



# IVUGER Report

## Domestic Air Conditioning in 2050

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## **Introduction to the Whole Systems Networking Fund**

Funded by EPSRC the Whole Systems Networking Fund aimed to improve equality, communications and collaboration between those working in the field of whole systems energy.

Administered by the UK Energy Research Centre between the years of 2016 and 2019, the fund aimed to develop best practice around networking, foster better representation of UK capacity in whole systems energy research, encourage fresh voices and build new working relationships within the community.

## **Introduction to the IVUGER project**

The aim of the IVUGER (Increasing Visibility of Underrepresented Groups in Energy Research) project was to increase participation and visibility of underrepresented groups within the energy sector. It specifically targeting female researchers, and worked to develop a strong Black, Asian and Minority Ethnic (BAME) presence. The project worked to create a network of unique and innovative women, providing space and resources for women to establish long-term, meaningful collaborations.

The funds from the project were spent on three distinct events, and four competitive bursaries for researcher exchanges.

1. A networking event including a speed networking activity, talks from individuals experienced in collaboration and funding success, and an afternoon training event on assertiveness, persuasive communication and negotiation.
2. A two-day intensive writing retreat, to produce collaborative grant applications, academic publications, policy briefs and/or technical papers. A facilitator helped identify common areas of overlap, with specific time focused on creating work.
3. A follow up day, for participants to tie-up and submit outputs. Participants presented work and undertook further networking.



# Background

The latest projections from the Met Office show that the UK annual average temperature is set to increase by 0.7-3 degrees from the 1981-2000 to the 2041-60 period (Met Office, 2019). Alongside average increases, summer temperatures will rise, as well as the frequency of heatwaves. The Met Office estimate that the extreme hot summer experienced in 2018 would be less than 0.5% likely with no manmade climate change, is 12% probable currently, and will be 50% likely by 2050 (Met Office, 2018). This raises the question of the likely uptake of domestic air conditioning.

## Previous cooling scenarios and assumptions

Little data exists for the UK quantifying the relationship between air conditioning (AC) uptake and its predictors. National Grid (2019) assumed a 60% penetration by 2050 (based on all homes in urban areas installing air conditioning). The Tyndall Centre (2016) constructed projections for 2030 using various scenarios. One was based on the current growth of the market (1.6% by 2030), one was based on growth as seen in other countries (2.9% by 2030), and two were based on simple DECC scenarios (33% and 67% by 2051). Finally, Peacock et al (2010) used the relationship between uptake and cooling degree days observed in America to predict 18% uptake in London by 2030, caveating this finding due to behavioural differences between the U.S. and England.

## Aims of this project

- To construct a set of socio-technical scenarios for 2050 AC penetration.
- To provide a first estimate of grid impacts based on temporal characteristics of air conditioning use.
- To identify the data gaps and areas for future collaboration.

## Scenario construction

The aim was to produce a small number of scenarios using a limited set of social and technical variables which are known from the literature to be important predictors of air conditioning uptake. In an ideal world, an uptake model from now to 2050 would have been constructed but the data for this were not available, hence using a scenario approach. We focus on England to narrow the scope.

Building simulation was carried out using UCL's HPRU model to explore some physical variables: geographical location, building age and dwelling type. Literature and other theory was used to examine the effect of other variables: heat stress, children, income, tenure, urban heat island.

## Four scenarios

Four narratives were constructed as follows:

1. Building-based scenario: homes built between 1990 and 2025 overheat more than others and all occupants install air conditioning. After 2025, the Future Homes standard for new buildings kicks in and overheating is significantly mitigated.
2. Age demographic (1): all households where the Household Reference Person is aged 75 or over install air conditioning. This takes place across the socio-economic and tenure spectrum, perhaps as a result of a policy equivalent to the Winter Fuel Discount which only considers age.
3. Age demographic (2): all owner-occupied dwellings with at least one dependent child install air conditioning.
4. Wealth demographic scenario: all owner-occupied dwellings with income above the median install air conditioning.

Since climate is known to be an important factor (Yun & Steemers, 2011), each of the above four scenarios had two implementations: one for all dwellings in the category, and one confined to urban environments in the south of England. 'Urban' was defined as the three 'predominantly urban' categories of conurbation defined by DEFRA (2011).

## Summary of scenario results

- The range of air conditioning penetration from the above scenarios was 5-32% of English households
- This is obviously a very simplistic treatment of uptake which uses crude and simple categories and some combinations of categories. In reality, within a given category, not 'all' the population of that category would adopt air conditioning.
- All of the scenarios resulted in less than a third of households adopting AC. This is much lower than National Grid's prediction of 60%.
- They have been constructed so that the location/weather variable (the south/urban flag) makes a big difference (5-12% of households if the flag is applied, 19-32% if it is not). The size of this difference in reality is currently unknown in England.

# Building modelling

In order to estimate the grid impacts of the above scenarios, the half hourly AC power consumption on a hot day was estimated for two of the most common building types in the UK. Therefore, a one-storey semi-detached house and a three-storey block of flats was modelled using Autodesk Revit. Both dwelling types were modelled using current standard construction.

## Method

It was intended to carry out building simulation using 2050 climate projections, however the free Prometheus files available displayed erroneously cooler weather than currently so were regarded as not compatible with the latest Met Office predictions (Met Office, 2019b). Therefore, current weather files for London Heathrow were generated using Meteonorm data. Design builder software was then used to carry out half hourly dynamic thermal simulations of the 2 buildings using the weather files.

**Key features of the building modelling are summarised here:**

- Timings of air conditioning use were based on the best available data: the UK-based empirical study by Pathan et al (2008) and some additional building simulation showing the time of the warmest internal temperatures to be 2-6pm
- Windows were assumed to be closed at night, in accordance with Mavrogianni et al (2017) who showed that this was the case in a proportion of London homes for reasons of noise and security
- Internal temperature above which AC was switched on was also based on Pathan et al (2008) as 25°C for living rooms during the day/evening and 20°C for bedrooms at night.

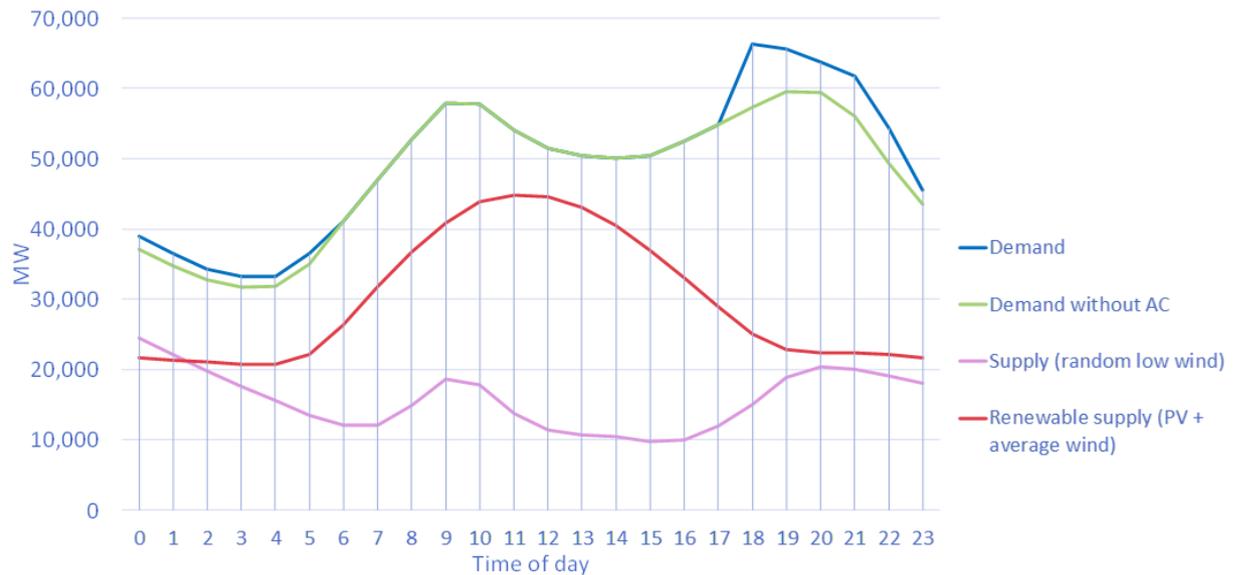
# Electricity system modelling

## Method

- The AC loads derived in the previous section were simply multiplied by the uptake scenarios above to give a total AC load. A COP of 3 was used to convert kW(th) to kW(elec)
- National Grid's 'Two Degrees' scenario (National Grid, 2019) was used to predict the other demands on the grid, as well as the solar and typical wind power. The other grid demands included significant EV charging.

- AC load was then added to the other grid demands to investigate the potential effect of air conditioning.

## Results



Our highest (i.e. worst case) scenario increases the evening peak by 7 GW. In this scenario the reason for the peak increase is the pre-existence of an evening EV charging peak coincidental with AC demand. AC is not coincidental with solar PV generation.

This is based on scenario modelling and not absolute truth, therefore the best interpretation of the results is perhaps to explore the issues and questions it raises:

- If EV charging and AC are coincidental, does this present a problem for the electricity system? If so, which demand should take priority and which should be shifted?
- How can renewable generation be reconciled with AC demand which occurs hours later?
- What is the effect of AC demand diversity on the results?

# Project summary

- Domestic cooling is an energy demand meriting more investigation.
- If air conditioning is used as we assume in our scenarios, summer peak will increase and demand will not coincide with optimum renewable generation.
- Key gaps in the evidence base were found to include:

*What motivates English households to install air conditioning? What time of day or night is air conditioning really used? How many rooms will air conditioning be installed in per home? How coincident is the AC demand across UK households?*

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