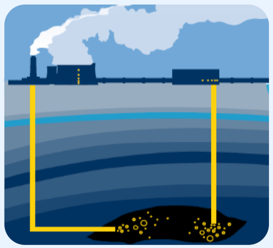


Electric Vehicle and Heat Pump Frequency Responsive Consumption

National Grid - NIA

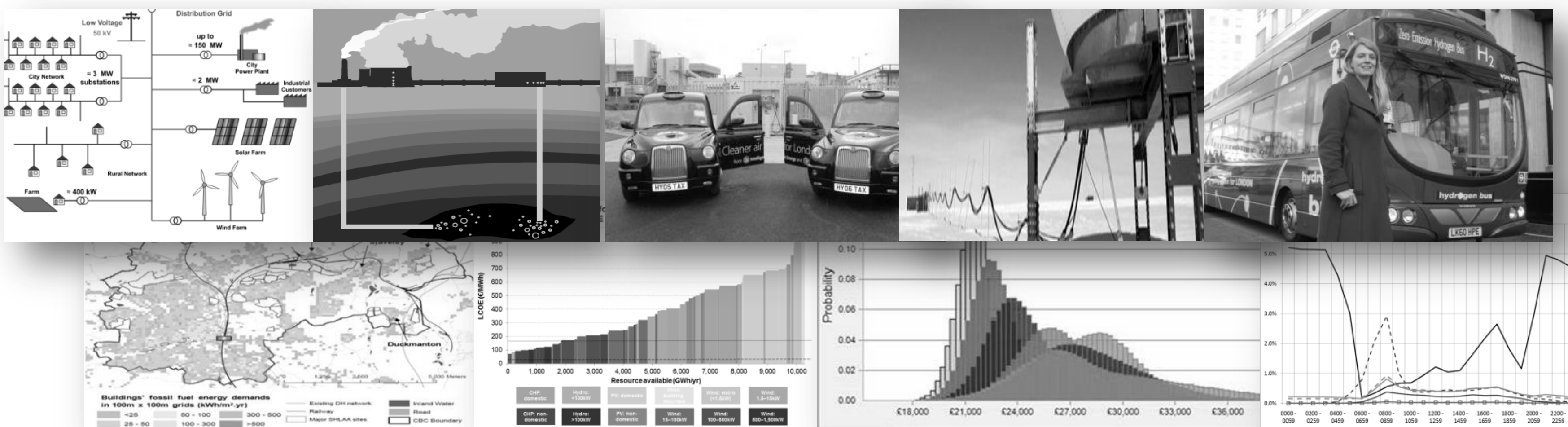
September 20th 2015

Element Energy Ltd
Joris Besseling
(joris.besseling@element-energy.co.uk)
Rebecca Feeney-Barry
(rebecca.feeney-barry@element-energy.co.uk)

Element Energy – a consultancy dedicated to the energy sector

- Element Energy is a **specialist energy consultancy**, with an excellent reputation for rigorous and insightful analysis.
- We provide consultancy services across a wide range of low carbon energy sectors, including: **smart electricity and gas networks, energy storage, carbon capture, renewable energy generation, built environment** and **low carbon vehicles**.
- We consult on **technical and strategic issues** – our technical and engineering understanding of the real-world challenges supports the strategic work and vice versa
- Our **dedication to fully addressing clients' needs** is often noted as a distinguishing feature of our approach

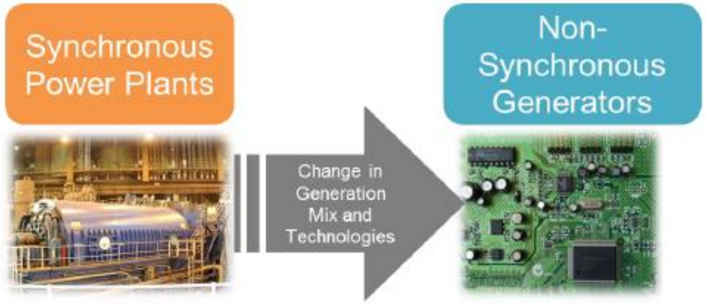
Energy technologies modelling	Consumer behaviour modelling	Energy network modelling	Advance geographic modelling	Project management
Policy recommendations	Strategic market analysis	Commercialisation strategies	Techno-economic studies	Project financing



Contents

Decarbonising electricity system poses new challenges for the system operator

Change in electricity generation



- More intermittent supply
- Network congestion
- **Reduction in system inertia**

Reduction of system inertia

- **System inertia will decrease**
- Especially at time of low demand and high renewable generation

And pose challenges for the system operator

- Plant outage will have a greater impact on system frequency
- Rate of change of frequency (RoCoF) in case of an event may increase, posing challenges for system stability.
- National Grid's System Operability Framework (SOF) showed that managing the frequency of the electricity system within statutory limits will therefore become increasingly challenging in the future.

Frequency responsive consumption is one of four options identified in the System Operability Framework to address these challenges

New approaches to address declining system inertia are being considered by National Grid

The SOF identified possible approaches to dealing with the reduction in system inertia, including:

- Increasing system inertia using de-clutched operation of synchronous generators;
- Synthetic inertia from non-synchronous generators;
- Shifting demand to low demand periods, potentially using energy storage
- **Use of demand side response**.

Demand side response is a strategic opportunity for National Grid

Duncan Burt, Head of Commercial Operations at National Grid

On balancing services from demand side sources: "We'd like to be buying 30 to 50% by 2020. To put that in numbers, that would mean we would be spending £200 million to £400 million a year on demand side services in Great Britain. That's an enormous amount. That's a huge market."[1]

Launch of Power Responsive Campaign

1. Coordinated approach
2. Education & Engagement
3. Customer-led Products
4. Certainty & Stability

1: http://www.energylivenews.com/2015/06/22/national-grid-to-spend-up-to-400m-on-demand-response/

New low carbon loads may pose further challenges, but also opportunities to support frequency management. Viability is however unclear

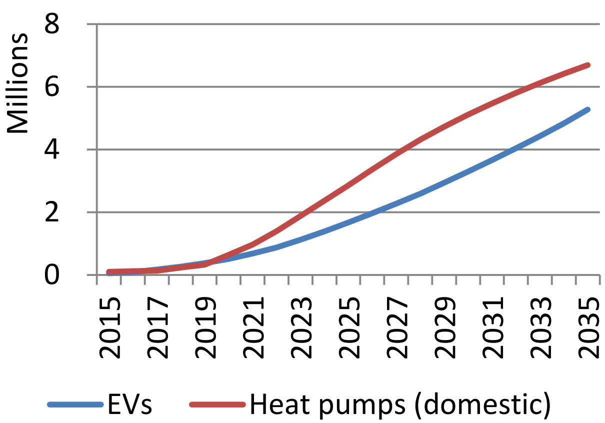
New low carbon loads may pose further challenges…

High uptake may pose **challenges**;

network operability (e.g. steep demand increases if HPs switch on simultaneously)

and network planning (e.g. peak demand increase)

EV and heat pump uptake in Gone Green scenario (FES 2015)



…and Demand Side Response opportunities…

May support **network management by providing energy services**;

- **Potentially flexible loads**;
  - Heat pumps: operation flexibility with storage or building thermal inertia
  - EVs: large inherent storage capacity and potential to schedule charging or deliver to the grid
- Supported by **developments in controls and automation**
- May provide **revenue streams or bill reductions** to customers

..but frequency management potential still unclear.

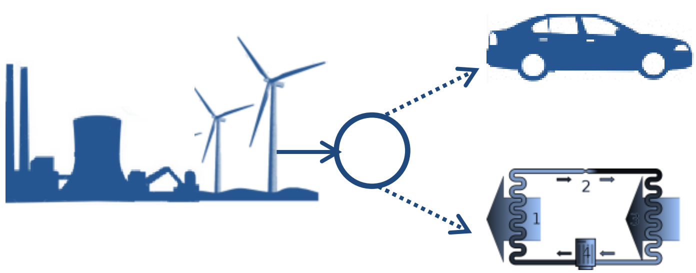
- **Limited experience** with frequency response from domestic customers or demand technologies
- **Little understanding of demand profiles** and flexibility for different EV and HP users
- **Technical requirements and barriers**
- **Route to market and infrastructure requirements**

[1] Source: National Grid Future Energy Scenarios (2015)

Project objective: understand the potential and challenges of EVs and heat pumps to contribute to frequency response requirements

EVs and heat pumps could provide services

- Large scale uptake of EVs and heat pumps may change the daily electricity demand profile and, without adequate measures, could pose further challenges to balancing the system.
- These technologies may also provide an opportunity to support network management and may be suited to provide system services because of the flexibility in their operation.



Aim to understand potential and challenges

- Determine the **technical potential and impacts** for EVs and heat pumps to provide frequency services.
- Look at the technical and commercial **barriers to implementation.**
- Determine the **potential benefit to asset owners** and examine the possible commercial models for service provision.
- Examine the necessary **next steps in the roll out** of frequency response provision by EVs and heat pumps.

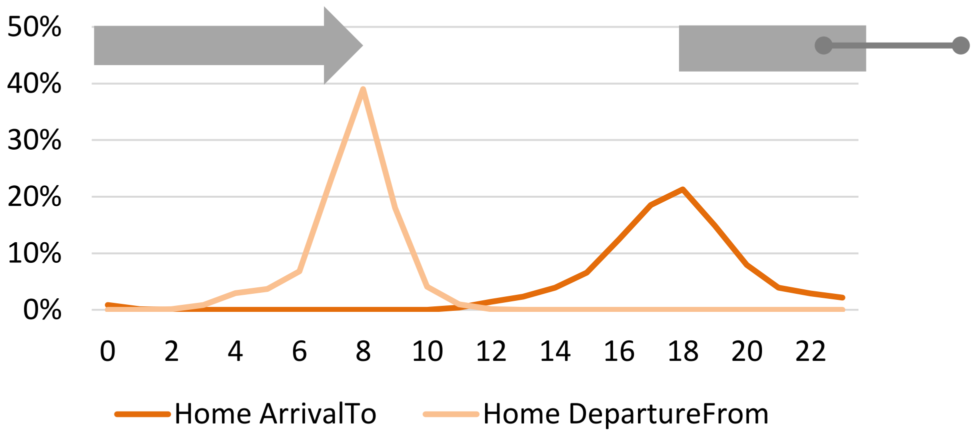
Contents

Storage and building thermal inertia allow EV charging and heat pump consumption to be shifted in response to system frequency deviations

Flexibility inherent in EVs and heat pumps enables frequency response provision

- EVs and heat pumps are potentially flexible loads:
  - EVs have a large inherent storage capacity and potential to interrupt and schedule charging
  - HPs have flexibility in operation due to storage, or thermal inertia in building

Illustrative EV home arrivals and departures



Plugged in overnight for hours

Typically need 2-3 hours to charge

EV charging options;

- interrupt charging
- charge more EVs than scheduled
- (export to the grid)[1]

Frequency response

Low frequency response

High frequency response

Low frequency response

[1] Not in scope of the study

Modelling approach

1 Key analysis parameters

Response service requirements

- Response time
- Duration
- Diurnal availability and utilisation requirements (historic National Grid frequency response requirements and turn out)

2 Participant archetypes

Characterise distinct groups

e.g. use profile and flexibility, unit power

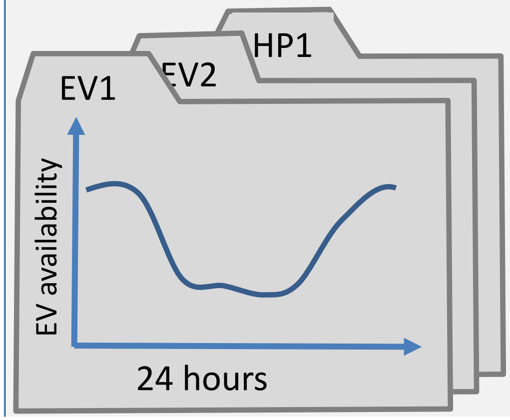
EV1 = residential

EV2 = fleet operator

HP1 = residential

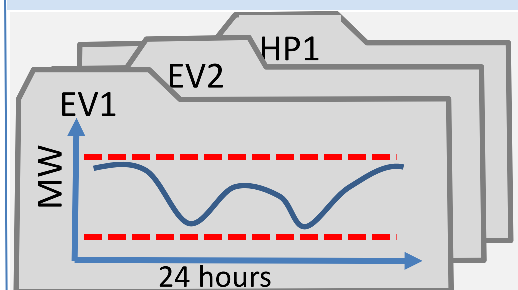
HP2 = I&C

3 Baseline consumption



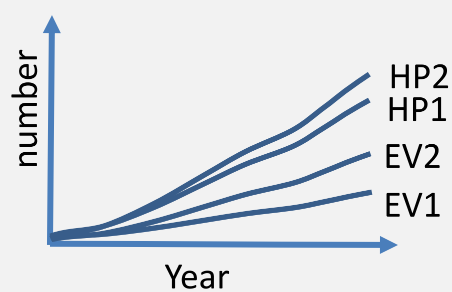
Freq responsive charging

4 Potential service provision

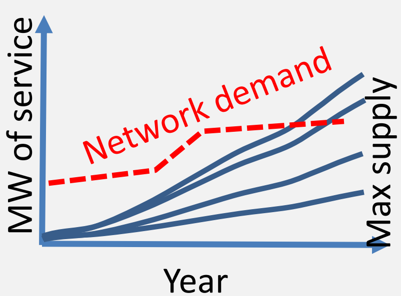


- Service requirements
- Customer constraints:
  - EV charged at departure
  - HP 180l storage cylinder

5 Technology supply



6 Constraints and potential

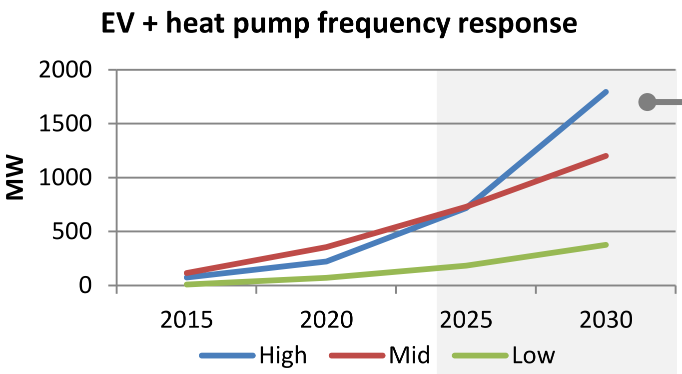


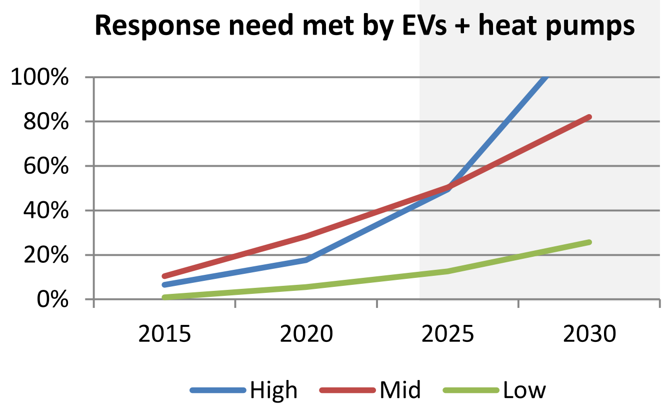
Contents

- Project background
- Approach
- **Results**

Technical potential for EVs and heat pumps combined, to provide average 1200MW in 2030, meeting 80% of frequency response requirements

With increasing deployment EV and heat pumps combined have the technical potential to provide a significant part of frequency response requirements



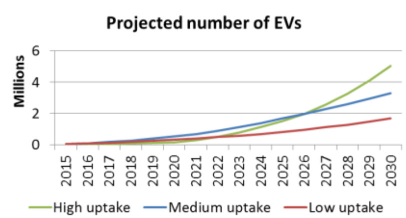


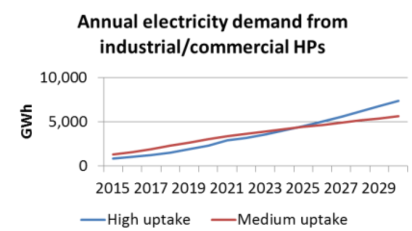
Response potential of home charging, work charging and fleet EVs, and industrial/commercial heat pumps

As the technical potential of EVs and heat pumps covers an increasingly significant fraction of requirements, other factors may be limiting;

- Incumbent and competing providers
- Cost effectiveness / decreasing marginal benefit
- Impact of large DSR share on pricing and procurement of services

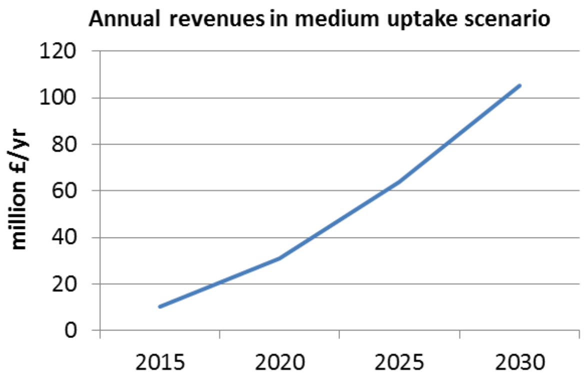
EV and heat pump deployment projections





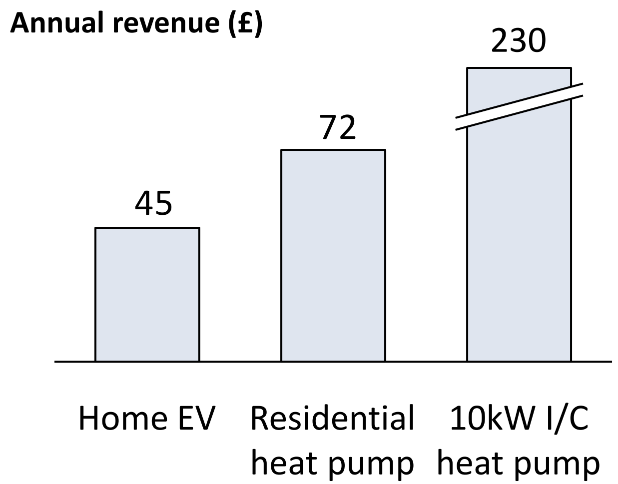
Although this represents significant system value, the diluted revenue at an individual asset level may pose a challenge to incentivise development

Significant system value



- Response potential of home charging, work charging and fleet EVs, and industrial/commercial heat pumps
- 2015 average availability payment of £10/MW/hour

Revenue diluted at an individual asset level



Market opportunities to address diluted value

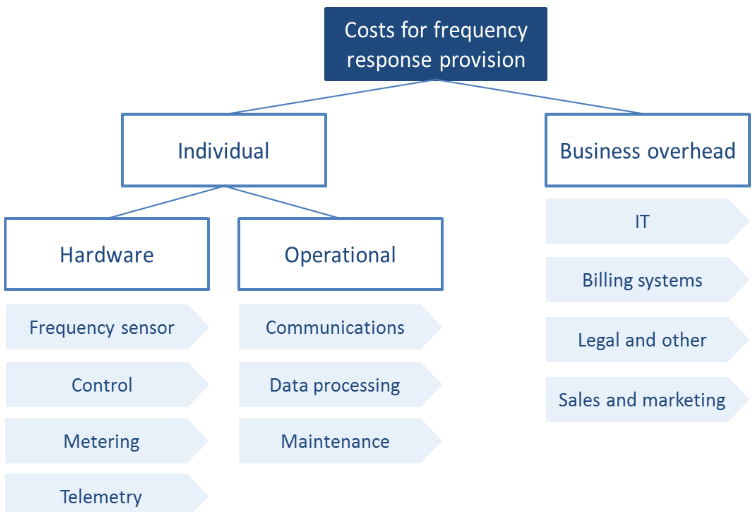
- Combine frequency response with **provision of other DSR services**
- Develop EV export to the grid
- Include as addition in other **consumer focussed management platform**

Procurement opportunities to address diluted incentive

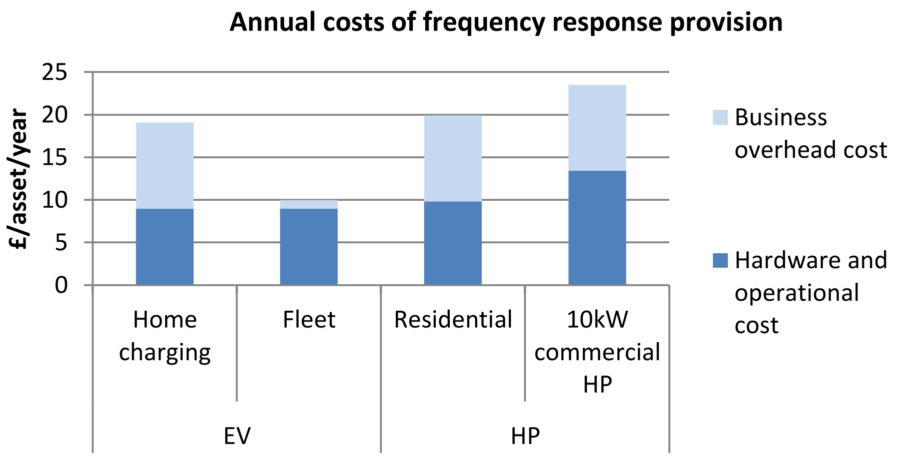
- Especially EVs may be able to provide very fast and accurate response, providing more effective response and reducing overall requirements, if reflected in prices this may increase EV benefit

Service costs include; asset hardware, operational costs and business costs

Cost components to provide response



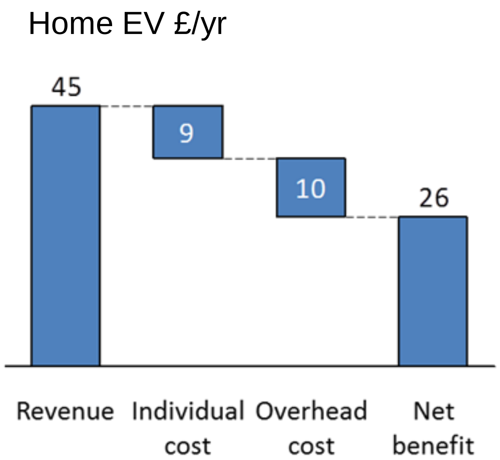
Total costs per asset type



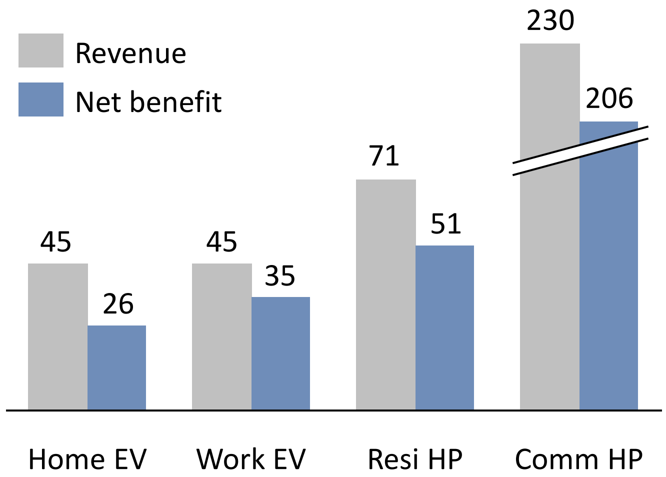
Fleet EV and commercial heat pump costs are lower due to opportunity to share (smart charging) infrastructure and economies of scale

The analysis shows that EV and heat pump frequency response revenues are higher than costs of implementing service

Breakdown of costs to provide response



Net benefit per asset type

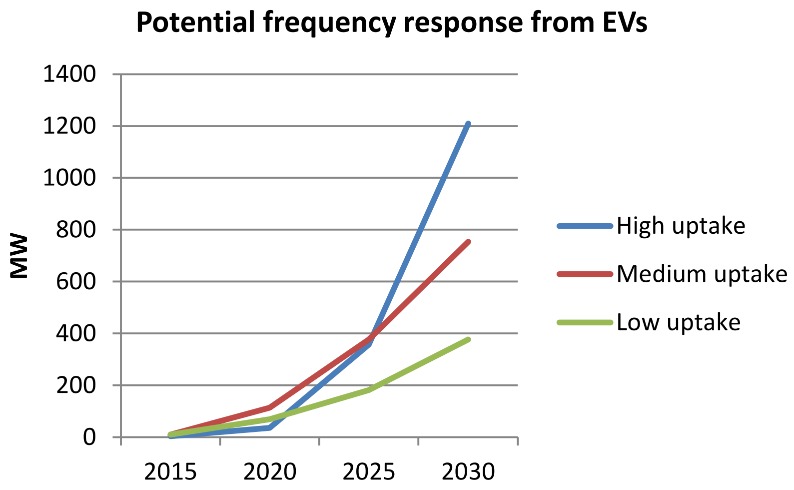


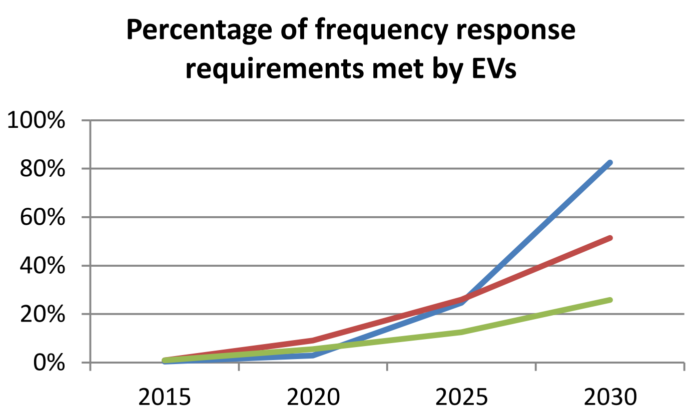
Further market opportunities to address diluted value

- Initially target **market segments with high potential net benefit: high revenues or potential to share (smart charging) infrastructure costs**, e.g. work fleet charging, commercial&industrial heat pumps

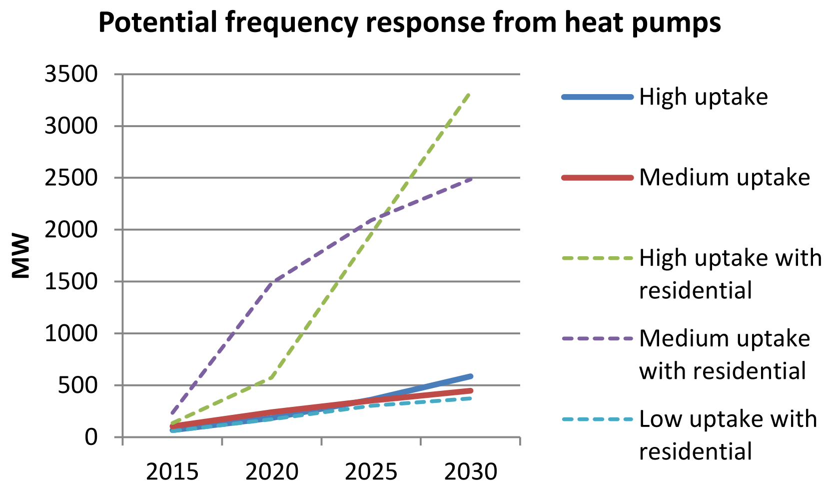
Analysis shows that both EVs and heat pumps have significant system potential

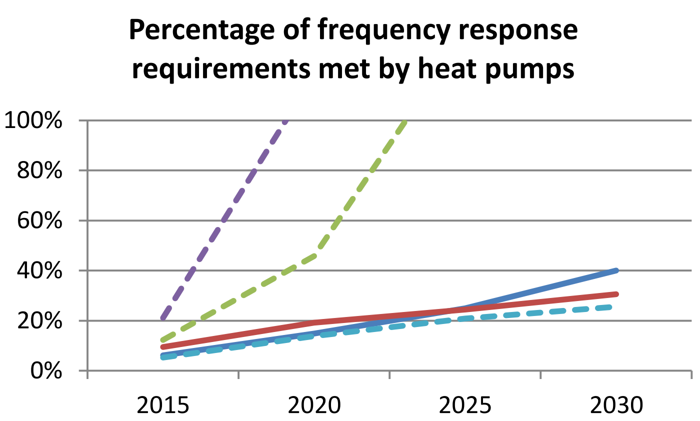
Potential response from EVs



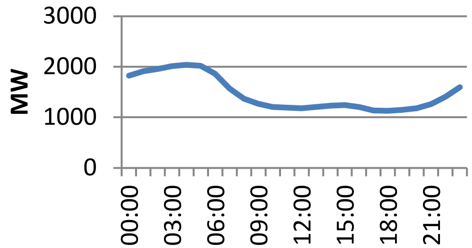


Potential response from heat pumps





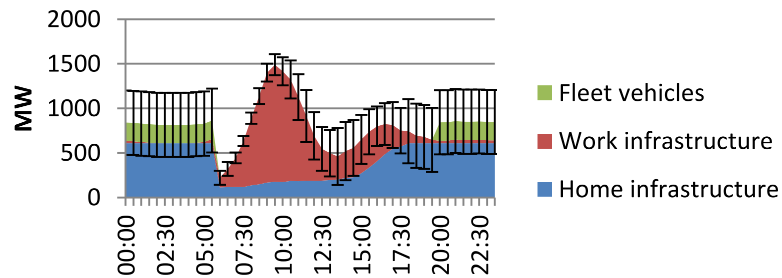
Individual asset net benefit for heat pumps is higher, but EVs provide a more sustained diurnal response…



National Grid's frequency response requirements are highest during the night, when system demand is low.

EVs

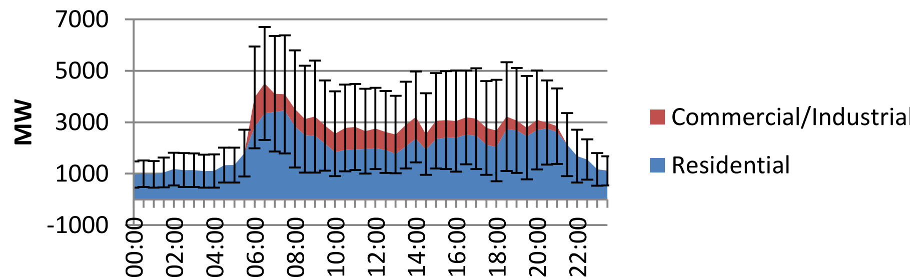
Diurnal variation in response from EVs



- For a home charging EV, the net benefit of frequency response provision is £25/year, or £35/year for a fleet EV.
- However, with smart charging, EVs offer a sustained level of service over the night.

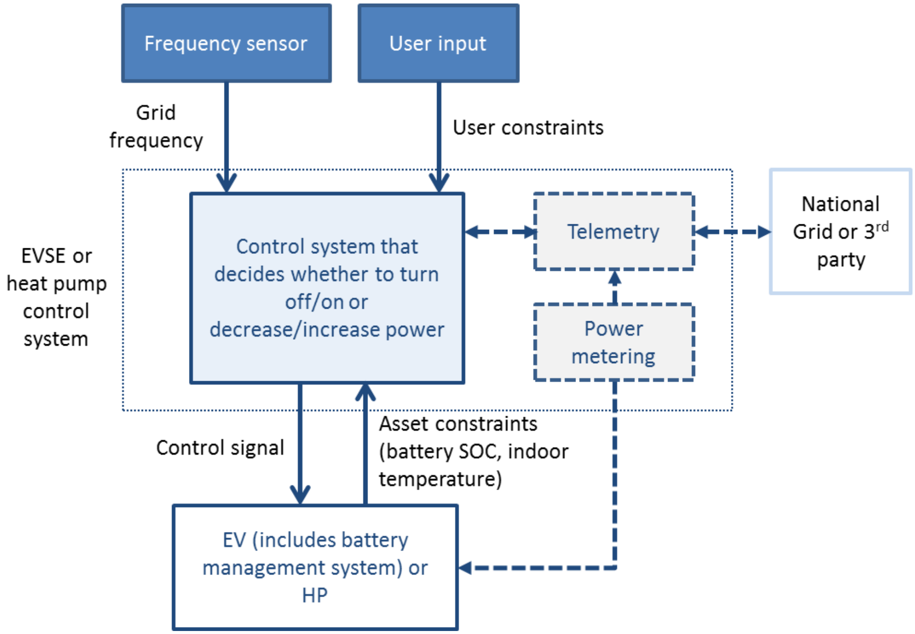
Heat pumps

Diurnal variation in response from heat pumps



- For a residential heat pump, the net benefit is higher at £51/year, or £200/year for a 10kW I/C heat pump.
- However, heat pumps, particularly I/C, offer a lower level of response overnight, when system need is highest.

Technical components for frequency responsive demand systems



EV and heat pump control systems require additional components to enable frequency response

- Dynamic frequency response requirements can be met by;
  - Modulating individual asset consumption, or
  - **Statistical control settings to emulate aggregated modulating response**
- Control signal may be provided by;
  - **Locally measuring system frequency and local response settings (current process)**
  - Centrally measuring frequency and instructing assets (increases response time)
  - National Grid broadcasted regulation signal (based on system frequency)

No fundamental technical limitations to enable frequency responsive consumption, but further technology development required

Technical development	EVs	Heat pumps
Hardware capability	• Charging -interruption or -reduction without significant adverse effects • Batteries particularly well suited to provide fast, accurate response	• Not all heat pumps can meet ramp-up speed requirements, and ramp-down may be limited for control and safety • Frequent cycling key issue for compressor, may be addressed aggregating many systems • Flexibility depends on thermal storage; in store (uncertain) or fabric (large variation, largely untested)
Control & automation	• EVSE do not typically provide all capabilities (e.g. EV signals charging, communication standards to notify SOC) • Frequency responsive charging may impact current safety settings	• Control systems do not typically provide all capabilities

Retrofitting may be expensive: ensure capabilities are defined, trialled, developed into standards and implemented in new equipment alongside service development

Manufacturers require a driver to address these in subsequent design iterations

No fundamental technical limitations to enable frequency responsive consumption, but further technology development required

Technical development

EVs & heat pumps

Telemetry & verification

- No standard platforms for communications;
  - Open protocols; supports interoperability, challenge to support extensive functionality
  - Range of proprietary protocols; more readily adaptable to provide extensive functionality, interoperability a challenges
- Metering and verification requirements key aspects in platform development; individual asset response verification requires high bandwidths and low latency

Clarify metering and verification requirements for development of platforms

No fundamental technical limitations to enable frequency responsive consumption, but further technology development required

Technical development	EVs	Heat pumps
Operation & network impacts	TSO: Correlated responses many distributed loads may result in system frequency oscillations. May be addressed in control design, with control over; response characteristics (in-out frequency sensitive mode, set dead band levels, adjust dynamic response characteristics). May require more extensive NG-aggregator-asset interaction DNOs: Reduction in demand diversity (especially after low frequency event), not expected to be general issue, but may pose challenges for already stressed parts of the network; • Voltage stability, especially in areas that are net-generation • Thermal overloads transformers • Harmonic emissions into the network (especially if charge rates are modulated in EVs with low performance inverters) • Transient effects on very localised level (flicker) IF EVs or heat pumps are part of an ANM area, frequency response actions may be negated by ANM	

TSO issue; develop control design, may require more extensive NG-aggregator-asset interaction

DNO issues; may require processes to be developed between DNOs and National Grid to identify where clustered uptake may result in issues on the distribution network in frequency response

Commercial models for frequency sensitive consumption of large fleets of small assets need proving; key issues and opportunities

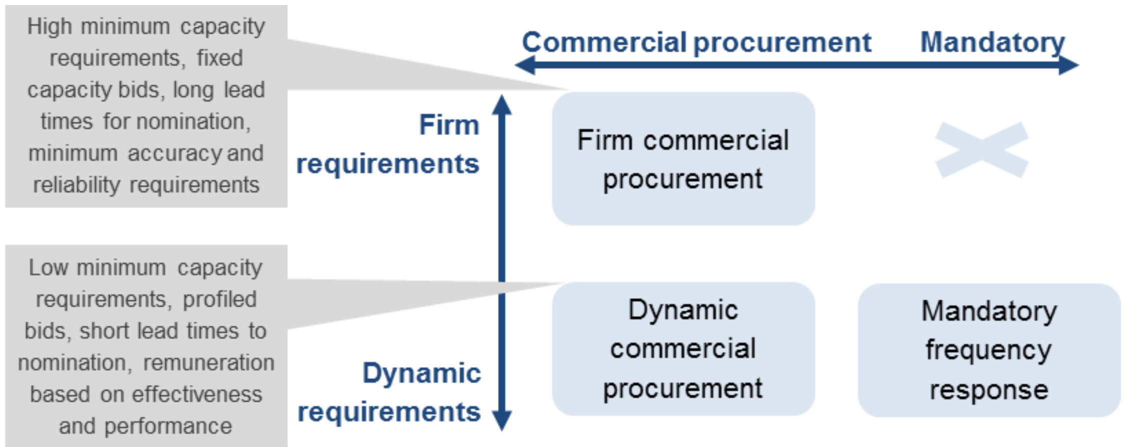
Key issues

- Diurnal variation in response available
- Service guaranteed through diversity
- Predictability of response
- Higher effectiveness of response from some assets
- Interaction with provision of other types of DSR by EVs and heat pumps
- Impact on distribution network and electricity suppliers (imbalance, settlement)
- Limited net benefit of frequency response on an individual basis

Opportunities and potential solutions

- Profiled bids or portfolio aggregation
- Adaptation of reliability requirements to reflect diversified reliability
- Shorter lead times to nomination of capacity
- Utilisation of fast and accurate response capabilities, and provision of equitable remuneration for these capabilities
- Transparency between DSR users
- Transparency of (aggregate) frequency response and coordination
- Combination with other DSR uses
- EV export to the grid
- Include as addition in other consumer focussed management platform

Commercial models for frequency sensitive consumption of large fleets of small assets need proving;



	Advantages	Disadvantages
Firm commercial procurement	• Most similar to current procurement	• May not unlock full response capability and value of demand assets • May not unlock full demand potential
Dynamic commercial procurement	• May unlock high response capability and value of assets • Supports development of novel propositions (with other DSR uses)	• Significant changes in procurement and processes • May not unlock full demand potential (diluted value)
Mandatory	• May unlock full demand potential (diluted value)	• Significant change in response management • May inhibit development of novel propositions • Range of asset capabilities & consumer constraints/preferences

Next steps to develop EV and HP frequency responsive services

Development of EV and heat pump frequency response

Commercial market development

1. Strategic agenda & business case
2. Enabling deployment
3. Market access

Impact on other stakeholders

1. Power quality (DNO)
2. Thermal overload and voltage stability
3. Settlement and supplier balance

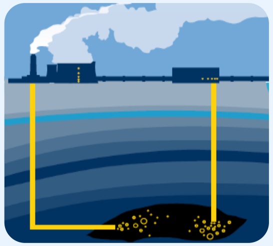
Technology and proposition development

1. Hardware capability
2. Control & automation
3. Telemetry and verification
4. Delivery model

Wrap up

Power responsive campaign	Outputs from this study
1. Coordinated approach Address barriers with industry	• Identifies key barriers and issues across stakeholders
2. Education & Engagement Awareness and clearer value proposition	• Public study demonstrating the potential scale of the opportunity • Shows potential value of propositions
3. Customer-led Products Creating a package of products that work for demand users	• Identifies key product issues and opportunities of EV and heat pump frequency response
4. Certainty & Stability Ensuring DSR is a long term investment proposition	• Demonstrates long term potential • Outlines next steps for development • National Grid support for NIA study shows engagement with the opportunities that EVs and heat pumps may provide to manage the electricity system







Electric Vehicle and Heat Pump Frequency Responsive Consumption

National Grid - NIA

September 20th 2015

Element Energy Ltd
Joris Besseling
(joris.besseling@element-energy.co.uk)
Rebecca Feeney-Barry
(rebecca.feeney-barry@element-energy.co.uk)