

Micro-CHP as an integral component of the UK's energy strategy

A strategy and policy roadmap

A Report by JDS Associates, on behalf of:



CeresPower



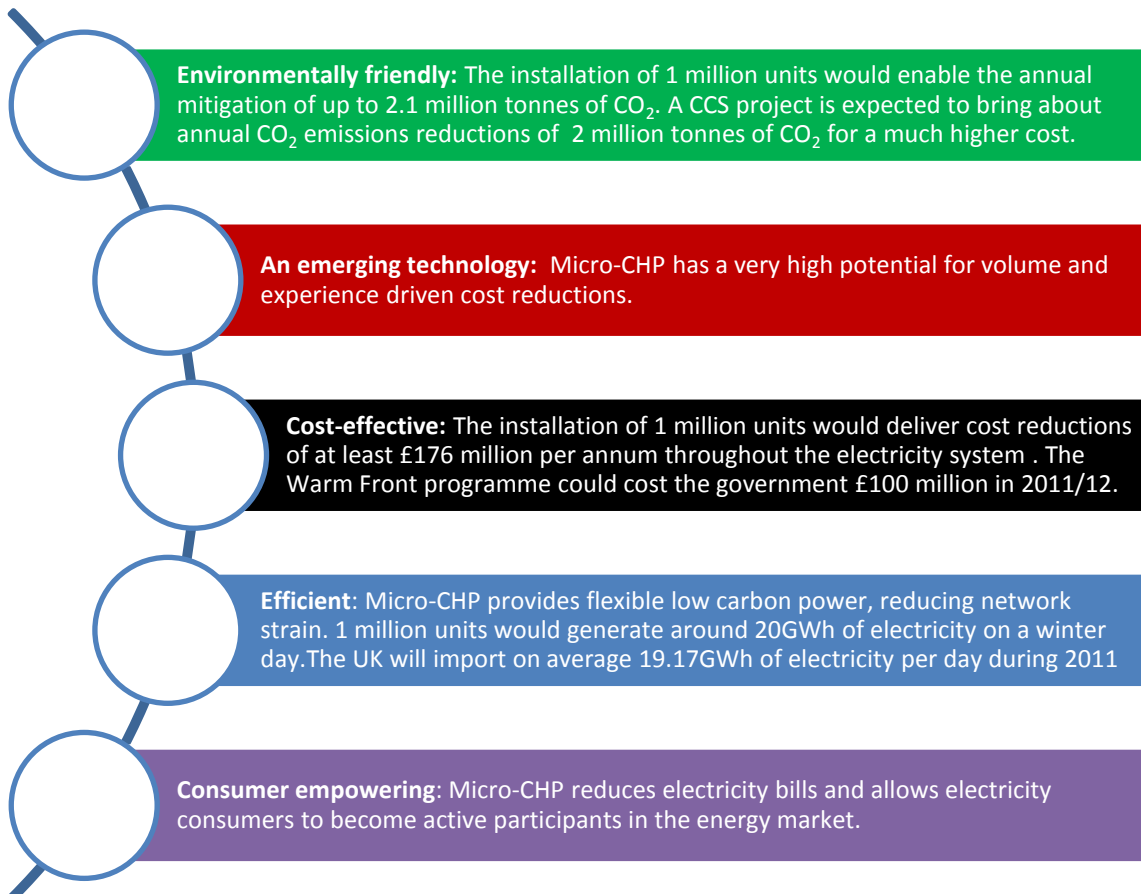
An overview of key points

Over the next few decades, energy efficiency improvements will reduce domestic heating demand while renewable systems are set to have an increasingly important role in delivering domestic heat. **However, this transition will take time and, in the medium term, traditional gas fired technologies will continue to play an important role.**

Micro-CHP is the next generation of gas boiler for households. It is an **available technology** that provides all the heating and hot water comfort of a modern condensing boiler whilst also generating low carbon electricity.

A group of leading developers of micro-CHP in the UK holds that, given the right policy framework, it is realistic and credible to aspire to more than 1 million installations by 2020, and the majority of new gas-fired heating systems being micro-CHP by 2025.

Such **rapid and wide deployment** of the technology would **revolutionise the UK's energy strategy** because micro-CHP is:



Drawing on existing analysis as well as information contributed by participating micro-CHP developers, **this report sets out a policy roadmap that could drive the installation of more than 1 million installations by 2020**. The key elements of this roadmap are:

Raising the feed in tariff for micro-CHP to at least 15p/kWh and abolishing the cap of 30,000 units in 2012

Allowing the gradual volume-based degression of the tariff to ensure cost control

Changing the Building Regulations to establish an emissions performance standard for new heating units

Eventually, removing the need for financial support for low carbon heating

Based on the illustrative scenario developed for the purposes of this report, **micro-CHP support under the Feed-in Tariff (FITs) scheme would come at a cumulative cost of around £12.7 million until the end of the Spending Review period in April 2015**. The cumulative cost, based on this illustrative scenario, is estimated to be around £200 million by 2020 and around £570 million by the end of FITs support for all micro-CHP units. That would translate to **an estimated policy cost of carbon abated throughout this period of as low as £60/t CO₂¹**.

¹ This report remains a work in progress. Continuous endeavour to update and refine it will be undertaken during the months after the report's initial publication

1. An introduction to micro-CHP technologies

A brief description of micro-CHP

Micro-CHP refers to a group of technologies that generate both usable heat and electricity, on a relatively small scale. Like a conventional condensing boiler, a micro-CHP appliance requires an input fuel. The most common input fuel is natural gas. The heat produced can be used for space heating and hot water².

The electricity generated by micro-CHP appliances displaces electricity generated remotely by central power stations and is used either on-site or exported to the low voltage electricity network. **The generation of lower carbon electricity where and when it is needed is the main benefit of micro-CHP compared to conventional heating solutions such as condensing boilers.** Technology maturity and specific product characteristics vary between the five principal technology categories (see Appendix, Chapter 1).

Graph 1: Micro-CHP produces both heat and low-carbon electricity



² Sustainable Energy Authority of Ireland (2011) 'Commercial micro-CHP Field Trial Report'

2. Climate and energy policy and the role of micro-CHP

Climate policy targets and the role of microgeneration

Successive governments have emphasised their goal to transform the UK into a low-carbon economy. The legally binding objective is to reduce greenhouse gas emissions by 34% by 2020 and at least 80% by 2050 (Climate Change Act, 2008). This is to be achieved by wide deployment of energy efficiency measures, together with low-carbon and renewable technologies. This requires the phasing out of fossil fuelled power generation which currently accounts for around 75% of the country's fuel mix³.

The actual feasibility of such a rapid phasing out of fossil fuels from the energy mix has been questioned on technical and economic grounds. Indeed, there are convincing scenarios indicating that allowing gas to continue to play a significant part in the country's energy mix would enable the attainment of the 2050 carbon targets and the 2020 renewable energy targets in a more cost-effective manner⁴. Irrespective of the precise emission mitigation path, this report assumes that decarbonisation of the electricity grid and uptake of renewables will take place in line with the trajectories set out in the 4th Carbon Budget.

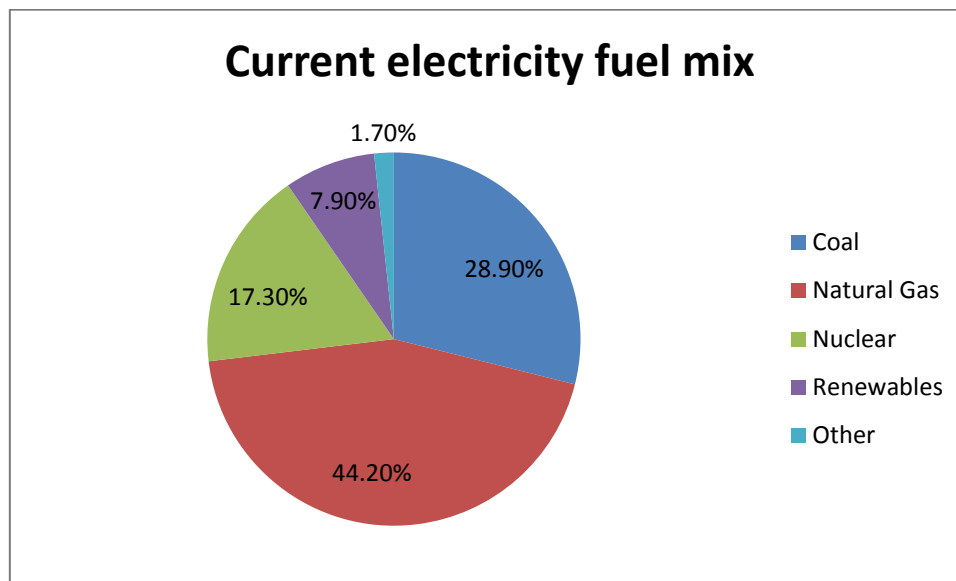
Encouraging the uptake of small-scale low carbon technologies forms an integral part of this emissions mitigation effort. Indeed, the UK has put in place a number of policies, including subsidy schemes such as the FITs scheme and the Renewable Heat Incentive (RHI) to support the development of a range of microgeneration technologies until they reach commercial maturity and viability. Moreover, the Government recently published a Microgeneration Strategy, reaffirming that 'onsite small-scale renewable and low carbon technologies – microgeneration – will be an important part of our energy future'⁵. **Micro-CHP has an important role to play in this context with substantial environmental, economic and strategic significance.**

³ DECC (2010) 'Fuel mix disclosure data table – 1 April 2010 to 31 March 2011'

⁴ Energy Networks Association Gas Futures Group (2010) 'Gas Future Scenarios Project – Final Report'

⁵ DECC (2011) 'Microgeneration Strategy'

Graph 2: The current electricity fuel mix of the UK



(Source: DECC, Fuel mix disclosure data table – 1 April 2010/31 March 2011)

Government policy for micro-CHP

Micro-CHP has already been identified by the Government as a technology with a role to play in the decarbonisation of the economy and it is eligible for support under the FITs scheme. Additionally, the recent Microgeneration Strategy report published by DECC acknowledged the UK's role as 'a world leader in this technology', while the 2050 Pathways Analysis report includes micro-CHP within a wide range of heating and cooling technology scenarios under consideration for 2050^{6 7}. **Despite the acknowledged potential and importance of micro-CHP, effective governmental support for wider deployment of the technology still remains in doubt.**

The risk of a missed opportunity for micro-CHP

The policy framework is cited by industry as a key uncertainty for those investing in the mass market commercialisation of micro-CHP. In the short-term, **the current FIT is 10p/kWh for the first 30,000 units with no support guaranteed after that. This has resulted in fewer than 200 registered installations in the first year**, compared to the Government's

⁶ DECC (2011) 'Microgeneration Strategy'

⁷ HM Government (2010) '2050 Pathways Analysis'

projection of 1,500 installations^{8 9}. **In the long-term, the Fourth Carbon Budget does not ascribe any role to micro-CHP in the country's emissions mitigation effort towards 2030¹⁰**¹¹. This uncertainty makes it difficult for manufacturers and their supply chains to invest in reducing manufacturing costs and this could prove to be an important missed opportunity.

The UK is the largest European gas boiler market, with around 17 million systems currently installed, and around 1.6 million sold annually, with the majority replacing existing gas boilers. This installation rate will translate into cumulative sales of about 16 million units and an almost complete replacement of the existing gas fired boiler market within the coming decade if the current rate continues¹².

According to the supporting analysis for the Regulatory Impact Assessment of the RHI, around 1.7 million of these heating system installations could be renewable heating systems, such as heat pumps or biomass boilers, by 2020¹³. Also, according to the Fourth Carbon Budget, 2.9 million could be heat pumps or biomass by 2025¹⁴. Both projections suggest that around 90% of the heating systems installed over the next decade will continue to be gas boilers. This presents a significant opportunity for micro-CHP.

With the right policy framework, micro-CHP could make a considerable contribution to additional, enduring decarbonisation of domestic heating over the next decade and beyond, by using the existing supply and support infrastructure of condensing boilers. This reinforces the imperative to develop the right policy tools to promote micro-CHP as a more efficient technology alternative to condensing boilers. **A group of leading developers of micro-CHP in the UK is in agreement that the installation of over 1 million micro-CHP units by 2020 is possible, assuming an appropriate policy framework.**

⁸ Micro-CHP uptake information under the FITs retrieved from Ofgem's 'Renewables and CHP register'

⁹ DECC (2009) Impact Assessment of feed in tariffs for Small-Scale, Low Carbon, Electricity Generation

¹⁰ Committee on Climate Change (2010) 'The Fourth Carbon Budget: Reducing Emissions through the 2020s'

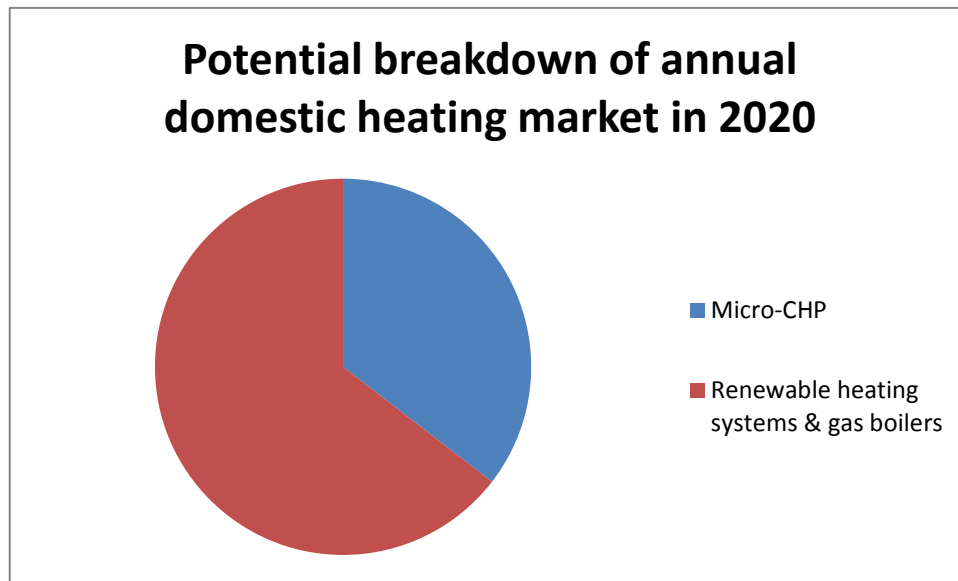
¹¹ The Government has though not yet published a report setting out proposals and policies for meeting the 4th Carbon Budget goals

¹² DELTA (2010) 'Micro-CHP Status and Opportunity for the UK: Future Energy – Ecobuild Seminar'

¹³ NERA (2010) 'Design of the Renewable Heat Incentive: Study for the Department of Energy & Climate Change'

¹⁴ Committee on Climate Change (2010) 'The Fourth Carbon Budget: Reducing Emissions through the 2020s'

Graph 3: The role for micro-CHP in the domestic heating market in year 2020



(Source: Renewable heating systems data from NERA, 2010)

3. The core benefits of micro-CHP

Micro-CHP presents a technology package that combines features that are highly compatible with a number of the Government's immediate priorities. Its core benefits are:

- i) it **delivers considerable cost effective emissions reductions** by being a convenient retrofit solution for existing homes and heating systems.

Replacing 1 million condensing boilers with micro-CHP units by 2020 would enable the annual mitigation of up to 2.1 million tonnes of CO₂¹⁵. This could be delivered at a cumulative policy cost until 2020 of around £200 million, with around £12.7 million of that being realised before the end of this Spending Review period in 2014-15.

For comparison, a CCS project is expected to bring around 2 million tonnes of annual emissions reductions for a cost of about £1.2 billion¹⁶.

- ii) it **enhances the grid's ability to meet increased electricity demand during peak periods**, thus improving the security of electricity supply

1 million micro-CHP units by 2020 would translate to the generation of about 20GWh of electricity on a typical winter day.

For comparison, the UK will import on average 19.17GWh of electricity per day during 2011¹⁷.

- iii) it **produces significant cost reductions throughout the electricity system** by displacing peak generation and deferring upgrades to the transmission and

¹⁵ All estimates assume a balanced micro-CHP technology mix

¹⁶ Scottish Enterprise (2011) 'Economic Impact Assessments of the proposed Carbon Capture and Storage demonstration Projects in Scotland – a Summary Report'

¹⁷ DECC (2010) 'Energy and Emissions Projections'

distribution networks. These cost reductions are not currently captured by micro-CHP customers.

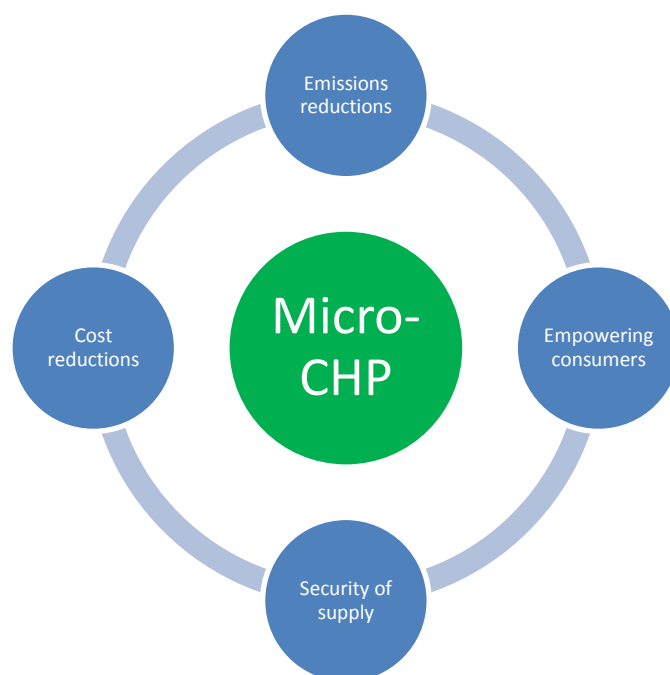
The total unaccounted cost reduction from the deployment of 1 million micro-CHP units by 2020 is estimated to be at least £176 million per annum.

For comparison, the Warm Front programme will cost the Government around £100 million in 2011/12.

- iv) it **empowers consumers** to produce electricity and heat domestically, while **allowing them to lower their energy bills** and become active participants in the energy system

1 million micro-CHP units by 2020 would transfer a considerable part of electricity generation from big centralised power stations to the domestic or local level, while micro-CHP combined with the introduction of smart meters would support the transition to a decarbonised electricity system

Graph 4: The core benefits of micro-CHP



Emissions reductions

Micro-CHP can deliver significant, cost-effective emissions reductions, especially if deployed on a wide scale, by replacing existing heating systems. Savings derive from combining efficient production of heat with the generation of low-carbon electricity to be used on site or exported to the grid.

Each micro-CHP unit can reduce annual household emissions of CO₂ by up to 2.1 tonnes when compared to a condensing boiler of 90% efficiency and network electricity¹⁸. **Meeting the goal of 1 million micro-CHP units by 2020 would enable the UK to mitigate up to 2.1 million tonnes of CO₂ annually, compared to a 'business as usual' deployment of condensing boilers (see Appendix, Chapter 2).**

Enhancing security of supply

Micro-CHP could reliably reduce national electrical demand, especially winter peak demand, and could help balance intermittent generation, reducing reliance on centralised power production.

Increased peak demand, due to the projected uptake of electric cars (the 4th Carbon Budget projects 60% of new vehicles to be electric by 2030) and heat pumps, will need to be covered by increased electricity generation from low utilisation fossil fuel 'peaking plants'. **Micro-CHP tends to generate more at times of peak demand (e.g. evenings and winter) and so naturally reduces the need to operate such 'peaking plants'.**

Similarly, as renewable and particularly wind energy uptake increases, new tools and processes will be needed to assist in managing the risk around balancing supply and demand¹⁹. Dealing with this volatility will become increasingly challenging as a quarter of

¹⁸ Emissions savings figures assume a balanced mix of micro-CHP products developed by participating companies

¹⁹ National Grid 2011 'TBE 2011: Development of Energy Scenarios'

existing generation capacity will be phased out over the coming decade with a simultaneous electricity demand increase²⁰.

Micro-CHP can assist with balancing this intermittency by adjusting when the electricity is generated. On a typical winter day, a period generally characterised by increased grid strain, a micro-CHP unit would generate around 20kWh of electricity on average²¹. Therefore, **the installation of 1 million micro-CHP units by 2020 would allow the UK to benefit from the additional daily supply of around 20GWh on an average winter day.**

Cost reductions

As shown above, micro-CHP generated electricity can displace centralised generation capacity due to the close alignment of the micro-CHP generation profile with the system load profile. By generating power at the point of use micro-CHP can also reduce the strain on transmission and distributions systems, deferring the need for upgrades. These functions **generate cost reductions and economic gains in different parts of the electricity generation and distribution supply chain**²². Some of these savings are captured by the consumer through the avoided purchase of electricity, but much of the value cannot be captured under current market arrangements and is socialised. Nevertheless, the value of these benefits is real and should be considered in any impact assessment of micro-CHP.

Specifically, expected cost savings from the wide deployment of micro-CHP will stem from²³:

- i) Reduced transmission and distribution losses, as a result of comparatively short distance power flows especially during peak periods
- ii) Reduced cost of holding capacity as micro-CHP will reduce the need to hold as much centrally connected generating capacity

²⁰ DECC (2011) 'Planning our Electric Future: A White Paper for secure, affordable and low Carbon Electricity'

²¹ Electricity generation figures assume a balanced mix of micro-CHP products developed by participating companies

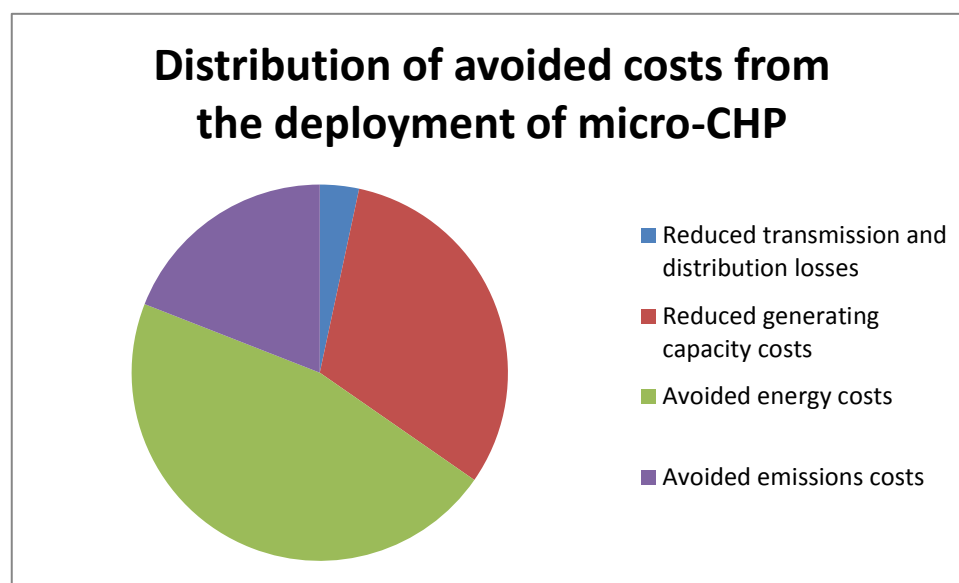
²² SIAM (2004) 'System Integration of Additional Microgeneration'

²³ Ibid.

- iii) Reduced energy costs as the output of micro-CHP can displace the output of centrally generated capacity
- iv) Avoided emissions costs due to the displacement of energy from centrally generated capacity

The total cost reduction from the deployment of 1 million micro-CHP units by 2020 is estimated to be at least £176 million per annum, or at least 6.2p/kWh (see Appendix, chapter 3 for further detail concerning this cost reduction calculation)²⁴.

Graph 5: Breakdown of avoided costs as a result of the significant rollout of micro-CHP



(Source: SIAM, 2004)

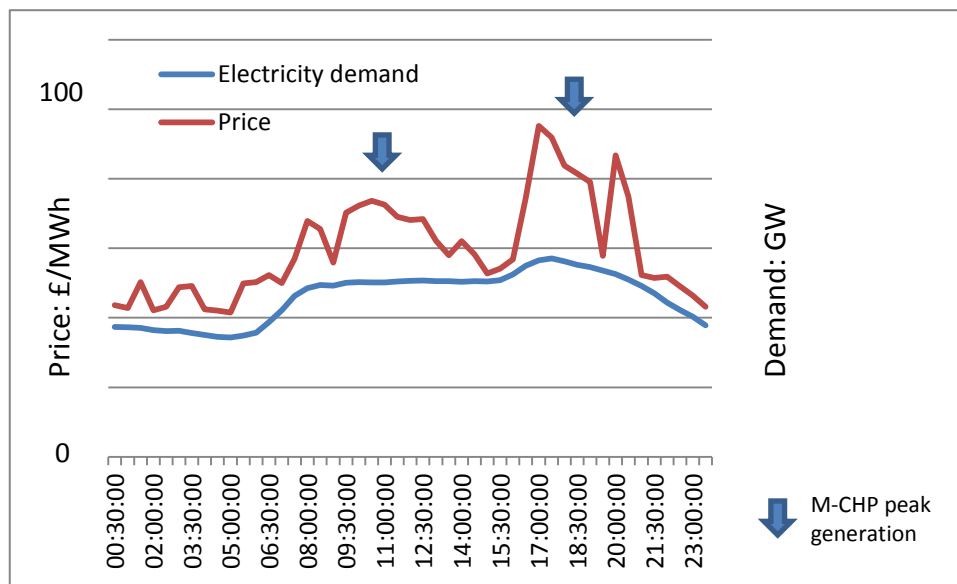
Empowering consumers

The use of micro-CHP to generate low carbon electricity and heat empowers consumers to manage their own energy consumption whilst lowering their energy bills. **Micro-CHP has the potential to genuinely democratise energy production as it could transfer a considerable proportion of electricity generation from big centralised power stations to the domestic or local level.**

²⁴ This figure is based on the conclusions of the SIAM report based on 2011 prices. Many of the cost drivers (e.g. peak power and carbon prices) are likely to continue to grow faster than RPI in the future, so the cost reduction figure represents a moderate estimation of the cost reduction potential of micro-CHP

Micro-CHP will tend to generate most electricity when the demand in the home is highest and when the national demand is highest. This correlation of supply with demand is one of the key drivers for both the energy bill savings that the consumer captures and the savings in the wider energy system that are socialised under current market arrangements.

Graph 6: Correlation of average electricity demand and cost on a typical winter day with micro-CHP peak electricity generation periods



(Source: Data for December 15th, 2010, retrieved from bmreports.com)

As the UK transitions to a decarbonised electricity system, supply will get more intermittent and demand will get 'spikier'. These changes will inevitably lead to a shift from flat tariffs to 'time of use' and even dynamic tariffs, encouraging consumers to respond to the needs of the system. **Modulating micro-CHP combined with smart meters will allow consumers to 'shift loads' and provide even more support to the system with no loss of comfort.**

The experience of the industry so far suggests that micro-CHP helps consumers to understand their energy consumption better and that giving consumers some control over their use of energy can have a more powerful effect on behaviour than passive measures.

4. A vision to enable the deployment of micro-CHP

Micro-CHP enables the substitution of heat produced by conventional residential boilers and electricity generated centrally by fossil fuel combustion plants with more efficient and environmentally beneficial heat and power generation on site. Many mitigation measures will be unable to make a significant impact on emissions before the end of the decade, either because of very long lead times for planning and construction, or because their savings are dependent on a decarbonised electricity network. In comparison, micro-CHP can reduce household emissions by 25% today and, given the right policy framework, could make a significant contribution to emissions reduction by 2020²⁵.

As the electricity grid decarbonises, some fossil fuel generation will still be needed for peaking and balancing. The operating characteristics of micro-CHP and the electricity market mean that it will be principally this fossil plant that micro-CHP displaces and hence micro-CHP will continue to reduce emissions for many decades^{26 27}.

Wide deployment of micro-CHP is key to exploiting the full potential of the technology. To achieve this, timely policy resolve along with a concrete long-term plan is urgently needed.

Installing over 1m Micro-CHP units by 2020 – a policy roadmap

Unlike condensing boilers, micro-CHP has not yet reached commercial maturity. Micro-CHP is a new technology, currently manufactured in low volumes, which leads to a relatively high starting price. However it must compete with condensing boilers, a mature technology with a large global market which benefits from significant economies of scale and ‘value engineered’ manufacturing processes.

²⁵ Assuming a balanced mix of micro-CHP technologies, and average emissions per dwelling of about 5.6t CO₂/yr. according to British Gas (2006) ‘Domestic Carbon Dioxide Emissions for Selected Cities’

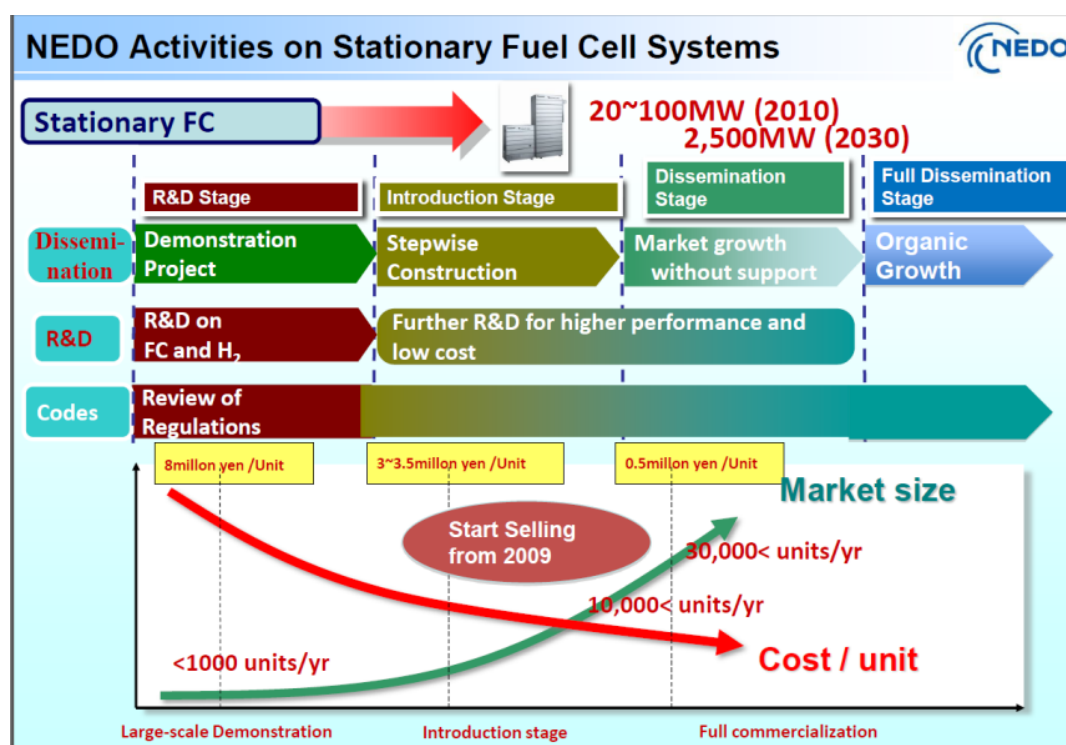
²⁶ DELTA (2010) ‘Gas Micro-CHP: A Limited Low Carbon Window of Opportunity?’

²⁷ Hawkes, A.D. – Estimating marginal CO₂ emissions rates for national electricity systems – EnergyPolicy (2010)

Experience from other new energy technologies shows that the relationship between volume and price (the 'experience curve') tends to be very steep in the early years. For example an analysis of the prices from 1976 onwards of photovoltaic panels in America shows that they halved in price in the first 2 years and had dropped by over 80% in the first 10 years²⁸.

Projections by governments that have included micro-CHP in their energy strategy plans also forecast a similar steep experience curve for micro-CHP (see Graph 7). To attain this, early sales would require significant financial support, but because the initial volumes are so low the overall policy cost of this support would remain low²⁹.

Graph 7: Cost reductions according to Japanese fuel cell micro-CHP programme



(Source: Presentation by Japanese government agency NEDO – March 2011)

Achieving timely economies of scale to reduce costs and provide an attractive payback for consumers is a considerable challenge for the industry as well as the Government. Early

²⁸ IEA (2000) 'Experience Curves for Energy Technology Policy'.

²⁹ See Appendix, Chapter 6 for further examples of past and project micro-CHP experience curves

policy support is critical towards that direction. **A straightforward and cost-effective policy plan could lead to the deployment of over 1 million micro-CHP units by 2020, which the industry believes is also an easily attainable manufacturing capacity goal.**

There is a variety of paths to attain this goal, although an effective policy mix should involve the following combination of actions in the proposed sequence:

i) Raising the FiT for micro-CHP to at least 15p/kWh and abolishing the cap of 30,000 units to receive support under the scheme in 2012

ii) Allowing the volume-based degression of the tariff to ensure cost control

iii) Changing the Building Regulations to establish an emissions performance standard for new heating units

The concrete policy path proposed below, relevant quantitative predictions and corresponding suggested timelines constitute only an illustrative path.

- **Setting an appropriate generation tariff path**

During the initial FIT consultation, the micro-CHP industry advised the Government that a generation tariff of at least 15p/kWh would be necessary to start the market. In April 2010, a generation tariff of 10p/kWh was introduced for the first 30,000 micro-CHP units. DECC's projections at that point were that this would lead to the installation of 1,500 units in the first year. In fact, there were fewer than 200 registered micro-CHP installations in the first year in receipt of the FIT.

Removal of the 30,000 unit cap and an increase of the tariff for micro-CHP from 10 p/kWh to at least 15 p/kWh as of April 2012 would allow this technology to become a financially viable heating solution for consumers and create the necessary incentive to put the industry on a steady path of growth (see Appendix chapter 4). Allowing the scheme to

continue beyond the initial 30,000 units would create the necessary certainty for the industry to invest in capacity and bring about reductions in manufacturing costs.

We have modelled an indicative scenario of generation tariffs and uptake for micro-CHP as an illustration (for main illustrative scenario assumptions, see Appendix, Chapter 5). Under this scenario, removal of the 30,000 unit cap and an increased tariff in 2012 attracts early adopters to the technology and initiates meaningful market growth, leading to about 12,000 cumulative micro-CHP installations and about £12.7 million of cumulative policy cost by the end of the spending review period in April 2015, i.e. less than 2% of the total FIT budget for this period. Later in the decade, volume triggered degression starts and, towards the end of the decade, FITs are replaced with regulations requiring a minimum carbon performance for heating products. This leads to over 1 million cumulative micro-CHP installations and about £200 million cumulative policy cost by 2020. This deployment objective is plausible based on other modelled scenarios of micro-CHP uptake³⁰.

- **Setting an emissions performance standard**

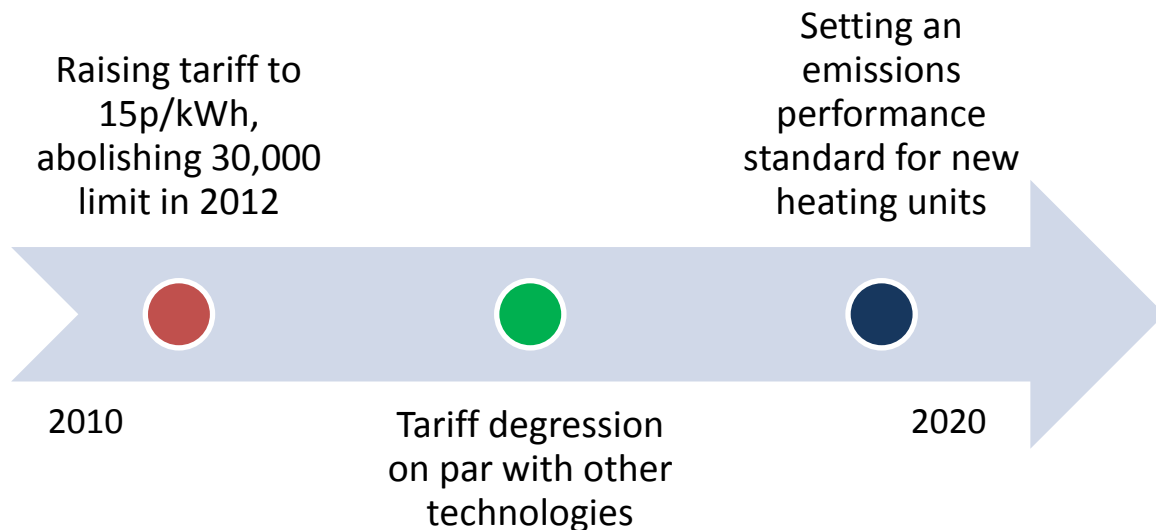
FIT support will have put the micro-CHP industry on a sustainable path of growth by the end of the decade. The introduction of an efficiency performance standard for boilers in 2005 under the Building Regulations effectively mandated condensing boilers and made the UK the biggest market for these products in Europe³¹. This standard was introduced when condensing boilers made up about a quarter of the boiler market. **Our modelling suggests that micro-CHP could reach a comparable market share towards the end of the decade and, as this point is reached, an emissions performance standard for heating products should be considered.** This would allow a shift from fiscal to regulatory support and allow all low carbon heating products to compete on a level playing field by the end of the decade.

³⁰ Elementenergy and Poyry (2009) 'Design of Feed-in Tariffs for Sub-5MW Electricity in Great Britain'. This extensive market study projects a cumulative uptake of 4.8 million sub-5MW CHP systems by 2020 if a fixed tariff of 15.5p/kwh were to be applied.

³¹ Office of the Deputy Prime Minister (2005), 'Gas and Oil central Heating Boilers: Advice to Householders'

The total cost of support for micro-CHP by the end of FIT support for all micro-CHP units, based on our illustrative scenario, is expected to be around £570 million leading to average carbon savings throughout this period of as low as £60/t CO₂³².

Graph 8: Illustrative path of key short-term policy steps to enable micro-CHP deployment



Setting a long-term vision for micro-CHP towards 2030 and beyond

While rapid uptake is important for micro-CHP to deliver fast and direct gains, it would also prepare the ground for the sector's contribution in a low-carbon economy from 2020 onwards. **Rapid reduction of generation and installation costs will render micro-CHP a financially attractive and energy efficient solution for home heating and for the generation of electricity in the near future.** That will gradually switch the role of micro-CHP from an emerging green and efficient alternative to condensing boilers to an integral part of the country's energy strategy.

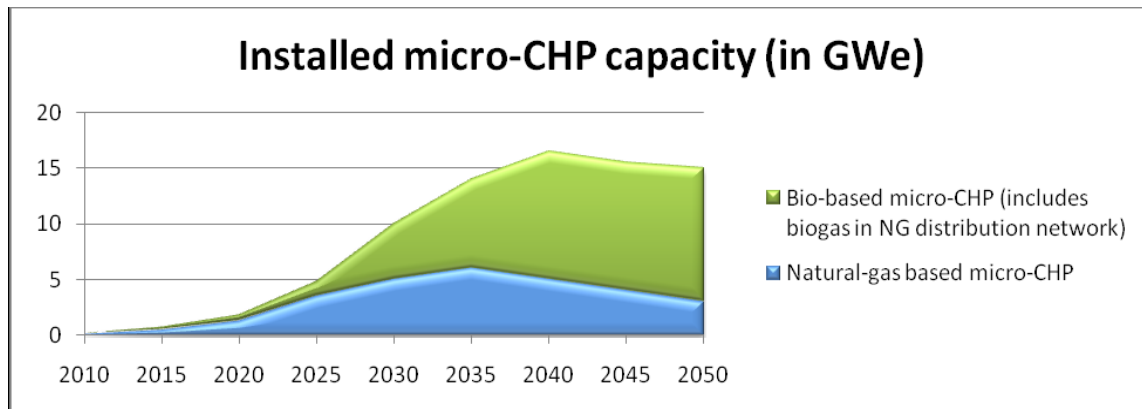
Indeed a series of studies has identified micro-CHP as a long-term option for the UK, as part of a wide solution that would combine dispersed micro-CHP and renewables^{33 34}. As part of

³² Cost savings in the wider electricity system are estimated elsewhere in this report as being at least £176m/yr. These savings have not been netted off this policy cost, but should be in any impact assessment.

such solutions, **millions of micro-CHP units dispersed across the country, forming what has been described as a ‘Virtual Power Plant’, would displace some centralised fossil fuel combustion plants during peak electricity periods.** Such solutions are already being seriously considered in a number of countries, such as the Netherlands³⁵.

The possibilities for micro-CHP are ample and do not end there. Technological and economic gains achieved during the initial period could be readily applied to micro-CHP applications fuelled by bioenergy resources (biomass and biogas). Indeed bioenergy use in electricity generation is a thermal combustion process to which cogeneration is ideally suited³⁶. As bioenergy resources become more ample, **micro-CHP using biomass or biogas would be unique among domestic microgeneration technologies in offering the advantage of simultaneously generating carbon neutral electricity and heat.** The carbon neutral prospects of micro-CHP applied at a mass scale should not be overlooked as the eventual application of preference for the technology beyond 2030.

Graph 9: Market opportunity for micro-CHP in the EU



(Source: Cogen Europe)

The ‘Virtual Power Plant’ concept and bio-CHP are two opportunities that are already technically possible and being explored in other countries. Given the UK’s role as a pioneer

³³ Boardman B, Darby S, Killip G, Hinnells M, Jardine CJ, Palmer J, Sinden G. (2005) The 40% House Report, ECI, Oxford, March 2005.

³⁴ Bakker V, Bosman M, Moldernik J, Smit G (2010) ‘Improved Heat Demand Prediction of Individual Households’

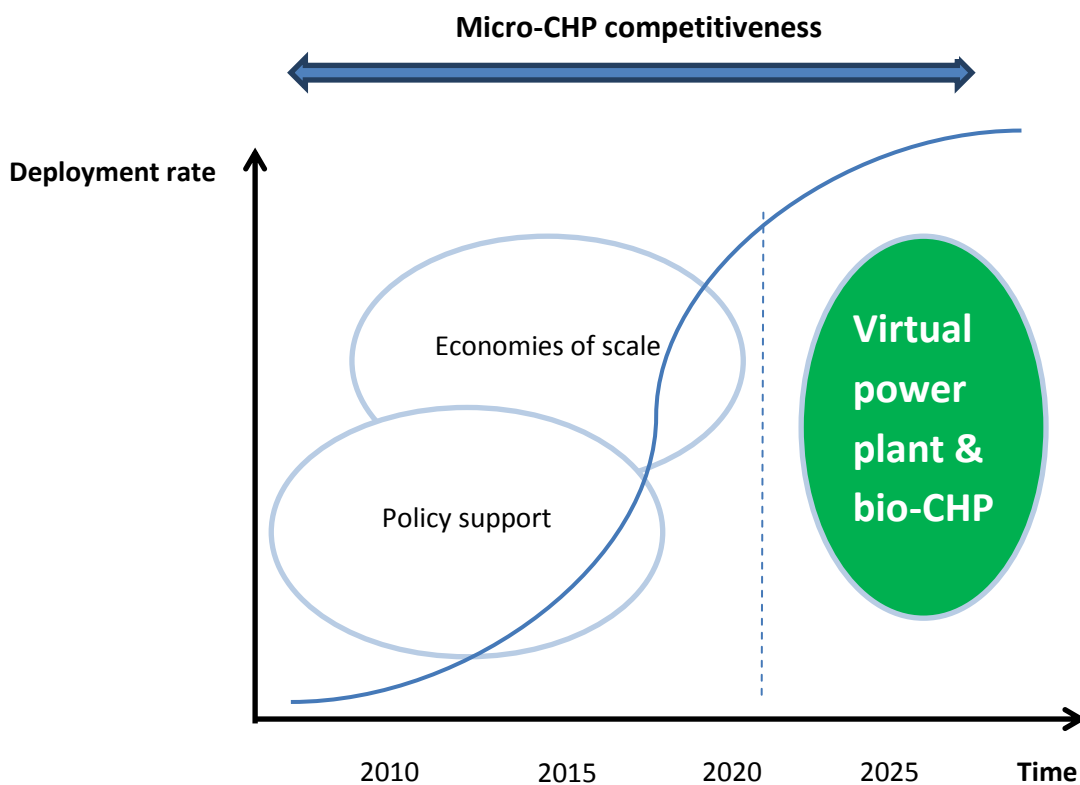
³⁵ Bongaerts, M (2007) ‘Dutch Direction: Integrating micro-CHP into a smart Electricity Grid’

³⁶ COGEN Europe (2010) ‘Micro-CHP: Empowering People today for a smarter Future Tomorrow’

in the micro-CHP sector, it is important that the UK does not miss its opportunity to become a leader in the future global market for micro-CHP.

In order to investigate the wider long-term opportunities that micro-CHP undoubtedly presents, the Government should undertake to publish a report, with industry and experts' active collaboration, to define a detailed roadmap for micro-CHP with explicit deployment targets and policy tools.

Graph 10: Setting a viable vision for micro-CHP



Appendix

1. Principal technology categories of micro-CHP

There are five main technology categories of micro-CHP at various stages of deployment and a variety of characteristics:^{37 38}

Internal combustion engine

The engines in internal combustion engine micro-CHP units are loosely based on the automotive engine and are the most established of all micro-CHP appliances. Possible fuels are diesel, biodiesel, gasoline, natural gas, biogas or landfill gas, which are all widely available today.

Stirling engine

Stirling engines are external combustion engines used in a smaller proportion of micro-CHP units, although they are fast gaining in popularity. They are currently being launched into the domestic market as a replacement for gas boilers. Stirling engines are often fired by natural gas, but the external combustion process makes them extremely flexible towards the use of various gaseous, liquid and solid fuels. Especially renewable carbon neutral sources such as biogas and biomass are interesting fuel options.

Fuel cell

Fuel cells operate on principles similar to those of a battery and thus are different from an IC, Stirling engine or Organic Rankine Cycle micro-CHP. Electrochemical cells consume fuel to produce a DC voltage. These cells are arranged in series in stacks and the DC voltage is converted into an AC voltage. The first fuel cell micro-CHP units are currently being launched into domestic and commercial markets. An appealing aspect of this technology is that it has a high heat/electricity ratio of approximately between 1:1 and 1:3.

³⁷ Sustainable Energy Authority of Ireland (2011) 'Commercial micro-CHP Field Trial Report'

³⁸ Boehnke (2007), 'Business Models for Micro-CHP in Residential Buildings'

Organic Rankine Cycle

An Organic Rankine Cycle (ORC) utilises a module, which can be compared to a refrigerator operating in reverse, with the compressor becoming an expander from which it drives a generator to produce electricity. These devices will be wall mounted and whilst initially using natural gas, can be flexible in the use of various gaseous, liquid and solid fuels. These appliances deliver approximately 1kW of electricity for every 10kW of heat provided and are as efficient as modern condensing boilers.

Gas Turbine

A gas turbine micro-CHP unit works by mixing air and gas in the combustion chamber and igniting it. This increases the velocity, temperature and volume of the gas which is then passed through a nozzle over the turbine blades. This turns the turbine which powers a compressor and generator. Despite its advantages this is still a relatively immature technology.

2. Calculating future and projected carbon intensity

DECC uses the carbon intensity numbers supplied by the Interdepartmental Analysts' Group (IAG) for all its calculations concerning cost effective carbon abatement. IAG has published guidance on how to use these numbers as well as some explanations and justifications concerning its conclusions³⁹.

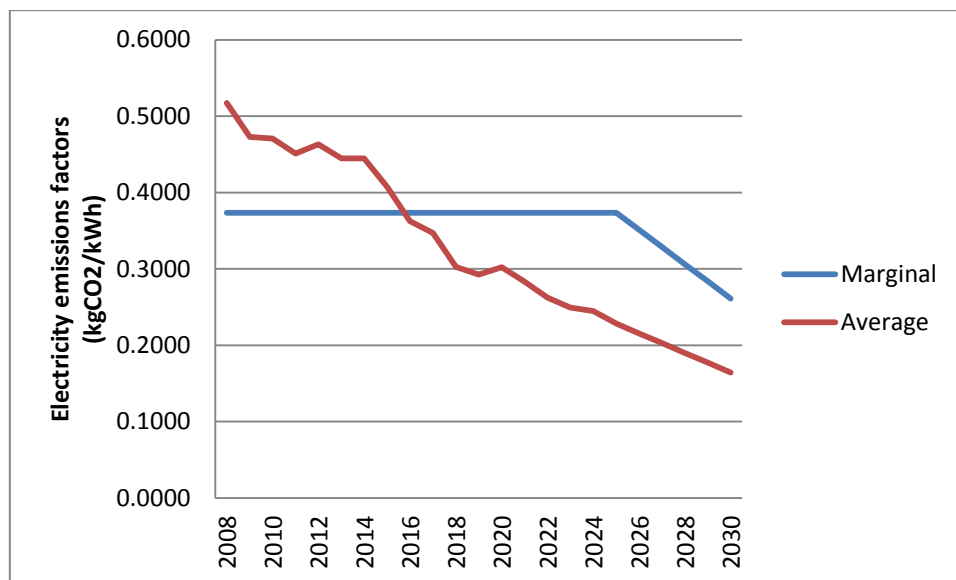
This 'Background Documentation' explains that IAG's energy model assumes that between 2009 and 2025 marginal plants will comprise only of CCGT. The marginal carbon intensity is 0.3939kgCO₂/kWh. After 2025 it is assumed that marginal plants will be a mix of CCGT and lower carbon plants, with the proportion of CCGT dropping over time so that the marginal carbon intensity continues dropping and converges with the average carbon intensity around 2040.

³⁹ IAG (2011) 'Background Documentation for Guidance and Valuation of Energy Use and Greenhouse Gas Emissions'

This rationale is based on a definition of a marginal plant as the plant that does or does not get built as a result of a policy. IAG does not consider existing plants that do or do not run as a result of policy. It also assumes that CCGT are the only types of fossil fuelled plants to be built again, when in reality some OCGT are likely to be expected.

This leads to the very unusual situation where the average carbon intensity is currently higher than the marginal carbon intensity (see graph below).

Graph 11: Marginal carbon intensity trajectory vs. average carbon intensity trajectory according to IAG, 2011



(Source: IAG, 2011 'Guidance Tables '1-24', supporting the Toolkit and the Guidance')

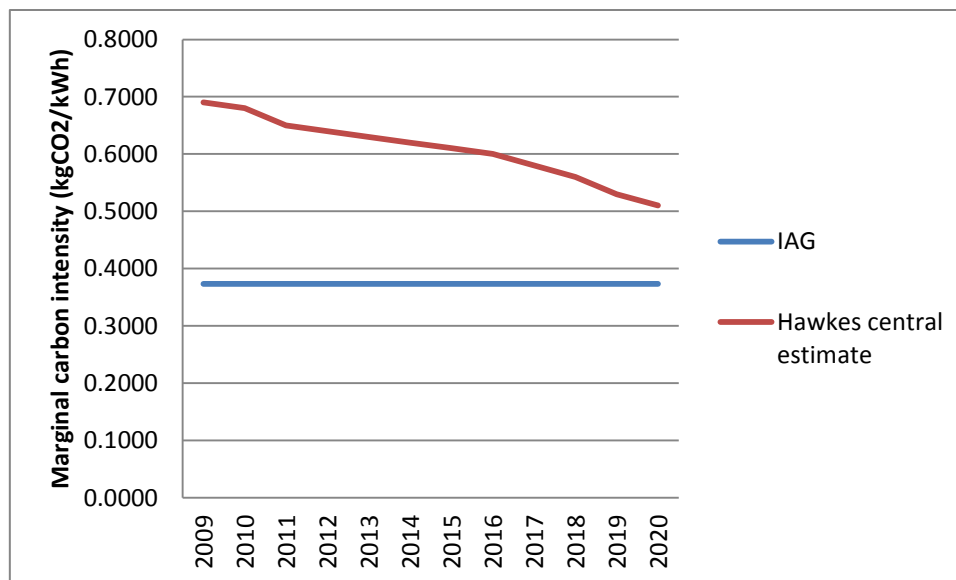
Contrary to the approach of IAG, most definitions of a marginal plant are a combination of the plant that does or does not get built and the existing plant that does or does not run as a result of policy⁴⁰. Because many of the existing fossil plants are far more carbon intensive than a new CCGT, a marginal intensity that includes this plant is much higher. Any modelling of an electricity system using Short Run Marginal Costs (SRMC) of operation (e.g.

⁴⁰ Hawkes, A.D. Estimating marginal CO₂ emissions rates for national electricity systems. Energy Policy, 2010, 38(10), 5977-5987

construction of a merit order) tends to find that the dirtiest plant is the most marginal, i.e. the first to turn down or up in response to a change.

Estimates of marginal carbon intensity differ by scenario and assumptions but indicate that actual marginal emissions rates are considerably higher than the figures typically used in policy analysis by DECC (see graph below).

Graph 12: IAG carbon intensity assumptions vs. actual carbon intensity assumptions



Also most models show the marginal carbon intensity dropping slower than the average carbon intensity, causing the gap between average and marginal to get wider over time. This is because all of the new low carbon power plants (wind, nuclear) will have very low SMRC of generation, so will not operate as marginal plants, so the addition of such plants reduces average carbon intensity but has no effect on the marginal carbon intensity. Marginal carbon intensity only drops as the carbon intensive plants on the system retire, which is a much slower process, particularly as many could be kept in operation longer as low utilisation balancing and peaking plants.

A good analysis of marginal intensities should also take into consideration that as the grid decarbonises marginal plants will be used mainly for balancing and peaking. This operation leads to sub optimal efficiencies, i.e. even if all of the marginal plants are CCGT, they will be

operating less efficiently than the standard efficiency assumptions, so their carbon intensity will be higher.

In light of the above line of argumentation, the group of co-signatories holds that the carbon abatement potential of micro-CHP should be calculated as a factor of actual marginal capacity displacement and calls for further discussion, under the auspices of DECC, concerning proper methods of calculating current and projected marginal carbon intensity.

3. Uncaptured economic benefits of micro-CHP

According to a credible study by Mott MacDonald titled 'System Integration of Additional Microgeneration', the deployment of 13.9GW micro-CHP, complimented by 1.9GW of renewables would lead to savings of £1.5 billion per annum in 2004 prices. If current prices are factored in then total savings amount to £3.08 billion per annum (see explanatory table below).

Assuming that savings are proportional to capacity and independent of technology, 1 million micro-CHP units – assuming 1kW average capacity of micro-CHP units - accounts for about £176 million per annum.

A micro-CHP unit in a standard house in the UK produces on average 2860 kWh of electricity per year. **Therefore, a micro-CHP unit complemented by renewables produces uncaptured savings of around 6.2p/kwh**

These are conservative estimates since cost drivers (e.g. peak power and carbon prices) are likely to continue to grow very fast until 2020⁴¹. During the coming months further efforts will be made to more accurately recalculate this figure.

⁴¹ For example, according to a Treasury report (2010), 'Carbon Price Floor: support and certainty for low-carbon investment', CO2 price could rise up to £40/t Co2 by 2020

Table 1: SIAM assumptions (13.9GW of micro-CHP complemented by 1.9GW of renewables)

Reduction in transmission losses (TWh)	1.57
Capacity displacement (GW)	13.4
Energy generation & 4% scaling for losses (TWh)	40.768
Carbon intensity (mt CO ₂ e/TWh)	0.7
Emissions abated (mt CO ₂ e)	28.5376

Table 2: Per annum savings cost driver's breakdown – SIAM price assumptions vs. 2011 prices

	2004 prices (SIAM)	2011 prices	Proportional contribution of 1 million (10GW) micro- CHP units
Transmission losses (£/MWh)	32	45 ⁴²	
Capacity value based on OCGT (£/GWh)	35	49.5 ⁴³	
Fuel cost (£/MWh)	17	40.125 ⁴⁴	
CO ₂ cost (£/t CO ₂)	10	14.3 ⁴⁵	
	Avoided costs - 13.9 GW of micro-CHP (£m)		
Reduced transmission and distribution losses	50	71	4
Reduced cost of holding centralised capacity	469	967	42
Reduced energy cost	693	1636	104
Avoided emissions' value	285	408	26
Total	1498	3082	176

⁴² Ofgem (2011) 'Impact Assessment on RWE Proposal P229 – seasonal zonal Transmission Losses Scheme'

⁴³ DECC (2011) 'Electricity Generation Cost Model – 2011 Update Revision 1', CCGT without CCS, capital costs and carbon costs not included

⁴⁴ Ibid.

⁴⁵ IAG (2011) 'Toolkit for Guidance on Valuation of Energy Use'

4. Assumptions supporting at least a 15p/kWh FiT

The authors of the report used information provided by all participating Stirling Engine micro-CHP developers in order to extract average data to calculate current and commercially viable internal rates of return (IRR) for Stirling Engine micro-CHP, a system currently available in the UK market (table 2).

Table 2: Average data used to estimate the internal rate of return of Stirling Engine micro-CHP

AVERAGE ASSUMPTIONS	
Product lifetime (years)	10
Electricity exported	50%
Electricity used on site	50%
Total electricity generation of SE micro-CHP (kWh/yr.)	2346
Domestic electricity cost without subsidy (p/kWh)	12.07 ⁴⁶
Domestic gas cost (p/kWh)	3.55 ⁴⁷
Additional gas consumption of SE micro-CHP compared to Band A boiler (kWh/yr.)	2480
Current marginal cost difference between m-CHP and Band A boiler (£)	4500

This data indicates that the current subsidy of 10 p/kWh gives an IRR of 0.5% that has not provided the necessary financial incentive for consumers, given current uptake rates under the FITs scheme. A subsidy of 15p/kWh would provide an IRR of 4.98% that would render the technology more competitive, so as to enhance its commercial appeal as a viable replacement for condensing boilers. **Based on feedback from micro-CHP developers, an IRR level of about 5% would be the lowest threshold of commercial viability, hence FIT subsidisation could be higher than 15p/kWh, based on the level of ambition to render micro-CHP an efficient alternative to condensing boilers.**

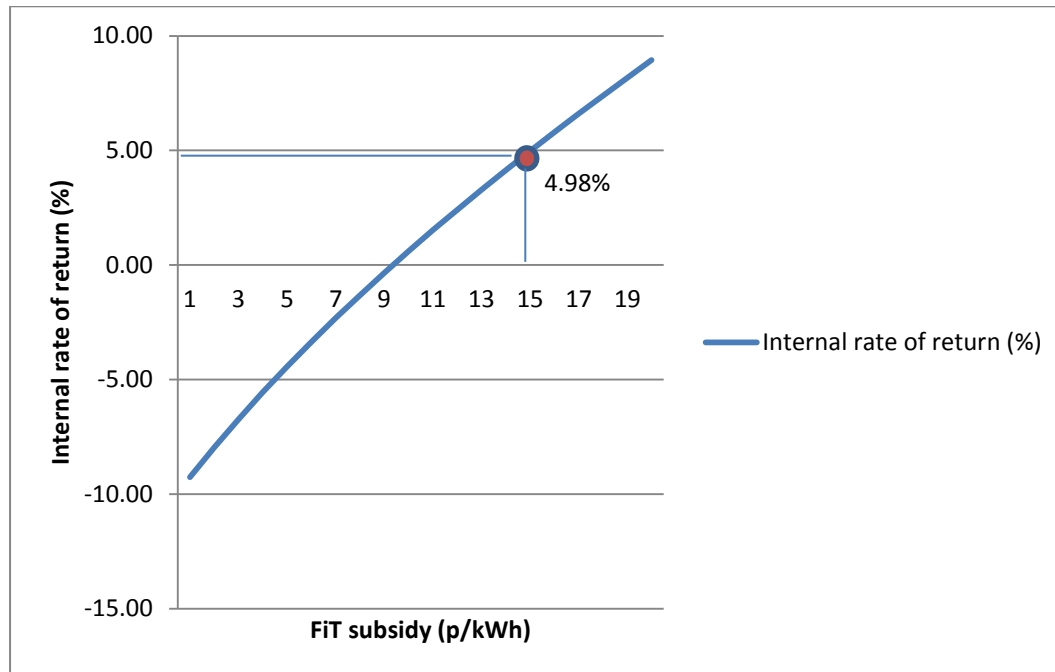
Given that micro-CHP is a technology that has currently not reached commercial maturity, it is bound to experience cost reductions as a result of technological improvements and economies of scale. As the cost of the technology drops and hence the marginal cost

⁴⁶ DECC (2011) 'Quarterly Energy Prices: September 2011', Table 2.2.3 Annual Domestic Electricity Bills in 2010 for selected Towns and Cities in the UK with average Cost Units'

⁴⁷ DECC (2011) 'Quarterly Energy Prices: September 2011', Table 2.3.3 Annual Domestic Electricity Bills in 2010 for selected Towns and Cities in the UK with average Cost Units'

difference between micro-CHP and condensing boilers reduces, FIT support for micro-CHP should degress to address this change.

Graph 13: SE micro-CHP – internal rate of return vs. FIT subsidy level



5. Main 'illustrative scenario' assumptions

The main assumptions used for the illustrative scenario have been the following:

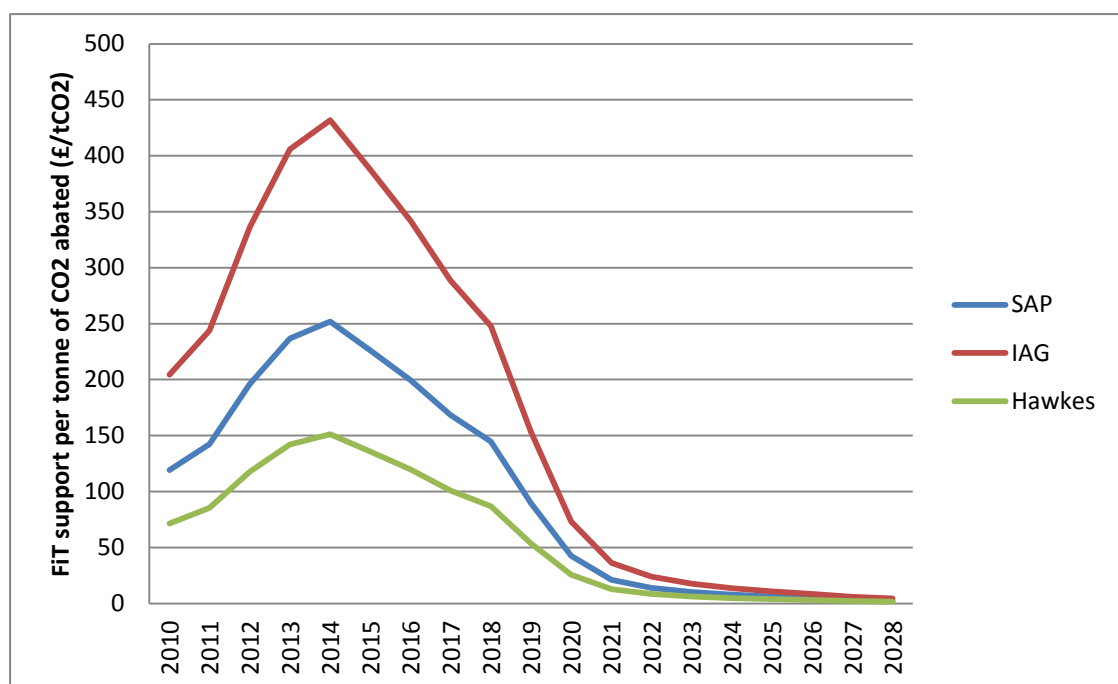
- 110% annual industry growth after the establishment of a 15 p/kWh tariff in 2012 and until 2020
- Tariff levels: 2012-2014: 15 p/kWh; 2015-2016: 10 p/kWh; 2017-2018: 7p/kWh; tariff phase out in 2019
- Tariff payment period: 10 years
- Output per unit per annum: 2860kWh
- Actual annual energy output is calculated at 50% of total annual output to address new installations dispersed throughout the year

The authors of this report requested relevant data from all participating micro-CHP developers in order to estimate the CO₂ abatement potential of micro-CHP, assuming a proportional uptake of the micro-CHP products developed by participants. This data was used in order to calculate the CO₂ abatement potential of FIT support for micro-CHP, taking into consideration different suppositions concerning marginal electricity carbon intensity.

Table 3: Micro-CHP missions abatement potential according diverse carbon intensity hypotheses

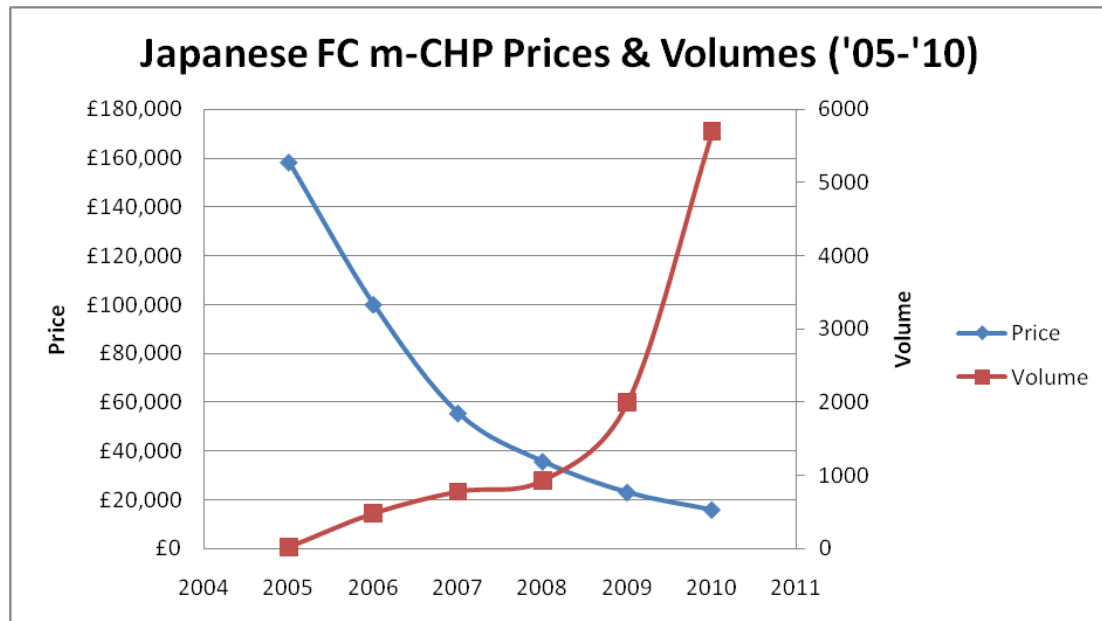
	SAP	IAG	Hawkes, 2010
Gas carbon intensity t CO ₂ /kWh	0.198	0.18358	0.18358
Marginal electricity carbon intensity t CO ₂ /kWh	0.517	0.3939	0.69
CO ₂ saved per micro-CHP unit – product average (tCO ₂ / yr.)	1.2	0.7	2.1
FIT support vs. CO₂ abatement (£ / t CO₂ saved)	90	154	60

Graph 14: Annual FIT support per tonne of CO₂ abated (illustrative scenario)



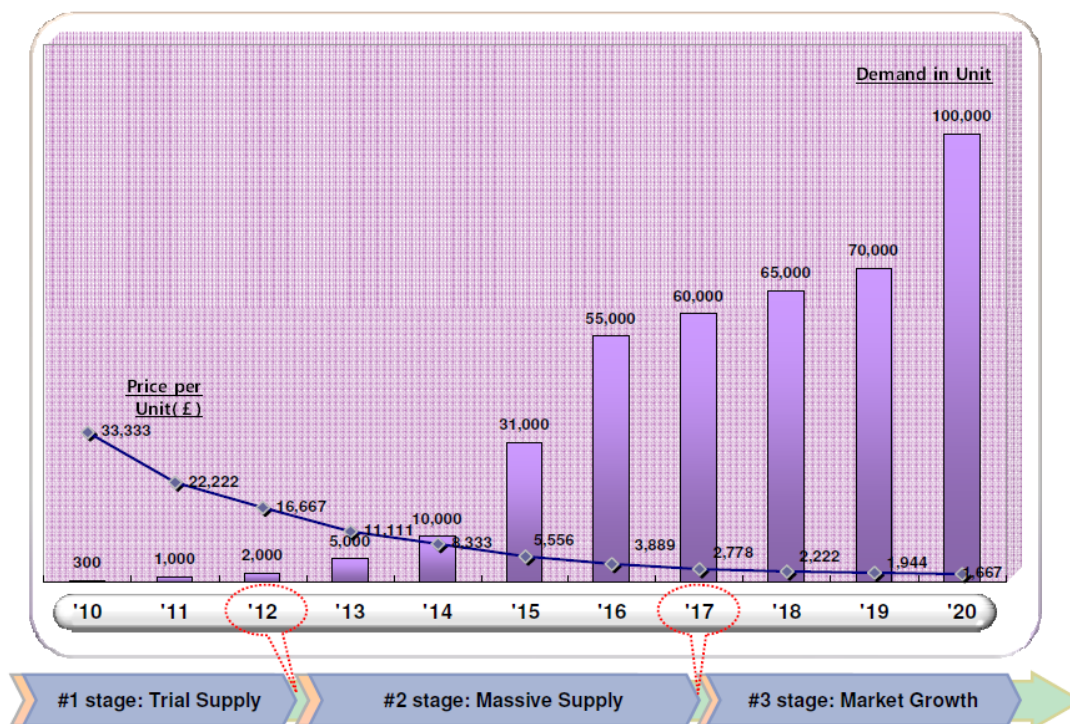
6. Past and projected micro-CHP experience curves

Graph 15: Japanese micro-CHP prices & volumes (2005-2010)



Source: Delta Energy & Environment newsletters from 2004-2011.

Graph 16: Projected micro-CHP prices & volumes in Korea (2010-2020)



Source: Korean Government