



***ENERGY EFFICIENCY GAP, BOUNDED RATIONALITY AND THE ROLE OF
ENERGY RELATED FINANCIAL LITERATURE***

IAEE, August 2019

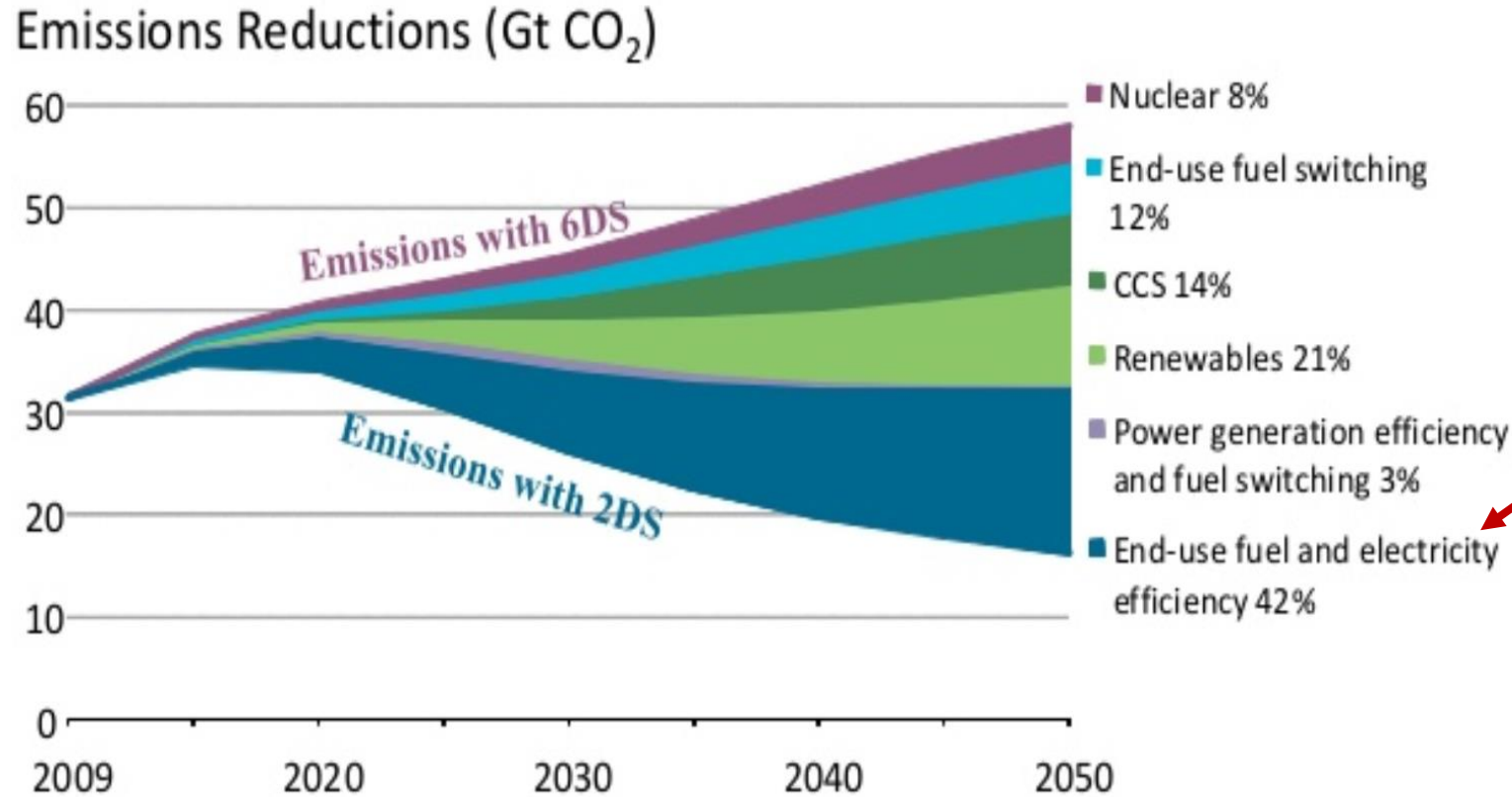
Massimo Filippini

Outline

- ↪ **Energy efficiency gap and bounded rationality**
- ↪ **Level of energy related financial literacy in three European countries**
- ↪ **How can we help consumers in taking energy related investment decisions in order to reduce the energy efficiency gap**

Energy efficiency gap and bounded rationality

Energy efficiency and climate change



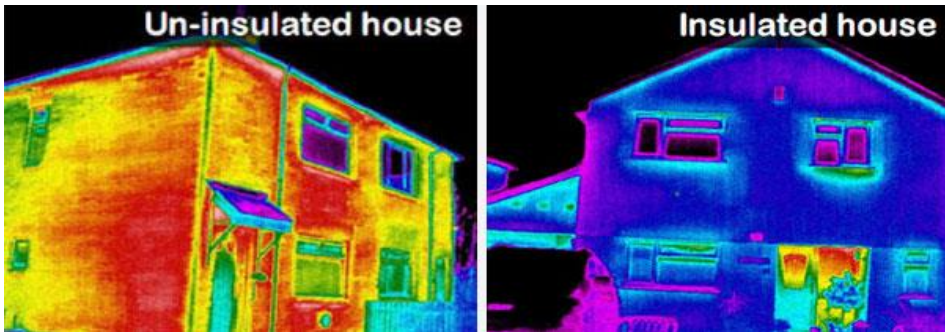
- *To fight climate change we need to cut CO₂ emissions*
- ***Increase of the level of energy efficiency is crucial***
- *Residential sector one of the areas with the greatest potential for energy savings*

Source: International Energy Agency

© IEA/NEA 2012

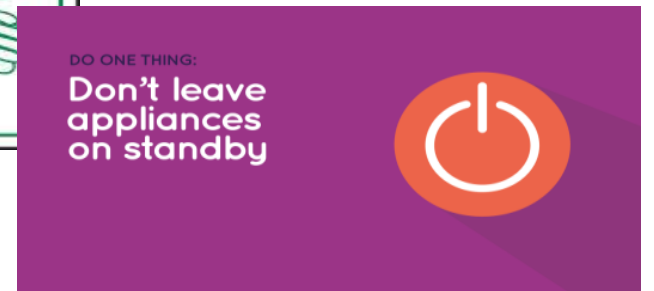
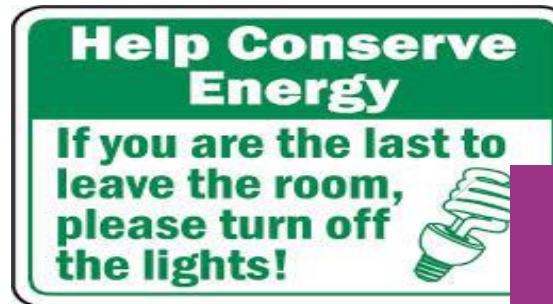
Inefficiency in the use of energy may be due to

low adoption of new energy-efficient technologies (energy efficiency gap)



Energy consumption strongly influenced by investment decisions (type of cars, heating system, electrical appliances, houses,..)

inefficient use of electrical appliances / heating and cooling systems, ... (inefficiency in the consumption)



Energy efficiency gap (private view)

Individual decision-makers do not choose the most energy-efficient technology, even if this technology is also the most cost-efficient choice (minimize the lifetime costs LTC)

$$\underbrace{P^I + \sum_{t=1}^T \frac{(P_t^E \cdot C_t)}{(1+r)^t}}_{\text{LTC}_{\text{energy-efficient}}} < \underbrace{P^I + \sum_{t=1}^T \frac{(P_t^E \cdot C_t)}{(1+r)^t}}_{\text{LTC}_{\text{energy-inefficient}}}$$

- P^I price of the house, appliance,...
- P_t^E energy price in t
- C_t energy consumption in t
- r discount rate
- t time
- T life time

Barriers to investments in energy efficiency

Barriers

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graph TD; Barriers[Barriers] --> MarketFailures[Market failures]; Barriers --> BehavioralAnomalies[Behavioral anomalies];
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Market failures

Negative externalities
Imperfect information
Credit and liquidity constraints
Principal-Agent issues
Learning-by-using
.....

Behavioral anomalies

(systematic deviations from the assumptions of the rationally self-interested model of man)

Bounded rationality

Cognitive Constraints, Status Quo Bias, Sunk Cost, Loss aversion, Endowment effect, limited attention

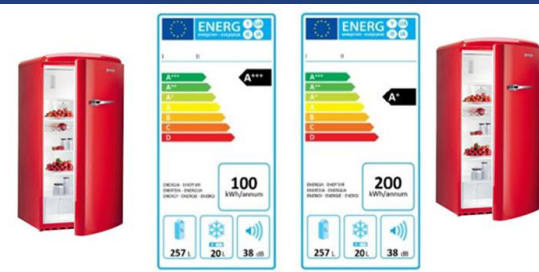
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Bounded willpower/Myopia

Hyperbolic discounting/present bias,...

Energy related investment decision and boundedly rational consumers

- Renovation of a house, change of the heating system, substitution of an electrical appliances, buying a new car,... are decisions that **show benefits and costs over a long period of time**
- ↳ these decisions imply an **intertemporal optimization**
- ↳ individuals need to collect **information**, make **assumption regarding the price, utilization over the life cycle**, perform an **investment analysis or calculate the lifetime cost**
- ↳ Different type of consumers : **rational** and **boundedly rational**



Different decision-making strategies

Rational consumer (standard economic model)

make decisions using information and cognitive skills to calculate the lifetime cost

Rational decision-making

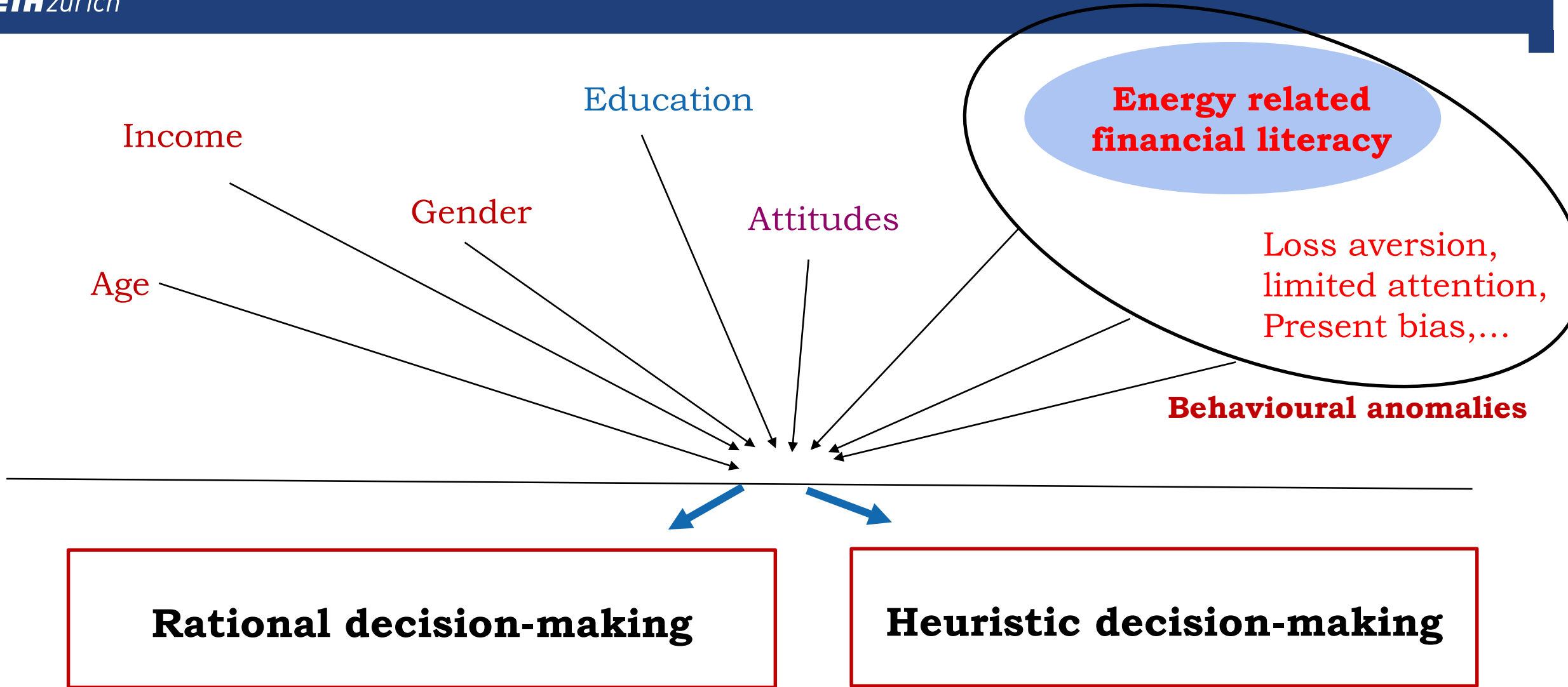
- ↪ Choose the appliance that minimizes lifetime usage cost based on upfront price energy price, intensity of use, lifetime

Boundedly rational consumer (behavioral economics (Simon 1982))

make decisions using limited information and with cognitive constraints in processing; limited computational skills and seriously flawed memories...

Heuristic decision-making

- ↪ Choosing by comparing purchase prices
- ↪ Choosing by comparing the energy label
- ↪ Choosing by comparing energy consumption
- ↪ ...
- ↪ choices that are simply „good enough“





<http://www.penny-project.eu/>

Level of financial and energy related financial literacy in three European countries



CER-ETH – Center of Economic Research at ETH Zurich

Empower the consumer! Energy-related financial literacy and its socioeconomic determinants

J. Blasch, N. Boogen, C. Daminato and M. Filippini

Financial literacy and Energy related financial literacy

- **Financial literacy:**

↳ “Knowledge of basic financial concepts, such as the working of interest compounding, the difference between nominal and real values, and the basics of risk diversification” (Lusardi and Mitchell (2008))

- **Energy related financial literacy**

↳ the combination of **energy-related knowledge** and **cognitive abilities** that are needed in order to take decisions with respect to the **investment for the production of energy services and their consumption**

(Blasch, Boogen, Daminato and Filippini (2018))

Measurement of energy related financial literacy

- **Energy related financial literacy measured with several questions**

↪ Interest rate

↪ Compound interest

↪ Stock option (risk diversification)

↪ **Lifetime cost**

↪ Energy prices

↪ Usage cost of appliances

↪ Knowledge of energy saving of different technologies

Financial literacy 2: Imagine that the interest rate on your savings account was 1% per year and inflation was 2% per year. After 1 year, how much would you be able to buy with the money in this account?

- More than today
- Exactly the same
- Less than today
- Don't know

Lifetime cost calculation: Suppose you own your home, your fridge breaks down and you need to replace it. As a replacement, you can choose between two alternatives that are identical in terms of design, capacity and quality of the cooling system. Fridge A sells for 400 Euro/CHF and consumes electricity for the amount of 300 kWh per year. Fridge B has a retail price of 500 Euro/CHF and consumes electricity for the amount of 280 kWh per year.

Assume the average cost of energy is 0.20 Euro/CHF per kWh, the two models have both a lifespan of 15 years and that you would get a return of 0 percent from any alternative investment of your money.

Which choice of purchase minimizes the total costs of the fridge over its lifespan?

Results for a sample of 4600 European households

Penny project, EU

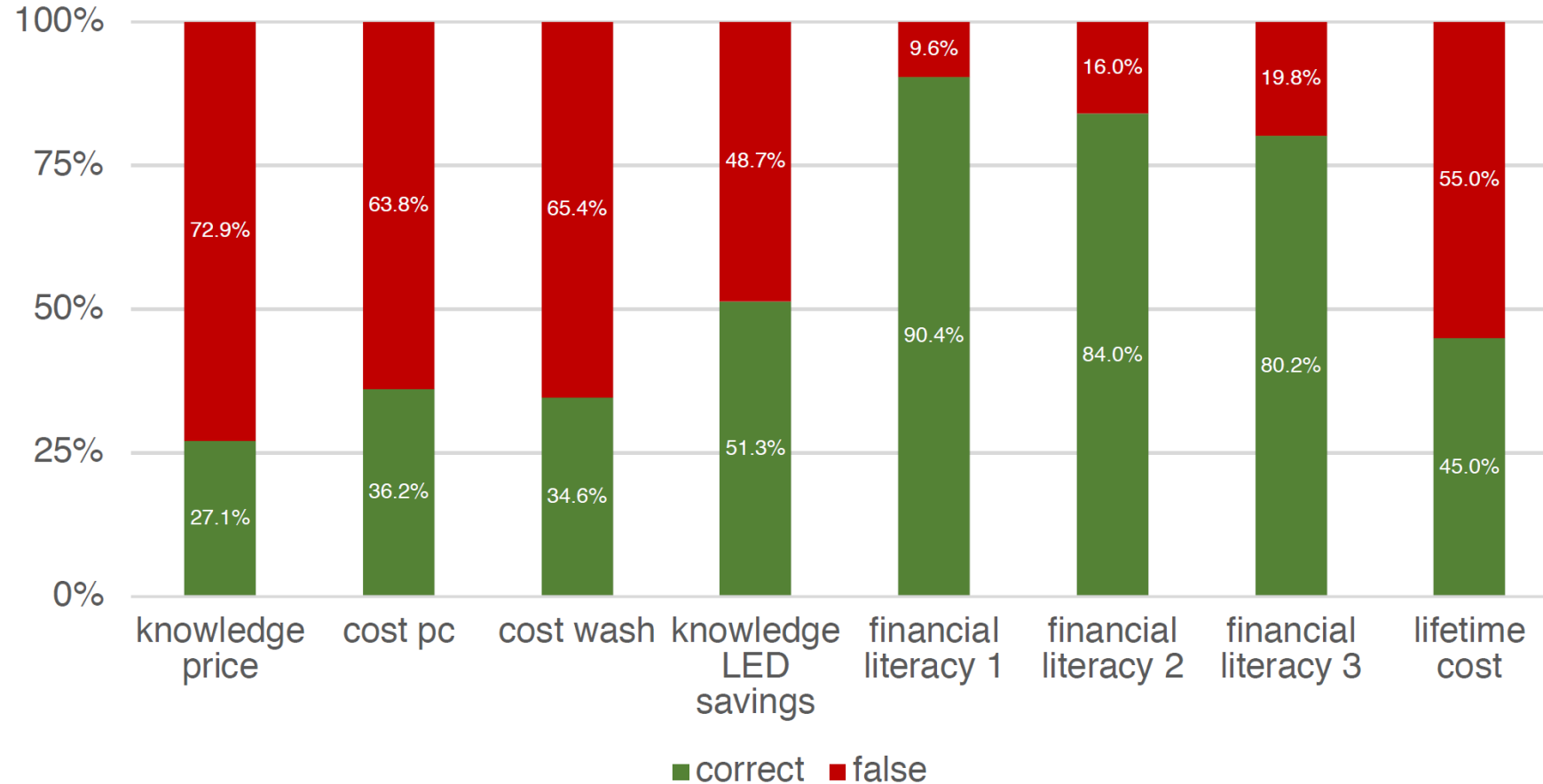
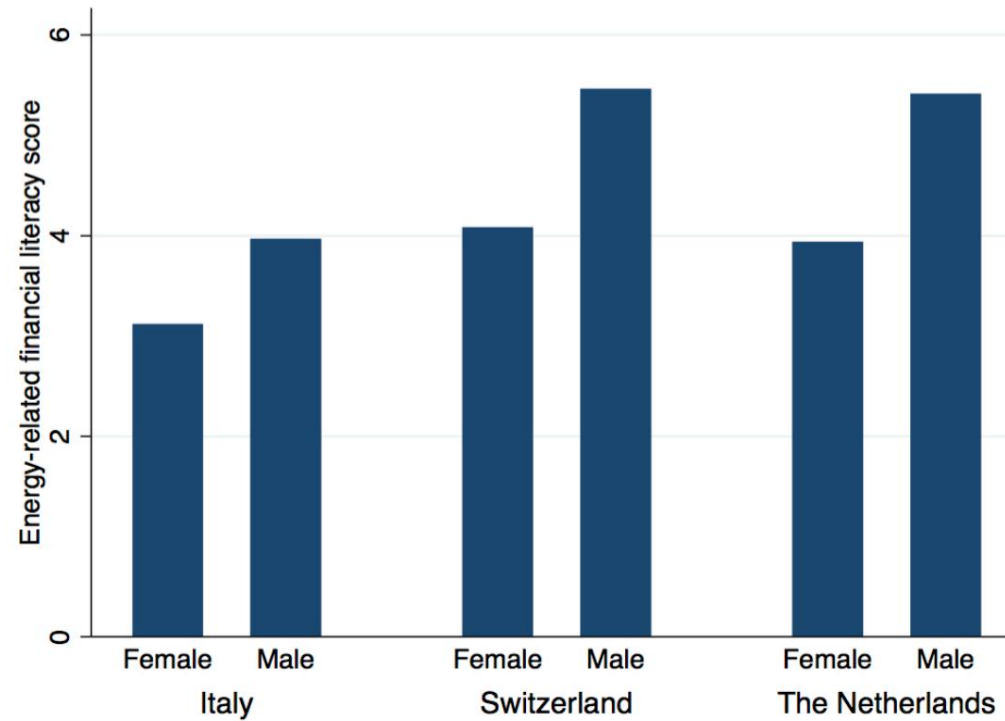


Figure 1: Results of survey questions on energy-related financial literacy.

Source: Blasch et. Al. (2018)

Table 4: Results of survey questions on energy-related financial literacy across countries.

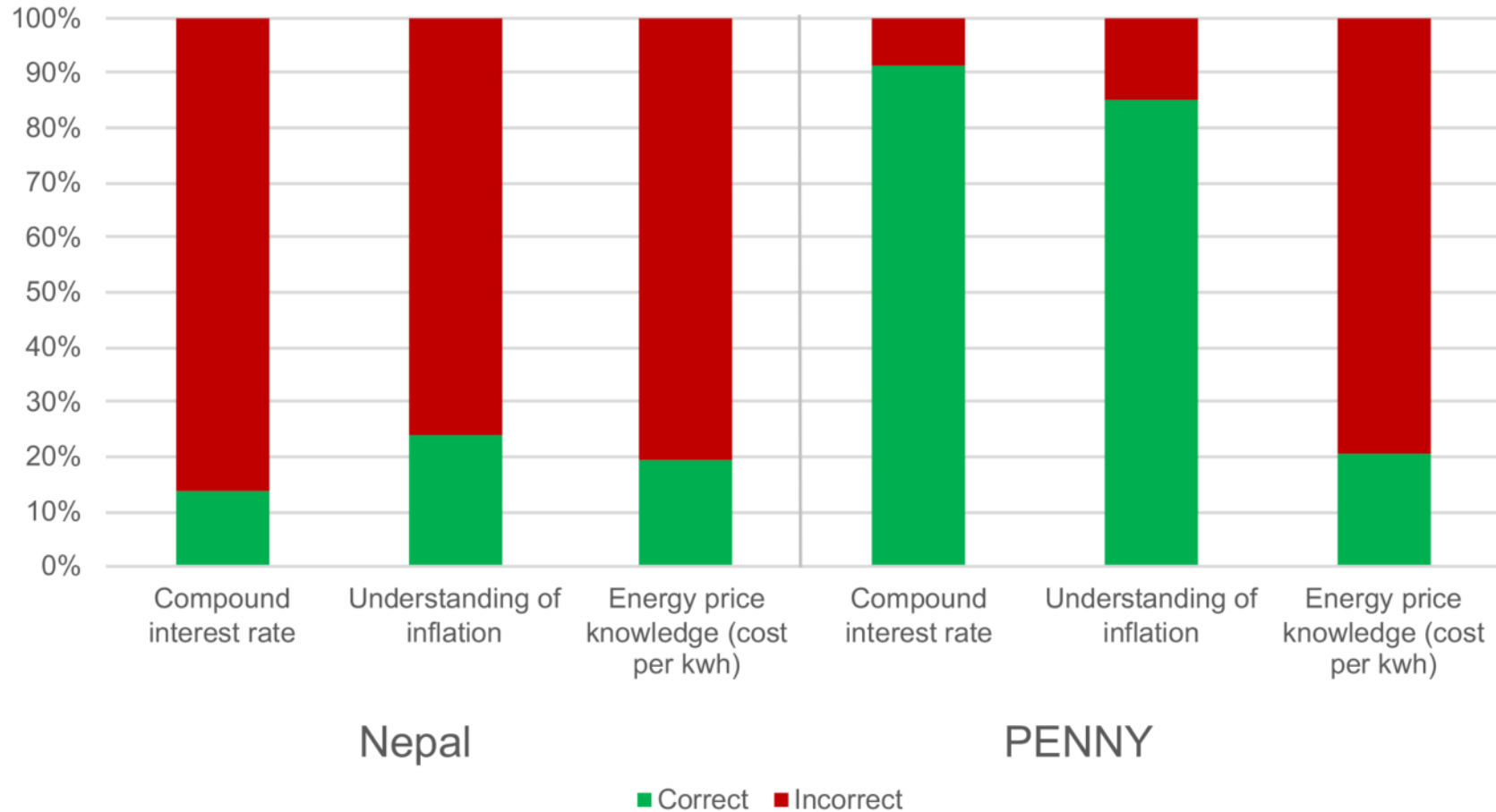
		Italy (%)	Netherlands (%)	Switzerland (%)
Knowledge price	Correct	11.41	36.77	29.15
	False/Don't know	88.59	63.23	70.85
Cost of washing	Correct	29.03	33.91	44.09
	False/Don't know	70.97	66.09	55.91
Cost of PC	Correct	31.1	33.73	48.37
	False/Don't know	68.9	66.27	51.63
Knowledge LED savings	Correct	41.78	54.46	59.13
	False/Don't know	58.22	45.54	40.87
Compound interest rate	Correct	84.62	92.65	94.49
	False/Don't know	15.38	7.35	5.51
Understanding of inflation	Correct	76.99	87.84	86.97
	False/Don't know	23.01	12.16	13.03
Risk diversification	Correct	72.08	83.59	85.42
	False/Don't know	27.92	16.41	14.58
Lifetime cost calculation	Correct	30.17	54.96	47.78
	False/Don't know	69.83	45.04	52.22



c) By gender

Figure 3: Energy-related financial literacy by country and household characteristics

Comparison with data from Europe

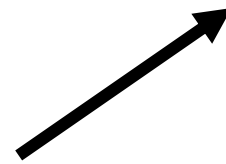


Socio-economic factors that influence the level of **energy related financial literacy (ERFL)**

$$\text{ERFL} = \alpha_0 + \mathbf{X}_i \beta + \varepsilon_{it}$$

Table 3: Regression of energy-related financial literacy, financial literacy and lifetime cost calculation

	Energy-related financial literacy index		Dummy for energy-related financial literacy		Financial literacy	
	(OLS)	(Ordered probit)	(OLS)	(Probit)	(OLS)	(Ordered probit)
Age	0.022* (0.012)	0.014* (0.007)	0.005 (0.003)	0.015 (0.010)	0.017*** (0.006)	0.022** (0.009)
Age ²	-0.000*** (0.000)	-0.000*** (0.000)	-0.000** (0.000)	-0.000** (0.000)	-0.000*** (0.000)	-0.000*** (0.000)
Income: 4'501-6'000	0.170** (0.082)	0.114** (0.056)	0.056** (0.022)	0.204** (0.080)	0.027 (0.032)	0.109 (0.075)
Income: 6'001-9'000	-0.040 (0.081)	-0.030 (0.056)	-0.005 (0.022)	-0.020 (0.079)	-0.014 (0.033)	0.070 (0.077)
Income: Above 9'000	0.057 (0.077)	0.044 (0.052)	0.026 (0.022)	0.126* (0.072)	-0.036 (0.036)	0.040 (0.067)
Income: Don't know	-0.524*** (0.068)	-0.345*** (0.044)	-0.107*** (0.020)	-0.308*** (0.057)	-0.248*** (0.037)	-0.316*** (0.052)
Upper secondary school diploma	0.701*** (0.122)	0.456*** (0.071)	0.183*** (0.033)	0.409*** (0.091)	0.502*** (0.067)	0.651*** (0.079)
Vocational secondary school diploma	0.283** (0.128)	0.174** (0.075)	0.083** (0.034)	0.168* (0.096)	0.304*** (0.069)	0.278*** (0.083)
3-year university degree	0.716*** (0.124)	0.465*** (0.072)	0.170*** (0.033)	0.449*** (0.094)	0.490*** (0.066)	0.621*** (0.083)
5-year university degree and more	1.062*** (0.120)	0.698*** (0.070)	0.237*** (0.032)	0.691*** (0.090)	0.663*** (0.065)	0.991*** (0.081)
Owned dwelling	0.203*** (0.065)	0.137*** (0.043)	0.056*** (0.019)	0.172*** (0.057)	0.112*** (0.032)	0.201*** (0.052)
Female	-1.094*** (0.102)	-0.749*** (0.069)	-0.189*** (0.028)	-0.694*** (0.097)	-0.230*** (0.043)	-0.534*** (0.089)
IT	-1.275*** (0.094)	-0.868*** (0.062)	-0.242*** (0.025)	-0.846*** (0.089)	-0.287*** (0.040)	-0.601*** (0.083)
NL	-0.394*** (0.083)	-0.275*** (0.056)	-0.044** (0.019)	-0.191** (0.087)	-0.027 (0.031)	-0.036 (0.080)
IT*female	0.357*** (0.133)	0.255*** (0.090)	-0.007 (0.039)	0.177 (0.121)	-0.086 (0.068)	0.108 (0.110)
NL*female	0.011 (0.124)	0.021 (0.084)	-0.028 (0.035)	-0.012 (0.118)	-0.021 (0.055)	-0.015 (0.109)
Couple household	0.148** (0.059)	0.097** (0.039)	0.042** (0.017)	0.119** (0.052)	0.055* (0.030)	0.072 (0.048)
(Log) number of rooms	0.262*** (0.076)	0.178*** (0.051)	0.052** (0.022)	0.193*** (0.069)	0.079** (0.036)	0.155** (0.064)
Intercept	3.618*** (0.329)		0.469*** (0.089)	-0.032 (0.278)	1.630*** (0.158)	
Observations	4,249	4,249	4,249	4,249	4,249	4,249
Adjusted R ²	0.25		0.16		0.17	
Log likelihood		-7715.49		-2277.90		-3346.72

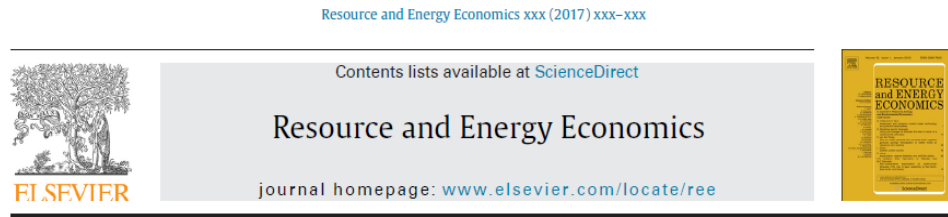


- For instance, the results indicate that
 - ↳ being female decreases the probability to have an outcome of 8 (high level of literacy) by 4.6 percentage points.
 - ↳ being Italian decreases the probability to reach a high level of energy-related financial literacy (outcome 8) by 5.6 percentage points compared to being Swiss.

Notes: Robust standard errors are reported in parentheses in Columns (5) to (8).

*/**/** indicate statistical significance at the 10, 5, and 1 percent level, respectively.

How can we help consumers in taking energy related investment decisions?



Boundedly rational consumers, energy and investment literacy, and the display of information on household appliances[☆]

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Narrowing the energy efficiency gap: The impact of educational programs, online support tools and energy-related investment literacy

J. Blasch, M. Filippini, N. Kumar A. Martinez.Cruz

Working Paper 17/276
September 2017

Insight from prior research (1)

Effectiveness of energy labelling/information

- Heinzle (2012), Newell and Siikamaki (2013); Houde (2014)
 - ↳ Mixed results on the impact of labelling on energy efficiency
- Allcott and Taubinsky (2015); Allcott and Sweeney (2015), Blasch. et. Al. (2017a)
 - ↳ Positive impact disclosing lifetime cost
 - ↳ No effect of more information through sales agents on energy efficiency
 - ↳ Positive impact of providing monetary information on energy efficiency

Insight from prior research (2)

The role of energy and financial literacy **on energy consumption** and on the **choice of energy technologies**

- Brounen et. al. (2013)

↳ *Financial literacy is unrelated to conservation behavior*

- Guetlein et al. (2019)

↳ Labelling schemes are more effective for customers with a higher level of energy literacy

- Brent and Ward (2018).

↳ *show that individuals with a higher financial literacy express a higher willingness to pay for reduced operating cost of energy using durables in a **stated preference setting**.*

- CEPE-ETH (2017a, 2017b, 2018,2019)

Possible instruments to increase the adoption of energy efficient appliances

1

Information on operating cost

2

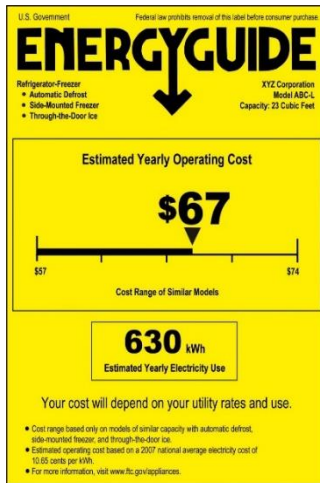
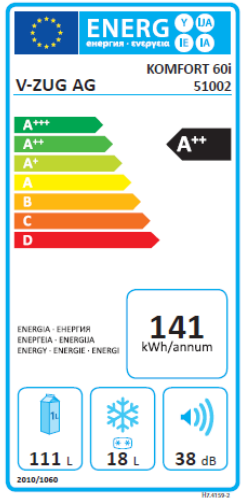
Educational program to increase the level of energy and financial literacy

3

Investment calculator

4

Audit at home and provision of monetary information about the potential of savings from the adoption of efficient appliances



Information for appliance choice

Which TV set is less expensive?

TV set A	TV set B
Price: 800 CHF	750 CHF
Electricity consumption: 50 kWh/year	150 kWh/year

Two steps are necessary to evaluate this:

- Calculating the total cost of every TV set
- Comparing the total costs of both TV sets

(a) Slide-1

Information for appliance choice

How to calculate the total cost of an electric appliance?

The total cost of an electric appliance is composed of the price of the appliance and its lifetime energy cost.

Price + Lifetime energy cost = Total cost

(b) Slide-2

Information for appliance choice

Example calculation for TV set B

Price of the TV set + Lifetime energy cost = Total cost

750 CHF + 150 CHF = 900 CHF

Assuming... a constant price of electricity that 1 CHF in 5 years has the same value as 1 CHF today

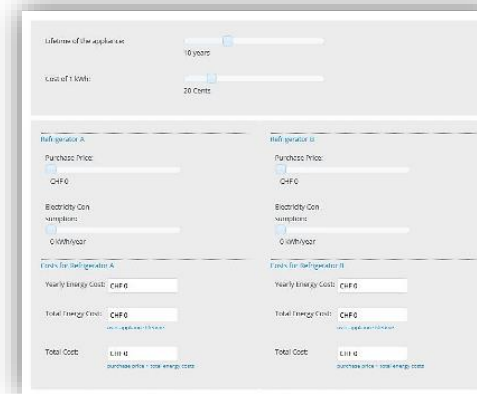
(c) Slide-3

Information for appliance choice

Which TV set is less expensive?

TV set A	TV set B
Price: 800 CHF	750 CHF
Energy cost per year: 10 CHF (at 20 c/kWh)	30 CHF (at 20 c/kWh)
Energy cost over 5 years: 50 CHF	150 CHF
Total cost over 5 years: 850 CHF	900 CHF

(d) Slide-4



Washing machine

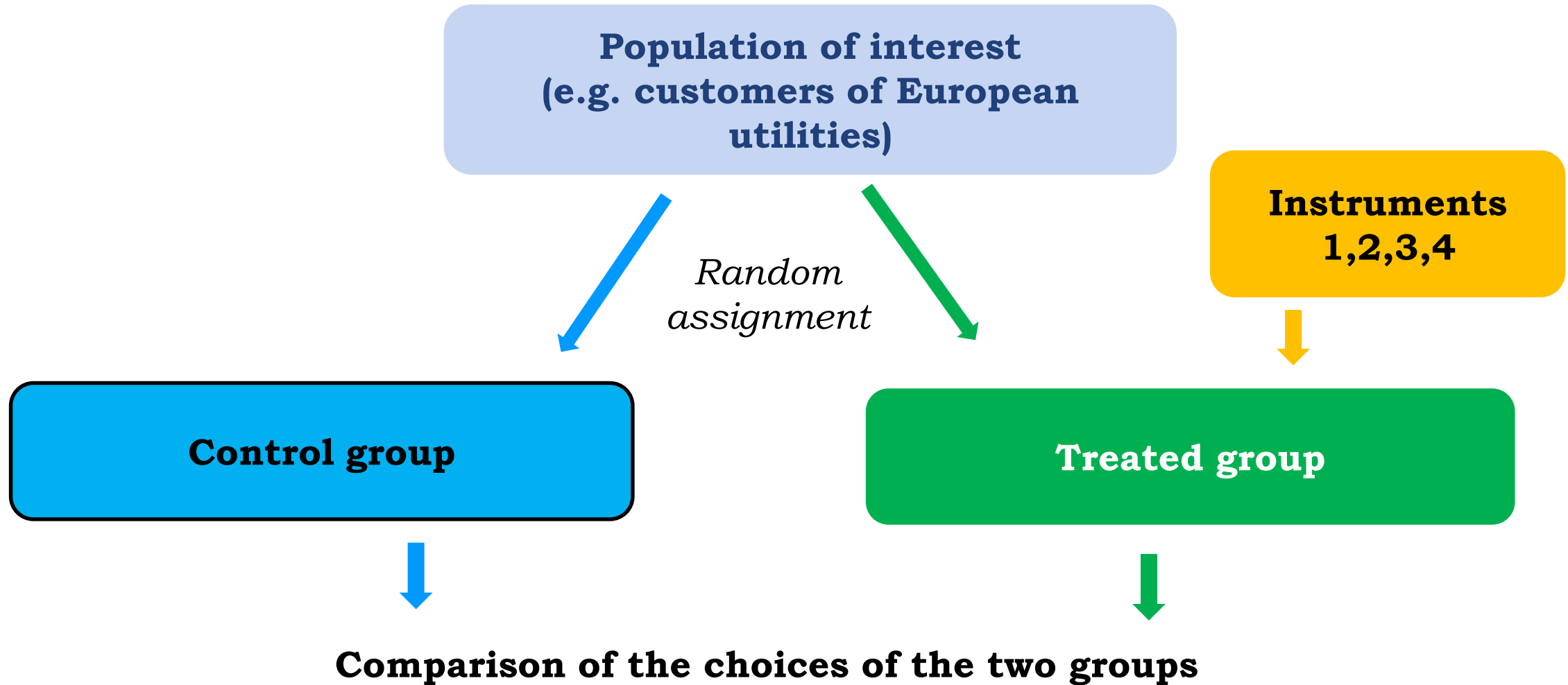
Characteristics of your appliance: Producer: Miele, Width: 60 cm, Height: 85 cm, Year of purchase: unknown

	Your appliance	Alternative appliance on the market (load capacity of 8 kg)	
		A++	A+++
Consumption per cycle	1.020 kWh	1.170 kWh	0.470 kWh
Cost of one cycle	0.204 CHF	0.234 CHF	0.094 CHF
Annual operating costs ⁽¹⁾	45 CHF	51 CHF	21 CHF
Approximate price range of new appliances		725-2309 CHF	440-4099 CHF
Estimate of potential annual savings on operating costs (compared to current appliance)		No savings	24 CHF

⁽¹⁾ The annual operating costs for the washing machine are estimated assuming 220 cycles.

- You can save an estimated CHF 24,- per year in electricity costs by replacing your washing machine with a new A+++ appliance.

Methodology to test the instruments: Randomized Control Experiments



Experiments to test instruments 1,2 and 3

Identification (not to choose) of the most (cost-)efficient appliance

Assume that you need to replace your fridge. You expect that you live in your current residence for another 10 years. In a shop you find the following two fridges which are identical in terms of size and cooling service.

	Fridge - A	Fridge - B
Purchase Price:	3300 CHF	2800 CHF
Electricity Consumption:	100 kWh/year	200 kWh/year

Assuming that one kilowatt hour (kWh) of electricity will cost about 20 Rappen on average during the next 10 years and that the value of 1 CHF in 10 years is the same as the value of 1 CHF today:

Which of the two fridges minimizes your expenditure for cooling food and beverages during the lifetime of 10 years?

- The fridge for 3300 CHF
- The fridge for 2800 CHF

- Random assignment of the households to one of the three groups
- ↪ **CONTROL** – the control group
- ↪ **TRINFO** – treatment 1 **information on operating cost**
- ↪ **TRSLIDE** – treatment 2 **education-slides**
- ↪ **TRCALC** – treatment 3 **simple web-based online calculator**

**We tested the effectiveness of these three instruments
(randomized control experiments)**

**Information on
operating cost**

*Treated group (N=1420)
with monetary
information*
*Control group (N=1415)
only information on kwh*

Educational program

*Treated group (N=785)
with educational program*
*Control group (N=4342) no
program*

**Investment
calculator**

*Treated group (N=804)
with investment
calculator*
*Control group (N=4342)
no calculator*

**Econometric/Statistical methods → Impact on the probability to
identify the least cost electrical appliances**

***Has an important
positive effect***

***Has a positive effect,
but not really large***

***Has an important
positive effect***

RCT treatment: letter with information on operating cost

Washing machine			
Characteristics of your appliance: Producer: Miele, Width: 60 cm, Height: 85 cm, Year of purchase: unknown			

	Your appliance	Alternative appliance on the market (load capacity of 8 kg)	
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Consumption per cycle	1.020 kWh	1.170 kWh	0.470 kWh
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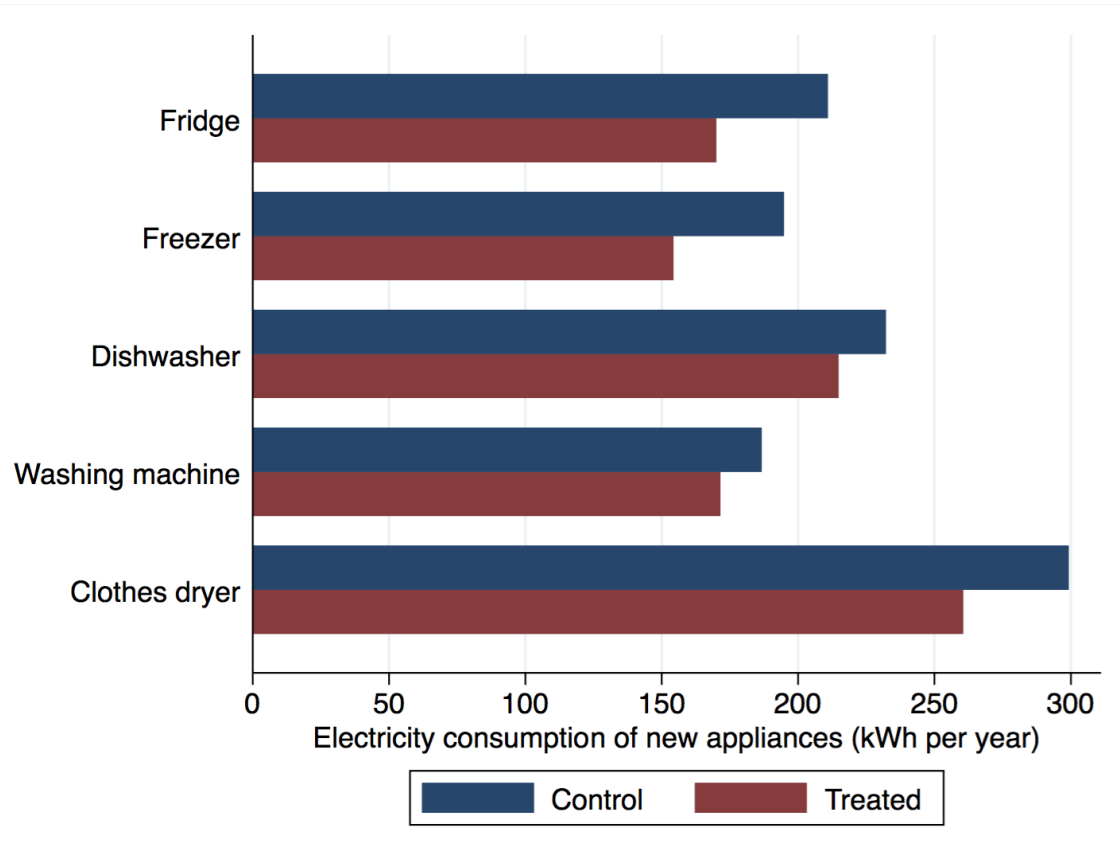
In-home visit

(collection of information on type, consumption, level of efficiency of lightbulbs and most important appliances)

Information treatment

(letter and webpage)
potential of monetary savings from the adoption of new energy efficient appliances (A++ and A+++)

Efficiency of the newly purchased durables



When treated households purchase a new home appliance, they choose new appliances that consume on average 15% less than those chosen by the control group.

Conclusions I

- From an energy policy point of view the results suggest that to improve, at least partially, the level of energy efficiency we could
 - ↳ Oblige the producers of electrical appliances to provide **monetary information** on yearly energy consumption on the energy label
 - ↳ Promote **educational training** on energy and investment related topics
 - ↳ Provide **decision support tools** such as online or mobile phone calculator tools or calculators at the point of sale
 - ↳ **Promote home energy audit**

Conclusion II

- In the near future, the set of digital and information technologies, home automation, new algorithms of artificial intelligence, "machine learning" will play an important role in helping consumers to make more sustainable development oriented choices.



Questions/Discussion...

Thank you for your attention!

- Blasch J., Filippini M., Kumar N., Martinez-Cruz A. (2017). Investment literacy and Choice of Electric Appliances: The Impact of Educational Programs and Online Support Tools, CER-ETH Working Paper No. 276.
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- Filippini, M., Kumar, N. and Srinivasan, S. (2019). Energy-related investment literacy and adoption of efficient household appliances in the Nepalese household sector. CER-ETH Economics Working Paper Series, 19/315.