UK Energy Research Centre

BEIS Consultation

Future support for low carbon heat

UKERC Consultation Response

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Introduction to UKERC

The UK Energy Research Centre (UKERC) carries out world-class, interdisciplinary research into sustainable future energy systems.

It is a focal point of UK energy research and a gateway between the UK and the international energy research communities.

Our whole systems research informs UK policy development and research strategy.

UKERC is funded by the UK Research and Innovation Energy Programme.

UKERC Phase 4

Currently in its fourth phase running from 2019-2024, UKERC delivers an ambitious programme of research on the challenges and opportunities for delivering the transition to a net zero energy system and economy. The programme brings together engineers, natural scientists and social scientists to generate evidence that informs real-world decisions.

Our research programme encompasses major themes on global energy challenges and their implications for the UK; the role of local and regional energy systems; interdependencies between energy systems and the environment; decarbonisation of specific sectors including transport, heat and industry; and transitions in energy infrastructures.

The programme is complemented by a set of national capabilities. These will carry out systematic evidence reviews, host and curate energy data, map and monitor public engagement with energy systems, and improve the transparency and understanding of energy models. UKERC also supports the wider energy research community in the UK by promoting engagement with other stakeholders, supporting career development and capacity building, and enhancing international collaboration.

Introduction

The UK Energy Research Centre (UKERC) has provided research and analysis across the whole energy system since 2004, with funding provided by the Research Councils through a succession of five year phases. Research related to low carbon heat became a significant focus during Phase 3 (2014 – 2019) and the current Phase 4 includes a research theme devoted to decarbonisation of heating and cooling, with several of our other themes providing relevant insights. Our whole systems research programme addresses the challenges and opportunities presented by the transition to a net zero energy system and economy.

In this submission we address specific consultation questions where UKERC evidence and analysis provides us with relevant insights. In addition there are a number of high level observations that we provide in these introductory remarks.

Overall, we are concerned that the measures outlined in the consultation need to be set within a coherent and ambitious package of policies that work together to drive the UK's transformation to sustainable heating at a rate commensurate with the goal of net-zero by 2050. While we appreciate there are some uncertainties over the future role of the gas grid and the potential for hydrogen for heating, immediate progress in heat system decarbonisation is clearly required as part of this multi-decadal transformation. As the consultation notes, heat pumps offer a low regrets option in some applications and it is widely acknowledged that the UK has a small supplier base and very low level of heat pump deployment compared to many countries. Increasing consumer and installer familiarity, and growing the skills base and supply chain all feature strongly in the process of 'learning by doing' that reduces heat pump costs. If heat pump deployment were to proceed linearly to 2050 in line with some scenarios for deployment, annual installations would need to increase by an order of magnitude. Whilst welcome, the current proposals are not sufficient to deliver a large scale market for heat pumps. Ambition and clarity of purpose are essential if heat system decarbonisation is to succeed.

We also stress the importance of providing support to support the development of large low carbon heating systems, including systems attached to heat networks. We appreciate that the provisions laid out in the consultation pertain only to specific schemes and note the observations made in the consultation about support for heat networks.

Alongside the required policy changes necessary to support specific heating technologies, wider governance changes will be needed to drive the UK transformation to low carbon heating. Whilst regulation and other forms of financial support for building efficiency improvement are noted in the consultation, we note that it is likely to be important to use 'sticks' as well as 'carrots' if the highest carbon heating systems are to be removed and building efficiency increased. However, it will also be important to consider ownership and regulation of heat networks, the role of local authorities and opportunities for innovation that may be unlocked through regulatory change – such as encouraging electricity suppliers to offer 'smart' heating tariffs or enabling community ownership of heat distribution schemes.

While we appreciate these issues are beyond the scope of the current consultation, it is important that these considerations inform policy choices made now.

Our detailed responses to the questions are below.

1. Do you agree that the tiering structure as outlined above is appropriate and would deliver the best value for money? Yes/No. Please provide evidence to support your response.

Yes. The new tiering structure seems an appropriate measure to encourage the development of large-scale plants that can achieve better economies of scale, whilst recognising that the availability of sustainable feedstock needs to be carefully assessed when sizing the plants. A tiering structure is popular across other European countries to support biogas plants. However it is important to note that tiering may be linked to plant capacity rather than gas output per year[1]. Overall we believe that the approach strikes a sensible balance between ensuring that smaller plants are provided with adequate levels of support, thus creating opportunities to use locally arising bio/waste feeds, without actively discouraging larger schemes. Defining the differentials between the tiers will of course be key to whether the scheme actively encourages an optimal mix of plant sizes. Please see the detailed comments on tariff levels below, and the use of auctions to set prices - based on the experience with Contracts for Difference (CfDs) in the renewable electricity sector.

2. What are your views on the impact of a 15-year tariff period to support biomethane? Please provide evidence to support your response.

We believe that the 15 year tariff period is pragmatic and aligns with other support schemes in the British market, such as the power sector CfDs for renewable schemes. Given the context of long-term transformation of heat provision and timeframe for scheme operation it would not appear sensible to offer longer contracts (noting that such contracts would continue to operate into the 2040s). It does not appear feasible to determine the 'optimal' time horizon because project costs lie within a range and the economics of investment are co-dependent on both tariff rate and scheme duration. In the sections that follow we consider project terms in more detail.

3. What are your views on the advantages and disadvantages of a shorter 10- or 12- year tariff period and whether they would help maximise value for money? Please provide evidence to support your response.

Some evidence suggests that some projects may be capable of recovering investment costs in less than 15 years – depending of course on project costs and revenues. Recent estimates highlight that under certain circumstances, even in a 'no subsidy scenario', an anaerobic digestion (AD) plant may recover investment costs in 11 years, showing a positive net present

[1] - for example in Lithuania a tiering structure based on AD plant capacity is used: Plant capacity ≤ 1300 kWh/hour = 0,072 € per kWh falling to 0,057 € per kWh for plants over 5200 kWh/hour http://www.res-legal.eu/compare-support-schemes/

value at an internal return rate of 8%[2]. Therefore, there could be space for setting a subsidy longer than 11 years but shorter than 15 years. However, it is difficult to see an overwhelming case for doing so rather than adjusting tariff levels downwards to avoid over-remuneration. We are not aware of any evidence to suggest that prospective investors in AD have a time preference or investment horizon better suited to shorter tariff lengths. This is an area where additional research would help inform policy.

As a range of actors invest in AD, time preferences probably do vary – for example between farms, water companies, local authorities, etc. One approach could be to provide differential support, offering options to investors that perhaps link tariff support and project duration and allow developers to choose between longer duration and higher tariff rates. This could help focus resources on projects that need it and may also allow the different business models of different types of AD developer to be reflected in policy. For example, we are aware of research that notes the difference between farm types (dairy/arable) and role of bio-methane income relative to other revenue streams[3]. However the practical difficulties associated with differentiating between projects in this way would appear to be significant and could be disproportionate to the size of the scheme overall. For all of these reasons, whilst it appears possible that shorter durations could be introduced it is difficult to ascertain any overwhelming rationale for doing so.

4. Do you have any views on the appropriate tariff level, within these ranges? Please provide evidence to support your response.

Given the proposed tiering structure, subsidies in the UK may vary from 1.5 to 5.5 p/kWh – down from over 8 p/kWh in 2013[4]. The global average cost of producing biomethane, through biogas upgrading, is around 5.22 p/kWh, although this cost varies significantly across regions[5]. Assuming the latter cost as a representative level, we note that larger projects may be over-subsidised at the highest tier threshold.

5. Do you have suggestions of other mechanisms that could be introduced to ensure tariffs deliver the best possible value for money – for example, additional evidence on costs and revenues that applicants to the Green Gas Support Scheme could be required to provide?

It may be useful to establish a strong monitoring process, which considers not only financial, but also technical evidence related to the (potential) production of bio-methane, including feedstock levels and composition or type, efficiencies of technologies, gas production and

[2] Achinas S, Euverink GJ. Feasibility study of biogas production from hardly degradable material in co-inoculated bioreactor. Energies. 2019 Jan;12(6):1040. This study considers a base installed capacity of 309,571m^3 biogas per year.
[3] Jones P, Salter A. Modelling the economics of farm-based anaerobic digestion in a UK whole-farm context. Energy Policy. 2013 Nov 1;62:215-25.
[4] Rajendran K, O'Gallachoir B, Murphy JD. The combined role of policy and incentives in promoting cost efficient decarbonisation of energy: A case study for biomethane. Journal Of Cleaner Production. 2019 May 10;219:278-90.
[5] Outlook for biogas and biomethane, IEA 2020.

injection into the grid. It would also be ideal to establish annual examinations or audits of projects receiving support. Another activity may be gathering information from companies about different types of AD projects with (potential for) bio-methane production, exploring size, technology, feedstock, etc. Gathering additional data would help in the development of a model of an ideal, representative AD plant, which could be used to determine costs, prices and efficiencies, and therefore facilitate policy review and monitoring. All of these measures might help to reduce the risk of over-subsidisation of projects in future.

6. From experience of degression, how do you think elements such as the frequency and size of degression, and spend triggers, should change in order to ensure value for money, whilst meeting the need for investment certainty? Please provide evidence to support your response.

It is important to collect, gather, and analyse comparative information from international experience. In Germany, for example, the degression rate for landfill gas, sewage gas and mine gas is 1.5% annually from January 2018; in the case of biogas, there is a basic degression rate of 0.5% every 6 months from April 2017[6]. The modelling of an ideal AD plant, based on extra information from applicants, and random audits may facilitate assessment of the degression process. In terms of size, this should be as representative and as close as possible to the market signals - based on costs, prices, projections, etc. - to avoid significant distortions in decision-making processes. Given that such degression evolution is critical for new entrants/applicants, the above would not be 'harmful' to a proper business cash flow projection, as long as the degression is transparent and open.

7. Do you have further suggestions, beyond those mentioned in this consultation, which would help the Green Gas Support Scheme to deliver the best possible value for money? Please provide evidence to support your response.

We note commentary on the operations of the RHI related to the potential for some market participants to manipulate the scheme and for lobbying[7][8]. For these reasons we welcome the proposals to gather information and data from participants and emphasise the importance of monitoring, as described above. We also suggest that it is important to ensure that independent expertise and the views of a range of actors are included in an open discussion with the aim of designing and deploying a fair, transparent, and economically efficient scheme.

[6] http://www.res-legal.eu/search-by-country/germany/single/s/res-e/t/promotion/aid/feed-in-tariff-eeg-feed-in-tariff/lastp/135/

[7] https://www.rhiinquiry.org/report-independent-public-inquiry-non-domestic-renewable-heat-incentive-rhi-scheme

[8] Lowes R, Woodman B, Fitch-Roy O. Policy change, power and the development of Great Britain's Renewable Heat Incentive. Energy Policy. 2019 Aug 1;131:410-21.

8. Do you agree with the proposals for tariff guarantees for biomethane? Yes/No. How could this be improved? Please provide evidence to support your response.

Yes, although it is important to ask, gather, and check all the necessary technical and financial information, which should be audited/certified by specialists. A homologation of the RHI tariff guarantees process seems appropriate in this case.

9. What are your views on increasing the minimum percentage of waste feedstocks above 50%, now or in the future? What could be a suitable new threshold? Please provide evidence to support your response.

We support this move as waste can be a key feedstock for biogas production, energy crops can have large associated emissions due to a number of factors including the type of land used for energy crop production[9]. Following engagement with the Committee on Climate Change, our understanding is that their analysis of biomass in a low-carbon economy sees only waste being used for biomethane production.

17. Do you agree with our proposal to allow biomethane producers to decide how much biomethane they wish to claim Green Gas Support Scheme payments for within a given quarter? Yes/No. Please provide evidence to support your response or provide an alternative proposal for scheme interaction.

Yes. For the reasons set out below it is important to allow producers flexibility to choose between green gas sales to the gas grid and other opportunities, notably to provide road fuels.

19. Do you have views on how the Green Gas Support Scheme could be improved, beyond the ways described in this consultation? Please provide evidence to support your response.

We understand the rationale for providing support through payments for gas produced rather than through grant funding. However if there is an objective to encourage a range of AD scheme types then there may be merit in considering whether some prospective participants may be best incentivised through grants that address upfront costs. This could reduce the risk of over-subsidy for some projects[10,11]. Capital grants also have inefficiencies in terms of lack of incentives for potential efficient operation.

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[9] Adams, P.W.R., Mezzullo, W.G., McManus, M.C., 2015. Biomass sustainability criteria: Greenhouse gas accounting issues for biogas and biomethane facilities. Energy Policy 87, 95–109. https://doi.org/10.1016/j.enpol.2015.08.031

[10] https://www.rhiinquiry.org/report-independent-public-inquiry-non-domestic-renewable-heat-incentive-rhi-scheme

[11] Lowes R, Woodman B, Fitch-Roy O. Policy change, power and the development of Great Britain's Renewable Heat Incentive. Energy Policy. 2019 Aug 1;131:410-21.

When financial aid is focused on addressing high upfront costs, it is also possible that new entrants would be able/willing to participate in an energy business derived from their main business activity, particularly farming. This could provide incentives to find the best way to run both businesses – such as farming and bioenergy. Capital grants may be better suited than long-term subsidies in helping businesses to integrate biogas production into their core business. Again however, this needs to be set against the risk of reduced incentives for efficient operation of biogas plants.

We welcome the changes proposed to make it easier for AD operators to switch between green gas scheme sales and other markets, notably renewable transport fuels and access the RTFO. Some authors argue that bio-methane is best used in buses and other heavy vehicles[12,13,14], although injection to the grid represents lower gas transportation costs[15].

20. Do you have any views on the most appropriate market-based mechanism for green gas support in the longer term, and how this might operate? Please provide evidence to support your response.

The consultation text refers to experience with the CfDs in the power sector. The principal functional difference between the CfDs and proposals for green gas is that the CfD contract prices are set through auctions. This has delivered remarkable reductions in the bid-prices for CfDs in recent Pot-2 auction rounds. Once a CfD contract has been secured, investors benefit from revenue stability (CfD beneficiaries are largely protected from wholesale electricity market price fluctuations). This reduces risk from the perspective of investors and has played an important role in attracting finance to the sector, increasing the potential to use lower risk (and cheaper) debt finance in projects, in turn reducing levelised costs of generation. Gas price fluctuations also have the potential to affect prospective investment in AD, since extended periods of low gas prices would be likely to create difficulties for AD operators in a manner that is analogous to renewable generators.

In the case of the CfDs the 'market-based' dimension in the policy design is the auction stage. It is not possible to go into detail on the pros and cons of this approach overall and the context of electricity market operation is rather different, given the particular challenges associated with electricity demand/supply balancing. Auctions also have limitations, associated with the potential difficulties/complexity they may introduce for smaller players and the risk of 'winners curse' if auction participants win projects based on overly ambitious bid prices. Nevertheless the potential to use auctions to set prices, combined with the investment securing created by a CfD or similar appears to be an obvious avenue to explore in the context

[12] Styles D, Dominguez EM, Chadwick D. Environmental balance of the UK biogas sector: An evaluation by consequential life cycle assessment. Science of the Total Environment. 2016 Aug 1;560:241-53.
[13] Achinas S, Euverink GJ. Feasibility study of biogas production from hardly degradable material in co-inoculated bioreactor. Energies. 2019 Jan;12(6):1040.
[14] Parkes R. Biomethane: green gas rising?. Renewable Energy Focus. 2017 Apr 1;18:33-5.
[15] Kelly S, Pollitt M. Policy Update: What does the renewable heat incentive mean for bioenergy in the UK?.

of green gas policy development. This is an area where UKERC can bring expertise to bear, should BEIS wish to undertake additional consultation and analysis.

21. Do you have any views on industry readiness for a market-based mechanism to support green gas in the longer term? Please provide evidence to support your response.

Again, we believe it would be helpful to assess the potential for the AD industry to engage with an auction based approach modelled on the power sector CfD. We are not aware of any evidence that considers the ability of prospective AD operators to engage with an auction based approach but believe that additional analysis in this area could offer important insights.

23. Do you agree that support for buildings technologies should change from a tariff to a grant? Yes/No. Please provide evidence to support your response.

Yes. Grants have been recognised to have more value rather than tariffs paid on the basis of heat delivery in this market and have been widely used internationally[16]. Grants can be particularly valuable for homeowners who may lack access to capital[17]. UKERC's analysis of international experience also emphasises that grants are most likely to be successful when combined with measures to disincentivise higher carbon alternatives (for example carbon tax on heating fuel), regulation and steps to ensure the quality of installation such as certification and training[18,19]. The international evidence is clear that grants need to be a portfolio of steps that work in combination to encourage the emergence of an installer base and supply chain, as well as increasing consumer familiarity. Policies need to be concerted and sustained, since large scale transformation of heating provision is a long-term project[20].

24. Do you agree with our proposal to offer a technology-neutral grant level? Yes/No. Please provide evidence to support your response.

No. The capital cost of a ground source or water source heat pump system will be higher than an air source heat pump system[21]. A technology-neutral grant would discriminate against the high capital but high efficiency, lower operating cost GSHP and WSHP systems compared to the lower capital cost, lower efficiency, high operating cost ASHP systems. There is a risk that larger households with the potential for GSHP/WSHP may be incentivised to adopt ASHP due

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[16] https://ukerc.ac.uk/project/best-practice-in-heat-decarbonisation-policy/
[17] Committee on Climate Change, 2016. Next Steps for UK heat policy [WWW Document]. URL https://www.theccc.org.uk/wp-content/uploads/2016/10/Next-steps-for-UK-heat-policy-Committee-on-Climate-Change-October-2016.pdf
[18] https://ukerc.ac.uk/project/best-practice-in-heat-decarbonisation-policy/
[19] https://www.gov.uk/government/publications/heat-decarbonisation-overview-of-current-evidence-base
[20] https://www.nature.com/articles/s41560-019-0383-5
[21] Modassar Chaudry, Muditha Abeysekera, Seyed Hamid Reza Hosseini, Nick Jenkins, Jianzhong Wu,Uncertainties in decarbonising heat in the UK, Energy Policy < http://www.sciencedirect.com/science/article/pii/S0301421515300306>

to the grant level. Inappropriately sized ASHP systems in larger households could potentially lead to performance issues[22,23].

25. Do you agree that £4,000 is an appropriate grant amount to meet the aims of the scheme? Yes/No. Please provide evidence to support your response.

No. See response above. The grant seems appropriate for ASHP, however as discussed in our response to Q24, this level of support is unlikely to lead to a significant uptake of GSHP and other technologies with higher capital cost.

26. Do you agree with the recommendation for a flat-rate grant? Yes/No. Please provide evidence to support your response.

Not necessarily. While simple to implement we are concerned that this could incentivise the installation of air source heat pumps at the expense of ground-source where ground source may be more suitable. Ground-source heat pumps can have higher up-front costs but lower operating costs due to higher coefficients of performance.

There is also a concern, that for bigger buildings, because of higher install costs, the £4000 rate would make a much smaller difference than for small buildings. This could lead to only smaller buildings moving to heat pumps.

27. If you believe a variation by capacity should be considered, please provide evidence to justify a process and level for varying the grant.

If the grant were varied by type of heat pumps, this could simply be based on the cost differential from current market data. If adjustments were made based on system capacity, this would be more complex and we would be concerned such a scheme, while valuable from a delivery perspective, could encourage gaming.

28. Please provide any relevant views to help inform development of the delivery mechanism.

We broadly agree with the steps proposed. The key issue is that consumers are at no stage exposed to the risk that the policy will not deliver them what they expect and have been promised by an installer. We also believe that the scheme should be designed to ensure simplicity of access to funds for installers. Highly complex schemes (such as the historic

[22] Dashamir Marini, Richard. A. Buswell, Christina. J. Hopfe, Sizing domestic air-source heat pump systems with thermal storage under varying electrical load shifting strategies, Applied Energy, Volume 255, 2019 <https://doi.org/10.1016/j.apenergy.2019.113811. (http://www.sciencedirect.com/science/article/pii/S0306261919314989)

[23] Matteo Dongellini, Claudia Naldi, Gian Luca Morini, Sizing effects on the energy performance of reversible air-source heat pumps for office buildings, Applied Thermal Engineering, Volume 114, 2017<https://doi.org/10.1016/j.applthermaleng.2016.12.010> (http://www.sciencedirect.com/science/article/pii/S1359431116338741)

Renewables Obligation) were often a burden to small companies wanting to get involved in the market who need both simplicity and low risk income. Reducing entry barriers would reduce the potential disadvantages small companies may face compared to large corporates. Our experience suggests that some of the most thorough and experienced low carbon heat installers are small or micro-businesses. Supporting these businesses could also create a potentially useful communication route between government and low carbon heat installers. For example, there could be a requirement that installers are required to provide data or feedback if they receive grant income and this information could lead to the development of a competent heat pump installer database or similar.

The Energy Performance Certificate of the dwelling could be an important part of this process in order to validate the required energy efficiency works in the building and also to check the seriousness of a voucher claim. Perhaps the receipt of an EPC could be part of the process which allows the funds to be released. We would add, that existing requirements under the domestic RHI require all cavity walls and lofts to be insulated. We believe this would be a sensible energy efficiency back-stop for anyone looking to get financial support for renewable heating. There may also be value in encouraging low carbon heating installs to take place at the same time as whole house retrofits, there is nothing in the current proposals that would support this.

We note the suggestion about heat loss surveys which we believe are required for good system design. We would suggest that some basic insulation measures are required (such as full loft and cavity wall insulation) for the installation of heat pumps to ensure reliable and cost effective performance. This could be simple to administer based on EPCs. We believe that good system design and performance are extremely important for ensuring consumer satisfaction with heat pump systems.

29. Do you agree with the minimum efficiency requirements for heat pumps and evidence requirements? Yes/No. Please provide further evidence to support your response.

The sCOP seems a little low. The MCS register currently list products which significantly higher sCOPs at 45 degree Celsius flow temperatures[24].

30. Do you agree with the proposal to require electricity metering for all heat pump installations? Yes/No. Please provide further evidence to support your response.

Yes, this can be relatively cheap and simple and can provide valuable data. Data from heating systems allow analysis of their performance and the efficacy of the support scheme, and could potentially inform the design of future support programmes for low carbon heating.

[24] https://mcscertified.com/product-directory/

33. Please provide views on the appropriate requirements for the heat loss calculation, as well as the minimum heat loss value that should need to be demonstrated.

While the MCS process may be the most suitable, there is a concern here that the system could be gamed so that surveys make a building demand look higher than it actually is. Because it's expected that bioenergy can only have a niche role in a sustainable energy system for heat[25] it may make sense that biomass is only funded in buildings which are technically and legally unsuitable - that is buildings with solid walls and heritage restrictions where those solid walls cannot be treated. It should be assumed that all solid walls without heritage concerns will be insulated by 2050.

34. Please provide views on any other criteria to ensure that biomass support is focused on hard to treat properties only

Please see response to previous question.

35. What do you consider to be the main consumer protection risks of providing support through an upfront grant and how might they be mitigated? Please provide evidence to support your response to question.

Our key concern is that consumers would be exposed to the risk of the grant not being issued once a consumer had paid for the heating system. However, this can be mitigated by policy and we think the current proposal that the installer receives the grant directly via a voucher scheme makes sense and should remove this risk. Getting the detail of this right will be critical to consumer protection. We are aware of examples under the RHI where a consumer had installed a system but not received RHI subsidy because of complex administrative reasons.

We also have concerns over the potential for poor quality installations with little after care. It would be good to ensure that as well as decent installations being required through MCS, there is a requirement for annual servicing. This could be encouraged through the use of product guarantees which guarantee an operating life-time but require service for this guarantee to be met. This requirement may be part of equipment guarantees but could be made a more explicit part of the policy.

37. Do you agree that quarterly grant windows would prevent overspend and manage demand to ensure an even spread of deployment? Yes/No. Please provide evidence to support your response.

Overall the key issue with the proposed funding is that it does not appear to be at a level which is commensurate with the need for net zero heating by 2050. A wider suite of polices

[25] Committee on Climate Change, 2018. Biomass in a low-carbon economy [WWW Document]. URL https://www.theccc.org.uk/publication/biomass-in-a-low-carbon-economy/

and regulatory measures should be developed alongside this grant scheme and deployed rapidly.

41. Do you agree with not supporting hybrid systems under the Clean Heat Grant? Yes/No. Please provide evidence to support your response.

No, these have been widely identified to be a potentially very important technology. The Committee on Climate Change[26] in their net-zero report suggest hybrid heat pumps (ASHP and hydrogen boilers) for off gas grid buildings, and also as a solution to avoid excessive electricity consumption by heat pumps during cold spells. While we appreciate concerns over their use once installed, we think there is value in supporting them. We propose this support could simply be at a level which is less than that received for full heat pump systems, representing the potential ease of adding these systems on - something which is possible in some circumstances.

Evidence from trials show[27] that hybrid heat pumps can be integrated to a range of consumer buildings without any changes to existing wet heating systems. They were shown to be particularly attractive to off-gas grid homes. In off-gas grid homes, hybrid heat pumps can provide a large fraction of the heat demand to be supplied from ASHP while delivering good system efficiency (80% of heating load in homes with LPG boilers). When combined with biogas, if available and produced from waste feedstocks, hybrid heat pumps could potentially deliver significant carbon savings and be an important element of a decarbonised heating system as recognised by the CCC's net zero report.

[26] https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

[27] FREEDOM Project Final Report, 2018. <https://www.wwutilities.co.uk/media/2829/freedom-project-final-report-october-2018.pdf>