Assessing the benefits of flexibility in residential and transport sectors with a whole energy systems model, UK TIMES

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Outline

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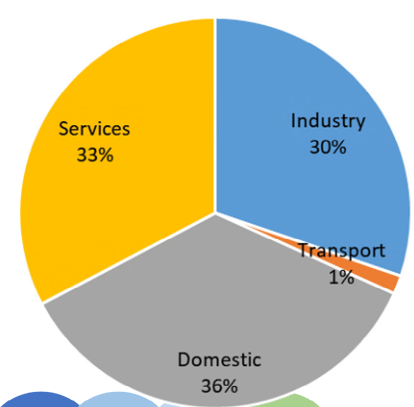
- UK TIMES
- Modelling framework for DSR
- Results
- Conclusions and Future Works

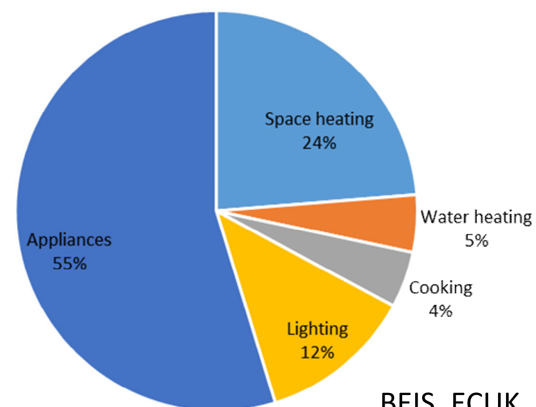
Introduction

- 2008 UK Climate Change Act: 80% reduction by 2050
- Electricity demand could be **50%~135% higher** than now (CCC, 2015)
- Electricity sector should be deeply decarbonised.
  - With VRE (up to **~46%** of total capacity by 2050) (National Grid, 2017)
- **Demand-side flexibility** is a promising measure to balance electricity supply and demand in the future UK low-carbon energy system.

Elc consumption by sector



Elc consumption by type in the residential sector



BEIS, ECUK, 2017

UCL

Previous studies

- Many previous studies have aimed to assess the benefits of demand-side flexibility in energy systems.
  - National-scale studies
    - Fehrenbach et al. (2014); Drysdale et al. (2015); Nistor et al. (2015); Stötzer et al.(2015); Teng et al. (2016); Gils (2016); Strbac et al. (2015)
  - Subnational-scale studies
    - Mahbub et al.(2016); Neves et al.(2015); Jaramillo and Weidlich(2016); Soares et al.(2016); Ayón et al.(2017)
  - Whole energy systems model-related studies **(very limited)**
    - Pina et al. (2014); Krakowski et al. (2016)
- Weakness of those studies:
  - Only focused on **a single sector**, or used **detailed electricity system model**, or **adopt projection** of DSR potential from other studies, without endogenously reflecting demand-side flexibility in the model
- Modelling demand-side flexibility in a **whole energy systems model**
  - **Long-term energy transition planning**
  - **Dynamic interactions between sectors**

- **Only focus on Direct Load Control via smart grid/smart system**

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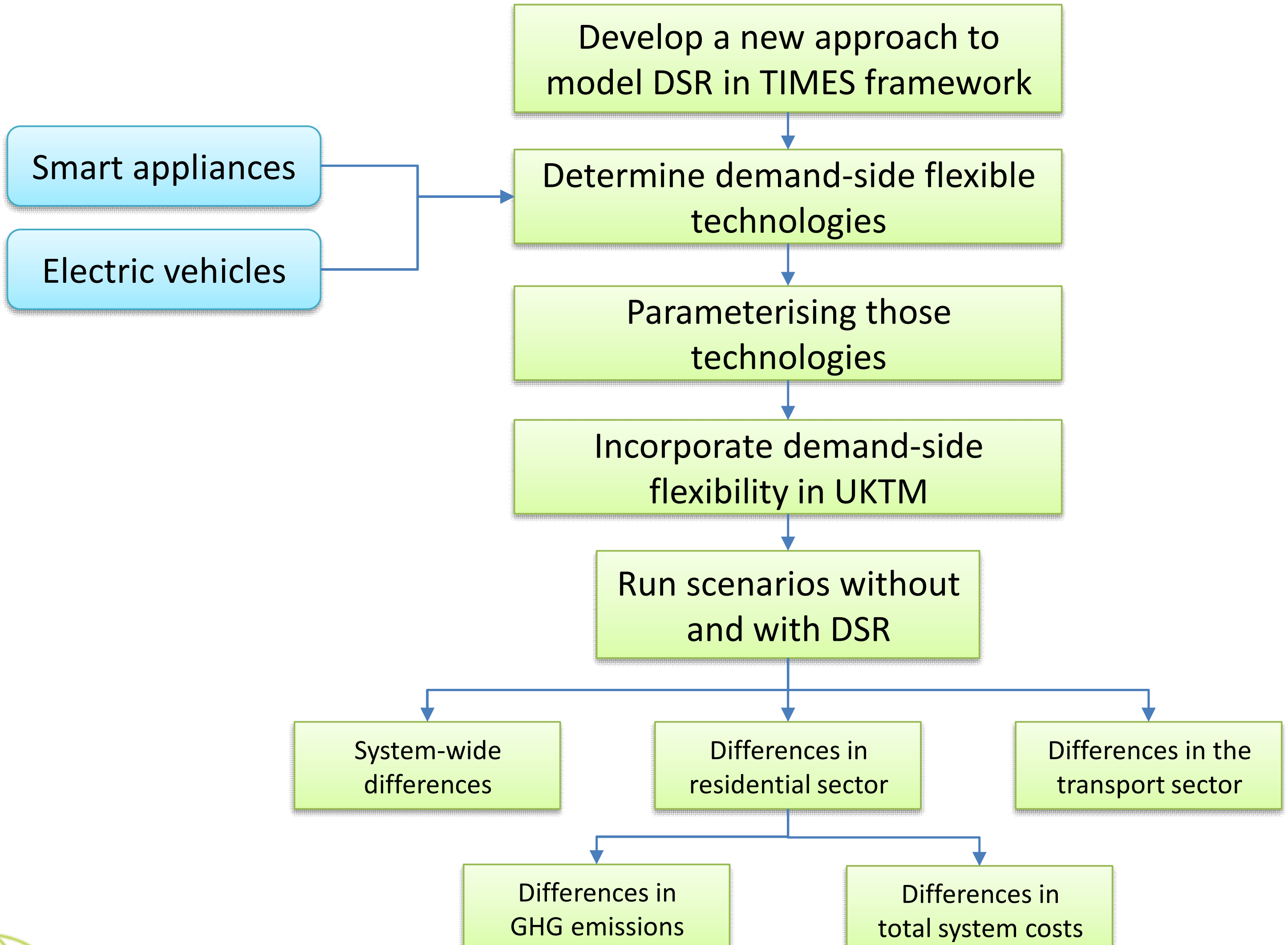
Research Procedure



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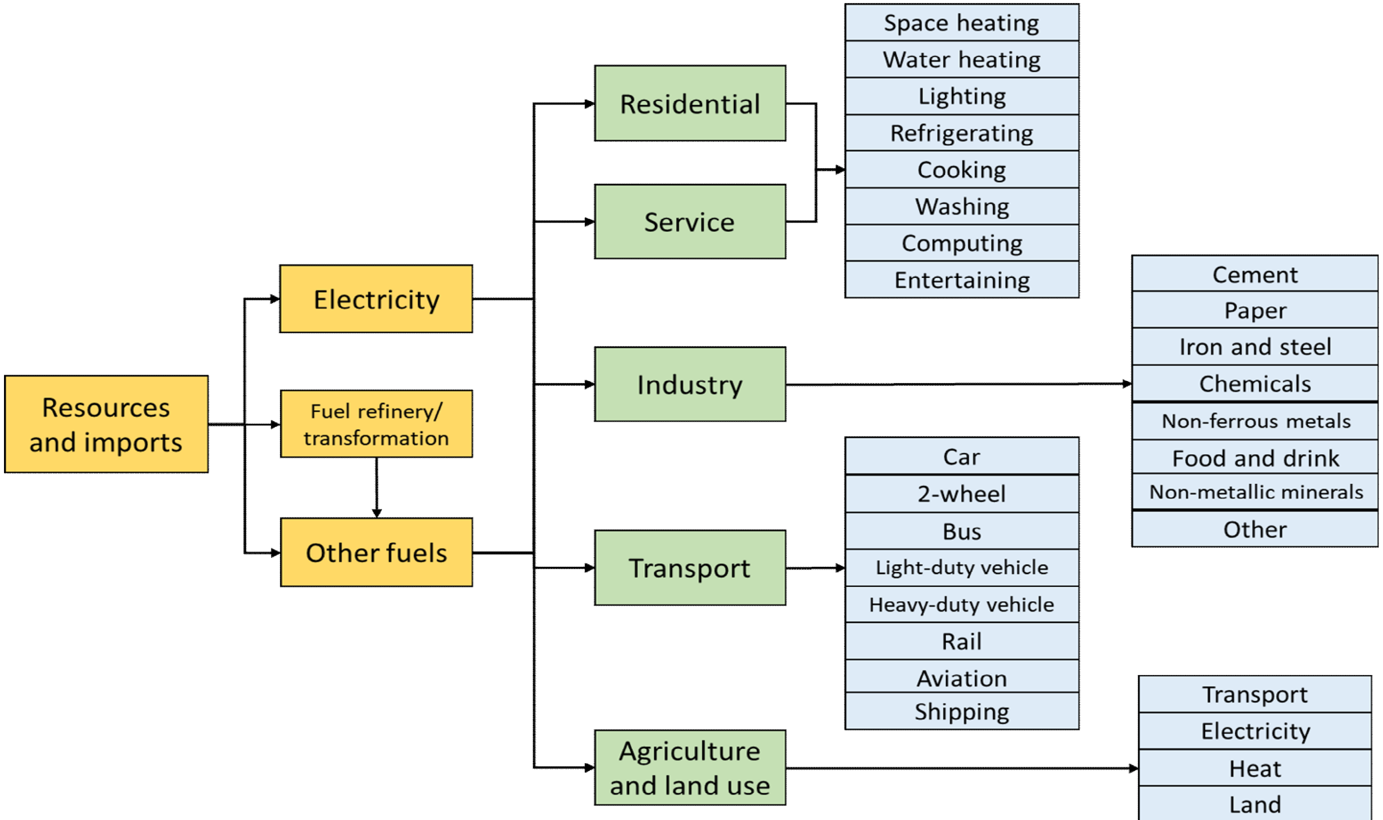
UKTM-The UK TIMES Model

- Developed by UCL Energy Institute with BEIS under wholeSEM project
- A whole energy systems model
- Technology-rich, Minimum cost
- Adopted by UK government (BEIS, CCC) for policy making

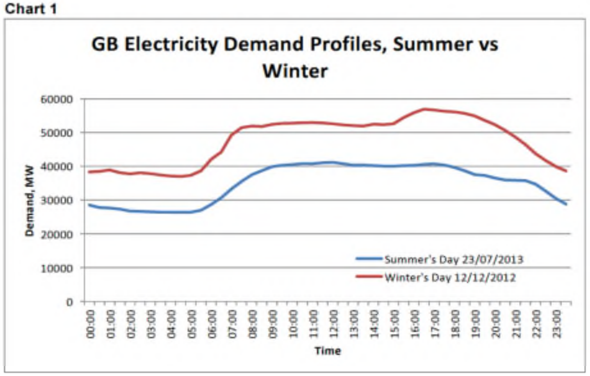


Temporal Representation in UKTM

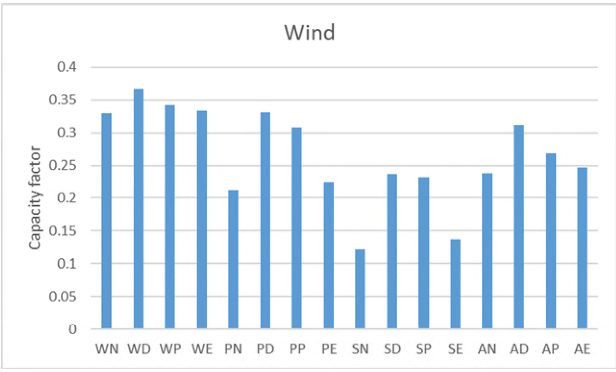
- Temporal representations of technologies are **based on empirical evidences**.

Season	Intra-day period	Time represented	Notes
Spring (P)	Night (N)	00:00–07:00	Lowest demand
Summer (S)	Day (D)	07:00–17:00	Includes morning peak
Autumn (A)	Evening peak (P)	17:00–20:00	Peak demand
Winter (W)	Late evening (E)	20:00–00:00	Intermediate

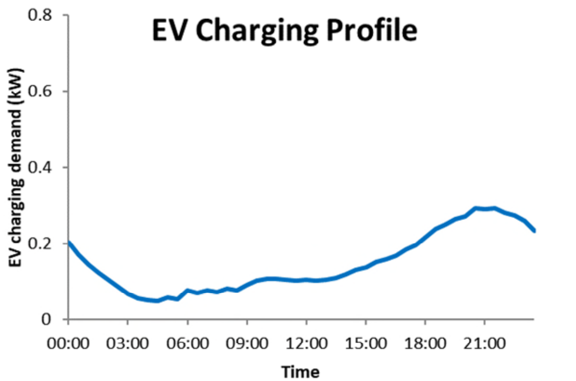
Chart 1



Source: Gavin, C. Special feature – Seasonal variation in electricity demand. DECC. 2014.



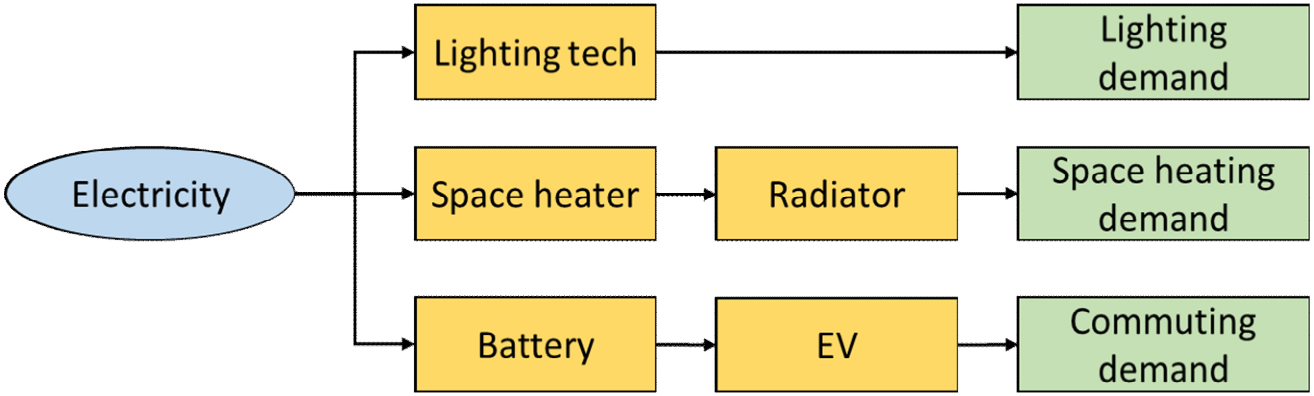
Sinden G. Characteristics of the UK wind resource: Long-term patterns and relationship to electricity demand. Energy Policy 2007



(Source: Low Carbon London, 2014, EV trials, Report 5-1

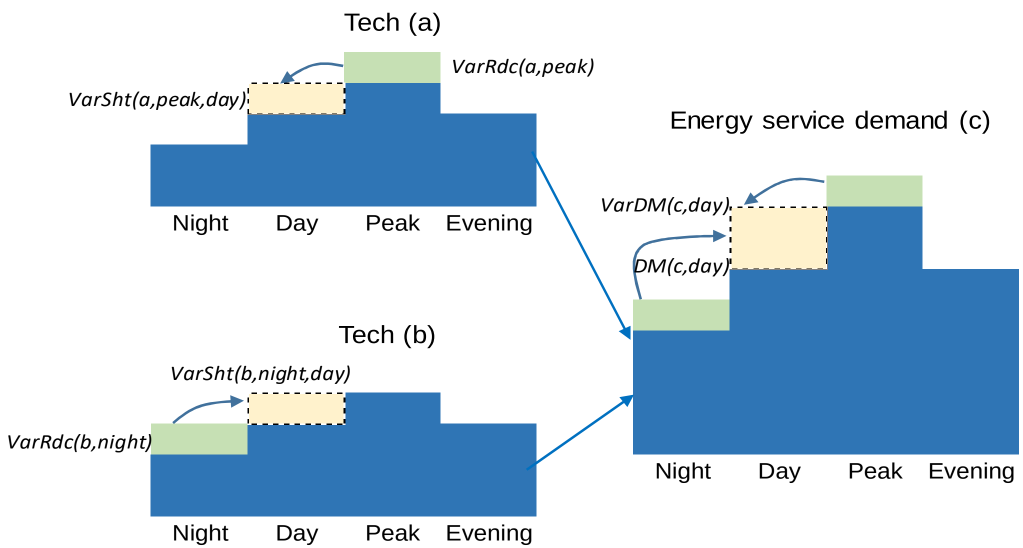
Challenges of modelling DSR in UKTM

- Lacking of existing modelling framework in the TIMES model
- Energy service demand (ESD)
  - Determined exogenously → basically fixed
  - Elastic demand → can only be reduced, not shifted
- ESD can be fulfilled by technologies using various fuels
  - Not all technologies should be considered
- Complicated modelling structure



Enhancing representation of DSR in UKTM

- New modelling framework
  - Following existing expandable TIMES model generation framework
  - Applicable to all flexible technologies
- Optimal scheduling of DSR is still determined by the original objective function



Parameterisation of DSR

- **Smart appliances won't cause too much hassle to consumers**
- **Potentials:** suggested by literature
- **Smart penetration rate:** deployment of smart meters by 2020 in the UK

Technology	Shifting mechanism	Shiftable potential	Smart penetration rate in 2020	Smart penetration rate in 2050
Lighting	Consumer behaviour	0%	0%	0%
Oven/Stove	Consumer behaviour	0%	0%	0%
TV/Computer	Consumer behaviour	0%	0%	0%
Washing machine	Central control	100%	0%	100%
Tumble dryer	Central control	100%	0%	100%
Water heater	Central control	1 hour	0%	100%
Space heater*	Central control	1 hour	0%	100%
Refrigerator/ Freezer	Central control	1 hour	0%	100%
Electric vehicle**	Central control	100%	0%	100%

*Electric night storage heaters, heat pumps and district heating from electric heaters and heat pumps are included.

**Only passenger EVs are taken into account.

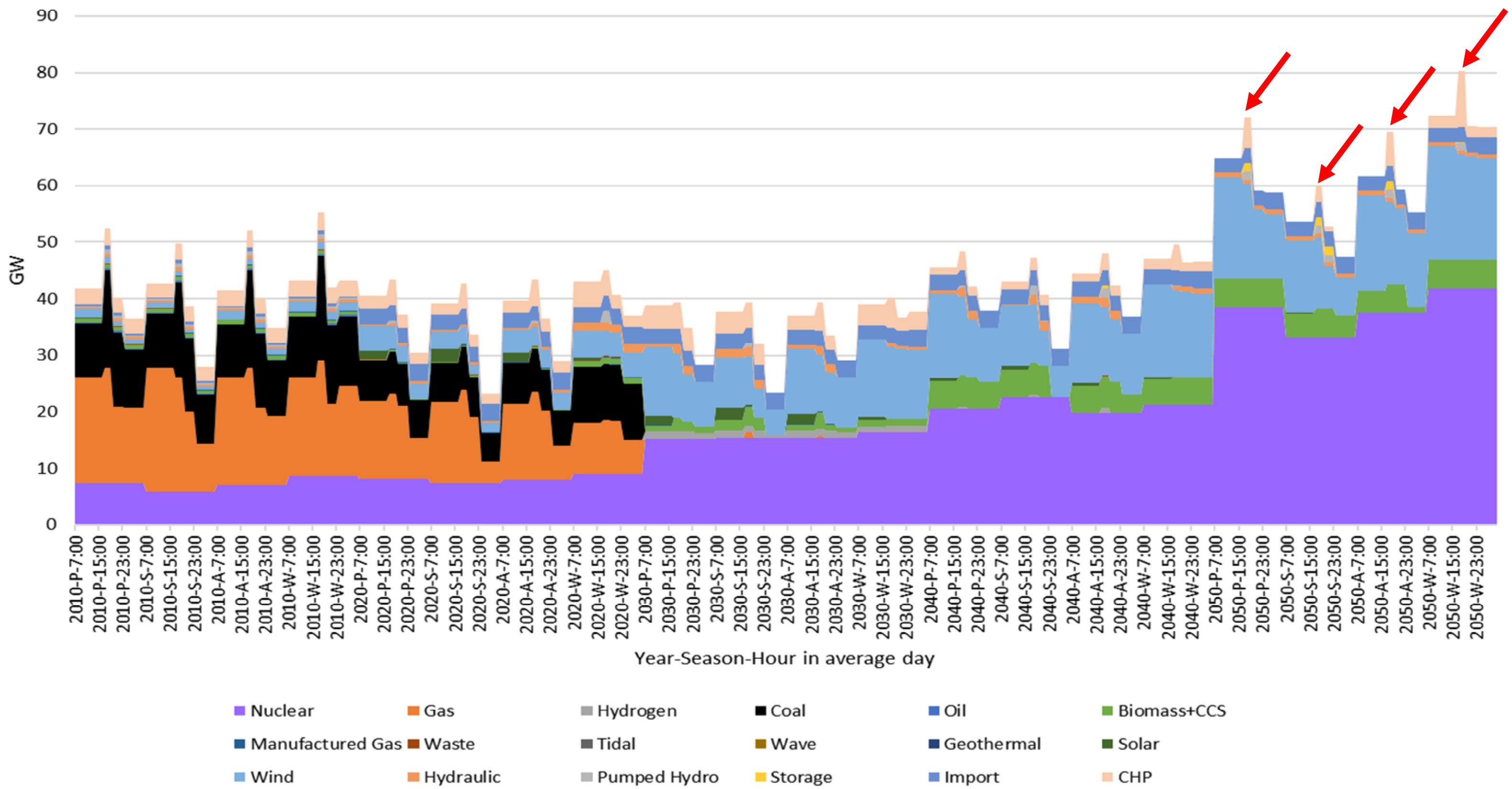
Scenarios: w/o and w/ DSR

- **To reveal the influences of demand-side flexibility from smart appliances and EVs on whole energy systems**
- **GHG targets:**
  - **The Climate Change Act 2008**: 80% reduction on 1990 level by 2050
  - **5th Carbon Budget:** 57% reduction on 1990 level by 2030

Scenario	GHG targets	Preference settings
LowGHG_Ref	• 80% reduction on 1990 level by 2050 • Carbon budgets (1st to 5th) • Bans on new petrol and diesel cars and vans from 2040	Without demand-side flexibility
LowGHG_DSR	• 80% reduction on 1990 level by 2050 • Carbon budgets (1st to 5th) • Bans on new petrol and diesel cars and vans from 2040	With demand-side flexibility

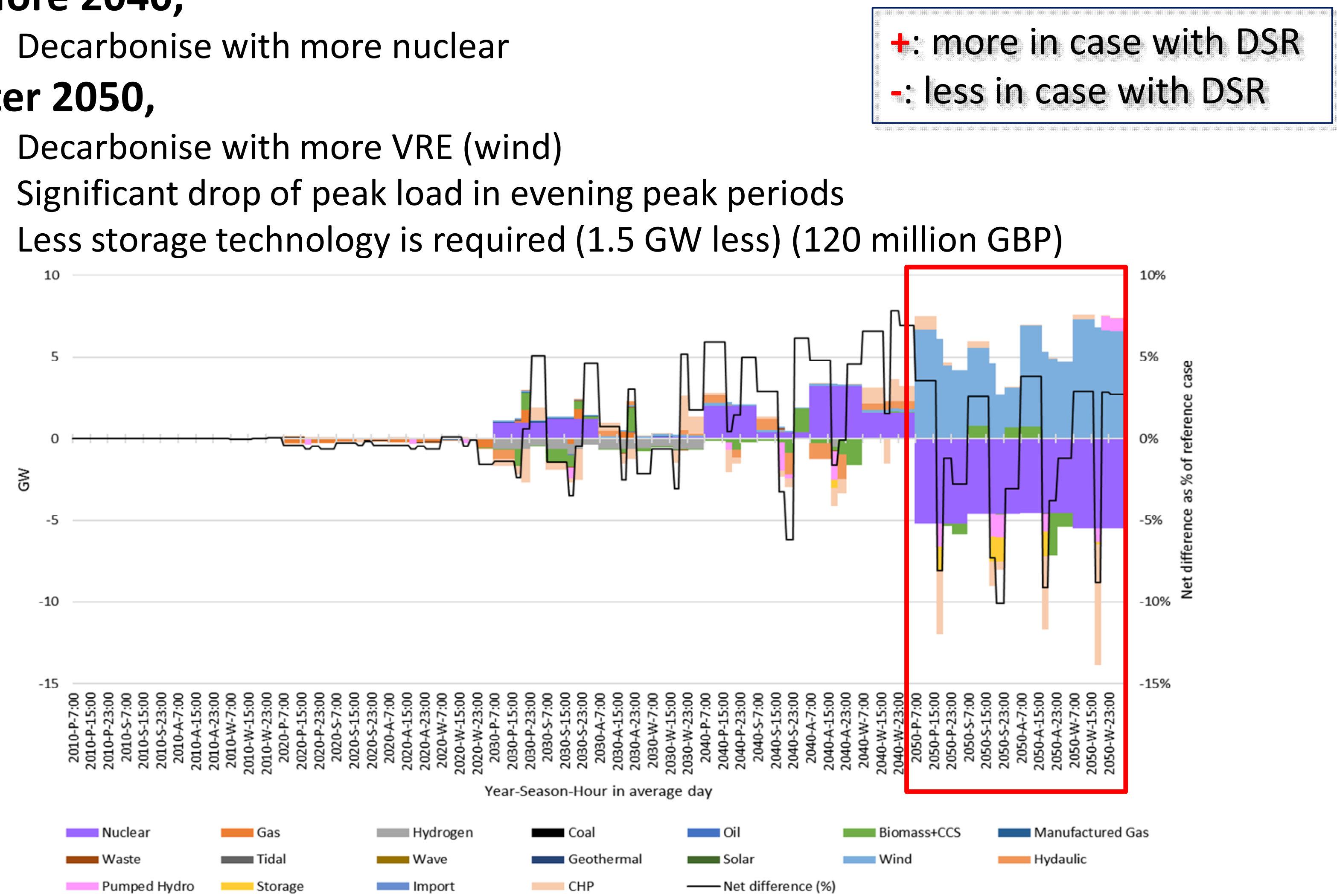
Electricity Supply of the Reference Case

- **Decarbonise electricity sector with nuclear and wind power, along with biomass + CCS**
- Evident peak loads in every season by 2050 (~10GW higher)



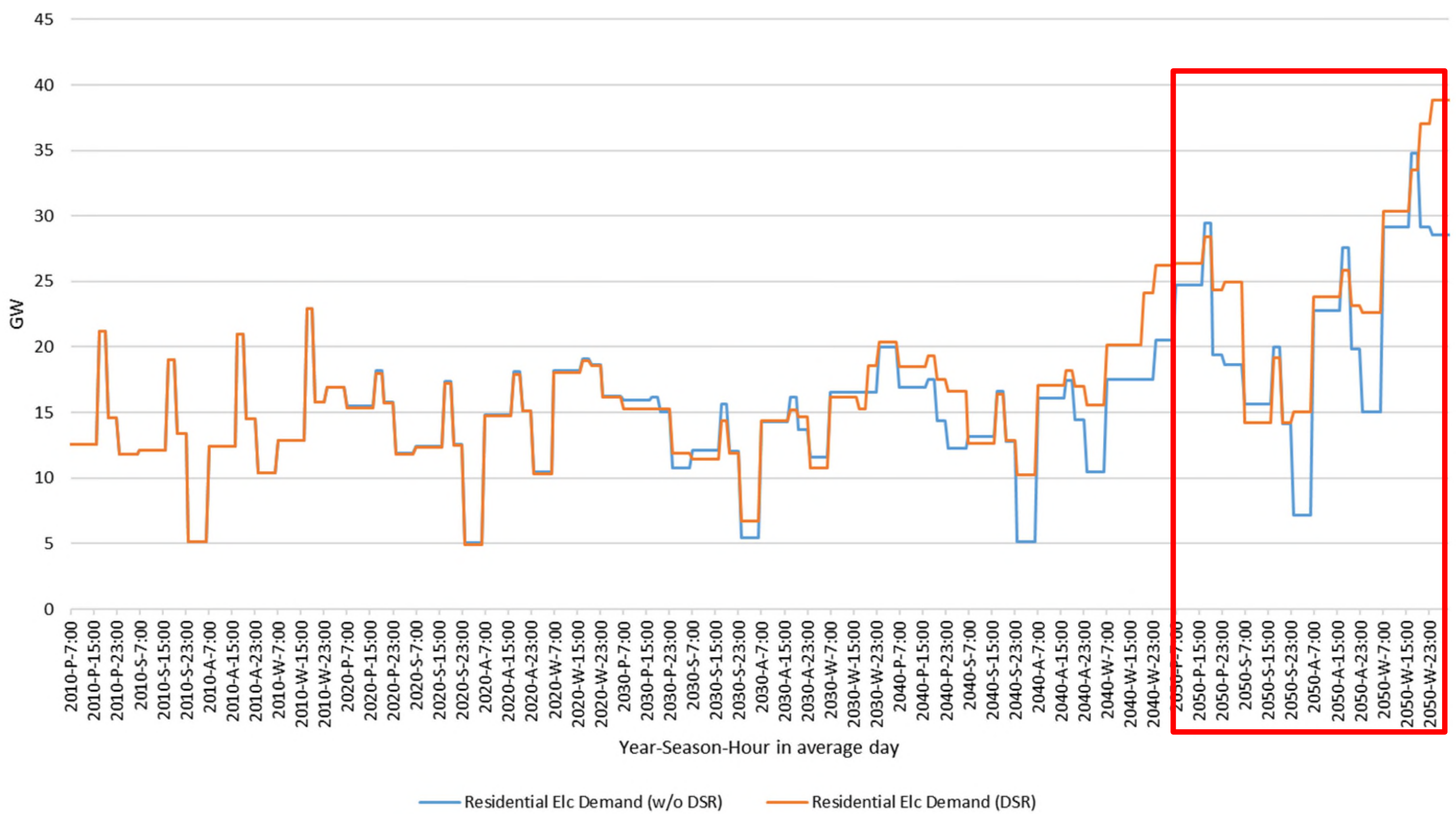
Differences in Electricity Supply and Demand

- **Before 2040,**
  - Decarbonise with more nuclear
- **After 2050,**
  - Decarbonise with more VRE (wind)
  - Significant drop of peak load in evening peak periods
  - Less storage technology is required (1.5 GW less) (120 million GBP)



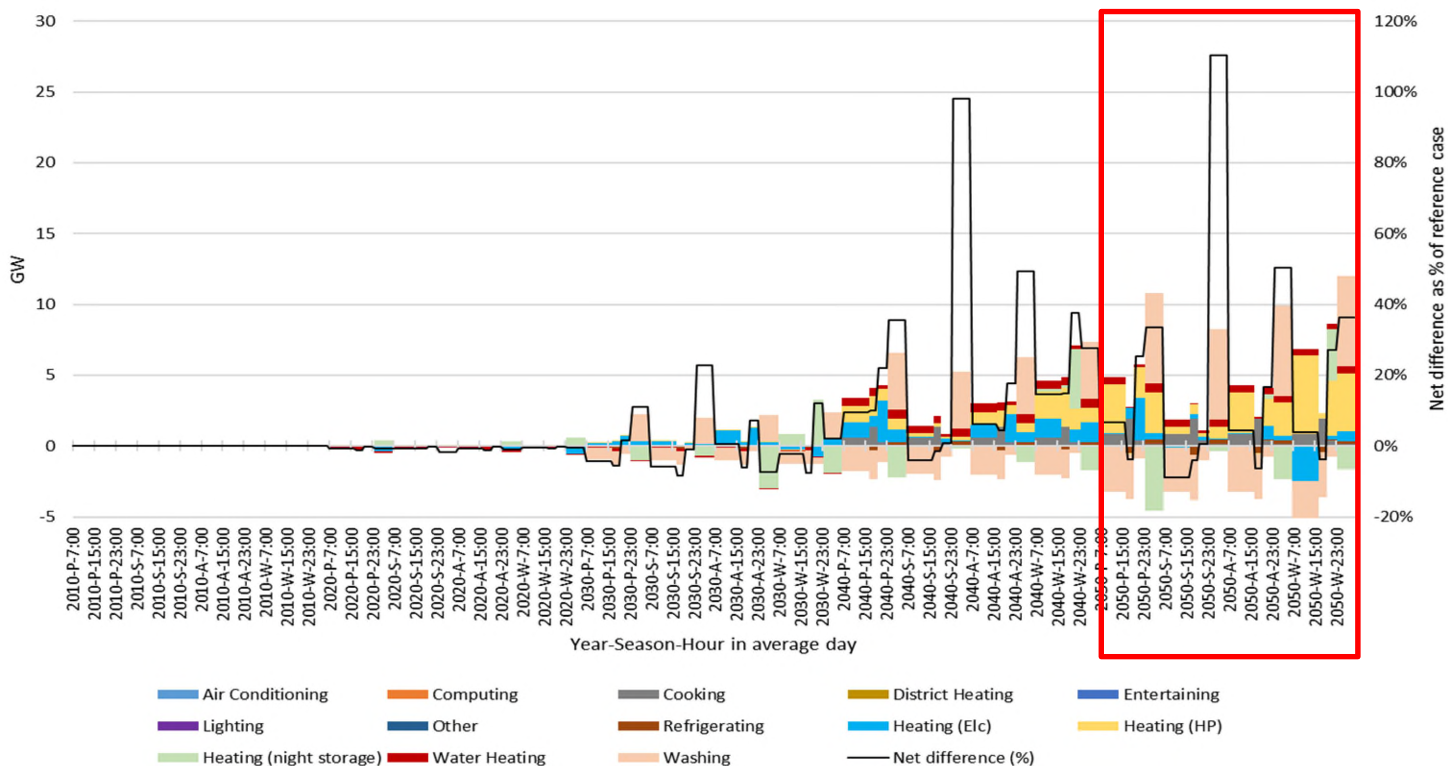
Demand Profiles in the Residential Sector

- **Demand is shifted away from period load period**
- In 2050, the electricity demand is much higher in the case with DSR



Differences in the Residential Sector

- **Heating** is shifted from peak load period to day and night times
- **Cloth-washing** is also shifted from peak load period to night time
- More **Elc stoves** are adopted
- **Elc heaters and Night storage heaters** are replaced with heat pumps



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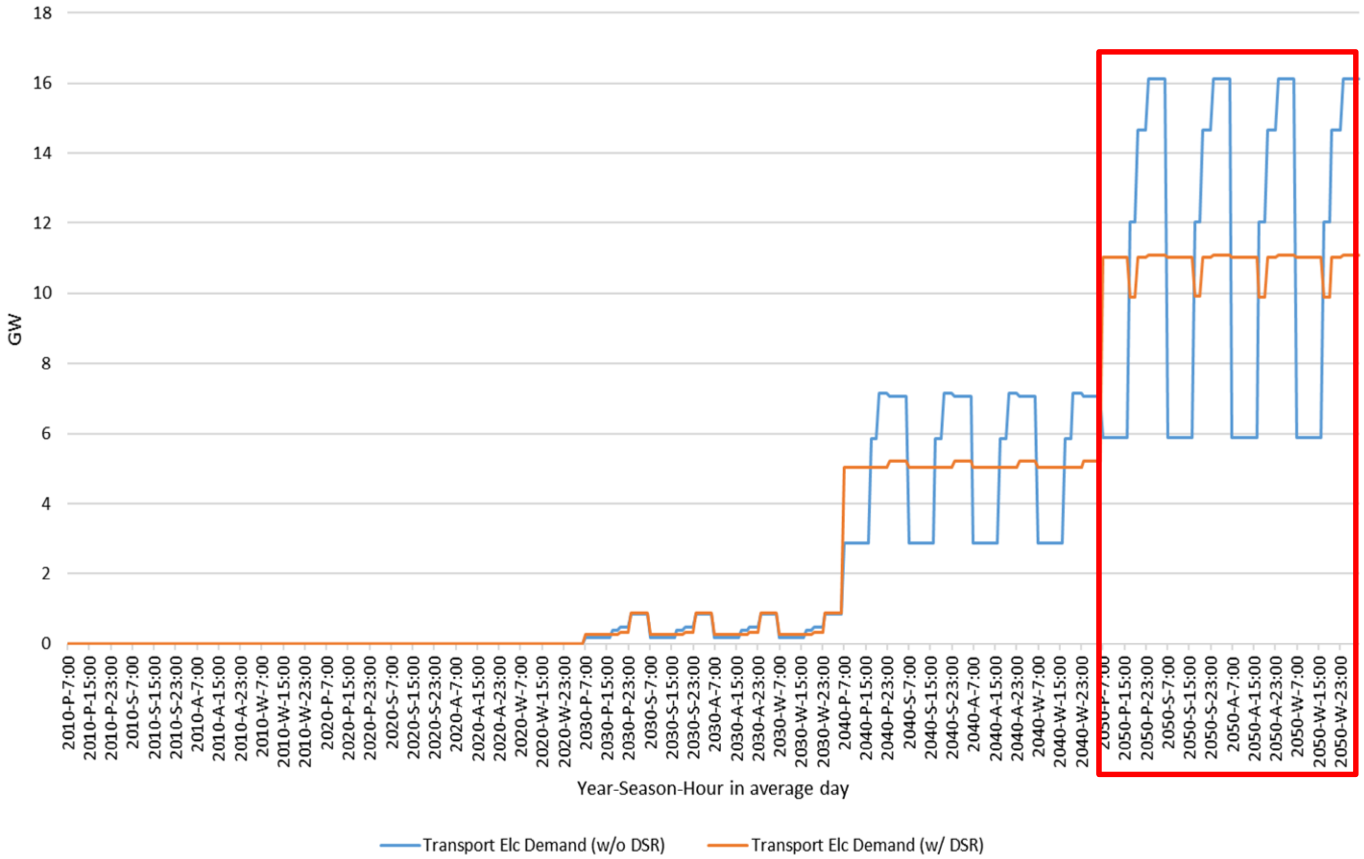
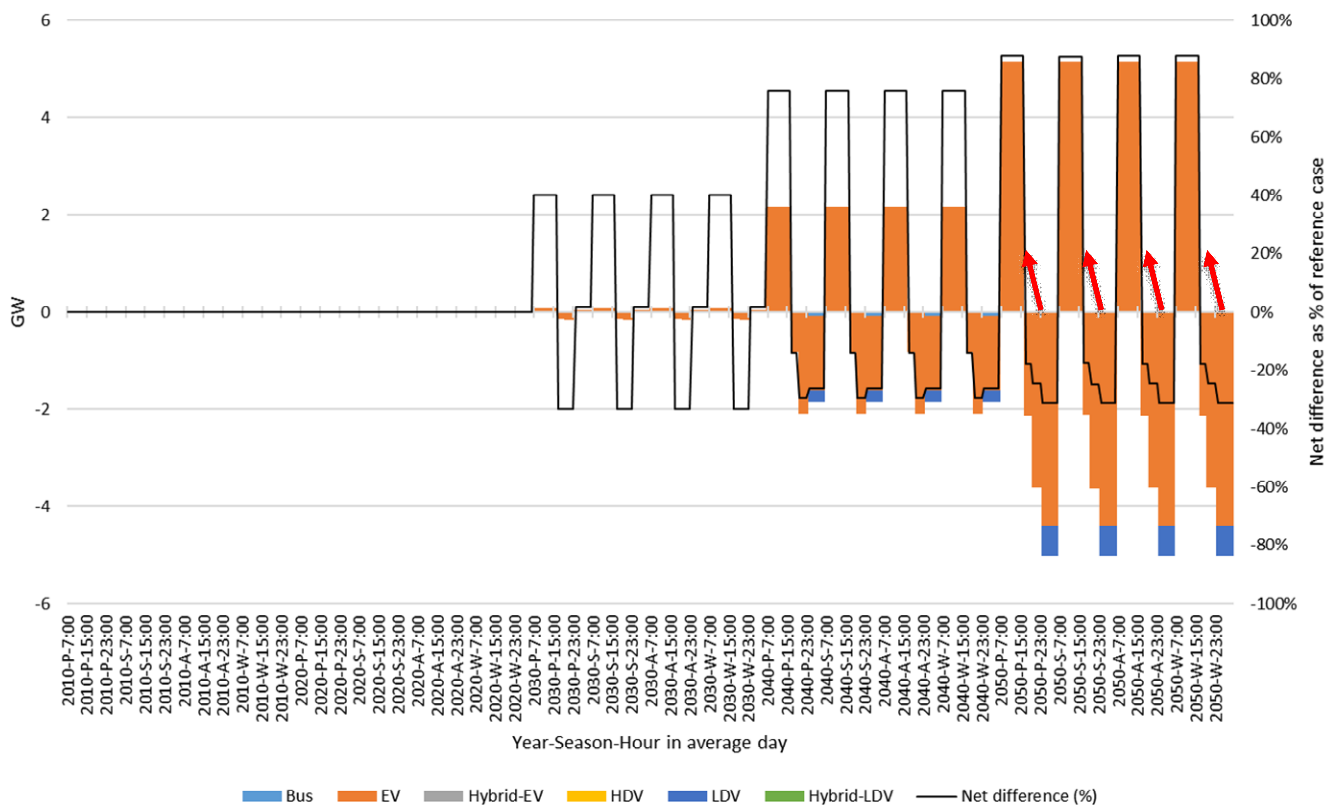
Differences in the Transport Sector

- Loads are shifted away from peak load periods to daytime
- Loads in night time have also been reduced dramatically



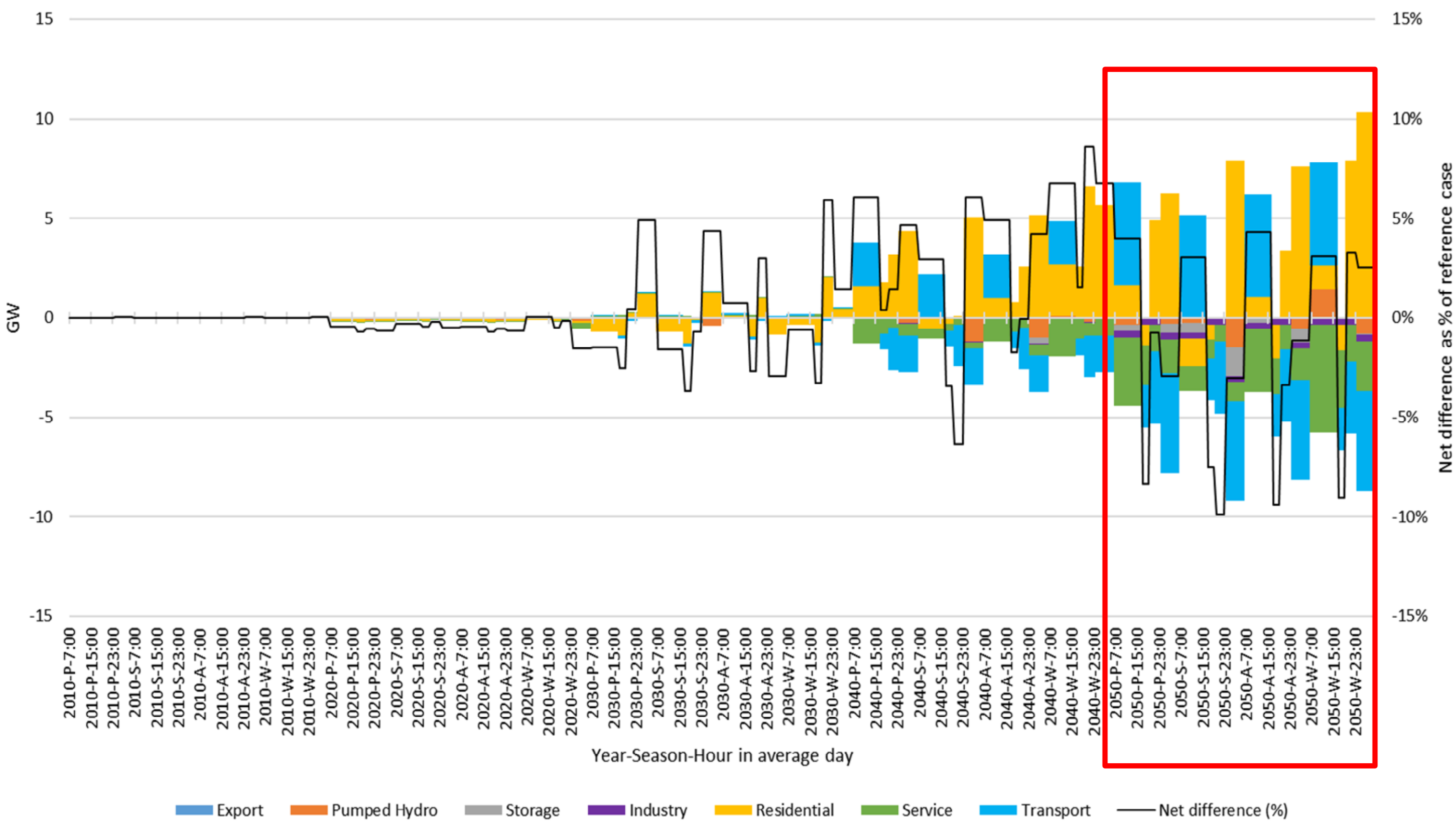
Differences in the Transport Sector

- **Passenger EVs:** charging loads are shifted to daytime (working places)
- **Elc LDVs:** much less (lower loads in night time; higher LDVs using fossil fuels)

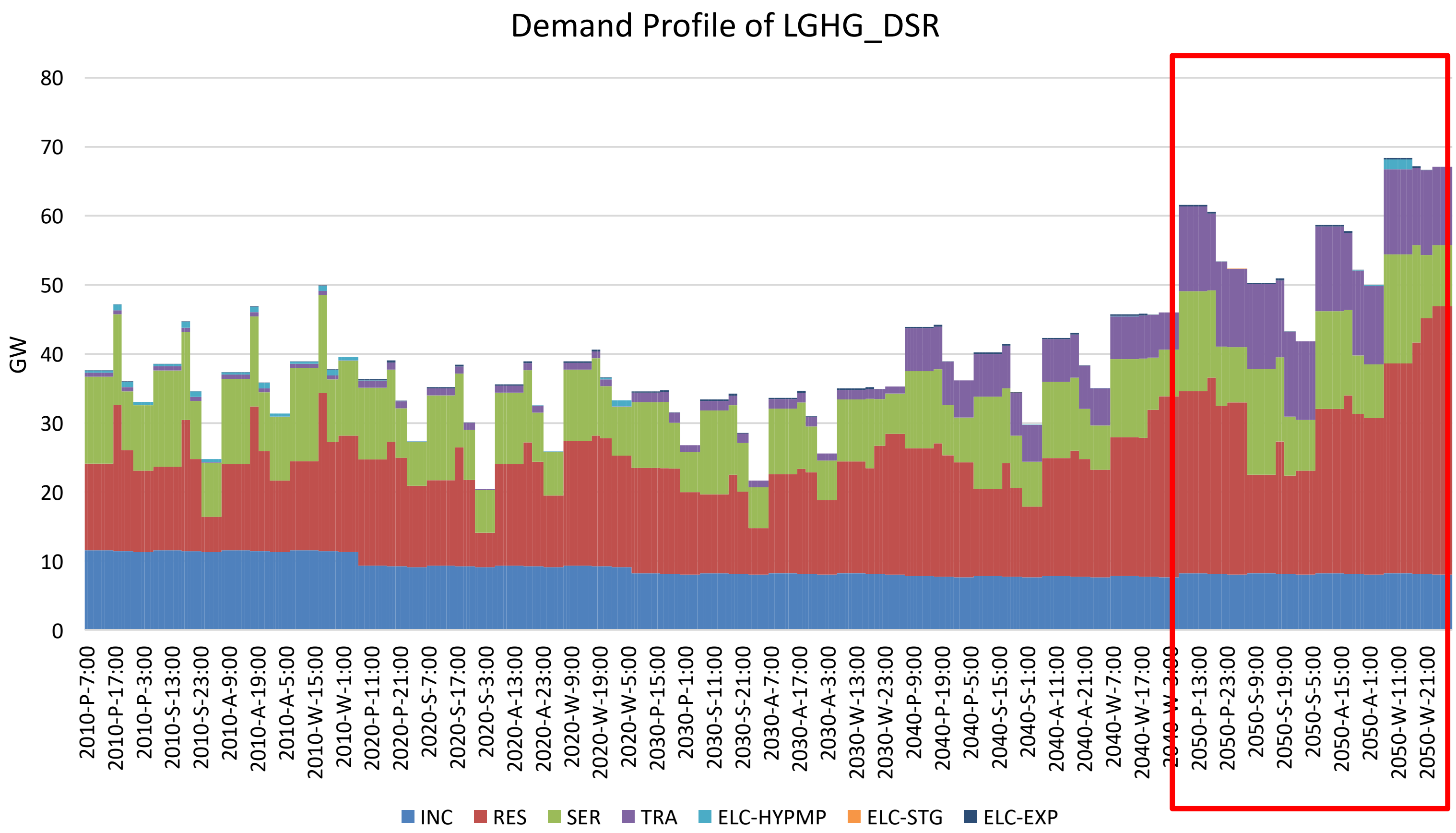


Differences in Electricity Demand by Sector

- **Impacts of demand-side flexibility have also been found in other end-use sectors, such as the service and industrial sectors.**



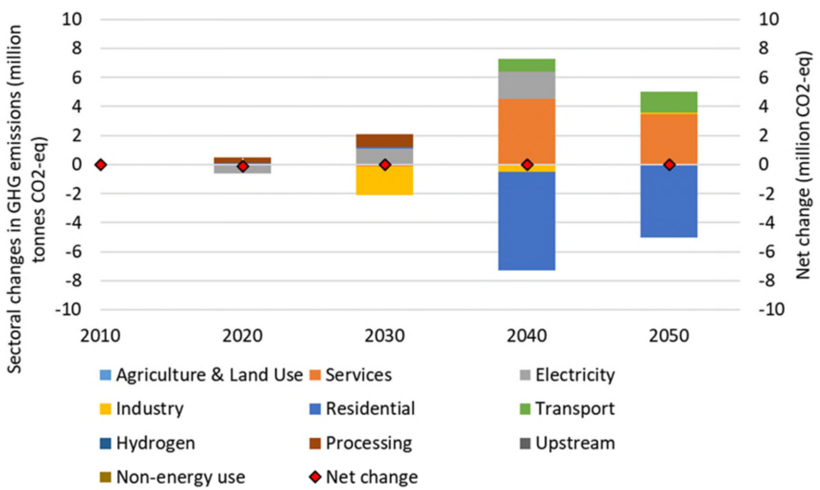
Demand Profile of the DSR Case by Sector



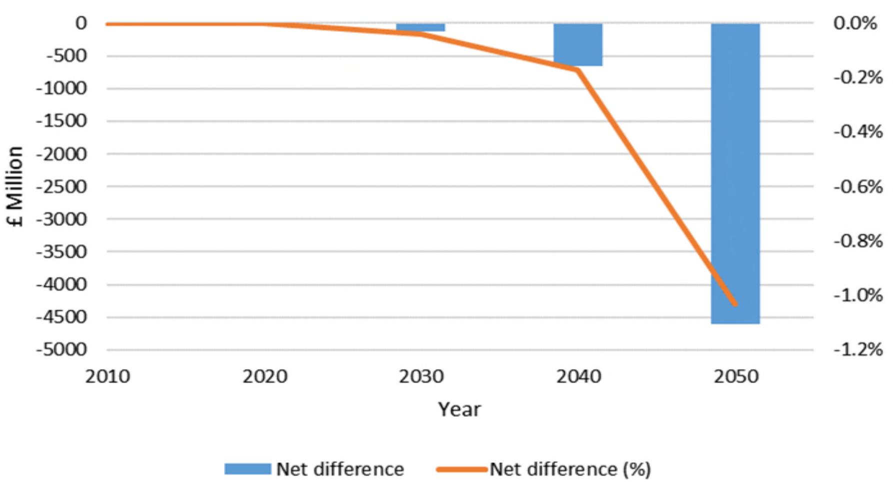
Differences in GHG emissions and Costs

- **GHG emissions** are the same in both cases
  - Strict GHG constraints
  - Differences in sectors for fuel switching
- **In 2050,**
  - **4.6 billion GBP (1.03%)** saved
  - Marginal electricity price reduced by **6.1% in winter; 56% in summer**.
- **Accumulatively,**
  - **30.9 billion GBP** (undiscounted) can be saved over the modelling period.

Diff in GHG emissions by Sector



Diff in total system costs



Conclusions and Future Works

- The developed framework can well represent demand-side flexibility in the whole energy systems model (TIMES)
- With DSR,
  - **7 GW (9%)** in peak load period can be reduced
  - **11 GW more VRE** can be introduced
    - **10% more** of total capacity
    - VRE contributes to **53% of total capacity**
  - **30 billion GBP (0.24%)** can be saved
- **Consumers' acceptance and participation** are crucial
- **Stronger policies are essential:** smart infrastructure and consumers' behavioural change
- **Future works**
  - Higher temporal resolution
  - Randomness of demand profiles
  - Demand-side flexibility in other sectors

Thanks for your attention!

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