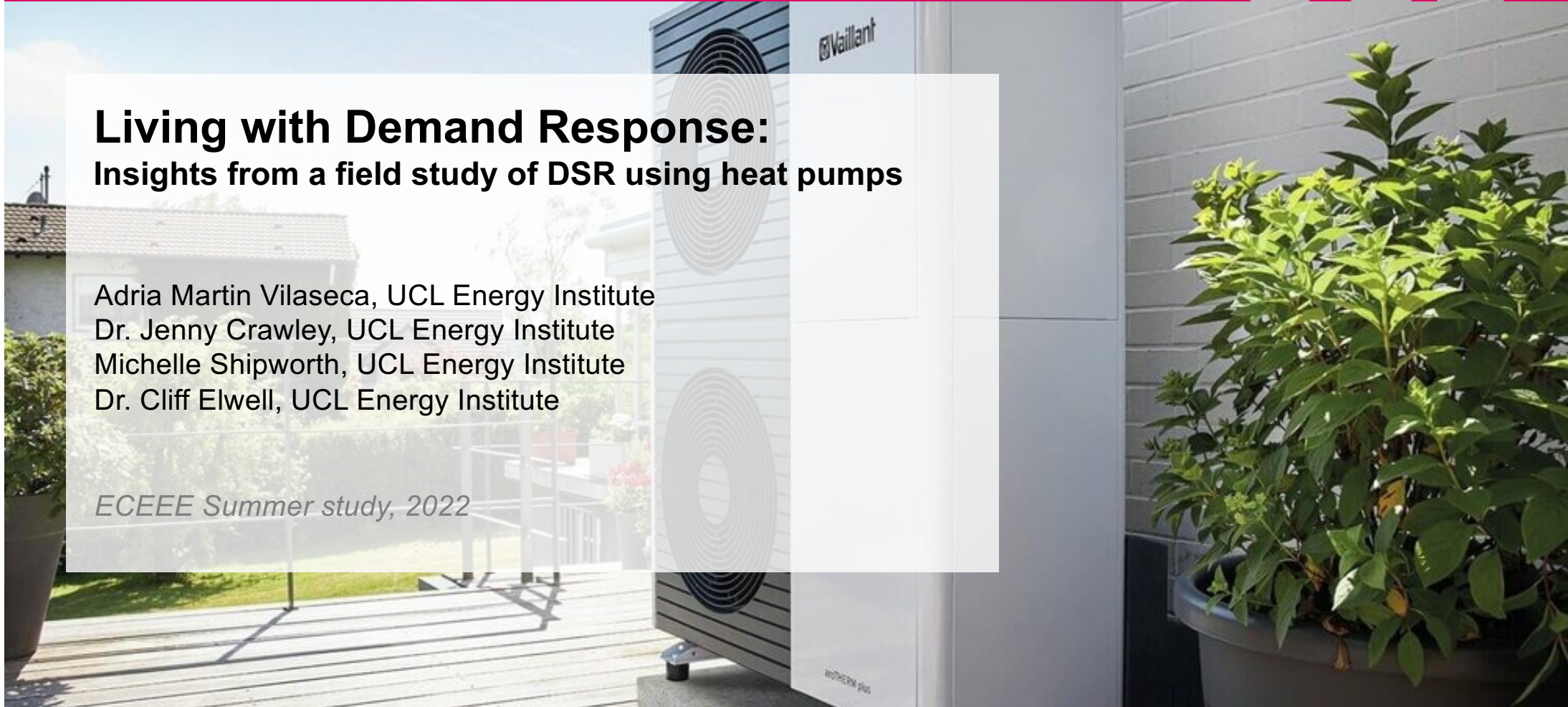


Living with Demand Response: Insights from a field study of DSR using heat pumps

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Background:

1 The electrification of energy services can create some challenges for the electricity grid

Increase the total electricity demand (IEA, 2020), exacerbate the existing electricity peaks (Love *et al.*, 2017) and difficulties to modulate the production of electricity to follow demand (IEA, 2020).

2 Demand-Side response can help to overcome some of these challenges

DSR is defined as "changes in the electricity usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time" (Albadi & El-Saadany, 2008: p1990).

3 Buildings can provide DSR by storing energy when there is excess supply or releasing it during times of limited supply.

The energy can be stored in the thermal mass of the building or in individual units (e.g., hot water tank).

3 Heat pumps can play a key role in DSR in buildings



Background:

- 1 Demand response with heat pumps has been widely studied using models but little empirical work has been done.**
- 2 Models and some commercial offerings rely on a limited set of assumptions:**
 - A Limited understanding of thermal comfort, often represented as a temperature band.**

A certain comfort temperature and the operative temperature is allowed to deviate from this within certain bandwidths before being classed as uncomfortable (usually 2 degrees Celsius).
 - B Passive role of occupants: recipients of certain indoor conditions.**
- 3 “Energy is used, not for its own sake, but as part of and in the course of accomplishing social practices” (Shove and Walker, 2014:p42)**



Research project

Three case study homes with heat pumps attempted to reduce their heat pump power consumption between **4pm and 7pm** (PEAK SHAVING).

- ① Analyse the changes in the material dimensions of comfort practices during DSR, focusing on indoor conditions during the peak period.
- ② Explore the know-how associated with comfort practices during DSR.
- ③ Explore the meanings associated with comfort practices during DSR.



Research project

Mixed-methods: Semi-structured interviews and technical monitoring of indoor conditions and heat pump operation

Social data

- Two interviews with each household (both adults in the household).

Technical data

- Air temperature (5 rooms)
- External temperature
- Radiant temperature (1 room)
- Radiator surface temperature (1 room)
- Internal surface temperature of external wall (1 room)
- Heat pump electrical power
- Heat pump flow temperature



Cases studied

	House A	House B	House C
House type	End terrace	Detached	End terrace
House age	1905	2011	1936
EPC rate before HP	D	B	D
Floor area	231 m ²	153 m ²	136 m ²
Thermal mass	High (30 cm solid walls)	Medium (cavity insulated walls)	High (23 cm solid walls)
Location	South West England	East England	South East England
Other building information	Uninsulated walls, insulated loft and ground floor. Some work done to improve airtightness	Well insulated	Uninsulated walls and floors, insulated loft. Some work done to improve airtightness.
New radiators?	No – existing radiators large	Yes	Some radiators replaced with fan assisted rads
Heat pump	Ground source heat pump. 15kW thermal	Air source heat pump. 8kW thermal	Ground source heat pump. 11kW thermal



Materials

The operation of the heat pump

Three different control strategies and three DSR provided

A Reduced temperature setpoint to 15°C

Semi-direct load control

The heat pump operates for brief periods, mainly on colder days

B Blocked the compressor

Direct load control

No heat delivered, only parasitic loads

C Reduced the flow temperature setpoint

Direct load control

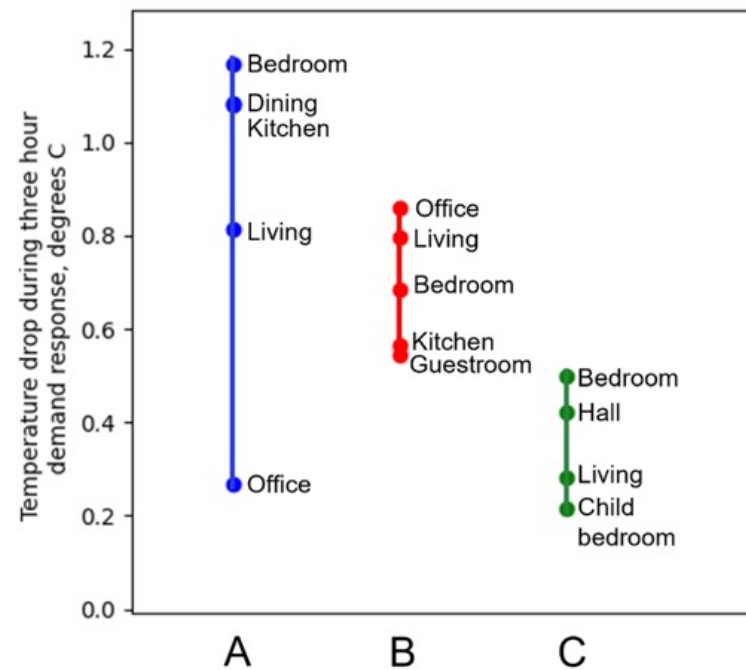
Heat pump on for the whole period but reduced heating output



Materials

The indoor conditions from 4pm to 7pm


Three different comfort practices and three different indoor conditions



**A. Noticed but
tolerated with
adaptation**

B. Not noticed

**C. Not tolerated:
reduced DSR**



"I think that it definitely gets cooler in here but for me it's acceptable for those 3 hours. Because it's 3 hours and we are busy doing stuff anyway... I just add a layer during that time. And that I'm fine with. For all of the benefits of turning it off, I can take the small disadvantage of having it cool down during that period."

Competences

Understanding and monitoring heat flows

How do people perceive demand side response with heat pumps?

1 Thermoception

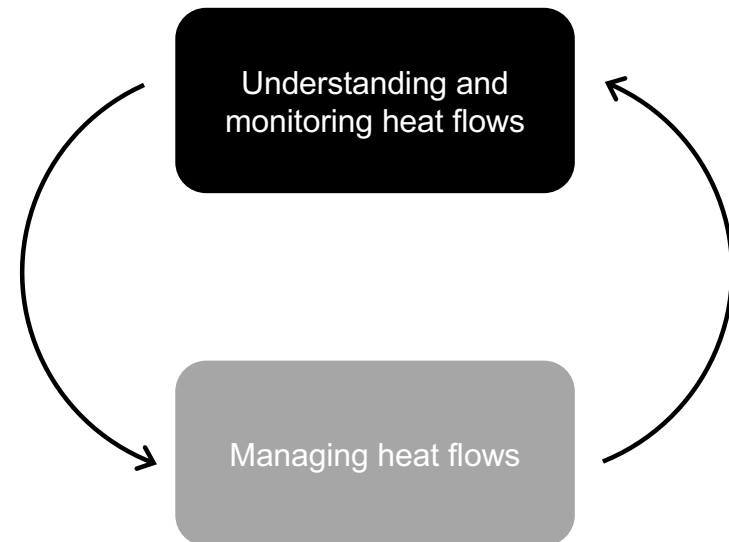
Temperature perception through the skin: changes in the air temperature, and surface temperature.

2 Hearing

Water flowing through the radiators or TRVs opening or closing.

3 Visually

Smart displays on the heat pump/heating system.



Competences

Managing heat flows

How do people manage heat to achieve what they want during DSR?

1 Changes in clothing used

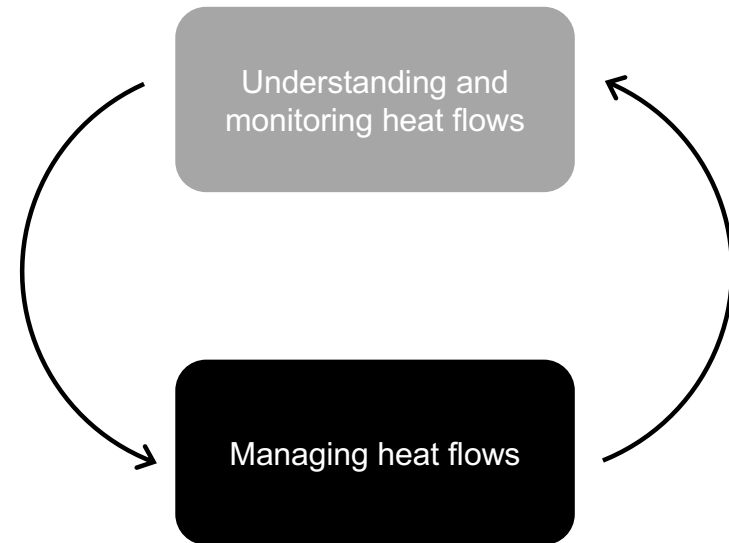
E.g., Wearing an outdoor jacket indoors during DSR.

2 Moving to warmer spaces

When the requirements of their routines made that possible.

3 Changes in the operation of the heat pump

The heat pump settings during DSR evolved during the trial through a process of household negotiation.



Meanings

Meanings associated with DSR

The way how DSR is perceived is influenced by several reasons

① Thermal expectations + Mentally prepare for DSR.

Thermal history, activities at home and spaces.

② Concerns for the environment

Which not only affected DSR but also the decision to adopt and the way how the heat pump is used.

③ Saving money

④ Feeling in control of the system



Conclusions

Implications for Demand Response with heat pumps

- The potential of DSR has been widely assessed in modelling studies but their findings rely on simplified assumptions that might not be accurate in some cases.
 - People can notice small temperature changes in some cases and steady-state models of thermal comfort might not be enough to explain people's experience of DSR.
 - Indoor conditions during DSR vary within the houses.
 - People might be able to adapt to new indoor conditions but this varies between cases.
- Householders are active in the creation of the thermal environments and in the provision of DSR
 - Monitoring heat flows through thermoception but also through touch, hearing and vision.
 - Managing heat flows through changes in clothing, changes in the spaces used or changes in the settings of the heat pump.
 - Attaching new meanings to DSR and changing their expectations and negotiating them with the other occupants.
- For some participants, DSR will always be “visible”. Offering more active roles for participants in DSR might be more acceptable for them and might make DSR more successful.



Thank you very much!

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