Programme Area: Smart Systems and Heat

Project: Value Management

Title: Overcoming barriers to smarter heat solutions in UK homes - Annexe 3a: Modelling customer uptake (including attitudes to risk)

Abstract:

This document was prepared at the time to contribute to ETI internal thinking and planning only.

Context:

This project studied how value can be delivered across a smart energy value chain - in the context of the UK. It built a clear understanding of how smart energy systems can deliver combined consumer value alongside commercial value for market participants - producers, suppliers, distributors. The analysis will help to make the commercial deployment of smart energy systems more likely. This £600,000 project was delivered by Frontier Economics, a leading economic consultancy.

Overcoming barriers to smarter heat solutions in UK homes

Annexe 3a: Modelling customer uptake (including attitudes to risk)

PREPARED FOR THE ETI

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1 Introduction

In our main report, we have considered how the interactions between the features of the market for low carbon heat; the way consumers behave in relation to the heating market and the characteristics of the interventions themselves drive barriers to uptake of low-carbon heating interventions.

We now show how the "rational agent" modelling used within BMET fits within this framework, and examine whether there is scope for BMET to incorporate a broader set of consumer behaviours.

This annex is structured as follows.

- First, we provide a brief summary of the framework for customer uptake used within the main report. This brings together various aspects of consumer choice, and can be used to explain why consumers may fail to take up propositions that may offer long-run benefits, and how such barriers to take-up may vary between different types of customers.
- Next, we provide further information on how customer attitudes to risk can be incorporated into this framework. We consider the types of risk that consumers may wish to avoid, and how they may value such risks.
- We then explain how customer uptake (both of interventions and of business models which can package up interventions) is modelled within BMET. The "rational agent" modelling within BMET focusses on a subset of the wider framework described above.
- Finally, we set out the implications for quantitative customer uptake modelling. We conclude that:
  - The "rational agent" approach to modelling adopted by BMET can provide important insights into the long-run potential for interventions, and how business models may be able to overcome specific barriers that can already be quantified (for example, credit constraints).
  - While theoretical predictive models of consumer take-up do exist, it would not be possible to produce a quantitative model that attempts to forecast all relevant aspects of uptake. However, BMET does provide a framework for thinking about uptake. It could help design questions and inform the design of trials to investigate how consumers make these types of decisions within the energy sector. The ETI is uniquely well-place to carry out this type of research, and which would help better understand the potential for future interventions and business models.

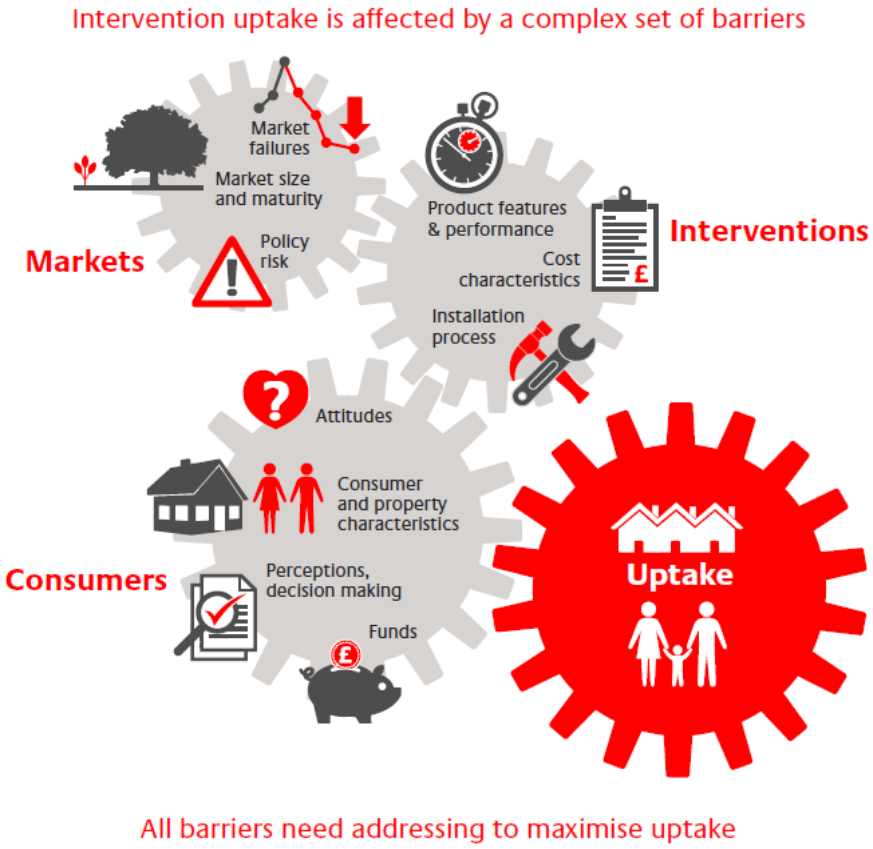
2 Framework for customer uptake

Figure 1 below, reproduced from the main report, illustrates the different types of factor that may affect the uptake of low-carbon interventions.[1] These can be broadly divided into the following categories:

- **Factors relating to the nature of the interventions themselves.** These include costs (both upfront capital costs and ongoing fuel costs), hassle of installation and performance (for example responsiveness).
- **Factors relating to consumers.** For example, awareness of and interest in new technologies, aversion to risk, the extent to which consumers focus on the near-term, and credit constraints.
- **Factors relating to market structures and policy**. For example, whether consumers face a cost of carbon, whether incentives are misaligned between groups such as landlords and tenants, and whether there is uncertainty around future government policy.

1 This draws on the literature on barriers to uptake which we summarise in appendix 1 of this document, as well as our characterisation of the barriers to the heating technologies that we consider, which is set out in appendix 2 of this document.

Figure 1. The interaction between the characteristics of the interventions themselves, the features of the market and the way consumers relate to the heating sector



Source: Frontier Economics

Often, it is a combination of different types of factor that produces a barrier to intervention take-up. In the main report, we discuss a number of areas where solutions are required including:

- **Cost and heating service delivered.** We cannot ignore the fact that many consumers are happy with their existing heating systems, and that some low-carbon interventions will not make them better off, either financially or in terms of the heating service they receive. While cavity wall insulation and HEMS can improve the heating service for consumers, and save them money, important barriers in this area exist for district heat, solid wall insulation and heat pumps. For district heat, costs need to come down so it can compete with the incumbent gas boilers. For heat pumps and solid wall insulation, it's about both bringing costs down *and* improving the service

consumers receive from these technologies, for example, by tackling issues around performance, aesthetics, risks and hassle associated with installation.

- **Decision making**. At the moment, consumers' decision making is stacked against low-carbon interventions. Low interest, low awareness and a tendency to choose in "distress", means that consumers will tend to go for the familiar incumbent heating system, or nothing at all. It is therefore necessary to find ways of making it easier for consumer to choose low-carbon interventions- for example by engaging with consumers at different times, in different ways, or with a different focus. Both business and policy can help in this area.

- **Upfront costs.** The high upfront costs associated with low-carbon interventions result in an important barrier to uptake, when combined with consumers' focus on near term costs and benefits, credit constraints and misaligned incentives between landlords and tenants. Again, this barrier means that even where interventions are in consumers' best interests, they may not take them up.

- **Natural monopolies.** Finally, intervention will be required to ensure natural monopolies in district heat can deliver the best possible service for consumers.

The barriers to intervention take-up can vary across both different types of consumer, and different types of intervention. Importantly, if multiple barriers prevent uptake of an intervention, it will be necessary to overcome them all to ensure uptake. For example, although improving the performance of an intervention may make it more attractive (even if it is still deficient in other areas, such as cost), this will not by itself increase consumer awareness, or help credit-constrained customers purchase it.

3 Consumer attitudes to risk

The future benefits that interventions will bring to consumers are subject to uncertainty. For example, given they are relatively unfamiliar in the UK context, a consumer may be uncertain over the future heating performance of a heat pump. This, in combination with consumer aversion to risks, can act as a barrier to take-up.

In this section, we provide additional information on methods that can be used to quantify the cost that consumers place on risky outcomes, and how these could relate to decisions regarding interventions and business models.

Any model that seeks to explain how consumers' attitudes to uncertainty affect their choices must do two things.

- First, it must **characterise the uncertain outcomes** that consumers face when making a particular choice (in this case, of intervention). Below, we examine what sources of uncertainty may exist for consumers when deciding whether or not to take up an unfamiliar intervention such as an air source heat pump.

- Second, it must explain **how consumers compare different sets of uncertain outcomes** when making a choice. We have briefly summarised some of the literature that seeks to explain how they weigh up competing uncertain choices (for example, when deciding whether to take up a heat pump or a boiler), which will be associated with quite different levels of uncertainty across some of these categories.

While it may be possible to quantitatively characterise sources of uncertainty (as we have started to do here), we explain below why it is not possible to forecast with confidence the impact they will have for any particular purchasing decision.

3.1.1 Characterising sources of uncertainty

Any intervention or business model will be associated with various sources of uncertainty. **Table 1** below summarises some of the forms of uncertainty that could be associated with the installation of an intervention such as a heat pump (most of these will also apply to other interventions such as HEMS, insulation, or district heating). The final column shows the effect that these forms of uncertainty would have on the consumer, which broadly fit into the following categories of outcome:

- monetary factors (for example, the intervention may cost more or less to run than expected);

- hassle factors (for example, the intervention may take longer or shorter to install than expected); and

- comfort factors (for example, the intervention may supply a lower or higher grade of heat than the consumer expected).

Table 1. Example risks

Source of risk	Description	Effect on customer outcomes
	Cost-related risks	
Uncertain fuel costs	Prices of fuels (e.g. gas, whether used by itself or as an input to electricity generation) cannot be perfectly forecasted by consumers	**Running costs** may be higher or lower than expected
Uncertain generation mix	The future generation mix cannot be perfectly forecasted by consumers, affecting electricity prices	**Running costs** may be higher or lower than expected
	Technological risks	
Uncertain technical efficiency	The technology may prove to be better or worse (e.g. more/less efficient at using fuel or preventing heat loss) than the consumer expected	**Running costs** may be higher or lower than expected
Uncertain heat grade	The technology may heat the house to a different temperature than expected by the consumer	**Comfort** may be higher or lower than expected
Uncertain flexibility	The technology may be more or less responsive than expected	**Comfort** may be higher or lower than expected
Uncertain reliability	The technology may be more or less reliable than expected, requiring more / fewer maintenance visits	**Maintenance** costs, hassle and comfort may be higher or lower than expected
	Financial risks	

Table 1. Example risks

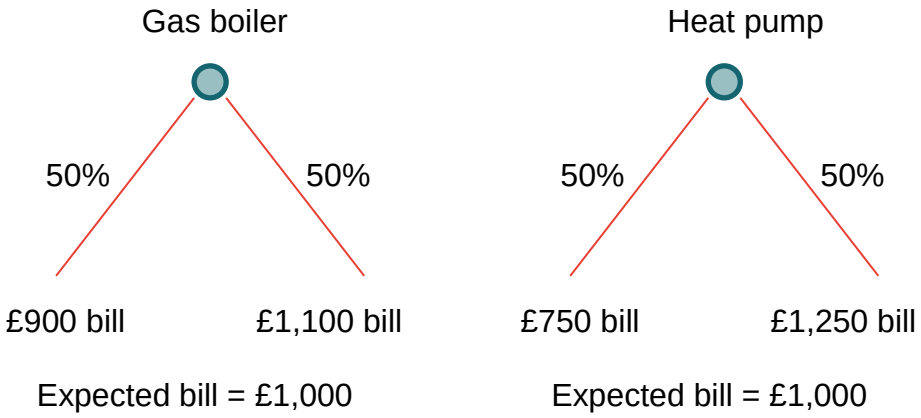
Source of risk	Description	Effect on customer outcomes
Uncertain future income	A consumer's income may be higher or lower than they expected, which could affect their ability to service a loan	**Disposable income** after the loan repayments are taken out may be higher or lower than expected
Uncertain market value of interventions	When the consumer moves house, the market may price in the benefits of the interventions to a greater or lesser extent	Change in **value of house** may be higher or lower than expected
Uncertain duration of tenancy	The consumer may move house earlier than expected – if intervention values are not reflected in house prices, this will lead to a loss	Effective **lifetime** of interventions may be higher or lower than expected
	Hassle-related risks	
Uncertain delay	The time taken between ordering an intervention and it being commissioned cannot be perfectly predicted	**Hassle** and **comfort** may be higher or lower than expected
Uncertain hassle associated with maintenance	It is hard to predict how much hassle (e.g. time spent without heat services) will be incurred during maintenance	**Hassle** and **comfort** may be higher or lower than expected

Source: Frontier

3.1.2 How customers compare uncertain outcomes

The textbook economic theory of how consumers make choices under uncertainty is known as *expected utility theory*. In its most basic form,[2] this assumes that consumers understand that a choice could lead to a variety of outcomes. For example, **Figure 2** illustrates a situation where a consumer expects on average that a gas boiler or a heat pump would have the same running costs of £1,000 per year. However, there is an element of risk – there is a 50% chance that bills could be higher, or a 50% chance they could be lower. In this example, the heat pump would be seen as riskier, as the difference between the "low bill" and "high bill" payments is greater than for a gas boiler.

Figure 2. Illustrative example of expected utility theory



Source: Frontier

Consumers in such a model are typically assumed to be **risk-averse**. This means that, when presented with two alternatives that have the same expected value but different levels of risk, they will choose the alternative with the lowest risk. In the example above, a risk-averse consumer would choose the boiler over the heat pump. To incentivise them to take up the heat pump, they would have to be rewarded with additional benefits such that the expected benefits of the heat pump exceeded those of the gas boiler.

Experimental evidence has shown that this relatively simple theory can fail to explain observed consumer behaviour in the presence of uncertainty. Behavioural economics, drawing upon more complex models of consumer behaviour can help us to understand how consumers deal with risks. *Prospect*

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2 A more rigorous explanation of expected utility theory can be found in any microeconomics textbook – for example Max-Colell, A. and Whinston, M. D. (1995) *Microeconomic Theory*

theory is such a model which can provide helpful insights on the way consumers perceive risks which can be an important barrier.[3] Prospect theory incorporates the following four components in explaining decision making under risk.

- **Reference dependence** – People think about gains and losses measured relative to some reference point rather than from absolute levels of wealth. This implies that people care about relative changes rather than absolute values.

- **Loss aversion** – People are much more sensitive to losses than to gains of the same magnitude.

- **Diminishing sensitivity** – People are more sensitive if replacing a £100 gain by a £200 gain compared to if they are replacing a £1000 gain by a £1100 gain.

- **Probability weighting** – Unlike the simple example above, consumers are rarely able to accurately attach probabilities to every possible outcome. Prospect theory suggests that people place subjective rather than (the true) objective probabilities for risks.

All these components indicate that consumers do not behave purely rationally in a traditional economic sense and that it is therefore crucial how consumers *perceive* risk (rather than the actual risk). However, there is no simple way to use such a theory to forecast a consumer's perception of risk for a specific situation. This is due in part to the reference-dependence described above: One type of customer making a particular decision (for example a consumer whose boiler has just broken and is deciding whether to purchase a heat pump) may weigh up uncertainty very differently to a different customer making a different decision (for example a consumer about to build a house from scratch deciding whether to install solid wall insulation). Rather than attempting to build a "bottom-up" model to predict choice under uncertainty, it can be more informative to observe actual consumer behaviour – potentially within trials if the markets within which the choices would be made do not yet fully exist.

3 See Kahneman, Tversky, Prospect Theory: An Analysis of Decision under Risk, Econometrica (1979).

4 Uptake within BMET

This section explains how customer uptake choices are modelled within BMET, setting out the ways in which this necessarily abstracts away from many of the elements of behaviour described above.

BMET models two distinct consumer decisions:

- whether to purchase specific interventions (insulation retrofits, HEMS, and heating system upgrades) or to stick with their incumbent technology; and
- whether to take up an entire service provided by a business model (which may provide interventions as part of a wider proposition), rather than carrying out upgrades themselves.

Since the tool has been designed primarily to evaluate business models, the second type of decision is modelled in greater detail than the first type of decision. The descriptions below highlight those areas that BMET is currently suited to modelling, and those that it omits.

4.1.1 Modelling of intervention take-up

Table 2 shows the extent to which BMET incorporates the various factors described in our uptake framework, when considering whether or not a consumer purchases an intervention in the absence of a business model.[4] This process can be observed within the "Bundle costs/benefits" sheet within BMET.

It can be seen that BMET does not model some aspects of the product or process which are hard to quantify (for example, levels of comfort, or most forms of hassle). In addition (and potentially more importantly), BMET assumes that consumers are perfectly rational, informed individuals.[5]

4 Within BMET, this is referred to as the consumers' *counterfactual* decision. BMET also models the decision by a business model provider of which interventions to purchase in a similar way.

5 It is worth noting two further limitations in the modelling. First, consumers in BMET treat each decision to take up an intervention as "now or never". For example, if solid wall insulation has a positive net present value in 2015, customers will take it up – even if it might be better for them to delay take-up until 2020. In technical parlance, BMET does not consider the "option value" of waiting to install an intervention. Second, various technical limitations are applied to the order in which customers can take up interventions – these are described in the separate annexe on intervention uptake ordering.

Table 2. BMET modelling of intervention take-up

	Taken into account	Not taken into account
Actual nature of the interventions – including the switching and installation process	The cost of purchasing the intervention and installing it. The future electricity and gas bills over the lifetime of the intervention.	Aesthetics, responsiveness, and levels of comfort. Hassle associated with installation of interventions.
Consumer characteristics and decision-making	As a simple proxy for customer unfamiliarity with interventions, it is assumed that a £1,000 "additional hassle factor" is incurred when HEMS, insulation, or a heating system upgrade is taken up in 2015[6]. This factor halves every five years, to represent increasing familiarity. If the consumer does not have sufficient income to purchase the intervention outright, they will purchase it using a loan. If they have insufficient income for this, they will not purchase the intervention at all.	Lack of interest in the heating market Lack of trust Other cognitive barriers (such as use of inaccurate rules of thumb). A focus on near term costs and benefits (customers are assumed to weigh up costs and benefits over as long as 50 years). A detailed analysis of trigger points that cause a customer to make a decision.[7] Perceived risk.
Market structures and policy	Within the default scenario, a carbon tax is levied upon both gas and electricity (at the DECC	Distinction between rented and owned properties (it is assumed that the landlords' incentives

6 Within the inputs for BMET, the "additional hassle factor" is entered into the model as being only associated with HEMS. However, HEMS is sufficiently attractive that all customer groups will ultimately take up a bundle with HEMS in it, and as explained in annexe 4c, BMET forces that customers must take up all interventions at once (and cannot delay HEMS without delaying any other interventions). The result is that the additional hassle factor effectively delays all interventions, not just HEMS.

7 It is assumed that, when individuals take up a contract that provides a heating technology, the trigger point is their old technology breaking (and that they would therefore have to replace it anyway). In practice, this would mean that only a small proportion of individuals would be "triggered" each year. However, as BMET models long-run take-up, we assume that eventually all existing heating systems will break.

	shadow price of carbon). This proxies for any government incentive aimed at increasing intervention uptake.	perfectly reflect those of tenants). More detailed government policies.

Source: Frontier Economics

4.1.2 Modelling of business model take-up

Table 3 explains how BMET models the decision of consumers to take up a business model. Underlined text highlights those areas where the modelling takes additional aspects of consumer behaviour into account.

Uptake within BMET

Table 3. BMET modelling of business model take-up

	Taken into account	Not taken into account
Nature of the interventions – including the switching and installation process	The cost of taking up the business model, compared to the cost of purchasing fuel and interventions in the counterfactual. A value of time associated with the duration of any installation works. This is considered in the same way as monetary costs.	Aesthetics, responsiveness, and levels of comfort.[8] Hassle associated with installation of interventions that goes beyond the value of customers' time.
Consumer characteristics and decision-making	As a simple proxy for customer unfamiliarity with interventions, it is assumed that a £1,000 "additional hassle factor" is incurred when HEMS, insulation, or a heating system upgrade is taken up in 2015. This factor halves every five years, to represent increasing familiarity. A limited treatment of risk (described below). This is considered in the same way as monetary costs. If the consumer does not have sufficient income to pay fees to the business model provider, they will not take up the business model.	Lack of interest in the heating market Lack of trust Other cognitive barriers (such as use of inaccurate rules of thumb). A focus on near term costs and benefits (customers are assumed to weigh up costs and benefits over as long as 50 years). A detailed analysis of trigger points that cause a customer to make a decision. Some other forms of risk (described below).
Market structures and policy	Within the default scenario, a carbon tax is levied upon both gas and electricity (at the DECC shadow price of carbon). This proxies for any government incentive aimed at increasing intervention uptake.	Distinction between rented and owned properties (it is assumed that the landlords' incentives perfectly reflect those of tenants). More detailed government policies.

Source: Frontier

8 The ability to introduce a monetised value for comfort is included in the model.

Overall, the approach to modelling taken by BMET can be summarised as follows.

- Monetary costs and benefits to taking up a business model are captured in a comparatively detailed fashion (for example, time-of-use tariffs are modelled). These appear as the monetary factors on the "Counterfactual and business model payment breakdown" graph within BMET.

- Consumer fund constraints are also modelled (although the inputs regarding consumers' access to credit are not based on detailed empirical evidence).

- Some non-monetary aspects of product and process are captured – for example, the time costs associated with installation, or a basic treatment of bill volatility risk, described in the box below. These are shown within the "Risk" and "Hassle / time" components of the graph. However, there are a large number of other non-monetary costs that are hard to quantity.

- Barriers around consumer awareness and perception are generally not modelled. Consumers are assumed to weigh up the costs and benefits of business models in a rational fashion, treating risk in a simple way consistent with expected utility theory.

The next section considers the implications of this for how BMET can be used, and how uptake modelling could be developed further.

Treatment of risk within BMET

The treatment of risk is based around a simple expected-utility framework, described in the preceding section. Two forms of risk are characterised:[9]

- a risk of uncertain utility bills (unless a business model is chosen which fixes them); and
- a (perceived) risk that the performance of a heat pump purchased by the consumer may be different to expected. This is modelled by assuming utility bills are even more uncertain if a heat pump is installed.

This risk is valued using a basic expected utility framework. It is assumed that customers care about their disposable income (income after required payments, which include utility bills). Greater uncertainty in bills will lead to greater uncertainty in disposable income, and thus a higher willingness to pay to fix bills. The use of risk-aversion also means that customers who already had a low disposable income are assumed to be willing to pay more to avert bill volatility (providing they have a sufficiently high income to support the extra payment, which works like an insurance premium). Intuitively, a consumer with £1,000 of discretionary spend a year is likely to care more about a £200 reduction than a consumer with £20,000 of discretionary spend.

9 The user of the tool can disable or amend these assumptions.

5 Implications for quantitative customer uptake modelling

Above, we have shown that BMET is consistent with the more general framework of uptake we have outlined but (as any model) is only able to account for a subset of uptake drivers. In this section, we first explain what this implies for the types of questions that BMET can be usefully used to answer (and those that it is less suited to).

5.1.1 Appropriate use of BMET

As shown above, BMET considers a world in which non-cost barriers to uptake (for example, those around consumer perception) do not exist. **BMET can therefore be used to model long-run intervention (heat pumps, insulation, HEMS) uptake under the assumption that it has been possible to overcome all the non-cost barriers that are not modelled.**

This can help answer the following sorts of questions:

- If some combination of business models and policies were to overcome the various non-cost barriers, what would be the maximum uptake we could expect of each intervention? How might uptake vary across time, and by customer group?
  - For some interventions (e.g. some kinds of insulation) in some customer groups, uptake will be strong. This suggests that a combination of business models and policies that remove the non-cost barriers may lead to uptake.
  - By examining payback periods within BMET, we can determine how great some of these non-cost barriers may be. If payback periods are far in excess of a reasonable contract length, it may be difficult to incentivise customers with a focus on near term costs and benefits to take up an intervention or business model. The tool can help determine how far costs need to fall to get payback down to 5 or 10 years, and, how this varies by property characteristics.
  - For some interventions (e.g. heat pumps) in some customer groups, this modelled uptake may be zero. This indicates that overcoming the non-cost barriers alone without also tackling the cost barriers would be insufficient to ensure uptake. How far would costs of the intervention have to fall before uptake takes off (assuming all the non-cost barriers are also tackled)? What if we additionally imposed a 5 or 10 year payback period? How does this vary across property characteristics? How does this vary by customer type once we

introduce the two main non-cost barriers covered by BMET (risk aversion and access to credit)?

- Credit constraints are modelled within BMET. It is therefore possible to use the tool to determine whether credit constraints are an important driver (assuming all other non-cost barriers are tackled?) This can give insights into the importance of policies such as reforming the Green Deal.

- Some elements of risk (the effect of bill volatility) are modelled within BMET. It is therefore possible to use the tool to determine the types of groups for which this may be significant, given the expected utility modelling in the tool.

- BMET can also be used to model business model responses to some of the barriers. For example, BMET can be used to examine the costs to businesses of managing risk and of accessing credit. This also can help us understand how solutions may increase uptake.

Naturally, BMET is not capable of providing insights into the relative importance of barriers not included within the modelling. In addition, BMET cannot be used to predict absolute levels of uptake, given that it does not account for all barriers/drivers. To the extent barriers exist that are not modelled by BMET, it will tend to over-estimate intervention uptake.

5.1.2 Future model development

As shown above, the appropriate uses for BMET depend on the elements of the uptake framework which it models. To what extent might the ETI (or other organisations) extend this type of modelling to capture more of the factors underlying uptake?

It is useful to distinguish between two tasks that are required in any modelling exercise:

- First, there must be an appropriate quantitative framework that can be implemented to explain whatever phenomenon is being modelled. For example, prospect theory provides one way in which choice under uncertainty can be understood.

- Second, it must be possible to estimate the parameters that the framework requires. For prospect theory, this would require characterising all the relevant risks, as well as parameters that describe the extent of loss-aversion, the customers' reference point etc.

Table 4 summarises potential future improvements that could be made to BMET.

Implications for quantitative customer uptake modelling

Table 4. Future improvements to BMET

Type of factor driving take-up	Which drivers are not accounted for in BMET?	Is there a framework that could be used in a model?	What empirical evidence is available on the parameters for this framework?
Actual nature of the interventions – including the switching and installation process	Some non-monetary characteristics of the interventions themselves. For example: Hassle other than installation time, heating system comfort, aspects of risk that go beyond bill volatility.	Non-monetary costs and benefits can potentially be quantified through revealed preference techniques.	Research exists on some of the non-monetary costs and benefits of different interventions (for example installation times for interventions), although there is less available regarding how these are perceived by consumers. More information may be from future trials.
Consumer characteristics and decision-making	Lack of interest, lack of awareness, lack of social norms, lack of trust, perceived risk, focus on costs and benefits that occur in the short run, and cognitive barriers in decision making.	Low interest and awareness could potentially be modelled by considering which trigger points may lead to awareness, and how often these will occur for different consumer groups. Frameworks exist that model consumer attitudes to subjective risk – for example Prospect Theory. However, a vast number of variants of this type of framework exist – without empirical evidence, it is not possible to say which are applicable. A focus on near term costs and benefits could be accounted for through	Much behavioural economics theory stresses the importance of context in decision-making. Research specific to choices made around SSH technologies is therefore likely to be required to populate these types of framework.

		applying hyperbolic discount rates (or simply increasing the existing discount rates). However, this would not account for 'rule of thumb' decision making.	
Market structures and policy	Misaligned incentives between landlords and tenants.	By modelling that energy efficiency is not accounted for in rental prices, and allowing tenants and landlords to have different payoffs resulting from this.	We have used this methodology as part of the CBA. However, further empirical evidence would be required to demonstrate whether there is truly no incentive for landlords to upgrade their properties – the prevalence of retrofits such as cavity wall insulation even in rented properties suggests that some incentive does exist.

Source: Frontier Economics

Implications for quantitative customer uptake modelling

The discussion above indicates that there are some ways in which the existing "rational" uptake modelling within BMET could be extended (for example by accounting for more sources of hassle). However, it would be impossible to produce a "bottom-up" quantitative model which takes into account consumer perceptions and decision-making to predict uptake. This is because some factors which affect consumer uptake are fundamentally impossible to model in a bottom-up way. For example, how would one produce a model which determines from a product's characteristics whether it will be fashionable, and thereby attract consumers' interest?[10]

If this type of modelling cannot be carried out, how is it possible to determine which business models and policies are required to ensure SSH uptake? The answer lies in using "bottom up" quantitative models such as BMET alongside more extensive qualitative frameworks (such as the market/consumer/business framework described in **Figure 1**) and – importantly – field trials and experiments. The ETI is in a uniquely strong position to provide this type of analysis, since it has extensive experience both in practical trials, and academic research. Additionally, the ETI's membership cuts across both the public and private sectors, covering both policies and business models.

The following framework explains how all three components (quantitative modelling, qualitative frameworks, and experimental trials) can work together:

1. **Diagnose** barriers to SSH uptake. Using frameworks of consumer behaviour like the consumers/interventions/markets one outlined above, the ETI can start to understand what may be holding back adaptation of these technologies.

2. **Target** those barriers which can be effectively removed using a combination of policies and business models. Rational uptake tools such as BMET (as well as ESME) can be used to determine the interventions that consumers would optimally take up in the absence of other barriers. This can help show which barriers are due to fundamental problems with products, as opposed to the way in which consumers view them. Models such as BMET can also be used to consider the impact of a subset of more quantifiable barriers, such as credit constraints.

3. **Create** business models or policies that may be able to overcome these barriers. Policy and business models have important, but distinct, roles in overcoming these barriers**.** Businesses are best placed to both understand what it is that consumers want, and to deliver on this. Therefore harnessing the initiative

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10 In addition, even where quantitative frameworks already exist (for example when looking at perceptions of risk), there are a vast number of different theories of consumer decision-making, requiring significant amounts of input data. To choose between these frameworks and to apply them requires knowledge of the context in which decision are made.

of businesses should be the first choice for overcoming the barriers. Policy then needs to set a framework that allows low-carbon interventions to compete with incumbent options (by correcting market failures) and deliver on distributional aims.

4. **Test** how consumers are likely to react to the targeted factors. Given the way in which consumer decisions depend on the context, "bottom up" quantitative modelling is no substitute for observing actual consumers. Due to the uncertainties in how consumers may react, it may be more informative to run a larger number of different trials, rather than a single large pilot. The results from trials can be fed back into further designs for policies and business models. Empirical modelling (similar to that in BMET) can show how a business or policy might fare, given the consumer reactions that have been observed.

5. **Deliver** the business models or policies once they have been shown to overcome the relevant barriers to SSH technology uptake.

Implications for quantitative customer uptake modelling

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