The effects of energy retrofits on residential energy expenditures and carbon emissions: Evidence from France (work in progress)

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Prendere due piccioni con una fava*

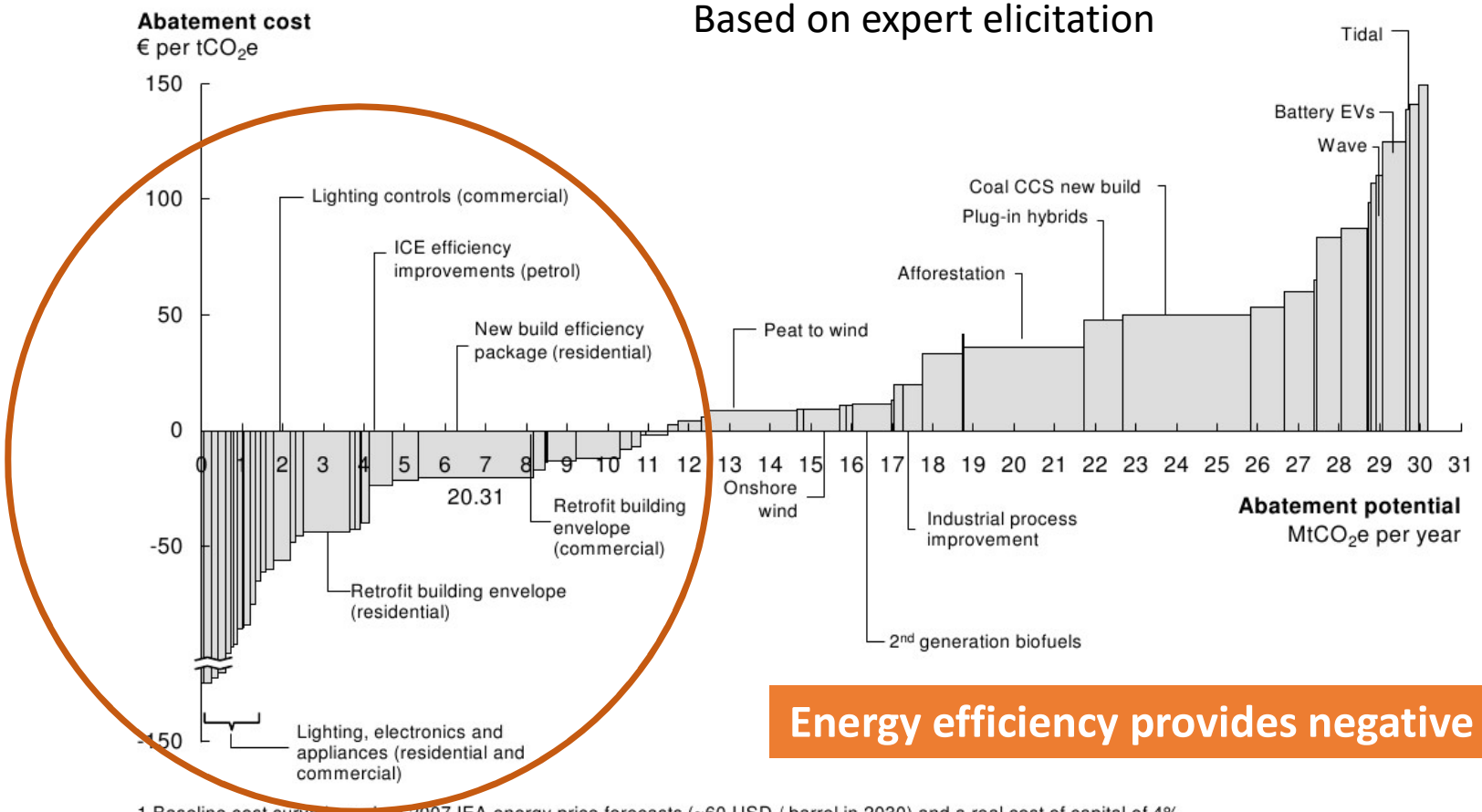
- A widespread view is that home energy retrofits would provide both economic and environmental benefits
  - Privately profitable while reducing carbon emissions and other pollutants
- This would imply that homeowners spontaneously invest in the absence of public intervention
- But they don't. So why?
- Because they are myopic. They underestimate the economic returns of energy retrofits
- The paternalistic regulator then needs to implement policies, in particular tax credits and investment subsidies, to help them correct their mistakes.

A belief increasingly challenged by recent empirical research which find limited impacts on energy use (Fowlie et al. 2018; Alberini et al. 2016; Graff Zivin and Novan 2016; Liang et al. 2017)

** kill two birds with one stone*

McKinsey GHG abatement cost curves (global 2030)

Based on expert elicitation



Energy efficiency provides negative cost options

1 Baseline cost curve based on 2007 IEA energy price forecasts (~60 USD / barrel in 2030) and a real cost of capital of 4%

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This paper

What is the average impact of home energy retrofits on energy expenditures and carbon emissions in the French residential sector? What is the corresponding CO2 abatement cost ?

Three steps

1. We conduct a panel data analysis
   - The panel includes around 8,000 households surveyed from 2000 to 2013
2. We improve the external validity of these results with data on investments made in 2017
   - This leads to increase the estimates by around 50%
3. We perform back of the envelop calculations to estimate the CO2 abatement cost

Data

ADEME survey « Maitrise de l'Energie »

- A representive panel of home occupiers
  - Tenants and owner-occupiers
- Between 7,100 and 8,900 households by year from 2000 to 2013
- Detailed information on
  - annual energy expenditures
  - investments made (amount, types…)
  - dwelling and household characteristics

Enquête TREMI

- A one-shot survey which describes the investments made in 2017

PEGASE

- A comprehensive database of all energy supply contracsts available to private individuals in a given year
  - Used to infer energy use from energy expenditures

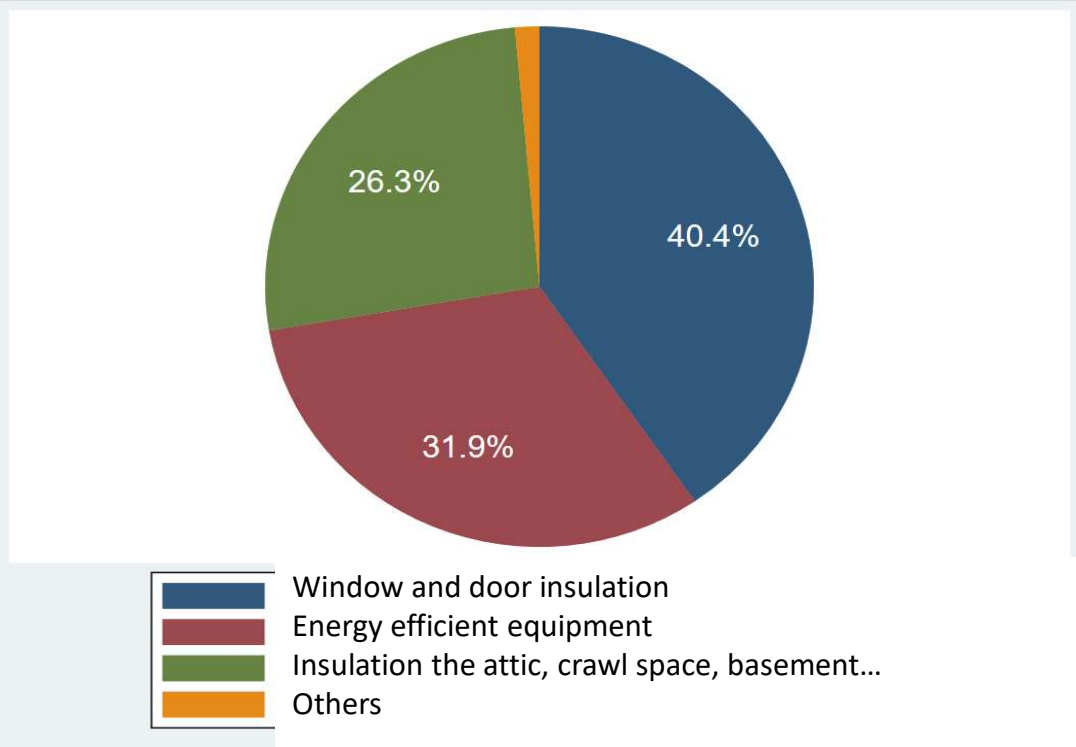
CARBONE

- Carbon footprint of each energy source in France

Descriptives

- 13.1% of the households upgrade their homes each yr and the average amount invested is 4,239 €

Variables	Mean	SD
Investment amount	4,239 €	4,601 €
Annual energy expenditures	1,296 €	640 €
% electricity	55%	30%
% gas	27%	31%
% heating oil	9%	23%



Share of investments made in different categories of home energy improvements

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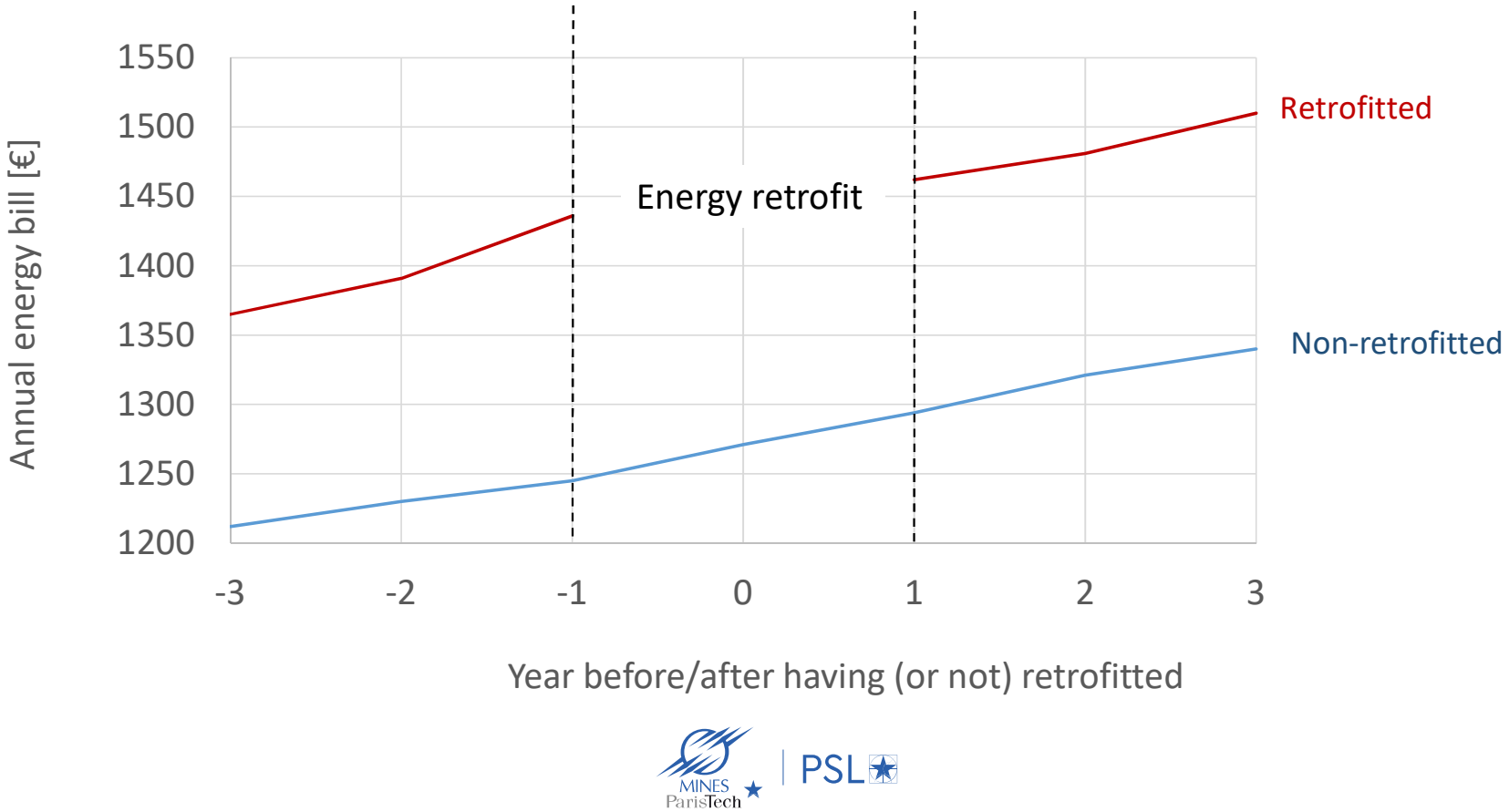
Annual energy expenditures of retrofitted vs non-retrofitted homes



Econometric model

We assume the following relationship between the capital invested in energy retrofit and the energy bill:

$$\ln(E_{it}) = \alpha\, K_{it-1} + \beta X_{it} + \mu_i + \delta_{r(i)t} + \lambda_{e(it)} + \varepsilon_{it}$$

- $\ln(E_{it})$ = log (energy bill) oh household i in year t.
- K_{it-1} = the stock of past investments in energy retrofits in year t-1
- X_{it} = a vector of control variables (household size, income, surface area)
- μ_i = household fixed effects
- $\delta_{r(i)t}$ = region-year fixed effects
- $\lambda_{e(it)}$ = fixed effects describing the heating energy source $e(it)$ used by i in year t
- ε_{it} = error tem

We estimate the same equation for carbon emissions

Endogeneity

- The decision to invest might be correlated with changes in energy consumption behavior, leading to biased estimates
  - Downward: the occupier will retire. Anticipating higher heating needs, she/he invests in order to moderate the potential increase in energy expenditures
  - Upward: the occupier's environmental awareness grows, leading him to reduce his/her energy use in the short term and to invest
- Our (imperfect) instrument
  - The household has declared in the past two years to know about two policies promoting investments in energy efficiency (grants, labeling…)

Results - Energy expenditures

Type of regression	OLS	IV
Capital Invested [k€]	-0.00230**	-0.00746**
	(0.00087)	(0.00331)
Income classes	Yes	Yes
Household size classes	Yes	Yes
Living space area classes	Yes	Yes
RegionYear FE	Yes	Yes
EnergyYear FE	Yes	Yes
Observations	28,703	28,703

The average investment (4,200 €) reduces the annual energy bill by 35 € (– 2.7%)

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Results – Carbon emissions

Type of regression	OLS	IV
Capital Invested [k€]	-0.00384***	-0.0129***
	(0.00119)	(0.00462)
Income groups	Yes	Yes
Household size	Yes	Yes
Living space area	Yes	Yes
RegionYear FE	Yes	Yes
EnergyYear FE	Yes	Yes
Observations	28,703	28,703

The average investment (4,200 €) reduces direct and indirect carbon emissions by 5.4%

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Comparaison with engineering estimates

Investment type	Energy savings for 1,000€ of investment
Individual condensing boiler	60 €
Attic and roof insulation	69 €
Wall insulation	93 €
Collective condensing boiler	69 €
Biomass heater	60 €
Energy-efficent windows	13 €
Our estimate for the average investment	**8.4 €**

Source : Les certificats d'économies d'énergie : efficacité énergétique et analyse économique (2014) Rapport du CGEDD, IGF, CGIET

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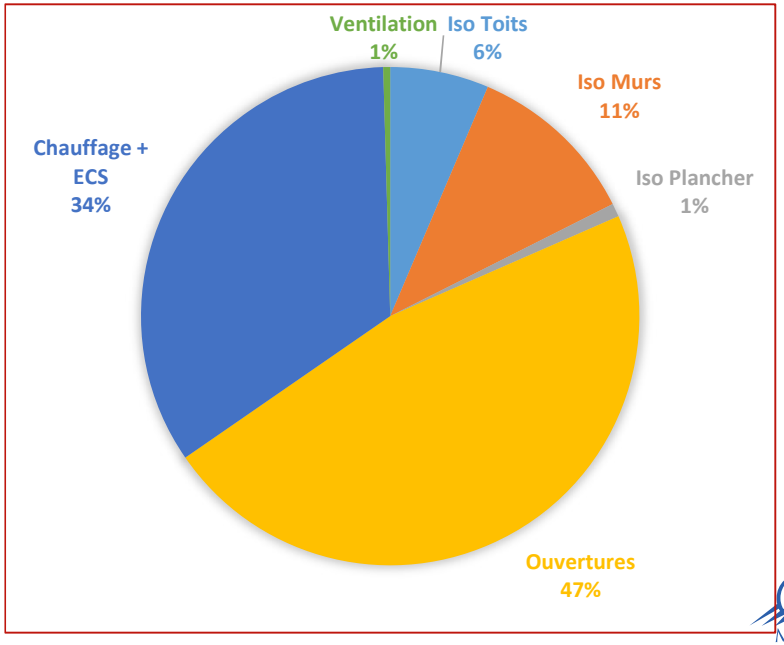
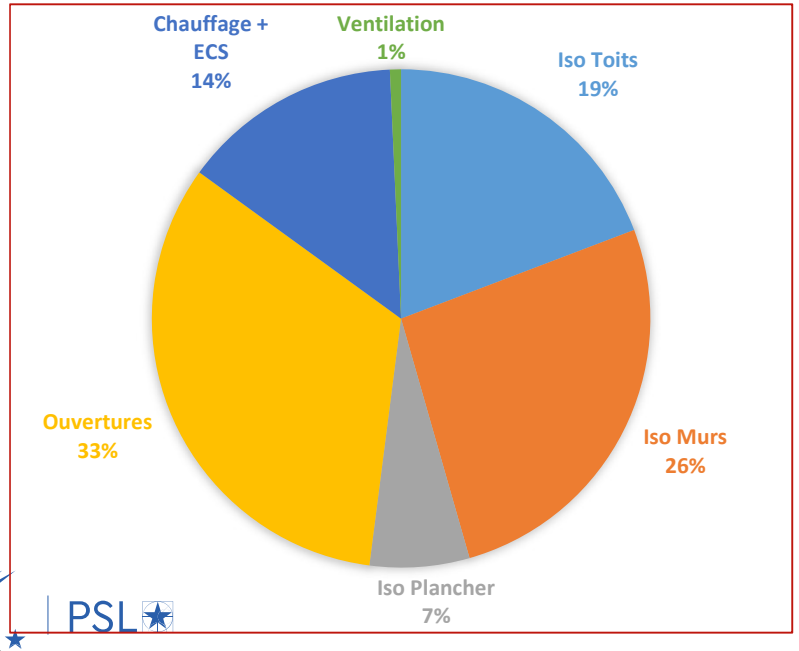
External validity?

- A crucial problem: the study period is 2000-2013 and we are in 2020
- The types of investments made have changed and the average amount invested has increased
  - Much more investments in attic, roof, and wall insulation

2000-2013



2017



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Adjusted results 2017

	Correction factor	**Impact of the average investment (12,000€)**	
Energy bill	1.37	- 12.3 %	- 160 €/yr
Carbon emissions	1.42	-21.7 %	- 760 kgCO2/yr

Comparison with other studies

Study	Year	Country	Scope	Methodology	Main results
This study	2021	France	All operations Residential	Fixed effects panel	15 € for 1000€ invested
Alberini, Grans, Towe	2016	Maryland, USA	Heat pumps	Diff-in-diff	36$ for 1000$ invested*
Fowlie, Greenstone, Wolfram.	2018	Michigan, USA	Modest households Building envelope	RCT	40$ for 1000 $ invested. No rebound effect evidence
Graff Zivin, Novan	2016	San Diego, USA	Modest households Electricity bill	Diff-in-diff	80 $ saved for 1000 $ invested (only for home with cooling)
Liang, Qiu, Ruddell	2017	Phoenix, USA	Residential & tertiary electricity bill	Fixed effects panel	12% savings for tertiary, 8% savings for residential

*Our extrapolation. We took 6000€ a heat pump, and 1775 kWh/month the energy consumption and 0,12$/kWh the electricity price in Maryland

CO2 abatement cost

- We have used these numbers to compute an estimate of the average CO2 abatement cost of 5 scenarios:
  1. Insulating walls
  2. Insulating the basement
  3. Replacing a standard gas boiler with a air-to-water heat pump
  4. Replacing a standard gas boiler by a gas condensing boiler
  5. Replacing a standard gas boiler with a biomass condensing boiler

Our best estimate of the average cost is **335€/tCO_2**

Policy implications

- The impact of the average investment is limited
  - which implies a very high CO2 abatement cost
- This probably explains why homeowners are reluctant to invest, which leads to very high subsidy rates
  - Up to 100% for low-income households
- Our estimate is an average that may hide important disparities => public intervention should be selective.
  - Targeting so-called deep renovation?
- Home energy retrofit is an experience good, which partly explains low quality
  - A market for lemons (Akerlof)
- The regulator shoud pay more attention to the supply-side of the home renovation market
  - Selective labeling of energy efficiency contractors
  - Promoting informational intermediaries (e.g. energy experts)