A Response To:

The Sixth Carbon Budget and Welsh emissions targets – Call for Evidence

Ref: https://www.theccc.org.uk/the-sixth-carbon-budget-and-welsh-emissions-targets-call-for-evidence/

Response Author:

- Dr **Ben Anderson** (b.anderson@soton.ac.uk, @dataknut): Principal Research Fellow, Energy & Climate Change, Faculty of Engineering & Physical Sciences, University of Southampton, UK and Centre for Sustainability, University of Otago, New Zealand.

Citation:

- Anderson, B (2020) *A Response To: CCC (2019) The Sixth Carbon Budget and Welsh emissions targets – Call for Evidence*. Southampton: University of Southampton.

Contents (questions addressed)

Question 8. What evidence do you have of the co-benefits of acting on climate change compatible with achieving Net Zero by 2050? What do these co-benefits mean for which emissions abatement options should be prioritised and why?

- There is significant evidence of the health co-benefits of significantly more energy efficient buildings and dwellings so that thermal comfort (and less damp/mould) is achieved with lower energy inputs – see below and (Telfar-Barnard et al. 2019; Chapman et al. 2009; Chisholm et al. 2019). However construction methods must ensure that air tight buildings (to reduce heat loss) are properly ventilated (to prevent the recurrence of damp and other low air quality issues) (De Groot and Leardini 2010; Schieweck et al. 2018). Changes to the building code to mandate standards such as PASSIV/E should be a priority in this regard and this may also address the emerging issue of summer over-heating in retrofitted insulated buildings (Mylona and Davies 2015).
- Radically improving the energy efficiency of the building stock will also mean a substantial reduction in the energy required for heating/cooling, especially in morning an winter peak periods when the demand for electric/heat pump heating will be greatest (Love et al. 2017; Anderson, Rushby, and Jack 2018). This in turn will mean LV distribution networks may avoid peak period re-inforcement costs (see below) and also reduce the costs of integrating large scale renewables into the grid (which, apart from pumped hydro, are not dispatchable during peak demand periods).
- Similarly a switch in the light vehicle fleet to EV or hydrogen is likely to have a significant positive health co-benefit with respect to air quality in urban areas and the need for other active transport modes (Chapman et al. 2018; Dirks, Salmond, and Talbot 2018; Barnes, Chatterton, and Longhurst 2019).

Question 26 (Buildings): For the majority of the housing stock in the CCC's Net Zero Further Ambition scenario, 2050 is assumed to be a realistic timeframe for full roll-out of energy efficiency and low-carbon heating.

a) What evidence can you point to about the potential for decarbonising heat in buildings more quickly?

b) What evidence do you have about the role behaviour change could play in driving forward more extensive decarbonisation of the building stock more quickly? What are the costs/levels of abatement that might be associated with a behaviour-led transition?

a) It is well known that per capita energy consumption scales (non-linearly) with the occupancy level of dwellings (Longhi 2015; Huebner et al. 2016). Put simply, single-person households use proportionately more energy due to the 'shared' nature of space heating as well as (in many cases) cooking, lighting, laundry, entertainment etc. Politically unpalatable though it may seem, one potentially fast-acting solution would be incentivise increased household occupancy (co-living) through housing provision, sub-letting tax allowances, social care, planning and any other policy mechanisms to reverse the current trend towards increased solo living (ONS: Families and households in the UK: 2019). A similar argument is well known in the spatial economics literature with respect to the trend towards (and normative projection of) suburban development comprising low density large footprint housing (Lee and Lee 2014).

b) It is unclear exactly what 'a behaviour-led transition' refers to in this context but with respect to the household/consumer sector there is evidence that voluntary behaviour change incentivisation and/or information provision has relatively limited effects (Abrahamse et al. 2005; Shove 2010; Barr 2006). Further:
   1. Residential space heating: it seems unlikely that behaviour change could produce substantial decarbonisation without triggering substantial and costly (in terms of both additional emitted GHG and £) health consequences (Huebner et al. 2015; 2018). Considerable work in New Zealand, which has a relatively poor housing stock in a broadly similar climate suggests that the optimum route is through reduced energy input enabling increased energy services (heat/cool) through substantial upgrades to the energy efficiency of the building stock (Chapman et al. 2009; Telfar-Barnard et al. 2019) rather than via behaviour change and this is confirmed by UK research (Huebner et al. 2018; Adan and Fuerst 2016).
   2. Residential cooling: The prospects for cooling may be more amenable to behaviour change although the risks of over-heating as a consequence of increased insulation to reduce winter energy inputs is an emerging concern in temperate climates (Lomas and Porritt 2017). There is evidence suggesting reductions in energy demand at 'peak cool' can be achieved through changes to household practices (de Vet and Head 2019; Moore et al. 2016; Sherriff et al. 2019), including reconfiguration of what is considered 'normal' in terms of thermal comfort, clothing and air flow (see also Japan's Cool Biz programme - http://www.demand.ac.uk/wp-content/uploads/2018/04/demand-insight-17-V3.pdf). However where deep retrofits have installed insulation and HVAC, 'normal' UK practices of window-opening and curtain/blind opening need to be reversed for best effect.

Question 30 Power: In Chapter 2 of the Net Zero Technical Report we presented an illustrative power scenario for 2050 (see pages 40-41 in particular):

a) Which low-carbon technologies could play a greater/lesser role in the 2050 generation mix? What about in a generation mix in 2030/35?

b) Power from weather-dependent renewables is highly variable on both daily and seasonal scales. Modelling by Imperial College which informed the illustrative 2050 scenario suggested an important role for interconnection, battery storage and flexible demand in a future low-carbon power system:

   i. What other technologies could play a role here?

ii. What evidence do you have for how much demand side flexibility might be realised?

b) ii. Current research suggests that the amount of residential demand side flexibility that can be realised depends on the time of day (to some extent) season and the energy using practices of the households. It's value to the system therefore depends on the value of the degree of flexibility available at a given time. Empirical research suggests that we can expect to realise at most 5-15% residential electricity demand flexibility during evening peak periods where behaviour-only interventions are used and that there is substantial variation between households and across studies (Frederiks, Stenner, and Hobman 2015; Srivastava, Van Passel, and Laes 2018). Recent reviews have shown that there is also large variation (0% - 30%) between studies aimed at reducing energy demand over time (sustained rather than flexibility) even where similar interventions are tested (Abrahamse et al. 2005; Andor and Fels 2018; Nicolson and Moon 2019).

We should expect the lower end of these ranges on a population-wide basis as many of the studies contributing to this evidence base are biased self-selecting samples of consumers who are more likely to respond to incentives (Anderson et al. 2020; Frederiks et al. 2016; Srivastava, Van Passel, and Laes 2018). We know that consumers are particularly price insensitive in this period although there are indications that this varies by social group (White and Sintov 2019). As far as we are aware there has not been a systematic review of the evidence for residential demand side flexibility at different times of day and seasons and we recommend that a rapid evidence review on this topic should be commissioned.

Finally, we should not expect consumers to make 'rational' choices about responding to price incentives to reduce or shift electricity demand (Nicolson and Moon 2019). We should also not presume consumers can (or will) make choices about appropriate tariffs. Recent work has shown that even when provided with full information in a task that required no greater then primary school level maths, only 44% of a representative sample of GB bill payers selected the 'best' ToU tariff for a presented consumption pattern (Moira Nicolson 2018 Table 13). Crucially, 'lower' social grades did even worse (39%). This raises serious questions about the 'energy justice' consequences of relying on price incentives to flex demand as Ofgem's recent working paper notes at some length (Ofgem 2019).

Question 37: **Infrastructure:** What will be the key factors that will determine whether decarbonisation of heat in a particular area will require investment in the electricity distribution network, the gas distribution network or a heat network?

With respect to residential space heating, the effect of heat pumps on the temporal profile of residential electricity demand is not well researched. It is assumed that there will be overall decreases in energy input for similar energy services (heat/cool) due to appliance efficiencies. However recent simulation of temporal loads (Eggimann, Hall, and Eyre 2019) based on analysis of observed demand patterns in the UK (Love et al. 2017) shows that substantially increased (up to 200%) local peak load may ensue (see also (Anderson, Rushby, and Jack 2018) for a comparative UK and New Zealand view with similar insights). This is likely to require either the decoupling of energy input from the timing of the energy service (shifting e.g. via thermal stores) and/or the integration of other forms of storage (e.g. V2G or local batteries) and/or network re-enforcement to prevent failure of at-capacity (or constrained) local distribution networks.

It seems clear therefore that the investment required will depend on the temporal usage patterns of the energy consumers in that area together with the socio-technical infrastructure in place. To some extent it will also depend on the low-emissions infrastructure vision of those energy users (Stephenson et al. 2015; Artelle et al. 2018).

Collected References

Abrahamse, Wokje, Linda Steg, Charles Vlek, and Talib Rothengatter. 2005. 'A Review of Intervention Studies Aimed at Household Energy Conservation'. *Journal of Environmental Psychology* 25 (3): 273–91. https://doi.org/10.1016/j.jenvp.2005.08.002.

Adan, Hassan, and Franz Fuerst. 2016. 'Do Energy Efficiency Measures Really Reduce Household Energy Consumption? A Difference-in-Difference Analysis'. *Energy Efficiency* 9: 1207–19.

Anderson, Ben, Thomas Rushby, and Michael Jack. 2018. 'Electrifying Heat: Patterns of Electricity Consumption in Electrically Heated Households in the UK and New Zealand'. In *8th International Conference on Energy and Environment of Residential Buildings*. Wellington, New Zealand. https://speakerdeck.com/dataknut/electrifying-heat-patterns-of-electricity-consumption-in-electrically-heated-households-in-the-uk-and-new-zealand.

Anderson, Ben, Tom Rushby, Abubakr Bahaj, and Patrick James. 2020. 'Ensuring Statistics Have Power: Guidance for Designing, Reporting and Acting on Electricity Demand Reduction and Behaviour Change Programs'. *Energy Research & Social Science* 59 (January): 101260. https://doi.org/10.1016/j.erss.2019.101260.

Andor, Mark A., and Katja M. Fels. 2018. 'Behavioral Economics and Energy Conservation – A Systematic Review of Non-Price Interventions and Their Causal Effects'. *Ecological Economics* 148 (June): 178–210. https://doi.org/10.1016/j.ecolecon.2018.01.018.

Artelle, Kyle, Janet Stephenson, Corey Bragg, Jessie Housty, William Housty, Merata Kawharu, and Nancy Turner. 2018. 'Values-Led Management: The Guidance of Place-Based Values in Environmental Relationships of the Past, Present, and Future'. *Ecology and Society* 23 (3).

Barnes, Joanna H., Tim J. Chatterton, and James W. S. Longhurst. 2019. 'Emissions vs Exposure: Increasing Injustice from Road Traffic-Related Air Pollution in the United Kingdom'. *Transportation Research Part D: Transport and Environment* 73 (August): 56–66. https://doi.org/10.1016/j.trd.2019.05.012.

Barr, Stewart. 2006. 'Environmental Action in the Home: Investigating the'value-Action'gap'. *Geography*, 43–54.

Chapman, Ralph, Philippa Howden-Chapman, H. Viggers, D. O'dea, and Martin Kennedy. 2009. 'Retrofitting Houses with Insulation: A Cost–Benefit Analysis of a Randomised Community Trial'. *Journal of Epidemiology & Community Health* 63 (4): 271–277.

Chapman, Ralph, Michael Keall, Philippa Howden-Chapman, Mark Grams, Karen Witten, Edward Randal, and Alistair Woodward. 2018. 'A Cost Benefit Analysis of an Active Travel Intervention with Health and Carbon Emission Reduction Benefits'. *International Journal of Environmental Research and Public Health* 15 (5): 962.

Chisholm, Elinor, Michael Keall, Julie Bennett, Anaru Marshall, Lucy Telfar-Barnard, Louise Thornley, and Philippa Howden-Chapman. 2019. 'Why Don't Owners Improve Their Homes? Results from a Survey Following a Housing Warrant-of-Fitness Assessment for Health and Safety'. *Australian and New Zealand Journal of Public Health*.

De Groot, Holger, and P. M. Leardini. 2010. 'Indoor Air Quality and Health in New Zealand's Traditional Homes'. In *Proceedings of the 44th Annual Conference of the*

Architectural Science Association, Unitec Institute of Technology, Auckland, New Zealand. Vol. 2426.

Dirks, Kim, Jennifer Salmond, and Nicholas Talbot. 2018. 'Air Pollution Exposure in Walking School Bus Routes: A New Zealand Case Study'. *International Journal of Environmental Research and Public Health* 15 (12): 2802.

Eggimann, Sven, Jim W. Hall, and Nick Eyre. 2019. 'A High-Resolution Spatio-Temporal Energy Demand Simulation to Explore the Potential of Heating Demand Side Management with Large-Scale Heat Pump Diffusion'. *Applied Energy* 236 (February): 997–1010. https://doi.org/10.1016/j.apenergy.2018.12.052.

Frederiks, Elisha R., Karen Stenner, and Elizabeth V. Hobman. 2015. 'Household Energy Use: Applying Behavioural Economics to Understand Consumer Decision-Making and Behaviour'. *Renewable and Sustainable Energy Reviews* 41 (January): 1385–1394. https://doi.org/10.1016/j.rser.2014.09.026.

Frederiks, Elisha R., Karen Stenner, Elizabeth V. Hobman, and Mark Fischle. 2016. 'Evaluating Energy Behavior Change Programs Using Randomized Controlled Trials: Best Practice Guidelines for Policymakers'. *Energy Research & Social Science* 22 (December): 147–64. https://doi.org/10.1016/j.erss.2016.08.020.

Huebner, Gesche M., Ian Hamilton, Zaid Chalabi, David Shipworth, and Tadj Oreszczyn. 2016. 'Explaining Domestic Energy Consumption - The Comparative Contribution of Building Factors, Socio-Demographics, Behaviours and Attitudes'. *Applied Energy* 159 (September): 692–702. https://doi.org/10.1016/j.apenergy.2016.04.075.

———. 2018. 'Comparison of Indoor Temperatures of Homes with Recommended Temperatures and Effects of Disability and Age: An Observational, Cross-Sectional Study'. *BMJ Open* 8 (5). https://doi.org/10.1136/bmjopen-2017-021085.

Huebner, Gesche M., Megan McMichael, David Shipworth, Michelle Shipworth, Mathieu Durand-Daubin, and Alex J. Summerfield. 2015. 'The Shape of Warmth: Temperature Profiles in Living Rooms'. *Building Research & Information* 43 (2): 185–196.

Lee, Sungwon, and Bumsoo Lee. 2014. 'The Influence of Urban Form on GHG Emissions in the U.S. Household Sector'. *Energy Policy* 68 (May): 534–49. https://doi.org/10.1016/j.enpol.2014.01.024.

Lomas, Kevin J., and Stephen M. Porritt. 2017. *Overheating in Buildings: Lessons from Research*. Taylor & Francis.

Longhi, Simonetta. 2015. 'Residential Energy Expenditures and the Relevance of Changes in Household Circumstances'. *Energy Economics* 49: 440–450.

Love, Jenny, Andrew Z. P. Smith, Stephen Watson, Eleni Oikonomou, Alex Summerfield, Colin Gleeson, Phillip Biddulph, et al. 2017. 'The Addition of Heat Pump Electricity Load Profiles to GB Electricity Demand: Evidence from a Heat Pump Field Trial'. *Applied Energy* 204 (October): 332–42. https://doi.org/10.1016/j.apenergy.2017.07.026.

Moira Nicolson. 2018. 'Using Behavioural Science to Increase Consumer Adoption of Time-of-Use Electricity Tariffs: Evidence from Survey and Field Experiments'. PhD Thesis, London.: University College London. https://www.researchgate.net/publication/324964229_Using_behavioural_science_to_increase_consumer_adoption_of_time-of-use_electricity_tariffs_evidence_from_survey_and_field_experiments.

Moore, Trivess, Ian Ridley, Yolande Strengers, Cecily Maller, and Ralph Horne. 2016. 'Dwelling Performance and Adaptive Summer Comfort in Low-Income Australian

Households'. *Building Research & Information* 0 (0): 1–14. https://doi.org/10.1080/09613218.2016.1139906.

Mylona, Anastasia, and Mike Davies. 2015. *BSER&T Special Issue: Overheating and Indoor Air Quality*. Sage Publications Sage UK: London, England.

Nicolson, Moira L., and Beth Moon. 2019. 'Applying Behavioural Insights to Forward Looking Charging Reform: Results from a Literature Review by Ofgem's Behavioural Insights Unit'. https://www.ofgem.gov.uk/system/files/docs/2019/12/behavioural_insights_and_forward_looking_charging_report.pdf.

Ofgem. 2019. 'Access and Forward-Looking Charges Significant Code Review – Winter 2019 Working Paper: Small Users – Discussion Note'. Ofgem. https://www.ofgem.gov.uk/system/files/docs/2019/12/winter_2019_-_working_paper_-_small_users_note_publish.pdf.

Schieweck, Alexandra, Erik Uhde, Tunga Salthammer, Lea C. Salthammer, Lidia Morawska, Mandana Mazaheri, and Prashant Kumar. 2018. 'Smart Homes and the Control of Indoor Air Quality'. *Renewable and Sustainable Energy Reviews* 94: 705–718. https://doi.org/10.1016/j.rser.2018.05.057.

Sherriff, Graeme, Trivess Moore, Stephen Berry, Aimee Ambrose, Barry Goodchild, and Angela Maye-Banbury. 2019. 'Coping with Extremes, Creating Comfort: User Experiences of "Low-Energy" Homes in Australia'. *Energy Research & Social Science* 51 (May): 44–54. https://doi.org/10.1016/j.erss.2018.12.008.

Shove, Elizabeth. 2010. 'Beyond the ABC: Climate Change Policy and Theories of Social Change'. *Environment and Planning. A* 42 (6): 1273.

Srivastava, Aman, Steven Van Passel, and Erik Laes. 2018. 'Assessing the Success of Electricity Demand Response Programs: A Meta-Analysis'. *Energy Research & Social Science* 40 (June): 110–17. https://doi.org/10.1016/j.erss.2017.12.005.

Stephenson, Janet, Barry Barton, Gerry Carrington, Adam Doering, Rebecca Ford, Debbie Hopkins, Rob Lawson, Alaric McCarthy, David Rees, and Michelle Scott. 2015. 'The Energy Cultures Framework: Exploring the Role of Norms, Practices and Material Culture in Shaping Energy Behaviour in New Zealand'. *Energy Research & Social Science* 7: 117–123. https://doi.org/j.erss.2015.03.005.

Telfar-Barnard, Lucy, Julie Bennett, Andrew Robinson, Albert Hailes, Jenny Ombler, and Philippa Howden-Chapman. 2019. 'Evidence Base for a Housing Warrant of Fitness'. *SAGE Open Medicine* 7: 2050312119843028.

Vet, Eliza de, and Lesley Head. 2019. 'Everyday Weather-Ways: Negotiating the Temporalities of Home and Work in Melbourne, Australia'. *Geoforum*, September. https://doi.org/10.1016/j.geoforum.2019.08.022.

White, Lee V., and Nicole D. Sintov. 2019. 'Health and Financial Impacts of Demand-Side Response Measures Differ across Sociodemographic Groups'. *Nature Energy*, December, 1–11. https://doi.org/10.1038/s41560-019-0507-y.