Home Energy Efficiency Investments in Response to Energy Price Variations: Evidence from France

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Abstract

This paper studies the effect of an increase in energy prices on home energy efficiency investments. Relying on French micro panel data, we find that a 10% increase of the expected heating fuel price increases the odds of investing in home energy efficiency by 5%. If we restrict to investments in heating renovation, the overall investment expenditures would then increase by 27% in France. These results suggest that energy taxation could substantially stimulate residential energy retrofits.

JEL classification: D12; Q41; Q58; R21

Keywords: Energy prices, Energy efficiency, Buildings, Carbon tax

1 Introduction

In 2010, residential buildings accounted for 24 % of final energy use at the global, more than one half used for heating (32% for space heating and 24% for water heating). Given these numbers, many policy makers view residential energy

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conservation as a major tool to limit greenhouse gas emissions. There is also robust evidence that, in existing buildings, 50-90% energy savings have been achieved throughout the world through deep retrofit (Intergovernmental Panel on Climate Change, 2014). This explains why many countries set quantitative energy retrofit target. In France, the governmental objective is the renovation of 500,000 dwellings per year from 2007 onward (out of 29 million principal residences).

Policymakers can and actually use several instruments to boost energy efficiency investments in existing buildings: home renovation subsidies, thermal standards, energy labeling, energy auditing. However, increasing energy prices through energy taxation and carbon pricing remains the most straightforward policy approach to do so. It is expected that, in the long run, households adapt to higher energy prices by purchasing energy-efficient appliances and lighting, insulating their home or improving their heating system. Home insulation and heating system renovation are of particular interest because they deal with the majority of home energy consumption (Intergovernmental Panel on Climate Change, 2014).

In this paper, we seek to estimate the impact of residential energy price increases on household investment decisions in home insulation and heating renovation. It is part of the broader research effort on the energy efficiency gap where a challenge is to evaluate if consumers pay sufficient attention to energy price when they make energy-related decisions (Allcott & Greenstone, 2012). In this literature, the papers that specifically examine investment decisions in home insulation and heating has mostly focused on household reaction to investment subsidies (Daussin-Benichou & Mauroux, 2014; Nauleau, 2014). The main contribution of our paper is the focus on instruments that increase energy prices (in particular, carbon taxes).

We use a panel data from France extracted from a survey describing household energy-related behavior over the period 2000-2013. This data set contains information about energy efficiency investments made by households along with other information about dwelling, households and heating system characteristics. We take advantage of the fact that households use different energy fuels with different energy prices to identify the effect of an expected price increase on their investment decision.

We find that a 10% increase of the expected heating fuel price increases the odds of investing in home energy management by 5%. More specifically, it increases the odds of investing in heating installation improvement by 6.6% and the amount spent on the heating installation by 19 %. By combining the two effects, we thus estimate that a sustained increase of energy prices of 10% would lead to additional expenditures of 1.0 billion euros for France in heating installation for the year 2013, which represents an increase of 27 % compared to the estimated 4.9 billion euros spent this year.

The rest of the paper is organized as follows: section 2 provides a literature review of the long-run response to energy price increase, section 3 introduces the data, section 4 presents the econometric specification, results are shown in section 5 and section 6 concludes.

2 Literature Review

The literature on long-run household response to energy prices mostly focuses on appliances and cars, probably because workable data are more easily available. Jacobsen (2015) finds no evidence that increases in electricity prices make consumers more likely to purchase high efficiency Energy Star appliances. On the other hand, Rapson (2014) has results that indicate that consumers are forward-looking and value the stream of future savings derived from energy efficiency for air conditioners. Cohen et al. (2017) also find that consumers factor fairly well energy prices when they purchase refrigerators and that they show only little myopia. When buying cars, recent econometric analysis tend to show that consumers are quite attentive to energy prices when purchasing their automobiles: Allcott & Wozny (2014) find little consumer myopia and Busse et al.

(2013) have results that are coherent with consumers who are not myopic with respect to energy prices.

When restricting to home insulation and heating system improvement, the literature is scarcer. Sahari (2017) analyzes heating technology choice for Finnish home builders. She shows that home builders substitute away from electric heating as electricity prices rise, resulting in increased installations of wood heating and ground source heat pumps. While she only focuses on new buildings and on the type of heating fuel, our paper focuses on all buildings and also includes investments in heating system improvement and home insulation. Moreover, our panel data structure allows us to have dwelling and household fixed effects which make our results more robust and which is not possible with her data.

When dealing with home insulation investments and heating system improvement, most papers that we find try to assess the impact of subsidies such as tax credits. Daussin-Benichou & Mauroux (2014) and Nauleau (2014)[1] look at the impact of the French tax credit on households investment decisions. They both find a positive effect even though free riding is rather large. To complement households reaction to subsidies that these papers look at, our paper aims at analyzing how consumers would react to an increase in the carbon tax in terms of home insulation investments and heating system improvements. To the best of our knowledge, this question has not been addressed before.

Finally, papers with a more aggregated or indirect approach suggest that households react to energy prices in the long run. Alberini et al. (2011) adopts an aggregated approach and studies the short term and long term residential demand for electricity and gas. They find higher elasticity of demand in the long run than in the short run, which is a hint for energy management investments. However, whether it is home insulation, heating installation system or energy-efficient appliances, we don't know. Myers (2017) finds that relative fuel price shifts cause relative changes in housing transaction prices consistent with home buyers being attentive to energy costs. This is an incentive for households to

[1]We use the same dataset as Nauleau (2014).

adapt their heating technology in the long run. However, she does not directly measure this adaptation. Harjunen & Liski (2014) do a similar job for the Finnish market and they find a difference in price between electricity dwellings and district heating dwellings that reflect the difference in energy prices.

3 Data description

3.1 Dataset

The data used in this paper mainly comes from the annual Energy Management (EM) survey carried out by ADEME[2] and TNS-Sofres[3]. This survey provides detailed information on French households dwellings, energy information, and their decision to insulate their dwelling or improve their heating system. A first questionnaire provides data on socio-economic variables, housing information (including heating energy source), and information about dweller's situation (occupation status, move-in date). Those who have invested in home insulation or heating system improvement during the last year (11–16% each year) answer a second questionnaire to provide additional information including investment type and costs.

The dataset covers the period 2000-2013. It has an unbalanced panel structure. It contains 103,083 observations from 31,979 distinct households. On average, households are present 3.2 years in the panel. Also, on average, 7,363 households are surveyed annually.

We complement the dataset with energy prices for French households from the Pegase database[4]. It provides annual prices paid by households for electricity, natural gas, heating oil, urban heating, propane and firewood which are the six energy fuels mainly used in France. Because the time series for firewood prices is incomplete (it only starts in 2003), we also use data from Agreste

[2] French public agency for environment and energy management (in french: Agence de l'environnement et de maitrise de l'énergie)

[3] Currently named Kantar TNS. French company which carries out surveys.

[4] The Pegase database is maintained by a statistical agency which reports to French ministries in charge of environment, energy, construction, housing and transportation.

(statistical service for the French Ministry of agriculture).

3.2 Descriptive statistics

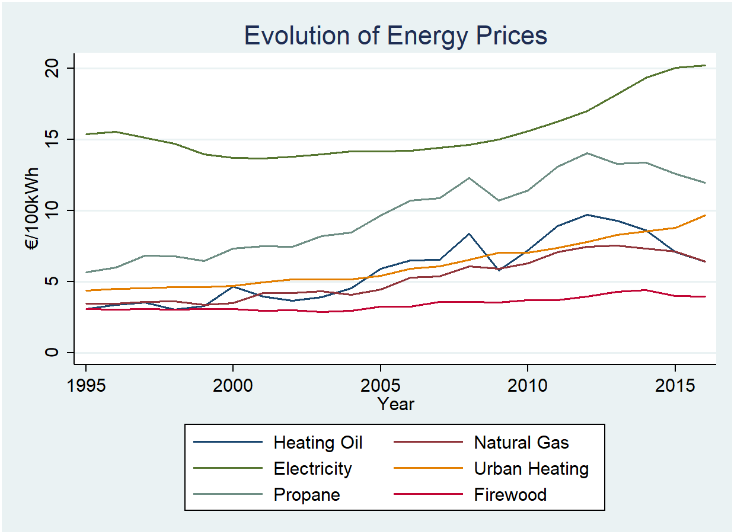
Figure 1 shows the evolution of energy prices over the period 1995-2016.[5] Figure 1b shows a differentiated relative evolution for energy fuel prices over this period. While all energy fuel have an upper trend, heating oil increases far more than electricity. Heating oil price tripled between 1995 and 2013. At the same time, electricity price increased by 26%, firewood price increased by 44%, natural gas and urban heating prices doubled, and propane prices were multiplied by 2.4. We will take advantage of this variation in our identification strategy.

As shown in figure 2, the three most used heating fuels in the panel are natural gas, electricity and heating oil. Firewood, propane and urban heating represent as a main heating energy fuel less than 10% of the households in our panel. Proportions shown in figure 2 are close to those of CEREN[6].

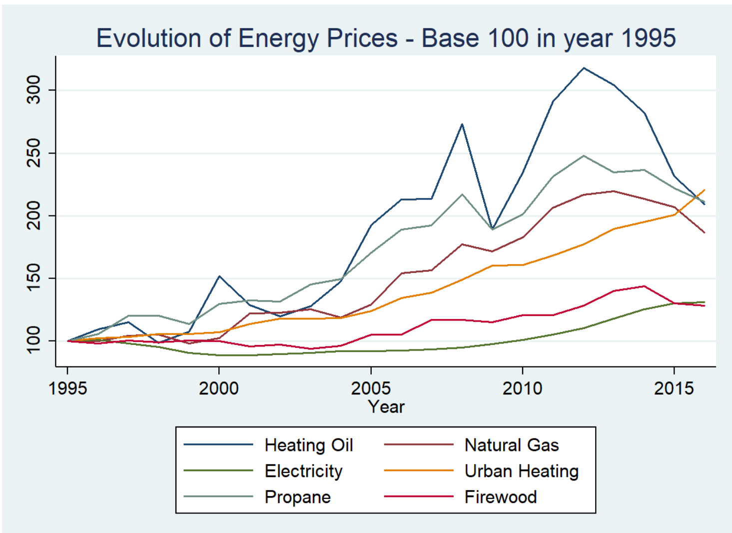
Table 1 shows the mean and standard deviation of the dependent variables used in the paper. Energy Management investment can be of two kinds: home insulation or improvement of the heating installation. A given household can undertake both types of investments in the same year. Home insulation investments are all investments which aim at limiting energy loss in the building without modifying the energy production and regulation system. They include wall, ceiling, floor and pipes insulation, weatherstripping, window and curtains change. On the other hand, heating installation investments include improvement, installation or replacement of the boiler/heat pump/fireplace/ventilation system or one of its components, installation or replacement of a water heater,

[5]Looking at figure 1a, one might wonder why every dwelling does not use firewood as an energy fuel (firewood is the cheapest energy fuel during the entire period). Let us recall that the price per kWh is only one element among others to chose an energy fuel. Among other considerations, we can mention the cost of the heating system, its size, the energy fuel flexibility, its ease of use, its accessibility, its safety, etc. Electricity is the most expensive energy fuel, but also the most flexible and it does not typically require any space for a boiler (it does however require some space for a water heater). Firewood is the cheapest energy fuel, but it requires substantial space (for wood storage and boiler or fireplace) and regular resupply.

[6]Statistics Obervatory for Energy Demand (french: Observatoire statistique de la demande en énergie). French company which produces statistical analysis in the energy sector and which is widely used by French energy actors including ADEME.



(a) Energy prices in euro/100kWh



(b) Energy prices - base 100 in year 1995

Figure 1: Evolution of energy prices over the period 1995-2016

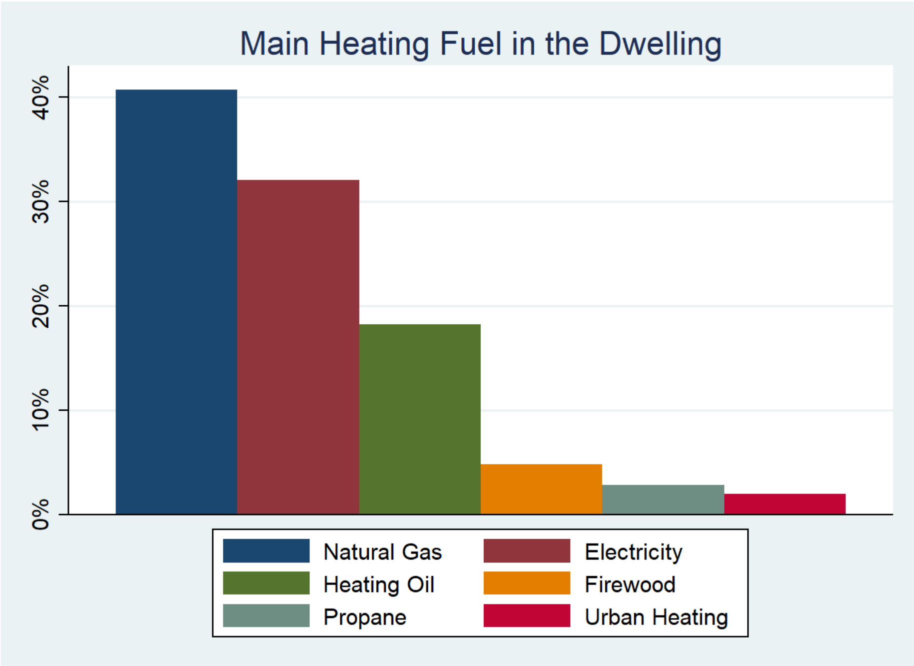


Figure 2: Main energy fuel used in the dwelling. Percentage sum is slightly above 100% as a small share of dwellings uses more than one main energy fuel.

installation of a (programmable) thermostat, a meter, a radiator or a thermostatic radiator valve.

Variable	Type	Mean	Standard deviation
Energy Management Investment	binary	0.13	0.34
Home Insulation Investment	binary	0.08	0.27
Heating Installation Investement	binary	0.04	0.20
Total amount invested	continuous	€3,865	€4,578
Insulation expenditures	continuous	€2,435	€3,758
Heating Installation expenditures	continuous	€1,431	€3,290

Table 1: Descriptive statistics of dependent variables

Table 2 shows basic descriptive statistics of control variables used in the statistical regressions of the paper. Because we had to remove highest incomes of the panel[7], the average income is lower than for the general population. In fact, the average disposable income in France over the period is €36,082 according

[7]Questionnaires use income brackets. Because income brackets change over time, we use the mean of the bracket. We can't do so for the highest incomes so we remove them from the data set.

to INSEE[8] versus an average income of €26,830 in our panel. INSEE gives an average number of rooms of 4.0 over the period 2001-2013 versus 4.2 in our sample. The repartition of socio-economic categories is also not substantially different from what we find in INSEE demographics statistics. Besides, the age distribution of the household head is shifted to the right (older) compared to the general population, which is not surprising (household head is more likely to be an older individual in the household). House-owners are overrepresented in our sample compared to the general population (70.7% in our sample versus 56.1%-58.2% over the period 2002-2012 according to INSEE). Conversely, tenants are underrepresented (tenants in social housing are 11.3% in our sample versus 17.1%-17.7% over the period 2002-2012; tenants in private housing are 15.1% in our sample versus 21.8%-22.0% over the period 2002-2012). One-person households are slightly underrepresented in our sample with 25.9% of the observations versus 30.8-35.0% in the general population over the period 1999-2014. Conversely, two-person households are slightly overrepresented with 38.8% of the observations of our sample versus 30.9-32.9% in the general population over the period 1999-2014. Last, the average surface of a dwelling in France was 90.9 m^2 in 2013 according to INSEE, which falls within the median interval of our sample (75-100m^2).

4 Econometric model

The econometric specification used in this paper is the following:

$$\mathbb{E}\left[y_{izt}|\hat{p}_{zt}, X_{it}, i, z, t\right] = f\left(\alpha \log(\hat{p}_{zt}) + \beta X_{it} + \mu_{iz} + \delta_t\right) \tag{1}$$

where:

- i is a couple (household, dwelling)
- z is the main heating fuel used in the dwelling; z is either heating oil,

[8]National Institute of Statistics and Economic Studies (french: Institut national de la statistique et des études économiques). INSEE is the French national statistics bureau.

Variable	Type	Mean	Standard deviation
Income	continuous	€26,830	€14,243
Length of stay	continuous	15.5	13.8
# past investments	discrete	0.31	0.74
# main rooms	discrete	4.2	1.3
Household head socio-economic category	categorical	Farmer	1.0%
		Shopkeeper, artisan, manager	2.5%
		Executive, liberal profession	10.5%
		Intermediary profession	14.7%
		Employee	11.5%
		Worker	17.2%
		Inactive	42.6%
Household head age	categorical	<25	1.2%
		25-34	14.0%
		35-44	18.8%
		45-54	17.4%
		55-64	17.8%
		≥65	30.8%
Occupation status	categorical	Tenant in social housing	11.3%
		Tenant in private housing	15.1%
		House-owner	70.7%
		Other	2.9%
Household size	categorical	1	25.9%
		2	38.8%
		3	14.3%
		4	14.7%
		≥5	6.2%
Dwelling surface	categorical	<50m^2	6.7%
		50-74m^2	19.4%
		75-100m^2	29.3%
		100-149m^2	33.0%
		≥150m^2	11.6%

Table 2: Descriptive statistics of control variables

natural gas, electricity, urban heating, propane or firewood

- t is the year
- y_{izt} is either a binary variable which indicates if the couple (household, dwelling) i which uses z as a main energy fuel has made an investment at time t, or a continuous variable which represents the amount invested
- f is either the logit function when y_{izt} is binary or the identity function when y_{izt} is continuous.
- $\hat{p}_{zt}$ is the expected price of energy fuel z in the future at time t
- X_{it} is the control variables which may vary over time (table 2 lists all the control variables used in the regressions)
- μ_{iz} is the household-dwelling-energy-fuel fixed effect
- δ_t represents time dummies

Potential unobserved characteristics of households and dwellings that can have an effect on the decision to invest in energy management or the amount invested and that are correlated with the heating fuel price (in particular via the choice of energy fuel) are numerous. Examples are: age of the dwelling, location, building insulation potential, characteristics of the heating system such as age, efficiency or size, environmental consciousness of the household, sensibility to safety, energy performance of the dwelling. This is why we use household-dwelling-energy-fuel fixed effects. Moreover, we use control variables to account for dwelling-household characteristics that might change over time: number of energy management investments made in the past, number of rooms in the dwelling, household head socio-economic categories and age, occupation status, household size and dwelling surface. We also use time dummies to account for all yearly changes that affect uniformly the whole sample such as macroeconomic conditions.

Expected price $\hat{p}_{zt}$ of energy fuel z in the future at time t Energy-management expenditures are long-term investments. Energy-saving benefits do not depend on current energy prices whereas they depend on future energy prices. Thus, households need to forecast energy prices when they weigh investment opportunities. To model household beliefs about future energy prices, we use an adaptive expectation model. In such a model, people form their expectation about what will happen in the future based on what happened in the past. Formerly:

$$\hat{p}_{zt} = \lambda \sum_{j=0}^{\infty} (1-\lambda)^j p_{z,t-j} \tag{2}$$

Typically, we use $\lambda = 0.5$ and equation 2 becomes:

$$\hat{p}_{zt} = \frac{1}{2} p_{zt} + \frac{1}{4} p_{z,t-1} + \frac{1}{8} p_{z,t-2} + \frac{1}{16} p_{z,t-3} + \dots \tag{3}$$

Because households do face energy prices when they pay their energy bill, it seems legitimate to include past energy prices in the households information set. It is possible that households use other sources of information to improve their energy price forecast. However, this information search is costly, unlike using past energy prices, and additional information is also very uncertain. Therefore, we believe such a restriction is a good approximation of how households forecast energy prices.

5 Results

5.1 Extensive margin: number of investments in energy management

We first look at the impact of expected energy price on the extensive margin, that is the number of investments in energy management that are made. Results are presented in table 3.

[9]When performing a conditional fixed-effects logistic regression, individuals (in our case, triples (household, dwelling, heating fuel)) who never invest or individuals who always in-

	(1) Energy Management Investment	(2) Home Insulation Investment	(3) Heating Installation Investment
log(Expected Fuel Price)	0.55**	0.12	0.67*
	(0.24)	(0.29)	(0.37)
Observations[9]	29,890	20,041	14,019

Standard errors in parentheses

* $p < 0.010$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Impact of expected heating fuel price on the decision to invest in energy management. Conditional fixed-effects logistic regression. List of control variables is in table 2. Time dummies are present.

When taking into account all kinds of investments in energy management (first column), we find a positive and significant effect (p-value under 5%) of an increase of expected heating fuel price on the decision to invest. A 10% increase of the expected heating fuel price increases the odds of investing in energy management by 5%. In 2013, ADEME estimated the share of households who invested in energy management in their primary residence at 12 %. It is also the average investment rate for the period 1986-2013. Using these numbers, it means that a sustained increase of energy prices of 10% will lead to an increase of 0.6 points in the number of households who invest in energy management. With the number of primary residences in France in 2013, it represents 156,000 additional dwellings. This number can be compared with the energy retrofit target set by the French government of 500,000 dwellings per year from 2017 onward[10].

We then restrict our analysis to home insulation investments on the one hand (column 2 in table 3), and heating installation investments on the other hand (column 3). [11] We do not find any significant effect of the expected fuel

vest are dropped because of the fixed effect. Consequently, the number of observations is substantially lower than in the full sample.

[10]Home Energy Retrofit Plan (in french: Plan de Rénovation Energétique de l'Habitat) is a plan presented by the French president on march 21st, 2013 which sets targets for home energy retrofit with different time horizons.

[11]Doing so reduce the number of observations used in the sample for two reasons. First, because of the fixed effects, individuals who never invest or who invest every year in home insulation (respectively heating installation) are dropped. There are more individuals who never invest in a specific kind of investment (insulation or heating installation) than individuals who never invest in any kind of investment; individuals who invest every year are marginal in

price on home insulation investments. However, we find a significant effect of the expected fuel price on heating installation investment (p-value under 10 %). According to our regression, a 10% increase of the expected heating fuel price increases the odds of investing in heating installation by 6.6%. In 2013, ADEME estimated the share of households who invested in heating installation in their primary residence at 4 %. It means that a sustained increase of energy prices of 10% will lead to an increase of 0.3 points in the number of households who invest in energy management. With the number of primary residences in France in 2013, it represents around 80,000 additional dwellings.

5.2 Intensive margin: amount invested in energy management

We then look at the impact of expected energy price on the intensive margin, that is the amount invested in energy management for households who carry out investments. Results are presented in table 4.

	(1) log(Total amount invested)	(2) log(Insulation expenditures)	(3) log(Heating installation expenditures)
log(Expected Fuel Price)	0.22	-0.49	1.94**
	(0.33)	(0.42)	(0.91)
Observations	7,751	5,601	2,942

Standard errors in parentheses
* $p < 0.010$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Impact of expected heating fuel price on the amount invested in energy management. Fixed-effect linear regression. List of control variables is in table 2. Time dummies are present.

When taking into account all kinds of investments in energy management (first column), we don't find any significant effect of the expected fuel price on the total amount invested. We also don't find any significant effect when we restrict our analysis to the amount invested in home insulation (second column).

front of the number of people who never invest. Second, there are less missing values for the variable "energy management investment" than for the variable "type of investment".

However, we do find a significant effect of expected fuel price on the amount spent on the heating installation (third column; p-value under 5 %). According to our regression, a 10% increase of the expected heating fuel price increases the amount spent on the heating installation by 19 %. In 2013, ADEME estimated the average amount spent on heating installation improvement at €3,441. Thus, a sustained increase of energy prices of 10% would lead to additional expenditures of €670. [12] Combining the extensive margin increase of the previous subsection with the intensive margin increase of the current subsection, we thus estimate that a sustained increase of energy prices of 10% would lead to additional expenditures of 1,0 billion euros for France in energy installation for the year 2013, which represent an increase of 27 % compared to the estimated 4.9 billion euros spent this year if we extrapolate statistics from ADEME.

6 Conclusion

We studied the impact of an increase in energy prices on investment decisions in home energy management, namely home insulation and heating installation improvement. We find that a 10% increase of the expected heating fuel price increases the odds of investing in home energy management by 5%. More specifically, it increases the odds of investing in heating installation improvement by 6.6% and the amount spent on the heating installation by 19 %. By combining the two effects, we thus estimate that a sustained increase of energy prices of 10% would lead to additional expenditures of 1.0 billion euros for France in heating installation for the year 2013, which represents an increase of 27 % compared to the estimated 4.9 billion euros spent this year.

These results suggest that a carbon tax could have a substantial impact to stimulate investments in home energy management. A natural extension of this paper would be to estimate additional energy savings and avoided CO2 emissions allowed by these investments.

[12] Using a 95% confidence interval, additional expenditures are between €120 and €1,220.

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