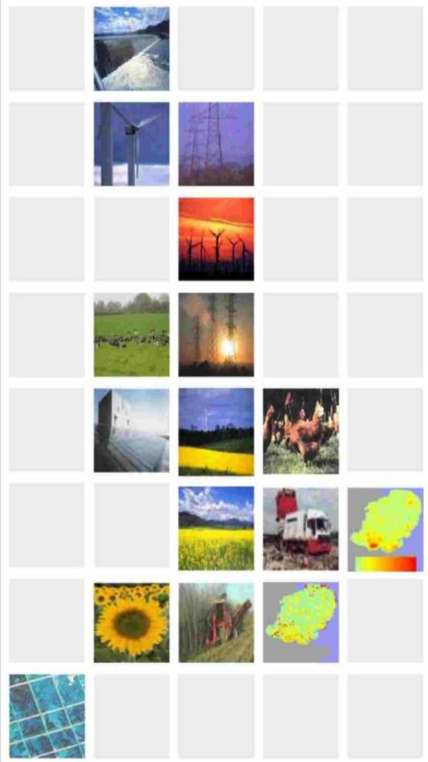
Grid Economics, Planning and Business Models for Smart Electric Mobility



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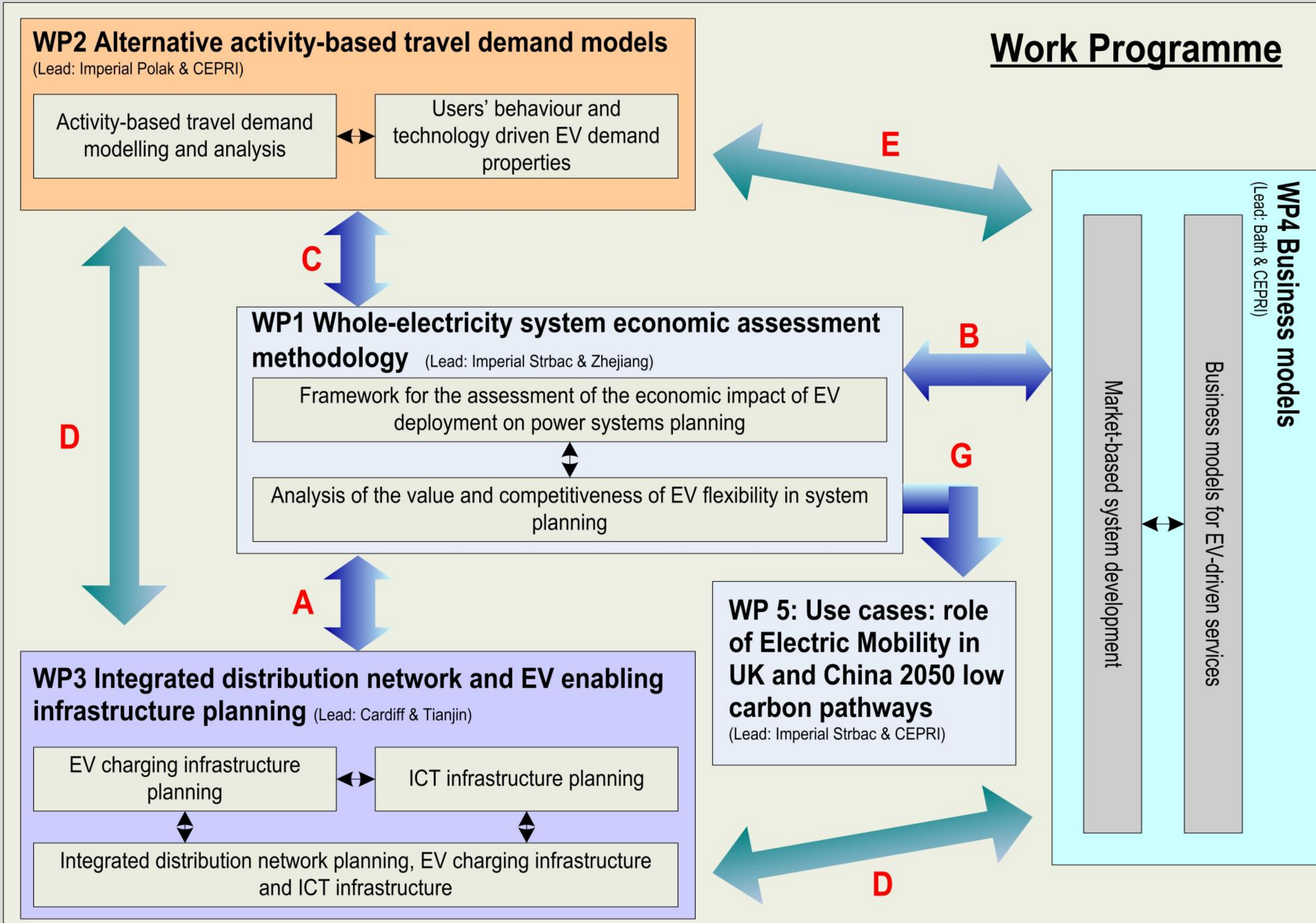
Research Challenges: supporting economically and environmentally effective transition to electric mobility

- Existing impact assessment and planning models analyse EV impacts on individual sectors of the power system separately.
- Traditional travel model are based on statistical prediction of aggregate-level travel demand without capturing the behavioural characterisation of users' driving requirements and preferences.
- EV charging infrastructure and ICT infrastructure planning almost completely neglected.
- Business models and price-based mechanisms that support the realisation of benefits through the provision of multiple services by EVs, including V2G, are yet to be investigated.
- Framework and methodology for the development of roadmaps for the evolution to electric mobility are yet to be developed.

Work Programme



Specific objectives /1

- Investigate a novel **whole-electricity system economic assessment methodology** to assess the economic effects of EV deployment on the distribution, transmission and generation infrastructures, under different EV management strategies and business models;
- Investigate alternative **activity-based travel demand models** and understand the interaction between demand for travel, alternative charging strategies that are consistent with vehicle owner flexibility and the electricity system economic performance and infrastructure requirements;
- Investigate and develop **risk-constrained multi-objective optimization** approaches in order to address the challenges of EV charging and ICT infrastructure planning, and develop models for assessing the interdependence between the electricity grid and EV enabling infrastructure planning;

Specific Objectives /2

- Quantify the **value of alternative charging strategies and EV flexibility** in supporting electricity system operation and investment including ancillary services provision by EV such as V2G and V2H concepts,
- Investigate alternative **business models for the EV market integration** providing the opportunity for EV to simultaneously support more efficient system operation and investment in assets across the entire electricity system chain and thus enhance the economic viability of the transport sector's electrification.

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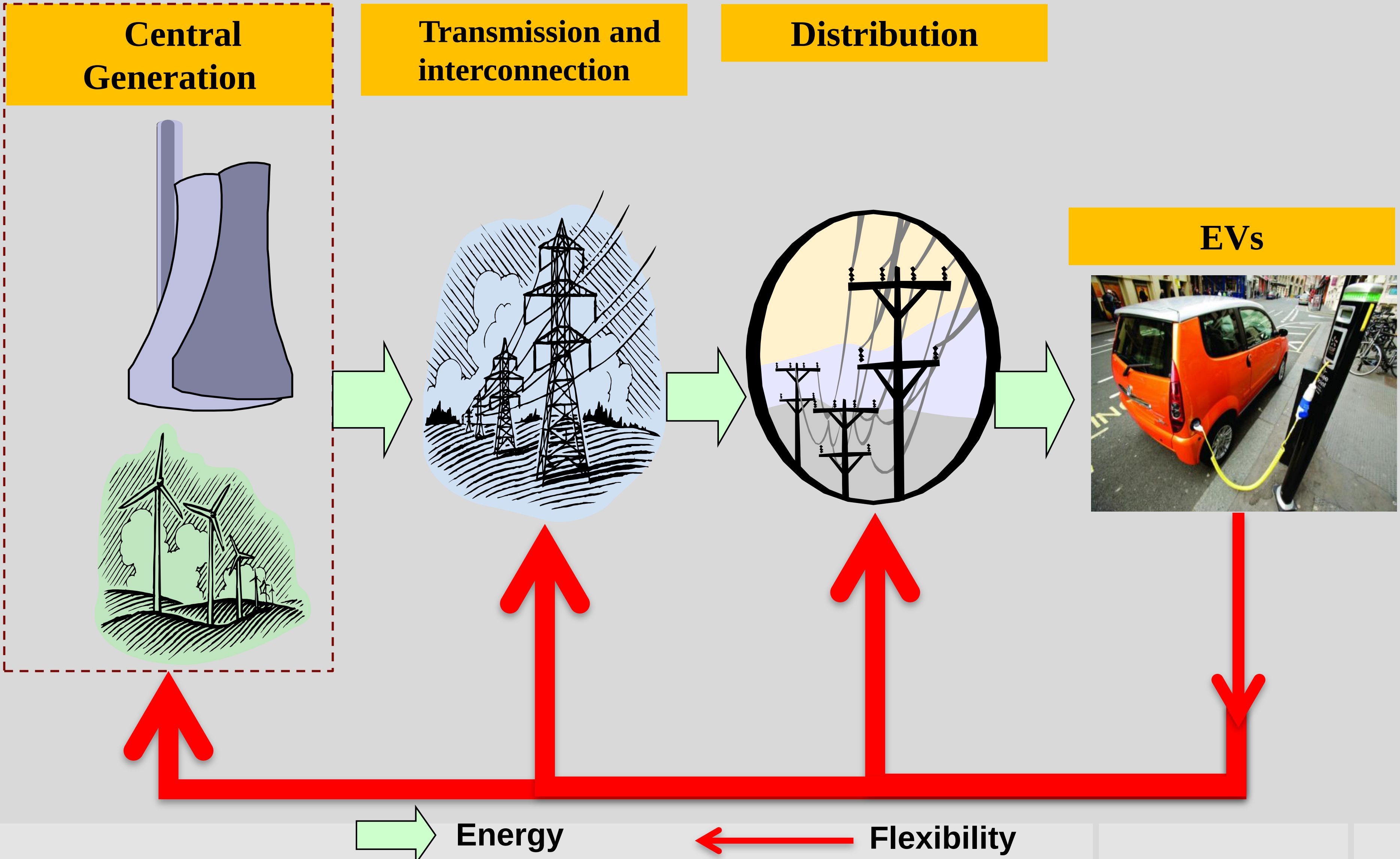
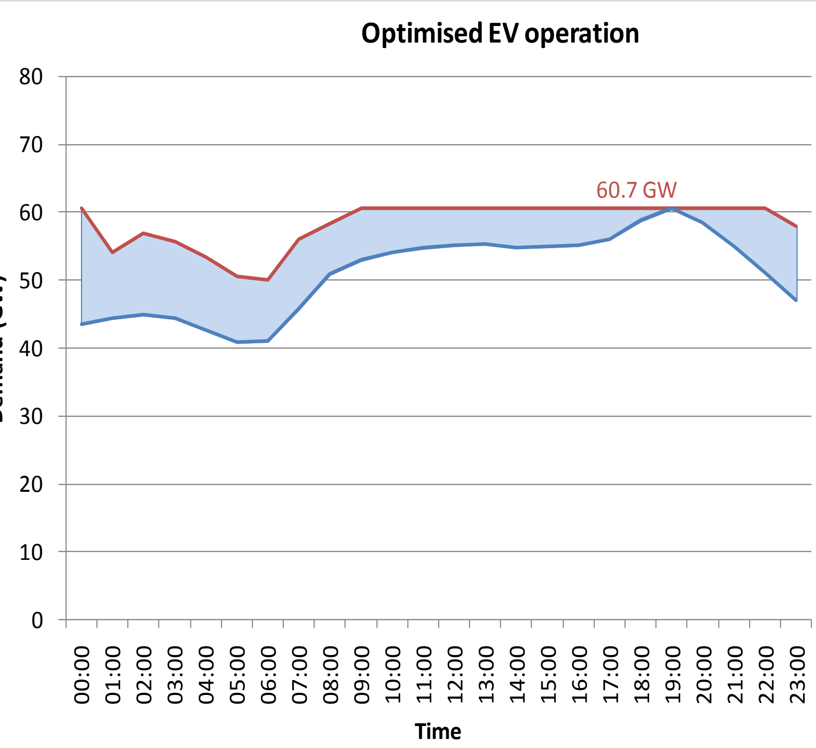
Whole-electricity system modelling of electric mobility

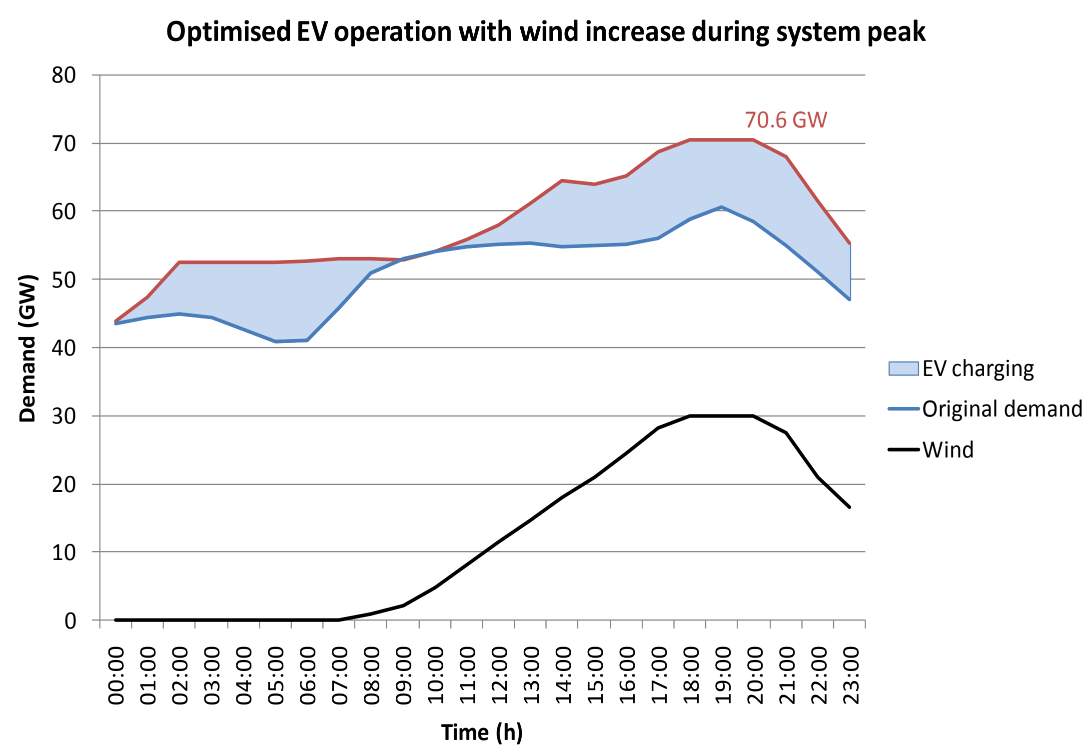
Energy: From the System to EVs

Flexibility: from EVs to the system



Conflict between energy market and local network capacity





Optimal EV response to electricity prices would increase peak demand and overload distribution networks

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Whole-systems approach to analysing the impact of mass rollout of EVs

Key objectives:

- Apply **whole-systems approach** to understand the simultaneous impact of EVs on:
  - Generation system operation
  - Generation system investment
  - Transmission network investment
  - Distribution network investment
  - Environmental emissions
- Understand the **impact of wide EV rollout** in the UK / China system
- Quantify **trade-offs** between objectives in various sectors resulting from different EV charging policies and different future development scenarios
- **Inform policy makers** and provide **evidence** about the high-level impact of different approaches to integration of electro-mobility across the electricity sector and the potential value of smart charging

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Whole-systems analysis: Time and Location effects

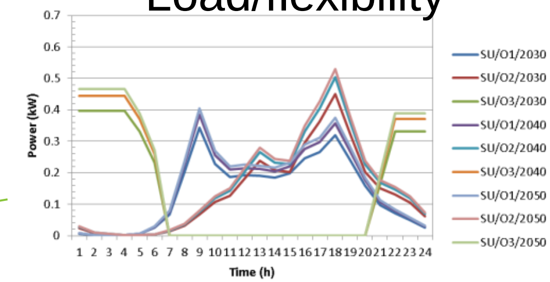
Generation, Transmission & Distribution Planning	Long-term Generation and Storage Scheduling	Day-ahead Generation, Storage & DSR Scheduling	System Balancing
Years before delivery	Months to days before delivery	One day to one hour before delivery	Actual delivery: physical generation & consumption

Whole-system modelling critical for capturing Time and Location interactions

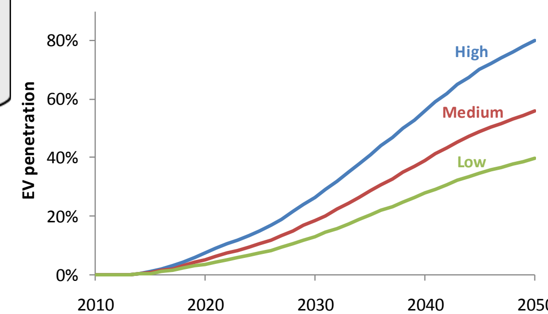
Optimisation across the conflicting objectives to reduce the cost of investment in generation and network assets and system operation

Model Overview

Charging Load/flexibility



EV penetration



Generation Data: technical and cost characteristics

Renewable Generation Data: wind, solar, hydro , etc.

Energy (heat/ electrical) Storage and Demand Response Data

Load Data

Transmission Network Configuration and Cost Characteristics

Dynamic System Investment Model

Optimisation Model

Objective function: Minimisation of the overall generation and transmission investment cost and generation operating cost

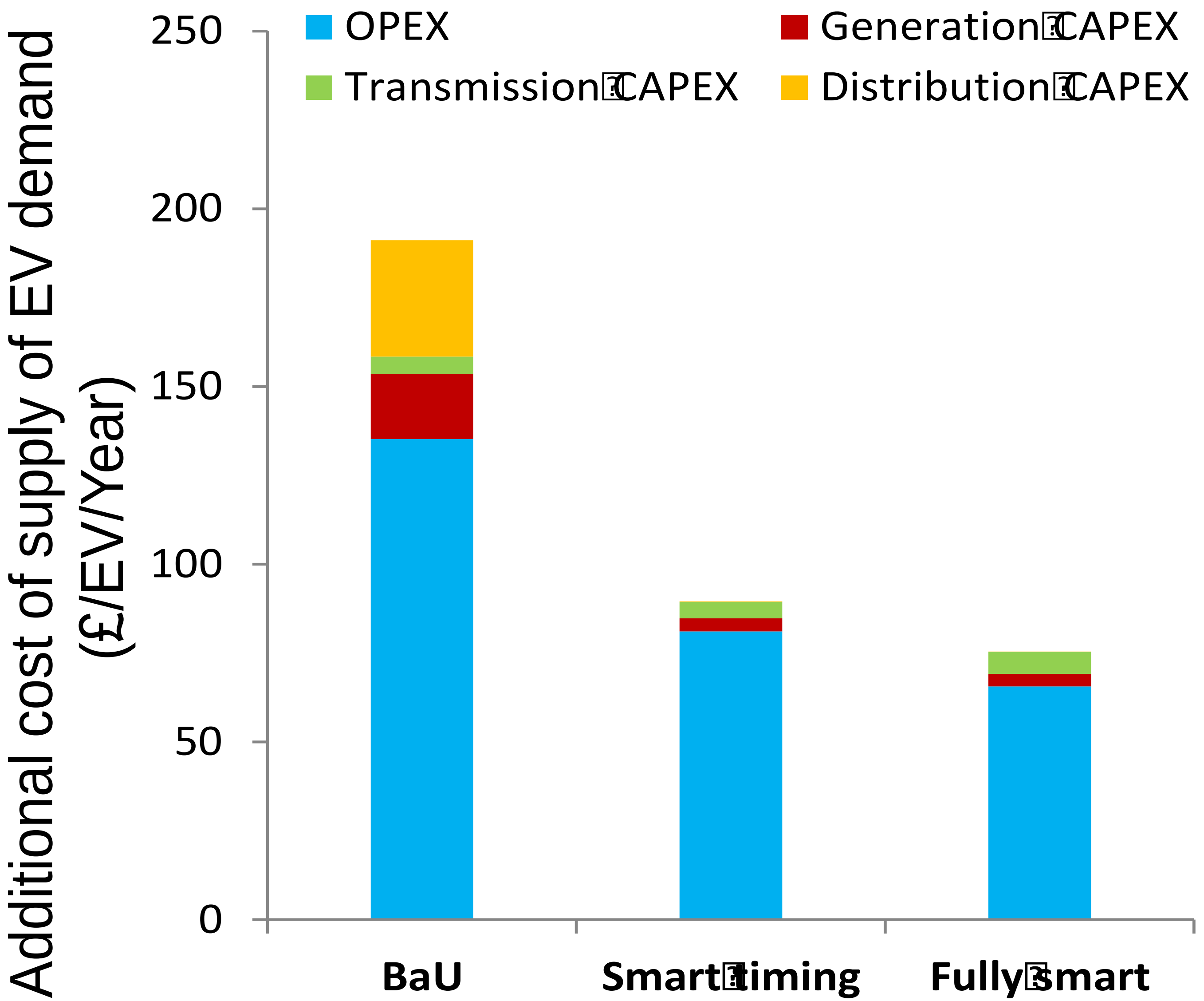
Investment decisions:

- **Generation, and transmission network capacities;**

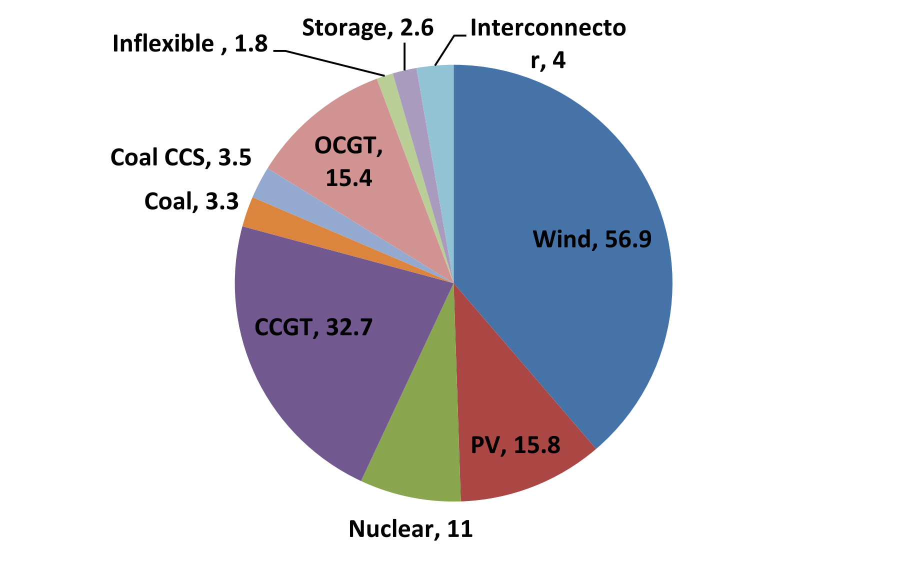
Operating decisions (further assessed in system balancing model)**:**

- **Overall system operation cost;**
- **Generation dispatch including RES and storage**
- **Demand response**
- **Power flows.**

Cost of supplying EV demand (2025 - Medium EV penetration)

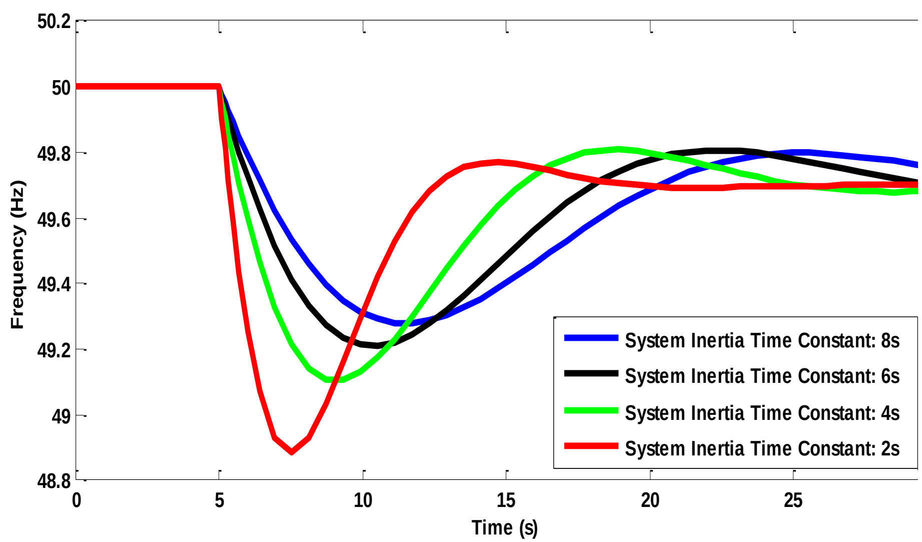


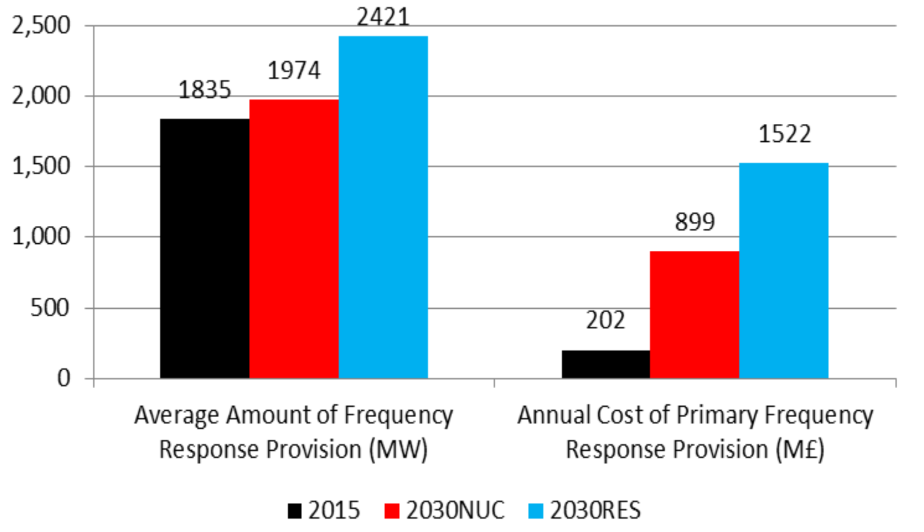
2030 Gone Green scenario- generation mix and case studies



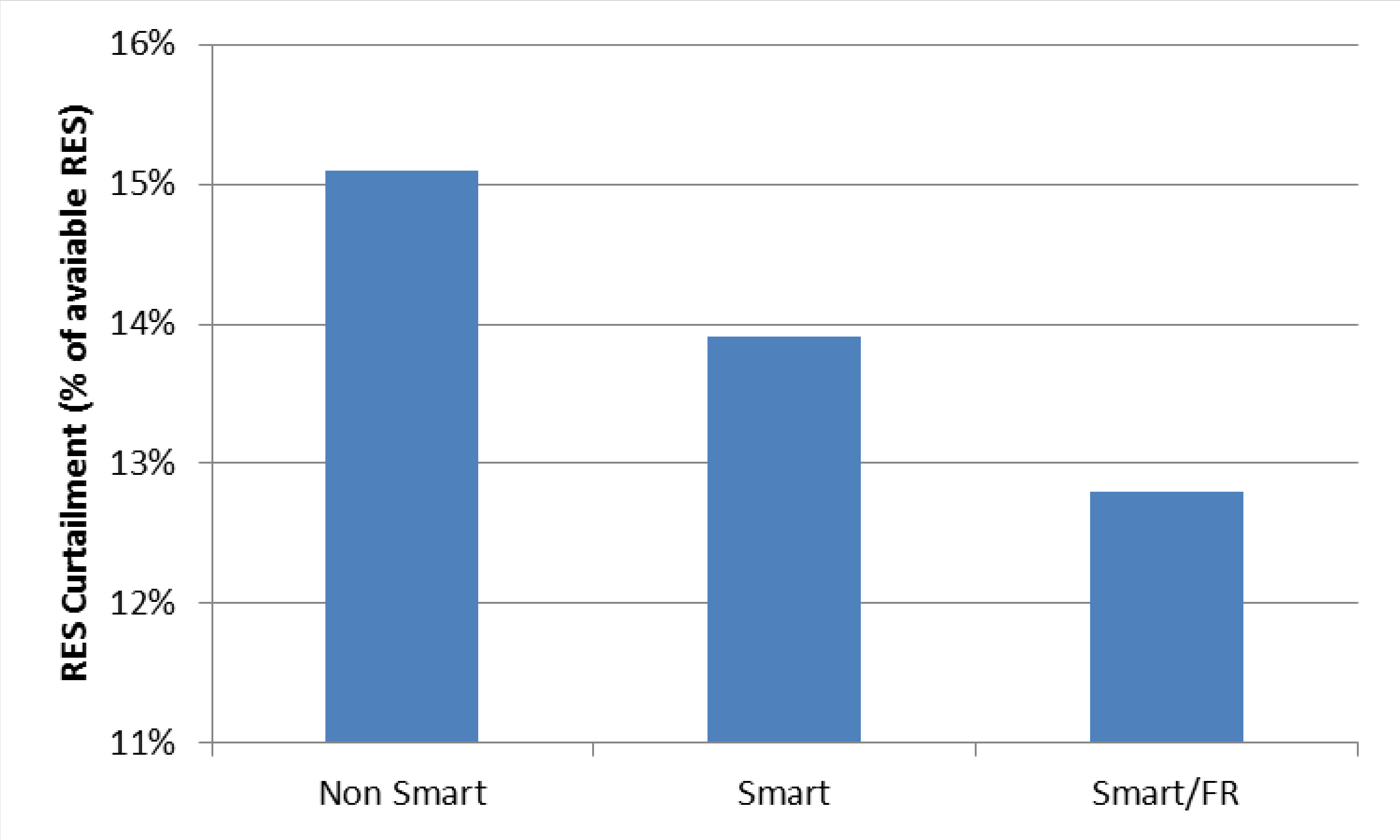
Case	Assumptions
Non-smart	EVs - inflexible
Smart EV	EVs - flexible but with low response capability
Smart EV / FR	EVs - flexible and with high response capability

Challenges of primary frequency control in the future GB system with high penetration of wind

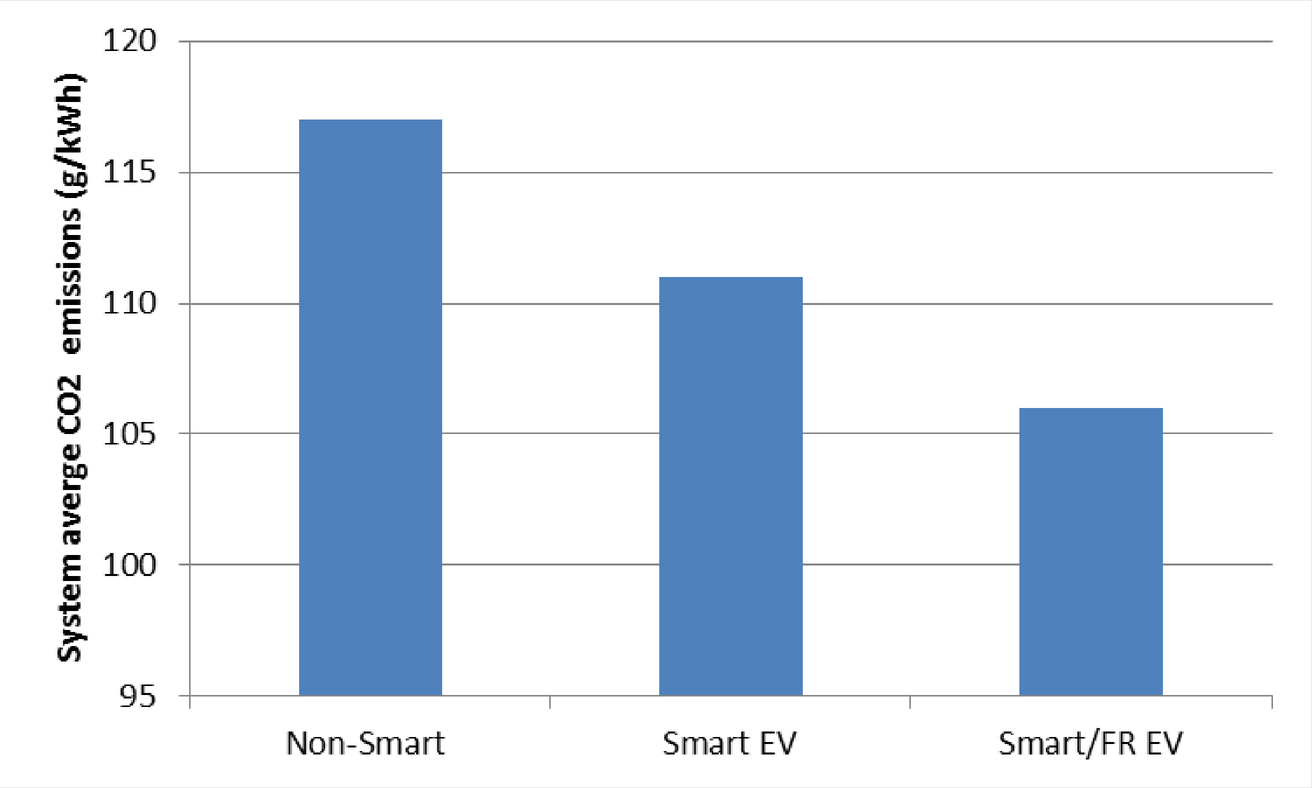




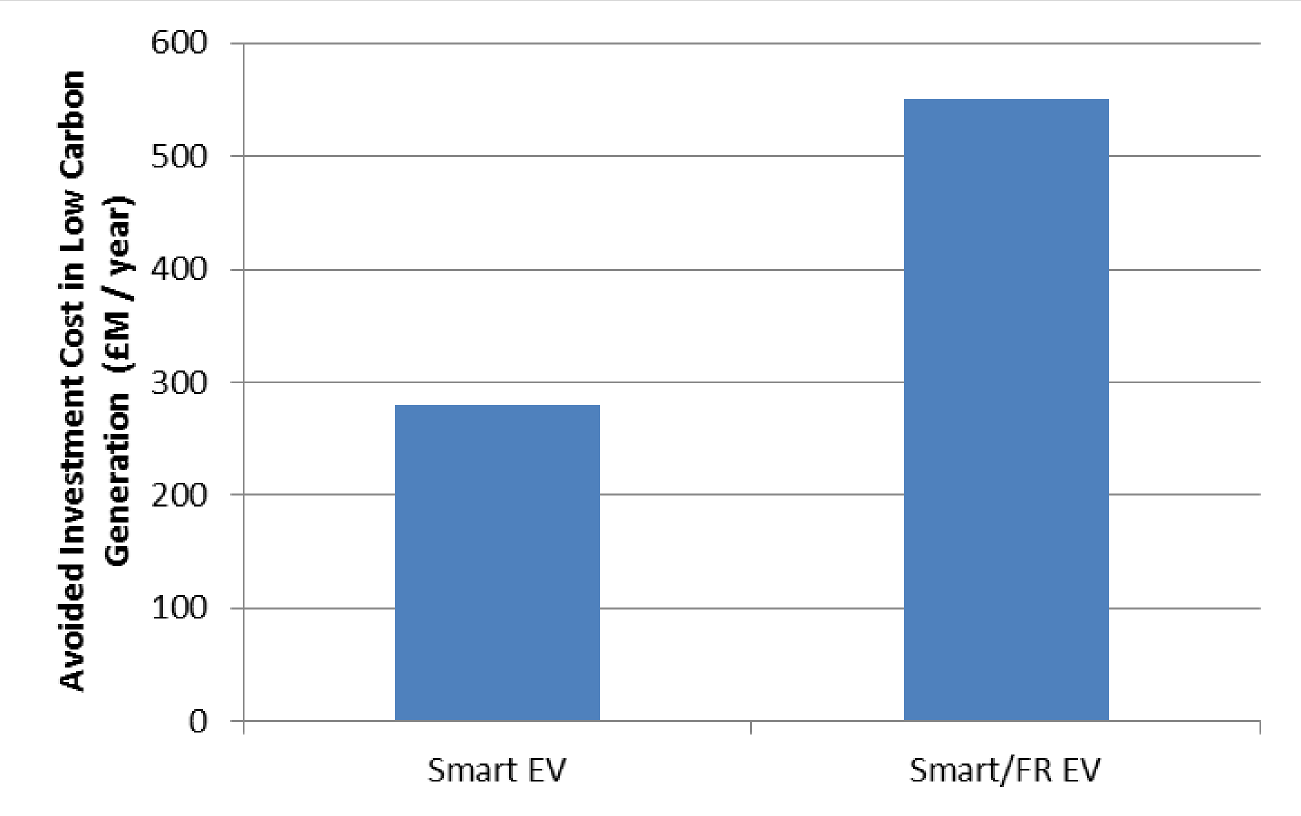
RES curtailment for Smart EVs deployment



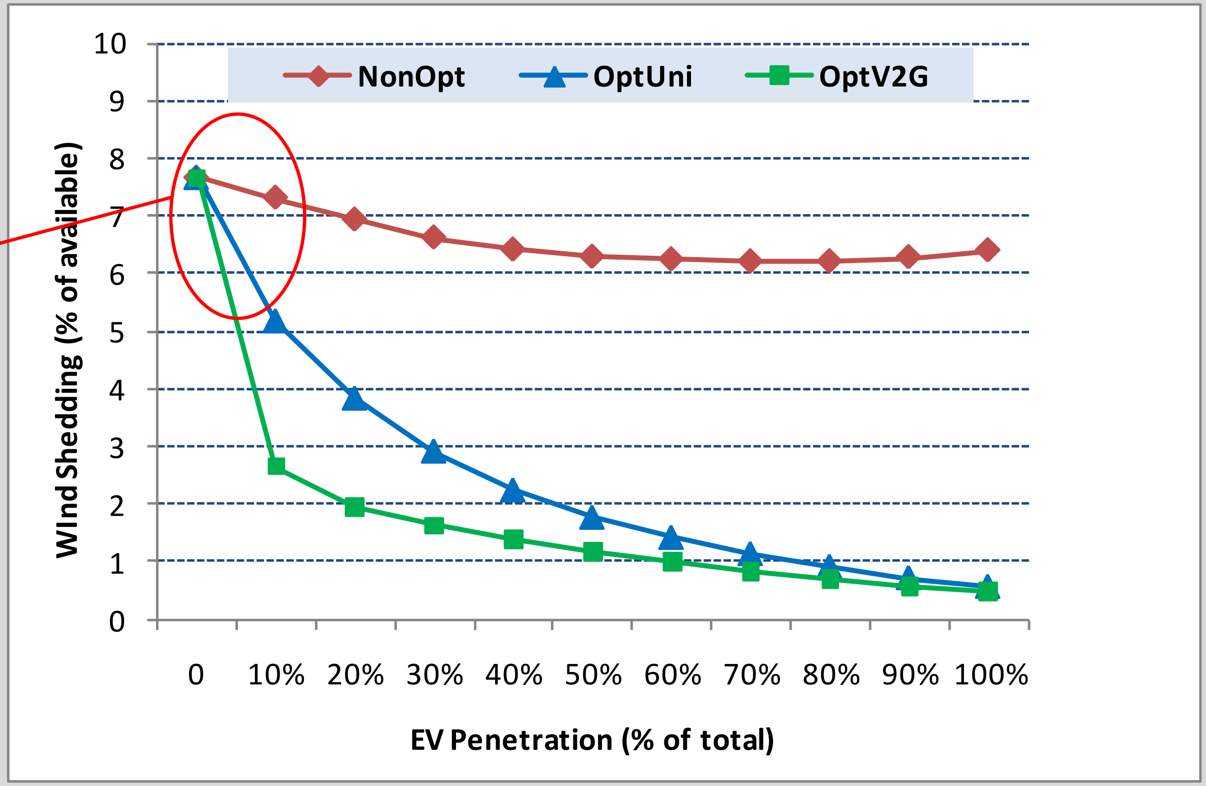
System average CO2 emission rate



Avoided investment cost in low carbon generation



Benefits of V2G: Wind Curtailment Reduction

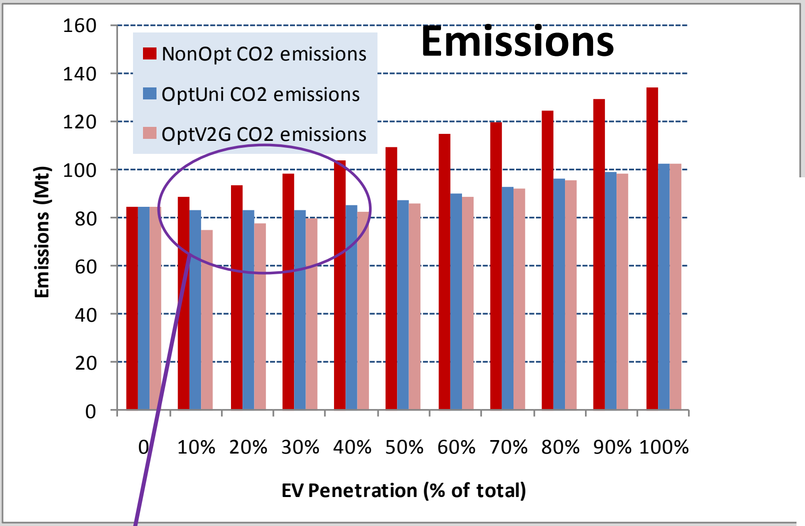


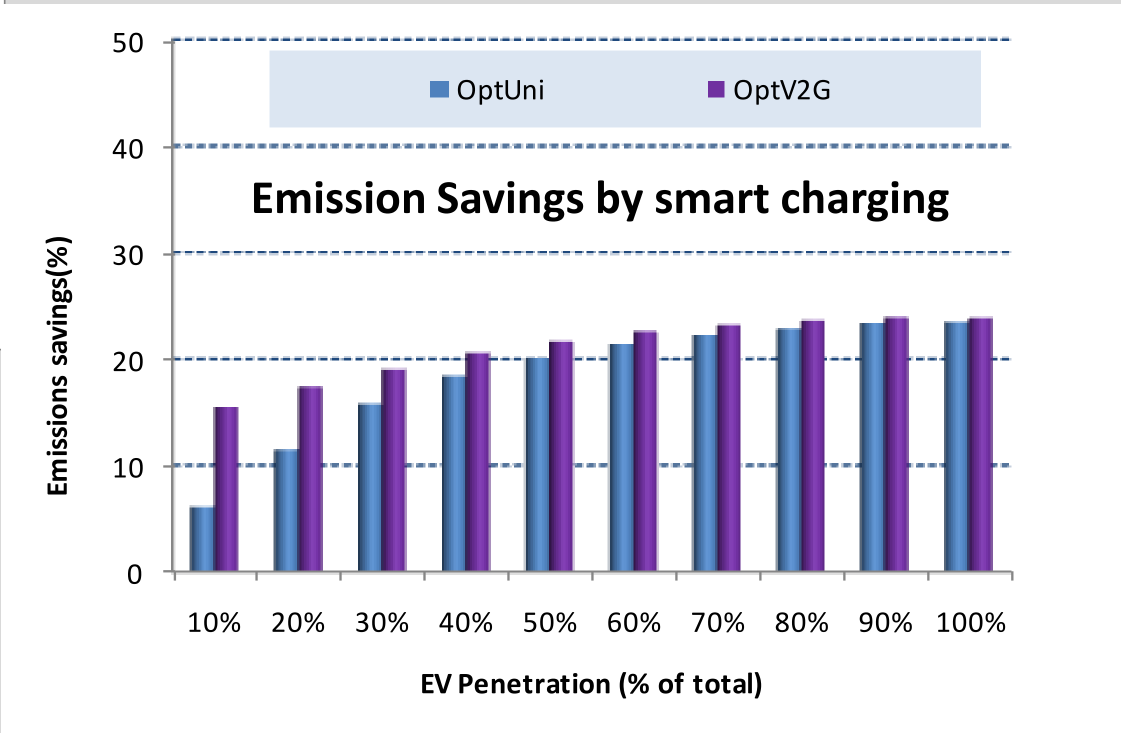
Annual curtailed energy is more than the energy required for annual charging req. of ~15% EV

Significant avoidance of wind energy curtailment by optimised EV charging, even at low levels of EV penetration.

G4V

Benefits of V2G: carbon emission Curtailment Reduction





Drop in CO_2 emissions when charging is optimised – enhanced ability to absorb wind energy and reduce outputs of fossil fuel plant

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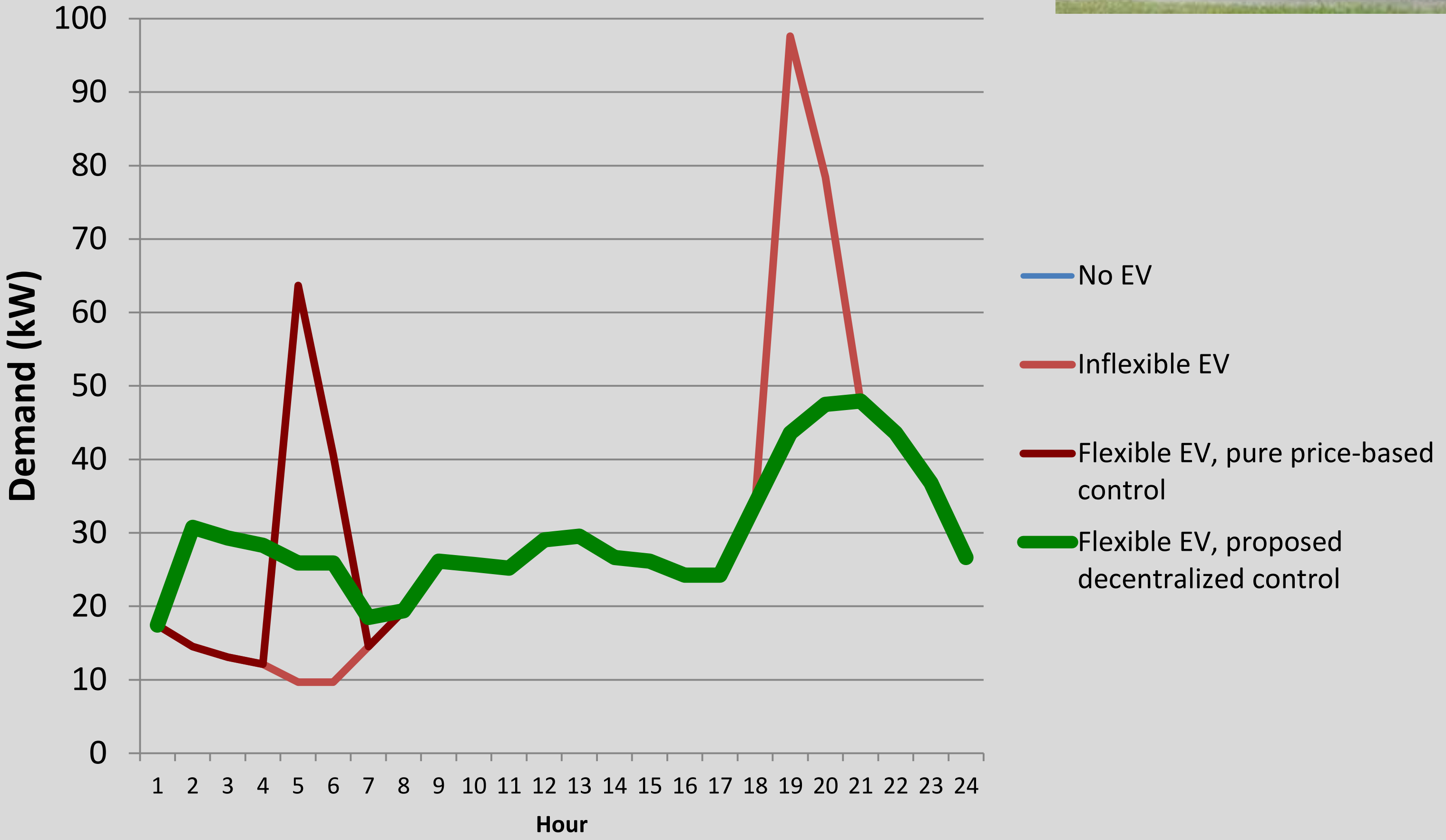
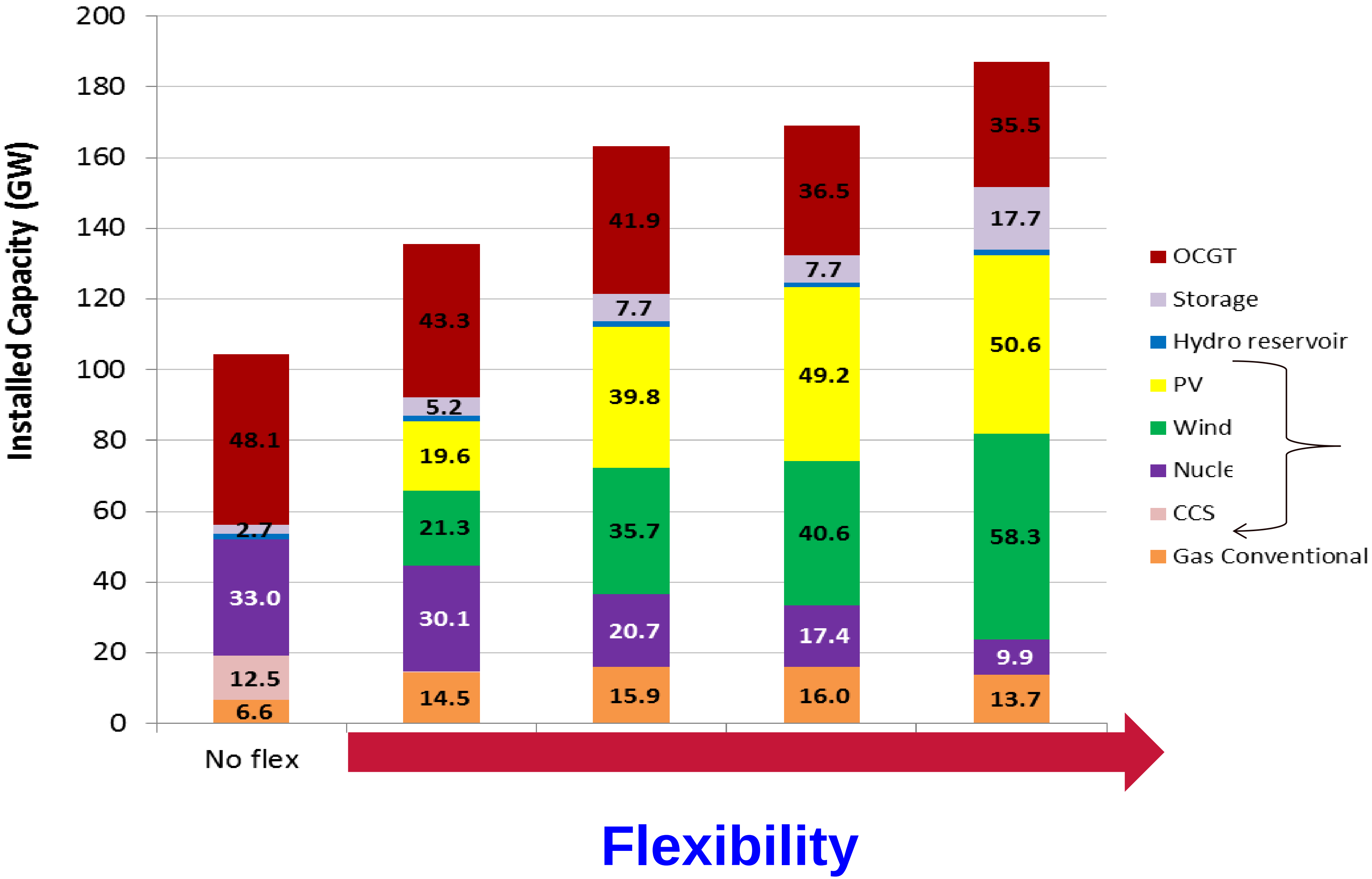
From Centralised to Distributed Control – Real Time Pricing



Flexibility – key driver for cost effective evolution to low carbon energy system



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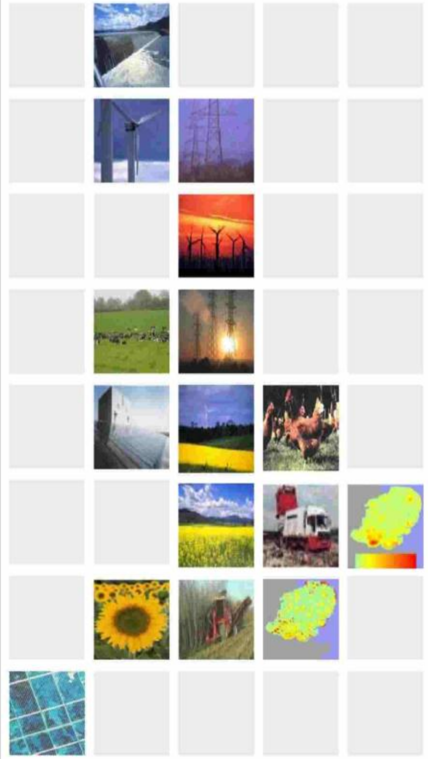

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