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Managing the future network impact of electrification of heat

FINAL report for ENWL

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Executive summary (1/7)
Key messages

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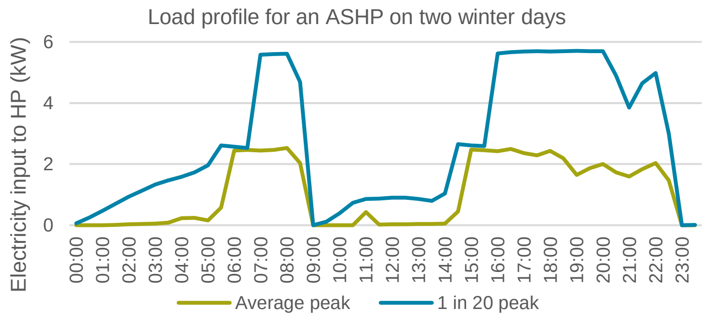
1. Electrification of heat using heat pumps will **increase winter electricity demand by around 2.5 kW – 5.5 kW per household**. For this project, a building physics model was used to generate half-hourly load profiles for different types of heat pumps in different house types at different outside temperatures.



2. Granular analysis of the types of heat pumps likely in Electricity North West's region suggests **additional peak loads of ~250 MW up to 3.5 GW by 2050**. If a significant proportion of heat demand is met by electricity, it will become important to plan network capacity for a '1 in 20' winter peak* (as currently done by gas), instead of for an 'average' winter peak (as is currently the case for electricity distribution). Diversity amongst heat pump operation will be low: based on a limited available evidence base, we estimate only 10-15% diversity in an 'average' winter peak, lower in a '1 in 20' winter.

Scenario	Share of homes with a heat pump	Additional network load on an 'average' winter peak	Additional network load on a '1 in 20' winter peak
Low	~5%	200 – 300 MW	400 – 500 MW
Reference	~20%	800 – 900 MW	1,400 – 1,500 MW
High	~50%	~2,500 MW	~3,500 MW

3. 'National' electricity system players may influence heat pump load profiles, so their operation depends on short-term electricity price. Imperial College modelled the national system, including analysis of potential flexibility of heat pump operation. This showed at times of low electricity prices, **flexibility could increase peak loads by 5 – 15% on 'average' peak winter days, and as high as ~25% on a '1 in 20' peak winter day**.

4. Using the detailed heat pump load profiles and scenario uptakes, EA Technology's Transform Model** forecasts **£150 million to £3.3 billion of required investment** in capacity on the Electricity North West LV network across our three scenarios, if the network is planned for a '1 in 20' winter peak. This corresponds to an additional 2,000 – 21,500 network interventions by 2050.

Network investment of £100s millions to £ billions by 2050

5. Electricity North West is unlikely to have much control over the uptake of heat pumps and their operation, but a number of customer-side measures could reduce the increases in peak load from the electrification of heat. **These could significantly reduce the additional network investment requirements**, but may be very expensive to introduce. For example, under the high scenario, improving the insulation levels of all dwellings installing a heat pump could reduce network investment costs to 2050 by ~£600 million (costing around £570 million to implement).

6. Policy / regulations may result in some of these measures being introduced without Electricity North West's intervention, and for others, **additional value (e.g. via demand response) could be captured by other energy system stakeholders so some of the costs of introducing these measures could be shared**. A full cost benefit analysis will be required to account for implementation costs.

7. The analysis in this report shows that **there may be tensions between customer-side measures which support the national generation and distribution system, and those that support the local distribution network**. It will therefore be **important that decisions consider both scales of network**, and that the wider economic impact is assessed.

** Outside temperatures are typically well below zero degrees C, all day, during a '1 in 20' winter peak day*

*** See Annex C of this report for a brief description of the Transform Model*

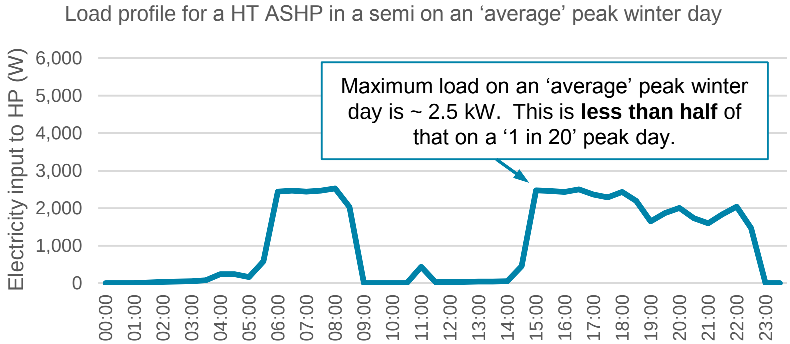
Executive summary (2/7)
Electrification of heat could increase peak load on ENWL's network by 3.5 GW

Heat pump uptake in ENWL's region by 2050 could add 0.25 – 3.5 GW of new load at peak times

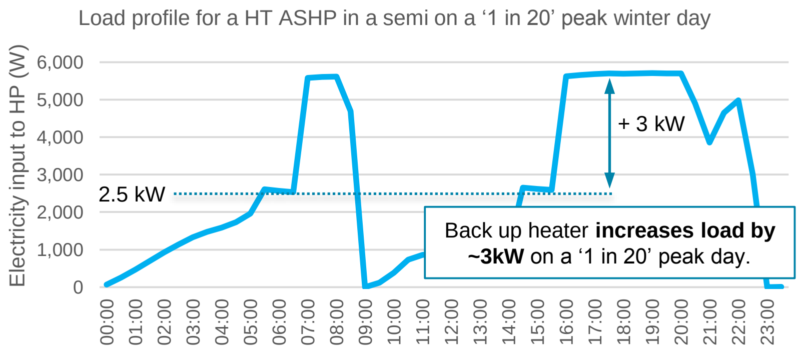
- Electrification of heat is a key pillar of the UK's strategy for decarbonising residential heating – with heat pumps being a key solution for delivering this.
- Three different uptake scenarios for heat pumps have been assessed, ranging from a low scenario (where around 6% of all homes in ENWL's region will have a heat pump by 2050) to a high scenario (where 50% of all homes will have a heat pump by 2050).
- Based on the forecasted uptake of different types of heat pumps in ENWL's region, the additional load from all heat pumps on ENWL's network in 2050 will peak at 0.25 GW – 3.5 GW (depending on the outside temperature, the mix of heat pumps being installed and the heat pump uptake rate).

Load profile* for an ASHP in a semi-detached dwelling

'Average' peak



'1 in 20' peak



At the household level, heat pumps can increase load by 2.5 – 5.5 kW

- On an 'average' peak winter day, the heat pump part of an ASHP meets all the heating needs of a dwelling and adds up to 2.5 kW of load per dwelling.
- Due to colder temperatures on a '1 in 20' peak winter day, the heat pump part of an ASHP is supplemented by a back up electric heater. This results in a much higher load of up to 5.5 kW per dwelling. Assuming an existing peak load of 1.5 kW per house, ASHPs will increase demand at peak times by ~2 – 4 times.
- This load increase from ASHPs varies depending on the house type considered, and varies more significantly in dwellings with a hybrid heat pump (as discussed on the next slide).

Overall impact of heat pump uptake on additional electricity load on ENWL's network by 2050

	Low scenario	Reference scenario	High scenario
'Average' peak	+0.25 GW	+0.85 GW	+2.5 GW
'1 in 20' peak	+0.45 GW	+1.5 GW	+3.5 GW

** The heat pump load profiles illustrated on this slide, and throughout the report, are for a week day.*

HT ASHP = Higher temperature ASHP

Executive summary (3/7)
Heat pump load profiles will vary widely across the network

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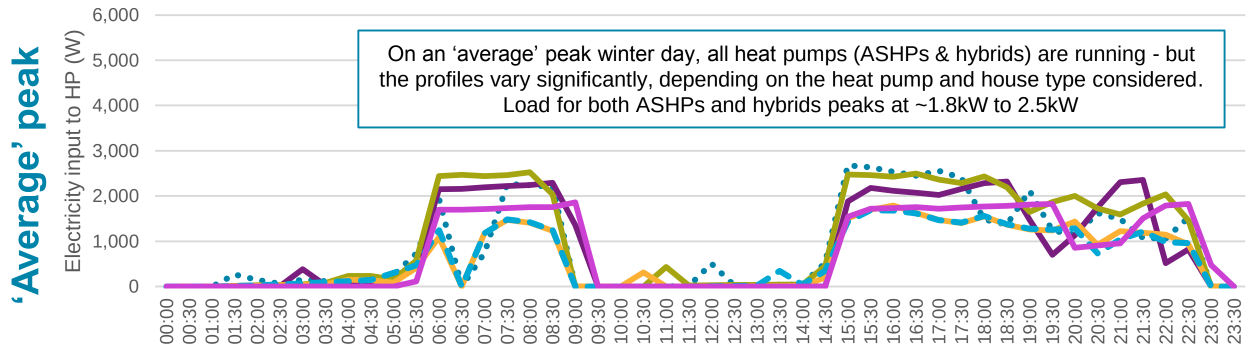
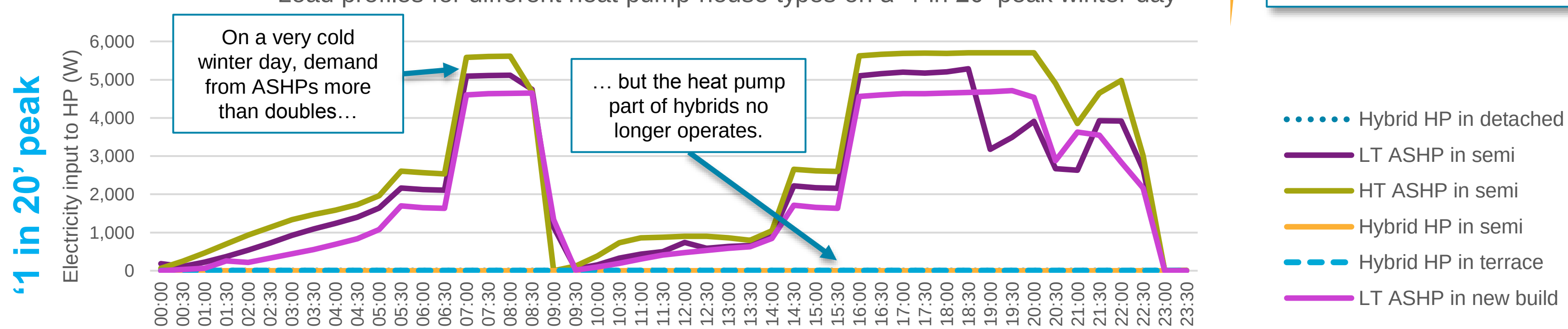
Understanding the uncertainty & variations in heat pump load profiles will be important for ENWL when preparing its network

- The additional peak load heat pumps add per dwelling varies significantly depending on: the house type the heat pump is installed in; the type of heat pump installed; the control strategy of the heat pump; and the outside air temperature (as illustrated below).
- On ‘average’ peak winter days, the maximum load from ASHPs in semi detached dwellings ranges from ~1.8kW in a new build dwelling to ~2.5kW in an older dwelling. This load more than doubles on ‘1 in 20’ peak days. Hybrid heat pumps offer the potential to reduce load on ‘1 in 20’ peak days through switching to ‘boiler only’ mode (using gas for heating, rather than electricity). This however requires controls in hybrids to be configured to enable this, and price signals to be provided to drive this mode of operation.
- Depending on the uptake of these different heat pumps & the clustering of uptake on certain areas of ENWL’s network, understanding these variations will be critical for influencing heat pump operation & managing investments in its network.

Load profiles for different heat pump-house types on an ‘average’ peak winter day



Load profiles for different heat pump-house types on a ‘1 in 20’ peak winter day



There is not one standard heat pump load profile

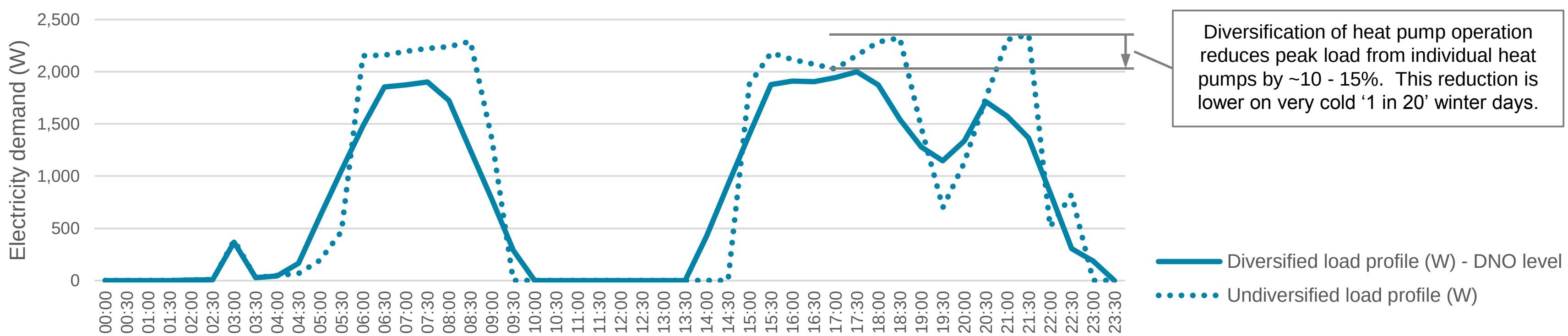
- For this study, we developed load profiles for 6 combinations of different types of heat pumps in different types of dwellings.
- As illustrated on the left, on an ‘average’ peak winter day, these profiles vary significantly in terms of the maximum electricity demand and the timing of the peak demand.
- This variation is even more significant on a ‘1 in 20’ peak winter day.

Diversification is unlikely to provide much mitigation to peak load increases

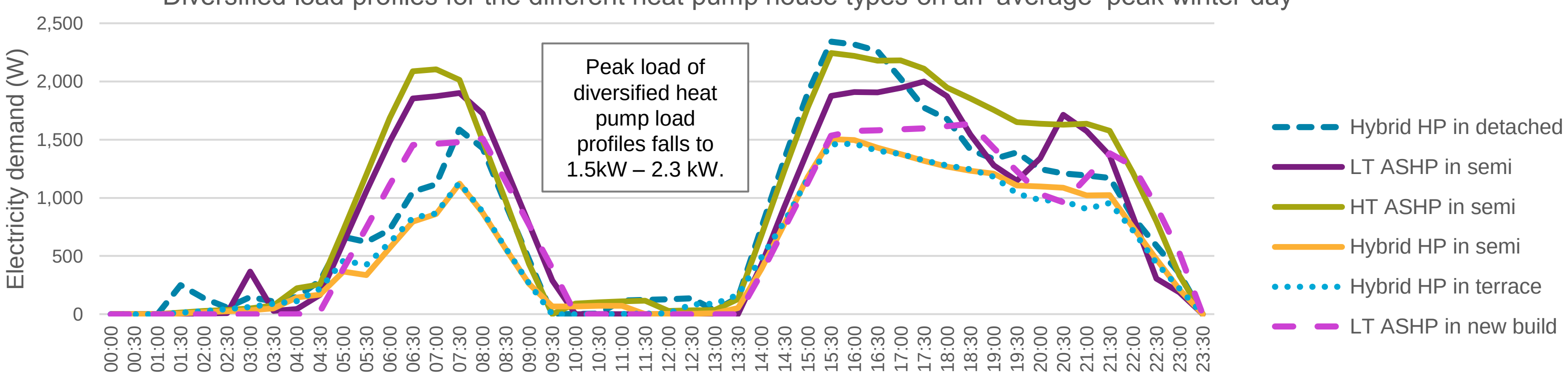
Diversification will reduce loads slightly, but unlikely to provide much mitigation

- Existing electricity demands (of household appliances) are highly diversified, due to a wide range of loads being incurred by different customers with different demand profiles. But for heating, there is much less diversity in operation of heating systems and the timing of when heat is needed.
- Diversification of operation of a single type of ASHP at the LV feeder level ('DNO level'), on an 'average' peak winter day, results in a small reduction in peak load of about 10 - 15%, with peak load falling from 2.3kW to 2kW. Across the six heat pump – house types considered in this study, diversification of heat pump operation reduces peak demand (per household) from ~1.8 – 2.5 kW to 1.5 kW - 2.3 kW on an average winter day.
- This will result potentially result in additional peak load from heat pumps falling by 10 – 15% on an 'average' peak day due to the diversified operation of heat pumps. This reduction is even lower on a '1 in 20' peak winter day, when outside temperatures are lower and households are likely to be running their heating systems for longer.

Undiversified vs diversified (@ DNO level) load profiles for a LT ASHP in a semi on an 'average' peak winter day



Diversified load profiles for the different heat pump house types on an 'average' peak winter day

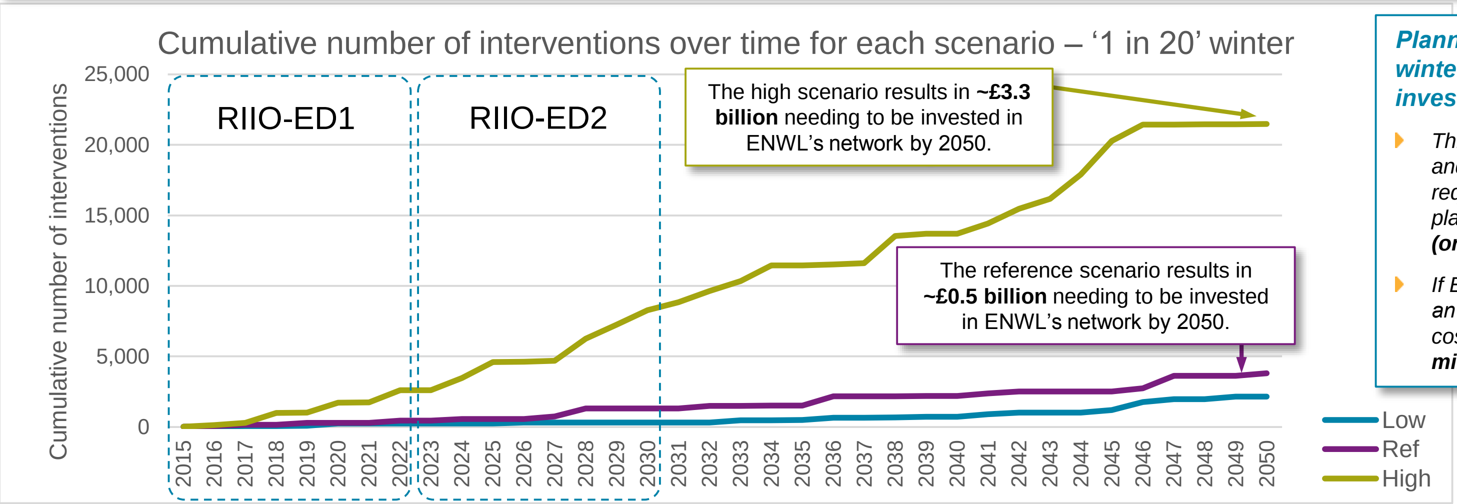


** At the 'DNO level', we diversified the operation of heat pump for a population of ~50 customers.*

Executive summary (5/7)
The impact on network reinforcement could be £100 millions to £ billions by 2050

Increases in peak load will require significant network reinforcement

- Based on the new heat pump load profiles developed, and using different uptake rates for heat pumps to 2050 in EA Technology's Transform v5.0 model, LV network reinforcement costs by 2050 are estimated at between £150million (under the low scenario) to £3.3 billion (under the high scenario), if ENWL plans its network for a '1 in 20' winter peak. The reference scenario investment costs, assuming around 20% of homes in 2050 have a heat pump, is around £340 million.
- These costs are incurred by varying numbers and types of network interventions being required under the different scenarios. Around 2,000 interventions are required by 2050 under the low scenario, growing to 21,500 under the high scenario (which also assumes high uptake rates for other low carbon technologies). The reference scenario estimate is around 4,000 interventions (which also assumes modest uptake rates for others low carbon technologies).
Based on ENWL's current allowance of 200 interventions per year, the high scenario represents up to 3 times the current average annual interventions.
- In the low scenario, most investment is required in the 2040s, but in the reference and high scenarios, significant investment starts in the 2020s (during RIIO ED2). Across all three scenarios, most interventions and investment is required on LV infrastructure in suburban streets.



Planning for an 'average' winter peak reduces network investment costs slightly

- *This slide illustrates the costs and volume of interventions required by 2050 if ENWL plans its network for a **'1 in 20' (or extreme) winter peak.***
- *If ENWL plans the network for an 'average' peak, investment costs by 2050 range from **~£25 million up to £2.6 billion.***

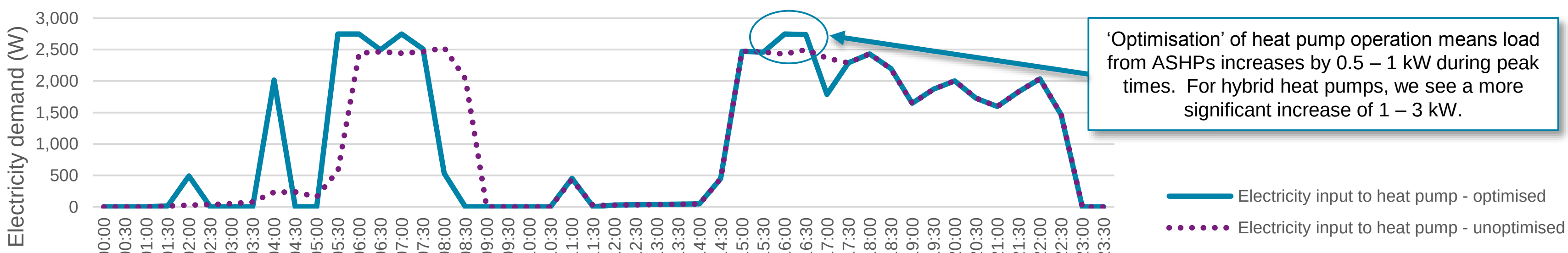
Intervention required if network is planned for a '1 in 20' winter peak	Low	Reference	High
Cumulative number of network 'interventions' by 2050 per scenario	**2,145**	**3,808**	**21,482**
LV transformer upgrades (ground mounted & pole mounted)	*1,346*	*1,754*	*6,607*
LV underground works (major & minor)	*799*	*2,054*	*14,865*
Other	*0*	*0*	*10*
Total investment required for upgrading the LV network (£)	**150 million**	**340 million**	**3.3 billion**

Executive summary (6/7)
Impact on the network may be increased if heat pump operation is 'optimised'*

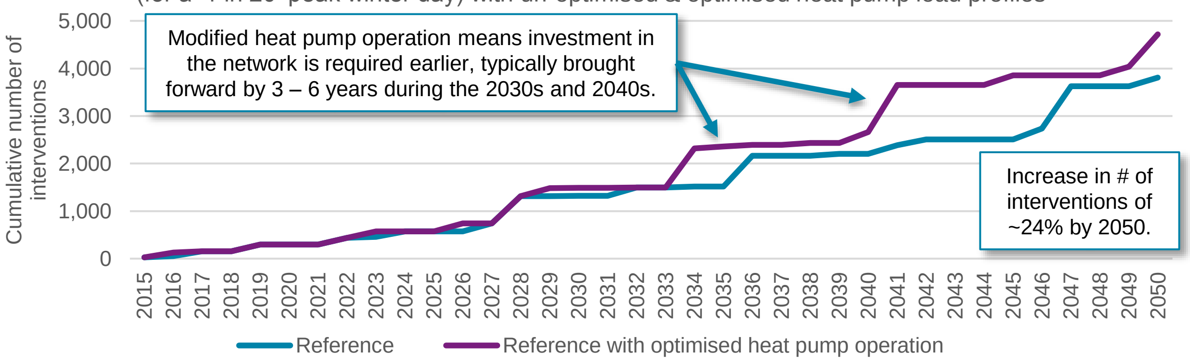
Influencing heat pump operation to maximise consumption of low cost renewable electricity could worsen network impacts for DNOs

- Installation of thermal storage & improved insulation of dwellings could allow heat pump operation to be shifted to earlier or later in the day. If this flexibility in heat pump operation is used to maximise consumption of lower cost renewable electricity, we could see even more heat pump load being shifted to peak times, if this coincides with a spike in renewable output.
- On 'average' peak winter days, 'optimisation' of heat pump load profiles by Imperial College suggests that load from ASHPs could be increased at peak times by up to ~1 kW, and for hybrid heat pumps by up to 2 kW. This increases overall heat pump load on the network at peak times **by 5 – 15%.** On '1 in 20' peak winter days, we see no increase in the load of ASHPs at peak times, but load from hybrids at peak times can increase by 3kW, which increases overall heat pump load on the network at peak times **by ~25%.**
- Under our reference scenario for heat pump uptake, 'optimisation' of heat pump load profiles increases the **number of network interventions required by 2050 by ~25 – 70%, and the associated investment costs increase by ~£100 - 200 million**. For an 'average' peak day, we see ~70% more interventions being required with investment costs increasing by £190 million, while on the '1 in 20' peak day the number of interventions increase by 24%, with costs increasing by ~£110 million.

Un-optimised & optimised load profile for HT ASHP in semi on an 'average' winter day



Cumulative number of network interventions required under the reference scenario (for a '1 in 20' peak winter day) with un-optimised & optimised heat pump load profiles



Impact of 'optimised' heat pump operation on ENWL's network during a '1 in 20' winter peak

Overall increase in number of interventions by 2050:

24 %

Overall impact on investment required by 2050:

£ 110 million

** optimised: for this part of the analysis, heat pump operation has been modified to maximise (or 'optimise') the use lower cost electricity within the UK wide energy system.*

Executive summary (7/7)
Customer side measures could reduce network reinforcement costs by up to 95%

Whilst DNOs do not have control over heat pump uptake, DNOs may be able to take customer orientated measures to mitigate the impact of peak loads

- ENWL could work with customers to reduce peak loads from heating through measures such as reducing heating demands with efficiency improvements, incentivising installation of more efficient heat pumps, or different control and storage strategies, or using distribution pricing structures to limit adverse impacts from other parties (such as suppliers).
- There are also wider measures outside of heating which could be used including the appropriate use of distributed generation, electric vehicle storage, reductions in demand across other electricity uses, demands side response across other electricity uses, and use of community energy schemes.
- The avoided costs of these measures (aimed at heating only) for the reference scenario could be up to £200 – 300 million. Under the high scenario, the avoided costs could be more than £3 billion by 2050.
- There will be additional costs for the implementation of the measures which could exceed the intervention savings. Some of these may be borne by ENWL where measures are directly implemented by ENWL, as part of other support mechanisms such as national programmes. It will be important for ENWL to coordinate activities with any external programmes to ensure there are no unintended consequences.

Avoided network interventions costs (£ millions) by 2050 from implementing different customer side measures under the high scenario, if ENWL plans its network for a '1 in 20' winter peak.

Customer side measures applied under the high scenario	2022	2030	2050
	Avoided network investment costs by 2050 (£ millions)		
Customer measure A1: increasing the level of insulation of all dwellings	95	302	595
Customer measure B1: installing higher capacity heat pumps (only for LT & HT ASHP)	175	301	2,358
Customer measure B3: installing higher efficiency heat pumps (for all HP house types)	98	285	-72
Customer measure C1: incentivise hybrid uptake rather than ASHP uptake	285	940	3,148
Customer measure C2: micro CHP installed alongside heat pumps	95	294	379
Customer measure D1: shifting HP operation with control strategies	285	940	3,170
Customer measure D2: battery storage installed alongside heat pumps	285	940	3,170