Effectiveness of Household Energy Efficiency Interventions in Advanced Economies:

What works and what doesn't

Final Report

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Scope and purpose

This report presents the findings from a project with the aim of providing a review of the evidence base regarding the design, characteristics and effectiveness of household energy efficiency interventions to help inform Australian energy policy, interventions and consumer advocacy. The project featured a systematic review of published household energy efficiency interventions in advanced economies to assess what works and what doesn't work. We assess how issues with the aims, design, target populations, theoretical frameworks, and implementation components, evaluation design and outcomes measured, influence the effectiveness of household energy efficiency interventions. The findings add to the evidence base regarding the effectiveness of household energy efficiency interventions, and will help inform better policy, interventions and consumer advocacy to help Australian households achieve better energy and related co-benefit outcomes, and provide good return on investment (ROI).

Method

Following a systematic search of published academic literature across three databases (Web of Science, Scopus and ScienceDirect) and grey literature (e.g. government reports) in Google searches, literature concerning a total of 107 household energy interventions were included in the review. The literature was then analysed to address the following research questions to help inform future energy policy and energy efficiency interventions in Australia:

- RQ 1. What is the overall evidence of the effectiveness of household energy intervention?
- RQ 2. Which theories/models/conceptual frameworks are used to inform energy interventions, and how do these influence their effectiveness?
- RQ 3. What populations or groups were the focus of household energy interventions?
- RQ 4. Which intervention approaches and elements are used, and which are most effective?
- RQ 5. How are outcomes measured in household energy interventions?

Key findings – what works and what doesn't

The review identified that 90 out of 107 interventions resulted in positive energy efficiency outcomes. This suggests that, overall, household energy efficiency interventions can be successful; in many cases because they focused on what mattered to the household. The review findings identified a number of key factors influencing the success of energy efficiency interventions.

What works

In terms of what works, we identified the following factors as important:

1) Using multiple intervention components that combine elements such as home retrofits, home audits, education and information, behaviour change marketing, and technologies like in-home displays can increase the chances of successfully impacting energy efficiency.
2) Develop insights that are region-/population-specific before conducting an intervention.

3) Identify clear aims and objectives from the outset and use appropriate methods to ensure that success can be evaluated. For example, if aiming to reduce electricity consumption, kWh reduction provides an objective measure; if aiming to increase awareness of energy efficiency then carefully designed surveys or interviews may be used.
4) Intervention measurement and impact and outcome evaluation, including measurement of co-benefits, cost effectiveness and ROI, should be designed from the beginning of any intervention.
5) Use appropriate social/behavioural theories to guide intervention design, implementation and evaluation.
6) Interventions should be segmented, targeted and tailored to the relevant target populations, and situational contexts as far as is possible.
7) Overall, the most effective intervention elements were home retrofits, digital tools (e.g., websites or apps) and workshops/training to support positive energy efficiency outcomes.

What doesn't work

In terms of what doesn't work, we identified the following factors for consideration:

1) Failing to identify clear aims and objectives, and agreeing on and designing-in impact and outcome evaluation measures from the start makes it difficult to evaluate the effectiveness of household energy interventions.
2) Not generating consumer insight and being aware of householders' preferences when designing an intervention can lead to failure. For example, many householders are unwilling to upgrade energy-inefficient heating systems if they regard them as very reliable.
3) Failure to use appropriate social/behavioural theory affected the likelihood of success.
4) Failure to understand and acknowledge contextual differences across geographic locations, and demographic and cultural groups can result in interventions that are not appropriately designed and tailored for purpose.
5) Delivering household energy efficiency interventions that incorporate some upfront costs borne by households can affect chances of success. Upfront costs can be deemed too high by some households and may lead to a lack of participation in interventions, even if over the long term they would be cost-effective.
6) Relying on the provision of energy usage feedback alone in interventions has mixed results. It is better to combine different feedback types (i.e., particularly cost and usage feedback) to householders.
7) Household energy efficiency interventions that rely on consumer self-report measures may overestimate the perceived benefits, and more objective measures (such as kWh) should be used as far as possible.
8) Cost effectiveness and ROI is rarely reported in household evaluations.

Implications and recommendations for energy policy and advocacy

The key findings offer useful direction for future energy policy and advocacy.

Use multi-layered approaches operating at the macro, micro and individual level, and multiple intervention elements

Energy behaviours are complex, and are subject to multiple levels of influence on behaviours and outcomes working at the macro level (e.g. policy, social norms), micro level (workplaces, local communities) and individual level (householders). Currently most energy efficiency interventions focus on individuals, creating an implicit assumption that the responsibility for energy efficiency rests solely with the consumer. However, the wealth of evidence from the behaviour change literature indicates that individuals alone cannot address wicked and complex problems such as energy efficiency, and therefore whole-of-systems interventions working at the macro level (e.g. policy change, shifting social norms, infrastructure), micro level (e.g. community development and support), and individual level (e.g. home retrofits, information and education) are required. Policymakers and relevant stakeholders should work to ensure that there are multiple intervention elements featured in household energy efficiency interventions, as the likelihood of success is greater.

Context really matters – ensure that policies and programs support the segmentation, targeting and tailoring of interventions according to the specific context

While the majority of household energy efficiency interventions take a general population approach (e.g. 90% of those identified in this review), those interventions that feature segmentation, targeting and tailoring of intervention components tend to be more effective. Policymakers should acknowledge the unique characteristics of target population groups, and their geographic, social, cultural, political, technological and environmental context. Pilot interventions can also be used to ensure interventions are fit for purpose in a specific context.

Ensure that energy policies and interventions are consumer-centred

Energy efficiency interventions need to be sensitive to peoples' needs, wants, desires and lifestyles. Generating consumer insight through research and engagement is a critical precursor to the design, delivery and success of interventions. Ideally, household energy efficiency interventions should involve working with and alongside householders, and foster co-design and co-delivery of intervention components.

Be clear about defining aims and objectives, and desired outcomes and impacts

It is critical to be clear about what the aims of objectives are for specific household energy efficiency interventions. While we found that most interventions are effective, comparability is difficult due to the variation in definitions of energy efficiency (e.g. only reducing kWh energy use, or also concerning comfort, health and wellbeing) and what success means. Some interventions may aim to reduce overall energy consumption as measured in kWh, while others may aim to produce health or wellbeing co-benefits. Therefore, aims and objectives need to be identified clearly at the outset of any intervention, and outcomes that are Specific, Measurable, Achievable, Relevant and Time-Bound (SMART) should be set to evaluate success.

Make use of appropriate social/behavioural theory to guide the design, implementation and evaluation of household energy efficiency interventions

Our findings identified the use of theory as an important success criteria for household energy efficiency interventions. Theory is critical to any efforts to bring about behavioural and social change as it relates to the underpinning ideas about why something is the way that it is, and the key factors influencing this. Theories are used to describe, classify and predict future behavioural responses. Therefore, theory provides a framework for conceptualising and analysing the process of behavioural influence and change, guiding research regarding specific behaviours, and assisting with planning and selecting household energy efficiency interventions.

Good evaluation is the key to demonstrating success

Evaluation of the process, outcomes and impact of household energy interventions is crucial to demonstrate success. Our review found that sound evaluation was not always a strong feature of interventions. A robust framework for evaluation should be considered and incorporated at the start of any intervention. It should also be designed to suit the context of the intervention, the outcomes sought and the resources available – drawing upon the full range of quantitative statistical and qualitative methods available as appropriate.

Be mindful of unintended consequences

Our review identified that some household energy efficiency interventions can backfire and generate unintended consequences and negative effects. Therefore, careful scoping and scenario planning is required prior to delivering interventions. Pilot-testing interventions and their consistent components can be a good way to identify unintended consequences and mitigate these prior to full intervention launch. Interventions that may have been successful in one context may not necessarily succeed in a different jurisdiction, and therefore direction policy and intervention transfer should be carefully considered, and local contextual factors accounted for.

Introduction and background

Improving energy efficiency for residential households is a policy emphasis for governments in developed countries as electricity prices rise. The need to balance the affordability, reliability and sustainability of a national energy supply has led to a large number of interventions that aim to increase the energy efficiency of households to save consumers money, reduce environmental impact and address the demand on the energy grid. In addition, technological development is on the rise, with the introduction of smart meters, as well as the advent of faster internet opening the way for Internet-of-Things-enabled devices to help consumers manage their energy use. In Australia and globally, there have been more than 1000 energy efficiency interventions over the past decade, and thus there is a significant evidence base for policymakers and industry to use as a foundation for societal and economic goals in the face of technological change. To date there has not been a systematic review of these interventions to identify the type and features of energy efficiency interventions that are most effective, particularly in light of the complexity and multiplicity of household energy use practices (Waitt, Roggeveen, Gordon, Butler, & Cooper, 2016). Energy interventions targeted at households vary widely and can involve engineering retrofits to the home, energy audits, in-home displays, education, changes to energy tariffs, incentives, influencing social norms, or various multifaceted behaviour change initiatives (Geller, Harrington, Rosenfeld, Tanishima, & Unander, 2006). As the electricity and societal landscape evolves, more information is needed on the relevance and efficacy of these campaigns in order to guide the role of government in electricity management now and in the future. A key question for energy policymakers is which of these different approaches are most effective in encouraging energy efficiency while maintaining a reasonable level of comfort and wellbeing for householders? Such insight can help ensure that energy policy and interventions are evidence based and more effective. Indeed, energy researchers (see Sorrell, 2007) have already recognised the need for evidence-based policy and practice (EBPP). A useful way to inform EBPP in energy is through the use of systematic reviews of the research evidence.

Purpose and objectives

For the purpose of this report, we refer to any energy efficiency scheme, program or initiative that aims to improve residential energy efficiency as an intervention. In this report we respond to the need for a concise review of the evidence-base on residential household energy efficiency interventions to address five research questions:

- RQ 1. What is the overall evidence of the effectiveness of household energy intervention?
- RQ 2. Which theories/models/conceptual frameworks are used to inform energy interventions, and how do these influence their effectiveness?
- RQ 3. What populations or groups were the focus of household energy interventions?
- RQ 4. Which intervention approaches and elements are used, and which are most effective?
- RQ 5. How are outcomes measured in household energy interventions?

To address these research questions, we use a systematic literature review process to focus the research and achieve holistic insights.

Energy efficiency context

The definition of energy efficiency used in this paper is “energy efficiency is using energy wisely and economically to sustain everyday life, live comfortably and support wellbeing” (Butler, Gordon, Roggeveen, Waitt, & Cooper, 2016, p.152). We have selected this definition due to the inclusion of the concepts of both cost-saving (economic) and co-benefits such as health (wisely). This broader approach to energy efficiency is aligned with the purpose of policy to provide affordable services that foster citizen wellbeing. Policymakers worldwide have identified energy security, sustainability and equity as the great trilemma of modern times (World Energy Council, 2016). As Australia, much like the rest of the world, struggles to ensure sustainable energy for its citizens, energy efficiency becomes ever more critical. Indeed, Australia is ranked poorly for energy efficiency when compared to other major developed countries, coming last out of 16 countries, indicating that there is a great deal more that can be done to improve (Castro-Alvarez, Vaidyanathan, Bastian, & King, 2018).

Household energy efficiency plays an important role by ensuring usage is sustainable and reducing strain on the grid, leading to energy supply that is more reliable, cheaper and more accessible to all (i.e., over-usage strains the grid, leading to blackouts and eventual investment in supply capacity, which necessarily raises prices and puts vulnerable consumers at risk). However, in part due to a delayed feedback mechanism with electricity use (Rothschild & Gaidis, 1981), there is a lack of visibility of energy usage and the impacts of efficiency changes – even when technology is available that addresses this delay, access and utility of these data are issues (i.e., smart meter data not available everywhere, or when provided is often not in a consumer-friendly format, or consumers are not able to understand and use the data). Hence, energy efficiency interventions are a key component of ensuring successful energy efficiency for the benefit of consumers, suppliers and society as a whole.

Between 2012 and 2016 the Australian Government awarded over a hundred million dollars to various interventions to support industry, community and individuals to manage energy usage and costs via the Community Energy Efficiency Program (Hargreave, Mcalester, Walters, & Yao, 2017). “Policy action to improve energy efficiency slowed in 2016, putting at risk the continuation of current efficiency trends” (International Energy Agency, 2017, p/ 37).To understand the effectiveness of energy efficiency for low-income earners the Australian Government ran a national funding initiative, the Low Income Energy Efficiency Program, in 2015–16 to trial different approaches to designing and delivering household energy interventions (Department of Environment and Energy, 2016).

Benefits of this research for energy consumers

Energy consumers bear the brunt of poorly designed energy efficiency interventions or reap the benefits from effective interventions. Increasing the likelihood of success for energy efficiency interventions ultimately benefits consumers as they save money and have long-term reliable access to electricity.

This research will assist the energy industry, policymakers and stakeholders to understand the core design principles that underpin effective energy efficiency interventions for the purpose of developing cost-effective, effective initiatives. Our intent is to:

- improve consumer energy efficiency outcomes through better interventions
- equip policymakers with the evidence to develop policies that encourage development of energy efficient goods and services by suppliers for consumers
- enable industry to confidently design and deliver energy efficiency interventions that will assist consumers in managing their electricity.

Key findings: What works and what doesn't

The findings of the review identified key success and failure features – what works and what doesn't – in a household energy efficiency intervention for a developed economy.

What works

In terms of what works, we identified the following factors as important. There are three broad categories of intervention features that can either enhance or detract from the success of interventions: design, process and evaluation (see Figure 1). A number of themes emerged from the evidence of what does and does not work. It should be noted that even though these are for three different phases (Design, Implementation, and Evaluation phases – please see), these insights as to what works actually apply to all phases. For instance, the importance of deciding on clear aims and objectives (Design phase), influences how the intervention is conducted (Implementation phase) and how it should be measured (Evaluation phase).

Design

1) Develop insights that are region-/population-specific before conducting an intervention.
2) Use appropriate social/behavioural theories to guide intervention design, implementation and evaluation.

Implementation

3) Using multiple intervention components that combine elements such as home retrofits, home audits, education and information, behaviour change marketing and technologies like in-home displays can increase the chances of successfully impacting energy efficiency.
4) Interventions should be segmented, targeted and tailored to the relevant target populations and situational contexts as far as is possible.
5) Overall, the most effective intervention elements were home retrofits, digital tools (e.g., websites or apps) and workshops/training to support positive energy efficiency outcomes.

Evaluation

6) Identify clear aims and objectives from the outset and use appropriate methods to ensure that success can be evaluated. For example, if aiming to reduce electricity consumption, kWh reduction provides an objective measure; if aiming to increase awareness of energy efficiency then carefully designed surveys or interviews may be used.
7) Intervention measurement and impact and outcome evaluation, including measurement of co-benefits, cost effectiveness and return on investment (ROI), should be designed from the beginning of any intervention.

Figure 1 Three phases of an intervention - Design, implementation and evaluation

What doesn't work

In terms of what doesn't work, we identified the following factors for consideration:

Design

1) Not generating consumer insight and being aware of householders' preferences when designing an intervention can lead to failure. For example, many householders are unwilling to upgrade energy-inefficient heating systems if they regard them as very reliable.
2) Failure to understand and acknowledge contextual differences across geographic locations and demographic and cultural groups can result in interventions that are not appropriately designed and tailored for purpose.

Process

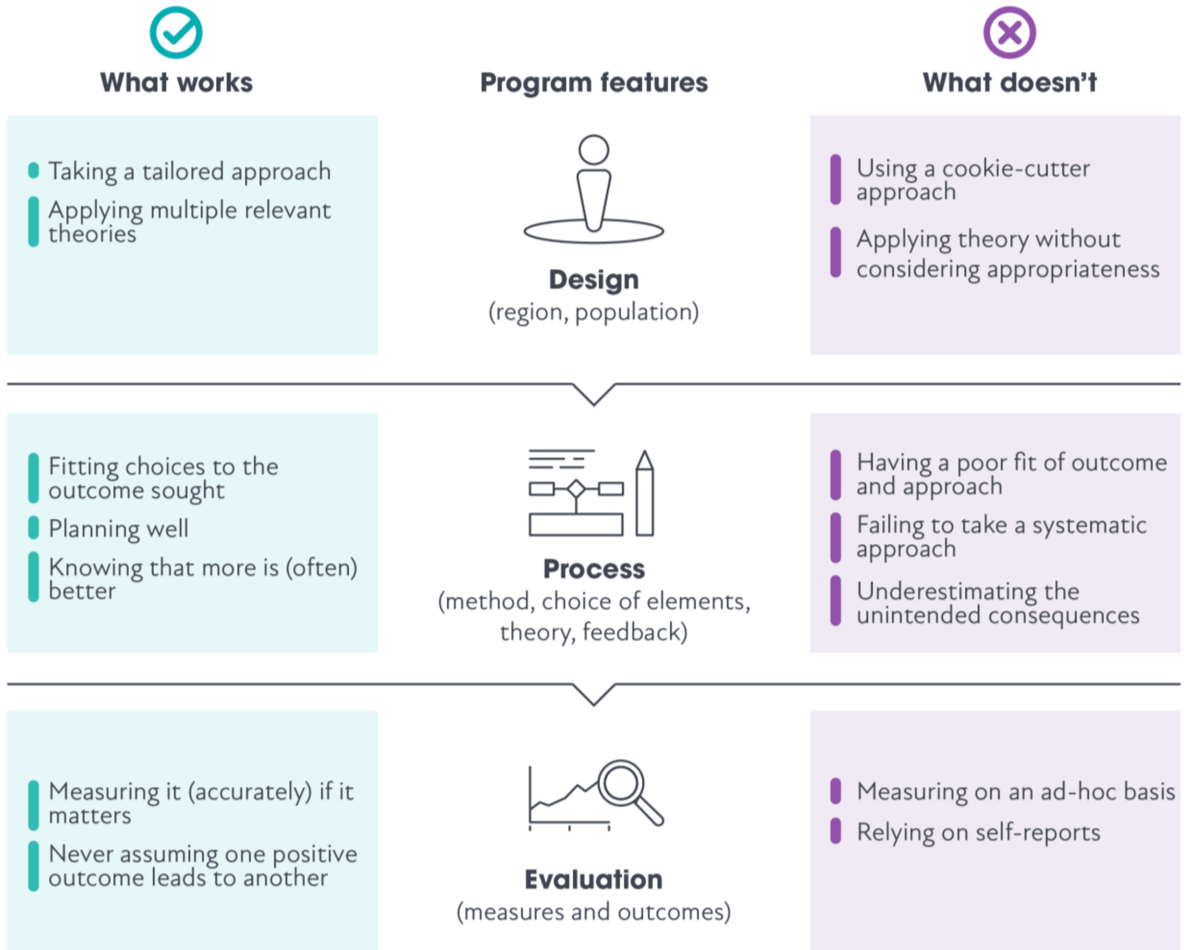
3) Failure to use appropriate social/behavioural theory affected the likelihood of success.
4) Delivering household energy efficiency interventions that incorporate some upfront costs borne by households can affect the chances of success. Upfront costs can be deemed too high by some households and may lead to a lack of participation in interventions even if over the long term they would be cost-effective.
5) Relying on providing energy usage feedback alone in interventions has mixed results. It is better to combine different feedback types (i.e., particularly cost and usage feedback) to householders.

Evaluation

6) Failing to identify clear aims and objectives, and agreeing on and designing-in impact and outcome evaluation measures from the start makes it difficult to evaluate the effectiveness of household energy interventions.
7) Household energy efficiency interventions that rely on consumer self-report measures may overestimate the perceived benefits, and more objective measures (such as kWh) should be used as far as possible.
8) Cost effectiveness and ROI is rarely reported in the household evaluation.

A summary of the main themes emerging from the findings around what works and what doesn't is represented visually in Figure 2.

Figure 2 Energy efficiency interventions – What works and what doesn't



Insights and policy implications

There were six categories of insights about energy efficiency interventions derived from the findings of the systematic literature review:

1. Energy efficiency is complex: A multi-layered approach is needed
2. Relevant benefits increase engagement: What's in it for me?
3. Unintended consequences can derail success: Caution advised
4. Targeted and relevant approaches work: Context matters
5. Intended goals should inform beginnings: Plan for strong evaluation
6. Guidance keeps interventions on track: Use theory appropriately

These insights each have implications for future energy policy, advocacy, innovation in the supply of goods and services, and provision and sale of energy. As such, each section presents the insight(s) followed by the resulting implication.

Energy efficiency is complex: A multi-layered approach is needed

Insight: Multiple types of feedback were more effective

There are five types of feedback that can be provided to households: usage, cost, emissions, health and social norms. Usage feedback was the most commonly used but on its own achieved mixed results, with only 50% of interventions achieving successful outcomes based on this feedback alone. Combining usage feedback with the other types of feedback significantly increases the success rate. Once usage feedback was combined with other forms of feedback – particularly cost feedback – the success rate increased to 88%.

Insight: Multiple intervention elements (and levels) were more effective

Most interventions (54%) had a single intervention element, while 25% used two intervention elements or more. Intervention elements include: information/education, pricing intervention elements (tariffs, rewards), smart meters/in-home displays, home retrofit, home audit, policy changes, digital (web/app) and workshops/training. An intervention might therefore combine providing education with the support of a digital app. The number of intervention elements has a direct impact on the success of the intervention: as the number of intervention elements increases, success is likely to increase. It should be noted that even though most interventions were at the individual or micro level, macro-level interventions can be just as successful – indeed, depending on the outcome sought, sometimes the macro level is more appropriate. Interventions across multiple levels provide a balance.

Insight: Most energy efficiency interventions achieve their aims; however, comparability is difficult due to the variation in definitions and measurement

The evidence for the effectiveness of energy efficiency interventions was very positive, with over 84% of interventions resulting in positive energy efficiency outcomes. However, while many studies reported a reduction in kWh as their key outcome, the systematic literature review actually uncovered five types of energy efficiency outcomes evident for energy efficiency interventions; adoption of energy efficiency technology, awareness and knowledge of energy efficiency information and practices, energy efficiency behaviour, bill savings and electricity/gas reduction (kWh). It is important to select how effectiveness will be determined based on what is appropriate to the given context.

Implication: Use multi-layered approaches operating at the macro, micro and individual levels, and multiple intervention elements

Energy behaviours are complex and are subject to multiple levels of influence on behaviours and outcomes working at the macro level (e.g. policy, social norms), micro level (workplaces, local communities) and individual level (householders). Currently, most energy efficiency interventions focus on individuals, creating an implicit assumption that the responsibility for energy efficiency rests solely with the consumer. However, the wealth of evidence from the behaviour change literature indicates that individuals alone cannot address wicked and complex problems such as energy efficiency, and therefore whole-of-systems interventions working at the macro level (e.g. policy change, shifting social norms, infrastructure), micro level (e.g. community development and support) and individual level (e.g. home retrofits, information and education) are required. Policymakers and relevant stakeholders should work to ensure that there are multiple intervention elements featured in household energy efficiency interventions, as the likelihood of success is greater.

Relevant benefits increase engagement: What's in it for me?

Insight: Information at a convenient, timely location assists adoption of energy efficiency technology

Interventions using information and smart meter/in-home displays provided immediate benefits for people and encouraged adoption of technology, such as adding thermostatic controls to their radiators, solar PV, and adding lagging jackets to hot-water tanks. According to the EAST framework from behavioural economics, in order to create lasting change, the desired behaviour must be easy, attractive, social and timely – hence these intervention elements make it easy (consumers do not have to act), attractive (immediate benefits to comfort and cost), social (affects the whole household) and timely (feedback is immediate).

Insight: Feedback that is clear and shows the benefits for the customer is effective

The most effective combination of feedback types was usage and cost. The reason for this may be that this information is clear, objective and inherently relevant to households – it neatly links cause (usage) and effect (cost) and helps to close the feedback loop that so often makes electricity habits hard to shift.

Implication: Ensure that energy policies and interventions are consumer-centred

Energy efficiency interventions need to be sensitive to peoples' needs, wants, desires and lifestyles. Generating consumer insight through research and engagement is a critical precursor to the design, delivery and success of interventions. Ideally, household energy efficiency interventions should involve working with and alongside householders, and foster co-design and co-delivery of intervention components.

Unintended consequences can derail success: Caution advised

Insight: Some interventions had unintended effects

Improvement in one aspect of a consumer's life can lead to detriment in another. Consider for instance those living below the poverty line, who appear to be very energy efficient but, in reality, are simply sacrificing their health and wellbeing to ensure a lower energy bill. It is therefore important for holistic measures to be utilised to ensure that any gains in energy efficiency are not at the consumers' expense.

Insight: Some interventions can backfire

Notably, sometimes interventions did not only fail to achieve a positive outcome but instead created the opposite outcome from what was intended. This effect was most commonly seen in home audits, smart meters/in-home displays and pricing interventions. This could be due to a number of factors, for instance consumer reactance (not wanting to be told what to do) or moral licensing (consumers find they are doing well in one area, and then tend to do worse in another).

Implication: Be mindful of unintended consequences

Our review identified that some household energy efficiency interventions can backfire and generate unintended consequences and negative effects. Therefore, careful scoping and scenario planning is required prior to delivering interventions. Pilot-testing interventions and their consistent components can be a good way to identify unintended consequences and mitigate these prior to full intervention launch. Interventions that may have been successful in one context may not necessarily succeed in a different jurisdiction, and therefore direction policy and intervention transfer should be carefully considered, and local contextual factors accounted for.

Targeted and well-planned approaches work: Context matters

Insight: Country-specific data are not necessarily transferable

The United States of America (USA) was the dominant country in the literature, with over 35% of all studies examining energy efficiency in a North American context. However, the climatic, infrastructure, social, cultural, political and technological environment of countries limits the transferability of evidence from one country to another. Hence, energy efficiency studies should be critically examined before their findings are applied to a different country.

Insight: Limited targeting of specific populations

The vast majority of the studies examined in this systematic literature review used general population approaches. This was largely due to random sampling and a lack of targeting. Indeed, rather than focusing on specific groups of people, energy interventions appear to be focused around housing types such as apartments (see Asensio & Delmas, 2016), homes with specific energy devices like Solar PV (see Hondo & Baba, 2010), specific geographic regions where an electricity network operated (see Allcott, 2011), or sometimes a combination of both housing type and area served by utility (Alberini & Towe, 2015). This means most interventions are tested where it is convenient to do so, and hence have missed focusing on some vulnerable consumers, high users of electricity or even the more advantaged.

Insight: The intervention needs to reflect local climatic and socio-cultural practices

Interventions that leverage local practices; that is, energy activism in countries or regions where activism is high will enhance outcomes. Indeed, Stephenson et al.'s (2010) seminal study found the significant importance of different 'energy cultures' and developed a model allowing for these cultures to be considered when developing interventions designed to change energy behaviours(Stephenson et al., 2010). Such considerations should be made during the design phase of interventions, as alignment with local socio-cultural practices as well as more pragmatic concerns such as climate, can dramatically influence an intervention's success.

Implication: Context really matters – ensure that policies and programs support the segmentation, targeting and tailoring of interventions according to the specific context

While the majority of household energy efficiency interventions take a general population approach (e.g. 90% of those identified in this review), those interventions that feature segmentation, targeting and tailoring of intervention components tend to be more effective. Policymakers should acknowledge the unique characteristics of target population groups, and their geographic, social, cultural, political, technological and environmental context. Pilot interventions can also be used to ensure interventions are fit for purpose in a specific context.

Intended goals should inform beginnings: Plan for strong evaluation

Insight: Effectiveness depends on the outcome sought

The review showed that different intervention techniques were more or less effective for different outcomes. Knowing the outcome that is sought will guide the intervention that should be pursued. To reduce overall household electricity consumption, look first at retrofitting as this will have a greater impact than pricing. When seeking to change specific behaviours (e.g., turning off lights, etc.), workshops tended to be more effective than changes to government energy policy, while those interventions looking for bill savings were more effective when they involved policy change than when pricing interventions (such as increasing prices) were involved. Once the outcome is decided, only then can the appropriate technique be selected – looking at a list of 'most to least effective' interventions is simplistic and misleading.

Implication: Be clear about defining aims and objectives, and desired outcomes and impacts

It is critical to be clear about what the aims of objectives are for specific household energy efficiency interventions. While we found that most interventions are effective, comparability is difficult due to the variation in definitions of energy efficiency (e.g. only reducing kWh energy use, or also concerning comfort, health and wellbeing) and what success means. Some interventions may aim to reduce overall energy consumption as measured in kWh, while others may aim to produce health or wellbeing co-benefits. Therefore, aims and objectives need to be identified clearly at the outset of any intervention, and outcomes that are Specific, Measurable, Achievable, Relevant and Time-Bound (SMART) should be set to evaluate success.

Insight: A claim of success does not equal reduction in electricity usage

The review identified that 90 out of 107 interventions resulted in positive energy efficiency outcomes. However, a finer-grained analysis reveals a mixed story of success. There is wide variety in the energy efficiency outcomes targeted and measured in these interventions, with only 51% defining success as a reduction in electricity use as measured by kWh. The remaining 49% of interventions measured other energy efficiency outcomes, such as awareness/knowledge, use of technology and practices. Evidence demonstrates that awareness/knowledge does not always translate into a corresponding reduction in kWh, therefore claiming success on the basis of a psychological or behaviour measure as a proxy for electricity usage is misleading. Also important is that most interventions do not report cost-effectiveness or ROI, which is unhelpful for policy and future intervention design.

Implication: Good evaluation is the key to demonstrating success

Evaluation of the process, outcomes and impact of household energy interventions is crucial to demonstrate success. Our review found that sound evaluation was not always a strong feature of interventions. A robust framework for evaluation should be considered and incorporated at the start of any intervention, including a way to measure ROI if appropriate. It should also be designed to suit the context of the intervention, the outcomes sought and the resources available – drawing upon the full range of quantitative statistical and qualitative methods available as appropriate.

Guidance keeps interventions on track: Use theory appropriately

Insight: Theory use is not clearly reported

Using theory can be an excellent way to guide an evidence-based intervention; however, the findings at first glance indicate that successful interventions did not need theory. Theory: provides a framework for conceptualising and analysing the process of behavioural influence and change, guides research regarding specific behaviours, and assists with planning and selecting household energy efficiency interventions. Many of the intervention details indicate an implicit use of theory but did not report that theory. This may be due to the differing requirements of journals about the use and reporting of theory as well as the lack of need in industry and government reports to include theoretical bases. There is a substantial evidence base in the behaviour change literature that demonstrates the value of theory for intervention success (Carins & Rundle-Thiele, 2014; Thornley & Marsh, 2010) so our findings may be an anomaly.

Insight: Interventions using multiple theoretical frameworks were more effective

Less than half of the 107 interventions (46%) reported the use of theory, models or conceptual frameworks in their design, implementation and evaluation – though some interventions may have used theory implicitly without reporting it. The most common approach drew on social norms theories, featuring in six interventions. In general, those interventions explicitly reporting theory-use were less successful than those not reporting it, with the exception being those studies using multiple theories in combination. This approach recognises the complex and multifaceted nature of energy efficiency, and may explain the greater success rates here.

Insight: Interventions with social and behavioural theories were more effective

The review indicated that the theories that were used most often (and most successfully) were those that used social norms, behavioural economics and economic theory. These approaches are successful because they focus on what matters to the consumer, not to the expert (i.e., what other people do/think, what value is in it for my household, etc). It is common that there is a disconnect between the experts/policymakers, who may see issues from a macro perspective, and the consumers, who are operating from a micro perspective. Theories that help address this disconnect are most effective.

Implication: Make use of appropriate social/behavioural theory to guide the design, implementation and evaluation of household energy efficiency interventions

Our findings identified the use of theory as an important success criteria for household energy efficiency interventions. Theory is critical to any efforts to bring about behavioural and social change as it relates to the underpinning ideas about why something is the way that it is, and the key factors influencing this. Theories are used to describe, classify and predict future behavioural responses. Therefore, theory: provides a framework for conceptualising and analysing the process of behavioural influence and change, guides research regarding specific behaviours, and assists with planning and selecting household energy efficiency interventions.

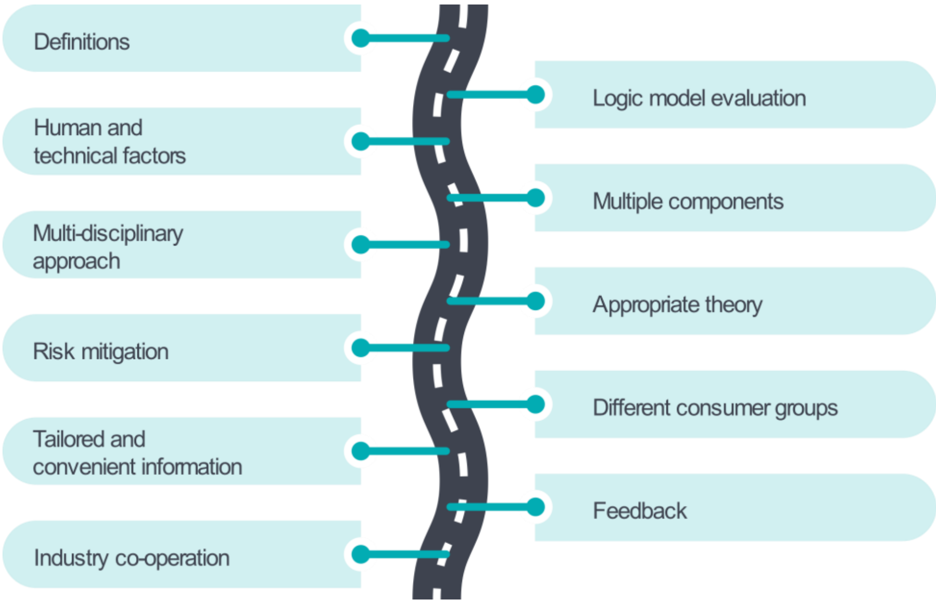
Recommendations for policy, industry and advocacy

The insights derived from the findings have been used to develop a roadmap (see Figure 3) and specific recommendations for the design and delivery of effective household energy efficiency interventions.

Future roadmap and recommendations

The insights presented provide a roadmap for the best way forward. This roadmap requires consumer advocates, policymakers and industry professionals to work together.

Figure 3 Roadmap for the future



Key items of importance are:

- developing and applying a consensus definition of energy efficiency
- use of a logic model in intervention planning to ensure outcomes and impact are distinct, and to assist with a plan for appropriate measurement
- ensuring that both the technical and human factors that motivate and create barriers for energy efficiency are part of the intervention design and delivery
- designing and recommending interventions that go beyond a single-shot simplistic approach
- encouraging multi-discipline teams to work together on multifaceted interventions.
- ensuring that theory, if used, is reported
- engaging in risk-mitigation strategies for interventions
- understanding regional differences and the need for targeted populations, and designing these into interventions
- incentivising the diffusion of energy technology that allows for tailored, convenient feedback and information
- facilitating industry cooperation to provide personalised information about electricity usage in a convenient, immediate manner.

Following on from the roadmap, specific recommendations are provided in Table 1.

Table 1 Recommendations for leveraging the insights

Insight	Recommendation – policymakers	Recommendation –advocacy groups	Recommendation – Industry
Most energy efficiency interventions are effective; however, comparability is difficult due to the variation in definitions	Incorporating a consensus definition into government promotional materials and policy documents	Guiding and promoting a consensus definition of energy efficiency	Ensuring intervention development is in line with consensus definition
A claim of success does not equal reduction in electricity usage Effectiveness depends on the outcome sought	Government-funded interventions should require a logic model of evaluation in the design of the intervention Objectives of the intervention need to mirror the evaluation stage	Provide guidance on the outcomes required to generate energy efficiency impact	Broader perspectives are needed on positive outcomes that are possible, beyond electricity wattage reduction
Theory use is not clearly reported Interventions with social and behavioural theories were more effective	Government-funded interventions to report theory basis if it is used Ensure that both the technical and human factors that motivate and create barriers for energy efficiency are part of the intervention design and delivery	Develop guidelines for reporting theory or frameworks	Ensure that the frameworks/models/mechanisms by which interventions are guided are comprehensively mapped and detailed in pre-design/implementation and evaluation stages
Interventions using multiple theoretical frameworks were more effective Multiple types of feedback are more effective Multiple intervention elements were more effective	Design and recommend interventions that go beyond a single-shot simplistic approach Incentivise multi-discipline teams to work together	Promote the need for multiple frameworks to be used in energy efficiency interventions	Investigate where combining frameworks can overcome potential limitations
Some interventions can backfire Some interventions had unintended effects	Include the potential hazards in risk-mitigation strategies	Develop tips and guidelines for avoiding unintended and negative effects for consumers	Resources and procedures should be devoted to investigating/reporting unintended consequences (backfires) of interventions
Country-specific data are not necessarily transferable Limited targeting of specific populations The intervention needs to reflect local climatic and socio-cultural practices	Where regional differences are likely to yield different results in an energy efficiency intervention, pilot specific and targeted interventions to build the evidence base	Identify regions and population groups that require different approaches in an energy efficiency intervention	Even within the same country, regional differences exist – energy efficiency interventions should be adapted for each region being targeted
Feedback that is clear and shows the benefits for the customer is effective. Information at a convenient, timely location assists adoption of energy efficiency technology	Incentivise the diffusion of energy technology that allows for personalised, convenient feedback and information Facilitate/regulate industry to provide personalised information about electricity usage in a convenient, immediate manner	Advocate for technology to be accessible and convenient for all population groups	Enhance customer value and loyalty by providing personalised information about electricity usage in a convenient, immediate manner

Design principles for effective energy efficiency interventions

When developing the roadmap and a path forward, seven design principles derived from the findings and insights can form a foundation for future implementation (see Table 2). Design principles are guiding criteria for the development of any intervention.

Table 2 Design Principles

Design principles and description
Evidenced Based: There is a sizeable evidence base available of different types of energy efficiency interventions, the elements used and the outcomes/impact sought. This evidence-base should be the starting point for the design and delivery of interventions or services.
Easy and Informative: Consumers are already overwhelmed by the sheer volume of information and tasks that come their way each day. As governments around the world focus on 'consumer empowerment', demands on consumers to take an active role in all aspects of their life increase. Interventions that require less effort (like structural changes or simple swaps) therefore have a greater chance of being effective.
Positive and Helpful: Consumers do not wish to feel judged or deprived. Interventions should come from a positively-framed perspective and show how they will help the consumer – rather than simply giving them another thing to worry about.
Personalised and Relevant: Interventions should be focused on the specific target audience they seek to influence and should be tailored to this group. Personalised and relevant interventions have a greater chance of consumer involvement.
Measurable: The influence of interventions should be able to be easily and accurately measured. During the initial planning for interventions, decisions should be made on the exact outcome or impact sought and how this will be measured.
Easy to Find: To enable interventions – and learnings from interventions – to have their full impact, they need to reach the right people. When interventions are planned and designed, a plan for a communication strategy to support dissemination to relevant stakeholders should occur at the same time (i.e., Who needs to see it? When? Where and how will they find it?). This may mean taking small, practical steps like completing journey mapping, boosting Search Engine Optimisation (SEO), ensuring correct keywords are used and placing the information on relevant databases.
Balance Ideal with Reality: The need to align the outcome or impact with the available resources and constraints of the organisation is a strong consideration. Matching the design, process and evaluation approach with the available resources overrides an aspirational ideal.

Suggested future funding for electricity efficiency initiatives

From the research, three themes regarding potential future electricity efficiency funding for initiatives emerged. These three themes, "*Which combinations work best and for who?*", "*Walking in the shoes of the consumer (taking a consumer perspective)*" and "*Developing a consistent benchmark framework for electricity efficiency*", provide strategic insight into where resources/funding can be allocated to gain a greater understanding of successful interventions.

1. Which combinations work best and for who?

A key finding of the research was that a combination of structural (installations) and behavioural approaches were the most effective. This provides a strong evidence base that future funding of energy efficiency interventions should be cautious of funding explorations of interventions or research which rely on leveraging one element (i.e. education) to achieve significant electricity efficiency changes. Instead, from the findings of this research, it is suggested that there needs to be a stronger focus and preference for funding interventions and research which explore a combination of approaches to change electricity efficiency. In addition, a finding from the research suggested that many of the interventions took primarily a holistic (whole) market approach. This is counter to key marketing principles whereby strategies should be tailored towards a target market to ensure greater ROI. This leads to the proposition that a key initiative for future funding should be investigating "Which combinations work best and for who?" This initiative can be guided by the following set of research questions:

1. What combinations of behavioural approaches are the most effective?
2. What combinations of structural approaches are the most effective?
3. What combinations of behavioural and structural approaches are the most effective?
4. What combinations with structural/installation-based interventions are the most effective?

2. Walking in the shoes of the consumer (taking a consumer perspective)

Another key finding of the research was that there is currently a lack of understanding both from practice and research as to the consumer perspectives of electricity efficiency. This is not to be confused with simply consumers' preferences to be energy efficient or "save the environment". Instead, this finding suggests future funding initiatives should focus on interventions which seek to provide a deeper understanding of the key consumer motivators and inhibitors for electricity efficiency. These motivators and inhibitors can and should include cultural, structural, economic and psychological factors which collectively contribute to consumers' ability to use electricity in a desired way. Funding future initiatives that seek to understand such factors and "walking in the shoes of the consumer" is important to ensure interventions are designed in such a way that they match the situation faced by consumers and maximise initiative effectiveness. To address this research priority, "Walking in the shoes of the consumer", the following research questions are suggested:

- What are the main consumer cultural motivators and barriers to electricity efficiency?
- What are the main consumer structural motivators and barriers to electricity efficiency?
- What are the main consumer economic motivators and barriers to electricity efficiency?
- What are the main consumer psychological motivators and barriers to electricity efficiency?

3. Developing a consistent benchmark framework for electricity efficiency

A common theme that emerged from the systematic review is that there are multiple, and at times conflicting, key performance indicators for electricity efficiency interventions. This suggests there is a need for a methodical process by which criteria and a framework are set for measuring the effectiveness of electricity efficiency interventions. Future funding should therefore be devoted to undertaking a multi-disciplinary approach to generating a set of criteria and or a framework by which the success of energy efficiency interventions can be assessed and compared. The questions which should be explored in developing the criteria/framework are:

- What is/are the electricity production key performance indicators for electricity efficiency interventions?
- What is/are the environmental key performance indicators for electricity efficiency interventions?
- What is/are the consumer key performance indicators for electricity efficiency interventions?

Method and approach

A systematic review attempts to collate all relevant evidence that fits pre-specified eligibility criteria to answer a specific research question (Moher et al., 2015). Furthermore, a systematic review uses explicit, systematic methods to minimise bias in the identification, selection, synthesis and summary of studies (Moher et al., 2015)As such, this systematic literature review followed the steps recommended by Sorrell's (2007) work on the role of systematic reviews in improving the evidence base for energy policy. The caveat to note is that this literature review is systematic not comprehensive, which means that research may exist that could have been useful but was not identified in the search and screening stages.

Limitations of this method are:

- Issues in searching for grey literature have been identified by Mallet, Hagen-Zanker, Slater and Duvendack (2012, p. 449): "differences in websites' search functions mean that search strings have to be either adapted or discarded altogether, and relevant websites may be excluded, whether unintentionally (lack of knowledge) or otherwise (time/resource constraints). This means that potentially high numbers of pertinent studies can be missed."
- The systematic review process is an extremely resource-intensive and time-consuming process often in part due to the higher number of studies that need to be individually screened (Mallett et al., 2012). As noted by Mallet and co-authors (2012), "since doing a systematic review properly implies following the same protocol for each study, each article had to be thoroughly screened and assessed – no short cuts could be taken."
- Another potential limitation is the use of participant self-ratings; individual studies can also be influenced by the decision-maker's perceptions and views (Wallace, Nwosu, & Clarke, 2012). Study design comparisons between papers can be hard to conduct as researchers have carried out their investigations in different ways (MacGill, 2019).
- An alternative method would be a meta-analysis, which statistically compares interventions with similar intervention designs and with similar outcome measures. However, meta-analyses are required to be heavily standardised and strictly conducted. They are much more common in areas where random controlled trials are possible such as pharmacy, where a controlled dosage of a drug can be administered to patients who are blinded to treatment or controls; whereas in energy interventions, blinding households and administering retrofits or new technology is much more difficult, if not impossible.

Systematic literature review stages

As outlined in Figure 4, the stages of the review process start with a clear specification of the research question or questions to be addressed, followed by an exhaustive search of the available literature. Next, an explicit criteria for the inclusion or exclusion of studies is applied, the quality of the included studies is appraised using transparent and standardised criteria and, finally, the results are summarised and synthesised in an objective manner, with the dissemination of results to the appropriate audience (Sorrell, 2007).

Figure 4 Stages in the systematic review process

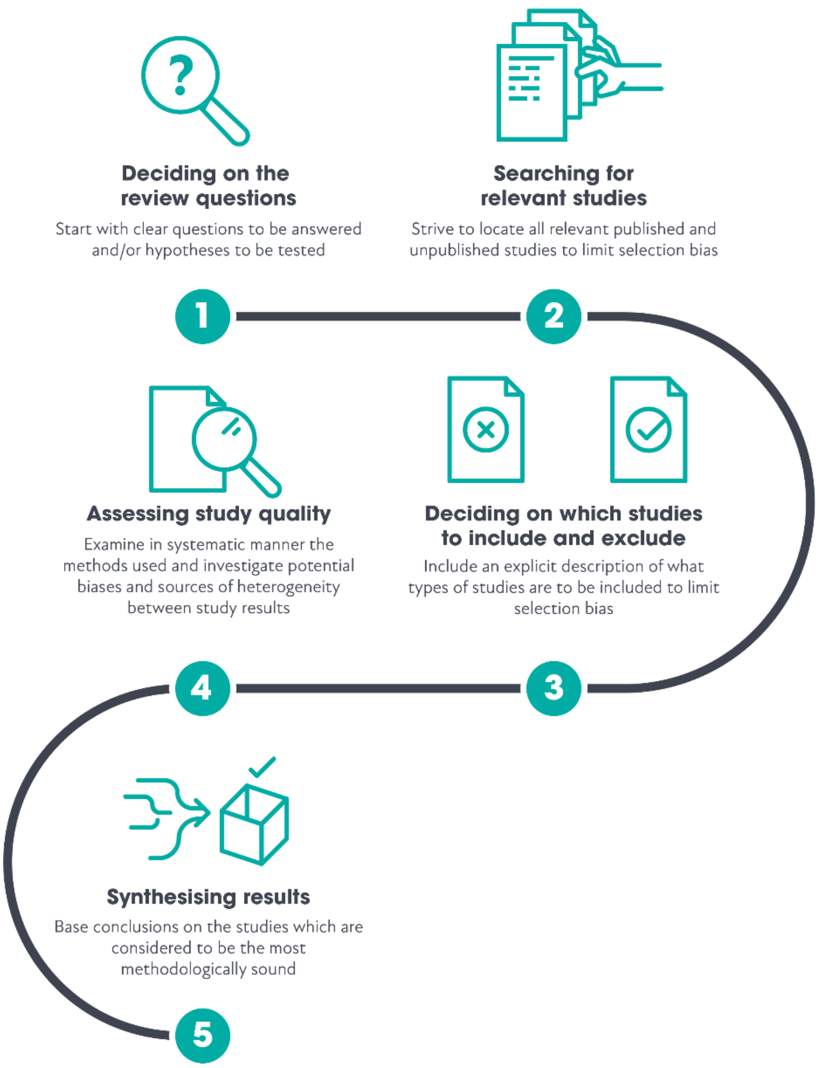


Figure adapted from Sorrell (2007).

Search and screening process

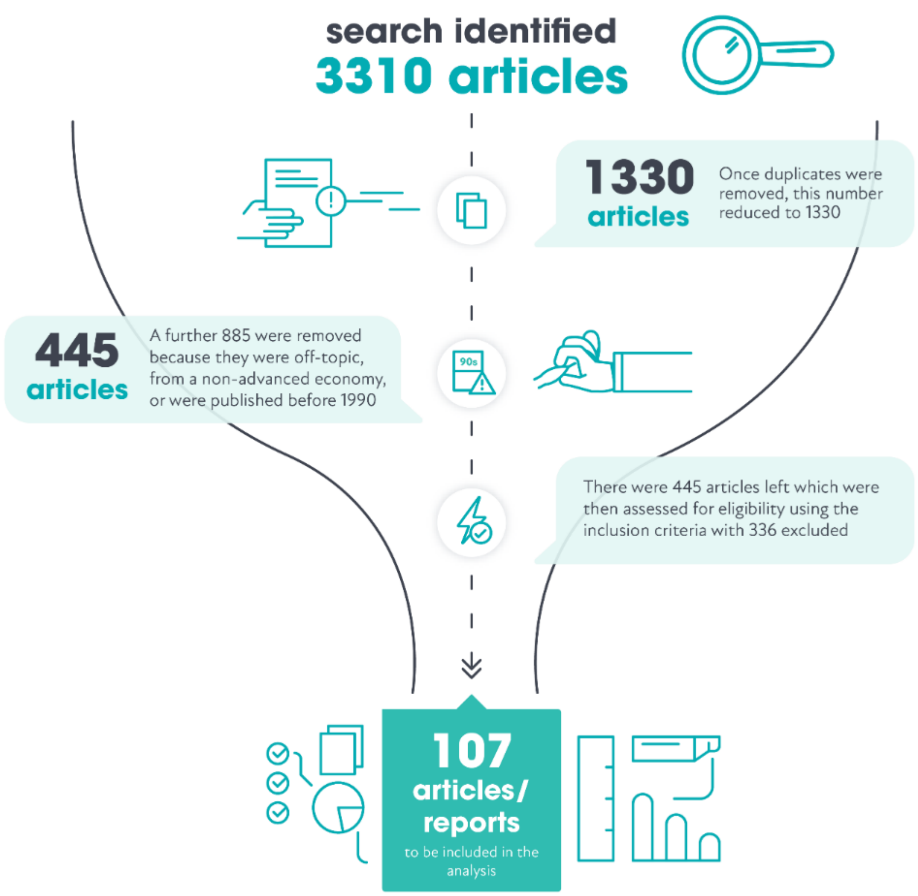
Three major databases (Web of Science, Scopus and ScienceDirect) were used to search for potentially relevant abstracts. These databases cover a wide range of published research in the fields of business, social science and engineering/built environment, with a total of over 100 million records. Search parameters included English-only manuscripts published prior to October 2017. Grey literature (reports and government documents) was also included, however these were limited to documents that were found using a Google search (this means that there are likely to be industry or government initiatives that exist but were not included due to lack of searchability; that is, search engine optimisation keywords). This constraint means that effort is needed when publishing grey literature online to ensure that keywords are included to enable appropriate searches. Inclusion and exclusion criteria were developed for the search (see Table 3). All articles were screened for relevance and quality.

Table 3 Inclusion and exclusion criteria

Focus	Inclusion	Exclusion
Consumer group	Households and homes	Commercial, office and dormitory
Language	English	Language other than English
Time frame	Between 1990 and August 2017	Older than 1990
Paper types	Journal articles	Editorials, conference papers, review, conceptual
Method types	Empirical	Laboratory experiments, formative, methodological
Locations	Advanced economies	

The search identified 3310 articles. Once duplicates were removed, this number reduced to 1330 of which 885 were removed because they were off-topic, from a non-advanced economy or were published before 1990. There were now 445 articles left which were then assessed for eligibility using the inclusion criteria, with 336 excluded. This left 107 articles/reports to be included in the analysis. This number is considered large when applying a systematic literature review process. Figure 5 provides a graphical representation of the screening process for articles.

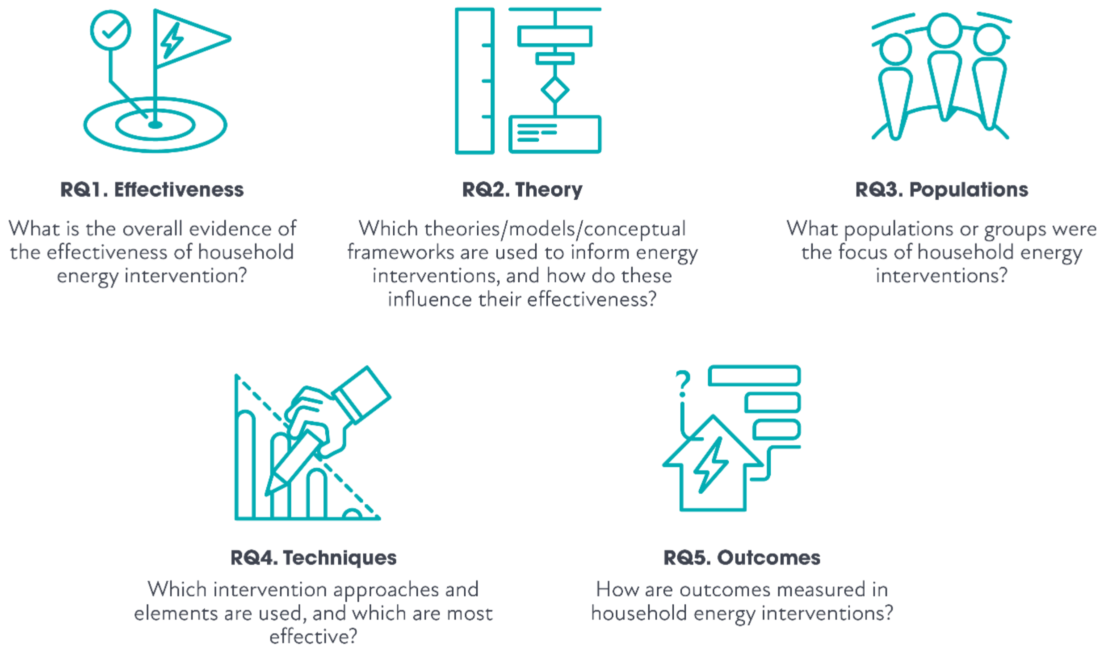
Figure 5 Screening process for articles

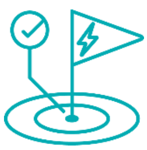


Findings

In addressing the five research questions (see Figure 6), the review identified 107 relevant energy efficiency interventions for inclusion, across 108 papers. One intervention had two published papers which investigated two different research questions (see Boudet et al., 2016, 2014). Interventions were varied in their impact on outcomes, geographic location and targeted populations/sub-groups, techniques and activities used in the intervention, design and outcome measures used in evaluation, and theories/models used to inform their design.

Figure 6 Research Questions





Effectiveness of household energy interventions

The findings from research question one relate to the themes of: *Energy efficiency is complex: A multi-layered approach is needed*; and *Unintended consequences can derail success: Caution advised.* These themes and the following insights also derive information from RQ4. Specifically, three insights are drawn from the findings:

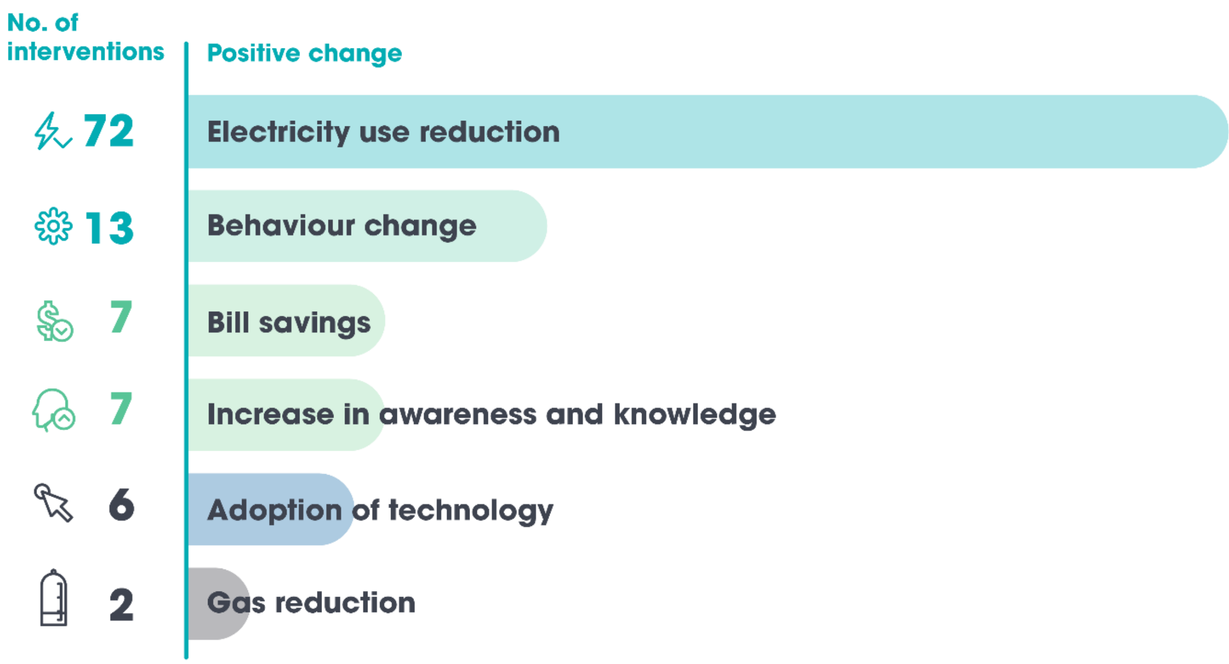
- most interventions achieve their aims, however direct comparability is complex
- unintended effects were found for some interventions
- interventions can backfire

Effective interventions

Of the 107 interventions included in the review, 91 were found to have had a positive impact on reported outcomes, twelve reported no change and four showed a detrimental effect, such as increasing electricity when reduction was the objective (see Figure 8). Thus, the evidence finds support for the effectiveness of household energy efficiency interventions in general. There was a lack of inclusion of energy efficiency co-benefits, such as thermal comfort or reduction in financial stress as outcomes (Bedggood, O'Mahony, Pervan, & Buergelt, 2018). This demonstrates a narrow definition of energy efficiency limited to electricity use (e.g. kWh).

Seventy-two interventions reported a reduction in electricity use, of these 69 measured electricity reduction with a median reduction of 9%. Electricity use reductions among these 69 interventions ranged from 80% for a comprehensive energy retrofit (Akbari, Bretz, Kurn, & Hanford, 1997) to 0.5% for a financial policy change intervention (Ó Broin, Nässén, & Johnsson, 2015). Thirty-five interventions reported other positive impacts on outcomes such as positive changes in awareness or knowledge about energy efficiency (seven studies), adoption of energy efficiency technology (six studies), or behavioural changes (thirteen studies), bill savings (seven studies) and gas reduction (two studies; see also Figure 7).

Figure 7 Number of interventions with positive energy efficiency outcomes

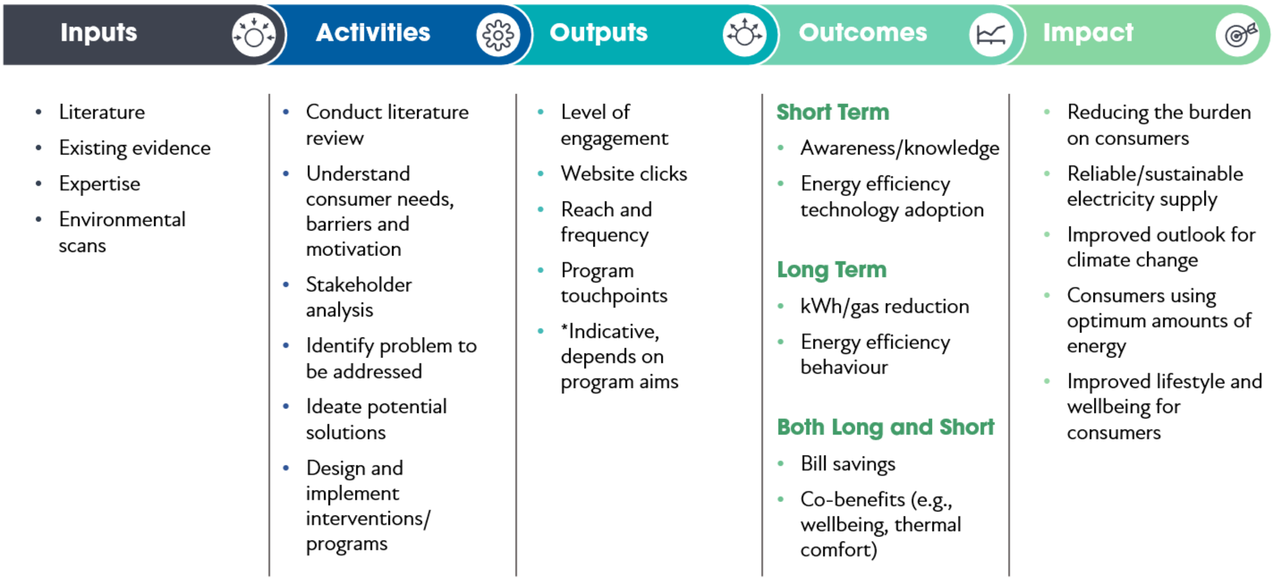


Defining effectiveness

The variation in outcomes ranging from awareness to kWh reduction indicates an assumption that all outcomes may be equal in their relationship to the impact of an energy efficiency intervention. For instance, when an intervention defines outcomes as awareness and then claims success, this may imply that there would be equivalent reduction in electricity usage and impact. Using the logic model of evaluation to classify the results of an intervention (see Figure 8), short-term outcomes such as awareness and knowledge are distinct from long-term outcomes such as behaviour, bill savings and kWh, and cannot be reported interchangeably or as proxies. Likewise, long-term outcomes are distinct from the impact of the intervention. While there may be a causal relationship between short- and long-term outcomes, they are different, and other factors, such as housing structure and ability to enact change, can reduce the relationship.

The impact of the energy efficiency outcomes is difficult to assess due to the variation in the measurement of these outcomes and in some cases no data reported. In particular, qualitative findings cannot be directly compared with quantitative findings.

Figure 8 Recommended logic model approach for energy efficiency interventions



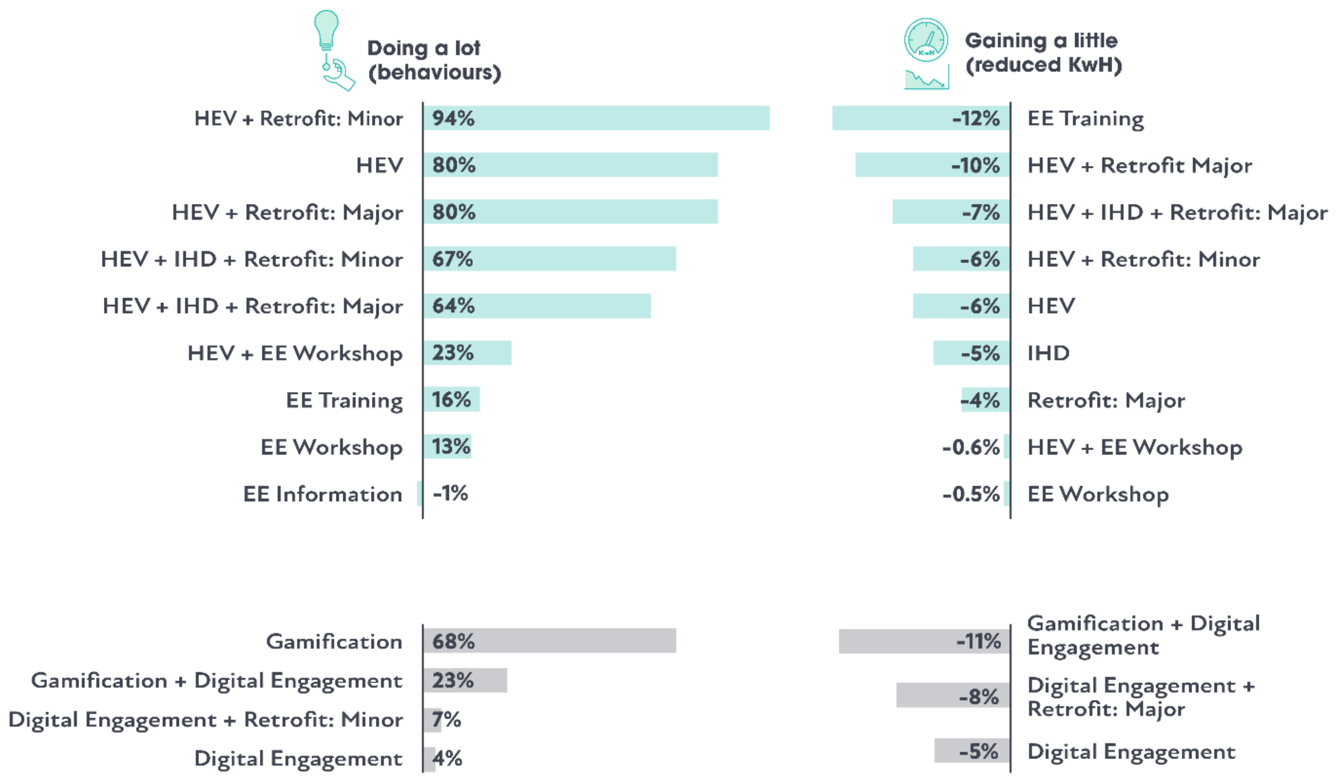
There were five types of energy efficiency outcomes evident for energy efficiency interventions: adoption of energy efficiency technology, awareness and knowledge of energy efficiency information and practices, energy efficiency behaviour, bill savings and electricity/gas reduction (kWh; see Figure 9).

Figure 9 Energy efficiency outcomes

Awareness and the behaviour gap

Prior research is clear that outcomes such as awareness and knowledge do not always translate into behaviours (Christiano & Neimand, 2017) and cannot be used as proxies. In particular the Powershift analysis by the GEER group on the 2015–16 Low Income Energy Efficiency Program (LIEEP) found that energy efficiency behaviours such as switching off lights and keeping the air conditioning at 24 degrees did not necessarily lead to the corresponding change in kWh and bill savings (see Figure 10 and Figure 11).Further, sometimes awareness and knowledge do not translate into the desired behaviours, for instance in studies reported by Tiefenbeck, Staake, Roth, and Sachs (2013) and Jacobsen, Kotchen and Vadenbergh (2010), where consumers engaged in moral licensing or overcompensation with their energy behaviours – in short, making consumers aware resulted in increased kWh (over and above what the participants actually required).

Figure 10 LIEEP program evaluation



Vignette: Retrofits in apartments

One of the most successful interventions was conducted in a Danish apartment complex called Traneparken (Thomsen et al., 2016). The project used an energy retrofit which involved many energy efficiency features, such as: new facades, new windows, additional insulation, mechanical ventilation with heat recovery and a photovoltaic installation on the roof. For the 12.9% (8.6% net) increase in rent, the tenants received a better indoor climate, flats that are easier to organise due to warmer walls and windows, fewer drafts, and glazed balconies overlooking renovated outdoor areas. A dramatic reduction of 31% was recorded, mostly due to the savings made in heating and domestic hot water before and after renovation. In addition, the tenants' overall satisfaction with perceived indoor climate before and after the retrofit was measured and was found to have improved. It should be noted, however, that retrofits can be a high-cost intervention relative to other types of intervention.

Results:

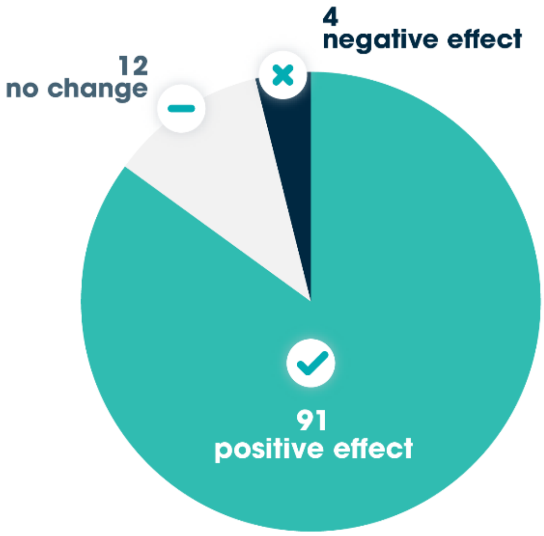
Reduction of 31% in energy use.

Tenants more satisfied with indoor climate.

Limited effectiveness

Twelve interventions reported very limited or no change to the outcome measure, with five showing no change in electricity use, four reporting mixed results in outcome evaluation and three reporting a marginal reduction in electricity use that was not statistically significant. Four interventions reported a negative impact in which there was an increase in electricity use, or where the environmental impact or cost of the intervention was deemed to be too high. Of these four, two reported increases in electricity use, one reported limited success due to high costs and lack of impact on carbon emissions, which were a stated focus in that intervention, and one reported a lack of adoption of energy efficiency grants, which was a stated focus in that intervention.

Figure 11 Impact of energy efficiency interventions



Lessons from Failure

Lessons can also be learnt from failure. There were four interventions that did not achieve their outcomes. The key reasons for these failures were:

- **Moral licensing:** People may adopt constructive conservation practices in one area but these can make people increase usage in other areas.
- **Over-compensation:** Some people largely increased their electricity usage when they enrolled in green-energy interventions, and these increases were not able to be offset by the marginal savings made by other households. In essence, using green energy seemed to reduce people's motivation to conserve energy.
- **Low awareness:** A lack of awareness by some participants of the range of "low energy" devices and bulbs in the marketplace.
- **Expenses:** Upfront costs were deemed too high by some participants, even if over the long term they would be better off financially.
- **Remaining with the status quo:** Unable to upgrade energy-hungry heating systems owned by participants because even though they were highly inefficient they were seen as very reliable.

Vignette: Green energy use increases energy use

Work by Jacobsen, Kotchen and Vadenbergh (2010) investigated a household's decision to engage in a form of environmentally friendly behaviour based on the desire to offset another behaviour that is environmentally harmful. The Green Power Switch (GPS) intervention gave customers the option to purchase electricity from alternative energy sources. They found that people enrolling in a green-electricity intervention increased their electricity consumption by 2.5%. The fact that electricity consumption increases for some households that purchase green electricity raises the question of whether the net effect on emissions is positive or negative for the environment. In essence, using green energy seemed to reduce people's motivation to conserve energy.

Result:

Residents who chose to use green energy used 2.5% more electricity.

Vignette: Moral licensing and electricity use

In the Tiefenbeck et al. (2013) article on moral licensing, the research question was: *Can isolated environmental campaigns focusing on defined target behaviours trigger cross-domain adoption of additional environment-friendly behaviours (positive spillover)?* In this study the real net performance of these interventions was evaluated by investigating the potential positive or perverse side effects dominate by exemplifying the impact of a water conservation campaign on electricity consumption. Drawing on both daily water (10,780 data points) and weekly electricity (1386 data points) consumption data from 154 apartments, their results show that residents who received weekly feedback on their water consumption lowered their water use (6.0% on average), but at the same time increased their electricity consumption by 5.6% compared with control subjects. After comparing possible confounding factors, Tiefenbeck et al. (2013, p. 160) found that their results were "consistent with the concept of moral licensing, which can more than offset the benefits of focused energy efficiency campaigns." Ultimately they advocate for the adoption of a more comprehensive view in environmental intervention design/evaluation in order to quantify and mitigate these unintended effects.

Result:

Residents who received weekly feedback on water consumption lower water use by 6% but increase electricity use by 5.6%

Theories and frameworks that inform energy efficiency interventions

The findings from research question two relate to the theme of *Guidance keeps interventions on track: Use theory appropriately*. Specifically, three insights are drawn from the findings:

- theory use is not clearly reported
- interventions using multiple theoretical frameworks were more effective
- interventions with social and behavioural theories were more effective.

Less than half of the 107 interventions (46%) reported the use of theory, models or conceptual frameworks in their design, implementation and evaluation (see Table 4). The most common approach drew on social norms theories, featuring in six interventions. Four interventions reported the use of a multi-theoretical approach, for example Schultz, Estrada, Schmitt, Sokoloski and Silva-Send (2015) combined feedback theory, social norms theory and framing theory. The remaining interventions may have used theories or frameworks implicitly; however, as these were not reported no assumptions can be made. On closer inspection, many interventions did not explicitly state a theoretical underpinning; however, on reading the details a theoretical approach appears evident. For example, (McCoy and Lyons, 2017) discussed concepts such as moral licensing and priming as possible theoretical explanations for the results, but these were reported as frameworks used.

Table 4 Use of theory in energy efficiency interventions

Theory	Number of interventions using the theory	Successful outcome	Intervention mechanism	Articles
Social norms	6 (6%)	6/6 100%	Pricing mechanism (tariffs, rewards) Information/education Policy changes Home retrofit Digital (web/app) Workshops/training Home audit Smart meter/in-home displays	Allcott (2011), Harries et al. (2013), Ozawa, Furusato, & Yoshida (2017),Podgornik, Sucic and Blazic (2016), Ro, Brauer, Kuntz, Shukla, & Bensch (2017), Schultz et al. (2015)
Behavioural economics	4 (4%)	3/4 75%	Pricing mechanism (tariffs, rewards) Information/education Policy changes Home retrofit Digital (web/app) Workshops/training Home audit Smart meter/in-home displays	Agarwal, Rengarajan, Sing, & Yang (2017), Asensio and Delmas (2016), Cosmo & O'Hora (2017), Guerassimoff & Thomas, (2015)
Theory of planned behaviour	3	2/3 66%	Pricing mechanism (tariffs, rewards) Information/education Policy changes Home retrofit Smart meter/in-home displays	Anda & Temmen (2014), Bjørnstad, (2012), Hondo and Baba (2010)

Theory	Number of interventions using the theory	Successful outcome	Intervention mechanism	Articles
Social practice theory	3	2/3 66%	Pricing mechanism (tariffs, rewards) Information/education Policy changes Home retrofit Smart meter/in-home displays	Murtagh, Gatersleben, & Uzzell, (2014), Schelly (2014), Strengers & Maller (2011)
Economic theory	5	4/5 90%	Pricing mechanism (tariffs, rewards) Information/education Policy changes Home retrofit Smart meter/in-home displays	Alberini and Towe (2015), Havas, Ballweg, Penna, & Race (2015), Ida, Murakami, & Tanak (2016), Ito, (2015) Kirkpatrick & Bennear (2014)
Feedback theory	4	3/4 75%	Information/education Digital (web/app) Smart meter/in-home displays	Iwafune, Mori, Kawai, & Yagita (2017), Nilsson et al. (2014); Ozawa et al. (2017), Schultz et al. (2015)
Learning theory	1	1/1 100%	Information/education Workshops/training	Craig & Allen (2015)
Multi-theoretical approach	6	4/6 66%	Pricing mechanism (tariffs, rewards) Information/education Policy changes Home retrofit Digital (web/app) Workshops/training Home audit Smart meter/in-home displays	Asensio and Delmas (2016), Bjørnstad (2012), Ozawa et al. (2017), Ro et al. (2017),Schultz et al. (2015), Wallenborn, Orsini, & Vanhaverbeke (2011)
No theory evident	58 (54%)	52/58 90%	Pricing mechanism (tariffs, rewards) Information/education Policy changes Home retrofit Digital (web/app) Workshops/training Home audit Smart meter/in-home displays	

The interventions where theory was reported appear to have lower effectiveness than interventions where theory was not reported (see Table 5). However, given that theory may have been present in some of the 58 articles, caution should be taken when drawing conclusions from this finding. Another consideration is whether those studies using theory had more rigorous evaluation processes – a likelihood, as appropriate theory-use requires planning from design through to evaluation.

Very few interventions used multi-theoretical approaches, despite research suggesting that energy use is a complex and multifaceted phenomenon (Owens & Driffill, 2008; Shove & Walker, 2014). Of the six interventions where a multi-theoretical approach was taken, four were effective – hence a 66% success rate is evident.

Table 5 Outcome of use of theory in energy efficiency interventions

Outcome	No theory reported		Theory reported		Total
Positive (electricity reduction)	52	90%	38	78%	
Negative (electricity increase)	2	3%	2	4%	
No change	4	7%	8	16%	
Nothing measured	0	0%	1	2%	
TOTALS	58	100%	49	100%	107

*Note: *Positive* = Achieved their objectives. Reduced electricity usage or increased energy efficiency awareness, behaviour adoption.

Negative = Did not achieve their objectives

No change = No change or very marginal change

Vignette: Gamification and household electricity consumption

A project by Ro, Brauer, Kuntz, Shukla, and Bensch (2017) made use of multiple theories, including normative influence, competition, self-perception, social diffusion and rewards. Ro et al. (2017) designed and implemented a social game that aims at getting individuals to reduce their household-level greenhouse gas emissions, including energy consumption. Using elements of gamification and behaviour change, the study tested its effectiveness in two large-scale field studies with a total of 1,975 people and found that the game significantly reduced people's household electricity consumption six months after the game and, also, that playing the game led to increased self-reports of household efforts to save energy and perceived importance of sustainability. Ro et al. (2017, p. 21) assert that “Gamification is an effective tool to change behaviours.”

Result:

Gamification led to significant reductions in household electricity consumption.

Geographic location and populations in energy efficiency interventions

The findings from research question three relate to the theme of: *Targeted and relevant approaches work: Context matters.* Specifically, three insights are drawn primarily from the findings:

- country-specific data are not necessarily transferable
- limited targeting of specific populations
- the intervention needs to reflect local climatic and socio-cultural practices.

The search revealed that the USA was the dominant country represented in the interventions analysed, followed by the United Kingdom (UK), Australia, Japan, Sweden, Canada and Denmark (see Table 6). Thus, there is a skew in the findings towards American interventions. Two interventions were conducted in more than one country, with one in Spain, France, Malta and Cyprus (Podgornik et al., 2016) and one in the European Union's 14 countries (Ó Broin et al., 2015).

Table 6 Countries with energy efficiency interventions

Country	Papers	Percentage	Country	Papers	Percentage
USA	38	35.51%	Italy	2	1.87%
UK	14	13.08%	Multiple	2	1.87%
Australia	7	6.54%	Netherlands	2	1.87%
Japan	6	5.61%	Belgium	1	0.93%
Sweden	6	5.61%	Cyprus	1	0.93%
Canada	5	4.67%	Finland	1	0.93%
Denmark	5	4.67%	France	1	0.93%
Ireland	4	3.74%	Greece	1	0.93%
New Zealand	3	2.80%	South Korea	1	0.93%
Singapore	3	2.80%	Norway	1	0.93%
Germany	2	1.87%	Spain	1	0.93%

The climatic, infrastructure, social, cultural, political and technological environment of countries limits the transferability of the evidence across countries. For instance in Japan, households use unit cooling and heating in every room and Japanese households make frequent purchase and replacement decisions for air-conditioners (Mizobuchi & Takeuchi, 2016). Consequently, people in Japan have more energy-efficient investment opportunities (i.e., chances to purchase energy-efficient air-conditioners for replacement or additional use) than those in European countries and the USA. As another example of cultural difference, in Denmark there is a strong cultural practice of local energy activism (Bauwens, Gotchev, & Holstenkamp, 2016), where alternative energy production is higher than in countries with lower levels of activism – something that could be leveraged for Danish interventions but perhaps not for interventions in other countries.

There is variation within countries with regard to the relative popularity of different types of energy saving behaviours. Compared with the overall trend, curtailing energy (i.e., a type of demand response where consumers reduce energy use in response to a request, or when the grid provides less energy for a set time period) is reported to be more common than investing in energy efficiency measures in a number of countries such as the UK, Hungary and France (Bauwens et al., 2016). For example, while the UK ranks as the top seventh country with regard to how often consumers curtail their energy use, it has the bottom fourth position with regard to energy efficiency investments. In a number of other countries—such as Austria, Poland and the Czech Republic—we observe the opposite situation, where efficiency behaviour is reported to be relatively more common than curtailment behaviour. Furthermore, external conditions, such as infrastructure, markets, industrial networks, regulations and policies, are likely to differ between countries. Even within more integrated economies, such as the European Union, the energy mix is highly variable between countries (Sarrica, Brondi, Cottone, & Mazzara, 2016). Different energy cultures exist across the world (Stephenson et al., 2010) and these are likely to influence the adoption of energy-intensive devices, energy efficiency practice and behaviours and adoption of energy saving or generating technologies, such as solar panels or smart devices.

When it comes to populations participating in energy efficiency interventions, analysis revealed four profiles of people participating in energy efficiency interventions, with a general approach more common than a targeted approach. Vulnerable groups that were included were those with low income and the elderly; however, there were other vulnerable groups who were not specifically reported (see Figure 12). While these groups may have been included in general population interventions, the lack of specific interventions for the groups most in need of energy efficiency to combat rising prices is evident. As many of the general population interventions involved random sampling methods, this precludes the ability to specifically sample for vulnerable groups. For instance, Hamilton et al. (2013) examined the UK's ambitious retrofit interventions that encompassed 13 million people, while Macintosh and Wilkinson (2011) detailed the Solar PV rebate interventions that were implemented in Australia with over 100,000 households. The random sampling used in each of these instances means that while some specific populations of interest are likely to be captured in the data, this is not necessarily guaranteed.

Figure 12 Participant profile for energy efficiency interventions

Rather than focusing on specific population groups, energy interventions appear to be focused around housing types, such a block of apartments with similar floor layouts (see Asensio & Delmas, 2016), homes with specific energy devices such as Solar PV (see Hondo & Baba, 2010), specific geographic regions where an electricity network operated (see Allcott, 2011), or sometimes a combination of both stock type and area served by utility (Alberini & Towe, 2015).

Vignette: Low-income and electricity feedback

Focusing on low-income households, Podgornik and colleagues (2016) evaluated the effect of customised consumption feedback and other information interactions on energy-behaviour patterns and energy savings. They tested two different consumption-feedback services: 1) appliance-specific consumption breakdown with a simple kWh, CO_2 and costs presentation of the electricity consumption; and 2) informative billing with and individualised periodic reports (efficiency indicators). The equipment-installation phase was used to install the monitoring equipment (smart meters and in-home displays) and educate the participating households about equipment usage, giving them a walkthrough of how the equipment worked.

This was accompanied by an interactive awareness campaign, which emphasised the proper understanding of the consumption feedback and other complementary energy services provided to low-income households. The research has demonstrated electricity savings of between 22% and 27% when individualised and household-specific awareness campaigns and contextualised consumption feedback are introduced to the targeted households. The savings reached as high as 36% when efficient energy behaviour was additionally stimulated by complementary measures.

Result:

Electricity savings of 22–27% when individualised and household-specific awareness campaigns and contextualised consumption feedback are used.

Techniques used in energy efficiency interventions

The findings from research question four relate to the themes of: *Energy efficiency is complex: A multi-layered approach is needed*; *Relevant benefits increase engagement: What's in it for me?*; and, *Unintended consequences can derail success: Caution advised.* These themes and the following insights also share information from RQ1.

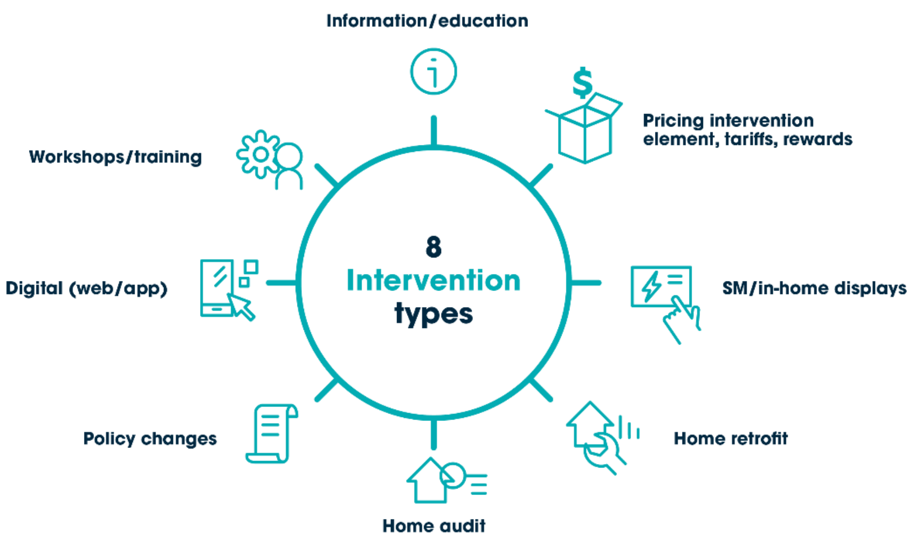
Specifically, four insights are drawn from the findings:

- multiple types of feedback were more effective
- multiple intervention elements (and levels) were more effective
- information at a convenient, timely location assists adoption of energy efficiency technology
- feedback that is clear and shows the benefits for the customer is effective

There were eight types of intervention elements used in the interventions (see Figure 13). These include the following options:

- Information/education
- Pricing intervention element (tariffs)
- Rewards
- Smart meter/in-home displays
- Home retrofit
- Home audit
- Policy changes
- Digital (web/app)
- Workshops/training

Figure 13 Eight types of intervention elements



Levels of intervention – macro and micro

Interventions were classified into one of two levels: macro or micro. The micro level includes individual and household interventions such as using in-home displays to provide smart meter feedback about household electricity consumption (Schultz et al., 2015) and the macro level which included policy-level interventions such as regulations. There were also interventions that spanned multiple levels. The majority of interventions were at the micro level (92, 86%), with only a small amount focusing on the macro level (9, 8%), and an even smaller amount focused on the multi-level (6, 6%) (see Table 7). The success of the intervention did not appear to vary according to level of intervention, with more than 80% of interventions across all levels being successful. Only a small number of interventions had negative outcomes, with none reported in either the macro- or multi-level groups and four found in the micro-level group. Success did not appear to vary according to the level of intervention, although this could have been affected by the very small number of interventions at the macro level included in the analysis.

Table 7 Outcomes for micro and macro intervention levels

Level	Number of interventions	% reporting successful outcomes	% reporting negative outcomes	% reporting no change
Micro	92 (86%)	85%	4%	11%
Macro	9 (8%)	89%	0%	11%
Multi-level	6 (6%)	83%	0%	17%
TOTAL	107			

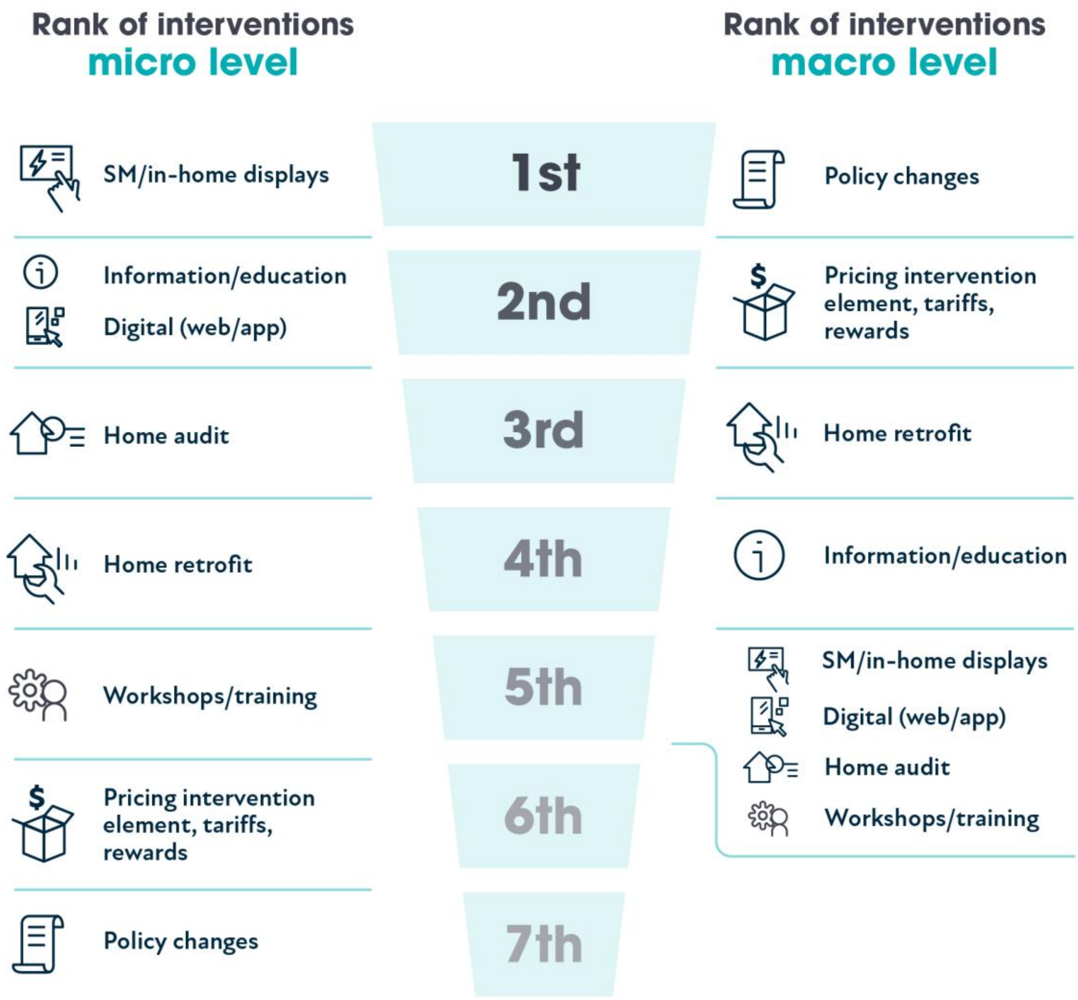
Of the eight types of intervention elements used in the interventions, the most used intervention element was information/education and the least used was workshops/training (see Table 8).

Table 8 Intervention elements for each level

Intervention element	Number of interventions	% of intervention element used at micro level	% of intervention element used at macro level	% of intervention element used across level
Information/education	43	91%	2%	7%
Pricing intervention element (tariffs) and rewards	39	77%	15%	8%
Smart meter/in-home displays	36	94%	0%	6%
Home retrofit	34	85%	9%	6%
Home audit	14	86%	0%	14%
Policy changes	12	50%	25%	25%
Digital (web/app)	11	91%	0%	9%
Workshops/training	9	78%	0%	22%

The most used intervention elements for micro-level interventions (households and individuals) were in-home displays, information/education, digital (web/app), retrofits and audits, and for macro-level interventions the most used intervention elements were policy changes and pricing intervention elements (see Figure 14). The most common intervention elements across both levels were workshops/training, policy changes and home audits.

Figure 14 Most and least used intervention elements across levels



Energy efficiency outcomes for intervention elements

This table details the median outcomes reported for each intervention element when quantitative outcomes were available. For instance, in the interventions that measured electricity reduction and used a pricing intervention, the median reduction was 8% compared to home retrofits where electricity use was reduced by 13%. The intervention element that appears to improve energy efficiency behaviours (e.g. switching off lights, using a clothesline and not a dryer, keeping the air-conditioning temperature at 24 degrees) is workshops/training compared to policy changes, which appear to have no behavioural improvement. The intervention element that appears to have the most effect on bill savings is policy changes compared to pricing interventions, which yielded no change. Gas reduction is most affected by home retrofits. Information/education elements and smart meters/in-home displays appear to be the most effective for encouraging adoption of technology while pricing interventions had the least effect (see also Table 9).

Table 9 Median outcomes per intervention element

Outcome	Pricing intervention element Tariffs Rewards	Information/ Education	Policy changes	Home retrofit	Digital (web/app)	Workshops/ training	Home Audit	Smart meter/ In-home displays
Adoption of technology increase	8%	15%						15%
Awareness improvement	-	22%	-	-	-	-	-	-
Behavioural improvement	0%	25%	0%	-	13%	31%	-	13%
Bill savings	0%	-	6%	3%	-	-	-	5%
Electricity reduction	8%	7%	4%	13%	9%	9%	8%	9%
Gas reduction	-	1%	-	30%	-	-	-	-

The most effective intervention elements were digital (web/app), workshop/training and retrofit, with the least effective being home audits. Policy changes had both positive and no effects, while pricing mechanics and information/education had negative effects by increasing electricity usage (see Table 10).

Table 10 Effectiveness of intervention elements

Intervention element used	% Positive outcome	% negative outcome	% no change
Digital (website/application)	100%	0%	0%
Workshops/training	100%	0%	0%
Home retrofit	97%	0%	3%
Information/education	93%	2%	5%
Pricing intervention element (tariffs, financial rewards)	77%	8%	15%
Policy changes	75%	0%	25%
Smart meters/in-home displays	30.8%	11%	0%
Home audit	12.1%	7%	0%

Vignette: Energy retrofit and apartments

Taylor's (2016) energy retrofit project was conducted in a multifamily apartment complex in the hot, humid region of Orlando, Florida. Retrofit packages addressed efficiency of the apartment units' mechanical systems, building envelope features and appliances. Specific energy conservation measures included SEER-15 heat pump HVAC systems, ENERGY STAR® certified refrigerators, solar window film, R-30 attic insulation, duct repair, compact fluorescent lighting (CFLs), and water saving showerheads and aerators. The average cost of retrofits, including equipment and installation, was US$4359 per unit. The total project cost for the four properties in this analysis was US$1,011,388 (US$4359 per unit), with an overall expected life of 12 years for the typical package of retrofits. Annual gross energy savings per treatment unit averaged 2094 kWh (21.9 %). As Taylor (2016, p. 397) points out, "Results of the analysis across complexes support a strategy of targeting upgrades to properties and units with poor pre-retrofit energy performance, which is likely to improve overall intervention savings and, in turn, cost-effectiveness."

Results:

Energy retrofit resulted in an average 21.9% reduction in kWh per annum.

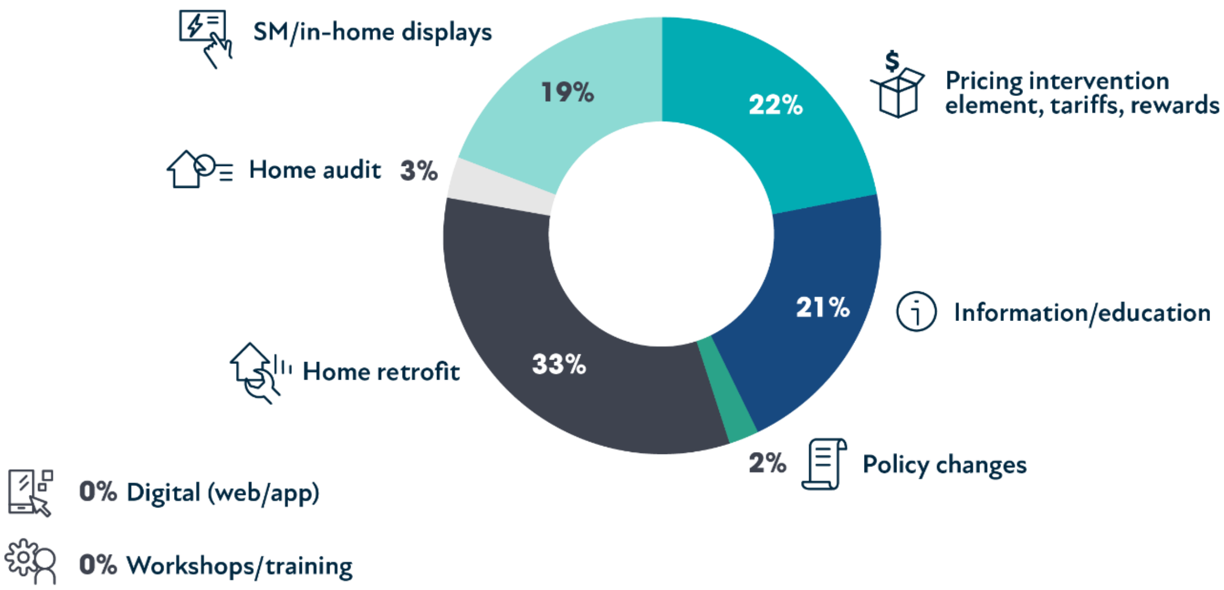
Most (54%) of the interventions had a single intervention element, while 25% used two intervention elements (see Table 11). The number of intervention elements is related to the reported success of the intervention. The number of intervention elements were positively correlated with successful outcomes (r = 0.88), negatively correlated with no change in outcome (r =-0.89), and negativity correlated with negative outcomes (r = -0.61). This means that as the number of intervention elements increases, success is likely to increase, and negative or no change in electricity usage reduces. Of the single intervention element interventions, the most used was home retrofits, followed by pricing intervention elements and information/education. The least used as a single intervention element intervention were digital (web/app) and workshops/training. For the interventions using two intervention elements, the most common combination was pricing intervention elements and smart meter/in-home displays, for those using three intervention elements the most common combination was information/education, home retrofit and smart meter/in-home displays.

Table 11 Number of interventions and successful outcomes

Number of intervention elements used	Number of interventions	% of interventions reporting success	% of interventions reporting no change	% of interventions reporting negative outcomes
1	58	79.2%	13.7%	6.90%
2	27	88.9%	11.1%	0.00%
3	9	88.9%	11.1%	0.00%
4	9	100.0%	0.00%	0.00%
5	2	100.0%	0.00%	0.00%
6	1	100.0%	0.00%	0.00%
7	1	100.0%	0.00%	0.00%
8	0	0%	0.00%	0.00%
Grand Total	107			

For interventions that used a single intervention element, the most likely choice was home retrofit, pricing intervention element or information/education (see Figure 15).

Figure 15 Single intervention elements used in interventions



Vignette: Community involvement and smart meters

Anda and Temmen (2014) used both information/education and smart meters to achieve an energy reduction of 10%. Their community-based social marketing (CBSM) program used eco-coaching to provide a feedback loop for household energy behaviour change. Development of educational materials and training packages was constructed for eco-coaching. Smart meters were installed to provide households with more accurate usage data, data were analysed to provide individualised feedback, specialist eco-coaches discussed savings possibilities with the households, and if this was implemented a change would be seen in the meter read. This completed one cycle of the loop.

Results:

Eco-coaching was successfully used to encourage the installation and use of smart meter technology.

Vignette: The importance of message framing

Bager and Mundaca's (2017) project on loss-aversion used behavioural economics and cognitive bias to test the assumption that consumers underestimate potential gains and overestimate potential financial losses resulting from electricity use. Using three intervention mechanisms of information and education, a digital application, and in-home displays, they found that the provision of loss-framed, salient information reduced daily demand by 7–11%, compared to unframed information. Data loggers were added to existing analogue meters to collect, store and transmit data between the electricity supplier and the end user. No in-home display unit was used, so users accessed consumption information using software installed on their smartphones, tablets or computers. Bager and Mundaca (2017, p. 68) suggests that policies that address smart meter technology need to consider not only the pure provision of information but also how it is designed and presented to users.

Results:

Provision of loss-framed, salient information via digital apps, in-home displays and information/education reduced daily electricity demand by 7–11%.

Energy efficiency outcomes and feedback

Feedback on electricity consumption has been posited as a tool for customers to better control their consumption and ultimately save energy (Fischer, 2008). Ehrhardt-Martinez (2018, p. 128) writes that "feedback is proving a critical first step in engaging and empowering consumers to thoughtfully manage their energy resources." Researchers Grønhøj and Thøgersen (2011) have found that feedback made household electricity consumption more visible and salient, empowered consumers to take action with respect to lowering their energy consumption, and even stimulated social influence processes related to energy savings between spouses as well as between (teenage) children and their parents.

Usage is the amount of electricity in kWh that is used by the household and is sometimes reported as live usage, usage compared to yesterday or usage compared to other timeframes. Device-specific usage was also sometimes obtained (Podgornik et al., 2016, p. 28): "In all addressed dwellings special attention was given to the appliance-specific consumption and end-users were able to decide which appliances would be monitored in their dwellings. Their decisions were based on the information provided during the awareness campaign in the pre-installation phase."

Cost feedback presents changes in electricity usage in dollar amounts, either as a cost to be paid or a saving amount made. Vassileva, Dahlquist, Wallin, and Campillo, (2013, p. 316) state, "The users were also able to see the cost [in Swedish krona] accumulated since the installation of the display." Emissions feedback focuses on quantifying changes in energy usage as changes in CO_2 emissions. For example, Nilsson's in-home display reports "carbon emissions (using values for marginal electricity, i.e. coal condensing emission intensities)" (2014, p. 22). Health feedback reports on the health impacts of reduced usage. For example, "Last week, you used 66% more/less electricity than your efficient neighbours. You are adding/avoiding 610 pounds of air pollutants which contribute to health impacts such as childhood asthma and cancer" (Asenio & Delmas, 2015, p. 12).

Social norms were also used. This provides feedback in the form of a comparison to similar households or neighbours. For example, "would then display the average consumption of similar households in addition to that household's current use. The lights were coded to provide an injunctive norm, which demonstrates the approval or disapproval of the resident's current energy use. If the household was using more than the 'similar households' average, the light displayed red. Similarly, the light displayed green if the household was using less, and yellow if usage was the same" (Schultz et al., 2015).

Vignette: Smart communities and energy feedback

In their project, Burchell, Rettie and Roberts (2016) draws on research carried out in Smart Communities – a two-year project in which electricity and gas consumption feedback played a key role. This study was distinctive because it was accompanied by a weekly email communication intervention and was provided within the context of community action. Time was invested in designing the emails and six main distinctive featuring were drawn upon, these were: Regularity (sent weekly and at always at the same time), Action-based (emphasising specific actions members could take), Locale (features information about local area), Community (emphasising community as a whole) and Style (written in an accessible, friendly and supportive way). The behaviour change was dramatic, with a 13% increase. Project findings suggest that, although by no means panaceas, approaches such as these can support long-term engagement with energy consumption feedback, including by women, and can support behaviour change.

Results:

A 13% increase in positive energy efficiency behaviours was reported.

A targeted and personalised weekly email campaign was utilised.

Vignette: Community events and energy efficiency

Scott's (2016) energy interventions used three community events to deliver increases in energy efficiency, such as switch lights off in unused rooms, close the curtains at night, and reduce heating in unoccupied rooms. The research team worked directly with the Brockville Community Development Project (BCDP). The three energy events in Brockville took place over 3 months. The first event was held in conjunction with a community potluck dinner. After dinner, the energy advisor presented a PowerPoint about household energy and led focus groups to discuss individual household energy issues. The second energy event was collaboratively shaped from feedback from the first event and discussions between the community, researchers and consultant. It consisted of practical workshops on how to install plastic glazing over windows, under-floor and ceiling insulation, and wrap hot water cylinders. The final energy event took part in conjunction with a Brockville spring clean event. This event consisted of community members and others sharing their stories of how they had changed their in-home energy use and aspirational stories associated with renewable energy.

Results:

Three community events were used to motivate and educate consumers on saving energy – these show the power of the social element of interventions.

Of the interventions in the analysis, 66% did not use feedback in their study and 44% used feedback, with usage and cost feedback being the most commonly reported (see Figure 16).

Figure 16 Feedback used in interventions

Type of Feedback	Frequency of Use
 Usage feedback	30.8%
 Cost feedback	23.4%
 Emissions feedback	7.5%
 Health feedback	2.8%
 Social norms feedback	11.2%

Of the 37 interventions that used feedback, most used multiple forms of feedback, with only 27% using one form of feedback. If a single feedback type was used, the most common choices were usage feedback, cost feedback or emissions, or social norms feedback. No intervention used health feedback on its own. The most common combination of feedback was usage and cost, with 88% of dual feedback interventions selecting this combination.

Usage feedback on its own achieved mixed results, with only 50% of interventions achieving successful outcomes. Once usage feedback was combined with other forms of feedback – particularly cost feedback – the success rate increased to 88% (see Table 12).

Table 12 Effectiveness of feedback in energy efficiency interventions

Feedback type used in intervention	Number of interventions using feedback	Percentage of interventions using feedback	% with successful outcomes	% with negative outcomes	% with no change
1 type of feedback					
Usage feedback	6	6%	50%	17%	33%
Cost feedback	1	1%	0%	0%	0%
Emissions feedback	1	1%	0%	0%	100%
Health feedback	0	0%	0%	0%	0%
Social norms feedback	3	2%	100%	0%	0%
2 types of feedback					
Usage and cost feedback	16	22%	88%	0%	13%
3 types of feedback					
Usage feedback Cost feedback Emissions feedback	2	2%	0%	0%	100%
Usage feedback Cost feedback Social norms feedback	3	3%	100%	0%	0%
Usage feedback Health feedback Social norms feedback	1	1%	100%	0%	0%
4 types of feedback					
Usage feedback Cost feedback Emissions feedback Social norms feedback	3	3%	100%	0%	0%
Usage feedback Cost feedback Emissions feedback Health feedback	1	1%	100%	0%	0%
5 types of feedback					
Usage feedback Cost feedback Emissions feedback Health feedback Social Feedback	1	1%	100%	0%	0%
No feedback	69				
Total	107				

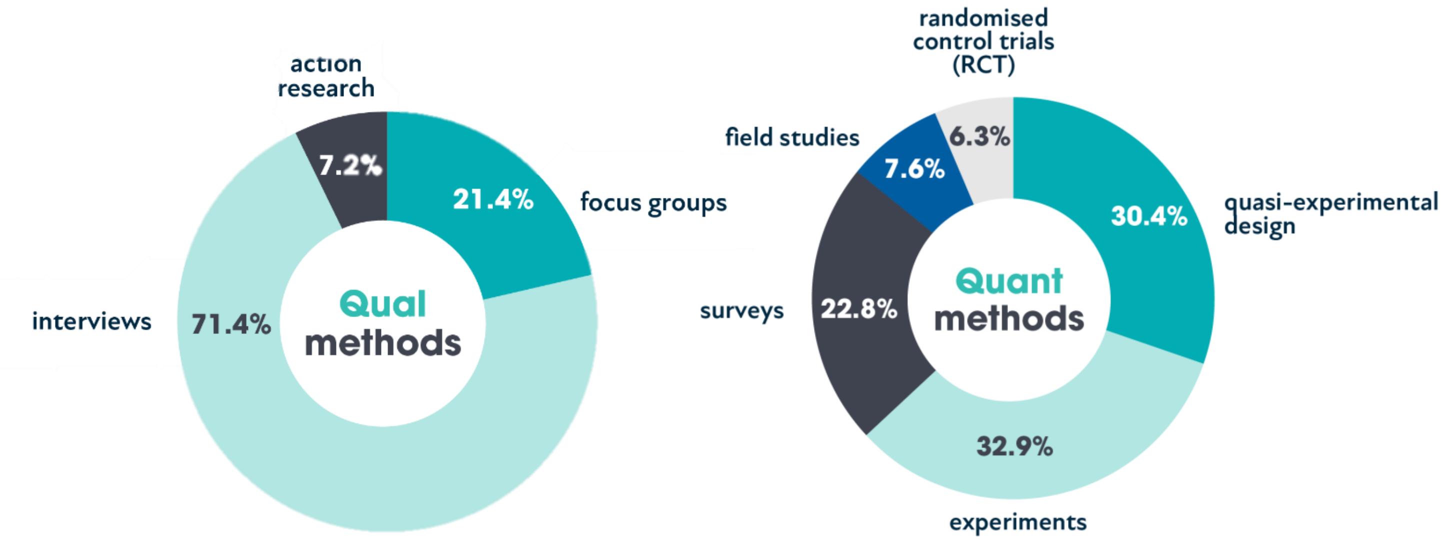
Measurement of energy efficiency outcomes

The findings from research question five relate to the theme of: *Intended goals should inform beginnings: Plan for strong evaluation.* Specifically, two insights are drawn from the findings:

- effectiveness depends on the outcome sought
- a claim of success does not equal reduction in electricity usage.

Quantitative evaluation methods were used in 79 interventions (74%), with 14 interventions using qualitative methodology (13%) and 14 used mixed methods (13%). The specific techniques used are shown in Figure 17. The types of data collected ranged from self-reported responses on a survey, to verbal responses in interviews to smart meter data.

Figure 17 Techniques used in qualitative and quantitative methods



Mixed methods adopted a variety of combinations, including: postal surveys and semi-structure interviews, family interviews and case-control comparisons, randomised control trials with interviews and focus groups, semi-structured interviews with energy demand measurement, household interviews in combination with surveys and energy usage data, and case studies with interviews and longitudinal usage data.

Some mixed-method studies used qualitative research to inform the design of an intervention, later using quantitative methods to measure changes in behaviour and electricity usage. Others designed the intervention before conducting primary research, followed by using quantitative techniques to measure changes in behaviour and usage, and afterwards using qualitative methods to understand why behaviour change had occurred or not occurred.

Many variations with and between measures reduces the comparability of the outcomes in the interventions:

- effect sizes were very rarely reported
- objective measures of electricity usage were typically recorded by smart meters and this made measurement very accurate
- 23 studies reported no quantitative outcome measures
- 84 studies reported a quantitative change in an outcome measure.

Electricity usage as the most used energy efficiency outcome

By far the most common outcome measured was a change in electricity usage, measured at the household level in kilowatts per hour (kWh), usually in the form of a reduction in electricity usage after the intervention has been implemented (see also Table 13). Sixty-nine studies reported an electricity reduction with a median savings of 9%. Two studies focused on adoption, one of an energy saving feature and another of solar installations with a median adoption rate of 8%. A further two studies focused on raising awareness levels of energy and recognising an energy efficiency campaign, reporting a median increase of 22.15%. Behaviour change was measured in three interventions and a median increase of 13% was reported. Bill savings were found in six papers, with a median saving of 4.45%. Lastly, quantitative measures of gas reduction were reported by two papers, with a median reduction of 15.39%.

Electricity bill reduction in dollar amounts was also compared, usually year-on-year to account for seasonal changes. Qualitative assessment examined behaviours in terms of good energy efficiency practices adopted and energy inefficiency practices abandoned, as well as positive and negative emotions associated with behaviour adoption or abandonment.While the data collection for awareness, behaviours and adoption was consistent (survey or interview) the operationalisation varied widely. For instance, awareness of level consumption patterns and carbon footprint was used by Salo et al. (2016) by delivering personal advice tailored for households on the basis of consumption measures, while Pelenur and Cruichshank (2013) probed the theme of awareness (learn about energy) with the question, “Why is learning about energy an advantage for you?” in an interview setting. Additionally, Bertrand, Goldman, Zhivan, Agyeman and Barber (2011) surveyed tweens regarding an energy awareness campaign using the following question, “Have you seen, heard, or read something about saving energy in the past 6 months?’’

Qualitative studies contained more variation in the measurement compared to the quantitative studies. For example, in some studies there were explicit interview questions to solicit information about awareness, while in other studies the concept emerged from the data (sometimes organically). When there was measurement of energy efficiency behaviours, there was a wide variety of behaviours investigated across the studies. The common behaviours were switching off appliances/lights, using a drying rack instead of a dryer, only using the washing machine when you have a full load. Others were context-specific, such as adjusting the hot water heater and refrigerator temperature or questions such as, “We use the Owl [in-home display device] more often now than when we started.”

Table 13 Measures used for energy efficiency outcomes

Outcome	Measure (s) used	Technique	Type of data
Electricity usage	kWh	Smart meter, wireless in-home display, interval meter	Continuous
Bill savings	Dollar amount in local currency	Actual energy bills to calculate expenditure Household estimate	Continuous
Awareness	"Became more aware of their electricity use because of the study" "Awareness of star energy ratings labels"	Survey Interview	Likert scale Dichotomous
Adoption (of energy saving features)	Added double glazing to some or all of your windows, installed attic or wall insulation Replaced appliances with A rated ones Fitted a new lagging jacket on your hot water tank, fitted other energy saving devices Added solar panels Added draught-proofing to your doors or windows, replaced a central heating boiler with a more efficient one Added thermostatic controls to radiators	Survey Interview	Likert scale Dichotomous
Behaviours	Turn off power strip at night	Self-reported residential energy-saving behaviours	Binary yes/no

Conclusion

The review identified that 90 out of 107 interventions resulted in positive energy efficiency outcomes. This suggests that, overall, household energy efficiency interventions can be successful; in many cases because they focused on what mattered to the household. The review findings identified a number of key success factors influencing the effectiveness energy efficiency interventions. The insights presented provide a roadmap for the best way forward. This roadmap requires consumer advocates, policymakers and industry professionals to work together. The findings add to the evidence base regarding the effectiveness of household energy efficiency interventions, and will help inform better policy, interventions and consumer advocacy to help Australian households achieve better energy and related co-benefit outcomes, and provide good return on investment (ROI).

References

Agarwal, S., Rengarajan, S., Sing, T. F., & Yang, Y. (2017). Nudges from school children and electricity conservation: Evidence from the “Project Carbon Zero” campaign in Singapore. *Energy Economics*. https://doi.org/10.1016/j.eneco.2016.10.014

Akbari, H., Bretz, S., Kurn, D. M., & Hanford, J. (1997). Peak power and cooling energy savings of high-albedo roofs. *Energy and Buildings*. https://doi.org/10.1016/S0378-7788(96)01001-8

Alberini, A., & Towe, C. (2015). Information v. energy efficiency incentives: Evidence from residential electricity consumption in Maryland. *Energy Economics*, *52*, S30–S40. https://doi.org/10.1016/j.eneco.2015.08.013

Allcott, H. (2011). Social norms and energy conservation. *Journal of Public Economics*. https://doi.org/10.1016/j.jpubeco.2011.03.003

Anda, M., & Temmen, J. (2014). Smart metering for residential energy efficiency: The use of community based social marketing for behavioural change and smart grid introduction. *Renewable Energy*. https://doi.org/10.1016/j.renene.2013.11.020

Asensio, O. I., & Delmas, M. A. (2016). The dynamics of behavior change: Evidence from energy conservation. *Journal of Economic Behavior & Organization*, *126*, 196–212. https://doi.org/10.1016/J.JEBO.2016.03.012

Bauwens, T., Gotchev, B., & Holstenkamp, L. (2016). What drives the development of community energy in Europe? the case of wind power cooperatives. *Energy Research and Social Science*. https://doi.org/10.1016/j.erss.2015.12.016

Bedggood, R., O’Mahony, C., Pervan, F., & Buergelt, P. (2018). *Power Shift Project Two: Delving into the Co-Benefits Identified in the Low Income Energy Efficiency Project Reports. Final Report*.

Bertrand, J. T., Goldman, P., Zhivan, N., Agyeman, Y., & Barber, E. (2011). Evaluation of the “lose your excuse” public service advertising campaign for tweens to save energy. *Evaluation Review*. https://doi.org/10.1177/0193841X11428489

Bjørnstad, E. (2012). Diffusion of renewable heating technologies in households. Experiences from the Norwegian Household Subsidy Programme. *Energy Policy*, *48*(0301), 148–158. https://doi.org/10.1016/j.enpol.2012.04.078

Boudet, H., Ardoin, N. M., Flora, J., Armel, K. C., Desai, M., & Robinson, T. N. (2014). Energy behaviours of northern California Girl Scouts and their families. *Energy Policy*. https://doi.org/10.1016/j.enpol.2014.05.044

Boudet, H., Ardoin, N. M., Flora, J., Armel, K. C., Desai, M., & Robinson, T. N. (2016). Effects of a behaviour change intervention for Girl Scouts on child and parent energy-saving behaviours. *Nature Energy*. https://doi.org/10.1038/nenergy.2016.91

Butler, K., Gordon, R., Roggeveen, K., Waitt, G., & Cooper, P. (2016). Social marketing and value in behaviour? *Journal of Social Marketing*, *6*(2), 144–168. https://doi.org/10.1108/JSOCM-07-2015-0045

Carins, J. E., & Rundle-Thiele, S. R. (2014). Eating for the better: a social marketing review (2000–2012). *Public Health Nutrition*, *17*(07), 1628–1639. https://doi.org/10.1017/S1368980013001365

Castro-Alvarez, F., Vaidyanathan, S., Bastian, H., & King, J. (2018). *The 2018 International Energy Efficiency Scorecard*. Retrieved from https://aceee.org/sites/default/files/publications/researchreports/i1801.pdf

Christiano, A., & Neimand, A. (2017). Stop Raising Awareness Already. *Stanford Social Innovation Review*, *Spring*, 34–41.

Cosmo, V. Di, & O'Hora, D. (2017). Nudging electricity consumption using TOU pricing and feedback: evidence from Irish households. *Journal of Economic Psychology*. https://doi.org/10.1016/j.joep.2017.03.005

Craig, C. A., & Allen, M. W. (2015). The impact of curriculum-based learning on environmental literacy and energy consumption with implications for policy. *Utilities Policy*. https://doi.org/10.1016/j.jup.2015.06.011

Department of Environment and Energy. (2016). Low Income Energy Efficiency Program (LIEEP). Retrieved May 31, 2019, from https://www.energy.gov.au/publications/low-income-energy-efficiency-program-lieep

Fischer, C. (2008). Feedback on household electricity consumption: a tool for saving energy? *Energy Efficiency*, *1*(1), 79–104.

Geller, H., Harrington, P., Rosenfeld, A. H., Tanishima, S., & Unander, F. (2006). Polices for increasing energy efficiency: Thirty years of experience in OECD countries. *Energy Policy*, *34*(5), 556–573. https://doi.org/10.1016/j.enpol.2005.11.010

Guerassimoff, G., & Thomas, J. (2015). Enhancing energy efficiency and technical and marketing tools to change people's habits in the long-term. *Energy and Buildings*. https://doi.org/10.1016/j.enbuild.2015.06.080

Hamilton, I. G., Steadman, P. J., Bruhns, H., Summerfield, A. J., & Lowe, R. (2013). Energy efficiency in the British housing stock: Energy demand and the Homes Energy Efficiency Database. *Energy Policy*. https://doi.org/10.1016/j.enpol.2013.04.004

Hargreave, B., Mcalester, J., Walters, N., & Yao, K. (2017). *Community Energy Efficiency Program Evaluation Impact Evaluation*. Retrieved from www.industry.gov.au/OCE

Havas, L., Ballweg, J., Penna, C., & Race, D. (2015). Power to change: Analysis of household participation in a renewable energy and energy efficiency programme in Central Australia. *Energy Policy*. https://doi.org/10.1016/j.enpol.2015.09.017

Hondo, H., & Baba, K. (2010). Socio-psychological impacts of the introduction of energy technologies: Change in environmental behavior of households with photovoltaic systems. *Applied Energy*. https://doi.org/10.1016/j.apenergy.2009.05.009

Ida, T., Murakami, K., & Tanak, M. (2016). Electricity demand response in Japan: Experimental evidence from a residential photovoltaic power-generation system. *Economics of Energy & Environmental Policy*, *5*(1). https://doi.org/https://doi.org/10.5547/2160-5890.5.1.itak

International Energy Agency. (2017). *Market Report Series: Energy Efficiency 2017*. Retrieved from https://webstore.iea.org/market-report-series-energy-efficiency-2017-pdf

Ito, K. (2015). Asymmetric Incentives in Subsidies : Evidence from a Large-Scale Electricity Rebate Program. *American Economic Journal: Economic Policy*. https://doi.org/10.1257/pol.20130397

Iwafune, Y., Mori, Y., Kawai, T., & Yagita, Y. (2017). Energy-saving effect of automatic home energy report utilizing home energy management system data in Japan. *Energy*. https://doi.org/10.1016/j.energy.2017.02.136

Kirkpatrick, A. J., & Bennear, L. S. (2014). Promoting clean energy investment: An empirical analysis of property assessed clean energy. *Journal of Environmental Economics and Management*. https://doi.org/10.1016/j.jeem.2014.05.001

MacGill, M. (2019). What is a systematic review in research?

Macintosh, A., & Wilkinson, D. (2011). Searching for public benefits in solar subsidies: A case study on the Australian government's residential photovoltaic rebate program. *Energy Policy*. https://doi.org/10.1016/j.enpol.2011.03.007

Mallett, R., Hagen-Zanker, J., Slater, R., & Duvendack, M. (2012). The benefits and challenges of using systematic reviews in international development research. *Journal of Development Effectiveness*. https://doi.org/10.1080/19439342.2012.711342

McCoy, D., & Lyons, S. (2017). Unintended outcomes of electricity smart-metering: trading-off consumption and investment behaviour. *Energy Efficiency*. https://doi.org/10.1007/s12053-016-9452-9

Mizobuchi, K., & Takeuchi, K. (2016). Replacement or additional purchase: The impact of energy-efficient appliances on household electricity saving under public pressures. *Energy Policy*. https://doi.org/10.1016/j.enpol.2016.03.001

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., … Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews*, *4*(1), 1. https://doi.org/10.1186/2046-4053-4-1

Murtagh, N., Gatersleben, B., & Uzzell, D. (2014). 20:60:20 - Differences in Energy Behaviour and Conservation between and within Households with Electricity Monitors. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0092019

Nilsson, A., Bergstad, C. J., Thuvander, L., Andersson, D., Andersson, K., & Meiling, P. (2014). Effects of continuous feedback on households' electricity consumption: Potentials and barriers. *Applied Energy*. https://doi.org/10.1016/j.apenergy.2014.01.060

Ó Broin, E., Nässén, J., & Johnsson, F. (2015). Energy efficiency policies for space heating in EU countries: A panel data analysis for the period 1990-2010. *Applied Energy*. https://doi.org/10.1016/j.apenergy.2015.03.063

Owens, S., & Driffill, L. (2008). How to change attitudes and behaviours in the context of energy. *Energy Policy*. https://doi.org/10.1016/j.enpol.2008.09.031

Ozawa, A., Furusato, R., & Yoshida, Y. (2017). Tailor-made feedback to reduce residential electricity consumption: The effect of information on household lifestyle in Japan. *Sustainability (Switzerland)*. https://doi.org/10.3390/su9040528

Pelenur, M. J., & Cruickshank, H. J. (2013). Investigating the link between well-being and energy use; an explorative case study between passive and active domestic energy management systems. *Building and Environment*, *65*, 26–34. https://doi.org/10.1016/j.buildenv.2013.03.020

Podgornik, A., Sucic, B., & Blazic, B. (2016). Effects of customized consumption feedback on energy efficient behaviour in low-income households. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2016.02.009

Ro, M., Brauer, M., Kuntz, K., Shukla, R., & Bensch, I. (2017). Making Cool Choices for sustainability: Testing the effectiveness of a game-based approach to promoting pro-environmental behaviors. *Journal of Environmental Psychology*. https://doi.org/10.1016/j.jenvp.2017.06.007

Rothschild, M. L., & Gaidis, W. C. (1981). Behavioral Learning Theory: Its Relevance to Marketing and Promotions. *Journal of Marketing*, *45*(2), 70. https://doi.org/10.2307/1251666

Salo, M., Nissinen, A., Lilja, R., Olkanen, E., O'Neill, M., & Uotinen, M. (2016). Tailored advice and services to enhance sustainable household consumption in Finland. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2016.01.092

Sarrica, M., Brondi, S., Cottone, P., & Mazzara, B. M. (2016). One, no one, one hundred thousand energy transitions in Europe: The quest for a cultural approach. *Energy Research and Social Science*. https://doi.org/10.1016/j.erss.2015.12.019

Schelly, C. (2014). Implementing renewable energy portfolio standards: The good, the bad, and the ugly in a two state comparison. *Energy Policy*, *67*, 543–551. https://doi.org/10.1016/j.enpol.2013.11.075

Schultz, P. W., Estrada, M., Schmitt, J., Sokoloski, R., & Silva-Send, N. (2015). Using in-home displays to provide smart meter feedback about household electricity consumption: A randomized control trial comparing kilowatts, cost, and social norms. *Energy*. https://doi.org/10.1016/j.energy.2015.06.130

Shove, E., & Walker, G. (2014). What Is Energy For? Social Practice and Energy Demand. *Theory, Culture & Society*. https://doi.org/10.1177/0263276414536746

Sorrell, S. (2007). Improving the evidence base for energy policy: The role of systematic reviews. *Energy Policy*, *35*(3), 1858–1871. https://doi.org/10.1016/j.enpol.2006.06.008

Stephenson, J., Barton, B., Carrington, G., Gnoth, D., Lawson, R., & Thorsnes, P. (2010). Energy cultures: A framework for understanding energy behaviours. *Energy Policy*. https://doi.org/10.1016/j.enpol.2010.05.069

Strengers, Y., & Maller, C. (2011). Integrating health, housing and energy policies: social practices of cooling. *Building Research & Information*, *39*(2), 154–168. https://doi.org/10.1080/09613218.2011.562720

Thornley, L., & Marsh, K. (2010). *What Works in Social Marketing to Young People? Systematic Review for the Health Research Council of New Zealand and the Ministry of Youth Development*. Otago. Retrieved from http://myd.govt.nz/documents/resources-and-reports/publications/microsoft-word-social-marketing-syst-rev-final.pdf

Tiefenbeck, V., Staake, T., Roth, K., & Sachs, O. (2013). For better or for worse? Empirical evidence of moral licensing in a behavioral energy conservation campaign. *Energy Policy*.

https://doi.org/10.1016/j.enpol.2013.01.021

Vassileva, I., Dahlquist, E., Wallin, F., & Campillo, J. (2013). Energy consumption feedback devices' impact evaluation on domestic energy use. *Applied Energy*, *106*, 314–320. https://doi.org/10.1016/J.APENERGY.2013.01.059

Waitt, G., Roggeveen, K., Gordon, R., Butler, K., & Cooper, P. (2016). Tyrannies of thrift: Governmentality and older, low-income people's energy efficiency narratives in the Illawarra, Australia. *Energy Policy*, *90*, 37–45. https://doi.org/10.1016/j.enpol.2015.11.033

Wallace, J., Nwosu, B., & Clarke, M. (2012). Barriers to the uptake of evidence from systematic reviews and meta-analyses: a systematic review of decision makers' perceptions. *BMJ Open*. https://doi.org/10.1136/bmjopen-2012-001220

Wallenborn, G., Orsini, M., & Vanhaverbeke, J. (2011). Household appropriation of electricity monitors. *International Journal of Consumer Studies*. https://doi.org/10.1111/j.1470-6431.2010.00985.x

World Energy Council. (2016). *World Energy Trilemma Index - 2016*. Retrieved from https://trilemma.worldenergy.org/reports/main/2016/2016 Energy Trilemma Index.pdf

Articles analysed (alphabetical order)

Authors	Title	Year
Abrahamse W., Steg L., Vlek C., Rothengatter T.	The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents	2007
Adan H., Fuerst F.	Do energy efficiency measures really reduce household energy consumption? A difference-in-difference analysis	2016
Agarwal, S., Rengarajan, S., Sing, T.F., Yang, Y.	Nudges from school children and electricity conservation: Evidence from the "Project Carbon Zero" campaign in Singapore	2017
Akbari, H., Bretz, S., Kurn, DM., Hanford, J	Peak power and cooling energy savings of high-albedo roofs	1997
Alberini, A., Towe, C.	Information v. energy efficiency incentives: Evidence from residential electricity consumption in Maryland	2015
Allcott, H.	Social norms and energy conservation	2011
Allcott, H.	Rethinking real-time electricity pricing	2011
Anda, M., Temmen, J.	Smart metering for residential energy efficiency: The use of community based social marketing for behavioural change and smart grid introduction	2014
Asensio, O.I., Delmas, M.A.	The dynamics of behavior change: Evidence from energy conservation	2016
Atikol, U., Abbasoglu, S., Nowzari, R.	A feasibility integrated approach in the promotion of solar house design	2013
Bager, S., Mundaca, L	Making 'Smart Meters' smarter? Insights from a behavioural economics pilot field experiment in Copenhagen, Denmark	2017
Balaras, C.A., Dascalaki, E.G., Droutsa, K.G., Kontoyiannidis, S.	Empirical assessment of calculated and actual heating energy use in Hellenic residential buildings	2016
Barnicoat, G., Danson, M.	The ageing population and smart metering: A field study of householders' attitudes and behaviours towards energy use in Scotland	2015
Bartusch C., Alvehag K.	Further exploring the potential of residential demand response programs in electricity distribution	2014
Bartusch, C., Wallin, F., Odlare, M., Vassileva, I., Wester, L.	Introducing a demand-based electricity distribution tariff in the residential sector: Demand response and customer perception	2011

Authors	Title	Year
Bertrand, J.T., Goldman, P., Zhivan, N., Agyeman, Y., Barber, E.	Evaluation of the "lose your excuse" public service advertising campaign for tweens to save energy	2011
Bjørnstad, E.	Diffusion of renewable heating technologies in households. Experiences from the Norwegian Household Subsidy Programme	2012
*Boudet, H., Ardoin, N.M., Flora, J., Armel, K.C., Desai, M., Robinson, T.N.	Energy behaviours of northern California Girl Scouts and their families	2014
*Boudet, H., Ardoin, N.M., Flora, J., Armel, KC., Desai, M., Robinson, T.N.	Effects of a behaviour change intervention for Girl Scouts on child and parent energy-saving behaviours	2016
Broin, E.O., Nassen, J., Johnsson, F	Energy efficiency policies for space heating in EU countries: A panel data analysis for the period 1990-2010	2015
Burchell, K., Rettie, R., Roberts, T.C.	Householder engagement with energy consumption feedback: The role of community action and communications	2016
Carlsson-Kanyama, A., Linden, A.L.	Energy efficiency in residences - Challenges for women and men in the North	2007
Carroll, J., Lyons, S., Denny, E.	Reducing household electricity demand through smart metering: The role of improved information about energy saving	2014
Caskey, S.L., Bowler, E.J., Groll, E.A.	Analysis on a net-zero energy renovation of a 1920s vintage home	2016
Cohen, S., Goldman, C., Harris, J.	Energy savings and economics of retrofitting single-family buildings	1991
Considine, T.J., Sapci, O.	The effectiveness of home energy audits: A case study of Jackson, Wyoming	2016
Cosmo, V.D., O'Hora, D.	Nudging electricity consumption using TOU pricing and feedback: evidence from Irish households	2017
Craig, C.A., Allen, M.W.	The impact of curriculum-based learning on environmental literacy and energy consumption with implications for policy	2015
Diffney, S., Lyons, S., Valeri, L.M.	Evaluation of the effect of the Power of One campaign on natural gas consumption	2013

Authors	Title	Year
D'Oca, S., Corgnati, S.P., Buso, T.	Smart meters and energy savings in Italy: Determining the effectiveness of persuasive communication in dwellings	2014
Fell, M.J., Shipworth, D., Huebner, G.M., Elwell, C.A.	Exploring perceived control in domestic electricity demand-side response	2014
Gaiser, K., Stroeve, P.	The impact of scheduling appliances and rate structure on bill savings for net-zero energy communities: Application to West Village	2014
Gans, W., Alberini, A., Longo, A.	Smart meter devices and the effect of feedback on residential electricity consumption: Evidence from a natural experiment in Northern Ireland	2013
Grimes, A., Preval, N., Young, C., Arnold, R., Denne, T., Howden-Chapman, P., Telfar-Barnard, L.	Does Retrofitted insulation reduce household energy use? Theory and practice	2016
Grønhøj, A., Thøgersen, J	Feedback on household electricity consumption: learning and social influence processes	2011
Guerassimoff, G., Thomas, J.	Enhancing energy efficiency and technical and marketing tools to change people's habits in the long-term	2015
Gupta, R., Barnfield, L., Hipwood, T.	Impacts of community-led energy retrofitting of owner-occupied dwellings	2014
Hamilton, I.G., Steadman, P.J., Bruhns, H., Summerfield, A.J., Lowe, R.	Energy efficiency in the British housing stock: Energy demand and the Homes Energy Efficiency Database	2013
Hamilton, I.G., Summerfield, A.J., Shipworth, D., Steadman, J.P., Oreszczyn, T., Lowe, R.J.	Energy efficiency uptake and energy savings in English houses: A cohort study	2016
Hargreaves, T., Nye, M., Burgess, J.	Keeping energy visible? Exploring how householders interact with feedback from smart energy monitors in the longer term	2013
Harries, T., Rettie, R., Studley, M., Burchell, K., Chambers, S.	Is social norms marketing effective? A case study in domestic electricity consumption	2013

Authors	Title	Year
Havas, L., Ballweg, J., Penna, C., Race, D.	Power to change: Analysis of household participation in a renewable energy and energy efficiency programme in Central Australia	2015
He, H.Z., Kua, H.W.	Lessons for integrated household energy conservation policy from Singapore's southwest Eco-living Program	2013
Herter, K., Wood, V., Blozis, S.	The effects of combining dynamic pricing, AC load control, and real-time energy feedback: SMUD'S 2011 Residential Summer Solutions Study	2013
Hondo, H., Baba, K.	Socio-psychological impacts of the introduction of energy technologies: Change in environmental behavior of households with photovoltaic systems	2010
Howden-Chapman, P., Crane, J., Chapman, R., Fougere, G.	Improving health and energy efficiency through community-based housing interventions	2011
Ida, T., Murakami, K., Tanaka, M.,	Electricity demand response in Japan: Experimental evidence from a residential photovoltaic power-generation system	2016
Ito K.	Asymmetric incentives in subsidies: Evidence from a large-scale electricity rebate program	2015
Iwafune, Y., Mori, Y., Kawai, T., Yagita, Y.	Energy-saving effect of automatic home energy report utilizing home energy management system data in Japan	2017
Jacobsen, G.D., Kotchen, M.J., Vandenbergh, M.P.	The behavioral response to voluntary provision of an environmental public good: Evidence from residential electricity demand	2012
Jensen, C.L., Hansen, LG., Fjordbak, T., Gudbjerg, E.	Providing Free Autopoweroff Plugs: Measuring the Effect on Households' Electricity Consumption through a Field Experiment	2012
Jessoe, K., Rapson, D.	Knowledge is (Less) power: Experimental evidence from residential energy use	2014
Kaiser, M.J., Pulsipher, A.G.	Preliminary assessment of the Louisiana Home Energy Rebate Offer program using IPMVP guidelines	2010
Kassirer, J., Korteland, A., Pedersen,, M.	Team power smart sparks increase in low - Priority, repetitive behaviors	2014
Kavousian A., Rajagopal, R., Fischer, M.	Determinants of residential electricity consumption: Using smart meter data to examine the effect of climate, building characteristics, appliance stock, and occupants' behavior	2013
Kirkpatrick, A.J., Bennear, L.S.	Promoting clean energy investment: An empirical analysis of property assessed clean energy	2014

Authors	Title	Year
Knox, A.	Getting to Net Zero on a Budget: A case study in cost-effectively reducing home and vehicle CO_2 Emissions	2015
Kua, H.W., Wong, S.E.	Lessons for integrated household energy conservation policies from an intervention study in Singapore	2012
Lynham, J., Nitta, K., Saijo, T., Tarui, N.	Why does real-time information reduce energy consumption?	2016
Macintosh, A., Wilkinson, D.	Searching for public benefits in solar subsidies: A case study on the Australian government's residential photovoltaic rebate program	2011
McCoy, D., Lyons, S.	Unintended outcomes of electricity smart-metering: trading-off consumption and investment behaviour	2017
Mizobuchi, K., Takeuchi, K.	The influences of financial and non-financial factors on energy-saving behaviour: A field experiment in Japan	2013
Mizobuchi, K., Takeuchi, K.	Replacement or additional purchase: The impact of energy-efficient appliances on household electricity saving under public pressures	2016
Morris, P., Buys, L., Vine, D.	Moving from outsider to insider: Peer status and partnerships between electricity utilities and residential consumers	2014
Morris, P., Vine, D., Buys, L.	Residential consumer perspectives of effective peak electricity demand reduction interventions as an approach for low carbon communities.	2016
Morris, P., Vine, D., Buys, L.	Application of a Bayesian Network complex system model to a successful community electricity demand reduction program	2015
Murray, A.G., Mills, B.F.	Read the label! Energy Star appliance label awareness and uptake among U.S. consumers	2011
Murtagh, N., Gatersleben, B., Uzzell, D.	20:60:20 - Differences in energy behaviour and conservation between and within households with electricity monitors	2014
Newsham, G.R., Birt, B.J., Rowlands, I.H.	A comparison of four methods to evaluate the effect of a utility residential air-conditioner load control program on peak electricity use	2011
Newsham, G.R., Galasiu, A.D., Armstrong, M.M., Beausoleil-Morrison, I., Szadkowski, F., Sager,	The zero-peak house: Full-scale experiments and demonstration	2013

Authors	Title	Year
J,M., Pietila, A,J., Rowlands, I.H.		
Nielsen, B.	Load-shape data for residential lighting – survey results for incandescent and compact fluorescent lamps	1993
Nilsson, A., Bergstad, C.J., Thuvander, L., Andersson, D., Andersson, K., Meiling, P.	Effects of continuous feedback on households' electricity consumption: Potentials and barriers	2014
Nilsson, A., Stoll, P., Brandt, N.	Assessing the impact of real-time price visualization on residential electricity consumption, costs, and carbon emissions	2017
Oltra, C., Boso, A., Espluga, J., Prades, A.	A qualitative study of users' engagement with real-time feedback from in-house energy consumption displays	2013
Ozawa, A., Furusato, R., Yoshida, Y.	Tailor-made feedback to reduce residential electricity consumption: The effect of information on household lifestyle in Japan	2017
Paetz, A.-G., Dütschke, E., Fichtner, W.	Smart homes as a means to sustainable energy consumption: A study of consumer perceptions	2012
Parker, P., Rowlands, I.H., Scott, D.	Innovations to reduce residential energy use and carbon emissions: An integrated approach	2003
Pelenur, M.J., Cruickshank, H.J.	Investigating the link between well-being and energy use; an explorative case study between passive and active domestic energy management systems	2013
Perez, K.X., Baldea, M., Edgar, T.F.	Integrated HVAC management and optimal scheduling of smart appliances for community peak load reduction	2016
Podgornik, A; Sucic, B., Blazic, B	Effects of customized consumption feedback on energy efficient behaviour in low-income households	2016
Pratt, R.G., Ross, B.A., Sandusky, W.F.	Analysis of water heater standby energy consumption from ELCAP homes	1993
Qiu, Y., Xing, B., Wang, Y.D.	Prepaid electricity plan and electricity consumption behavior	2017
Reeves, B., Cummings, J.J., Scarborough, J.K., Yeykelis, L.	Increasing energy efficiency with entertainment media: An experimental and field test of the influence of a social game on performance of energy behaviors	2015
Reiss, P.C., White, M.W.	What changes energy consumption? Prices and public pressures	2008
Rhodes, J.D., Bouhou, N.E.I., Upshaw, C.R.,	Residential energy retrofits in a cooling climate	2016

Authors	Title	Year
Blackhurst, M.F., Webber, M.E.		
Ro, M., Brauer, M., Kuntz, K., Shukla, R., Bensch, I.	Making cool choices for sustainability: Testing the effectiveness of a game-based approach to promoting pro-environmental behaviors	2017
Salo, M., Nissinen, A., Lilja, R., Olkanen, E., O'Neill, M., Uotinen, M.	Tailored advice and services to enhance sustainable household consumption in Finland	2016
Salvalai, G., Sesana, M.M., Iannaccone, G.	Deep renovation of multi-storey multi-owner existing residential buildings: A pilot case study in Italy	2017
Schelly, C.	Implementing renewable energy portfolio standards: The good, the bad, and the ugly in a two state comparison	2014
Schultz, P.W., Estrada, M., Schmitt, J., Sokoloski, R., Silva-Send, N.	Using in-home displays to provide smart meter feedback about household electricity consumption: A randomized control trial comparing kilowatts, cost, and social norms	2015
Schwartz, D., Fischhoff, B., Krishnamurti, T., Sowell, F.	The Hawthorne effect and energy awareness	2013
Scott, M.G., McCarthy, A., Ford, R., Stephenson, J., Gorrie, S.	Evaluating the impact of energy interventions: Home audits vs. community events	2016
Seo, H., Sung, J., Oh, S.-D., Oh, H.-s., Kwak, H.-Y.	Economic optimization of a cogeneration system for apartment houses in Korea	2008
Sovacool, B.K.	The importance of comprehensiveness in renewable electricity and energy-efficiency policy	2009
Steinhorst, J., Matthies, E.	Monetary or environmental appeals for saving electricity? Potentials for spillover on low carbon policy acceptability	2016
Strengers, Y., Maller, C.	Integrating health, housing and energy policies: Social practices of cooling	2011
Sudarshan, A.	Deconstructing the Rosenfeld curve: Making sense of California's low electricity intensity	2013
Taylor, N.W., Searcy, J.K., Jones, P.H.	Multifamily energy-efficiency retrofit programs: A Florida case study	2016

Authors	Title	Year
Thomsen, K.E., Rose, Jø., Mørck, O., Jensen, S.O., Østergaard, I., Knudsen, H.N., Bergsøe, N.C.	Energy consumption and indoor climate in a residential building before and after comprehensive energy retrofitting	2016
Tiefenbeck, V., Staake, T., Roth, K., Sachs, O.	For better or for worse? Empirical evidence of moral licensing in a behavioral energy conservation campaign	2013
Van Dam, S.S., Bakker, C.A., Van Hal, J.D.M.	Home energy monitors: Impact over the medium-term	2010
Vassileva, I., Dahlquist, E., Wallin, F., Campillo, J.	Energy consumption feedback devices' impact evaluation on domestic energy use	2013
Waite, M., Deshmukh, A., Modi, V.	Experimental and analytical investigation of hydronic system retrofits in an urban high-rise mixed use building	2017
Wallace, A.A., Fleming, P.D., Wright, A.J., Irvine, K.N.	Home energy efficiency grants and advice: Findings from the English Midlands	2010
Wallenborn, G., Orsini, M., Vanhaverbeke, J.	Household appropriation of electricity monitors	2011
Webb, J., Hawkey, D., McCrone, D., Tingey, M.	House, home and transforming energy in a cold climate	2016
Woo, C.K., Zarnikau, J., Shiu, A., Li, R.	Winter residential optional dynamic pricing: British Columbia, Canada	2017
Zivin, J.G., Novan, K.	Upgrading efficiency and behavior: Electricity savings from residential weatherization programs	2016

* Part of the same intervention, representing different components