The Effect of Energy Efficiency Obligations on Residential Energy Use: Empirical Evidence from France

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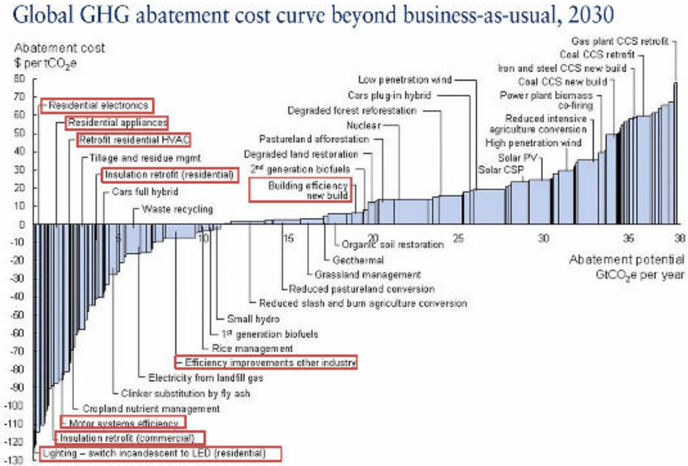
The McKinsey curve



Conventional wisdom : Major negative-cost opportunities to invest in energy efficiency (particularly in buildings)

The Energy Efficiency Gap

Many energy efficiency investments, though seemingly privately profitable, remain unimplemented.

- A popular concept in policy circles and in academia
- With crucial implications for EE policies:
  - Energy taxation is not enough
  - Investments subsidies, information provision, energy performance standards...
- Fatih Birol, head of the International Energy Agency, introducing the last IEA report "Energy Efficiency 2018"

The report looks at why efficiency's massive potential remains untapped, and through the new Efficient World Scenario explores what would happen if countries maximized all available cost-effective efficiency potential between now and 2040, highlighting what policy makers can do to realise this opportunity.

The contribution of buildings energy efficiency

- In France, a recent government report indicates that **72%** of the investment needed to meet the 2030 target should be devoted to energy-efficient building renovation (Pisani Ferry, Mahfouz, 2023).

Heat-pump installation

Insulation

Energy Efficiency Obligation Schemes (EEOs)

- A widespread instrument: 24 States in the US, 16 Member States in the EU + the UK, China, etc.
- The French program *Certificats d'Economies d'Energie*, CEE herafter, is the largest EEOs in Europe $\simeq$ 6 bln EUR/yr.
- The program implemented to comply with the EU Energy Efficiency Directive (2012/27/EU)

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- Obligated parties provide grants to energy users to support investments in energy efficiency.
- For each subsidized investment, they receive a certain number of energy savings certificates corresponding to projected lifelong savings achieved.
  - These projections are based on ex ante engineering estimates.
- Certificates are then submitted to the regulator as proof of compliance at the end of the obligation period
- They are tradable

What we do

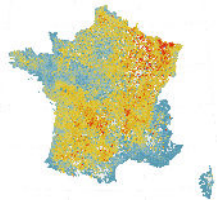
Questions

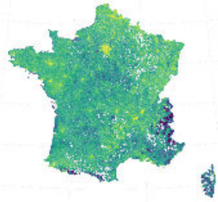
- What is the impact of 1 kWh of *projected* savings on residential gas and electricity use?
  - Does France comply with the Energy Efficiency Directive?
- What is the implied CO_2 average abatement cost?
  - revealed by the CEE market price

Approach

- A two-way fixed effects instrumental variable design
- Data on 4,774 municipalities over the period 2018-2020.
  - 5.18 million inhabitants
  - Prior to the COVID-19 pandemic

Municipal-level data for > 30k municipalities



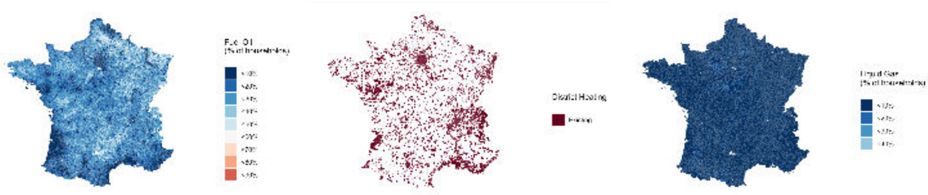


Over the period 2018-2020:

- 3.1 millions retrofit works subsidized through the program
- Number of certificates issued for each qualifying investment
  - Reflecting their projected energy savings
- Yearly residential electricity & gas consumption
  - No information on fuel oil, district heating, biomass
- Determinants of energy use
  - Degree Days, precipitations, income, population

Estimation sample

- 4,774 municipalities with no district heating and where liquid gas and fuel oil is the heating source in less than 10% of the housing units (5.18 million inhabitants)



Descriptive statistics

	Mean	SD
Panel A: Energy use		
Per capita annual electricity use (kWh)	3,429.959	1,213.841
Per capita gas use (kWh)	1,263.306	1,722.556
Panel B: Retrofit works		
Projected lifelong savings (kWh/capita)	2,816.795	2,001.76
Projected annual savings (kWh/capita)	77.643	61.008
Panel C: Demographics		
Median per capita income (EUR/year)	21,363.438	3,625.951
Population size	1,078	1,365
Panel D: Weather		
HDD	2,066	575
CDD	381	188
Precipitation (mm)	928	263

Top 5 operation types

Code	Operation	% projected savings
BAR-EN-101	Roof insulation	53.7
BAR-EN-103	Floor insulation	16.9
BAR-EN-102	Wall insulation	8.4
BAR-EN-106	Heat pump (air-water, water-water)	8.0
BAR-EN-104	High energy efficient individual boiler	7.1

- Insulation accounts for 80.6% of the total, mostly on non-electricity heated units (80.14%).

Empirical strategy

$$Y_{i,t} = \beta X_{i,t} + \delta W_{i,t} + \lambda D_{i,t} + \alpha_i + \gamma_t + u_{i,t}$$

- $Y_{i,t}$ is residential gas and electricity consumption in municipality i in year t
- $X_{i,t}$ is the cumulative amount of *projected* savings achieved through the works completed each year since 2018
- $W_{i,t}$ = the number of cooling degree days (CDD) and heating degree days (HDD), and annual precipitations
- $D_{i,t}$ = population and median income
- α_t and γ_t are municipality and year fixed effects.

Endogeneity of $X_{i,t}$

$$Y_{i,t} = \beta X_{i,t} + \delta W_{i,t} + \lambda D_{i,t} + \alpha_i + \gamma_t + u_{i,t}$$

- Energy efficiency investments are correlated with unobserved municipality shocks $u_{i,t}$ which also affect energy use $Y_{i,t}$.
- Examples
  - Shocks on green preferences
  - Investments made outside the CEE program
  - Retirement which increases heating needs

Instrumenting with lagged temperature shocks

- Our instrument for $X_{i,t}$ is:

$$Z_{i,t} = HDD_{i,t-2} + CDD_{i,t-2}$$

- Relevance: Lagged temperature shocks increase the salience of heating- and cooling-related home characteristics and thus influenced the decision made a couple of years ago to invest in energy efficiency

- Exogeneity: Past temperature shocks do not correlate with **changes** in contemporaneous energy use through other channels than EE investments.

The specific case of non-CEE investments

- Investments made without CEE support are unobserved. The second stage equation thus rewrites:

$$Y_{i,t} = \beta^{2SLS}\,\widehat{X}_{i,t} + \delta_2\,W_{i,t} + \lambda_2\,D_{i,t} + \alpha_i + \gamma_t + \phi R_{i,t} + \varepsilon_{i,t}$$

where $R_{i,t}$ represents the energy savings achieved through unobserved investments, while $\varepsilon_{i,t}$ encompasses other unobserved factors.

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- We overestimate the energy impact

$$\beta^{2SLS} = \beta + \phi \times \frac{Cov(R_{i,t}, Z_{i,t})}{Cov(X_{i,t}, Z_{i,t})} \quad \Rightarrow \quad |\beta^{2SLS}| > |\beta|.$$

$$\{<0\} + \{>0\} \times \{>0\}$$

Results

	OLS-FE	2SLS-FE
Expected Savings	-0.475***	
	(0.072)	
Fitted Expected Savings		-0.377**
		(0.141)
Log. of Pop.	738745.964***	728364.288***
	(173486.421)	(170699.193)
Median income	-3.438	-3.662
	(5.530)	(5.563)
HDD	552.095**	530.966**
	(191.877)	(190.791)
CDD	-384.731	-285.867
	(410.071)	(404.373)
Precipitation	109.505+	106.239+
	(62.960)	(62.405)
Num.Obs.	12207	12207
R2 Within	0.079	0.076
F-test (1st stage)		89.807

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Clustered standard errors at the municipality level

- **1 kWh of projected savings** associated with at best **-0.38 kWh** in residential electricity and gas use

	Electricity	Natural Gas
Fitted Expected Savings	0.049	-0.426***
	(0.078)	(0.111)
Log. of Pop.	475252.743***	253111.544+
	(59769.412)	(149227.181)
Median income	0.908	-4.570
	(2.071)	(5.049)
HDD	180.636*	350.330*
	(71.909)	(175.504)
CDD	282.629**	-568.496
	(107.691)	(387.648)
Rain	-13.716	119.955*
	(25.575)	(56.323)
Num.Obs.	12207	12207
R2 Within	0.006	0.102
F-test (1st stage)	89.807	89.807

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Clustered standard errors at the municipality level

- Energy savings mostly achieved through a decrease in gas consumption

Discussion

- The energy performance gap is at least 62%. Very wide, including in comparison with foreign programs
- Why ? Program design?
  - No energy audits or ex post work quality inspections.
  - The flexibility granted to obligated parties leads to cheap, low-quality renovations
  - Infra-marginal investments
- The government uses projected savings to report compliance with the Energy Efficiency Directive
  - Reported compliance rate: 114% for the period 2014-2021
  - The actual rate would be 43%

Robustness checks

	Fuel Oil	Liq. Gas	SEM 10km	SEM 20km
Expected Savings	-0.395*	-0.366*	-0.377*	-0.377*
	(0.156)	(0.146)	(0.154)	(0.157)
Log. of Pop.	716195.933***	715501.880***	728364.288***	728364.288**
	(186760.249)	(185123.240)	(178504.527)	(225326.485)
Median income	-3.355	-4.947	-3.662	-3.662
	(6.106)	(6.102)	(5.785)	(6.656)
HDD	613.887**	564.809**	530.966*	530.966*
	(207.813)	(194.364)	(207.055)	(244.690)
CDD	-398.847	-284.803	-285.867	-285.867
	(455.936)	(386.304)	(436.056)	(595.683)
Rain	136.141+	112.012+	106.239	106.239
	(71.570)	(64.408)	(70.040)	(86.878)
Num.Obs.	10966	11775	12207	12207
R2 Within	0.074	0.077	0.076	0.076

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Clustered standard errors at the municipality level (1-2) / Spatial Error Model (3-4)

1. Restricting the sample to municipalities with less than 1% of fuel switching out of fuel oil and liquid gas (1) & (2)
2. Introducing spatial correlation of the error term (3) & (4)

The implied CO_2 abatement cost

- **A revealed-preference approach**: The certificate price captures the marginal cost of saving energy through the program

- A comprehensive scope
  - All transaction and administrative costs incurred by the obligated parties
  - Both monetary and non-monetary costs and benefits experienced by the participating households:

	Monetary	Non-monetary
Costs	Investment	Inconvenience caused by the work, information & risk costs
Benefits	Energy bill savings	Comfort, private health benefits

Estimating the marginal CO_2 abatement cost

- An estimate of the CO_2 marginal abatement cost would be:

  CEE price $\times$ projected savings $\times$ β^{2SLS} $\times$ CO_2 emission factor

But the price gives the *marginal* cost, whereas:

- β^{2SLS} is a (local) average treatment effect
- We only have data on the average CO_2 emission factor
- There exists infra-marginal CEE investments

From the certificate price to the average CO_2 abatement cost

Assumptions

- The CEE market is competitive
- The energy savings cost curve is linear
- 30% of the CEE projects infra-marginal (ADEME, 2021)

The average cost of projected savings is then:

$$\frac{\textit{CEE price}}{2(1-0.3)}$$

The average CO_2 abatement cost is **= 114 [86-120] EUR/tCO_2**

An alternative estimate

An estimation limited to the direct monetary costs and benefits for households

- The investment monetary cost
- The energy bill reduction

190 [140-290] EUR/tCO2

- Suggests high non-monetary benefits

Next steps

- An alternative shift-share instrument. Done, does not alter the results
- Integrate in our estimation of the CO2 abatement cost:
  - unrelated positive externalities: improved public health, avoided air pollution (indoor and outdoor)
  - overlapping public subsidies
  - the CEE energy price effect (relying on energy demand elasticities estimated by Douenne, 2019)