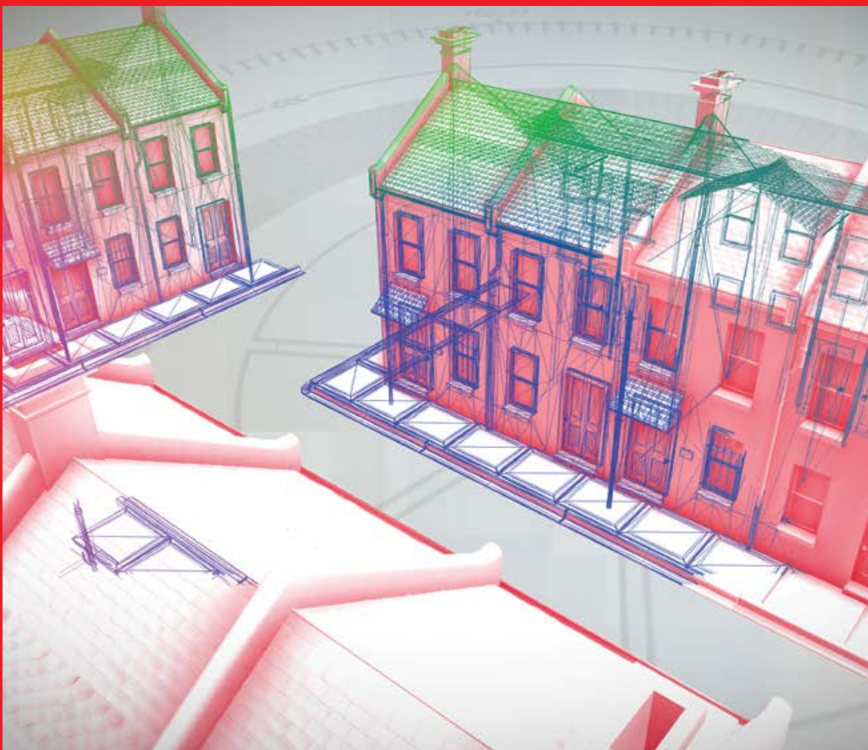
energy technologies institute

An insights report by the Energy Technologies Institute

Smart Systems and Heat

Decarbonising Heat for UK Homes



The buildings sector needs to be largely decarbonised as part of a least cost low carbon energy system. There are two principal pathways for domestic space and water heating, with different inherent features. Consumers want better control of the time, effort and money they spend making a comfortable, healthy home – it is not simply about minimising their running costs.

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Key headlines

» The near total elimination of carbon emissions from existing homes is required by 2050

» There are two key solutions for low carbon home heating – local area schemes using heat networks and individual home systems using electric heat, each with different challenges

» Compelling consumer propositions and business models are needed. Social benefits will also be important and affordability needs to be a key element of transition planning

» A system level framework is required to package known but underdeveloped technologies into integrated solutions

» System designs and local spatial plans are needed for the efficient development of energy assets and to support end-user engagement

» Integrating the delivery of an energy system transition strategy into local planning processes, with local ownership, will be key to the delivery of near zero emissions

» Low carbon heating systems will introduce the need for new heat production and network assets, along with significant electricity network reinforcement, whilst the utilisation of local gas distribution networks will be reduced

» The next decade will be critical in preparing for the transition and building confidence. A policy framework is required that supports the combination of individual and collective decisions and investments. Rapid implementation is then required from 2025

Executive Summary

» There are two principal pathways towards the decarbonisation of domestic space and water heating

» The most cost effective solutions involve decarbonisation of the energy supply combined with efficiency measures that are selectively rather than universally applied

» The real issues are centered around the integration of existing technologies to meet consumer needs, and the development of consumer products and system design tools to support the transition

» Before 2050 around 26 million homes will each require new low carbon installations – the equivalent of ten Milton Keynes' each year

Around 20% of the nation's carbon emissions are generated by domestic heating. Analysis of the many ways the energy system might be adapted to meet carbon targets shows that the elimination of emissions from buildings is more cost effective than deeper cuts in other energy sectors such as transport. This effectively means that alternatives need to be found for domestic natural gas heating systems.

Enhanced construction standards are ensuring that new buildings are increasingly energy efficient, but the legacy building stock, of around 26 million homes, has relatively poor thermal performance and over 90% are expected to still be in use in 2050. Even if building replacement was seen as desirable, the cost is unaffordable, and the carbon emissions associated with the construction would be considerable.

The scope for cost effectively reducing the energy demand of existing buildings to the great extent required to meet emissions targets is limited as comprehensive insulation and improvement measures are expensive and intrusive. A several hundred billion pound investment in demand reduction for the entire building stock might deliver less than half of the emissions abatement needed.

The most cost effective solutions therefore involve the decarbonisation of the energy supply combined with efficiency improvements that are selectively rather than universally applied, as part of a composite package.

Current boiler based heating technology is very responsive to peak heating demand, generally delivers appropriate levels of comfort and is the accepted solution in over 90% of households with central heating. Consumers are not greatly engaged in the complexities of energy systems so it will be challenging to displace gas heating in a way they find acceptable. Low carbon heat solutions will need to be at least as effective in meeting consumer requirements as the incumbent gas system and be capable of integration within the building space. The associated new consumer offerings must also be compelling and reinforced by supportive market frameworks and price signals.

There are two principal pathways towards the decarbonisation of domestic space and water heating which largely reflect the spatial characteristics of housing, but have quite different inherent features. In both situations there is a balance to be struck between the investment in demand reduction or efficiency measures and the cost of low carbon heat generation.

In more densely populated urban and suburban areas, and potentially some rural towns the solutions are likely to involve shared heat network installations with relatively limited household intrusion during conversion. The challenges are building the social and political momentum necessary to introduce new local energy production and distribution assets that are shared by users across whole areas.

In locations with lower density housing the solutions are more likely to be focused on individual properties, using electrically powered heat pumps or direct resistance heating. Here, the challenges are more about integrating solutions into homes and the wider energy system as these solutions generally have significant space requirements and involve extensive efficiency improvement measures, resulting in substantial investment in the individual properties coupled with electricity infrastructure reinforcement.

It is important to understand the local asset infrastructure requirements of these options, either to facilitate the installation of heat delivery networks or to reinforce the local power networks to meet the electricity demands of the individual home solutions. A process of strategic energy planning that takes account of the spatial characteristics and infrastructure should therefore become an essential component of local planning procedures.

Executive Summary (continued)

Whilst innovation in technology will continue to deliver some improvements, the impact will be incremental. The real issues are centred around the integration of existing technologies to best meet consumer needs, and the development of consumer products and system design tools that support the transition.

Here, national climate change objectives reach every street in the country. Success will depend on strong leadership alongside effective community decision-making and governance to ensure the coordination and implementation of systems that meet the objectives are cost efficient and make sense at a local level.

2050 may well be considered to be a distant horizon, but before then around 26 million homes will each require new low carbon installations.

This transition will involve whole areas of housing, working at a rate of around 20,000 homes per week over a 25 year period – the equivalent of ten Milton Keynes' each year. One of the key enablers is the decarbonisation of the electricity networks in readiness for the transition, and one of the key considerations is the likely contraction of the local gas grid.

The human and financial resource implications and economic opportunities of such an endeavour are significant, requiring a substantial extension of the existing workforce alongside the development of a new skill base. However, the market will not provide a spontaneous reaction and will only have the confidence to engage if it sees an appropriate framework, and understands and believes in the opportunity.

It is clear then that a preparation phase cannot be delayed. This should be a time of vigorous action to develop a succession of pilot schemes that increasingly build at scale to test the design approach and strengthen the market pull for the deployment of solutions, so building the evidence base, capability and confidence around the national plans and policies that are the essential foundations of any successful transition.

20,000

Homes per week

This transition will involve whole areas of housing, working at a rate of around 20,000 homes per week over a twenty five year period – the equivalent of ten Milton Keynes' each year.

Introduction

» Household heating contributes some 20% of national carbon emissions

» The challenge is to establish new heating solutions that substantially remove

Household heating contributes some 20% of national carbon emissions. There are many plausible low carbon transition pathways but the overall mitigation opportunities in the buildings sector are generally more cost effective than other sectors such as transport. From a total system perspective this highlights the need to essentially decarbonise the nation's buildings.

The real challenge is establishing new heating solutions that substantially remove natural gas use from homes. The approach being developed by the ETI's Smart Systems and Heat (SSH) Programme is designed to help build the capability and confidence needed in a market required to deliver a coherent energy system transition. This is being tackled by more fully understanding the underlying requirements of consumers, designing integrated consumer solutions and planning tools, so building the capability to gain consensus and develop local plans. The programme produces an evidence base to inform the policy framework that helps link national objectives to local delivery.

Introduction
» Continued

This booklet summarises both the challenges and a practical approach to the decarbonisation of heat in domestic and smaller commercial buildings by considering –

1. Why Heat Matters - What drives the need for building decarbonisation?

2. Consumer Requirements - What do consumers actually seek and what drives energy decisions in the home?

3. Heating Technologies - What are the technical components and how might they be assembled to meet consumer needs and climate change targets?

4. Energy System View - What design choices are available at an energy system level, how are peak demands met, and how should power, heat and gas systems be integrated?

5. Consumer Propositions and Business Models - What kind of propositions and business models would drive the transition?

6. National Targets to Local Strategies - How can national targets be translated to local actions?

7. Preparedness, Policy and Leadership - What leadership and governance is needed to drive successful transition?

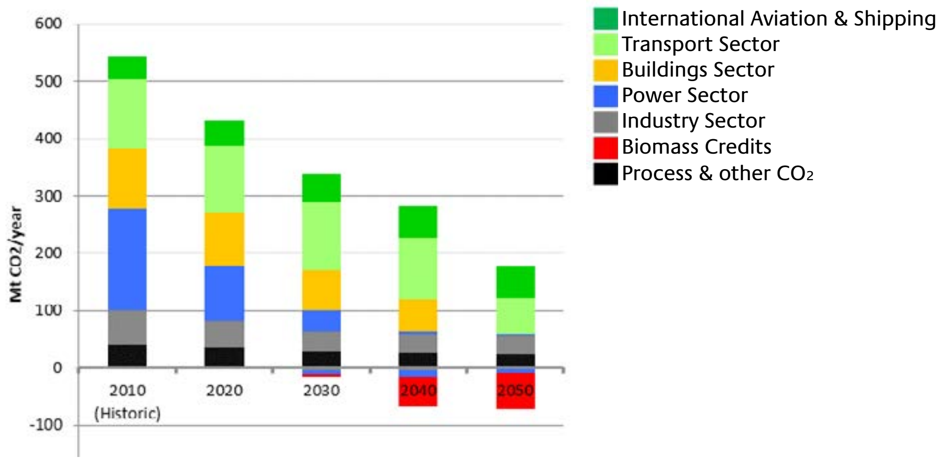
1. Why Heat Matters

» Domestic space and water heating accounts for 23% of UK energy demand

» 90% of UK's housing stock will still be in use in 2050

Space and water heating accounts for around 23% of UK energy demand and 20% of the nation's carbon emissions. The predominant source of this energy is natural gas. ETI's national energy system modelling tool (ESME) looks at all energy demands and sources to identify least cost solutions across heat, power, transport, industry and the supporting infrastructure. Its analysis clearly points to the need to substantially decarbonise the buildings sector in order to most cost effectively achieve overall 2050 emissions targets (Figure One).

Figure One: UK Net CO_2 Emissions



Why Heat Matters
» Continued

Whilst construction standards increasingly deliver good thermal performance in new homes, it is expected that more than 90% of UK's existing housing will still be in use in 2050. The replacement of this stock, even if considered to be a desirable objective, would cost several times the annual defence budget each year to 2050, with the process itself producing substantial carbon emissions. The answer must therefore involve the installation of low carbon solutions to the many archetypes and variants of the existing housing stock to provide acceptable alternatives to the high performance delivered by incumbent natural gas, oil or LPG fired boiler based installations. The technical challenge for any new solutions will be to meet the massive seasonal and diurnal variations in peak heat demand shown in Figures Two and Three, whilst delivering reliable, responsive and affordable heat so important for consumer acceptance.

Figure Two: Half-hourly GB electricity & low grade heat demand variation, 2010[1]

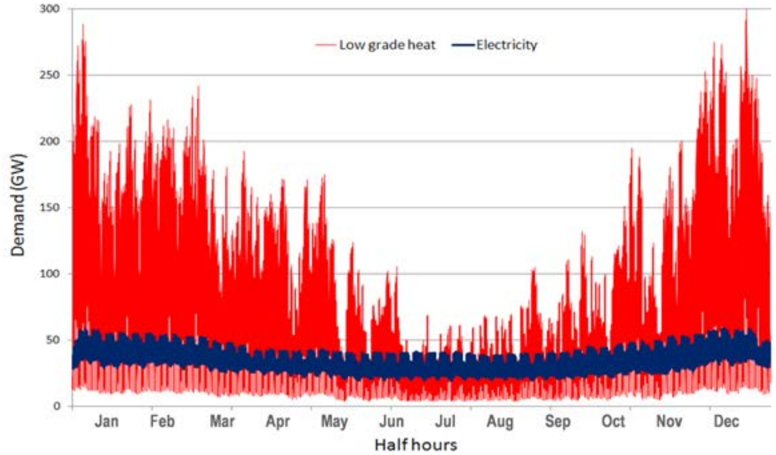
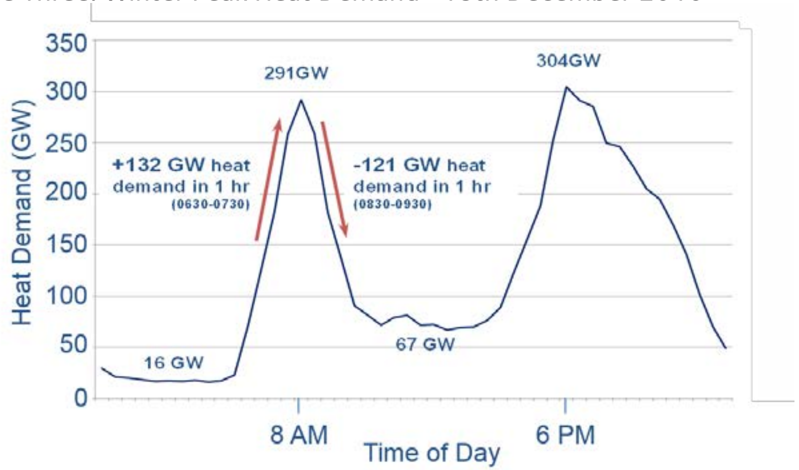


Figure Three: Winter Peak Heat Demand - 18th December 2010[2]



1 Half Hourly Electricity and Low Grade Heat Demand Variation 2010 - Robert Sansom, Imperial College.

2 Winter Peak Heat Demand - Data provided by Robert Sansom, Imperial College.

2. Consumer Requirements

» A broad set of physiological and psychological factors influence household decisions and energy use

» At a superficial level consumers are generally happy with existing heating arrangements

The foundations of any long-term success will include newly developed and engaging products and services based on a detailed understanding of consumer behaviour. This includes understanding the needs people seek to meet through the use of energy, and why these needs and behaviours vary across the population. Without this insight, proposals based just on technical considerations and general assumptions will ultimately find little favour in the market place.

The ETI has completed a comprehensive review of the fundamentals of domestic thermal comfort as a component of its consumer research. This review, alongside complementary analysis, reveals a broad set of physiological and psychological factors about domestic behaviour and household decisions that influence energy use.

Insights from further studies by the ETI, including detailed monitoring of real homes coupled with extensive consumer interviews and surveys, are supporting the development of robust consumer centric solutions.

The research indicates that consumers are generally happy with existing heating arrangements at a superficial level. When observed and questioned however, a number of important themes emerge that provide some clear pointers towards the required characteristics of future successful heating solutions. Some of these themes are shown on the following page.

01	Low carbon heating must appeal to consumers if the UK is to meet its emissions targets.
02	People want better control of the time, effort and money they spend making a healthy, harmonious home - they do not simply want to minimise their running costs.
03	Households have different priorities - there is no simple relationship between the occupants, their property and what they need
04	Major obstacles discourage those few who might want to upgrade to lower carbon heating - people want to get more from their current system before replacing it.

Before turning to the development of consumer products that might meet consumer needs it is important to understand the various energy system technologies that they will be based upon.

3. Heating Technologies

» Comprehensive retrofitted efficiency measures would be most appropriately deployed selectively to around seven million homes with a cost in the order of £100billion

» Heat pumps are generally most effective when delivering constant background heat rather than producing rapid temperature changes

» Heat networks could become the system of choice for many UK consumers as they have in a number of Western European cities

» Opportunities exist for the further development of high density thermal storage media for domestic situations

» A sophisticated Home Energy Management System could support the design and operation of heating solutions and deliver tailored "consumer propositions"

» Improvements to the thermal performance of UK buildings may improve health and comfort, reduce fuel poverty and improve energy security

The components of potential heating solutions that will form the technical building blocks of overall energy system design can be considered in four broad classes:

'Heat Demand Reduction' - energy efficiency measures that help meet consumer needs with reduced energy input.

'Heat Production' - technologies that convert an energy source to useful heat.

'Energy Storage' - technologies that help break the link between demand and supply.

'Energy System Management' - system wide measures, including home energy management.

Heat Demand Reduction

Heat demand reduction measures include potential significant enhancements to the energy efficiency of the UK's building stock, which result in reduced energy demand and might be initiated in parallel with the decarbonisation of the energy supply. Improvements to the thermal performance of the UK's buildings could not only help to meet future carbon emission targets, but may also improve health and comfort, reduce fuel poverty, improve energy security and smooth peaks of heating demand by using the building fabric effectively as a heat store.

Through its "Optimising Thermal Efficiency of Existing Housing" project the ETI has assessed the tools, processes and technologies required to improve the fabric of the housing stock by analysing the emissions from the most prevalent nine house archetypes and proposed a suite of mitigation actions. The project concluded that a basic 'Retrofix' package of measures could achieve CO_2 savings of around 33% at costs in the range of £7,500 to £21,000 per building. A more extensive 'Retroplus' package could reduce CO_2 by around 45% for between £15,000 and £31,000 per dwelling. A subsequent project is studying the real challenges of retrofit activity in five real homes, and measuring actual efficiency improvements.

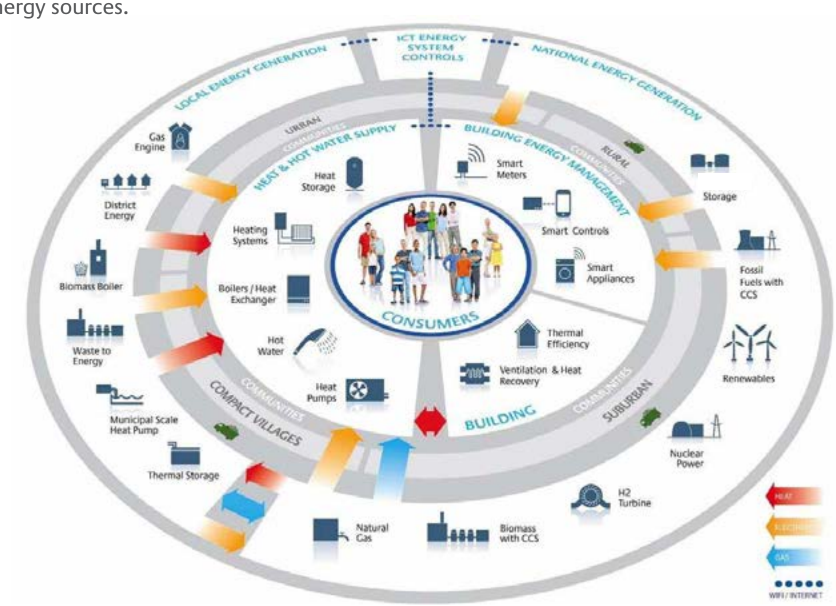
So, even with this scale of investment and degree of household intrusion, the emissions savings across the UK house archetypes are somewhat lower than half the desired 80% target. ETI's analysis indicates that retrofitted efficiency measures would therefore be most appropriately deployed selectively to around seven million homes, suggesting a national programme with costs in the order of £100 billion. The above case represents a reduction in the UK's total primary energy consumption of around 7% over the base case. Clearly the extent of this efficiency improvement could be adjusted to meet other drivers such as a greater emphasis on energy security.

33%
Savings
A basic 'Retrofix' package of measures could achieve CO_2 savings of 33% at costs in the range of £7,500 to £21,000 per building

Heat Production

Integrated Smart Systems and Heat

A view of the smart energy system showing the interaction with consumers, and the multiple energy sources.



There are a number of broad considerations that set the various heat production options apart. Firstly, the distance that heat can be transported is limited relative to electricity, whilst storage is simple and cost effective, space permitting. Conversely, electrical power can be readily transported, but economic and scalable storage possibilities are yet to emerge. The production asset may be centrally owned (as with a heat network), with the consumer having little direct responsibility for the infrastructure, but making appropriate payments through the energy bill. Conversely, the assets such as a heat pump or direct resistance heaters are associated with an individual property, but rely on the shared electricity infrastructure.

There is also a balance to be struck between the capital cost and the ongoing fuel and operating costs, along with those of the supporting infrastructure such as the electricity network. The key features of the most relevant energy conversion technologies and their potential for contribution to future low carbon heat production are outlined in the following pages.

The first group of technologies convert natural gas to heat –

Natural Gas ➡ Gas / Oil Boiler ➡ Heat

Despite the highly efficient performance of condensing boilers which directly convert natural gas to heat, the inherent carbon emissions preclude their general use for domestic heating in 2050.

Natural Gas ➡ Gas Absorption Heat Pump ➡ Heat

Heat pumps are designed to move thermal energy from a cold space and release it to a warmer one. The key feature is the ability to release more energy than that used by the heat pump. Gas absorption heat pumps use a gas burner to drive the refrigeration cycle which draws on the available energy from the surrounding ambient air, and can provide some emissions reduction. The efficiency of this process is described by the Gas Utilisation Efficiency (GUE) which is the ratio of input energy to output heat, and is likely to be around 1.4 in summer, but rather lower on the coldest days.

If combined with retrofitted demand reduction measures, these installations could provide some transition benefits, but emissions arising from natural gas use will ultimately fall well short of the required target for the buildings sector.

Heat Production
» Continued

Electricity ➜ Electric Heat Pump ➜ Heat

This group of options converts electricity to heat, generally at individual building level, and relies on the progressive decarbonisation of the electricity system.

Electric heat pumps use an electricity driven compressor to derive a low grade heat source from the local mass of air (or ground if space is available). Their efficiency is described by a Coefficient of Performance (COP), and they typically produce around three times as much heat as energy consumed. Whilst efficiency is inherently lower on the coldest days when heat is most needed, the technology continues to improve, albeit with some uncertainty around the overall performance and suitability for typical UK houses and climatic conditions. Systems need careful design to ensure that the output water temperature is matched to the capability of radiators.

For retrofit in the UK this generally requires specification of a high temperature output though with a lower COP to avoid radiator replacement. Smaller, low temperature units have higher COPs but may not be effective without the replacement of the existing radiators with assisted convection types that can extract more useful heat from the lower temperature source. The introduction of heat pumps into existing homes would usually be associated with retrofitted demand reduction measures, so effectively allowing the building fabric to act as a heat store.

Electricity ➜ Direct Resistance Heater ➜ Heat

Whilst lacking the efficiency enhancement of heat pumps, direct resistance heating has lower capital costs, and can be attractive in situations where insulation levels are good, occupancy is intermittent or fast acting top-up heat is needed. A particular feature is the potential for ready provision of low cost local heat storage, given the higher operating temperatures. This is not the case with heat pumps, and this solution could therefore deliver beneficial opportunities that support the balancing of electricity supply and demand over usefully long time periods, so reducing upstream costs.

Electricity + Natural Gas ➜ Hybrid Electric Heat Pump ➜ Heat

Hybrid systems exploit heat pump capabilities to deliver the base heating requirement throughout the year, but combine this with support from gas (or direct resistance electric heating) to provide peak heat requirements during cold spells when the heat pumps are at their least effective. This enables the installation of smaller and therefore cheaper heat pumps.

For the gas hybrid version there is some reduced dependence on the early decarbonisation of the electricity system, though gas usage to deal with peak heat demands would ultimately need to be minimal to meet emissions targets.

The final group of production options operate at a local area level, distributing heat from a heat production facility through an insulated pipe system. Heat networks are widely accepted across many parts of Europe. They generally deliver accurately metered hot water in the range of 70°C and 90°C, and have the potential to exploit a variety of local heat sources including energy produced from commercial or domestic waste and geothermal resources where available. In the UK they are used extensively in commercial and public buildings, but domestic use is, as yet, quite limited, particularly in owner-occupier homes. The networks can support cooling systems during summer periods, and give some inherent future strategic flexibility as new heat or energy sources such as marine heat pumps or hydrogen can be introduced, and networks progressively expanded or interconnected throughout a transition period. ETI's strategic analysis suggests significant benefits from the use of recoverable heat from electricity generation, both fossil fuel with Carbon Capture and Storage (CCS) and nuclear. Studies are assessing the national opportunities for future low carbon power generation including siting, heat recovery and linkage with the infrastructure for CCS.

Heat Production
» Continued

Natural Gas → Heat Network → Heat (+ Electricity)

Natural gas used within a combined heat and power station can deliver overall efficiencies in the order of 80% (compared to just electrical generation efficiencies in the range 40% to 60%), by directing the waste heat output to buildings. Combined heat and power can provide solutions at an individual building level, but economies of scale favour larger units where the flexibility of the energy source can also provide valuable future energy security benefits.

Energy Storage

Disconnecting the time dependency between the demand and supply of energy offers the prospect of leaner system designs that make better use of assets and resources, resulting in keener consumer prices. Commercial systems quite routinely combine thermal storage with heat and power schemes, and there are very effective domestic demonstrations that store surplus energy in new high temperature storage radiators and enlarged high temperature water tanks, helping to defer electricity system reinforcement.

Whilst future energy centres will generally include thermal storage, there remains an opportunity for the further development of high density thermal storage media for domestic situations. The challenge here is to store heat produced at the relatively low output temperatures available from heat pumps that will provide sufficient useful thermal input into homes, including many that have already utilised water tank space released when fitting combi-gas boilers.

Energy System Management

The fourth technology class considered links consumers to the energy system and market. This linkage potentially stretches from the appliances or devices in the home such as heating systems or vehicle charging points via home energy management systems and smart metering, through the distribution and transmission networks to national production and energy market systems.

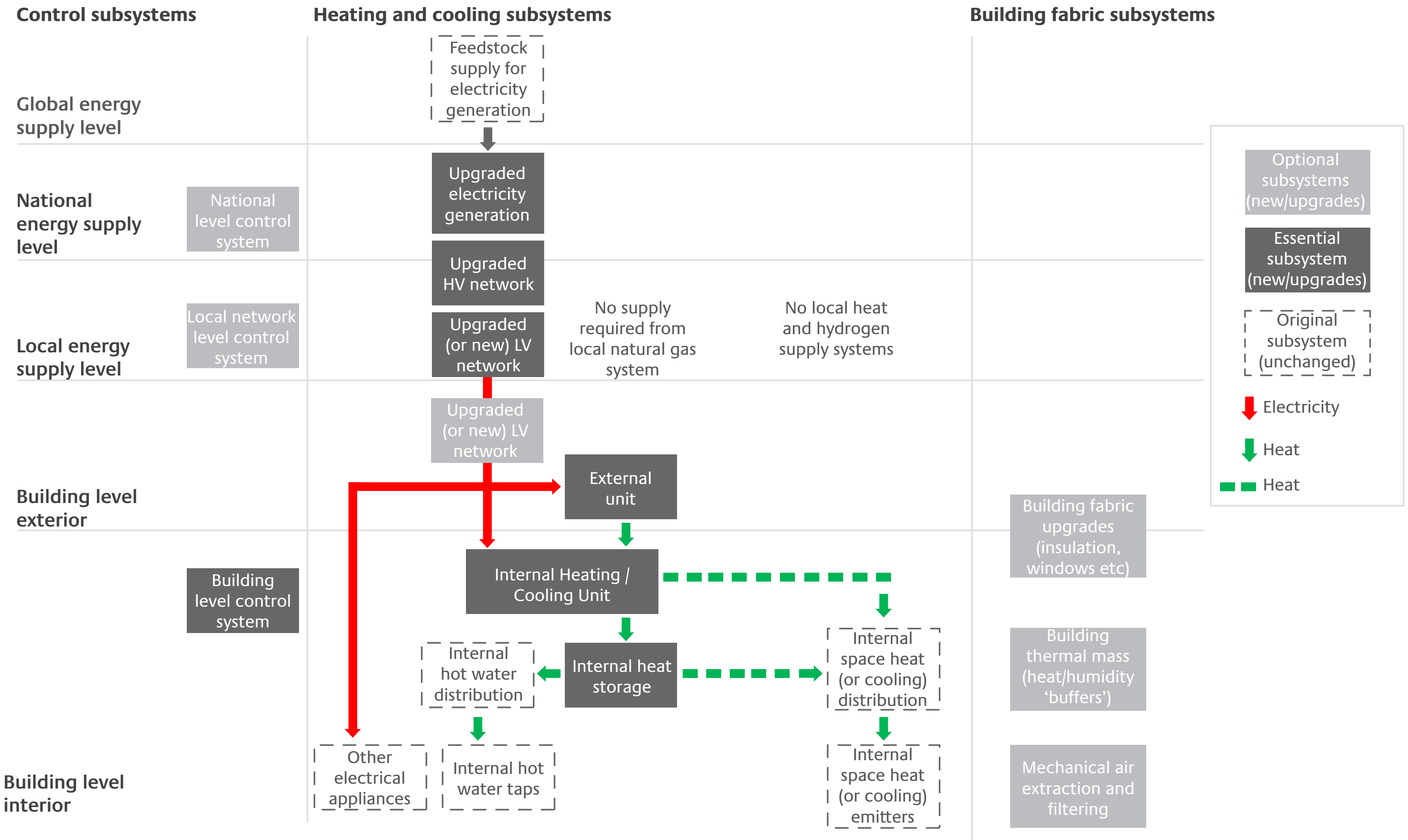
Energy systems are complex, and few consumers would be motivated to spend time learning about the many technical details and then supervise them personally. Therefore, a home energy management system with functionality that provides various levels of sophistication could readily support the design and operation of the heating solution, and help the delivery of tailored 'consumer propositions' that provide the required comfort, cost and degree of automation or control.

This functionality includes support for demand side participation propositions where consumer choices about the timing of their energy usage can help match demand with variable supply availability and therefore maximise asset utilisation.

Heat Technologies
» Continued

Figure Four: System Design – Individual High Temperature Air Source Heat Pump[3] (simplified example)

A range of candidate design options has been considered in some detail that help illustrate and evaluate the inherent characteristics, energy vectors and components involved in the production and distribution of heat. An example of this assessment for high temperature air-source heat pumps is shown in Figure Four.

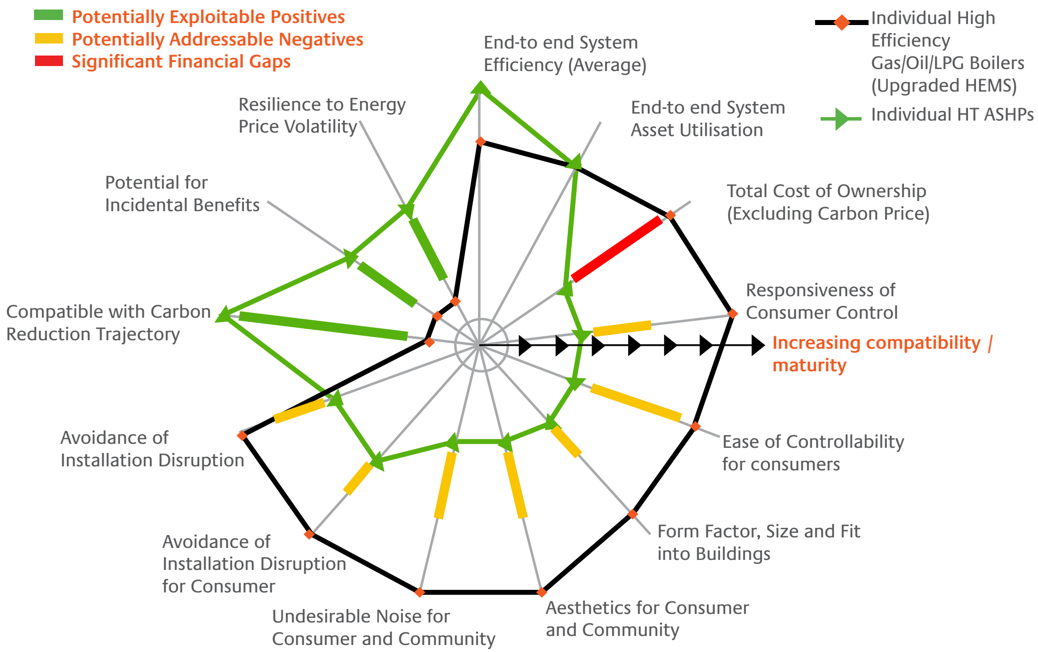


3 System Analysis of Concept Design, November 2013 - John Batterbee, Energy Technologies Institute.

Heating Technologies
» Continued

In addition, candidate design options have been considered to assess the maturity of the systems and their compatibility with consumer needs. The focus of this maturity analysis is on solutions for existing buildings. For new buildings, the degrees of freedom of the design space are largely unconstrained and any 'gaps' that exist for existing properties can largely be overcome at the building design stage. Figure Five illustrates for example an assessment of the high temperature heat pump, showing the relative scores for maturity, and gaps or opportunities for further development.

Figure Five: System Design 'Gaps' – Individual High Temperature Air Source Heat Pump[4]



4 System Analysis of Concept Design, November 2013 - John Batterbee, Energy Technologies Institute.

The overall assessment shows that whilst the various assemblies of technologies described deliver heat to the home, they actually have quite different characteristics, and deliver quite different outcomes. A heat pump for example could be seen as a reasonable exchange technology for the gas boiler, and have some exploitable benefits as shown in the diagram opposite.

Heat pumps are however physically much larger than gas boilers, require a water storage tank many of which will have been removed during the fitting of combi-gas boilers, and are generally most effective when delivering constant background heat rather than producing the rapid temperature changes possible with gas boiler systems.

In contrast, a heat network system requires only a relatively small in-home heat interface unit, produces heat on demand and could therefore actually become the system of choice for many UK consumers living in more densely populated areas.

The assessment of the various technology building blocks, including their performance and compatibility with consumer needs supports the development of design options for energy systems that incorporate technical performance, consumer satisfaction and commercial viability. This analysis will provide an input to the local spatial system design tools and process development described later.

> "Whilst the various assemblies of technologies described deliver heat to the home, they actually have quite different characteristics, and deliver quite different outcomes"

4. Energy System View

» The transition to low carbon heating provides an opportunity to build in appropriate levels of resilience and develop flexibility around future energy sources

» Decisions not to deploy district heat networks, domestic buildings retrofits and air source heat pumps result in significant additional costs

» Biomass resources are ultimately most valuable when used to generate hydrogen but heat from biomass can play an important transition role, and help to establish a market for domestically produced feedstock

» A consequence of a low carbon transition is the significant reduction in the flexibility of supply provided by gas heating systems

» It is important to minimise the overall cost of energy assets required to meet peak demands to maximise system utilisation

» The interaction between energy vectors seems set to increase in future systems with a need to integrate the operation of the gas, electricity and heat sectors

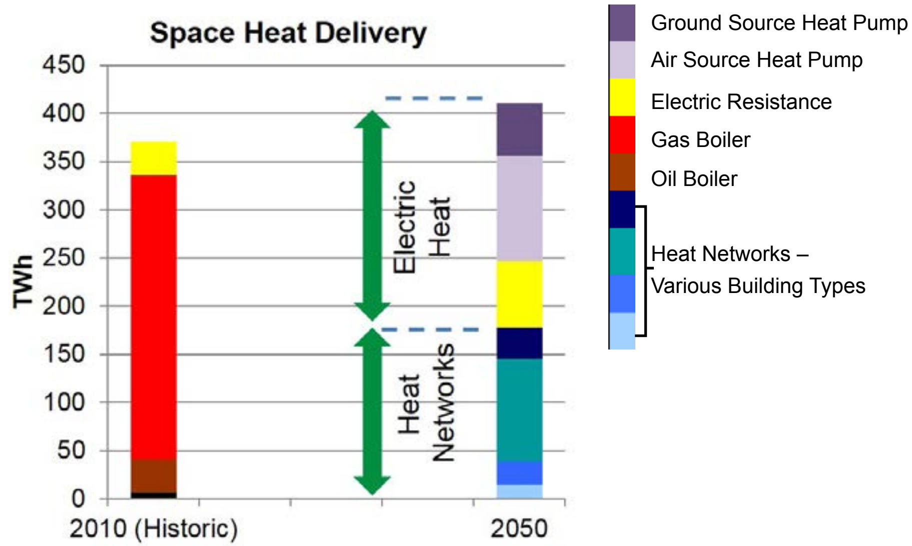
» There is currently no owner for the holistic view of integrated electricity, gas and heat systems

» National scenarios need to be translated for local analysis to bridge the gap to transition by developing real consumer products and business models in real localities

There are a number of options and choices for consideration in identifying the most effective use of energy resources and the determination of potential pathways towards 2050 targets. ETI's ESME analysis is well accepted as a strategic model that helps inform energy system and associated industry and government strategy, provoking debate about the preferences and trade-offs around the attainment of climate change mitigation objectives.

Figure Six below shows potential space heat delivery in 2050, within the context of a least cost transition. This depicts the necessary displacement of natural gas use for domestic heating, with a growing dependence on district heating and electrically powered solutions.

Figure Six: Space Heat Delivery - 2050



Energy System View
» Continued

Energy system security is both important from a consumer viewpoint in terms of the reliability of the services provided, and from a national perspective in terms of the overall resilience of the system and supply chain. The transition therefore provides an opportunity to incorporate appropriate levels of resilience and develop some flexibility around future energy sources.

One implication of the reduced dependence on natural gas is that gas distribution would not be required on a street by street basis in areas heated by district heat networks. In those areas served by individual building systems, the heating demand will ultimately be met by electrically powered solutions, also leading to the progressive reduction in the utilisation of this asset. The inherent fixed costs of the gas network would in both cases need to be met by the diminishing consumer base.

> “The transition provides an opportunity to build in appropriate levels of resilience and develop some flexibility around future energy sources”


UK Heat Network Installation
Galliford Try

Energy Systems Options

It is also insightful to consider the ‘opportunity cost’ of various energy system options, so providing a view on the additional system cost if certain technologies are excluded from the optimisation process. The approach is not to suggest that there is only one rational solution, but more to help understand the additional costs across the whole system that would accrue from other available choices.

This assessment suggests for example that decisions not to deploy district heat networks, domestic buildings retrofits and air source heat pumps result in significant additional costs. Furthermore there is a profound abatement cost increase of around 30% (NPV costs to 2050) if electric heating solutions are not used within the system transition.

> “There is a profound abatement cost increase of around 30% if electric heating solutions are not used within the system transition”

The debate around heat provision often includes the potential roles for both hydrogen and biomass. ETI’s optimisation studies suggest that biomass could be a resource for heat, though it is ultimately most valuable when used for hydrogen production, using CCS to create negative emissions, with the hydrogen having industrial application along with some peak electricity production. The role for bio-heat could be important in helping to establish and strengthen the market for domestically produced biomass feedstock which is necessary for the scale up and transition to bio CCS plants producing hydrogen in the longer term.

Meeting Peak Demands

Figure Two (page 11) showed very clearly the significant inter-seasonal and diurnal variability in demand for heat and electricity. An inevitable consequence of transition to a low carbon future is the significant reduction in the flexibility of supply currently provided by gas heating systems, and the introduction of new renewable energy sources with predictable, but very variable and less responsive output patterns. Clearly from an efficiency and therefore consumer perspective, it is usually important to minimise the overall cost of the assets required to meet peak demands, so maximising system utilisation. The potential role for demand side management services that reward electricity consumers who help to balance the system by reducing demand at peak times is well documented and the subject of a number of schemes and trials.

Some of the low carbon technology systems have the potential to usefully extend such a system balancing role. For example an energy centre delivering heat from a gas driven combined heat and power station could optimise its operation across heat, electricity and gas vectors by storing heat either within the energy centre or in domestic water tanks, so reducing peaks in demand and consequently increasing asset utilisation. A similar outcome could be a feature of hybrid heat pumps installed in homes, which could automatically adjust their heating operation to best suit the prevailing electricity supply availability. As with the demand side management approaches already being introduced for electricity, these services could be managed directly by the end consumer, supplier, energy services company or an aggregator.

> "Some of the low carbon technology systems have the potential to usefully extend such a system balancing role"

Integrating Power, Heat and Gas

Energy system value chains are already complex and the extent of interaction between the energy vectors seems set to increase in future systems. This points to the need to integrate the operation of the electricity, gas and heat sectors in pursuit of the most efficient overall system, and raises a real question about ownership of the holistic view. The Institution of Engineering and Technology (IET) has already identified such a need specifically for the electricity system, and is seeking to assist in building an integrated perspective for the planning and operation of the future electricity network through its Power Networks Joint Vision initiative[5].

The macro analysis of energy systems is extremely valuable when considering future national or regional scenarios, and considerable insight continues to be gained and debate stimulated by the outputs and implications. However, these national scenarios and assessments for the whole energy system need to be translated to allow more local analysis and bridge the gap to transition by determining real consumer products and business models in real localities.

5 Electricity Networks - Handling a Shock to the System – IET

5. Consumer Propositions and Business Models

» Previous rapid transitions have been driven by strong policy requirements

» More consumer led and costly changes can be seen to take effect over a period of decades

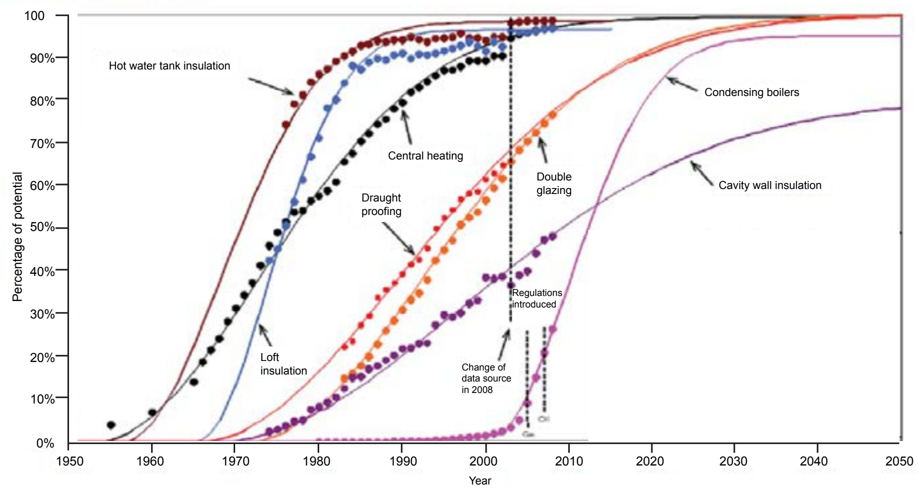
» Solutions lie in the development of a true and segmented understanding of consumer needs

» Whilst the cost of heating is important, cost alone is not necessarily the prime determinant of consumer satisfaction

Previous experience with national market penetration programmes that impact the fabric of homes (Figure Seven) suggests that the rate of adoption varies greatly depending on the cost of the measures, the scale of their intrusion, the value delivered to consumers and importantly the extent to which they are optional. Generally speaking the more rapid transitions have been driven by strong policy requirements such as the mandated change to condensing gas boilers. Here the cost implications were relatively minor, with the transition largely assured over the typical 15 years lifecycle of that item. Conversely, the more consumer led and costly changes can be seen to take effect over a period of decades.

> "The rate of adoption varies greatly depending on the cost of the measures, the scale of their intrusion, the value delivered to consumers and importantly the extent to which they are optional"

Figure Seven: Market penetration of home energy measures[6]



The challenges of the energy system transition are particularly acute for a number of reasons. The incumbent gas / oil boiler solution is for most people an attractive one in that it is reliable, has few components and on the face of it provides the required utility for much of the population at a cost that is reasonably affordable. Replacements for this system will require combinations of new equipment and adaptations to building fabric with the associated household intrusion, extensive street works, possible changes to more locally based solutions, and finally significant costs. Without incentive support or consumers being required to face carbon price signals, these costs show lengthy payback periods against the savings delivered on current and forecast energy prices.

6 Time for Change, Proceedings of the European Council for an Energy Efficient Economy - Les Shorrock BRE, 2011.

Consumer Propositions and Business Models
» Continued

The solutions lie in part in the development of a true and segmented understanding of consumer needs. It seems from early analysis of interviews undertaken as part of an ETI research project that whilst consumers are generally happy with their gas or oil boiler systems, there are actually many shortcomings in the level of control they have. Also whilst the cost of heating is important, cost alone is not necessarily the prime determinant of consumer satisfaction.

The issue though is not just about willingness to pay, but for many the concern is the ability to pay. In its response to the government's fuel poverty strategy consultation, the Committee on Climate Change highlighted several potential solutions, including the targeting of energy efficiency measures and the acknowledgment that fuel poverty is a social issue that could be addressed through general taxation[7]. Better heating will no doubt contribute to the nation's health and welfare, but whilst there are no ready answers on fuel poverty it is very clear that this has to be recognised as a big question for the transition planning process.

Consumer choice is clearly important, though this has to be subject to the constraints of shared infrastructure decisions reflecting local community preferences. The approach to developing a viable market should therefore build consumer propositions based upon developed knowledge of the attractiveness of both the performance and commercial features, along with the identification of the business models that would support the transition.

In doing this, an understanding of the consumer's willingness to pay for the new service offerings will emerge, along with a greater understanding of the barriers to change, and the costs and welfare benefits of new solutions. This should provide essential guidance to policymakers on the extent and functionality of the policy frameworks required to help provide the consumer pull, commercial investment and new products that will both stimulate and sustain the market.

> “An understanding of the consumer's willingness to pay for the new service offerings will emerge, along with a greater understanding of the barriers to change, and the costs and welfare benefits of new solutions”

7 Committee on Climate Change – Fuel Poverty Strategy Consultation

6. National Targets to Local Strategies

» Future local energy infrastructure requirements are quite different. There is a real need to develop local energy strategies that identify the key inherent characteristics of the area

» Strategies need to consider the geographical layout, house types, individual consumer preferences, availability of local energy resources, natural features and constraints

As discussed earlier, for domestic properties the transition away from natural gas involves two principal routes that are largely dependent on local spatial characteristics, house archetypes and consumer preference. These solutions are either area based or serve individual homes, so the future local energy infrastructure requirements are quite different.

Where local circumstances suggest that new local energy centres serving heat networks provide the most appropriate solution, a strategy needs to be developed that considers the immediate and longer term objectives for that locality. Given that these solutions are entirely dependent upon high take-up rates for efficient operation, the transition strategy depends very heavily on community engagement and consensus building, along with an appropriate policy framework, rather than just the asset deployment.

Conversely, solutions serving individual homes do not present consumers with this fundamental switch to a remote heat source. Their heating solutions are however likely to be electrically driven and dependent upon the transition of the power system to low carbon electricity sources. Much of the power network has however been designed around typical domestic diversified demands of 2kW or less per dwelling. The demand implied by the widespread installation of electric resistance heating or heat pumps, even without the addition of electric vehicle charging, is a multiple of this network design capacity, and the ability to time shift heat demand is very dependent on the thermal characteristics of the building stock and the preferences of consumers. The impact of these increased demands may be mitigated in part by more 'active' management of the networks as part of a smarter grid, but in most situations where gas heating is currently prevalent, distribution systems will require reinforcement.

National Targets to Local Strategies
» Continued

The many pathfinder low carbon energy projects undertaken around the country have their own individual merits and help to demonstrate new approaches. Projects have though not generally been considered as a part of an overall strategic plan and are often opportunistic, understandably dealing with the more immediately tractable situations such as social housing redevelopments where decisions are often directed by a single body. There is therefore a real need to develop local energy strategies that identify the key inherent characteristics of the area, and provide solutions for all buildings, particularly including the owner-occupied group where energy based decisions are not currently collectively made.

These strategies need to consider the geographical layout, house types, individual consumer preferences, availability of local energy resources and natural features and constraints. Without such a strategic framework and design tools it would not be possible to build a coherent transition pathway or gain the essential consensus of the local population and stakeholders. The design process outputs would provide guidance on the most cost effective overall solutions, and help plan the efficient introduction or reinforcement of key infrastructure investments, many of which are the cables and pipes which cannot be efficiently duplicated and therefore as monopoly assets should be the subject of economic regulation. Recognising this vital requirement, the ETI is developing a set of tools, under the brand of EnergyPath[8], along with processes which act together to support the systematic assessment of future solutions for local areas.

These include:

a) the local infrastructure
b) the consumer propositions and business models
c) the ICT (Information and Communications Technology) arrangements required for dynamic operation and
d) the potential benefits of new heating solutions to society.

The multi-decadal software tools, which ETI aims to make widely available, consider all relevant energy vectors together and identify what, where and when assets should be built to support the development of cost-effective and future-proof local energy system designs.

> "There is therefore a real need to develop local energy strategies that identify the key inherent characteristics of the area"

8 EnergyPath is a registered trademark of the Energy technologies Institute LLP

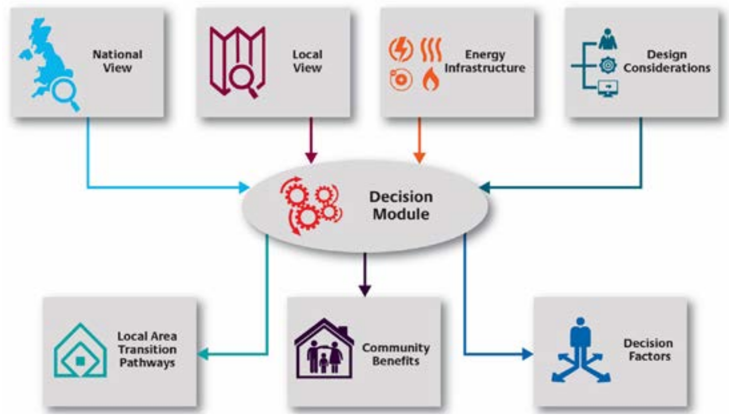
a) Local Infrastructure

To help fulfil the need to identify the most effective asset strategies for local areas the multi-vector EnergyPath Networks tool and associated design process will take a number of inherent characteristics such as local topographical information, the energy demands of house archetypes with their associated consumer requirements, and the availability of local energy resources and synthesise these into a local area infrastructure strategy for the key assets needed in that locality.

This process will effectively identify those areas that would be most efficiently supplied by area based schemes, and those areas where individual home solutions are more appropriate, as well as how the localities should develop over time. Sub-sets of the strategy can then be selected for development of a concept design for the associated heat sources, building fabric measures, and also the heat and power network requirements.

The ETI is already working with selected local authorities to help develop local energy strategies using this approach.

EnergyPath Networks



National Targets to Local Strategies
» Continued

b) Consumer Propositions and Business Models

Meeting carbon targets will entail significant technology changes within buildings which need to be associated with viable consumer product propositions as well as being capable of supporting successful business models. ETI has developed a Business Model Evaluation Tool (BMET) to help structure thinking around the appraisal of business models and also build understanding around the key consumer uptake value drivers of various product options.

c) Information and Communication Technologies for Dynamic Operation

The increasing dependence on renewable energy that is not centrally managed, together with the requirement to ensure efficient deployment of energy production, transmission and distribution assets suggests the need for enhanced ICT design, management and operations functionality. This essentially builds on the national smart metering facilities and forms the connection between the demands of consumers and the energy or market systems serving them. There are also clear links to Smart Cities initiatives and the potential functionality enabled by the Internet of Things.

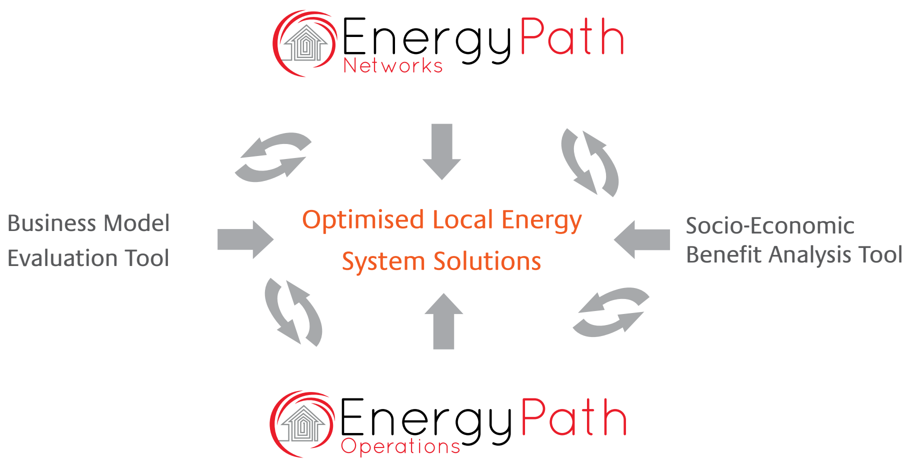
The ETI is developing the EnergyPath Operations analysis tool to help provide the capability required to undertake outline design and costing of the enabling overall ICT architecture. Additionally, in order to build confidence in the viability of consumer propositions it is necessary to dynamically simulate the energy system solutions including potential market designs, business processes and the interaction of the various actors within the energy system.

d) Society Cost-Benefit Assessment

The fourth important area being addressed is an examination of the local societal benefits such as health and employment, that potentially accrue from building fabric and energy system enhancements within local areas. A ‘Treasury Green Book’ compliant software model allows a more systematic analysis of these wider economic benefits that can help build the investment case in local areas.

> “ More systematic analysis of these wider economic benefits that can help build the investment case in local areas ”

Figure Eight: National targets get local



7. Preparedness, Policy and Leadership

» ETI's aim is to develop local system design capability by creating real solutions in real local areas

» Markets cannot be expected to engage without the essential foundations of leadership, clear strategic direction, effective policy and proven business models

» There is an immediate need for a "preparedness phase" to translate overall targets into plans for action, deciding on policy requirements and building supply chain momentum

» The real challenges are not so much technology based, but around gaining public consensus and trust

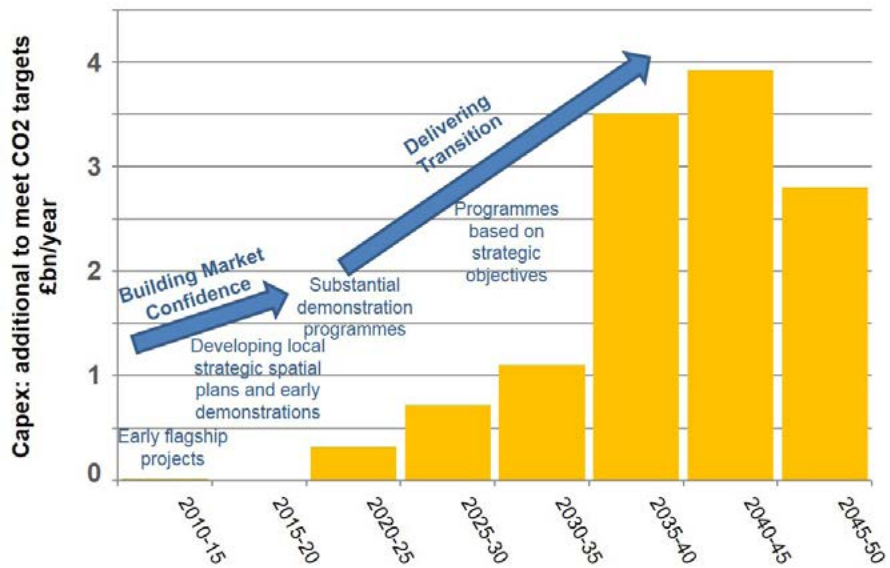
» It is essential to lay the foundations of transition by defining the necessary local responsibility and leadership expectation through a national policy framework

The ETI's aim is to help build the confidence of industry and government by developing local system design capability leading to the demonstration of real solutions that would be valued by consumers and can be commercially deployed by the market.

Figure Nine illustrates the stages of energy system transition envisaged, starting with the more opportunistic projects already being delivered, progressing through more strategically targeted trials such as the demonstrations being proposed by the ETI's SSH programme.

25
Years
Meeting the objectives will then involve a period of around 25 years of intense, sustained activity including almost every household and engaging many thousands of trained personnel

Figure Nine: Stages of Market Transition



A period of concurrent development of substantial programmes across the UK is needed (perhaps totalling a million homes), which follows the early demonstrators and continues the validation of strategic solutions to build market confidence and the resources and momentum required to begin the transition.

Meeting the objectives will then involve a period of around 25 years of intense, sustained activity including almost every household and engaging many thousands of trained personnel.

The market cannot be expected to engage in such delivery without the essential foundations of transformational leadership, clear strategic direction, effective policy and proven business models to build the confidence required for mass scale deployment. If transition is to happen there must be another period of intense activity in the years to the early 2020's, a 'preparedness phase', translating overall targets into plans for action, deciding on the policy requirements that build confidence in sustained investment, and importantly building supply chain momentum

Preparedness, Policy and Leadership
» Continued

through ever larger demonstration projects guided by coherent spatial energy planning.

The real challenges are not so much technology based, but more around gaining public consensus and trust. The approach must balance individual choices of solutions and costs with those of the local area or community, including the impact on consumer energy charges, whilst meeting emissions targets in the most appropriate way. There are also many important stakeholder views to be understood, including those with significant commercial interests, and inevitable uncertainty surrounding their roles during and after transition.

Local authorities are well placed to take a key role developing and managing the local strategies. Whilst some authorities are themselves engaging with this challenge they presently have no defined mandate to deliver an efficient energy system transition, and there are many competing demands which direct local attention and resource. It is essential to lay the foundation of transition by defining the necessary local responsibility and leadership expectation through national policy. This foundation could direct the requirement for local spatially based energy strategies using a systematic process and tools such as the EnergyPath suite outlined earlier, with an expectation that this becomes an integral component of the local planning process.

The introduction of emissions abatement measures may well spawn innovation in the energy services provided and so increase the consumer's 'willingness to pay' for additional services or comfort. Nationally though, 26 million homes require a significant level of intervention across just 25 years, so the consumer pull, market push and resource capabilities need to be stimulated to consistently deliver at the rate of some 20,000 home upgrades per week from 2025. The scale of the policy commitment required to overcome the barriers to change, and initiate such a programme can be gauged by considering the presently modest impact of the Green Deal scheme which is currently resulting in around 40 installations per week[9].

26 Million
Homes require a significant level of intervention across just 25 years

9 Domestic Green Deal and Energy Company Obligation in Great Britain, Monthly Report, 19 June 2014.

Policies are needed that recognise the two principal solution routes which essentially require incentives to effect either significant investment in the home for individual building solutions such as heat pumps, or local area solutions comprising large shared energy centre and network assets. From a finance perspective, the transition has the potential to compete with other markets for investment attention, but only if the returns are judged to be based upon a stable policy framework. This framework needs to include regulatory measures for monopoly assets such as the local heat networks which effectively become a new utility that actually shares the characteristics of existing public distribution systems and would therefore seem to need a similar regulatory mechanism.

The importance of the 'preparedness and confidence building phase' leading to the early 2020's cannot be over emphasised as a lack of market confidence and delay in building the necessary momentum will inevitably lead to higher costs driven by harder pressed resources, along with missed targets and business opportunities.

Through its SSH programme, the ETI is continuing to invest in building the understanding of consumer needs and the development of energy system product and design tools. Working in partnership with a small group of local authorities it is intended to demonstrate real solutions in real local areas to help inform policy and support the introduction of local strategic energy system plans, consumer products and business models that can help generate the momentum required to achieve 2050 climate goals.

> “A lack of market confidence and delay in building the necessary momentum will inevitably lead to harder pressed resources and higher costs, along with missed targets and business opportunities”

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