Executive Summary

In 2008 the UK adopted legally binding targets mandating an 80% reduction in greenhouse gas emissions by 2050. Several scenario modelling exercises have sought to explore how the energy system could meet these new targets whilst minimising costs. These scenarios depict a future energy system with an increased share of electricity in the energy mix due to the electrification of space heating and road transport. In its Low Carbon Transition Plan (DECC 2009), the government has also undertaken to produce 'route-maps' towards a decarbonised energy system. If the UK follows a path towards a highly electrified future then we must carefully examine the issues and challenges associated with it.

This report first examines the energy system scenarios to 2050 that have contributed to current government energy policy. It highlights the consensus around a highly electrified[3] future energy system, which we refer to as the 'all-electric future'. It then considers the role of high and low-grade heat in the energy mix. It presents and discusses energy flows in both 2007 and the energy system implied by the all-electric future in 2050. This is accompanied by an investigation of the issues associated with delivering such a system. These issues are referred to as the 'criticalities' of the all-electric energy future. Finally, the report presents an 'integrated' scenario, which delivers improvements in conversion efficiency and a more diverse delivery of heat.

The key findings of this study are:

- The all-electric future is low carbon but associated with continued reliance on fossil fuels and large losses of energy at the power generation stage. This future also creates challenges related to the management of power flows, demand peaks associated with electric heat and end-user adoption of insulation, heat pumps and other measures.
- Higher conversion efficiency is possible through the utilisation of power station waste heat through CHP and biomass fired CHP plant. Diversifying the mix of options used to meet heat demands has the potential to reduce peak power demands, provide a thermal 'buffer' to help manage the matching of electricity demand and supply and may help address some of the end-user issues.
- No route to low carbon heat is without challenges. A diverse combination of technologies can help overcome some of the criticalities, and it is likely that action on a range of options for low carbon heat will provide a more robust energy system in the long run. Action on a range of heat options in the short run also provides a resilient approach to uncertainties about the energy system of the future.

The Scenarios

In order to meet the binding targets set out in the Climate Change Act, the Department of Energy and Climate Change (DECC) must consider its policy options. In its Low Carbon Transition Plan (LCTP) DECC reference several reports which investigate scenarios of the energy system out to 2050. The scenarios considered in the LCTP which meet an 80% reduction in carbon emissions are:

- The Committee on Climate Change (CCC) 80% Carbon reduction scenario
- The Department of Food Agriculture and Rural affairs 80% high bioenergy scenario
- The DECC 80% Renewable Energy Strategy scenario
- The UK Energy Research Centre Low Carbon Resilient scenario

These scenarios have some common characteristics, including a high degree of electrification of both final user heat and transport energy provision. This leads to a highly electricity- dependent future energy system which we refer to in the report as the all-electric future. All the scenarios were modelled using MARKAL, a cost optimisation system modelling tool. Such approaches have many benefits but also some drawbacks that are particularly relevant to systemic changes such as wider utilisation of heat flow through CHP and district heating. It may also be a challenge for such models to attach value to diversity,

[3] This refers to an energy system in which electricity is used to provide the majority of energy for end-uses.

or to reflect a range of real world factors that prevent end-users in particular from making pure 'economically rational' (but not necessarily reasonable) choices. Engineering limits must be considered off-model. As a result, a number of criticalities are associated with the all-electric future. These can be summarised as follows:

- Build rates – the all-electric future requires rapid and sustained progress on all low carbon electricity supply options.
- Power flows – the all-electric future gives rise to problems associated with intermittent/variable and inflexible generation. It also creates new demand-side issues associated with electrifying heat and road transport. In the worst-case, a time of day winter heat demand increment of the order of several 10s GW could be created, perhaps 50 GW on top of today's 60 GW peak.
- End-user issues – the feasibility of the targets and the suitability of heat pumps is contingent upon very high adoption levels for insulation and other domestic energy efficiency measures. Yet all such measures face considerable barriers to adoption. The interaction between options/sectors means that the feasibility of electrifying heat depends in large part upon successful measures to change individual patterns of behaviour.

Heat in 2050 and an alternative 'integrated' scenario

Heat losses in 2050
Heat is a very important end-use of energy in the current energy system and is expected to remain so out to 2050. In 2007, heat represented 41% of total final energy consumption in the UK. Over half of this heat demand comes from the domestic sector, highlighting the significant challenge associated with decarbonising this sector particularly.

The energy flows of both the current energy system and the all-electric future are presented in the form of energy flow or 'Sankey' diagrams. This provides a novel view of the whole-system implications of an electricity dependent future and allows a comparison between the current state of the energy system and the possible future in 2050.

Total energy demand is significantly reduced by 2050, but demand for electricity increases. Moreover, there is a significant increase in thermal power generation, since both fossil fuel plants with carbon capture and nuclear power feature prominently in this scenario. The scenario does not envisage a large role for CHP, so the scenario is associated with high levels of conversion losses in the form of waste heat from power stations.

An 'integrated' scenario
The project team developed an integrated scenario which seeks specifically to utilise waste heat efficiently and diversify the means by which heat is provided to end users. This is an adaptation of the CCC 80% carbon reduction scenario that seeks only to alter assumptions regarding the delivery of heat, specifically the use of CHP and networked heat:

- Biomass: The current literature on potentially available biomass feedstock supports the proposition that excess biomass could be available to power significant volume of medium scale CHP plant by 2050. We therefore allocate 5.2 MTOE of extra bioenergy resource to CHP in the integrated scenario;
- CCS- CHP: The potential to combine CHP and CCS technologies has been explored by energy utilities and published work on plant efficiency is available. We assume that these facilities will be built on existing power station sites on the east coast of the UK with sequestration under the North Sea. The scenario seeks to maximise conversion efficiency so we assume new CCS-CHP will be gas-fired, and that district heat displaces resistive heating and electric heat pumps, while reduced electricity demand displaces coal-fired electricity generation with CCS;

- District heat networks (DHN): DHN potential for delivery of the heat captured at these locations is assessed in two stages. First, we assume a 30 km maximum radius for heat transmission networks. This is achievable with current technology and can therefore be viewed as conservative with respect to 2050. We then apply this radius to our selected power station locations, giving us a level of heat demand within each radius. We add to this a level of potential industry heat demand deliverable through CHP and CCS plant, based upon existing analysis.

This diversified scenario offers a number of benefits:

- By providing 4.2 MTOE heat and 4 MTOE electricity from gas-fired CCS-CHP plant, and 3.7 MTOE heat and 0.5 MTOE electricity from biomass fired CHP plant, demand for electricity is reduced by 13% and demand for primary energy is reduced by 5%[4];
- Use of networked heat has the potential to reduce peak power demand and offer a degree of energy storage in the form of heat. This may provide system management benefits such as providing a buffer to diurnal electricity demand peaks and mitigating the effects of intermittency;
- Finally, heat networks also obviate the need for installation of heat pumps, reducing the disruption associated with the installation of large surface area heating systems, such as under floor heating, and may offer one route to decarbonisation for some of the hardest to insulate buildings

Conclusions

The transition to a low carbon energy future presents the UK with some difficult choices. Through the course of our analysis we find the following:

- The all-electric future can be seen as a common outcome from current 2050 energy scenario modelling. It is one possible vision of an 80% decarbonised future. It is low-carbon but not necessarily optimally efficient, since thermal losses from power generation are large;
- The all-electric scenario is also contingent on overcoming certain critical issues, which are neither easy nor fully understood. If the roll-out and performance of heat pumps, insulation and low carbon generation is not as expected, then the scenario will not be able to deliver the emission reductions required. It also gives rise to a set of challenges associated with the management of power flows;
- The conversion efficiency of this scenario can be improved through the use of CHP and DHNs without impinging upon our ability to decarbonise. This can be achieved through use of CCS-CHP technology and biomass as a fuel for CHP plant. This will also require the installation of DHN infrastructure across parts of the country.
- An integrated scenario, using more CHP and less electric heating, will assist with a number of power flow and electricity network issues; particularly, by reducing a potential heat-driven demand peak, providing an energy store in the form of heat and in supplying an alternative means by which to decarbonise hard to insulate buildings;
- No route to 80% carbon reduction is without challenges; the integrated scenario will also create some critical issues. Diversifying heat provision can mitigate the criticalities associated with each individual option. This may help in providing a more robust energy system, and manage critical issues such as increased peak electricity demands, intermittency and end-user behaviour. As we consider the policies required in the short run to create options for the long run, it is important to take action on a range of fronts, maximising diversity.

To download a full version of the report see: http://www.chpa.co.uk/downloads

[4] Reductions compared to CCC 80% carbon reduction scenario.