ENERGY EFFICIENCY

Dr Lee White

Australian National University

lee.white@anu.ed.au

Executive Training

ENERGY TRANSITION PARTNERSHIP

Australian National University

Intended learning outcomes

Learning outcome 1: Understand the key technologies that will enable the transition to a zero-emissions energy system

Learning outcome 3: Consider the market, regulatory and policy frameworks that underpin the operation and facilitate the transition of the energy sector

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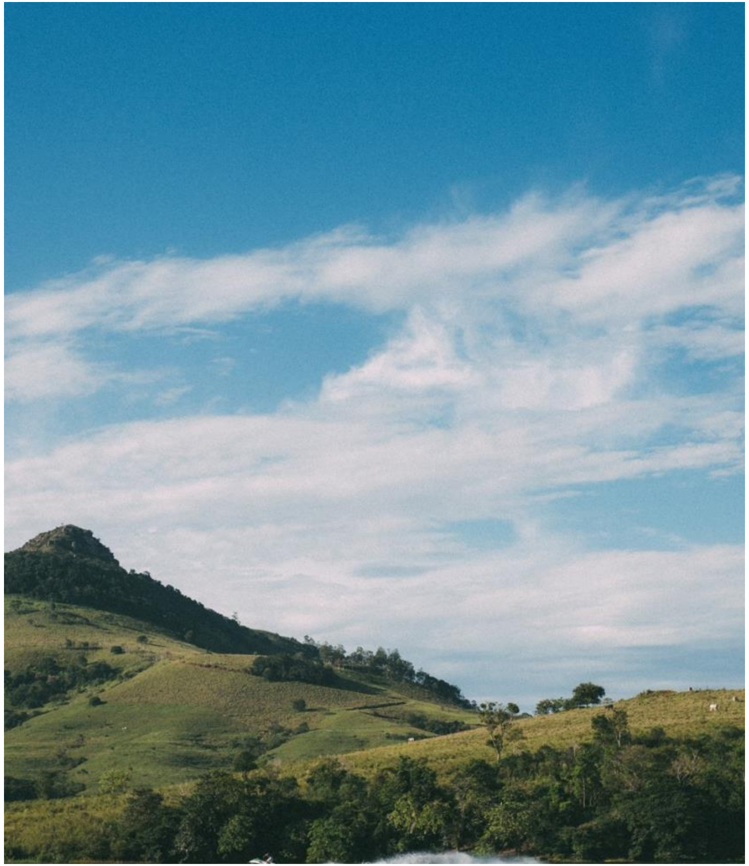
Energy efficiency

What is it?

Achieving the same thing using less energy

e.g.,

- Improved insulation and glazing let a building stay warm (or cool) with less energy input
- A more efficiently designed fridge uses less energy to keep food cool
- Can also cover behavioural changes, such as doing laundry with cold water, or setting back thermostats



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Answer the quiz on Zoom:

What kinds of strategies does your country currently have for energy efficiency? (Select all that apply)

- Labels to rate energy efficiency (on products or buildings)
- Financial support to homes or businesses wanting to make energy efficiency upgrades
- Rules stating minimum required energy efficiency (such as for new buildings, certain products)

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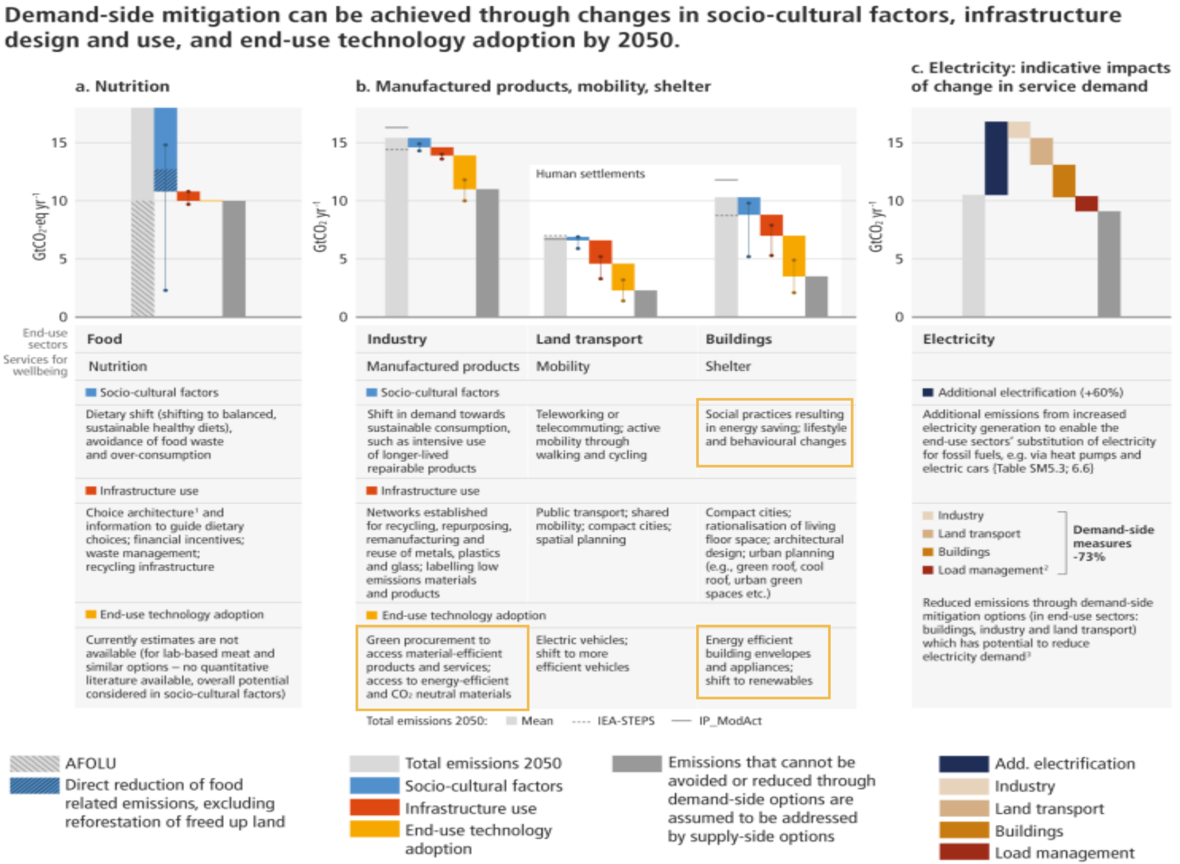
01 SCOPE OF IMPACT

Role of Energy Efficiency

One of many demand-side strategies

IPCC AR6 WGIII:

By 2050, comprehensive demand-side strategies across all sectors could reduce CO_2 and non-CO_2 GHG emissions globally by 40–70% (compared to the 2050 emissions projection of scenarios consistent with policies announced by national governments until 2020)



Cost of Energy Efficiency

IPCC AR6 WGIII

- Avoided demand and efficient appliances can save money relative to references scenarios
- In contrast, new construction of energy efficient buildings is expensive
- Energy efficiency measures in industry can also be low-cost

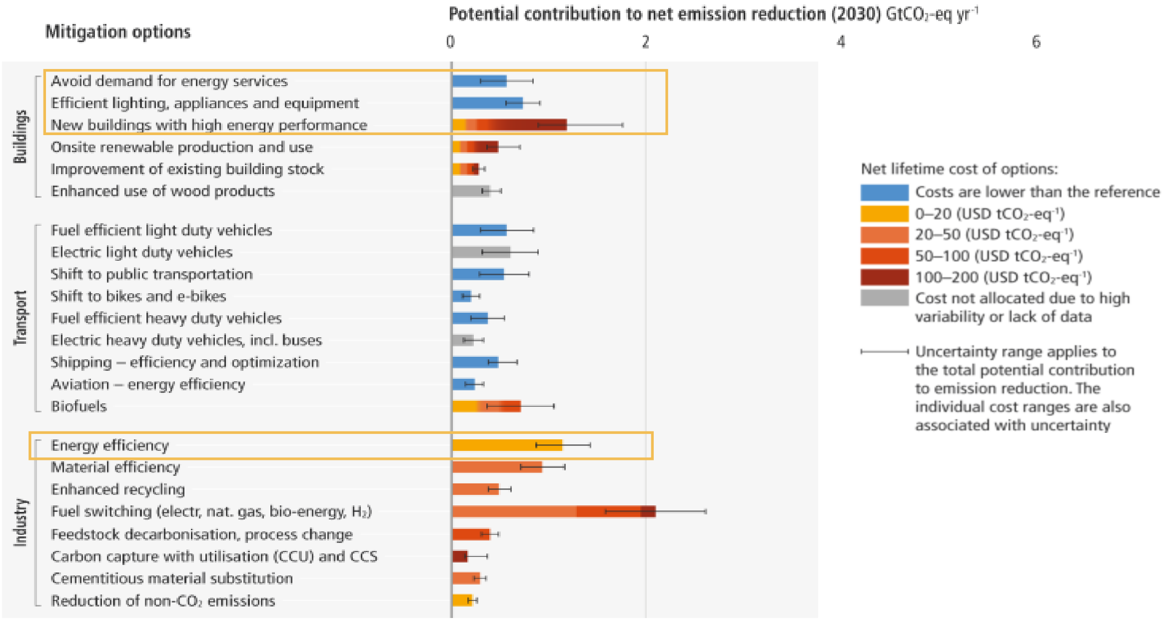


Figure SPM.7: Overview of mitigation options and their estimated ranges of costs and potentials in 2030.

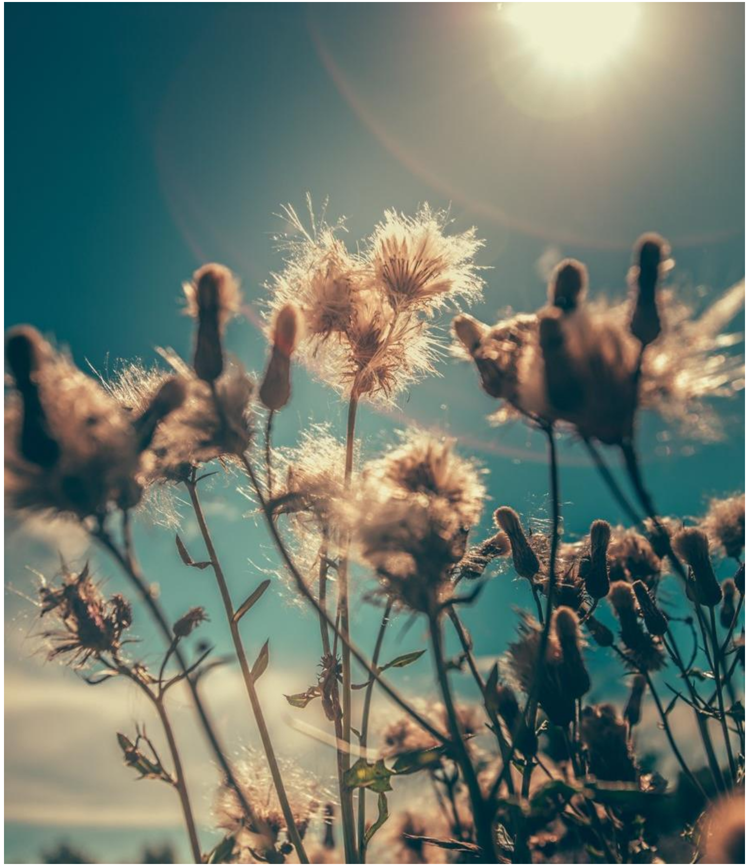
Energy efficiency

Energy is generally a means to an end, not an end itself

We use energy to access the services it provides, such as heating, lighting, cooling, and cleaning

Access to sufficient energy services is generally considered essential to being able to lead a good life

Energy efficiency can have benefits not just for climate, but also for increasing affordable access to energy services across the population (e.g. ability to keep homes a comfortable temperature)



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Synergies of Energy Efficiency

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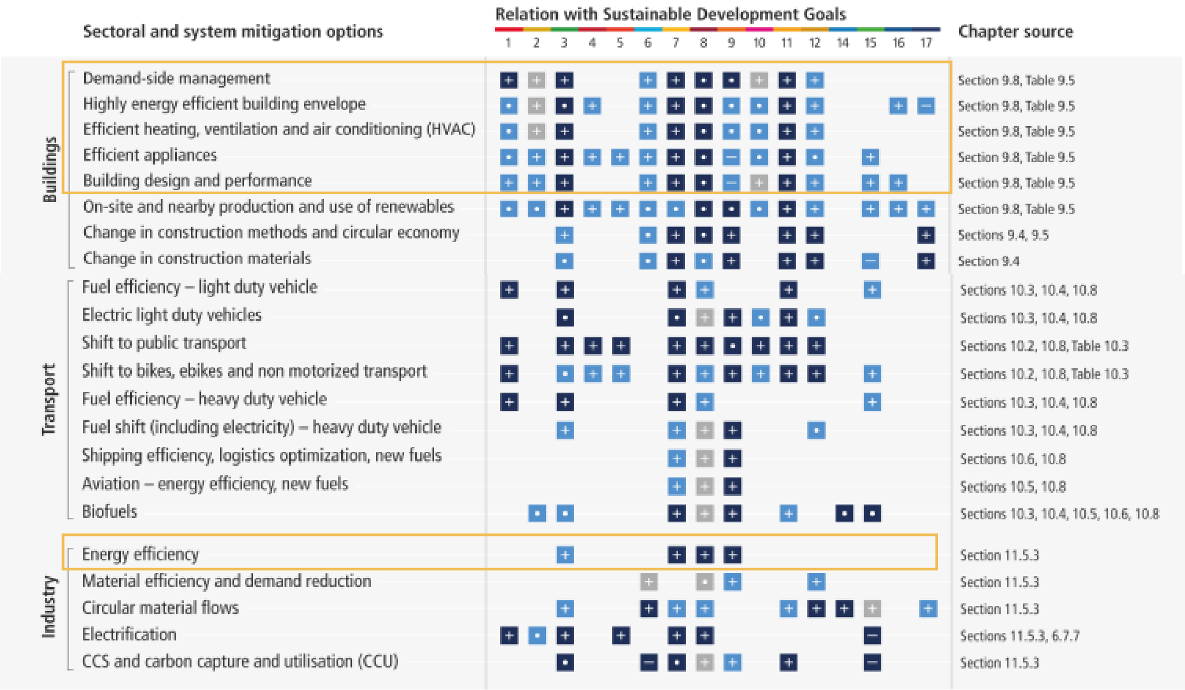
Several mitigation measures can also support sustainable development goals



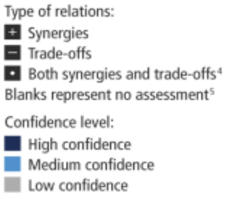


Figure SPM.8 Synergies and trade-offs between sectoral and system mitigation options and the SDGs

Related Sustainable Development Goals:

- 1 No poverty
- 2 Zero hunger
- 3 Good health and wellbeing
- 4 Quality education
- 5 Gender equality
- 6 Clean water and sanitation
- 7 Affordable and clean energy
- 8 Decent work and economic growth
- 9 Industry, innovation and infrastructure
- 10 Reduced inequalities
- 11 Sustainable cities and communities
- 12 Responsible consumption and production
- 13 Climate action
- 14 Life below water
- 15 Life on land
- 16 Peace, justice and strong institutions
- 17 Partnership for the goals

What areas are the current focus in your country?

How do you think energy efficiency works alongside sustainable development goals in these areas?

02 TYPES OF POLICIES

Types of energy efficiency policies

Table 1 Policy types and policy functions

Policy type	Policy function	Theory of change (for the end user)	Behaviour type	Policy class
energy or CO_2 taxes	To increase the price of energy or carbon-based energy in line with the polluter-pays principle	Response to economic incentives (dependent on elasticity of demand)	Purchase and habitual	Taxation
Energy efficiency obligations	To reduce the price of energy-efficient options (UK model)	Response to economic incentives	Purchase	Purchase subsidy
Grants	To reduce the price of energy-efficient options	Response to economic incentives	Purchase	Purchase subsidy
Tax rebates	To reduce the price of energy-efficient options to taxpayers	Response to economic incentives	Purchase	Purchase subsidy
Loans	To give people/organizations access to capital so they can buy energy-efficient options	Lack of access to capital/ high cost of capital as a barrier to investment	Purchase	Access to capital
On-bill finance	To give people/organizations access to capital so they can buy energy-efficient options	Lack of access to capital/ high cost of capital as a barrier to investment	Purchase	Access to capital
Regulations	To set legally enforceable minimum standards of energy efficiency for products, vehicles and buildings	Inefficient options no longer available	Purchase	Minimum standards
Voluntary agreements	To set minimum or fleet-average standards of energy efficiency for products, vehicles and buildings	Inefficient options no longer available	Purchase	Minimum standards
Standards and norms	To enable other efficiency policies to work	n.a.	Purchase	Underpinning measurement standards
Energy labelling schemes	To enable individuals and organizations to take account of energy in their purchase decision-making	Relevant information/ advice provided at the right time can influence choices	Purchase	Information and feedback
Information, advice, billing feedback, smart metering	To enable individuals and organizations to take account of energy in their purchase decision-making and/or habitual behaviours/practices	Relevant information/ advice provided at the right time can influence choices	Purchase and/or habitual (depends on instrument)	Information and feedback

Policies to target energy efficiency can fall into regulatory, financial, or informational categories

e.g.

- Legally enforceable minimum standards for energy efficiency of buildings or products
- Grants to reduce the price of energy-efficient options
- Energy labelling schemes to enable people to take account of energy in their purchase decision-making

(Table from Rosenow et al., 2016)

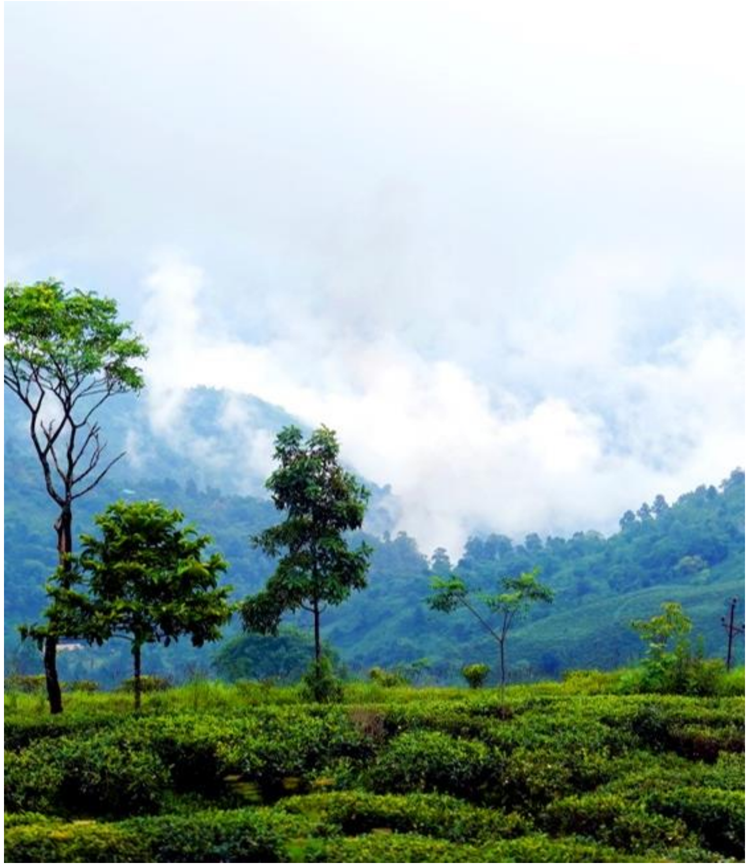
Policy overview

These strategies generally work, though imperfectly

Regulated minimum standards do tend to improve building stock over time, though not always to the anticipated level

Finance measures can sometimes increase purchase of energy efficient goods, though other times they are unsuccessful

Information in the form of labelling schemes for energy efficiency does tend to be used by consumers; consumers generally value energy efficiency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Building codes

Improved building codes can reduce energy consumption (e.g., Hjortling et al. 2017),

Buildings built after construction codes were improved have lower energy use (Hjortling et al. 2017)

In the EU, residential building code requirements have been strengthening over time (Economidou et al, 2020)

Energy use intensity has generally declined over time; this is particularly visible when correcting for increases income and other factors that change over time (Economidou et al., 2020)

Table 7
Average energy performance [kWh/m²] according to building type and construction period.

Source: Hjortling et al., 2017

Average energy performance [kWh/m²]			
Building type	Construction period (count)		
	1979	1980–2009	2010
Multi-dwelling buildings (320 and 321 A and B)	151 (91,679)	129 (35,024)	85 (1022)
Farms (100)	142 (8969)	108 (883)	74 (77)
Mainly offices (325)	159 (8761)	137 (4175)	87 (122)
Mainly hotels and restaurants (322)	171 (1256)	188 (647)	122 (12)
Healthcare facilities (823)	181 (4292)	156 (3253)	102 (96)
Schools (825)	178 (10,247)	155 (3523)	97 (100)
Sports facilities (824)	191 (952)	148 (603)	104 (26)

Source: compiled by the author using data from the GRIPEN database, September 2015.

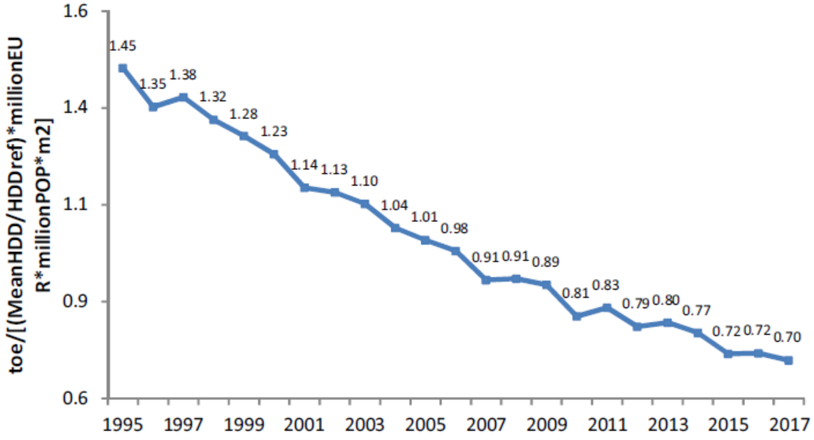


Fig. 5. Residential energy consumption climatic corrected per capita, per average floor area of dwellings and per adjusted disposable income of households in EU-15 minus PT & BE (1995–2017). Portugal (PT) and Belgium (BE) were excluded from the analysis due to unavailability of floor area data.

Source: Economidou et al., 2020

Finance

Finance instruments are not always effective

Sometimes they are regressive in nature; people with less ability to pay bear more of the policy cost (and receive less of the benefit)

Sometimes perverse price effects occur

Subsidies and rebates can also be expensive to implement

(Sola et al., 2021)

Table 2 Effectiveness of EE policies: overview of studies and main results of command and control and price instruments (in order of appearance)

EE policy	Reference	Year of the study	Country	Sector/product category	Methodology	Evidence on the effectiveness of the policy	Comments
Command and control							
Codes	Aroonruengsawat et al. (2012)	2005–2007	USA	Appliances	Difference in Difference	+	Decrease in energy consumption
	Jacobsen and Kotchen (2011)	2000–2009	USA	Appliances	First difference regression with EPA's Energy Star data base	+	Decrease in electricity and gas consumption
	Papineau (2013)	2007	USA	Buildings	Modelling	+	Price premium: 2.7–10%
Standards	Rosenow et al. (2018)	–	Global	–	Review	–[a]	
	Lang (2004)	–	China	Buildings	Review	–[a]	
Price instruments							
Taxes	Villca-Pozo and Gonzales-Bustos (2019)	2018	Spain	Buildings	Modelling	–[a]	
	Sterner (2012)	–	–[a]	Transport	–[a]	–	The main beneficiaries are not the poor
	Sterner (2007)	–	OECD countries	Transport	Analysis of price elasticities	–	The main beneficiaries are not the poor
Subsidy	Jiménez et al. (2016)	2007–2010	Spain	Transport	Difference in difference	+	Subsidies lead to an increase in selling price of €600
Combination of tax and subsidies	Galarraga et al. (2016)	2012	Spain	Appliances	Dead weight loss estimation	–[b]	Optimal combination of taxes and subsidies
	Jacobsen (2019)	–	–[a]	Appliances	Theoretical framework	–[a]	
	Markandya et al. (2009)	2007	Europe	Household durables	Modelling	–[a]	Boilers: taxes are cost-effective in Denmark and Italy Lightbulbs: subsidies are cost-effective in France and Poland
	Panzone (2013)	2010–2012	UK	Appliances	Modelling	–[b]	Washing machines should be subsidised; lightbulbs and refrigerators taxed
Rebates	Galarraga et al. (2013)	2008–2009	Spain	Appliances	Dead weight loss estimation	–	Effect
	Houde and Aldy (2017)	2009	USA	Appliances	Difference in difference	–[a]	Consumers do not always buy energy-efficient appliances
	Datta and Filippini (2016)	2005–2007	USA	Appliances	Difference in difference	+	Increase in the sales share of US Energy Star appliances
	Drivas et al. (2019)	2011–2015	Spain	Buildings	Econometric model	+	Increase in the subsidy rate for lower income households
	Olsthoorn et al. (2017)	2016	EU	Heating systems	Choice experiment	–[b]	A share higher than 50% of free riders

Source: own work

'+' positive impact; '–' negative impact

[a] No impact

[b] Non-conclusive results

Value of energy labels

- More energy efficiency products are generally more valued, and certificates help realise that value
- For both building and appliance labelling schemes, the exact design of the scheme can affect impact

(Ramos et al., 2016)

Table 2
Empirical research on the value of certificates or labels for energy products.

Study	Sector	Results: WTP	
		Rent (effective)	Sales
Eichholtz et al. (2010)	Commercial U.S.	3% (7%)	16%
Eichholtz et al. (2013)	Commercial U.S.	3% (8%)	13%
Wiley et al. (2010)	Commercial U.S.	7–9% Energy Star 15–17% LEED	30$/f2 Energy Star 130$/f2 LEED
Fuerst and McAllister (2011a)	Commercial U.S.	4–5%	25%
Fuerst and McAllister (2011c)	Commercial U.S.	3% Energy Star 5% LEED 9% Energy Star + LEED.	18% Energy Star 25% LEED 28–29% Energy Star + LEED.
Reichardt et al. (2012)	Commercial U.S.	2.5% Energy Star 2.9% LEED.	
Das et al. (2011)	Commercial U.S.	Positive and dynamic	
Bloom et al. (2011)	Commercial U.S.		8.66$/f2
Kok and Jennen (2012)	Commercial Netherlands	−6%	
Fuerst and McAllister (2011b)	Commercial UK	Not significant	Not significant
Chegut et al. (2013)	Commercial London	19.7%	14.7%
Brounen and Kok (2011)	Residential Netherlands		3.6%
Högberg (2013)	Residential Sweden		Positive WTP
Hyland et al. (2013)	Residential Ireland	A: 1.8% B: 3.9% C: not significant E: −1.9% F/G: −3.2%	A: 9.3% B: 5.2% C: 1.7% E: not significant F/G: −10.6%.
Cajias and Piazolo (2013)	Residential Germany	Total returns: B: 2.27% C: 2.34% D: 2.69% E/F: not significant G: reference	
Yoshida and Sugiura (2011)	Residential Tokyo		Negative
Deng et al. (2012)	Residential Singapore		4%
Zheng et al. (2012)	Residential Beijing	Negative	Negative
Wall et al. (2013)	Residential U.S.		Positive for houses built 1996–2005. Not significant for newer houses. Values reach up to 20%
Kahn and Kok (2014)	Residential California		9%.

Source: The authors.

Comparing policies

ST: Product energy performance standards (exclude minimum)

LA: Product labels (voluntary)

SL: Standard labelling (combination of standards and labels)

BC: Building codes

BL: Building certificates and labels

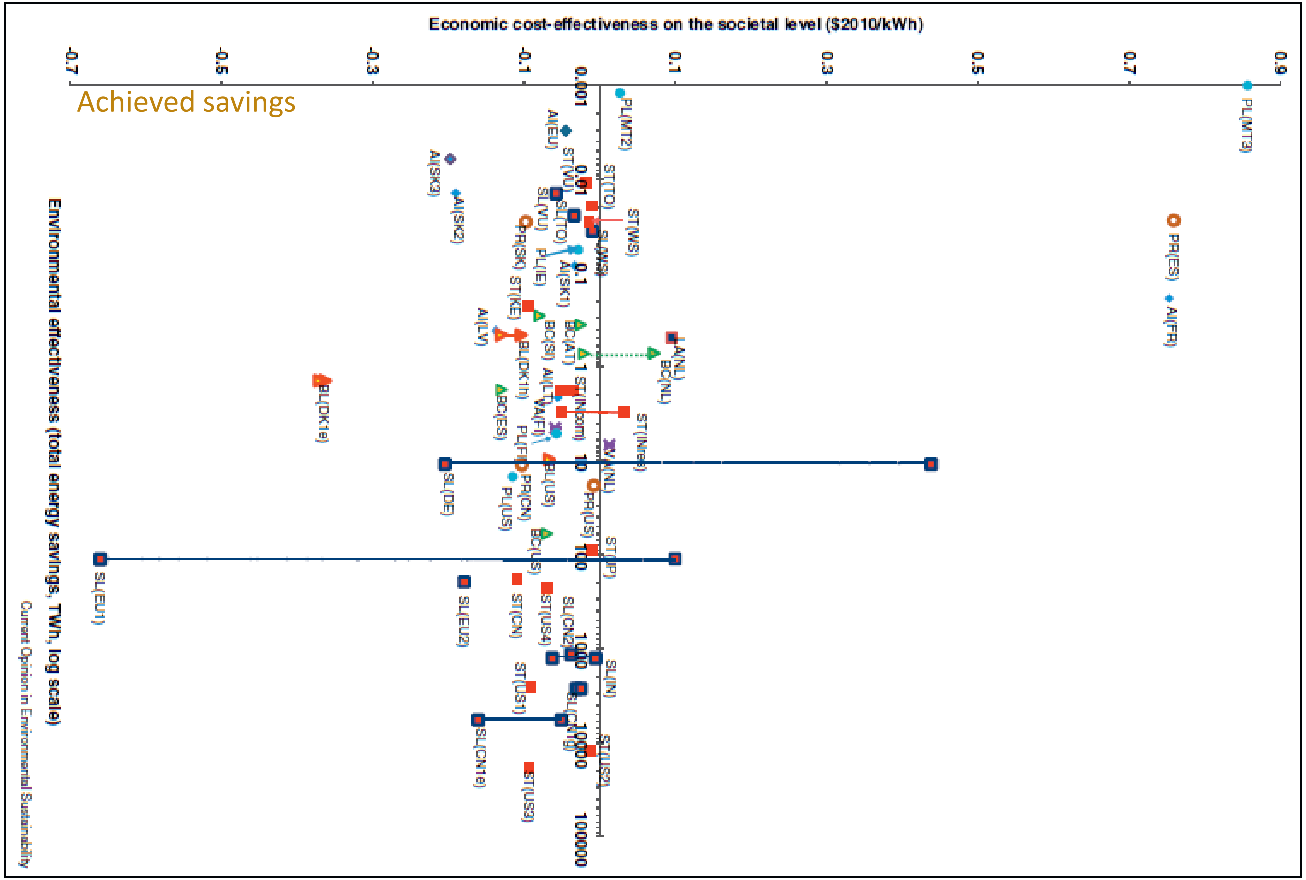
PR: Green (or efficient) procurement rules

PL: Public leadership programs

AG: Voluntary agreements

AI: Awareness raising and information programs

(Boza-Kiss et al., 2013)



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Existing building stock

No one has yet come up with a good solution for mass improvements of existing building energy efficiency

Rules and mandates can prevent new building stock from adding to the issue, but it is generally not practicable to require existing buildings be brought up to code

This leaves it to the private market and mechanisms such as finance, information, and subsidy – limited efficacy

Buildings occupied by renters face particular challenges – the renters benefit from improvements but need owners to pay to make them

Table 1
Categorization of policy measures [Source: Bertoldi & Economidou., 2018].

Regulatory	Building codes; Minimum energy performance standards (MEPR) for new and existing buildings; Energy efficiency standards for appliances & equipment; Refurbishment obligations; Procurement Regulations; Phase-out of inefficient equipment.
Financial and fiscal	Grants/subsidies; Preferential loans; Tax incentives; Energy taxation.
Information and awareness	General Information; Information campaigns; Information Centres; Energy Audits; Energy labelling schemes; Governing by Example; Information exchange; Awareness campaigns; Demonstration programmes.
Qualification, training and quality assurance	Professional training; Training courses; Vocational education, quality standards.
Market-based	Incentives facilitating Third Party Financing/ ESCOs; Energy Efficiency Obligation Schemes (EEOSs); White certificates; Incentives for the producers of innovative technologies; Technology deployment schemes.
Voluntary action	Voluntary certification and labelling programs; Voluntary and negotiated agreements.
Infrastructure investments	Investments in transportation infrastructure (e.g. railways, road networks), Energy infrastructure (e.g. generation plants, electrical grid, substations, and local distribution); Smart meter roll-out.
Other	Other measures that do not fall under one of the above categories (e.g. research innovation and innovation programme, demonstration projects).

From Economidou et al., 2020

Policy for existing buildings

“So far, the evaluation and assessment of existing policies for EE in buildings (Table 1) suggest that there is no single policy that alone can achieve a substantial transformation of the existing building stock and reduce significantly energy consumption.” (Economidou et al, 2020)

It is particularly critical for countries that are rapidly expanding built infrastructure to consider implementing strong standards sooner rather than later

Thinking about energy efficiency policies currently used in your countries, why do you think these strategies were chosen?

Existing policies	Reasons for choices

What do you see as opportunities for future policy?

Opportunities for future	Why?

03 DEVELOPING TOOLS

What situations is each tool good for?

Voluntary standards tend to have lower costs, but less certain environmental benefits

Minimum required standards have clear environmental benefits, but without sufficient underlying data can be challenging to implement and may raise concerns about cost to consumers

Financial measures can be expensive to implement and may not reach desired effectiveness

Information measures don’t always have expected impact, but can be relatively cheap to implement and can begin to build a database for future improvements

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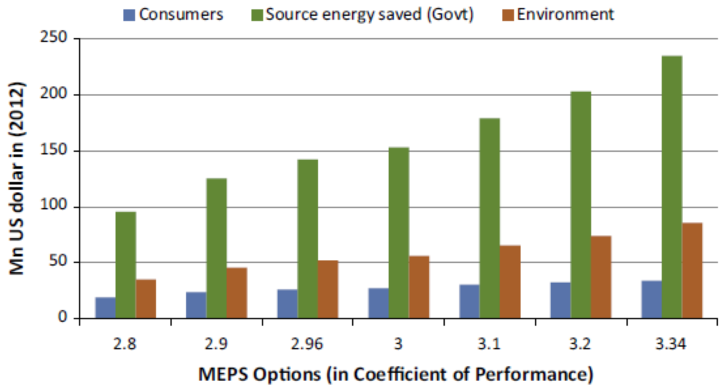


Fig. 5. Benefits of consumers, government, and the environment through 2030.

Shi , 2015

Local policies

Policies for energy efficiency (and anything else) need to make sense for the place where they are implemented

In setting minimum energy performance standards, for example, governments tend to run extensive assessments to find a level of policy that supports energy goals without too much burden on consumers and country (Shi, 2015)

This can be challenging in places that do not have a lot of resources for testing and analysis, or do not have a lot of historical data to work with (Shi, 2015)

They develop an assessment method with a lower data burden, using a relatively small consumer survey and collecting information from manufacturers on available technologies (including how international market shapes cost and availability)

Energy labels in the Philippines and Ghana

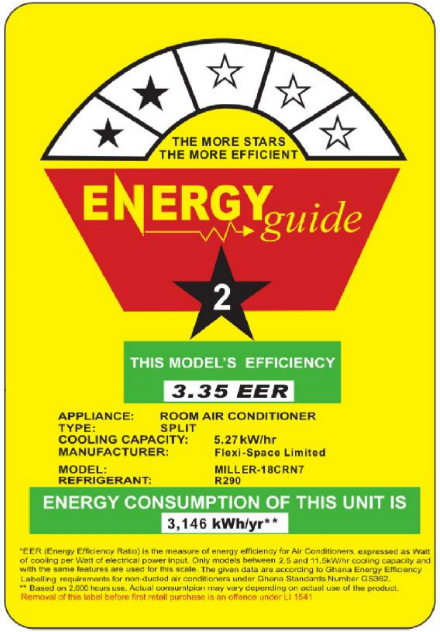


Fig. 1. Ghanian Energy label.

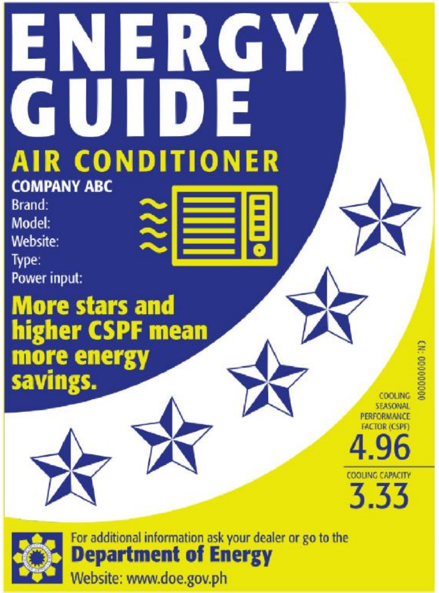


Fig. 2. Philippine Energy label.

Kuhn et al., 2022

Study of middle-income households in Philippines and Ghana (Kuhn et al., 2022) found that:

- Consumers care for energy efficiency and are influenced by an energy efficiency label.
- ACs with a higher energy efficiency rating are preferred and so are ACs with a better cooling technology.
- Within the range of existing market prices, the energy rating has a bigger impact on AC choices than the price.
- Higher environmental concern and knowledge increased the value of energy efficiency in the Philippines and, partially, in Ghana.

Change over time

A key feature of energy efficiency policy in places like the EU and Australia is evolution over time

There is often growing complexity and addition of more policy types over time

e.g. Figure to the right of UK of energy efficiency policy over time (from Kern et al., 2017)

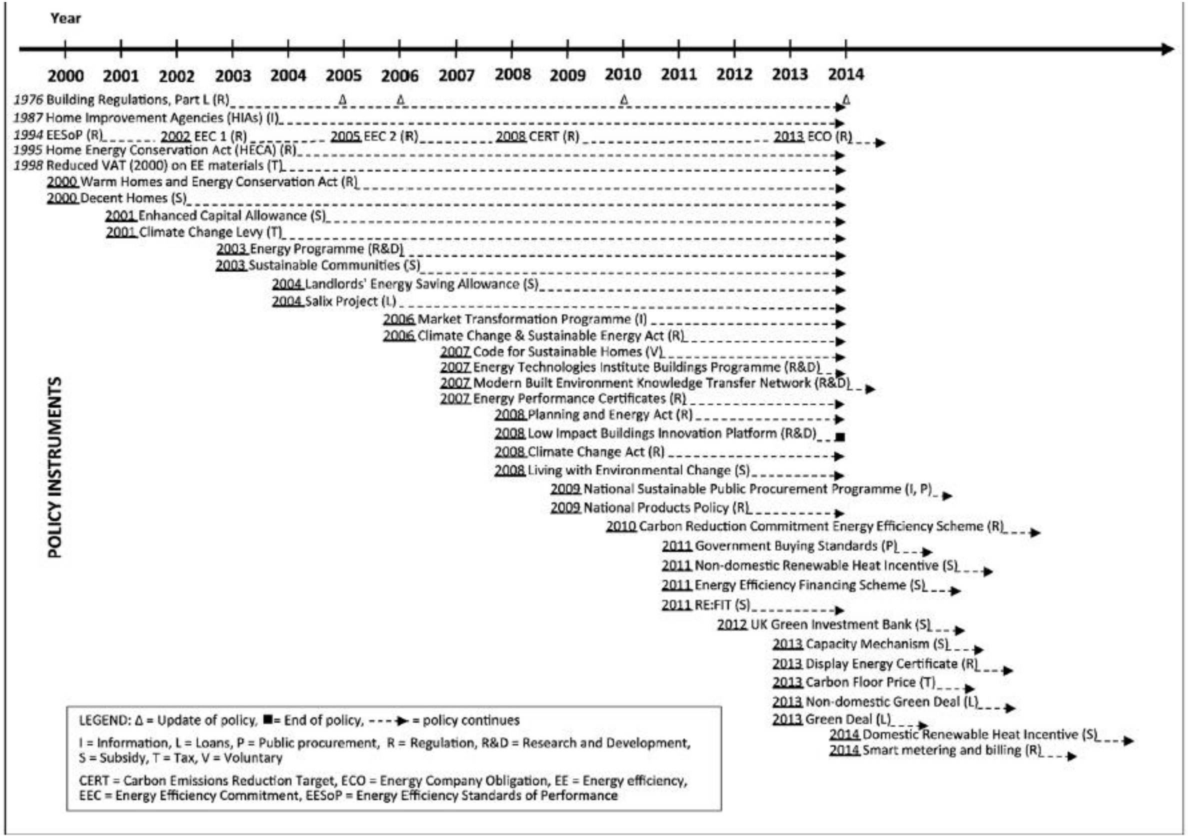


Fig. 2. The development of the UK policy instruments for building energy efficiency, 2000–2014.

Change over time

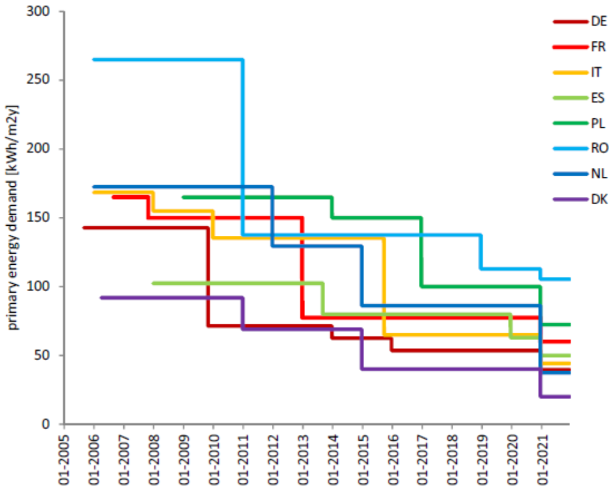


Fig. 3. Improvement of residential minimum energy performance requirements in some key Member States, since the entry in force of the first EPB Directive.

Economidou et al., 2020

Standards are often tightened over time

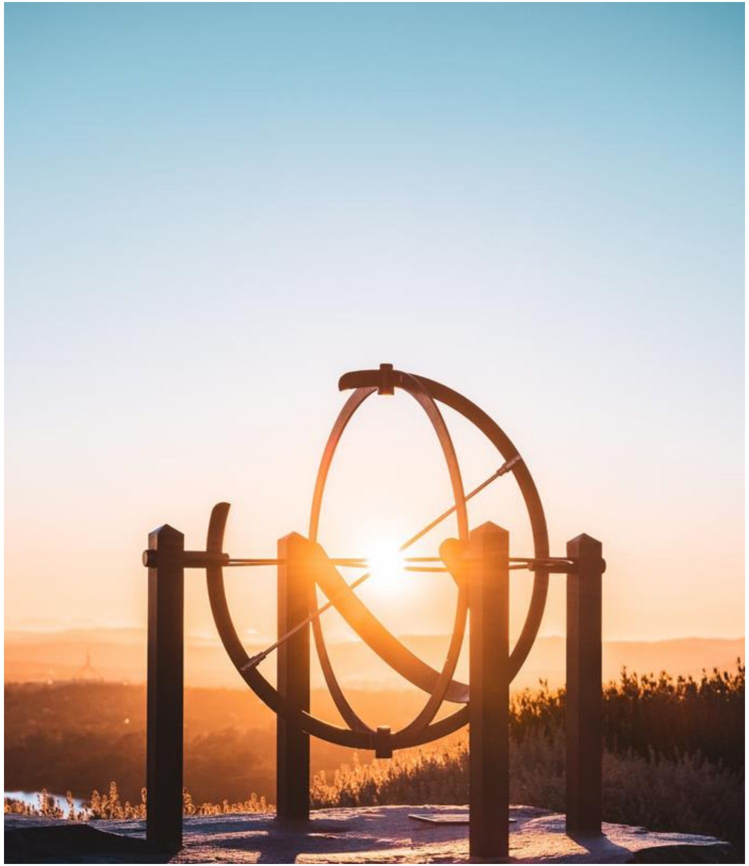
For example, in the EU, many member states have increased minimum energy performance requirements over time

Australia has also increased these standards over time, and is continuing to do so

This is also often the case for appliance and product standards

For example, US Corporate Average Fuel Economy (CAFÉ) standard has changed over time to increase mile/gallon requirements for vehicle fuel efficiency

Sometimes led at the sub-national level



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Tracking data is important

Without collection/tracking over time of housing stock energy efficiency, it can be challenging to determine what to target for future change, and challenging to understand which existing strategies are most effective

Setting in place mechanisms to collect information on building and product energy efficiency can support future efforts for improvement

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Climate change

Climate change is expected to increase frequency and severity of extreme weather events including heatwaves

These events can place severe stress on electricity grids

Buildings that are able to stay within safe temperature ranges while using less energy will be one of the many things that it's important to have in this new environment

Lock in is also an issue

In places were cities are growing, a lot of infrastructure is being built

If more efficient infrastructure is built, fewer emissions will be locked in for future

Much harder to change retroactively

What constraints do you see to improving energy efficiency in your country?

Which of the strategies discussed today do you think may be useful? Why this strategy?

Summary

What stood out to you?	How could your country use it?

Did you begin the session with questions about energy efficiency that you still don't know the answers to?

Do you have new questions, and if so what are they?

THANK YOU

Contact Us

Lee White
Zero Carbon Energy for the Asia-Pacific Grand Challenge
School of Regulation and Global Governance
lee.white@anu.edu.au

Australian National University

References

Boza-Kiss, B., Moles-Grueso, S., Urge-Vorsatz, D.: Evaluating policy instruments to foster energy efficiency for the sustainable transformation of buildings. Curr. Opin. Environ. Sustain. 5, 163–176 (2013). https://doi.org/10.1016/j.cosust.2013.04.002

Economidou, M., Todeschi, V., Bertoldi, P., D'Agostino, D., Zangheri, P., Castellazzi, L.: Review of 50 years of EU energy efficiency policies for buildings. Energy Build. 225, 110322 (2020). https://doi.org/10.1016/j.enbuild.2020.110322

Hjortling, C., Björk, F., Berg, M., Klintberg, T. af, af Klintberg, T.: Energy mapping of existing building stock in Sweden – Analysis of data from Energy Performance Certificates. Energy Build. 153, 341–355 (2017). https://doi.org/10.1016/J.ENBUILD.2017.06.073

IPCC AR6 WG III: IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926

Kern, F., Kivimaa, P., Martiskainen, M.: Policy packaging or policy patching? The development of complex energy efficiency policy mixes. Energy Res. Soc. Sci. 23, 11–25 (2017). https://doi.org/10.1016/j.erss.2016.11.002

Kuhn, S., Kutzner, F., Thøgersen, J.: How to make energy efficiency labels more effective: Insights from discrete choice experiments in Ghana and the Philippines. Energy Res. Soc. Sci. 84, (2022). https://doi.org/10.1016/j.erss.2021.102320

Ramos, A., Gago, A., Labandeira, X., Linares, P.: The role of information for energy efficiency in the residential sector. Energy Econ. 52, S17–S29 (2015). https://doi.org/10.1016/j.eneco.2015.08.022

Rosenow, J., Fawcett, T., Eyre, N., Oikonomou, V.: Energy efficiency and the policy mix. Build. Res. Inf. 44, 562–574 (2016). https://doi.org/10.1080/09613218.2016.1138803

Shi, X.: Application of best practice for setting minimum energy efficiency standards in technically disadvantaged countries: Case study of Air Conditioners in Brunei Darussalam. Appl. Energy. 157, 1–12 (2015). https://doi.org/10.1016/j.apenergy.2015.07.071

Solà, M. del M., de Ayala, A., Galarraga, I., Escapa, M.: Promoting energy efficiency at household level: a literature review. Energy Effic. 14, (2021). https://doi.org/10.1007/s12053-020-09918-9