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Registered Office: Floor F, Argyle House, 3 Lady Lawson Street, Edinburgh, EH3 9DR

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Managing the future network impact of electrification of heat

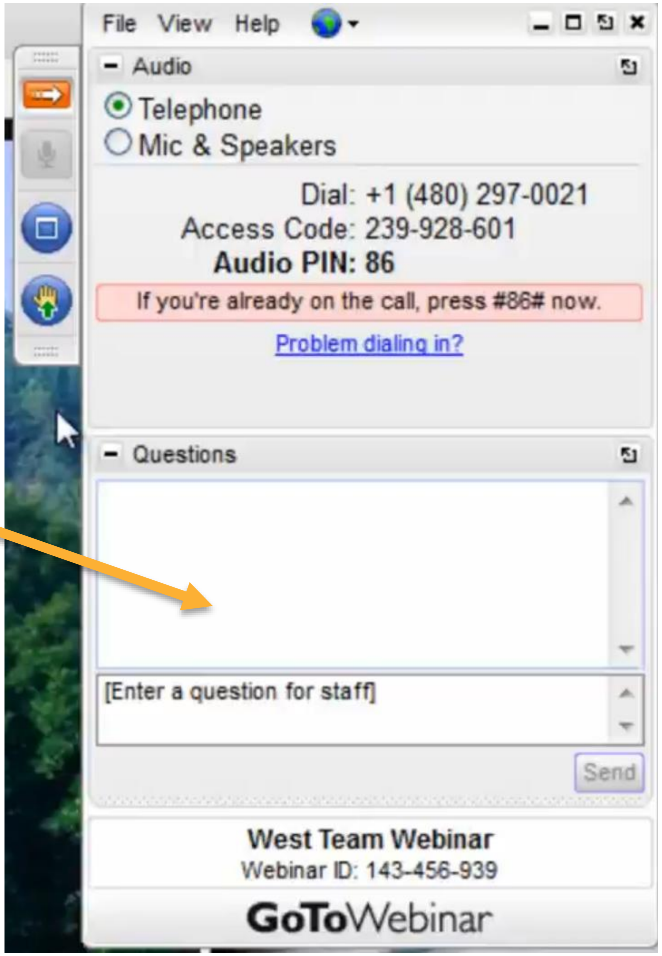
Headlines from an NIA funded project for Electricity North West

14th July 2016

Stephen Harkin	stephen.harkin@delta-ee.com	+44 131 625 1005
Rita Shaw	rita.shaw@enwl.co.uk	+44 8433 113989
Jon Slowe	jon.slowe@delta-ee.com	+44 131 625 1004

Do you want to ask questions?

You can <u>write down a question</u> which we can bring up during the webinar if time allows



Speaking today

Energy & Environment

Stephen Harkin, Delta-ee

Principal Analyst

+44 131 625 1005
Stephen.harkin@delta-ee.com

Dr Rita Shaw, Electricity North West

Modelling Strategy – Load and Innovation

+44 8433 113989
Rita.Shaw@enwl.co.uk

Jon Slowe, Delta-ee

Director

+44 (0) 131 625 1004
Jon.Slowe@delta-ee.com

Dave Openshaw, Millhouse Power

Delta-ee Associate

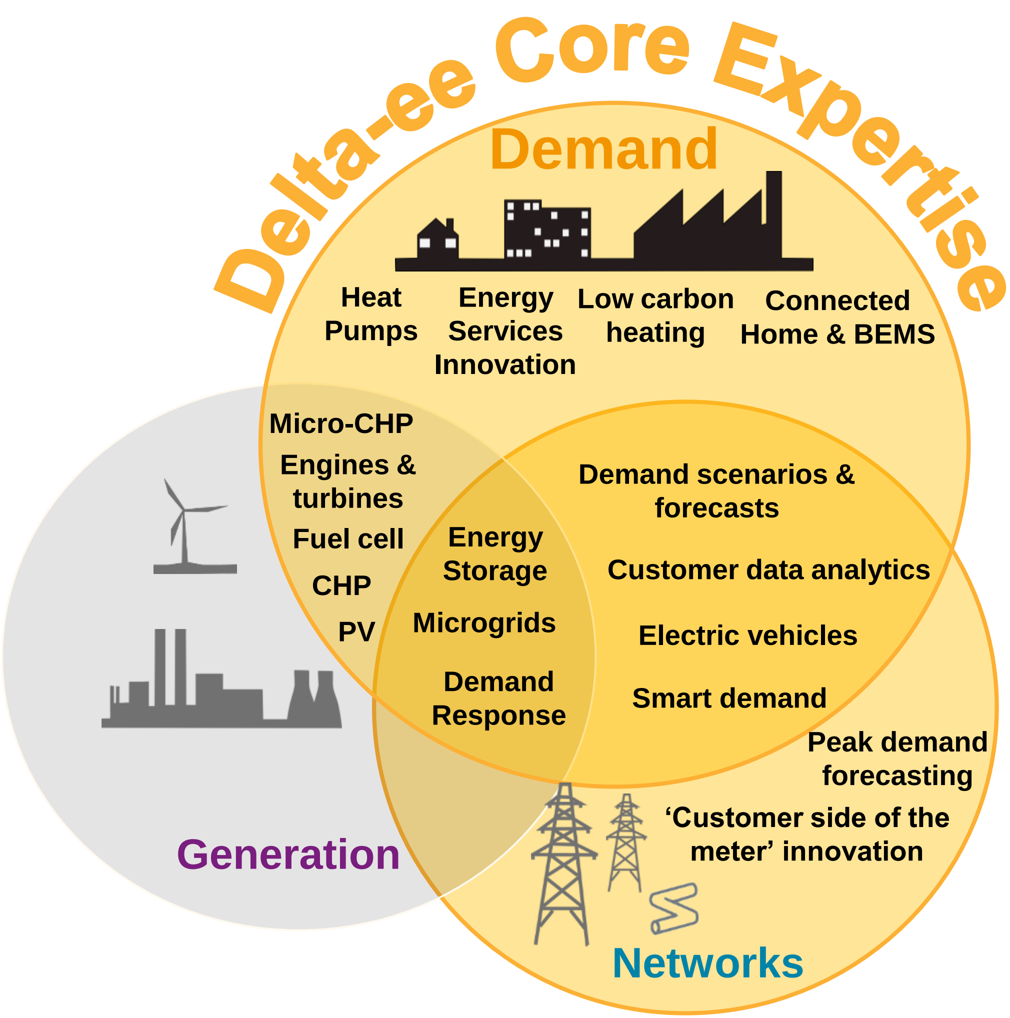
+44 (0) 7949 213636
dave.openshaw@millhousepower.co.uk

Agenda

1. Introduction & focus of this webinar
2. Development of heat pump load profiles
3. Scenarios for heat pump uptake & impact on the distribution network
4. Optimisation of heat pump operation & impact on the distribution network
5. Summary

<45 minutes

Helping clients navigate the transformation of the energy system



Energy Companies

SGN, EDF, e-on, GrDF, ESB, JX, RWE, SSE, Gazprom, Calor, eni, Osaka Gas, British Gas, electricity north west, Vattenfall, nationalgrid, Fortum, ENGIE, gasNatural fenosa, Wales&West Utilities, EDF Energy, ExxonMobil, Lubrizol, BC hydro, Ennet

Manufacturers

Vaillant, BOSCH, Schneider Electric, Ariston Thermo Group, BAXI, Viessmann, flow energy, Saint-Gobain, CeresPower, Turbomach, Volkswagen, SOFCpower, Danfoss, netatmo, GE, Caterpillar, Jabil, AO Smith, Honda, Panasonic, Doosan, Daikin, Mitsubishi Electric, NGK Spark Plugs, Sharp

Others

Credit Suisse, Greenpeace, ena energy networks association, Berenberg, COGEN Europe, ARGB, Department of Energy & Climate Change, iea International Energy Agency, HHIC, Allianz

What Delta-ee offers to clients

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Research Services

Digital & Services Innovation

- Connected Home Service
- Customer Data Analytics
- Energy Services Innovation

Distributed Generation & Demand Side Flexibility

- Energy Storage Service
- Distributed Power Service
- Demand Response In Europe

Heat

- Microgen Insight Service
- Heat Pump Research Service
- Roadmap Service
- Pathways® Tool
- Micro-CHP Service

Consultancy

- Market analysis and forecasts
- Strategy
- Propositions and customer research
- Technology and product
- Policy & regulation
- Demand forecasts

Summits

- European ‘Connected Homes and Energy’
- Energy Services
- Micro-CHP
- Heat Pumps & Utilities

Who is Electricity North West & what does it do?

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electricity north west

- Owns, operates & maintains the north west of England's electricity **distribution** network
- Serves 2.4 million properties, 5 million people
- 1 of the 14 original GB DNO licence areas
- 1 of 6 DNO companies

http://www.enwl.co.uk/the-future

Delta-ee's analysis is a component of larger project

"Demand Scenarios with Electric Heat and Commercial Capacity Options"

Network Innovation Allowance project

April 2015 – October 2016

A. Improved Peak Load Scenarios with Electric Heat

1. Generate baseline and future scenarios of 'Grid and Primary' load with initial improvements to method (summer 2015)
2. **Develop disaggregated domestic heat pump scenarios – moving on from the single domestic heat pump type in the 'Transform' model to up to ten heat pump / house type combinations, and modelling how load profiles are affected by both thermal load and supplier/ system operator incentives – working with DELTA EE and Imperial College (end 2015)**
3. **Deliver an improved assessment of thermal and voltage constraints for the secondary networks including heat pump inputs (early 2016)**
4. Generate baseline and future scenarios of load at 'Grid and Primary' and secondary networks including various incremental improvements to inputs and method (summer 2016)

B. Commercial Capacity Options (based on Load Scenarios)

1. Definition of a 'real options' approach and tool to support decisions on DSM versus various scales of 'Grid and Primary' reinforcement under demand uncertainty
2. **Identification and prioritisation of intervention options beyond the customer meter to address secondary networks constraints**

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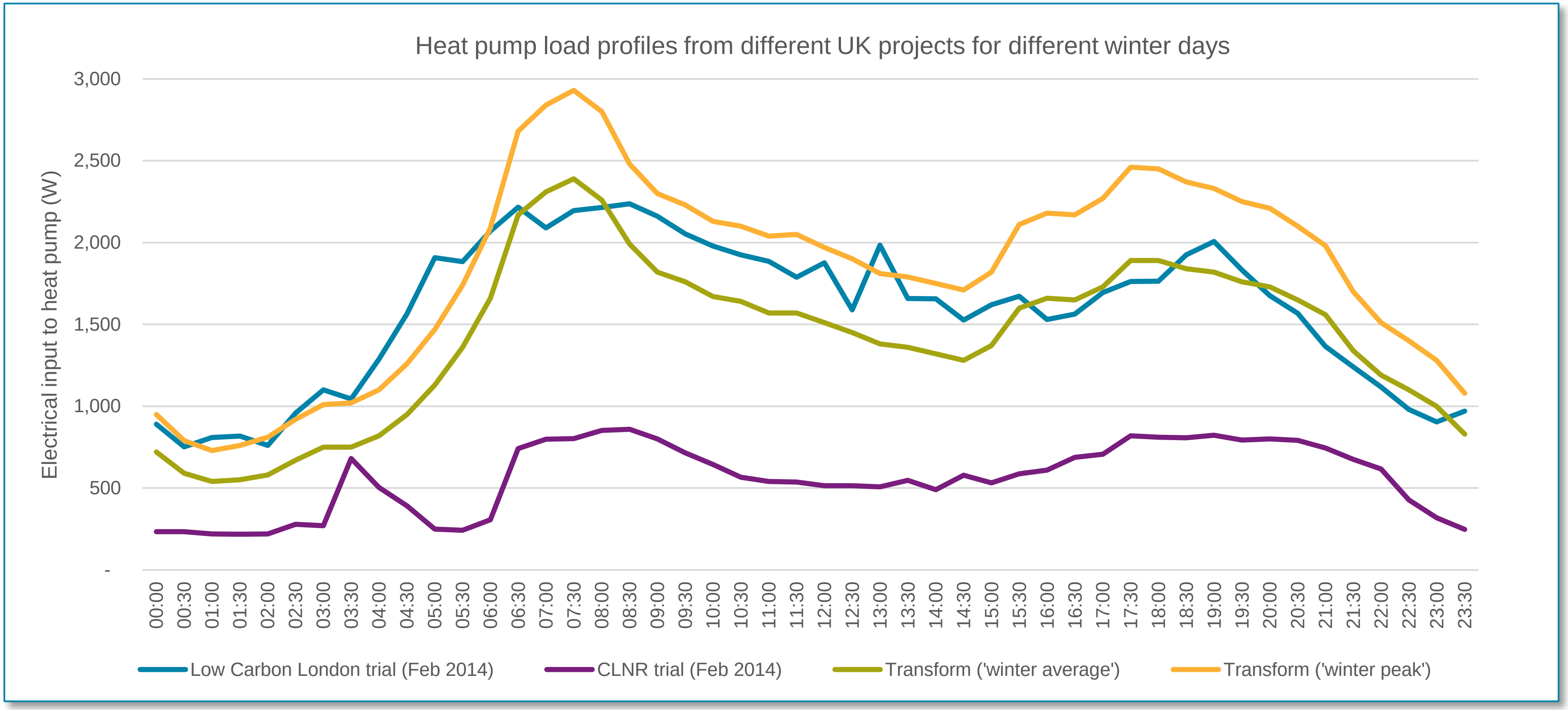
Overview of existing research & results on heat pump load profile analysis



Key electric heat pump types considered

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'Lower temperature' ASHP

- Seasonal performance factor of **2.5 – 3.0**
- Generates **flow temperatures of up to 55° C**
- **Well insulated buildings & new builds**

'Higher temperature' ASHP

- Seasonal performance factor of **2.3 – 3.0**
- Generates **flow temperatures of up to 80° C**
- **Older dwellings with a *moderate* thermal demand**

Hybrid ASHP

- 'Lower temperature' ASHP plus a boiler
- Switches between fuel sources, based on efficiency / running costs
- **Older, poorly insulated dwellings with larger thermal demand**

~~Ground source heat pump~~

- Seasonal performance factor of **3.5 – 4.0, or higher**
- **High cost due to ground works**
- **New build or larger rural properties with moderate – high thermal demand**

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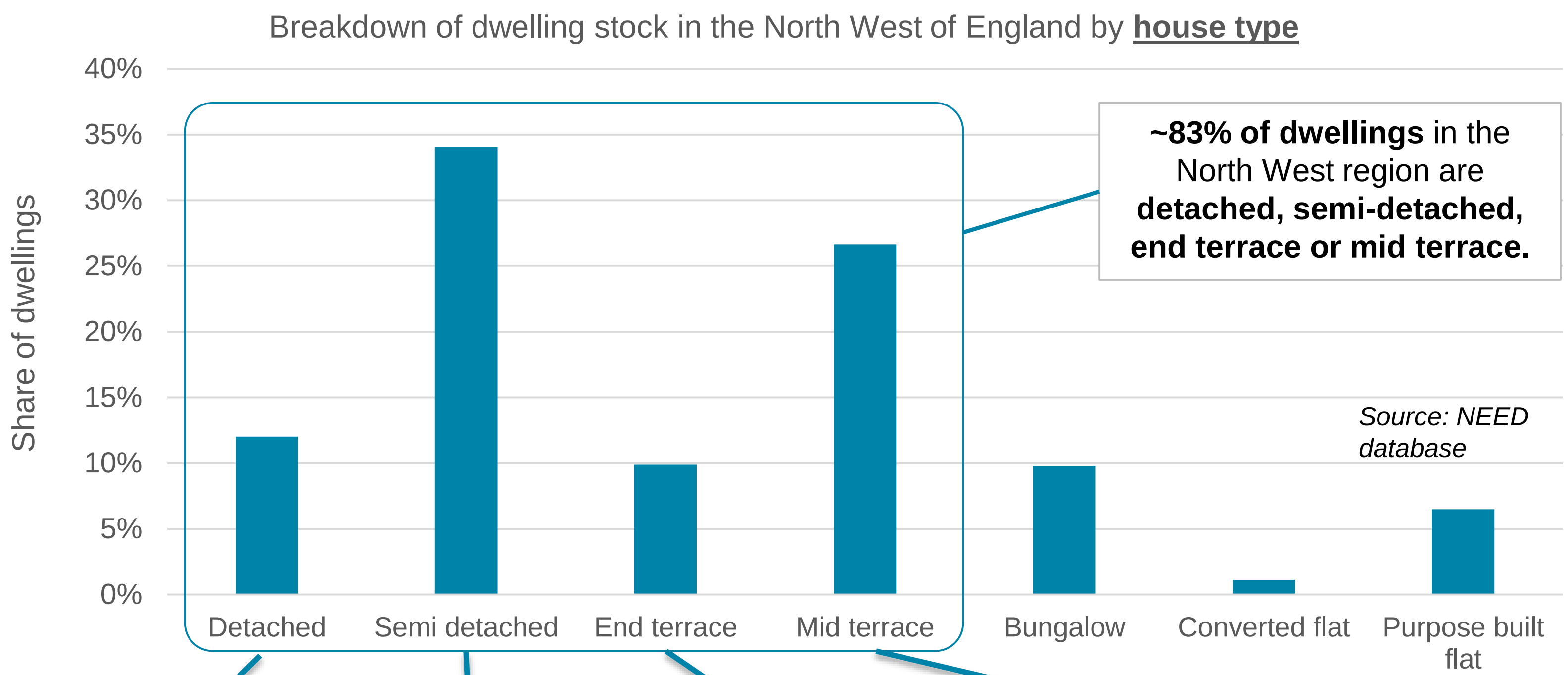
The housing stock in ENWL's region (the 'North West') is dominated by semi detached and terraced dwellings.



The six 'heat pump – house type' combinations considered in this study

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The **six 'heat pump – house types'** considered in this study are:

1. Semi-detached dwelling with a hybrid heat pump
2. Semi-detached dwelling with a lower temperature ASHP
3. Semi-detached dwelling with a higher temperature ASHP
4. Terrace dwelling with a hybrid heat pump
5. Detached dwelling with a hybrid heat pump
6. New build semi detached dwelling with a lower temperature ASHP

Factors influencing suitability of types of heat pumps to different house types:

- **Space inside** for hot water tanks / internal units.
- **Space outside** for external units / ground loops.
- **Gas connection** for hybrid heat pumps
- The **density of housing**.

1950s semi detached

Hybrid Heat Pump

Lower temperature ASHP

Higher temperature ASHP

1900s mid terrace

Hybrid Heat Pump

1930s detached

Hybrid Heat Pump

New build semi detached

Lower temperature ASHP

Outside air temperature is a critical factor that influences heat pump load profiles

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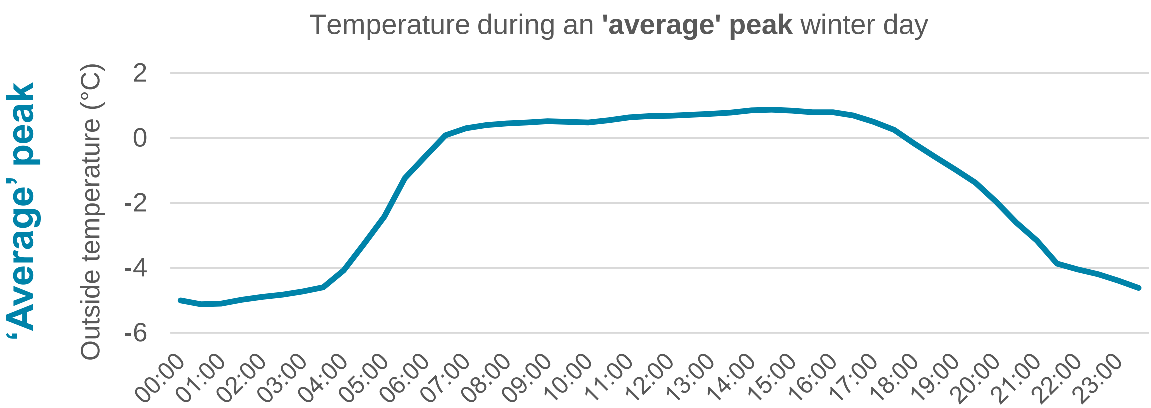
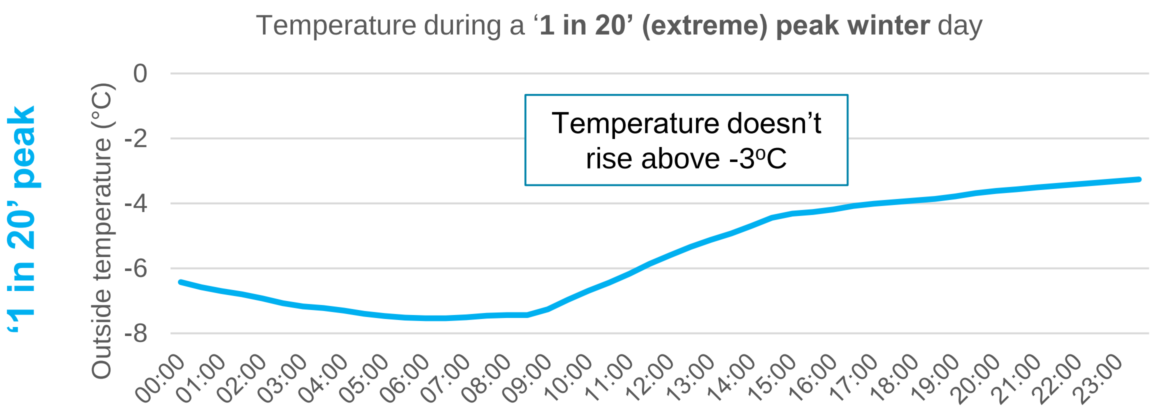
The load profile of a single heat pump in one dwelling varies significantly across the year for three key reasons:

- Heat pump efficiency is significantly influenced by the **outside air temperature**.
- The **type of dwelling (age, size, insulation levels)** the heat pump is installed in
- The **controls strategy / system set up**



- Av. daily temperature = **-2°C.**
- Heat pump runs during the morning and evening heating periods to provide space heating & hot water.
- Back up heaters will typically not run (unless daytime temperatures drop below zero or -1 degrees).



- Av. daily temperature = **-5.5°C.**
- Temperatures typically vary from -8 to 0°C during '1 in 20' peak days.
- The back up heaters of ASHPs will be operating.
- The heat pump part of hybrids will not be operating.

High level approach for developing heat pump load profiles

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Step 1: **Review of existing studies & trials** focusing on understanding heat pump load profiles

Step 2: In-depth **research & discussions with heat pump manufacturers and installers** to understand heat pump performance, control strategies and operation in real life installations

Step 3: **Modelling** of heat pump load profiles in different house types, using a **building physics model** (enabling us to consider dwellings common in ENWL's area, different heat pump types & different temperatures)

Step 4: **Testing & challenging of the heat pump load profiles** with heat pump manufacturers and our heat pump industry network

Step 5: **Modification** of the building physics model & heat pump assumptions to **update & improve the heat pump load profiles**

Step 6: **Final testing and validation of the heat pump load profiles** with heat pump manufacturers and our heat pump industry network

OUTPUT:
Robust and validated half-hourly load profiles for different types of heat pumps in different house types

Methodology for the development of the heat pump load profiles using the Building Physics model

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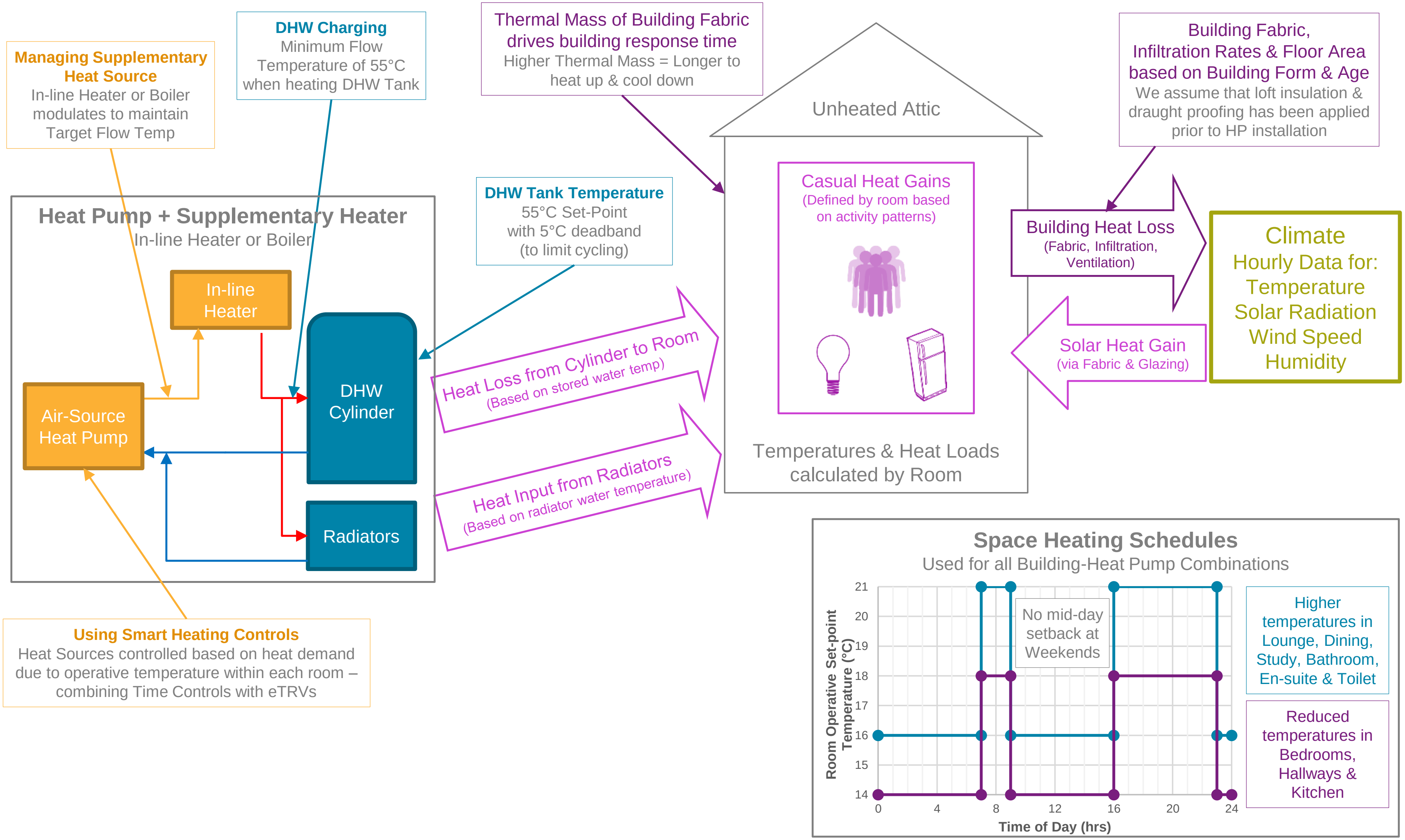
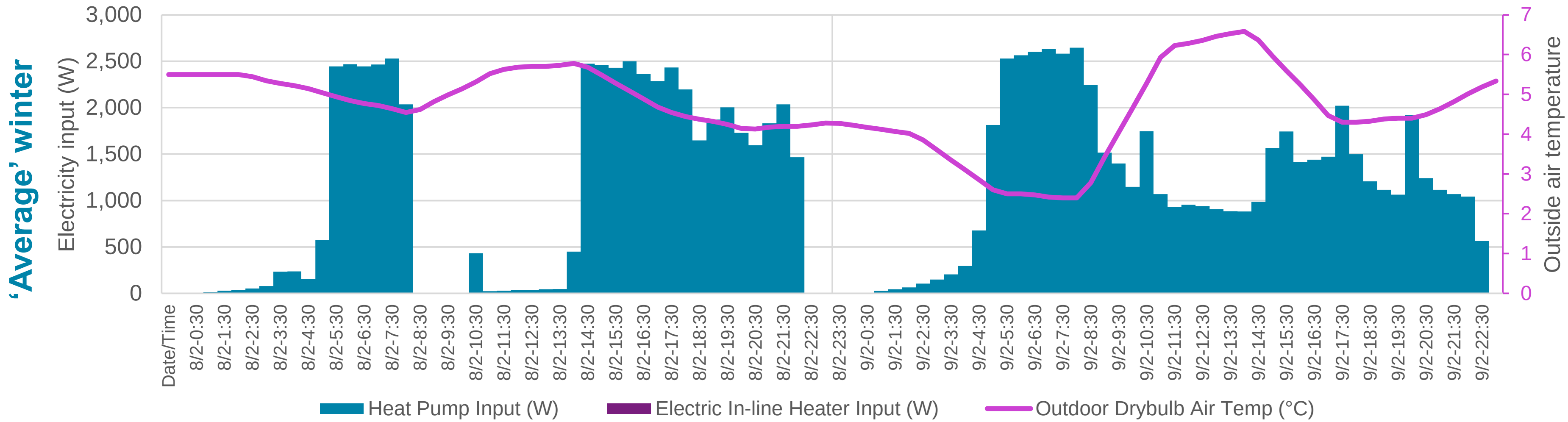
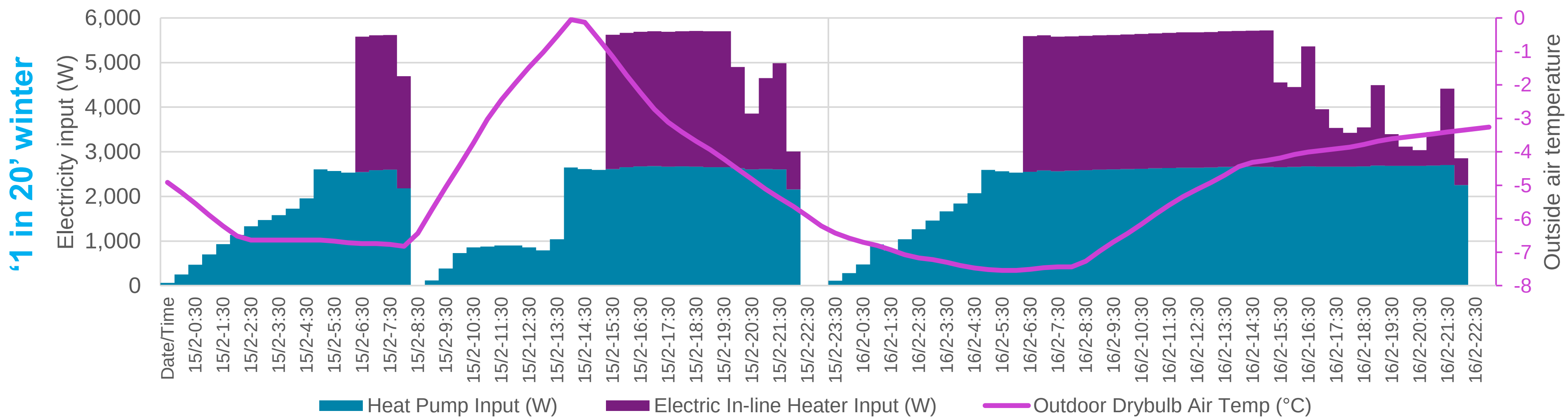


Example outputs from the building physics modelling

Load profile for a HT ASHP in a semi over 2 days in an ‘average’ winter



Load profile for a HT ASHP in a semi over 2 days in a ‘1 in 20’ winter

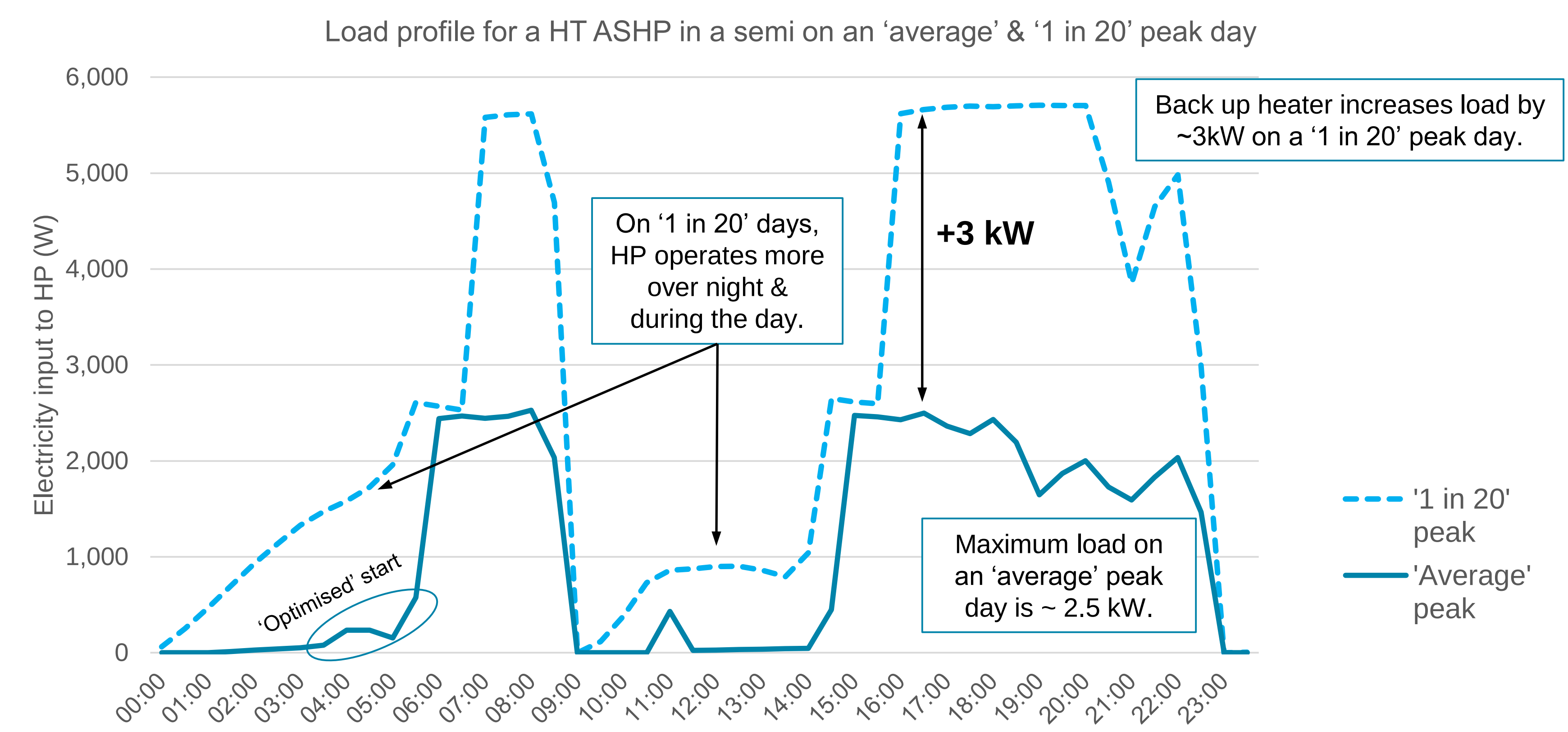


Example load profiles for heat pumps: Higher temperature ASHP in a semi detached dwelling, on different days of the year

Load profile (un-diversified) for a **higher temperature ASHP in a semi detached dwelling**:

- On an **'average' peak** winter day electricity demand peaks at ~2.5kW
- During the **'1 in 20' peak** winter day, the back up electric heater is needed for large portions of the day. The back up heater is 3kW in size resulting in an additional 3kW of electricity demand on very cold days.

Higher temperature ASHP in a semi

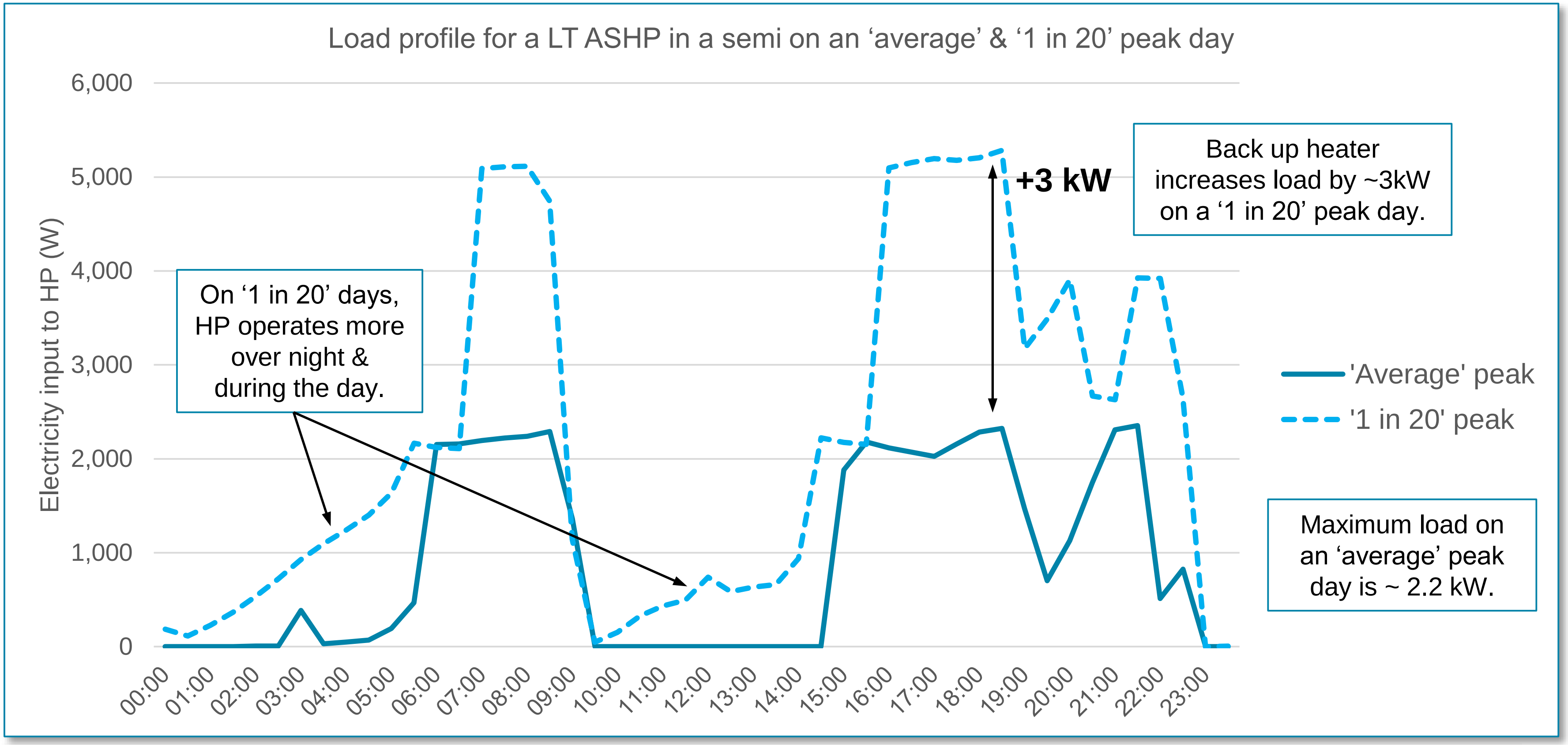


Example load profiles for heat pumps: Lower temperature ASHP in a semi detached dwelling

Load profile (un-diversified) for a **lower temperature ASHP in a semi detached dwelling**:

- On an **'average' peak** winter day electricity demand peaks at ~2.2kW
- During the **'1 in 20' peak** winter day, the back up electric heater is needed for large portions of the day. The back up heater is 3kW in size resulting in an additional 3kW of electricity demand on very cold days.

Lower temperature ASHP in a semi

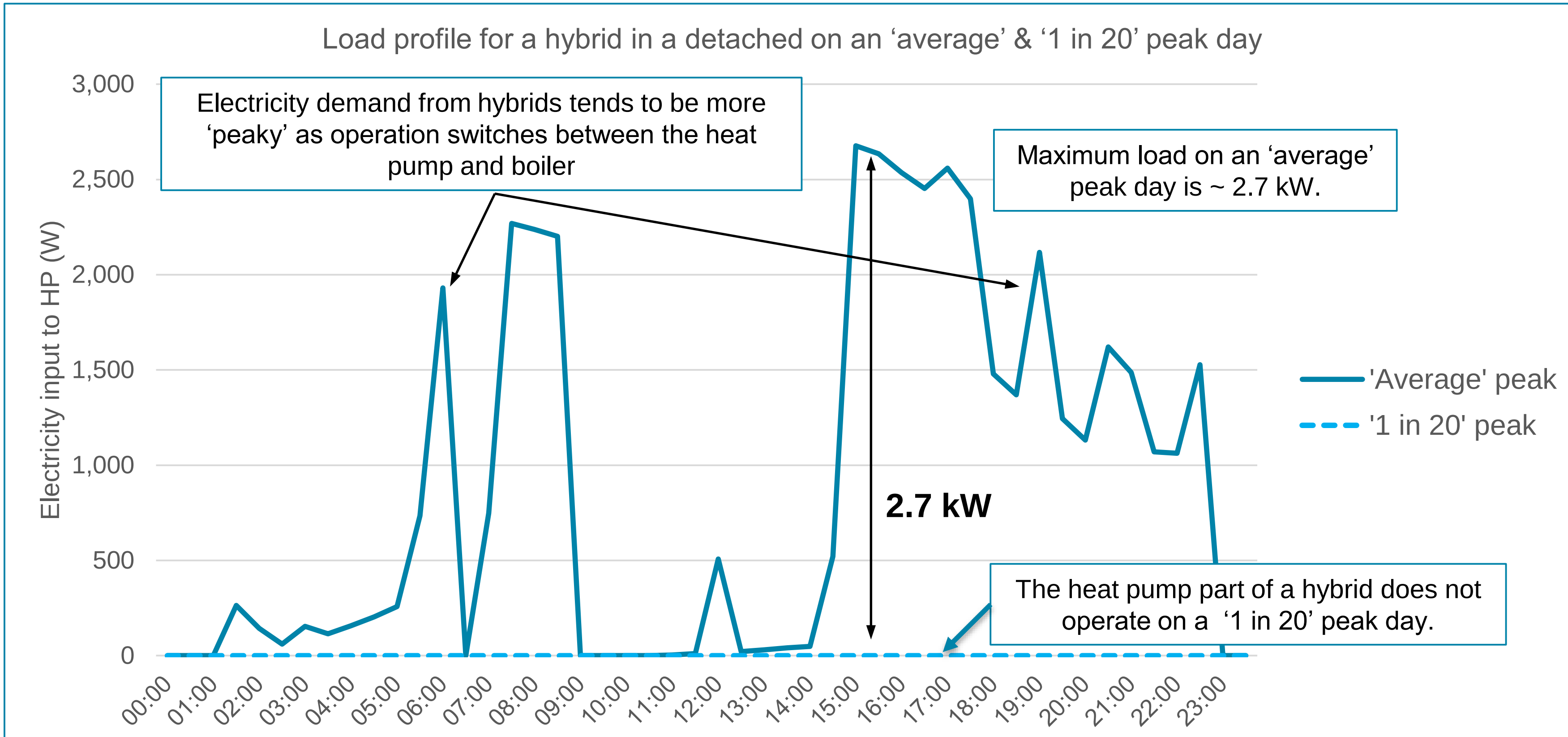


Example load profiles for heat pumps: Hybrid heat pump in a detached dwelling

Load profile (un-diversified) for a **hybrid heat pump in a detached dwelling**:

- On an **'average' peak** winter day electricity demand peaks at ~2.7kW
- During the **'1 in 20' peak** winter day, the heat pump part of the hybrid does not operate due to a reduction in the efficiency of the heat pump. This results in zero load from the hybrid on '1 in 20' days.

Hybrid heat pump in a detached



Comparison of all six heat pump-house type load profiles on an ‘average’ peak and a ‘1 in 20’ peak winter day

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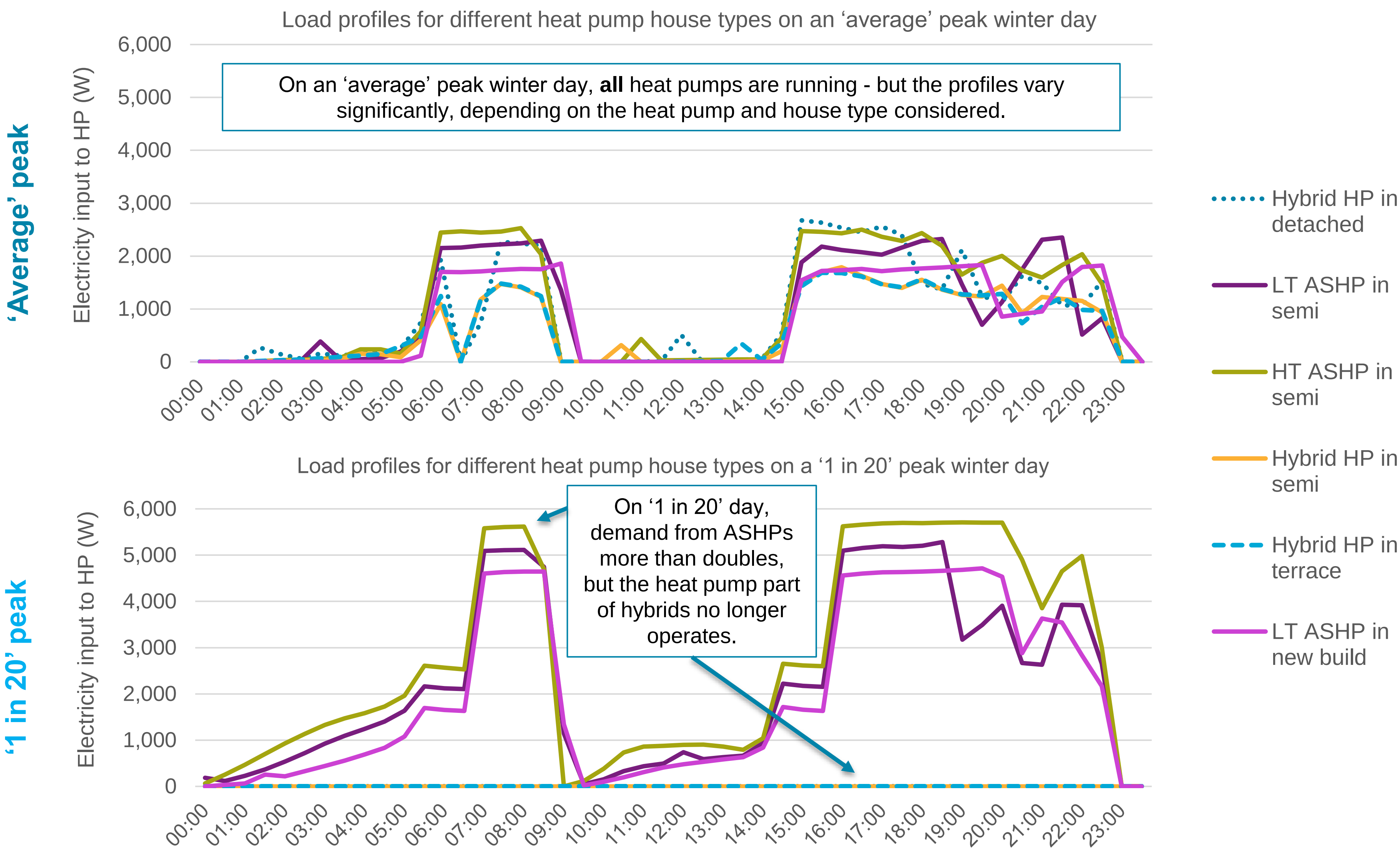

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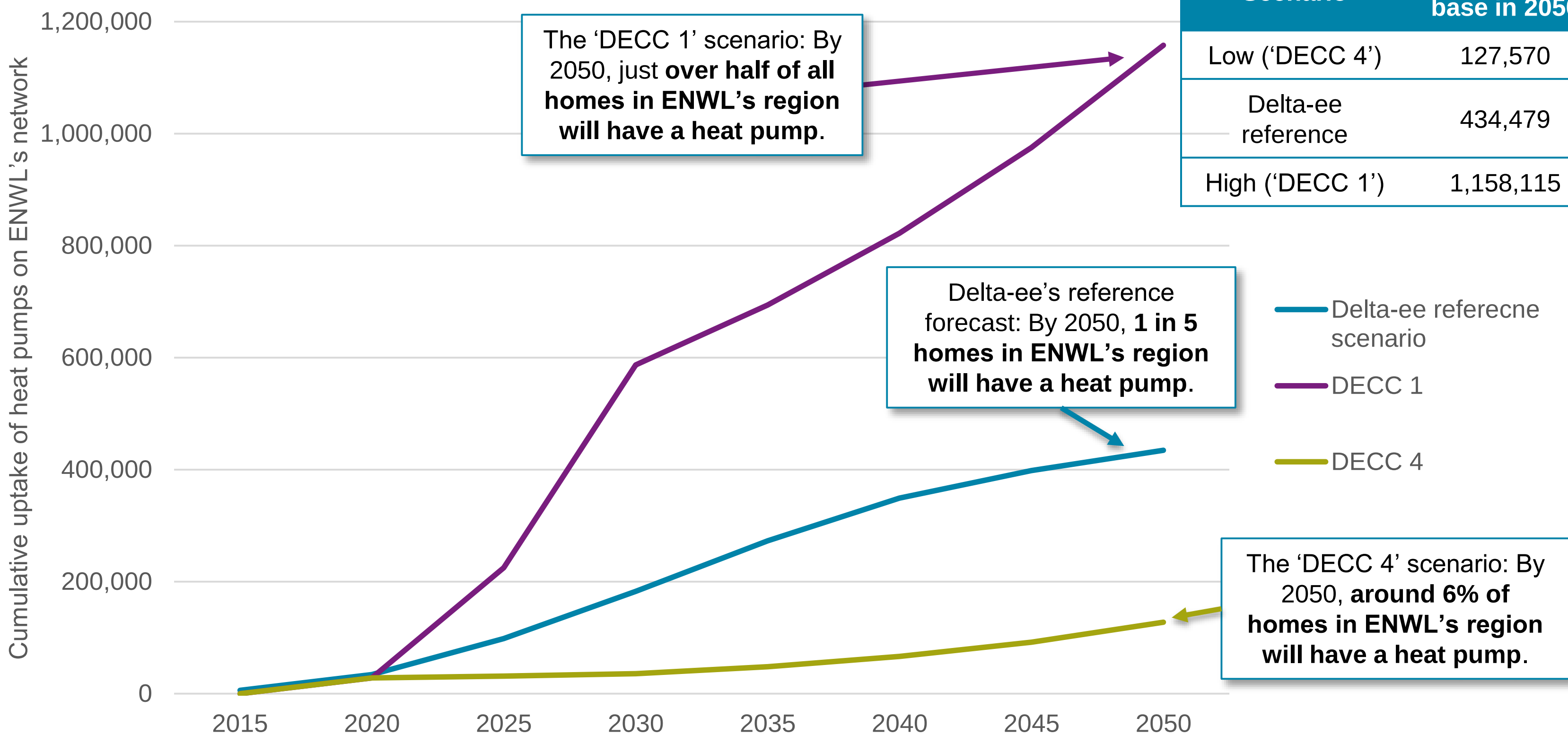
Three key scenarios for heat pump uptake on ENWL's network to 2050

The **three scenarios** considered are:

- The 'Delta-ee reference scenario'.
- The 'high' scenario, aligned with the Transform interpretation of the national DECC high heat pump uptake, referred to as DECC 1'.
- The 'low' scenario, aligned with the Transform interpretation of the national DECC low heat pump uptake, referred to as 'DECC 4'.

Comparison of heat pump uptake under the three scenarios



Scenario	HP installed base in 2050
Low ('DECC 4')	127,570
Delta-ee reference	434,479
High ('DECC 1')	1,158,115

Delta-ee REFERENCE Scenario forecast for heat pump Cumulative UPTAKE in ENWL's region

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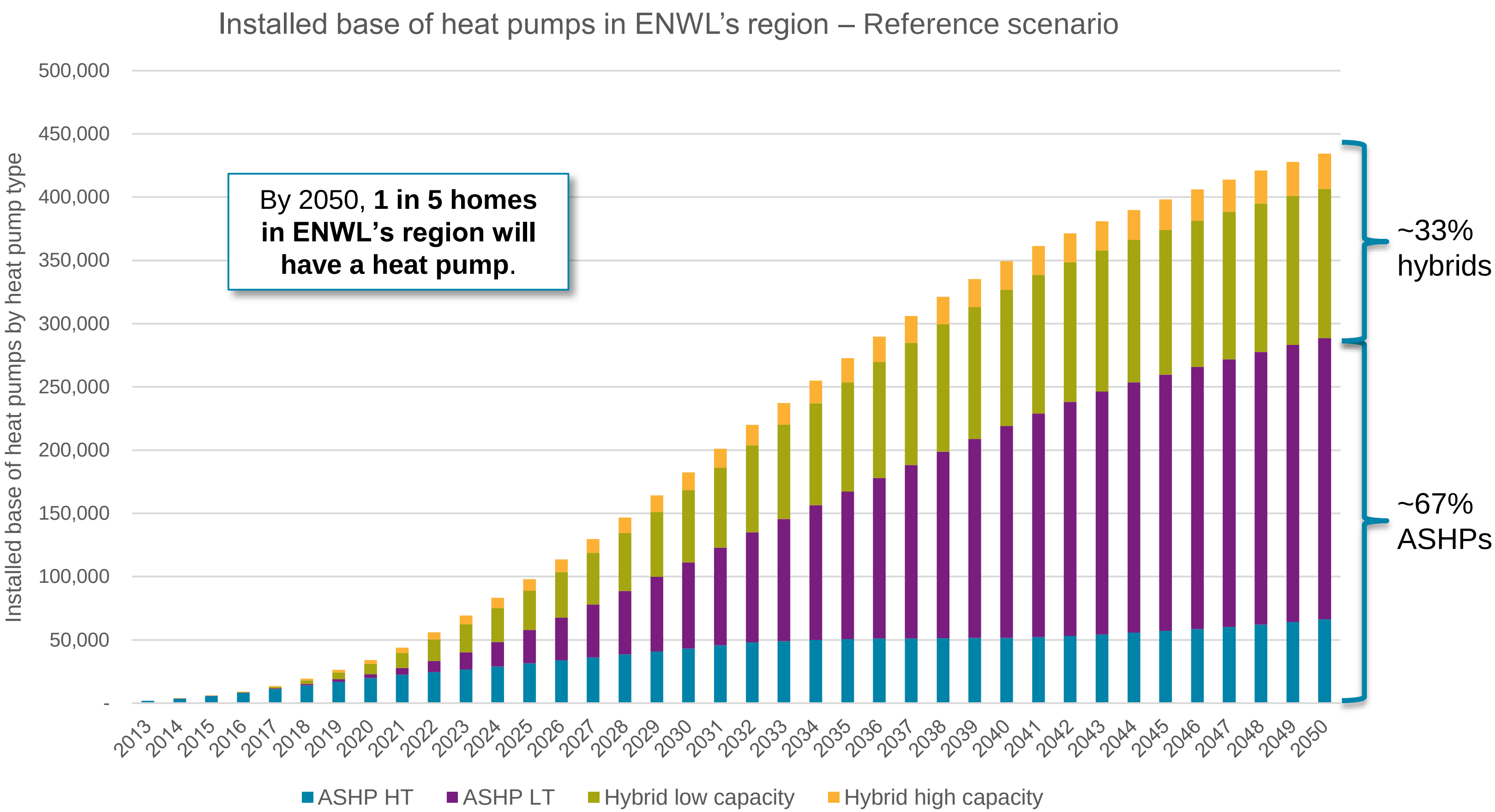
By 2025, we see close to 100,000 heat pump solutions being connected to ENWL's network. This grows to ~430,000 units by 2050

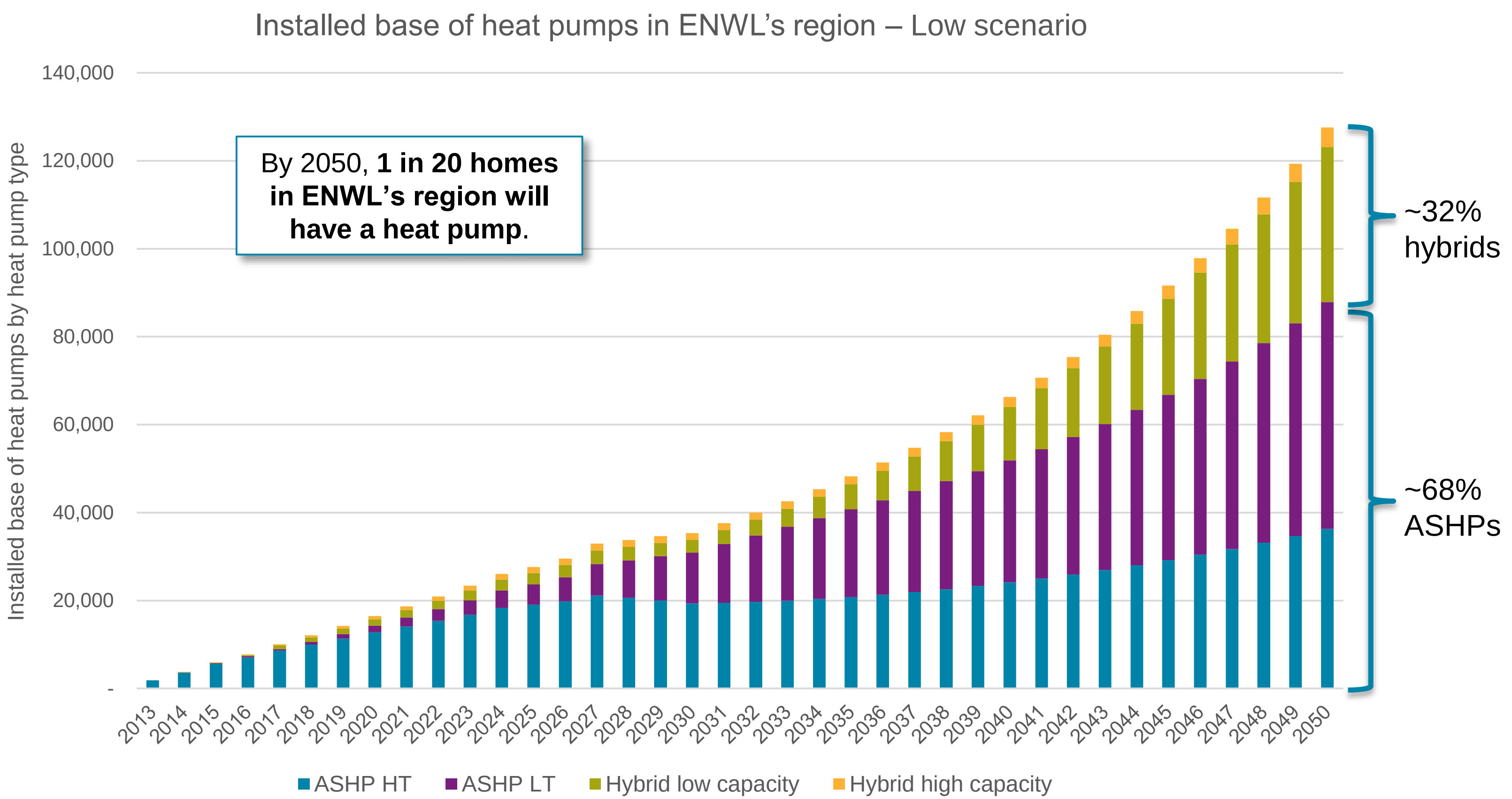
- Pure electric ASHPs will account for just over half of the heat pumps connected to ENWL's network by 2025, with high temperature systems still accounting for the majority of this. ASHPs account for two thirds of systems connected by 2050.



'DECC 4' ('Low') scenario forecast for heat pump Cumulative UPTAKE in ENWL's region

We see little growth in the number of heat pump solutions being connected to ENWL's network to 2030, with modest growth occurring towards 2050. The installed base reaches ~130,000 units by 2050.

- Pure electric ASHPs will dominate the sales and installed base of heat pumps connected to ENWL's network to 2050, with low temperature systems accounting for the majority of this.
- Hybrid heat pump installations will see a very slow and small growth in penetration to 2050.



‘DECC 1’ (High) scenario forecast for heat pump Cumulative UPTAKE in ENWL’s region

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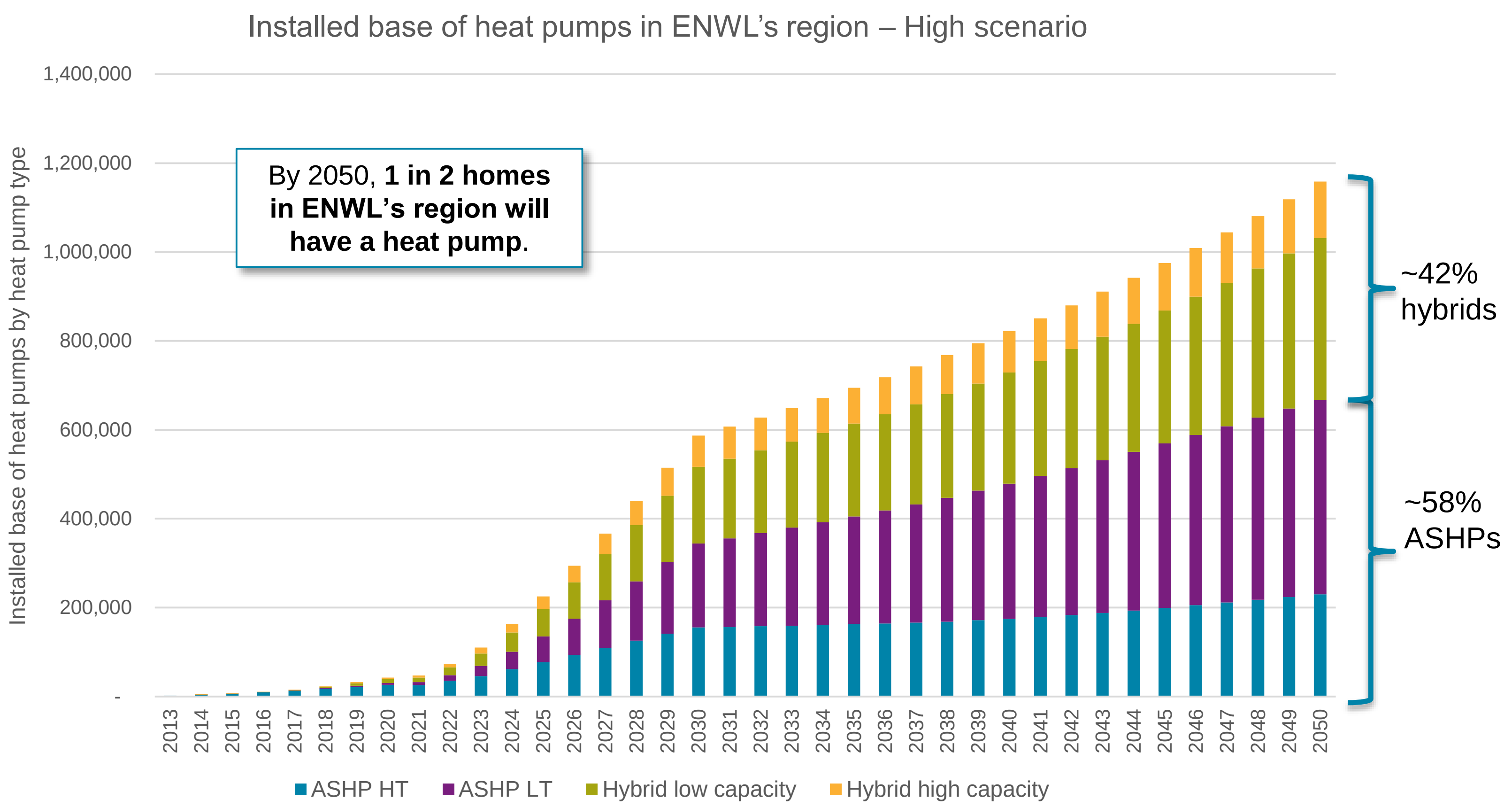
By 2025, we see over 200,000 heat pump solutions being connected to ENWL’s network, growing to 600,000 in 2030 and 1.1 million by 2050.

- Pure electric ASHPs will account for just over half of the heat pumps connected to ENWL’s network by 2025, with high temperature systems still accounting for the majority of this.
- In the 2030 to 2050 period, ASHPs and hybrids will each account for ~50% of installations.



Diversification of heat pump load profiles

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Key factors influencing the diversity of heat pump operation

- Occupancy levels in dwellings
- Unimodal versus bimodal heating system operation (i.e. one heating period – all day, or two heating periods – AM and PM).
- The timing at which homes are required to be 'warm'.
- The volume of heat pumps over which diversification needs to occur (10s, 1,000s, 1,000,000s…)

Existing insights on diversification of heating system operation used in this study:

DECC:
Assessment of heating controls impact on domestic energy demand (2014)

→ Heating system 'switched on / off', unimodal vs bi-modal operation insights

Loughborough University:
Domestic active occupancy modelling (2008) & four-state domestic active occupancy modelling (2014) studies

→ Occupancy patterns in the UK dwelling stock

National Grid:
Data shared on gas demand of different dwelling types over the year

→ Indication of the period of time over which heating systems **start up** in the morning, **switch off** in the evening.

Approach used to diversifying heat pump load profiles

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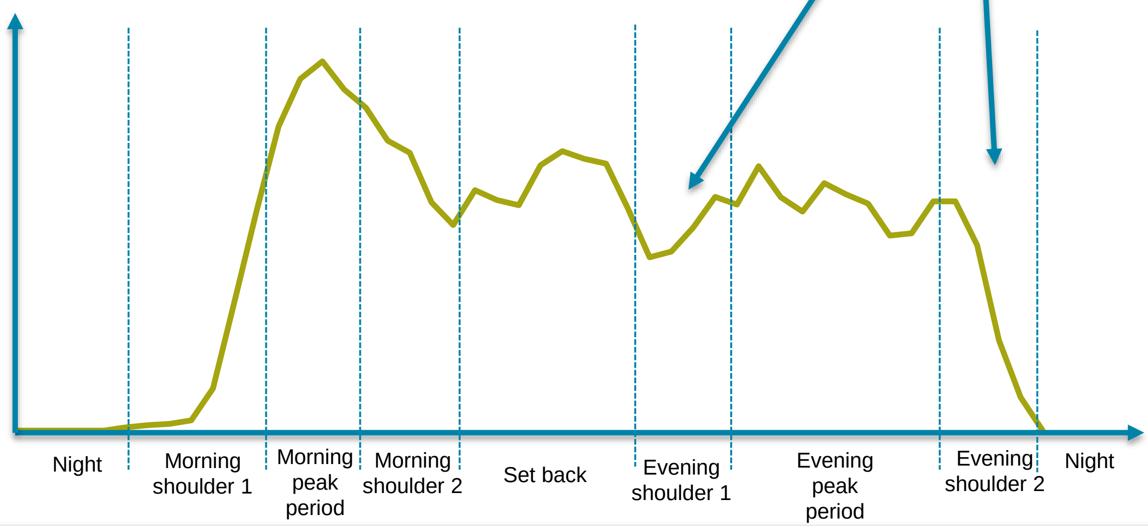
Diversification factors applied to heat pump load profiles on an 'average' peak winter day

Period of day	Diversification % @ National level
Type of winter day	'Average' peak winter day
Morning heating period – peak period	80%
Morning heating period – shoulder	80%
Evening heating period – peak period	86%
Evening heating period – shoulder	86%
Set back	86%
Night	95%
Duration over which heating systems are switched on	3 hours

Defines the proportion of heating systems that are in operation at any one time.

Illustrative heat pump load profile (undiversified), with the 'period of day' indicated.

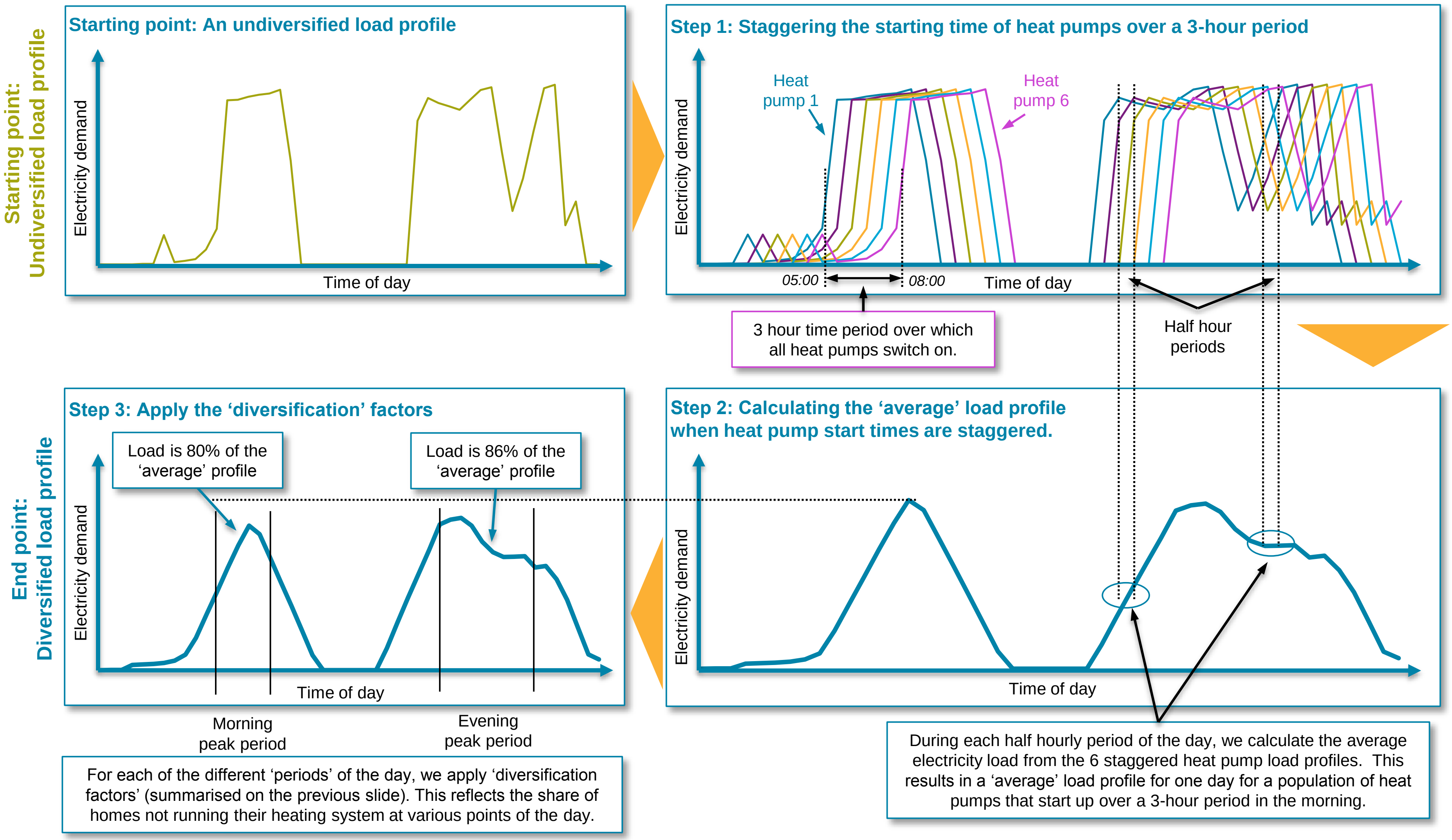


High level diversification approach

- %s above applied to *undiversified* profiles at each period of the day.
- Beginning in 'morning shoulder 1' we stagger the start time of heat pumps to reflect to 2 – 3 hour period over which heating systems start up in the morning.
- This 'staggering' continues throughout the day until the end of 'evening shoulder 2'.

Approach used to diversifying heat pump load profiles

Below, we illustrate our approach for diversifying heat pump load profiles at the national level.



Diversified heat pump load profiles

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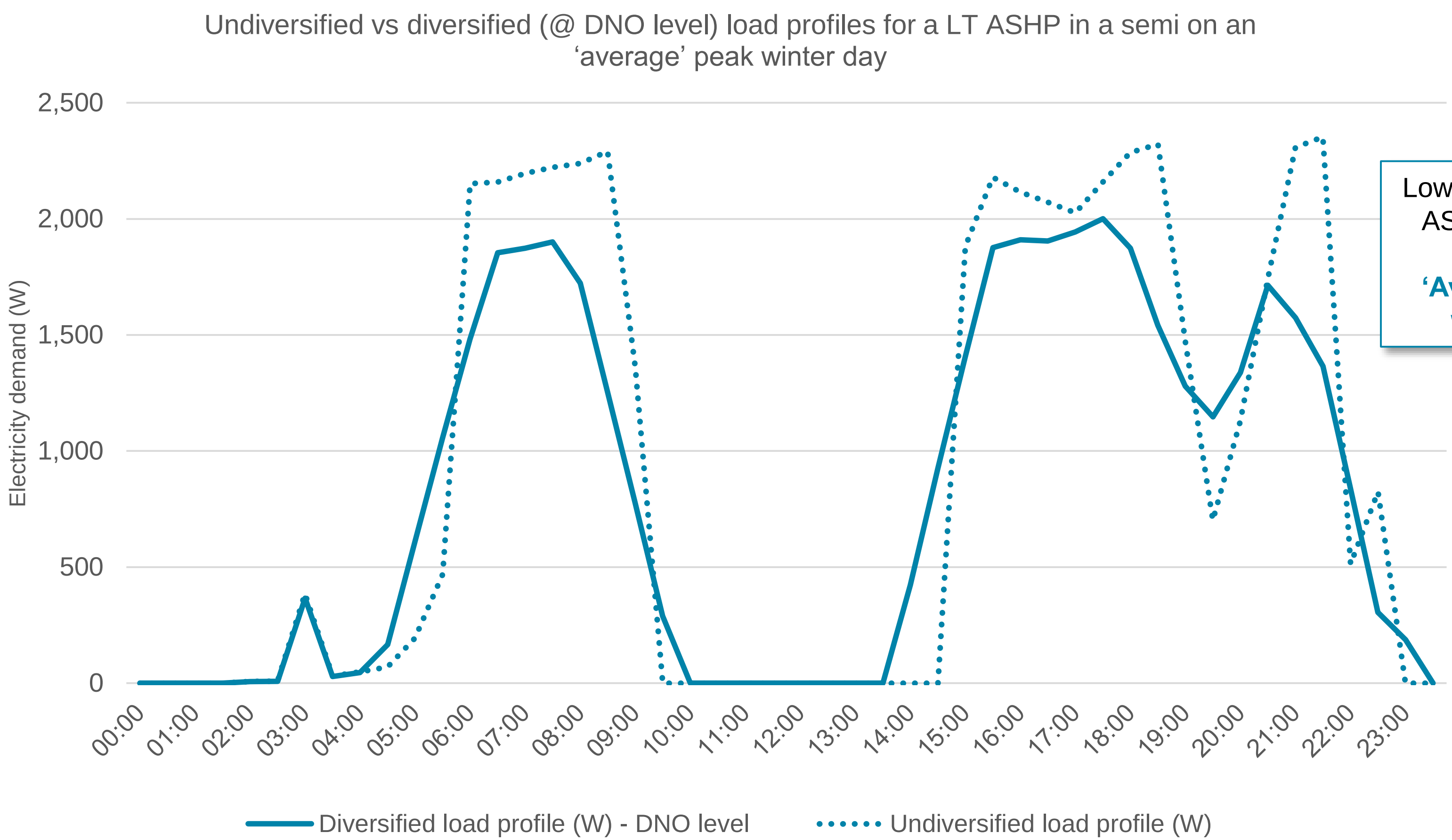
Diversified (at the DNO level) and un-diversified load profiles for a lower temperature ASHP in a semi detached dwelling an ‘average’ peak winter day.

- Typically, the diversification approach results in the maximum load of the profile of LT ASHP in a semi on an **‘average’ peak** day falling by ~20%, with the load profile being smoother and less ‘peaky’.



Lower temperature ASHP in a semi

‘Average’ peak winter day

Electrification of heat could increase peak load on ENWL's network by 3.5 GW

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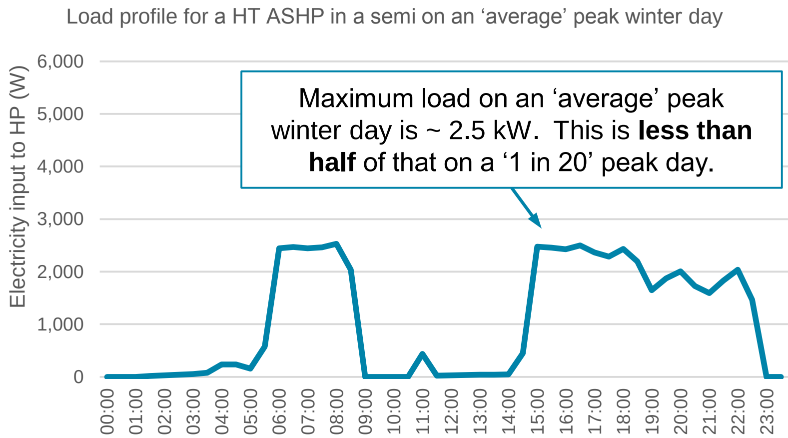
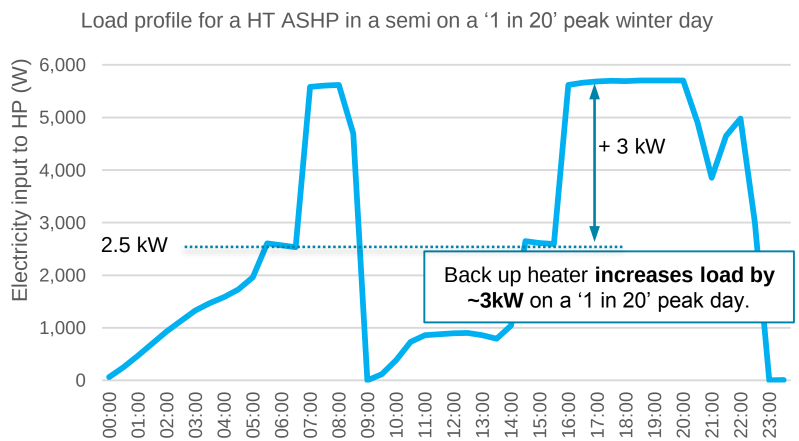
Load profile* for an ASHP in a semi-detached dwelling

'Average' peak



'1 in 20' peak



At the household level, heat pumps can increase load by

2.5 – 5.5 kW

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**

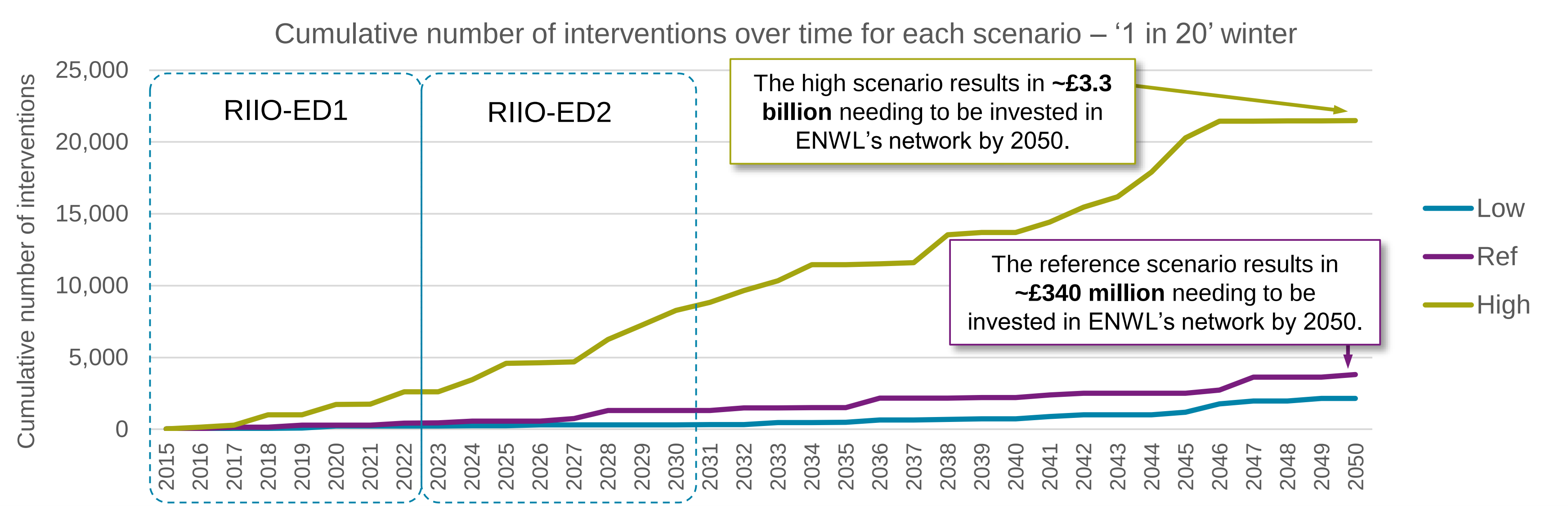
** The heat pump load profiles illustrated on this slide, and throughout the report, are for a week day.*

HT ASHP = Higher temperature ASHP

The impact on network reinforcement could be £100 millions to £ billions by 2050

Increases in peak load will require significant network reinforcement

- Applying the heat pump uptake rates to 2050 & the load profiles developed to 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.



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**

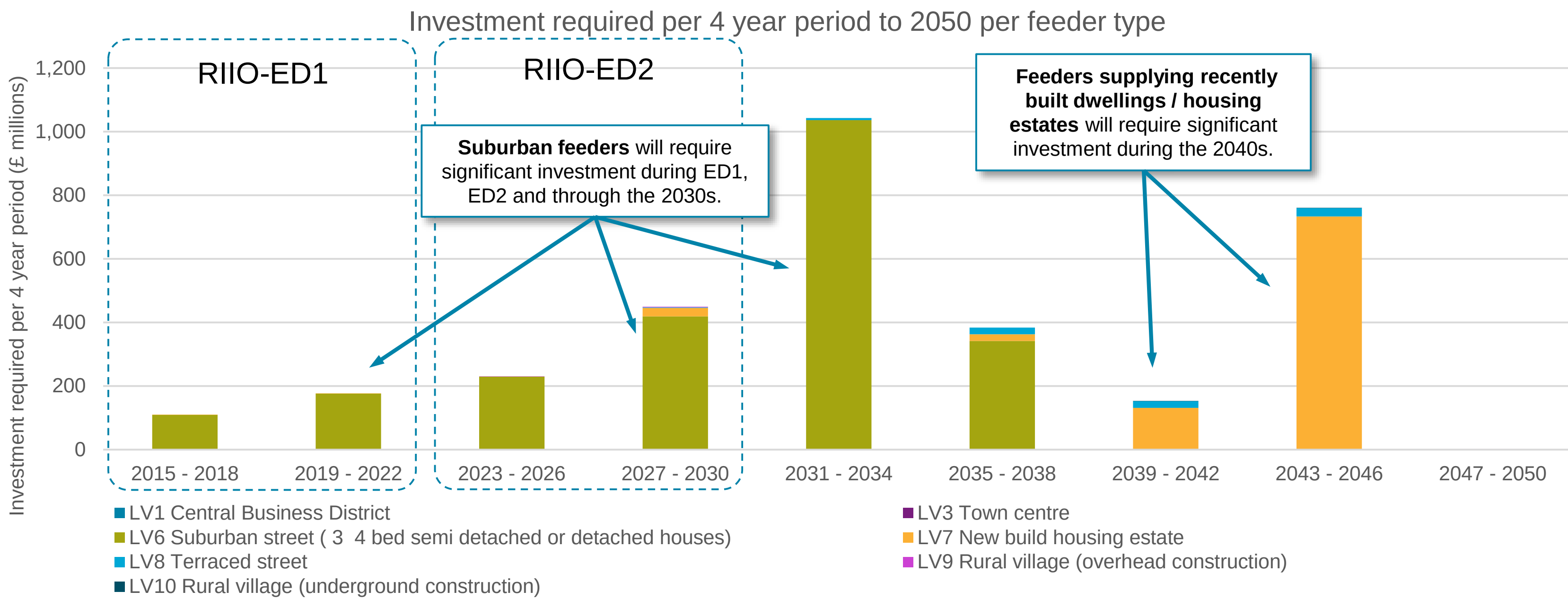
Impact on ENWL's LV network of heat pump uptake under the high scenario on a '1 in 20' winter peak

Heat pump uptake under the high scenario:
1.15 million by 2050

Huge investments will be required in suburban feeders by 2030, and through to 2040. New build estate feeders will require modest investments closer to 2050.

- Under the high scenario, significant investment will be required during ED1, ED2 & during the 2030s in feeders serving suburban areas (with large proportions of semi detached & detached dwellings).

'1 in 20' winter peak



	2022	2030	2050
Cumulative costs associated with LV 6 suburban street (£ millions)	285.9	933.8	2,311.6
Cumulative costs associated with LV 7 new build housing estate (£ millions)	0.7	27.9	913.4
Cumulative costs associated with LV 8 terraced street (£ millions)	0	1.6	77.1
Cumulative costs associated with other LV feeder types (£ millions)	0	2.1	3.4
Total (£ millions)	**286.6**	**965.4**	**3,306.5**

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‘Optimisation’ of heat pump load profiles

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Approach to optimising heat pump load profiles

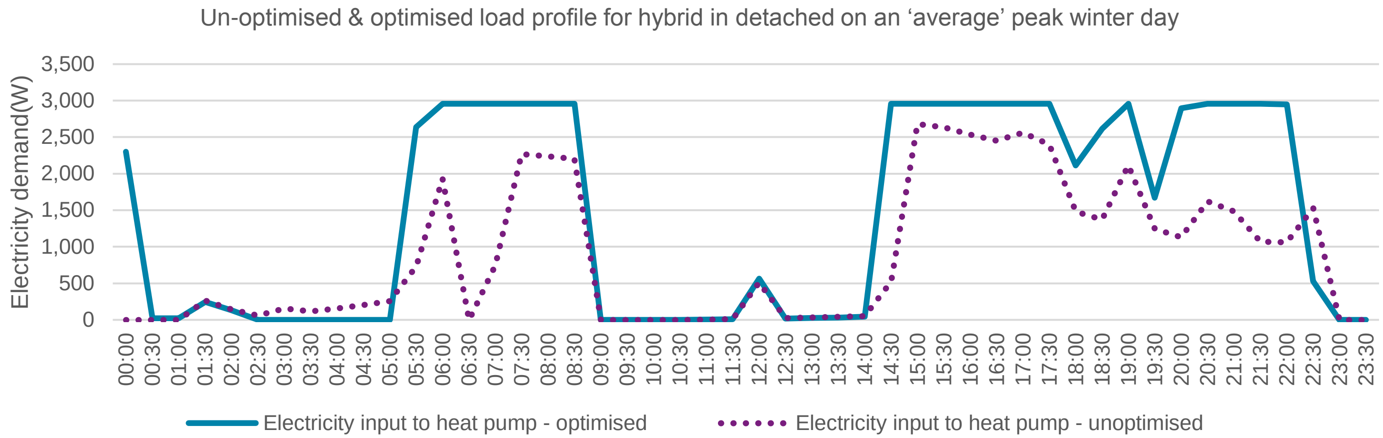
Step 1:	Diversify heat pump load profiles **at the national level**
Step 2:	Identify the **flexibility options & constraints** around the operation of heat pumps *(without compromising on the level of comfort and timing of delivery of heating in a dwelling)*
Step 3:	**Define a scenario to 2050 for the evolution of electricity demand, the generation mix, and the uptake of heat pumps at the national level**
Step 4:	**‘Optimise’ the operation of the electricity system at the national level via shifting the operation of heat pumps to maximise use of lower cost electricity generation. [IMPERIAL COLLEGE MODELLING]**
Step 5:	**Sense check and validation of modified load profiles**

OUTPUT: Modified heat pump load profiles

Note: By ‘optimisation’, we mean that the operation of heat pumps are modified to maximise the use of low cost electricity generation. The operation of heat pumps (and therefore the load profiles) <u>are not</u> optimised to benefit the distribution network.

Impact of optimisation on hybrid heat pump operation on a day in a ‘1 in 20’ winter and an ‘average’ winter week – Reference scenario

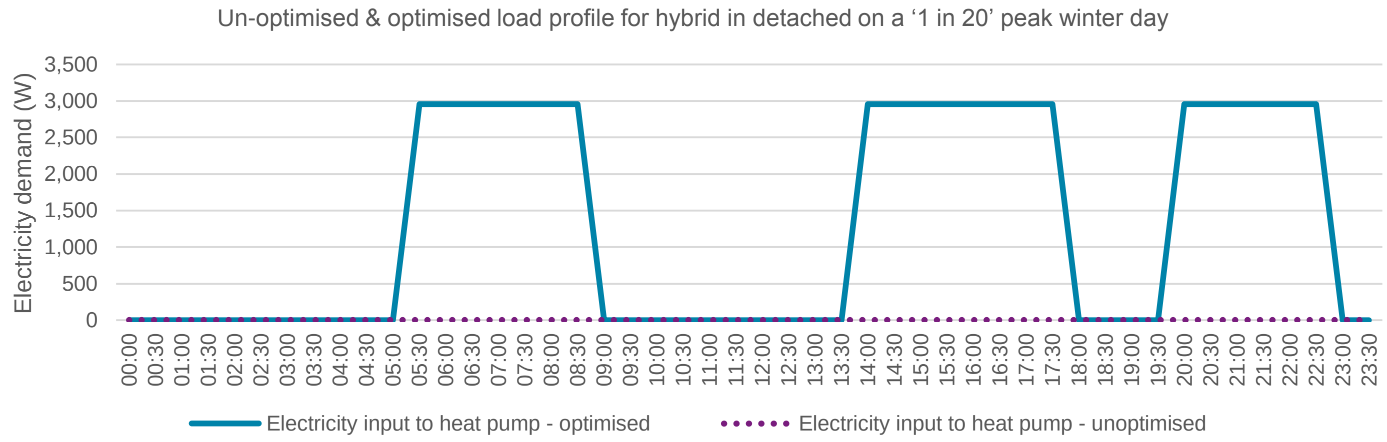
Optimisation of hybrid heat pump operation can increase demand at peak times by up to 3kW



Reference scenario

Hybrid in detached

‘Average’ winter day



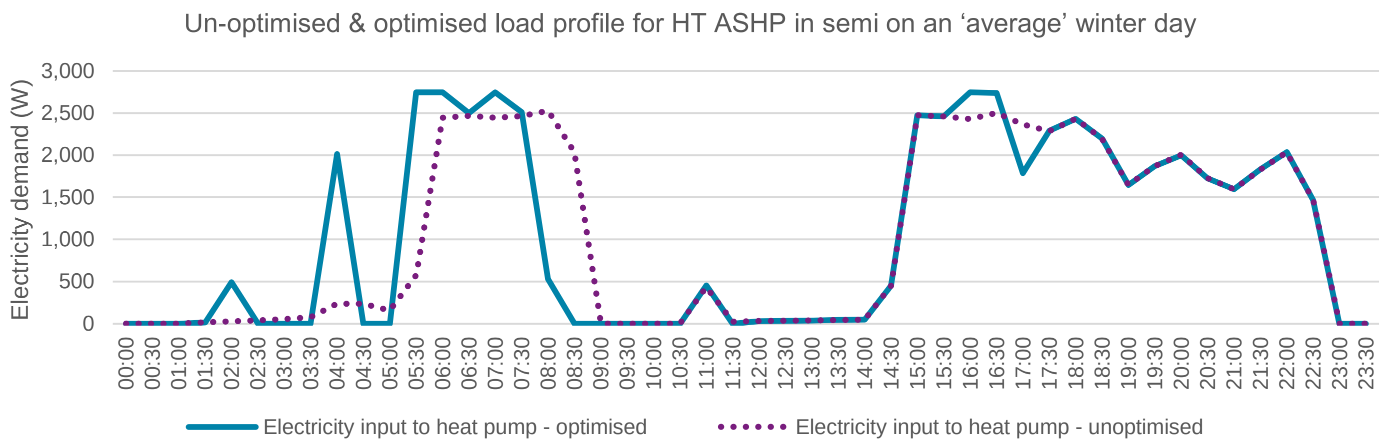
Reference scenario

Hybrid in detached

‘1 in 20’ winter day

Impact of optimisation on electric heat pump operation on a day in a ‘1 in 20’ and an ‘average’ winter week – Reference scenario

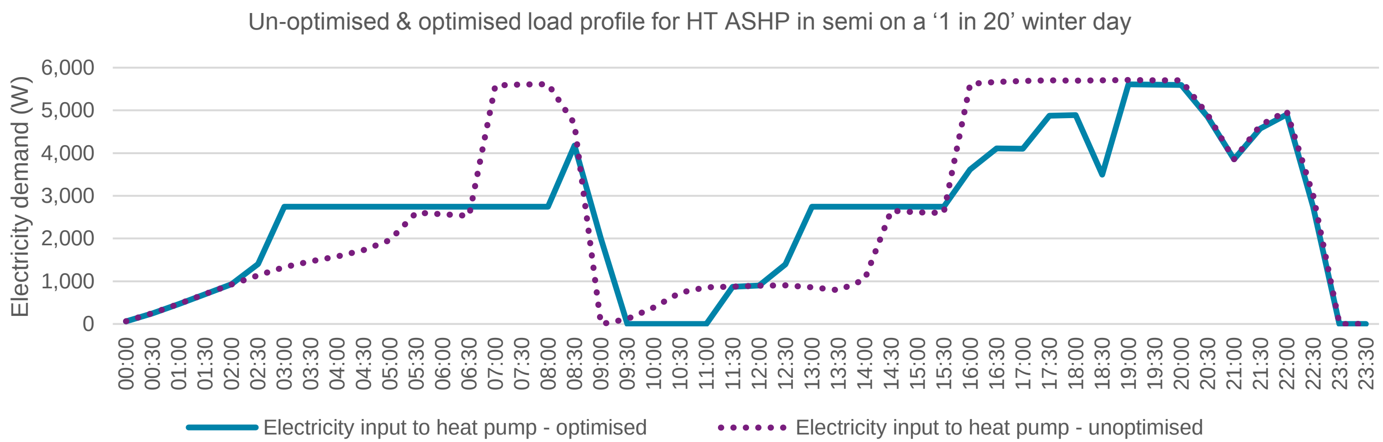
Optimisation of ASHP operation can increase demand at peak times by up to 0.5 – 1 kW (and in some cases by a few kWs if the back up turns on).



Reference scenario

HT ASHP in semi

‘Average’ winter day



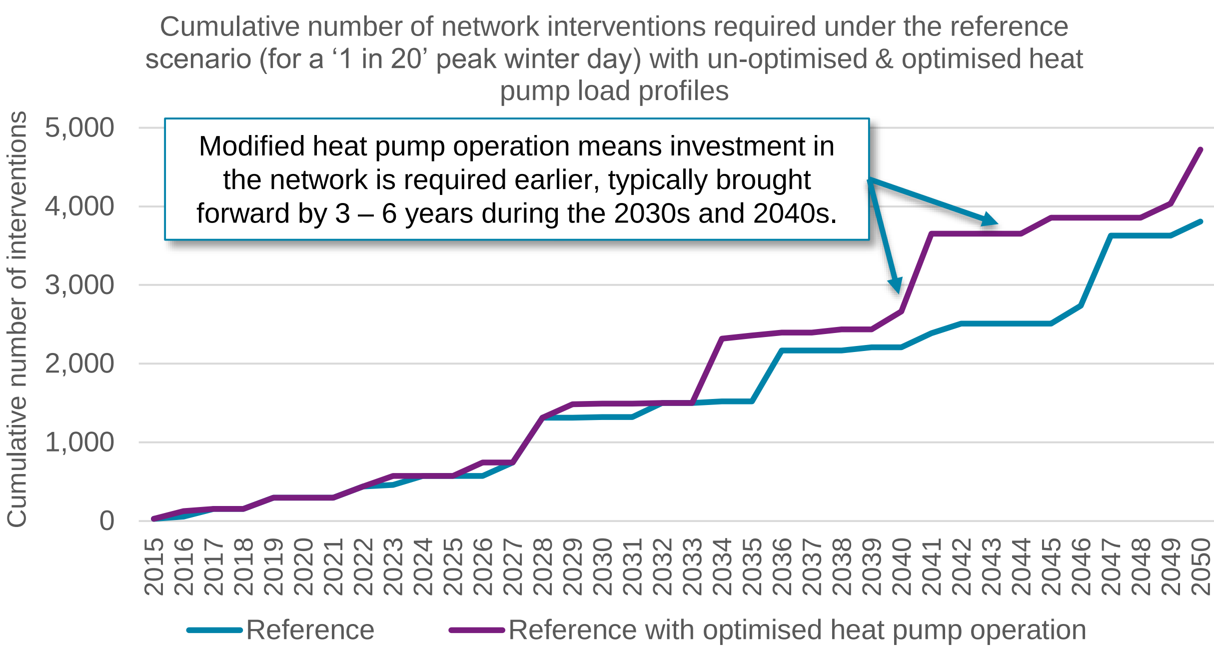
Reference scenario

HT ASHP in semi

‘1 in 20’ winter day

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



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

30% increase

** 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.*

Agenda

1. Introduction & focus of this webinar
2. Development of heat pump load profiles
3. Scenarios for heat pump uptake & impact on the distribution network
4. Optimisation of heat pump operation & impact on the distribution network
5. Summary

A few key messages

1. **Electrification of heat using heat pumps will increase winter electricity demand by around 2.5 kW – 5.5 kW per household.**

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.**

3. **The Transform Model suggests this could result in network investment costs of £100s millions to £ billions being required by 2050.**

4. **'Optimisation' of heat pump operation in the interests of other energy system stakeholders could increase peak loads on the distribution network by 5 – 15% on 'average' peak winter days, and as high as ~25% on a '1 in 20' peak winter day.**

For more information…

Stephen Harkin, Delta-ee

Stephen.harkin@delta-ee.com

Dr Rita Shaw, Electricity North West

Rita.Shaw@enwl.co.uk

- E-mail us for a **copy of the presentation**
- **We'd be delighted to talk with you** by phone or in person

Download the report here:

http://www.enwl.co.uk/about-us/the-future/nia-lcnf-tier-1/demand-scenarios