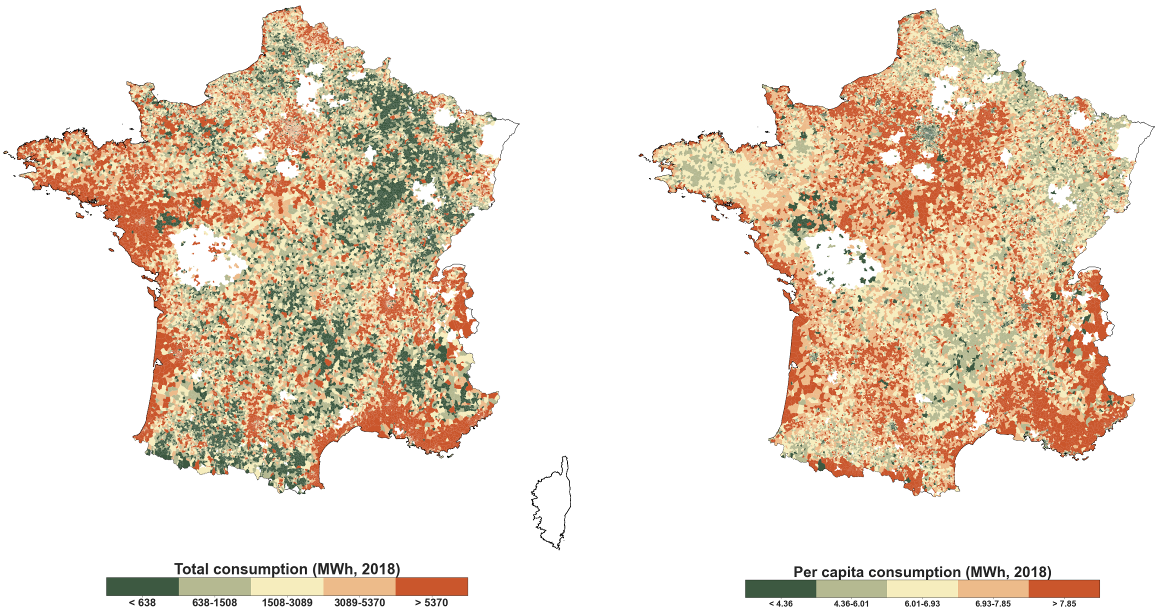
Figure 5: IRIS-level mean energy consumption

Information on gas consumption has been published by the French company *Gaz Réseau Distribution France* (GRDF). It is the main provider of natural gas in France and in Europe, serving roughly 11 million French households as of 2018. Their distribution network has a length of 200 000 km, serving 9 515 cities and 77% of the population of these cities[15]. There are 30 other distributors in France, serving the remaining households. Gas meters are read every 6 months for "6M" clients, who represent 99% of the total; they are read every month for roughly 100 000 "MM" clients and every day for nearly 3 000 "JJ" clients. The annual consumption is thus computed by summing daily measures for JJ types, and by summing mean daily consumption for MM and 6M types. The sample is restricted to their residential-sector clients, meaning those who consume less than 300 MWh per year and are subject to the T1 and T2 natural gas transmission tariffs set up by the French state. Following legal restrictions on open data, IRIS-level information can be made available only if there are strictly more than 10 distribution points within the IRIS and if the measured consumption is above the "residential threshold" of 200 MWh - in practice, 4% of the 23 634 IRIS were removed. Overall, 95.28% of the annual measures made by GRDF are available. The residential sector holds a fairly constant share in total physical gas consumption over time before, peaking at 28% in 2013 and in 2018 (Figure 5).

There are clear disparities in electricity consumption in metropolitan France (Figure 6). At first glance, cities come out as the more important consumers, but the picture changes when looking at per-capita quantities. Focusing for instance on the Paris urban area on these maps, it is in the 5th quintile with respect

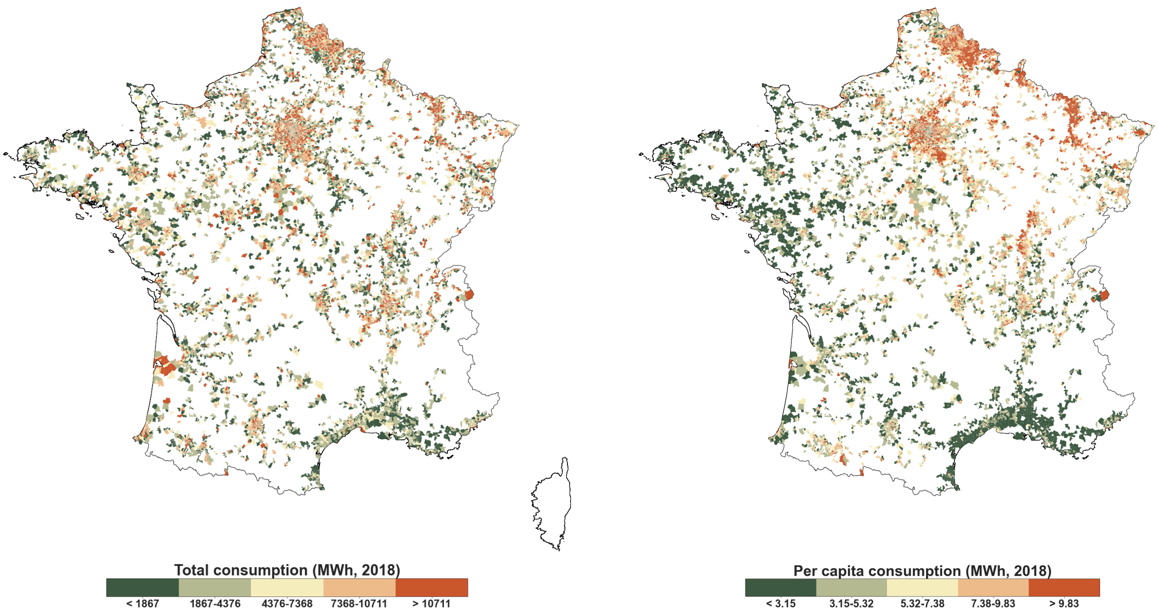
[15]See Appendix B for a map of their 2018 network.

to overall consumption and falls in the first in terms of per-capita consumption. This can be linked back to aggregation externalities, as urban centers are more densely populated. There is a similar spatial pattern for gas consumption total and mean consumption, but it is less pronounced (Figure 7). Given these spatial differences in consumption for a given year, controls for local weather and housing densities have to be included.




Source: ENEDIS.
Note: Data is represented by quintiles. For instance, 20% of IRIS zones had a total electricity consumption of less than 638 MWh in 2018.

Figure 6: Electricity consumption in physical units in the residential sector

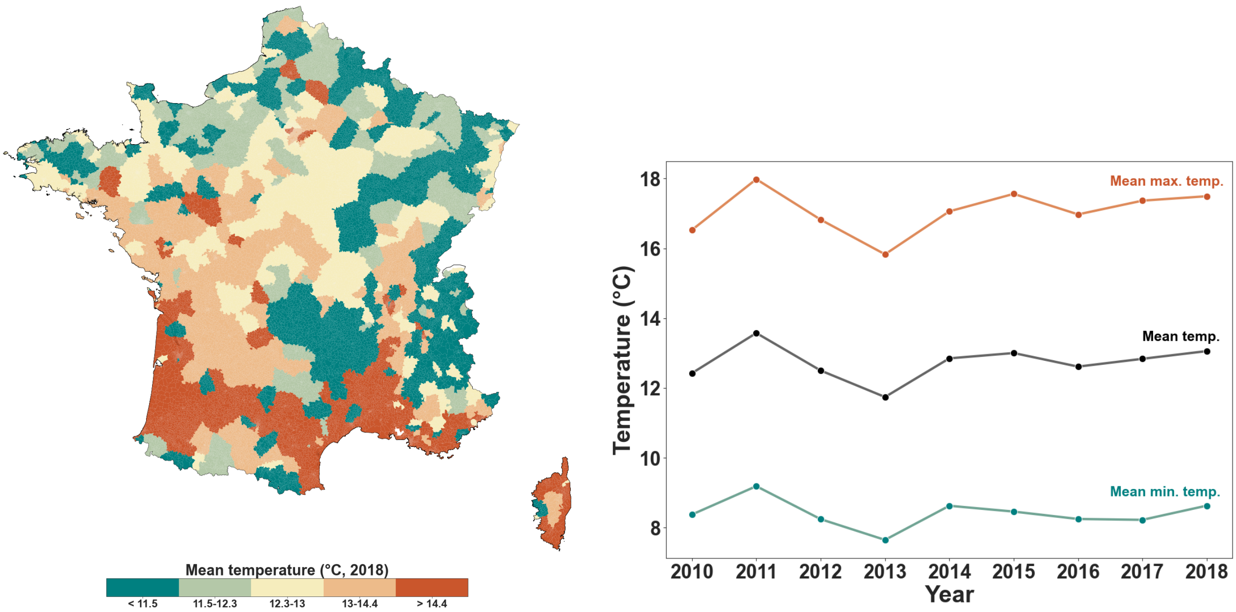



Source: GRDF.
Note: Data is represented by quintiles. For instance, 20% of IRIS zones had a total gas consumption of less than 1867 MWh in 2018.

Figure 7: Gas consumption in physical units in the residential sector

### 3.5. Local weather

Local weather is proxied by average temperatures. For each IRIS, they are equal to the temperatures measured by the nearest weather station. The information was scrapped from the French NGO *Infoclimat*, which publishes monthly records from every station in France on their website. Appendix C provides an overview of stations across the metropolitan territory. Temperatures are higher in the South and along the West coast.(Figure 8, left). Large urban areas, such as Paris or Lille, appear relatively warmer than their surroundings, which is likely due to density effects. Averages are not constant throughout time, with 2013 being an especially cold year (Figure 8, right). Mean maximal and minimal temperatures refer to daily minimal and maximal recorded temperatures, averaged over the year. They appear to follow similar trends, which is well captured by the overall mean.

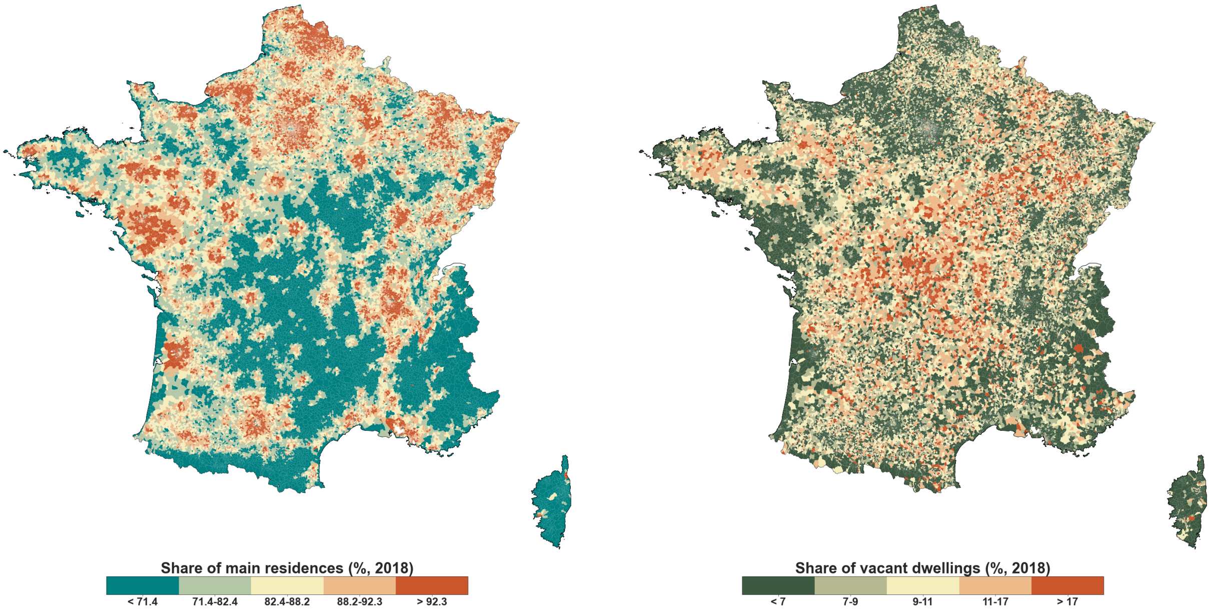



Source: Infoclimat.
Note: Data is represented by quintiles on the map. For instance, 20% of IRIS zones had a yearly average temperature below 11.5°C in 2018. Yearly averages are derived from weather station-level data on the right-hand side graph.

Figure 8: Local temperatures

### 3.6. Insee data on French households

French census data is collected over five-year cycles, which limits year-to-year comparisons. For instance, part of the information contained in the 2012 dataset will be exactly the same as the information provided for the year 2011, as some cities would not have been subjected to new data collection. Cities with less than 10 000 residents conduct a full census collection every five year, meaning a fifth of them provide new information for every survey year. Cities with more than 10 000 residents conduct a yearly survey among a representative sample of roughly 8% of their inhabitants and housing. The estimations are run on a time span larger than 5 years, which allows for at least one complete collection cycle.

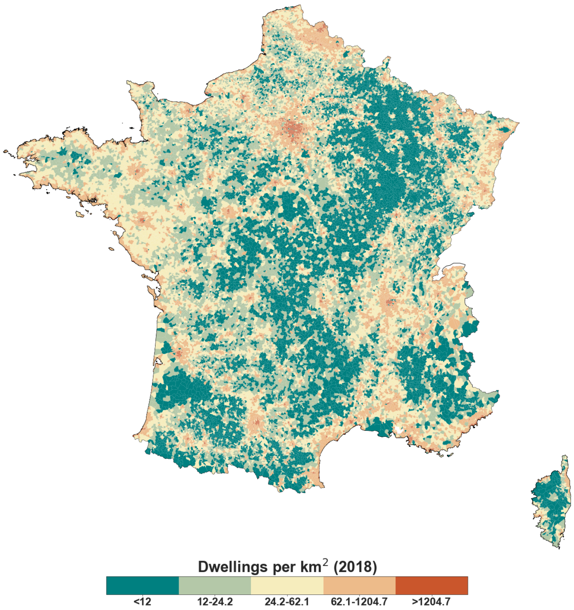



Source: French census.
Note: The share of main residences is represented by quintiles on the map: for instance, the share of main residences was below 71.4% in 20% of IRIS zones in 2018. For clarity, because the share of vacant dwellings is rather low everywhere in France, the categories used here are not quintiles but follow the typology used in reports from public institutions (eg. DGT 2020).

Figure 9: Dwelling usage

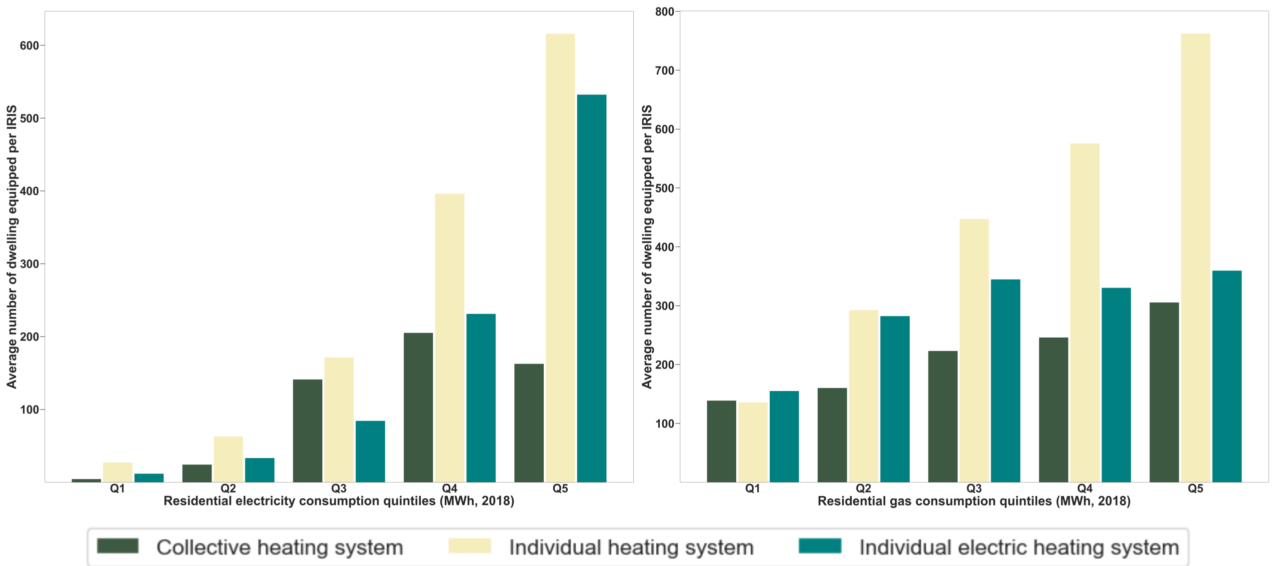
As the data is aggregated, it is crucial to control for the share of houses that are actually inhabited. Most areas contain mostly main residences (Figure 9, left). There are relatively more secondary residences along coastal areas and in the South, while cities are clearly defined by the highest shares of main residences. Vacant dwellings[16] are also quite rare (Figure 9, right). The center regions, which are more rural and less populated, have relatively higher shares. It appears correlated to large differences in dwelling densities (Figure 10, right). Gaps are especially large between the two top quantiles and the rest, with city centers having up to 100 times the number of dwellings per square kilometer found in rural areas. Dwelling types are also accounted for. The French societal standard is the individual house, which is the least energy-efficient kind of dwelling possible. More than 50% of dwellings are individual houses in the vast majority of France, except in the Paris urban area and in eastern regions. Shared housing is only the norm in dense city centers (Figure 10, left), keeping in mind that less than 20% of IRIS zones have a majority of flats. This is consistent with the fact that dwellings are on average smaller for a given household size in denser areas. Collective heating infrastructures are also mostly found in cities. As expected, there are more dwellings equipped with electric heating systems in areas belonging to higher electricity consumption quintiles (Figure 11, left), while there is no significant difference in the last three gas consumption quintiles (Figure 11, right). There are also relatively more dwellings equipped with individual heating systems in high-consumption areas.

[16]Vacant dwellings refer to unfurnished dwellings that were never used during the reference fiscal year, while secondary residences are occupied for at least a few days annually.




Source: French census.
Note: Data is represented by quintiles. For instance, the density of dwellings was above 1204.7 units per km$^2$ in 20% of IRIS zones in 2018.

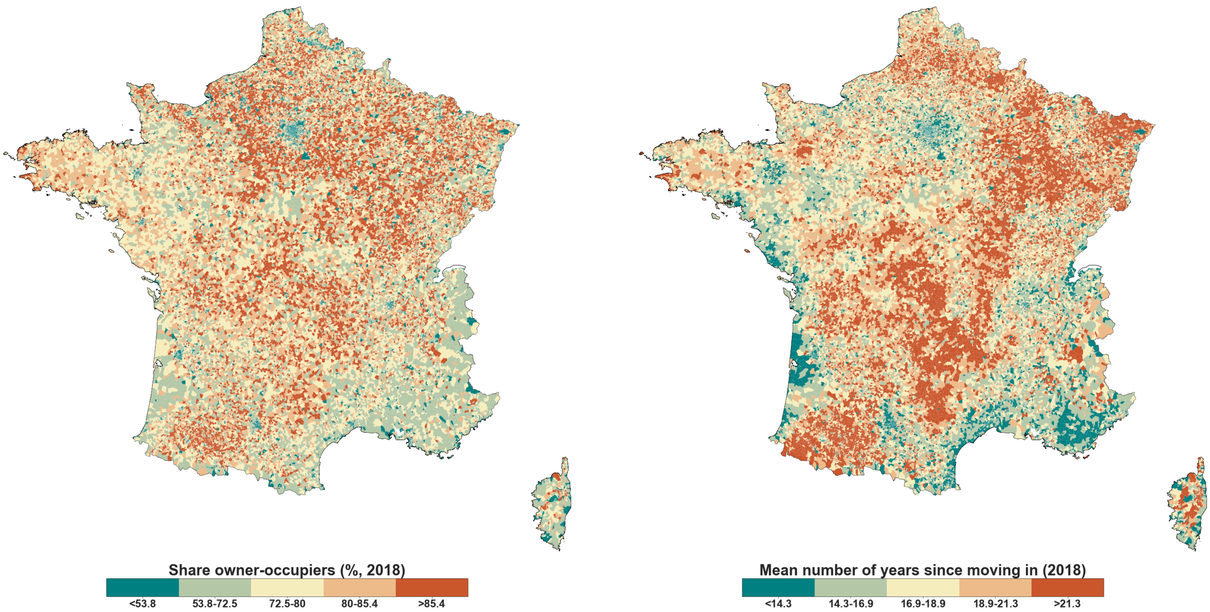
Figure 10: Dwelling distribution




Sources: ENEDIS; GRDF; French census.
Note: Quintiles are derived from the whole sample of IRIS-level observations.

Figure 11: Energy consumption and heating systems

Census data provides further information on households characteristics. The majority of residents are owner-occupiers in 80% of IRIS areas (Figure 12, left). The share of owner-occupiers in main residences is significantly smaller in the Paris urban area and in the South-East, which is in line with higher property prices. The number of years since moving in is expectedly lower in these areas (Figure 12, left). The turnover is lower in rural areas, where ownership is more accessible. Mobility remains rather low overall, as the bottom quintile threshold was set at 14 years in 2018. Other household characteristics used in the controls include household size, local age structure, mean square meters per dwellings, local unemployment rate, etc.

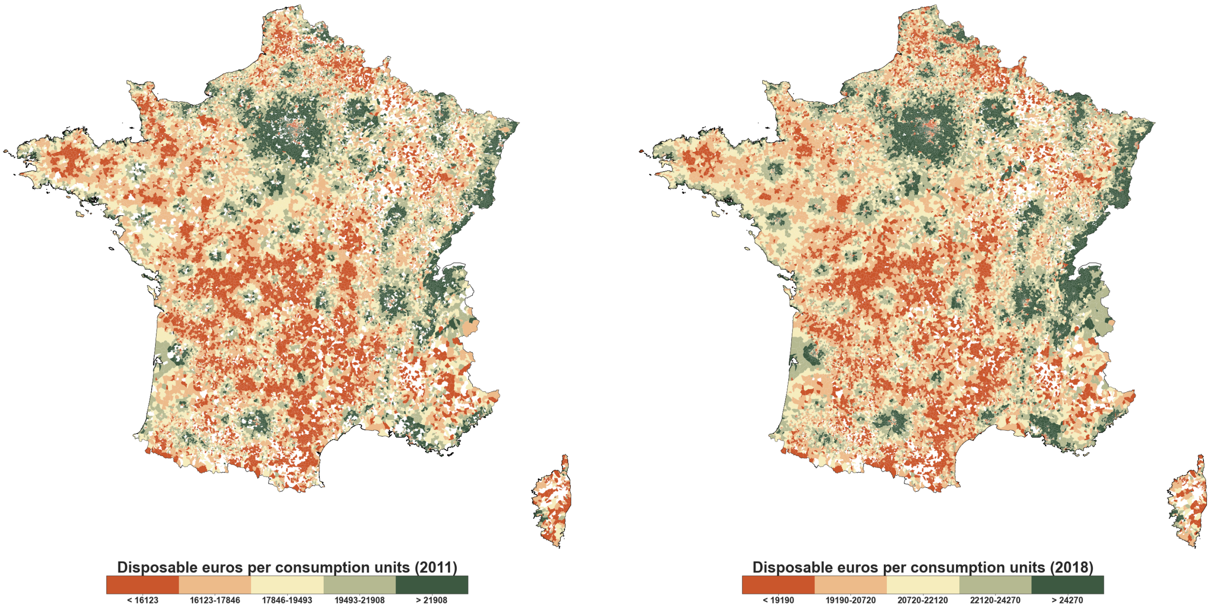



Source: French census.
Note: Data is represented by quintiles. For instance, the share of owner-occupiers was below 53.8% in 20% of IRIS zones in 2018.

Figure 12: Main residences

Information on income is not directly available from the census, but found in the "*Fichier Localisé Social et Fiscal*" (Filosofi)[17] database. It is also produced by the Insee and gathers several indicators measuring living standards, fiscal incomes and post-tax disposable revenues at different geographic levels. It is derived from the annual "*Enquête Revenus Fiscaux et Sociaux*" (ERFS)[18], and replaced the "*Revenus Fiscaux Localisés*" (RFL)[19] module in 2012. The RFL survey provides income information for the years 2010 and 2011, but it is less exhaustive. Contrary to previous studies, income is not self-declared by households, but derived from their tax forms, which is both more precise and more reliable. Median living standards will be used to control for households' purchasing power. They are computed by the Insee as a household's disposable income divided by the number of consumption units (CU), and are equal for all household members. Consumption units are computed following a modified OECD scale: the first adult represents 1 unit, every person older than 14 counts as 0.5 unit and every child under 14 counts as 0.3 unit. Median living standards are the indicator that is available for the larger number of IRIS zones, and they have the advantage of not being distorted by extreme revenues, contrary to the mean. There are significant spatial disparities, but the evolution over time is not drastic (Figure 13). Cities are again clearly identifiable, with an interesting and somewhat surprising distribution: the very center of urban areas seems to be characterized by low living standards, and they increase in the greater periphery.

[17] "Localised disposable income system".
[18] "Tax and social income survey".
[19] "Localised tax revenues".




Sources: RFLM; Filosofi.
Note: Data is represented by quintiles. For instance, median living standards were below 16 123 €/CU in 20% of IRIS zones in 2011, while that threshold rose to 19 190 €/CU in 2018.

Figure 13: Median living standards

# 4. Estimation results

## 4.1. Estimation procedure and endogeneity issues

| Variable | Mean | Standard deviation | Max | Min |
|---|---|---|---|---|
| Elec. consumption (total) | 50416.43 | 3451.87 | 0.00 | 3268.13 |
| Elec. consumption (per capita) | 436.58 | 6.41 | 0.00 | 2.74 |
| Gas consumption (total) | 408770.12 | 7730.36 | 0.00 | 6122.00 |
| Gas consumption (per capita) | 152459.45 | 13.43 | 0.00 | 587.37 |
| RGE firms (20 KM) | 3932.00 | 240.70 | 0.00 | 570.53 |
| Construction firms (20 KM) | 128625.00 | 9054.72 | 10.00 | 23932.70 |
| Eco loan | 26.92 | 8.76 | 0.00 | 4.95 |
| ANAH | 22.46 | 9.06 | 2.90 | 4.12 |
| Tax credits | 43.43 | 19.57 | 0.00 | 8.76 |
| Reduced VAT | 79.91 | 59.47 | 46.53 | 12.19 |
| White certificates | 17.91 | 7.65 | 2.58 | 5.86 |
| Average temperature (°C) | 24.20 | 12.13 | -6.76 | 2.38 |
| Dwellings | 29584.48 | 698.90 | 0.00 | 754.48 |
| Sh. main residences (%) | 100.00 | 81.21 | 0.00 | 15.09 |
| Sh. owner-occupiers (%) | 100.00 | 69.36 | 0.00 | 20.94 |
| Sh. flats (%) | 100.00 | 23.95 | 0.00 | 31.60 |
| Sh. coll. heating (%) | 100.00 | 10.11 | 0.00 | 20.26 |
| Sh. elec. heating (%) | 100.00 | 24.67 | 0.00 | 14.42 |
| Sh. families (%) | 100.00 | 42.29 | 0.00 | 11.10 |
| Med. living std. (€/CU) | 67153.00 | 20675.60 | 2124.00 | 4244.66 |
| Unemployment rate (%) | 100.00 | 12.05 | 0.00 | 6.68 |

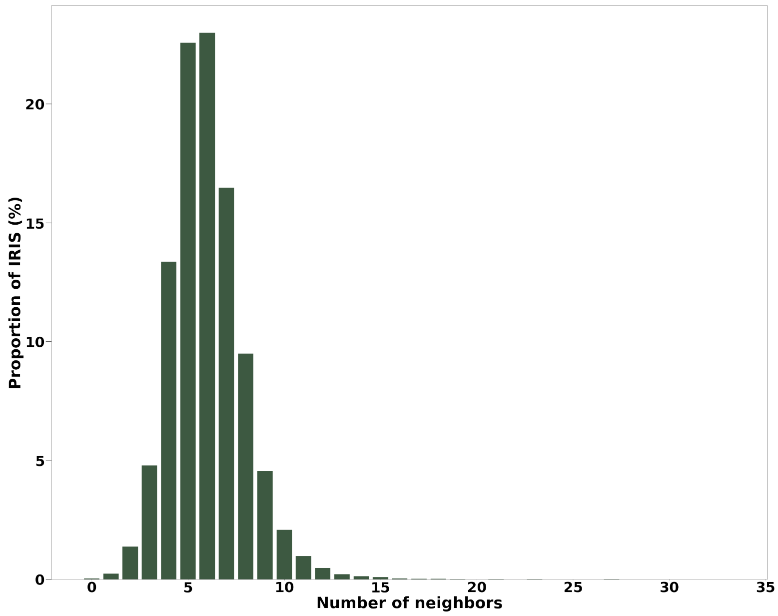
Values are computed on the entire panel.

Table 1: Summary statistics

This section presents and discusses several regression results to identify the impact each policy had on firms' labeling decisions and households' energy consumption over time. Table 1 displays summary statistics for the total sample, with public spending expressed in euros per capita and energy consumption given in megawatts per hour (MWh). Estimations are run using the random effect spatial error model developed by Kapoor, Kelejian, and Prucha (2007). The main assumptions are that unobserved heterogeneity is uncorrelated to the independent variables. The non constant part of the error term is modeled following a normal distribution. Contrary to previous specifications, the KPP estimator allows for a spatial diffusion effect in both the idiosyncratic part of the error term and the individual effect. In other words, observations can be correlated both spatially and time-wise. The KPP approach to spatial dependence for each period takes after Cliff and Ord (1981), which they extended to a panel specification. Formally, denoting the spatial autoregressive parameter $\lambda$, the $(n \times 1)$ outcome vector $y_t$ and the $(n \times k)$ independent variable matrix $x_t$ for each time period $t$:

$$\begin{cases} y_{it} = x_{it}\beta + \alpha + u_{it} \\ u_{it} = \lambda \sum_{j \neq i} \omega_{ij} u_{jt} + v_{it} \\ v_{it} = \alpha_i + \epsilon_{it} \qquad \text{where:} \quad \epsilon_{it} \overset{i.i.d.}{\sim} \mathcal{N}\left(0, \sigma^2\right) \end{cases} \tag{1}$$

The weight matrix $\omega$ is computed using queen continuity, meaning two IRIS zones are considered to be neighbors if their borders share a common edge. Each zone has 6 neighbors on average and 15 IRIS are "islands" in the statistical sense, which means that they do not have any neighbor (Figure 14).




Source: Author's computations from Insee data.
Note: Queen continuity was used to match neighbors on the whole sample.

Figure 14: Distribution of IRIS zones per number of neighbors

The model is estimated through a generalized method of moments (GMM) procedure. As the presence of RGE firms may be affected by public policies, they will be instrumented by the overall number of construction firms in the same buffer. The rationale behind this instrument is that the number of firms does not impact residential energy consumption directly, but skilled firms may choose to get the label to differentiate themselves from their competitors, meeting the exclusion restriction. First stage results will assess the stenght of the instrument, as well as the impact each policy had on the the number of RGE firms. Second-stage results will review their impact on energy consumption. Policy spendings are expressed in euros per capita, energy consumption is measured in megawatt per hour (MWh) and the number of observations are given per year. The intercept was included in the regressions but is not displayed on the summary tables. The regressions results presented in this section only account for the 2014-2018 period, meaning after the eco-conditionality law, but estimations run on the entire period can be found in the appendix.

### 4.2. First stage : RGE firms

Table 2 presents regression results for the first stage regression, each column corresponding to a different buffer size. The instrument appears to perform well. The number of construction firms in the same buffer has a significantly positive effect on the number of RGE firms in all specifications. This is consistent with labels being a strategic choice for firms, allowing them to stand out in competitive markets. The RGE certification is a straightforward quality signal for households. The number of dwellings has a negative effect for all dependent variables for buffers larger than the IRIS itself. This is consistent with the idea that a larger potential market decreases the need to get the certification. Turning to household characteristics, log median standards of living and the share of main residences seem to drive the implantation of RGE firms. This may reflect a higher willingness to pay, as hiring RGE contractors is more costly. The share of flats has a positive impact, while the share of owner-occupiers seems to affect the number of RGE firms negatively. These results may indicate that RGE firms are primarily located in city centers. Regressions run on the reduced time-period are overall a better fit (see Appendix D for estimation results run on the 2011-2018 period). The pseudo-$R^2$ increases up to the 20km buffer and decreases for larger buffers, hence the 20km buffer will be used in second-stage regressions. Overall, these results support the idea that heterogeneous access to RGE companies leads to inequalities in policy attributions across the territory. Obtaining the certification is currently up to the companies, which make strategic decisions based on their local market conditions. These findings call for a better monitoring of the diffusion of the label, as a lack of RGE firms could seriously hinder the effectiveness of the policies in some areas.

There is clear link between policy spending and RGE diffusion, which supports the need for an instrument. Focusing on the 20 km buffer, all policies have a positive effect on the number of RGE firms, except spending related to the reduced VAT measure. This further supports the idea that getting the label is a strategic choice for firms, as the only type of aid non-labelled firms can benefit from is reduced VAT. Firms may strategically choose to either get the costly RGE label, or differentiate themselves by selling at a lower price using the reduced VAT rate. There are also signs of heterogeneity between aid schemes. For instance, at the regional level, one euro spent per capita on ANAH spending seems to induce double the number of RGE firms than one euro spent on tax credits. Using IRIS zones' average population in 2018, it means that increasing ANAH grant spending by 1 334 € in an IRIS led to the certification of 7 more firms within 20km, against 3 if the same amount was spent in tax credits. This difference holds even when considering variations in amounts perceived by households through each policy. The average ANAH grant was 8 101 € per dwelling in 2018 (ANAH 2018), meaning that retrofitting one dwelling in an IRIS area induced on average 42 new certifications within 20 km. The average tax rebate obtained in 2018 was 1 242 €, hence one retrofit in an IRIS would lead to almost 3 new certifications. Overall, these first stage results not only support the instrumental strategy, but

| | Number of RGE firms | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Within IRIS | 5KM buffer | 10KM buffer | 15KM buffer | 20KM buffer | 25KM buffer | 30KM buffer | 35KM buffer | 40KM buffer | 45KM buffer | 50KM buffer |
| Eco loan | -0.0302*** | 0.6723*** | 2.5586*** | 4.9538*** | 6.3035*** | 8.9975*** | 10.2691*** | 11.0386*** | 11.7316*** | 12.1674*** | 12.0171*** |
| | (0.0014) | (0.0452) | (0.1191) | (0.181) | (0.2313) | (0.3279) | (0.3849) | (0.4342) | (0.4789) | (0.5189) | (0.5571) |
| ANAH | 0.0042** | 1.4855*** | 4.1803*** | 6.2786*** | 6.8401*** | 17.1678*** | 20.2138*** | 22.3271*** | 23.7522*** | 24.3388*** | 23.8544*** |
| | (0.0018) | (0.0492) | (0.1253) | (0.1862) | (0.2363) | (0.3931) | (0.4612) | (0.5202) | (0.5737) | (0.6214) | (0.667) |
| Tax credits | 0.0333*** | 0.3414*** | 0.6189*** | 1.8298*** | 3.4941*** | -18.7464*** | -21.6286*** | -23.391*** | -24.2714*** | -24.485*** | -23.7398*** |
| | (0.0004) | (0.0213) | (0.0623) | (0.1028) | (0.138) | (0.2085) | (0.2438) | (0.2742) | (0.302) | (0.3273) | (0.3517) |
| White Certificates | 0.0377*** | 1.9576*** | 6.0752*** | 11.021*** | 16.2678*** | 15.031*** | 18.8439*** | 22.746*** | 26.8669*** | 31.1498*** | 35.3024*** |
| | (0.0005) | (0.0283) | (0.0896) | (0.1594) | (0.2259) | (0.4983) | (0.5723) | (0.6345) | (0.6966) | (0.7594) | (0.8218) |
| Reduced VAT | -0.0412*** | -2.803*** | -9.1181*** | -15.9518*** | -22.5296*** | -51.6915*** | -62.8887*** | -72.7888*** | -82.1687*** | -91.3988*** | -99.6065*** |
| | (0.0011) | (0.0648) | (0.2052) | (0.3645) | (0.5157) | (1.1151) | (1.2808) | (1.4198) | (1.5586) | (1.6987) | (1.8378) |
| Construction firms | 0.0229*** | 0.0139*** | 0.0185*** | 0.022*** | 0.0242*** | 0.1169*** | 0.1224*** | 0.1265*** | 0.1298*** | 0.1326*** | 0.135*** |
| | (0.0003) | (0.00005) | (0.00004) | (0.00004) | (0.00004) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| Average temperature | -0.0043*** | 0.724*** | 1.7314*** | 2.2642*** | 2.0439*** | 0.9112*** | 0.8393*** | 0.6245*** | 0.3566 | -0.0909 | -0.4531* |
| | (0.0014) | (0.0331) | (0.0887) | (0.1454) | (0.1965) | (0.1496) | (0.1757) | (0.1982) | (0.2185) | (0.2364) | (0.2536) |
| Households | 0.0019*** | 0.0159*** | 0.0338*** | 0.043*** | 0.0422*** | 0.0782*** | 0.0882*** | 0.1075*** | 0.1218*** | 0.1386*** | 0.1626*** |
| | (0.00004) | (0.0006) | (0.0014) | (0.0019) | (0.0023) | (0.0135) | (0.0158) | (0.0178) | (0.0197) | (0.0213) | (0.0229) |
| Dwellings | 0.0001*** | -0.0082*** | -0.0173*** | -0.0188*** | -0.0159*** | -0.0292** | -0.0463*** | -0.0714*** | -0.091*** | -0.1122*** | -0.1371*** |
| | (0.00003) | (0.0004) | (0.001) | (0.0013) | (0.0016) | (0.0114) | (0.0134) | (0.0151) | (0.0166) | (0.018) | (0.0193) |
| Med. living std. (log) | -0.0725* | 16.0329*** | 59.6925*** | 100.1244*** | 119.8548*** | -78.8409*** | -88.8411*** | -122.5602*** | -138.0256*** | -148.3644*** | -144.3522*** |
| | (0.0425) | (0.7827) | (1.9038) | (2.7152) | (3.372) | (7.2478) | (8.5092) | (9.5991) | (10.5835) | (11.4557) | (12.2867) |
| Sh. vacant dwellings | 0.0136*** | -0.3794*** | -1.4884*** | -2.4581*** | -2.8273*** | -1.0405*** | -0.8068*** | -0.5325** | -0.218 | -0.0394 | 0.1372 |
| | (0.0013) | (0.0244) | (0.0607) | (0.0891) | (0.1122) | (0.1842) | (0.2163) | (0.244) | (0.269) | (0.2912) | (0.3123) |
| Sh. main residences | 0.0026*** | 0.2802*** | 0.7722*** | 1.2083*** | 1.7119*** | -2.224*** | -2.1494*** | -2.0796*** | -1.8048*** | -1.5974*** | -1.426*** |
| | (0.0007) | (0.0119) | (0.0281) | (0.0391) | (0.0479) | (0.2239) | (0.2629) | (0.2966) | (0.3271) | (0.354) | (0.3797) |
| Sh. owner-occupiers | -0.002*** | 0.0228* | 0.1436*** | -0.0641 | -0.3457*** | -0.0306 | 0.0508 | 0.0807 | 0.1106 | 0.1703 | 0.2149 |
| | (0.0007) | (0.0123) | (0.0299) | (0.0428) | (0.0532) | (0.1094) | (0.1284) | (0.1449) | (0.1597) | (0.1729) | (0.1854) |
| Sh. flats | -0.0275*** | 0.7286*** | 1.3592*** | 1.3743*** | 1.1969*** | 0.714*** | 0.6553*** | 0.5032*** | 0.329* | 0.2998 | 0.3886* |
| | (0.0005) | (0.0086) | (0.0206) | (0.029) | (0.0359) | (0.1289) | (0.1514) | (0.1708) | (0.1884) | (0.204) | (0.2188) |
| $\lambda$ | 0.152772 | 0.689531 | 0.733698 | 0.744395 | 0.747073 | 0.935319 | 0.933439 | 0.931914 | 0.93153 | 0.932138 | 0.932898 |
| Observations | 40727 | 40727 | 40727 | 40727 | 40727 | 40727 | 40727 | 40727 | 40727 | 40727 | 40727 |
| Pseudo R-squ. | 0.35496 | 0.779207 | 0.833786 | 0.863236 | 0.875198 | 0.842041 | 0.837298 | 0.827892 | 0.815308 | 0.800136 | 0.782634 |

Standard errors in parentheses.
$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 2: RGE firms : estimations results for years 2014-2018

also suggest that aid schemes have a heterogeneous impact on RGE certifications. From the firms' perspective, there seems to be an arbitrage between getting the certification and resorting to reduced VAT rates. From the state's perspective, ANAH grants, eco-loans and white certificates seem to have a larger effect on certifications than tax credits.

### 4.3. Second stage: energy consumption

Tables 3 and 4 display coefficients from the regressions on residential electricity and gas log-consumption respectively, run on the 2014-2018 period. Coefficients from estimations run on the 2011-2018 period can be found in Appendix E. Again, regressions run on the reduced time period have better overall fit, suggesting the eco-conditionality law did increase retrofit quality and efficiency. Specifications (1) and (2) are included as baselines, since they respectively do not include RGE firms, and do not treat endogeneity. Focusing first on electricity, the pseudo R-squared is higher for per-capita consumption than for total consumption within the IRIS. All policies have a significantly negative impact on per capita consumption, except tax credits. At the national level, the effect of reduced VAT spending is on average larger in magnitude than white certificate spending - similar results hold for total consumption. These policies do seem to be efficient to decrease energy consumption, even if their cost-effectiveness is heterogeneous. The positive coefficient associated with tax credits does however raise concern. This echoes criticism made towards this policy, as rebates are obtained through a declarative form, and very few audits have been undertaken. Another drawback of grants is that as the perceived cost of the renovation diminishes for the household, they may become less attentive to the contractor they hire or to the overall renovation process. This is typically not a problem in the case of loans, which rely on their own funds, and could explain the differences in signs. The design of this tax credit also favored partial renovations, which have raised questions regarding their efficiency. Turning to control variables, the impact of the total number of dwellings and the share of main residences is positive on total consumption but negative on per-capita consumption, which is consistent with the literature on density effects. Everything else equal, individual heating needs are lower in denser areas. This result is also consistent with the positive coefficient associated with the share of flats, as they are mostly found in city centers. The shares of owner-occupiers, electric heating and families are increasing energy consumption, conforming with the literature on energy demand. Income indicators are also in line with previous papers, as energy is a normal good and the demand for it should increase with revenue.

Results are somewhat different for gas consumption (Table 4). The pseudo $R^2$ is much lower than for electricity consumption. One should keep in mind that gas is not accessible everywhere, hence there might be a selection bias. It is mostly available in urban areas (Appendix B), where dwellings are typically older. Contrary to electricity, not all households in an IRIS may choose to use gas, which may also be an issue. As 39% of households have a primary heating system requiring gas, it is however important to consider how policies affect gas consumption.(ADEME 2018). The coefficients associated to tax credits remain significantly positive in all specifications, as well as eco-loans. Coefficients associated with controls also remain in line with previous results on energy demand and density effects. White certificates, reduced VAT and ANAH grants have the most consistent negative effects on consumption throughout all specifications. The ANAH's target is substandard housing, hence it is not surprising that there is a significant impact. Those dwellings are so unfit that any improvement would provoke a drastic change in their energy efficiency. In the case of reduced VAT, it could be explained by the fact that the eligible type of renovations have a more substantial impact on energy

| | Consumption per capita (log) | | | Total consumption (log) | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (1) | (2) | (3) |
| Eco loan | -0.0035*** | -0.0036*** | -0.0035*** | -0.0034*** | -0.0034*** | -0.0033*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| ANAH | -0.0042*** | -0.0041*** | -0.0042*** | -0.0044*** | -0.0042*** | -0.0043*** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| Tax credits | 0.0009*** | 0.0009*** | 0.0009*** | 0.001*** | 0.001*** | 0.001*** |
| | (0.00004) | (0.00004) | (0.00004) | (0.00004) | (0.00004) | (0.00004) |
| Reduced VAT | -0.0026*** | -0.0028*** | -0.0033*** | -0.0032*** | -0.0033*** | -0.0035*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| White certificates | -0.0017*** | -0.0016*** | -0.0012*** | -0.0005*** | -0.0004*** | -0.0003*** |
| | (0.00005) | (0.00005) | (0.00005) | (0.00005) | (0.00005) | (0.0001) |
| Average temperature | 0.0005*** | 0.0005*** | 0.0006*** | 0.0004*** | 0.0004*** | 0.0004*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Dwellings | -0.0001*** | -0.0001*** | -0.0001*** | 0.0006*** | 0.0006*** | 0.0006*** |
| | (0.000001) | (0.000001) | (0.000001) | (0.000002) | (0.000002) | (0.000002) |
| Sh. main residences | -0.0079*** | -0.0079*** | -0.0078*** | 0.0093*** | 0.0092*** | 0.0093*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Sh. owner-occupiers | 0.0024*** | 0.0024*** | 0.0024*** | -0.000009 | -0.00001 | -0.00001 |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Sh. flats | -0.0056*** | -0.0056*** | -0.0053*** | 0.0019*** | 0.0019*** | 0.002*** |
| | (0.00006) | (0.00005) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Sh. elec. heating | 0.0064*** | 0.0065*** | 0.0065*** | 0.005*** | 0.005*** | 0.005*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Sh. coll. heating | -0.0007*** | -0.0006*** | -0.0005*** | -0.0001 | -0.0001 | -0.0001 |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Sh. families | 0.0018*** | 0.0019*** | 0.002*** | 0.0004*** | 0.0004*** | 0.0004*** |
| | (0.00005) | (0.00005) | (0.00005) | (0.0001) | (0.0001) | (0.0001) |
| Med. living std. (log) | 0.2604*** | 0.2659*** | 0.2806*** | 0.2026*** | 0.2041*** | 0.2067*** |
| | (0.0044) | (0.0044) | (0.0044) | (0.006) | (0.006) | (0.0061) |
| Unemployment rate | -0.0011*** | -0.0012*** | -0.0013*** | -0.0002* | -0.0002* | -0.0002** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| RGE firms | | -0.000005*** | -0.00003*** | | -0.000004*** | -0.00002*** |
| | | (0.0000007) | (0.000002) | | (0.0000007) | (0.000003) |
| $\lambda$ | 0.005803 | 0.157132 | 0.125519 | 0.007584 | 0.139615 | 0.13802 |
| 2SLS | | No | Yes | | No | Yes |
| Observations | 36303 | 36303 | 36303 | 36303 | 36303 | 36303 |
| Pseudo R-squ. | 0.780358 | 0.782815 | 0.783327 | 0.694378 | 0.694332 | 0.694803 |

Standard errors in parentheses. "RGE" refers to RGE firms within 20km of the IRIS of residence.
$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3: Residential electricity consumption (2014-2018)

| | Consumption per capita (log) | | | Total consumption (log) | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (1) | (2) | (3) |
| Eco loan | 0.006*** | 0.006*** | 0.0061*** | 0.0076*** | 0.0076*** | 0.0076*** |
| | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) |
| ANAH | -0.0024*** | -0.0024*** | -0.0025*** | -0.0032*** | -0.003*** | -0.0033*** |
| | (0.0007) | (0.0008) | (0.0007) | (0.0008) | (0.0008) | (0.0007) |
| Tax credits | 0.0086*** | 0.0086*** | 0.0086*** | 0.0087*** | 0.0087*** | 0.0086*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Reduced VAT | -0.0081*** | -0.0081*** | -0.0074*** | -0.0083*** | -0.0084*** | -0.0076*** |
| | (0.0004) | (0.0004) | (0.0004) | (0.0003) | (0.0004) | (0.0004) |
| White certificates | -0.0085*** | -0.0085*** | -0.009*** | -0.008*** | -0.0079*** | -0.0084*** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| Average temperature | -0.0052*** | -0.0052*** | -0.0054*** | -0.0045*** | -0.0045*** | -0.0048*** |
| | (0.0005) | (0.0005) | (0.0005) | (0.0005) | (0.0005) | (0.0005) |
| Dwellings | -0.0001*** | -0.0001*** | -0.0001*** | 0.0006*** | 0.0006*** | 0.0006*** |
| | (0.000006) | (0.000006) | (0.000006) | (0.000006) | (0.000006) | (0.000006) |
| Sh. main residences | -0.0042*** | -0.0042*** | -0.0044*** | 0.013*** | 0.0131*** | 0.0129*** |
| | (0.0004) | (0.0004) | (0.0004) | (0.0004) | (0.0004) | (0.0004) |
| Sh. owner-occupiers | -0.0005** | -0.0005** | -0.0005* | -0.001*** | -0.001*** | -0.001*** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0003) | (0.0003) | (0.0003) |
| Sh. flats | 0.0057*** | 0.0057*** | 0.0054*** | 0.0081*** | 0.0082*** | 0.0078*** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| Sh. elec. heating | -0.0128*** | -0.0128*** | -0.0128*** | -0.01*** | -0.01*** | -0.01*** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| Sh. coll. heating | -0.011*** | -0.011*** | -0.0111*** | -0.0096*** | -0.0096*** | -0.0097*** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| Sh. families | -0.0012*** | -0.0012*** | -0.0014*** | -0.0021*** | -0.0021*** | -0.0022*** |
| | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) |
| Med. living std. (log) | 0.5674*** | 0.5681*** | 0.539*** | 0.5355*** | 0.5392*** | 0.5072*** |
| | (0.0183) | (0.0184) | (0.019) | (0.0195) | (0.0196) | (0.0202) |
| Unemployment rate | 0.0008* | 0.0008* | 0.0009** | 0.0006 | 0.0006 | 0.0007 |
| | (0.0004) | (0.0004) | (0.0004) | (0.0004) | (0.0004) | (0.0004) |
| RGE firms | | -0.0000005*** | 0.00003*** | | -0.000002 | 0.00003*** |
| | | (0.000002) | (0.000005) | | 0.000002) | (0.000006) |
| $\lambda$ | 0.045641 | 0.147145 | 0.139403 | 0.045846 | 0.129728 | 0.116159 |
| 2SLS | | No | Yes | | No | Yes |
| Observations | 18577 | 18577 | 18577 | 18577 | 18577 | 18577 |
| Pseudo R-squ. | 0.257211 | 0.257192 | 0.262431 | 0.450066 | 0.450159 | 0.452863 |

Standard errors in parentheses. "RGE" refers to RGE firms within 20km of the IRIS of residence.
$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 4: Residential gas consumption (2014-2018)

consumption than the ones suitable for eco-loans and tax credits. Namely, only boiler replacement, wall insulation and the installation of sustainable energy production technologies qualify for the reduced TVA rate. These measures are known to produce much more noticeable changes to a dwelling's energy efficiency than double glazing or swapping out lights. Table 5 provides an estimation of the energy savings induced by an increase of policy spending of 1000 € per capita - which corresponds to a 1.3 million € increase at the IRIS level given their average population. These figures should be interpreted with caution, as the estimates are based on aggregate and imperfect data. In particular, the coefficients presented in tables 3 and 4 are the results of estimations run on different samples. They do however illustrate the differences between each policy: an increase of white certificates would induce an annual saving of 47 305 € in an IRIS area's total consumption, while the same amount spent on tax credits could increase total household expenditure by 51 889 €. The last column translates the total energy saving achieved in terms of dwelling consumption, given that the 2014-2018 average annual consumption of electricity and gas in a dwelling were 4.5MWh and 10.4MWh respectively. Based on these numbers, increasing spending related to VAT reduction would lead to an overall energy saving equivalent of removing 75 dwelling from an IRIS area, which corresponds on average to 10% of its housing stock. These extrapolations highlight the large differences in policy impact, as well as the importance of not limiting the analysis to one source of energy.

| Policy | Electricity | | | Gas | | | Total | |
|---|---|---|---|---|---|---|---|---|
| | % | MWh | € | % | MWh | € | € | Dwelling |
| Eco loan | -3.3 | -106 | -16467 | 7.6 | 564 | 41445 | 24978 | 28 |
| ANAH | -4.3 | -138 | -21458 | -3.3 | -245 | -17996 | -39454 | -52 |
| Tax credits | 1.0 | 32 | 4990 | 8.6 | 638 | 46899 | 51889 | 65 |
| Reduced VAT | -3.5 | -112 | -17465 | -7.6 | -564 | -41445 | -58911 | -75 |
| White certificates | -0.3 | -10 | -1497 | -8.4 | -623 | -45808 | -47305 | -58 |

Note: These figures are inferred from the coefficient displayed in Tables 3 and 4 and the average IRIS-level consumption of gas and electricity over the 2014-2018 period. Household energy prices are aggregated from the DIDO database, which is updated monthly by the French Ministry of Ecological Transition.

Table 5: Extrapolated annual impact of a 1000 € per capita increase of policy spending

The number of RGE firms within 20km also has a differentiated effect depending on the energy source. It has a significant negative impact on electricity consumption, but a positive one on gas consumption. Contrary to household determinants, this effect can only transit through actual energy retrofits. Though counter-intuitive, this result can be explained by looking into how energy performance was measured in France during that period. Beyond comfort issues, energy retrofits are undertaken to increase a dwelling's energy etiquette, which is measured by the DPE scale, going from A to G depending on the dwelling's energy consumption and the type of energy used for heating. In practice, the type of energy was included in the formula by attaching a 2.58 coefficient to households with electric heating systems, versus 1 for any other type of heating (JORF 2012). It was meant to account for losses due to energy conversion: gas can be used either to heat a dwelling directly, but also to produce electricity. Electricity is thus seen as a less efficient heating source, since there are losses when it is produced. The goal was also to incentivize households to get rid of old and inefficient electric heaters, which were very commonly found in France. Taking a practical example, Table 6 provides the energy etiquette of a dwelling with an annual consumption of 148 kWh/m$^2$ depending on its primary heating system.

| Observed consumption | Energy used for heating | Primary energy consumption | Energy etiquette |
|---|---|---|---|
| 148 | Electricity | 382 | F |
| | Gas | 148 | C |

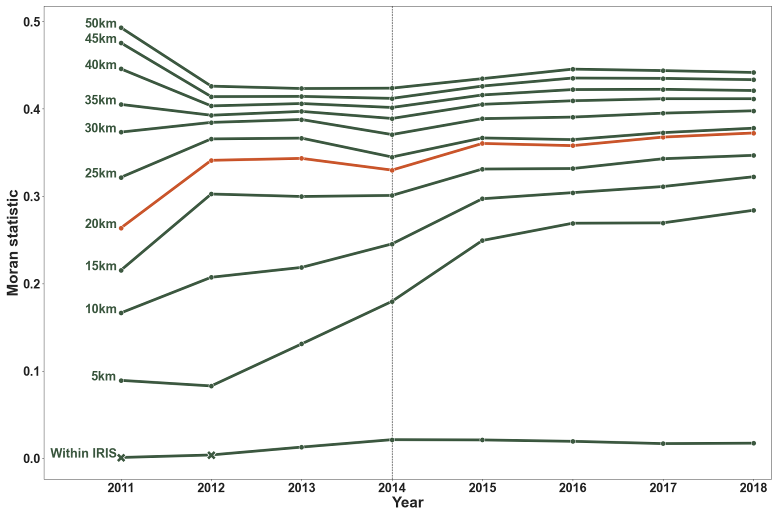
Note: Energy consumption is expressed in kWh/m$^2$. Energy Etiquette refers to the French DPE scale, as it was computed between 2012 and its 2020 revision.

Table 6: Energy consumption to energy etiquette conversion

Introducing this primary energy coefficient created a bias towards gas-powered heating systems for households who had access to the gas network, especially knowing that dwellings with an F etiquette will not be allowed to be rented out as of 2028. Hence the negative impact of eco-loans and access to RGE firms on electricity consumption could translate into an increase of gas consumption. Our results further suggest that access to RGE firms in itself seems to boost energy retrofits, which have a consistent effect on the efficiency of dwellings locally. Controlling for the quality of retrofits should hence be at the heart of aid programs, independently of their design.

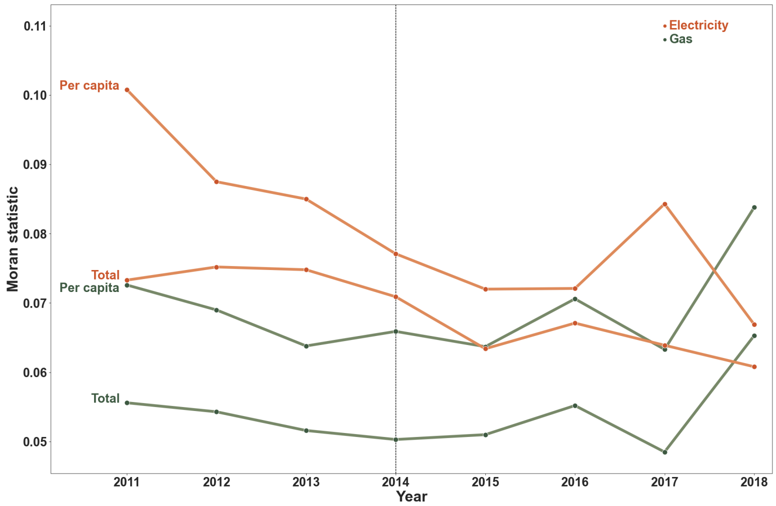
### 4.4. Robustness and alternative specifications

Moran tests were performed to check the validity of the spatial error model against a baseline OLS. Figure 15 displays the Moran statistics obtained from cross-section first-stage regressions. Everything else equal, the value of the Moran statistic increases with buffer size and converges over time. The difference between them decreases over time, all values being close to 0.3 in 2018. It is significant for almost all specifications, except when using RGE firms within the IRIS in 2011 and 2012, which strongly supports the use of a spatial error model. Results are less clear-cut for the second-stage regressions, but the statistic remains significant across all regressions (Figure 16). Statistics are positive in all cases, which indicates a positive spatial autocorrelation. It means that neighbor areas tend to be characterized by similar parameter values, generating local clusters. This is consistent with the positive $\lambda$ values found in the main results.




Source: Author's computations.
Note: Each point corresponds to the Moran statistic obtained from cross-section regressions for each year. Non-significant results are indicated by crosses.

Figure 15: First stage results from cross-section Moran tests




Source: Author's computations.
Note: Each point corresponds to the Moran statistic obtained from cross-section regressions for each year. RGE firms are instrumented.

Figure 16: Second-stage results from cross-section Moran tests

Tables 7 and 8 display second-stage results with alternative specifications. Columns (1) correspond to the specification discussed in the previous section and columns (2) include cross variables between the number of RGE firms in the 20km buffers and non eco-conditional policies. The negative coefficient associated with the presence of RGE firms still holds for electricity consumption per capita. The effect is reinforced by ANAH grants, and mitigated by spendings related to reduced VAT. The positive impact of RGE firms on gas consumption still holds, even if it is reduced by the interaction with ANAH grants. It means that the effect of having access to RGE firms does not only transit through eco-conditional schemes. The implantation of more certified firms locally impacts the overall quality of retrofits. It can be due to more renovations being conducted by RGE firms, or to an increase of competition on quality due to their presence. Columns (3) include a proxy for revenue dispersion, namely the relative interquartile coefficient $\frac{Q_1-Q_3}{Q_2}$. Dividing the interquartile range by the median revenue provides a measure of the relative distance to the median. The coefficient is significant and positive in all cases, meaning larger revenue disparities in an IRIS lead to higher consumption, everything else equal. A possible explanation is that inequalities are tilted towards higher income households, who consume relatively more energy.

| | Consumption per capita (log) | | | Total consumption (log) | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (1) | (2) | (3) |
| Eco loan | -0.0055*** | -0.0058*** | -0.0054*** | -0.0041*** | -0.0042*** | -0.004*** |
| | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) |
| ANAH | -0.0054*** | -0.0048*** | -0.0054*** | -0.0024*** | -0.0024*** | -0.0023*** |
| | (0.0004) | (0.0004) | (0.0004) | (0.0004) | (0.0005) | (0.0004) |
| Tax credits | 0.0007*** | 0.0005*** | 0.0007*** | 0.0012*** | 0.001*** | 0.0012*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Reduced VAT | -0.0023*** | -0.0028*** | -0.0024*** | -0.003*** | -0.0034*** | -0.0032*** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| White certificates | -0.0019*** | -0.0018*** | -0.0018*** | -0.0017*** | -0.0016*** | -0.0014*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Average temperature | 0.0009*** | 0.001*** | 0.0009*** | 0.0008*** | 0.0008*** | 0.0009*** |
| | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) |
| Dwellings | -0.00004*** | -0.00004*** | -0.00004*** | 0.0004*** | 0.0004*** | 0.0004*** |
| | (0.000003) | (0.000003) | (0.000003) | (0.000003) | (0.000003) | (0.000003) |
| Sh. main residences | -0.0113*** | -0.0112*** | -0.0111*** | 0.0021*** | 0.0023*** | 0.0024*** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| Sh. owner-occupiers | 0.0013*** | 0.0013*** | 0.0014*** | 0.0008*** | 0.0007*** | 0.0008*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Sh. flats | -0.0059*** | -0.0059*** | -0.006*** | -0.0038*** | -0.0038*** | -0.004*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Sh. elec. heating | 0.0053*** | 0.0053*** | 0.0053*** | 0.0043*** | 0.0043*** | 0.0043*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Sh. coll. heating | -0.0005*** | -0.0005*** | -0.0005*** | -0.0015*** | -0.0015*** | -0.0014*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Sh. families | 0.002*** | 0.002*** | 0.0021*** | 0.0005*** | 0.0005*** | 0.0006*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Med. living std. (log) | 0.2631*** | 0.2681*** | 0.2528*** | 0.3928*** | 0.4014*** | 0.3816*** |
| | (0.0078) | (0.0078) | (0.0079) | (0.0093) | (0.0093) | (0.0092) |
| Unemployment rate | -0.0006*** | -0.0006*** | -0.0007*** | -0.002*** | -0.002*** | -0.002*** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| RGE firms | -0.00001*** | -0.00002*** | -0.00001*** | -0.00002*** | -0.00003*** | -0.00002*** |
| | (0.000002) | (0.000003) | (0.000002) | (0.000002) | (0.000003) | (0.000002) |
| RGExANAH | | -0.000004*** | | | –0.000003*** | |
| | | (0.0000005) | | | (0.0000005) | |
| RGExVAT | | 0.0000006*** | | | 0.0000005*** | |
| | | (0.0000001) | | | (0.0000001) | |
| (Q3-Q1)/Q2 | | | 0.0779*** | | | 0.1419*** |
| | | | (0.0108) | | | (0.0117) |
| $\lambda$ | 0.152882 | 0.161414 | 0.154398 | 0.137729 | 0.168763 | 0.141468 |
| 2SLS | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 11103 | 11103 | 11103 | 11103 | 11103 | 11103 |
| Pseudo R-squ. | 0.732826 | 0.734719 | 0.733947 | 0.75587 | 0.757165 | 0.758264 |

Standard errors in parentheses. "RGE" refers to RGE firms within 20km of the IRIS of residence.
$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 7: Alternative specifications for electricity consumption (2014-2018)

| | Consumption per capita (log) | | | Total consumption (log) | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (1) | (2) | (3) |
| Eco loan | 0.0062*** | 0.0044*** | 0.0067*** | 0.0071*** | 0.0053*** | 0.0076*** |
| | (0.0009) | (0.0009) | (0.0009) | (0.0009) | (0.0009) | (0.0009) |
| ANAH | 0.0007 | 0.0095*** | 0.0013 | 0.002* | 0.0102*** | 0.0028** |
| | (0.0011) | (0.0012) | (0.0011) | (0.0011) | (0.0012) | (0.0011) |
| Tax credits | 0.0077*** | 0.0082*** | 0.0077*** | 0.008*** | 0.0084*** | 0.008*** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| Reduced VAT | -0.0074*** | -0.01*** | -0.0084*** | -0.0082*** | -0.0107*** | -0.0093*** |
| | (0.0005) | (0.0005) | (0.0005) | (0.0005) | (0.0005) | (0.0005) |
| White certificates | -0.0079*** | -0.0068*** | -0.0068*** | -0.0074*** | -0.0064*** | -0.0062*** |
| | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) |
| Average temperature | -0.0079*** | -0.007*** | -0.0078*** | -0.0072*** | -0.0064*** | -0.0072*** |
| | (0.0008) | (0.0008) | (0.0008) | (0.0008) | (0.0008) | (0.0008) |
| Dwellings | -0.0001*** | -0.0001*** | -0.0001*** | 0.0004*** | 0.0004*** | 0.0003*** |
| | (0.000008) | (0.000008) | (0.000008) | (0.000009) | (0.000009) | (0.000009) |
| Sh. main residences | -0.0094*** | -0.0096*** | -0.0083*** | 0.0041*** | 0.0039*** | 0.0052*** |
| | (0.0005) | (0.0005) | (0.0005) | (0.0005) | (0.0005) | (0.0005) |
| Sh. owner-occupiers | 0.0006** | 0.0006** | 0.0008*** | 0.00005 | 0.00002 | 0.0002 |
| | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) |
| Sh. flats | 0.0006** | 0.0004* | 0.0001 | 0.0018*** | 0.0016*** | 0.0012*** |
| | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) |
| Sh. elec. heating | -0.0123*** | -0.0125*** | -0.0125*** | -0.0109*** | -0.0111*** | -0.0112*** |
| | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) |
| Sh. coll. heating | -0.0107*** | -0.0108*** | -0.0106*** | -0.0108*** | -0.0108*** | -0.0106*** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| Sh. families | -0.0008* | -0.0009** | -0.0004 | -0.0017*** | -0.0018*** | -0.0014*** |
| | (0.0004) | (0.0004) | (0.0004) | (0.0004) | (0.0004) | (0.0004) |
| Med. living std. (log) | 0.5459*** | 0.5403*** | 0.4962*** | 0.6543*** | 0.6488*** | 0.604*** |
| | (0.0244) | (0.0244) | (0.0244) | (0.0251) | (0.0252) | (0.0251) |
| Unemployment rate | -0.0006 | -0.0005 | -0.0009 | -0.0021*** | -0.002*** | -0.0024*** |
| | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) |
| RGE firms | 0.00002*** | 0.0001*** | 0.000005 | 0.000006 | 0.00005*** | -0.00001** |
| | (0.000006) | (0.000008) | (0.000006) | (0.000006) | (0.000009) | (0.000006) |
| RGExANAH | | -0.00002*** | | | -0.00002*** | |
| | | (0.00001) | | | (0.000001) | |
| RGExVAT | | 0.000002*** | | | 0.000002*** | |
| | | (0.0000002) | | | (0.0000002) | |
| (Q3-Q1)/Q2 | | | 0.4989*** | | | 0.5661*** |
| | | | (0.0323) | | | (0.0328) |
| $\lambda$ | 0.123613 | 0.113782 | 0.122447 | 0.119983 | 0.110497 | 0.118343 |
| 2SLS | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 10900 | 10900 | 10900 | 10900 | 10900 | 10900 |
| Pseudo R-squ. | 0.34022 | 0.345891 | 0.350059 | 0.388365 | 0.394023 | 0.400528 |

Standard errors in parentheses. "RGE" refers to RGE firms within 20km of the IRIS of residence.
$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

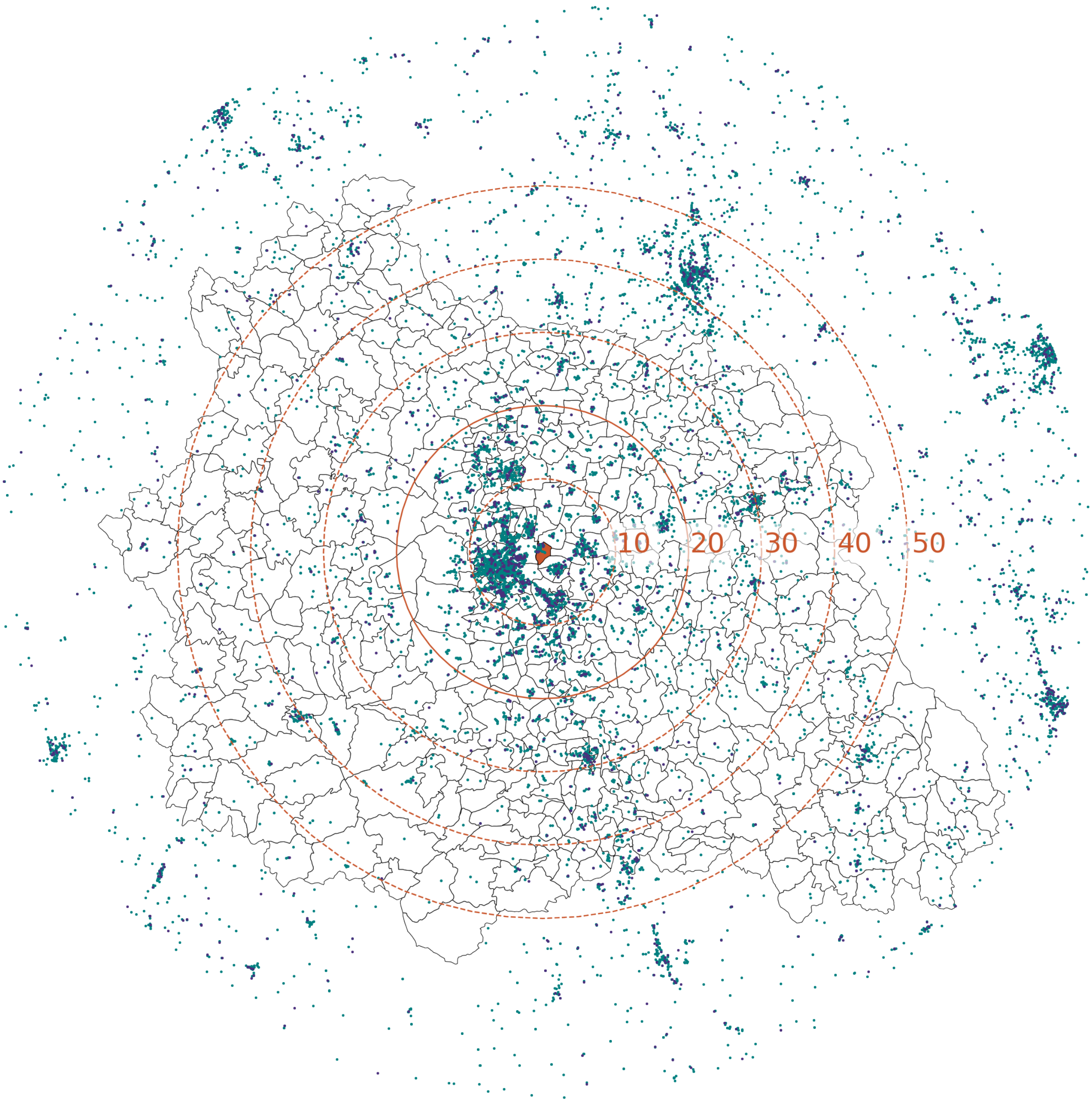
Table 8: Alternative specifications for gas consumption (2014-2018)

## 5. Discussion and conclusion

In France, the residential sector accounts for roughly a third of total energy consumption. The current 50% consumption reduction target set for 2050 implies that 2% of the existing buildings needs to be efficiently retrofitted every year. This paper provides insights on the impact of the 5 national-scale policies implemented to achieve this goal, while controlling for access to skilled companies. First-stage estimation results using the KPP estimator indicate that the number of RGE firms is driven by both the number of competing firms and financial aid to households. This supports the idea that the label is used as a differentiation strategy on the quality of service in a competitive context. This is further reinforced by the fact that there are less RGE firms when spending for reduced VAT rates increase. The heterogeneous distribution of RGE firms is a concerning result in itself, since it has had a direct consequence in terms of access to public aid schemes for households since 2014. The instrumented second-stage results are consistent with previous papers on density effects and on residential energy demand, and reveal differences in the determinants of gas and electricity consumption. With the exception of tax credits, all policies seem to contribute to a decrease of electricity consumption, but with different magnitudes. This is consistent with previous results on the cost-effectiveness of different policy designs. Results on gas consumption however suggest that part of the decrease in electricity consumption induced by eco-loans is compensated by a shift to gas heating. This is likely due to a bias induced in the computation of energy etiquette and further analysis would be needed to see the total impact on households' overall energy consumption. A more alarming result is the significantly positive coefficient associated with tax credits across all specifications, which signals a design issue with this scheme. Our data does not allow to differentiate between a rebound effect and phony installations, but recent audit of the systems have revealed severe flaws in the way retrofits were handled. Our results further support the need to improve the oversight of this policy.

Like any empirical paper, these results have limitations. First, the data does not include information on the number of renovations and the actual work done. It is solely inferred from aggregated policy spending and the localization of labeled firms. Household and dwelling characteristics are also not observed at the individual level. Even if the aggregation scale is the smallest possible, the results are valid only if there is not too much heterogeneity among households in the same IRIS zone, which is supposed to be the case but cannot be checked. Any estimation relying on aggregated data is however subject to the Modifiable Areal Unit Problem (MAUP) raised in Briant, P.-P. Combes, and Lafourcade (2010). Organizing the data in discrete units is sensitive to zoning, meaning changing how the borders of these units are drawn and the scale of aggregation may alter the results. As it is a nonrandom spatial classification, using IRIS-aggregated data might bias the results in unpredictable ways. This holds true for any analysis using aggregated geographical zoning and is not an issue that is specific to this work. This is however less constraining regarding the firm count variables. Figure 17 illustrates how the number of firms around IRIS zones were computed, taking the example of Aulnat, located in a central French department. This methodology has the advantage of going beyond administrative borders, and the actual IRIS contours become less and less relevant as the buffers get larger.

Despite these drawbacks, this paper brings an interesting perspective on policy design for energy retrofits. These policies come with a non-negligible cost, and their effect has to be more clearly measured and monitored. There is room for improvement when it comes to including firms in the implementation of these programs. They are key actors of the retrofitting process, yet the RGE label is the only measure directly




Source: Author's computations from ADEME data.
Note: Only the 571 IRIS zones located in the Puy-de-Dôme department (63) are displayed. Firms are restricted to the 11 540 firms that were active in 2018 and located within 75km of Aulnat - among which 1 889 had the RGE label.

Figure 17: Buffers around the IRIS of Aulnat

involving them. The construction sector has historically not been heavily regulated, with very little barriers to entry. Diplomas are less valued than in other markets, as they can be honorarily obtained with three years of experience in a domain. Since this sector is now at the forefront of the French plan to transition to a low-carbon economy, it is more important than ever to ensure a baseline quality of the final product. Smaller-scale ethnographic papers have already highlighted the need for continuous training of contractors, as it is a very labor-intensive market (eg. Killip 2012). Green labelling is not a new concept, but its application to the construction sector remains limited in the EU. It could be interesting to see it implemented in countries with a similar supply-side structure (ESCSO 2020). There is also room for improvement when it comes to both monitoring retrofits and the list of eligible renovations. There is growing criticism towards small-scale renovation projects, which were particularly favored by the tax credit scheme, regarding their effectiveness to improve energy efficiency. The results presented in this paper also raise questions around the multiplicity of aid schemes, and suggests a more unified approach could be more impactful given the heterogeneity of their impact. Overall, the French policy mix seem to foster energy savings, but these key points should be more carefully looked at, especially considering the cost of these programs and the future ban on renting out dwellings with an etiquette F and G.

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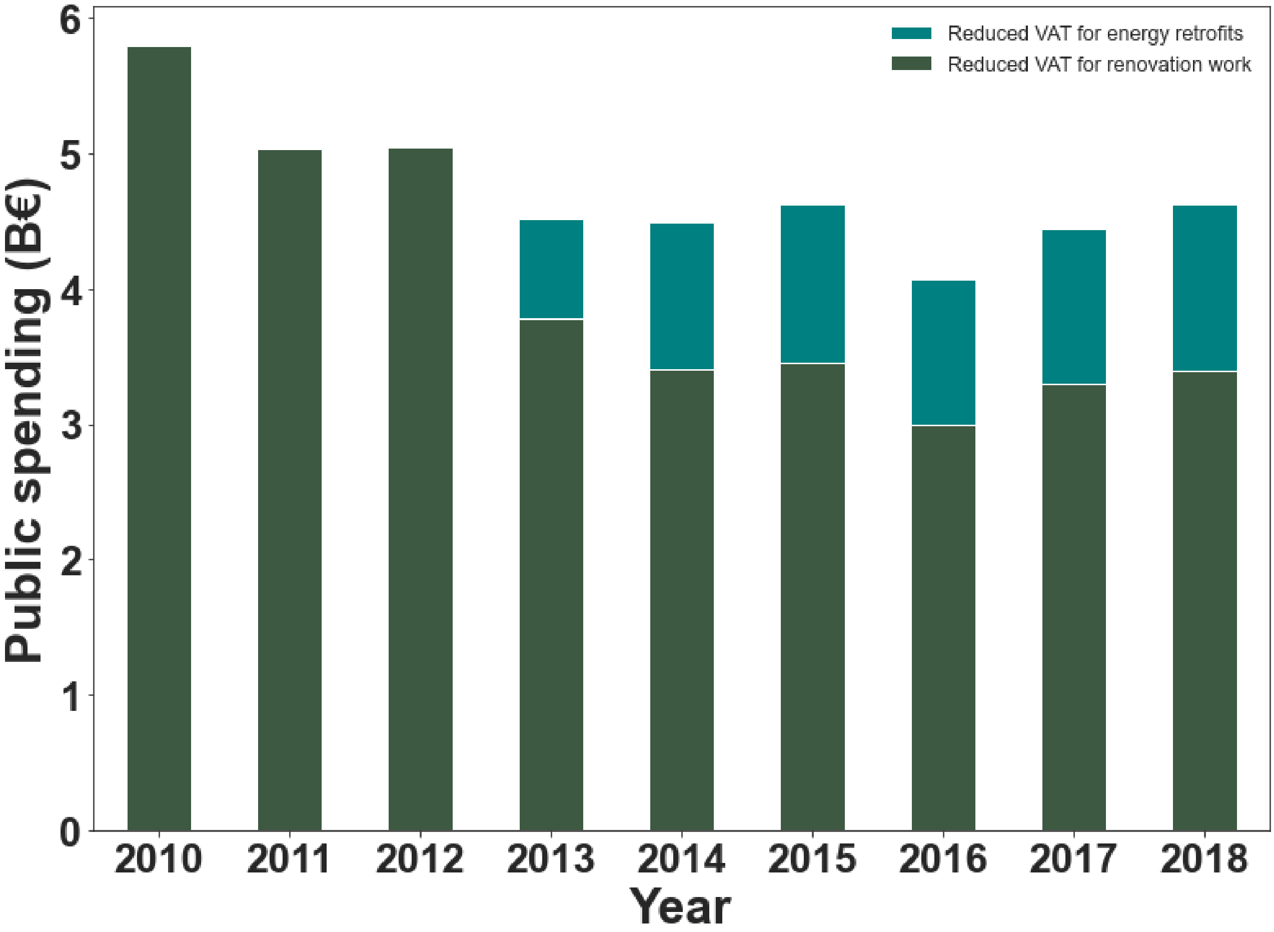
# Appendices

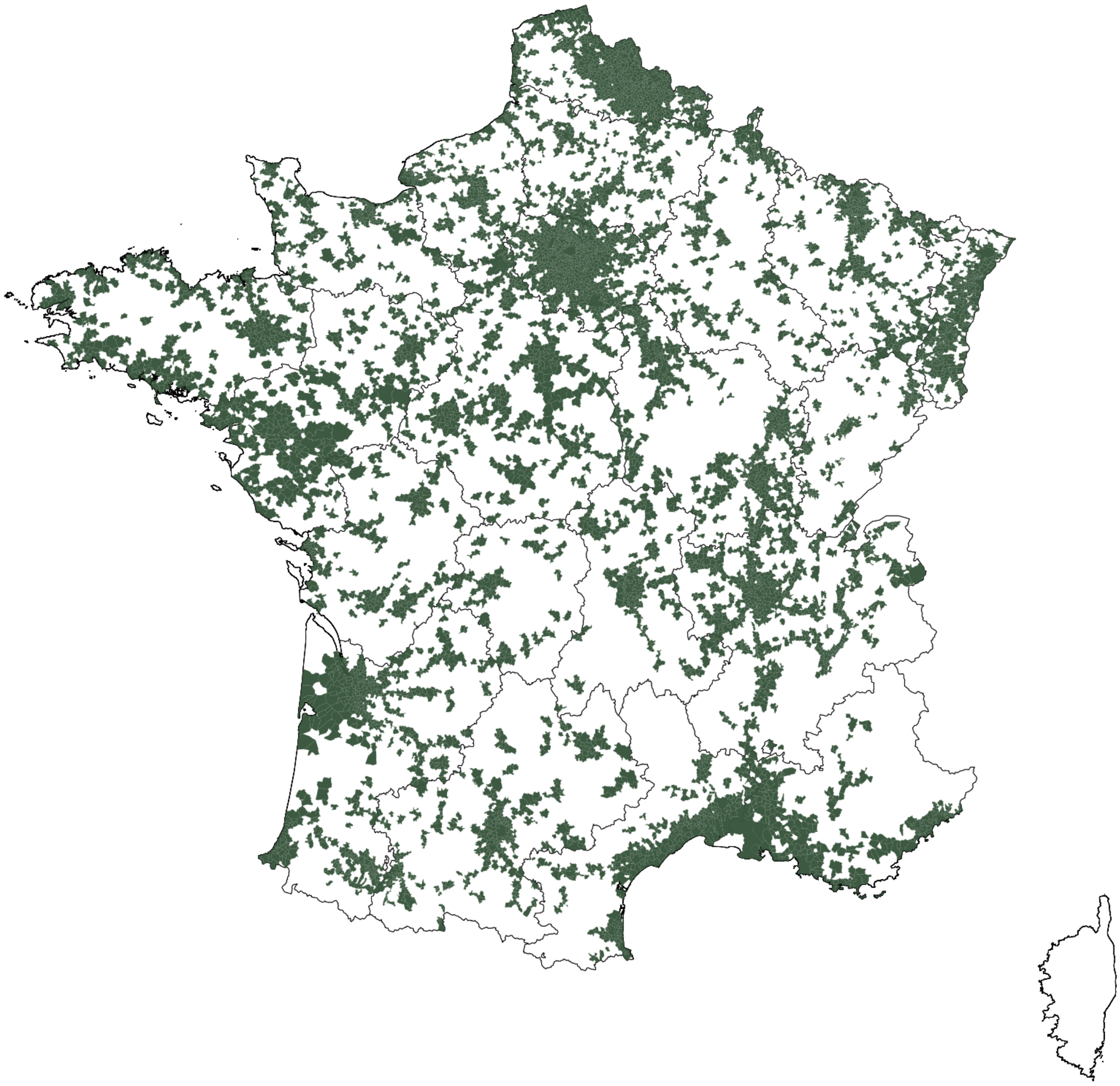
## A. Evolution of VAT reduction measures




Sources: Yearly Finance Acts.
Note: Public spending refers to what households actually received during each given year.

Figure 18: Public spending related to VAT reduction measures since 2010

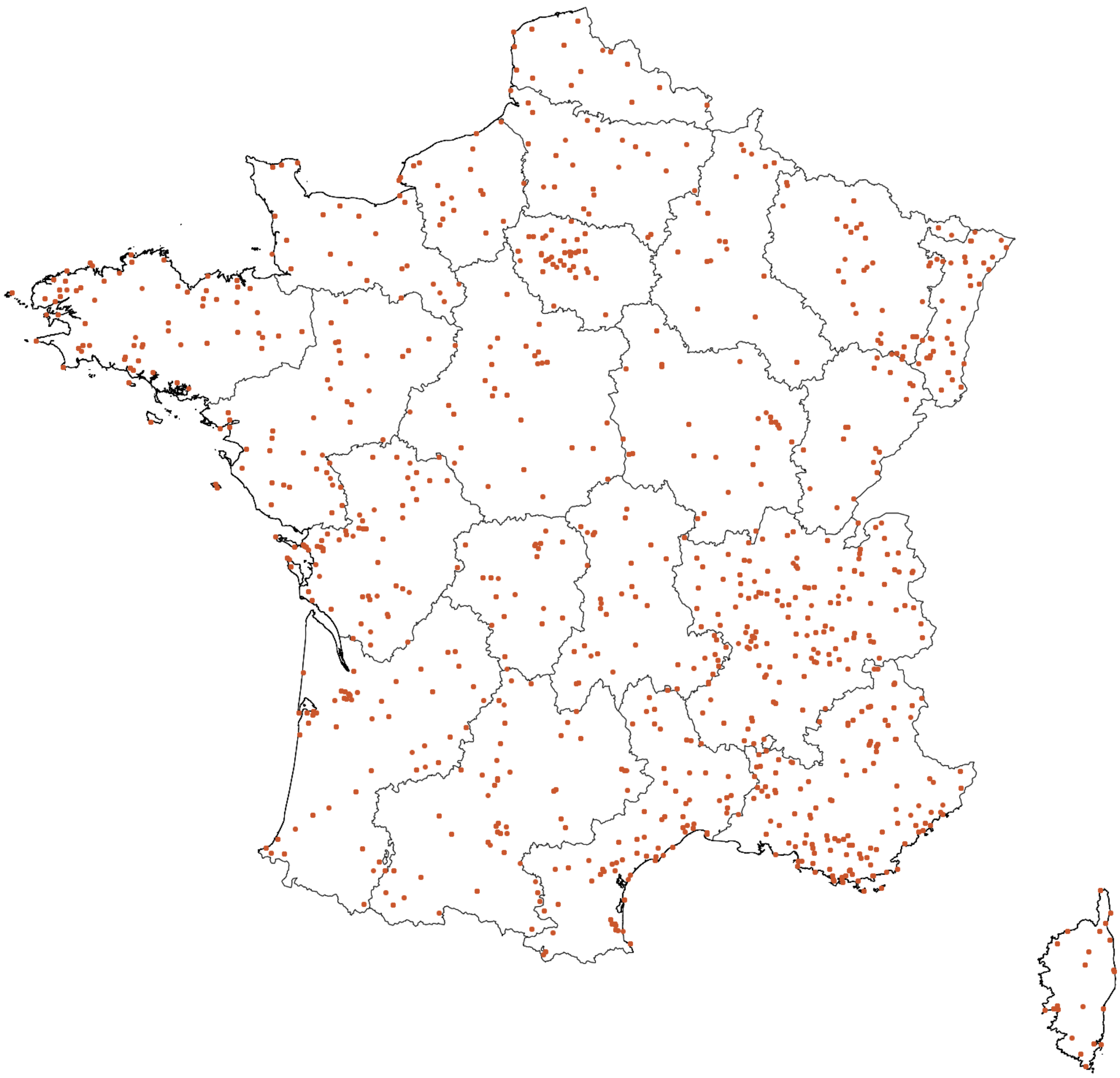
## B. Metropolitan France gas distribution network



Source: Cerema.

Figure 19: Gas distribution network: cities with access to gas in metropolitan France (2018)

## C. Weather stations



Source: Infoclimat.

Figure 20: Weather stations in metropolitan France

## D. First stage results for the 2011-2018 time period

| | Number of RGE firms | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Within IRIS | 5KM buffer | 10KM buffer | 15KM buffer | 20KM buffer | 25KM buffer | 30KM buffer | 35KM buffer | 40KM buffer | 45KM buffer | 50KM buffer |
| Eco loan | -0.0224*** | 1.6188*** | 5.369*** | 8.9621*** | 7.628*** | 9.9486*** | 11.5237*** | 12.4398*** | 13.2158*** | 13.7635*** | 13.6005*** |
| | (0.0011) | (0.0319) | (0.0842) | (0.1285) | (0.227) | (0.2741) | (0.3178) | (0.3594) | (0.401) | (0.4404) | (0.4799) |
| ANAH | 0.0093*** | -2.0375*** | -5.7795*** | -8.7781*** | 2.7166*** | 3.0897*** | 3.7418*** | 3.8083*** | 3.0765*** | 2.1987*** | 1.8214*** |
| | (0.001) | (0.036) | (0.0971) | (0.1539) | (0.1708) | (0.2067) | (0.2404) | (0.2727) | (0.305) | (0.3356) | (0.3664) |
| Tax credits | 0.038*** | 0.3921*** | 0.9343*** | 2.5919*** | -6.2598*** | -8.1381*** | -8.9269*** | -8.6576*** | -7.5276*** | -5.6297*** | -2.58*** |
| | (0.0004) | (0.02) | (0.0585) | (0.0969) | (0.1271) | (0.1532) | (0.1771) | (0.1998) | (0.2226) | (0.2444) | (0.2662) |
| White Certificates | 0.0436*** | 2.5915*** | 8.0843*** | 14.3051*** | 13.9455*** | 18.7148*** | 23.3878*** | 27.977*** | 32.7994*** | 37.7744*** | 42.3793*** |
| | (0.0006) | (0.0361) | (0.1156) | (0.2067) | (0.4596) | (0.5488) | (0.6234) | (0.691) | (0.7624) | (0.8365) | (0.9116) |
| Reduced VAT | -0.0187*** | -1.2963*** | -3.9678*** | -6.7481*** | -4.8663*** | -6.7571*** | -8.5131*** | -10.4259*** | -12.5549*** | -14.8002*** | -16.8599*** |
| | (0.0003) | (0.0186) | (0.0583) | (0.1031) | (0.2232) | (0.2666) | (0.3031) | (0.3362) | (0.371) | (0.4071) | (0.4438) |
| Construction firms | 0.0155*** | 0.0102*** | 0.0136*** | 0.016*** | 0.1033*** | 0.1098*** | 0.115*** | 0.1187*** | 0.1216*** | 0.1239*** | 0.1258*** |
| | (0.0002) | (0.00003) | (0.00003) | (0.00003) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Average temperature | -0.0128*** | 0.3788*** | 0.7301*** | 0.5322*** | 0.3115*** | 0.0252 | -0.4039*** | -0.8234*** | -1.3187*** | -1.8244*** | -2.1101*** |
| | (0.0013) | (0.031) | (0.082) | (0.1319) | (0.1079) | (0.1303) | (0.1512) | (0.171) | (0.1909) | (0.2095) | (0.2282) |
| Households | 0.0016*** | 0.0105*** | 0.0221*** | 0.0279*** | 0.1122*** | 0.1507*** | 0.1835*** | 0.2258*** | 0.2619*** | 0.305*** | 0.3548*** |
| | (0.00003) | (0.0004) | (0.001) | (0.0014) | (0.0082) | (0.0099) | (0.0115) | (0.013) | (0.0145) | (0.0159) | (0.0173) |
| Dwellings | 0.00003* | -0.0053*** | -0.0107*** | -0.0111*** | -0.0192*** | -0.044*** | -0.0748*** | -0.1173*** | -0.1523*** | -0.1888*** | -0.2305*** |
| | (0.00002) | (0.0003) | (0.0007) | (0.001) | (0.0067) | (0.0081) | (0.0094) | (0.0107) | (0.0119) | (0.0131) | (0.0142) |
| Med. living std. (log) | -0.3772*** | 6.0794*** | 23.3559*** | 41.8776*** | -102.9945*** | -93.6586*** | -89.868*** | -93.832*** | -89.3637*** | -83.1481*** | -73.8116*** |
| | (0.0281) | (0.523) | (1.2987) | (1.8997) | (3.9166) | (4.7308) | (5.4888) | (6.2113) | (6.9314) | (7.6094) | (8.2911) |
| Sh. vacant dwellings | 0.0059*** | -0.357*** | -1.181*** | -1.7659*** | -2.4108*** | -2.2094*** | -1.7226*** | -1.143*** | -0.4379** | 0.1146 | 0.6003** |
| | (0.001) | (0.0186) | (0.0466) | (0.0694) | (0.1174) | (0.1418) | (0.1645) | (0.1861) | (0.2077) | (0.228) | (0.2483) |
| Sh. main residences | -0.0011** | 0.1583*** | 0.4384*** | 0.6802*** | -3.5829*** | -3.365*** | -2.9266*** | -2.6736*** | -2.2672*** | -2.0231*** | -1.7972*** |
| | (0.0005) | (0.008) | (0.0196) | (0.0282) | (0.1342) | (0.162) | (0.188) | (0.2128) | (0.2374) | (0.2606) | (0.2839) |
| Sh. owner-occupiers | 0.0021*** | 0.0356*** | 0.1727*** | 0.0526* | -0.3761*** | -0.1281 | 0.0807 | 0.1817* | 0.2142* | 0.2452* | 0.2986** |
| | (0.0005) | (0.0087) | (0.0216) | (0.0315) | (0.0683) | (0.0825) | (0.0957) | (0.1083) | (0.1208) | (0.1326) | (0.1445) |
| Sh. flats | -0.0188*** | 0.4444*** | 0.7967*** | 0.7533*** | 1.5714*** | 1.7954*** | 1.6982*** | 1.4509*** | 1.1336*** | 0.9714*** | 0.9164*** |
| | (0.0003) | (0.006) | (0.0146) | (0.0212) | (0.0812) | (0.0981) | (0.1139) | (0.1289) | (0.1439) | (0.158) | (0.1721) |
| $\lambda$ | 0.133211 | 0.675134 | 0.727075 | 0.741058 | 0.9332 | 0.932236 | 0.93039 | 0.92854 | 0.927507 | 0.927444 | 0.927465 |
| Observations | 40727 | 40727 | 40727 | 40727 | 40727 | 40727 | 40727 | 40727 | 40727 | 40727 | 40727 |
| Pseudo R-squ. | 0.342667 | 0.598615 | 0.6466 | 0.675768 | 0.591844 | 0.589618 | 0.581654 | 0.569889 | 0.555558 | 0.539326 | 0.521829 |

Standard errors in parentheses.
$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 9: RGE firms : estimations results for years 2011-2018

## E. SECOND STAGE RESULTS FOR THE 2011-2018 TIME PERIOD

| | Consumption per capita (log) | | | Total consumption (log) | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (1) | (2) | (3) |
| Eco loan | -0.0037*** | -0.0035*** | -0.003*** | -0.0052*** | -0.0046*** | -0.0039*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| ANAH | -0.0073*** | -0.0074*** | -0.0085*** | -0.0066*** | -0.0071*** | -0.0079*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Tax credits | -0.0014*** | -0.0014*** | -0.0012*** | -0.0014*** | -0.0014*** | -0.0012*** |
| | (0.00003) | (0.00003) | (0.00003) | (0.00003) | (0.00003) | (0.00003) |
| Reduced VAT | -0.0004*** | -0.0005*** | -0.0011*** | -0.0008*** | -0.0011*** | -0.0017*** |
| | (0.00003) | (0.00003) | (0.00003) | (0.00003) | (0.00003) | (0.00004) |
| White certificates | -0.0021*** | -0.0019*** | -0.0007*** | -0.0009*** | -0.0004*** | 0.0008*** |
| | (0.00004) | (0.00005) | (0.0001) | (0.00004) | (0.00005) | (0.0001) |
| Average temperature | -0.0021*** | -0.0019*** | -0.0019*** | -0.0024*** | -0.0023*** | -0.0023*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Dwellings | -0.0001*** | -0.0001*** | -0.0001*** | 0.0004*** | 0.0004*** | 0.0004*** |
| | (0.000001) | (0.000001) | (0.000001) | (0.000002) | (0.000002) | (0.000002) |
| Sh. main residences | -0.0078*** | -0.0078*** | -0.0076*** | 0.0072*** | 0.0071*** | 0.0073*** |
| | (0.00005) | (0.00005) | (0.00005) | (0.0001) | (0.0001) | (0.0001) |
| Sh. owner-occupiers | 0.002*** | 0.002*** | 0.002*** | 0.0002*** | 0.0001** | 0.0001** |
| | (0.00005) | (0.00005) | (0.00005) | (0.0001) | (0.0001) | (0.0001) |
| Sh. flats | -0.005*** | -0.005*** | -0.0046*** | 0.0023*** | 0.0024*** | 0.0027*** |
| | (0.00004) | (0.00004) | (0.00004) | (0.0001) | (0.0001) | (0.0001) |
| Sh. elec. heating | 0.0051*** | 0.0052*** | 0.0052*** | 0.0036*** | 0.0035*** | 0.0036*** |
| | (0.00005) | (0.00004) | (0.00004) | (0.00005) | (0.00005) | (0.00005) |
| Sh. coll. heating | -0.0011*** | -0.0011*** | -0.001*** | 0.0001 | 0.0001 | 0.0001** |
| | (0.00005) | (0.00005) | (0.00005) | (0.0001) | (0.0001) | (0.0001) |
| Sh. families | 0.0012*** | 0.0012*** | 0.0013*** | 0.0003*** | 0.0004*** | 0.0003*** |
| | (0.00004) | (0.00004) | (0.00004) | (0.00004) | (0.00004) | (0.00004) |
| Med. living std. (log) | 0.2004*** | 0.2015*** | 0.2154*** | 0.1304*** | 0.1273*** | 0.1364*** |
| | (0.0028) | (0.0028) | (0.0029) | (0.0033) | (0.0033) | (0.0033) |
| Unemployment rate | -0.0012*** | -0.0013*** | -0.0014*** | -0.0003*** | -0.0004*** | -0.0004*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| RGE firms | | -0.00001*** | -0.00009*** | | -0.00002*** | -0.00001*** |
| | | (0.0000006) | (0.000003) | | (0.0000006) | (0.000004) |
| $\lambda$ | 0 0.006322 | 0.250783 | 0.226586 | 0.009173 | 0.208066 | 0.207433 |
| 2SLS | | No | Yes | | No | Yes |
| Observations | 36303 | 36303 | 36303 | 36303 | 36303 | 36303 |
| Pseudo R-squ. | 0.750292 | 0.754551 | 0.75528 | 0.666134 | 0.665958 | 0.671299 |

Standard errors in parentheses. "RGE" refers to RGE firms within 15km of the IRIS of residence.
$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 10: Residential electricity consumption (2011-2018)

| | Consumption per capita (log) | | | Total consumption l(og) | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (1) | (2) | (3) |
| Eco loan | 0.0002 | 0.0008** | 0.001** | -0.0001 | 0.0008* | 0.0009** |
| | (0.0004) | (0.0004) | (0.0004) | (0.0004) | (0.0004) | (0.0004) |
| ANAH | -0.015*** | -0.0154*** | -0.0161*** | -0.0148*** | -0.0153*** | -0.016*** |
| | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) |
| Tax credits | 0.002*** | 0.0021*** | 0.0021*** | 0.002*** | 0.0021*** | 0.0022*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Reduced VAT | -0.0012*** | -0.0014*** | -0.0019*** | -0.0014*** | -0.0017*** | -0.0021*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| White certificates | -0.009*** | -0.0085*** | -0.0077*** | -0.0085*** | -0.008*** | -0.0071*** |
| | (0.0001) | (0.0002) | (0.0002) | (0.0001) | (0.0001) | (0.0002) |
| Average temperature | -0.0099*** | -0.0096*** | -0.0096*** | -0.0096*** | -0.0093*** | -0.0094*** |
| | (0.0004) | (0.0004) | (0.0004) | (0.0004) | (0.0004) | (0.0004) |
| Dwellings | -0.0002*** | -0.0002*** | -0.0002*** | 0.0004*** | 0.0004*** | 0.0004*** |
| | (0.000004) | (0.000004) | (0.000004) | (0.000005) | (0.000005) | (0.000005) |
| Sh. main residences | -0.0074*** | -0.0075*** | -0.0073*** | 0.007*** | 0.0068*** | 0.0071*** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| Sh. owner-occupiers | 0.0001 | 0.0001 | 0.0001 | -0.0004** | -0.0004** | -0.0004** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| Sh. flats | 0.0032*** | 0.0033*** | 0.0035*** | 0.0058*** | 0.0059*** | 0.0062*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0002) |
| Sh. elec. heating | -0.0074*** | -0.0075*** | -0.0074*** | -0.0056*** | -0.0057*** | -0.0056*** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| Sh. coll. heating | -0.0072*** | -0.0071*** | -0.0071*** | -0.006*** | -0.006*** | -0.0059*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Sh. families | -0.0018*** | -0.0017*** | -0.0016*** | -0.0022*** | -0.0021*** | -0.0021*** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| Med. living std. (log) | 0.196*** | 0.1972*** | 0.2081*** | 0.1664*** | 0.1675*** | 0.1787*** |
| | (0.0098) | (0.0098) | (0.0099) | (0.01) | (0.01) | (0.0101) |
| Unemployment rate | 0.0002 | 0.00003 | -0.00005 | 0.0002 | 0.000009 | -0.00004 |
| | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) |
| RGE firms | | -0.00002*** | -0.00007*** | | -0.00002*** | -0.00008*** |
| | | (0.000002) | (0.000008) | | (0.000002) | (0.000008) |
| $\lambda$ | 0.045457 | 0.186302 | 0.183609 | 0.04741 | 0.176865 | 0.170375 |
| 2SLS | | No | Yes | | No | Yes |
| Observations | 18577 | 18577 | 18577 | 18577 | 18577 | 18577 |
| Pseudo R-squ. | 0.142418 | 0.140766 | 0.136884 | 0.405422 | 0.404171 | 0.402785 |

Standard errors in parentheses. RGE" refers to RGE firms within 15km of the IRIS of residence.
$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 11: Residential gas consumption (2011-2018)

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