THE ROLE OF ENERGY STORAGE IN DECARBONISATION OF DIFFERENT POWER SYSTEMS

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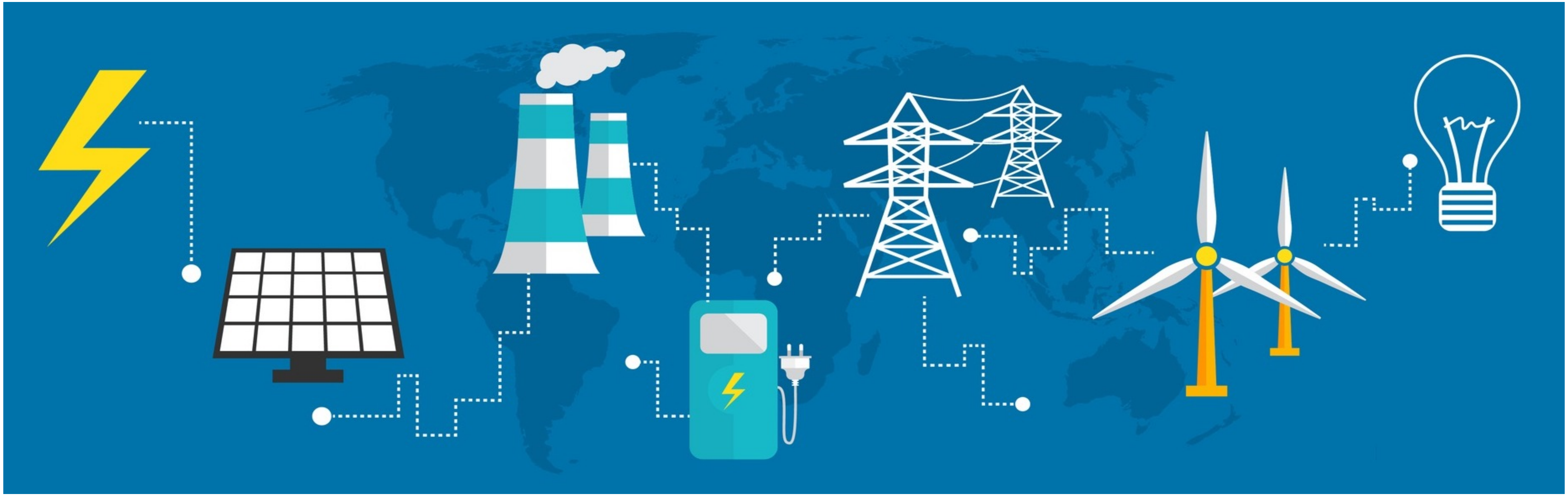
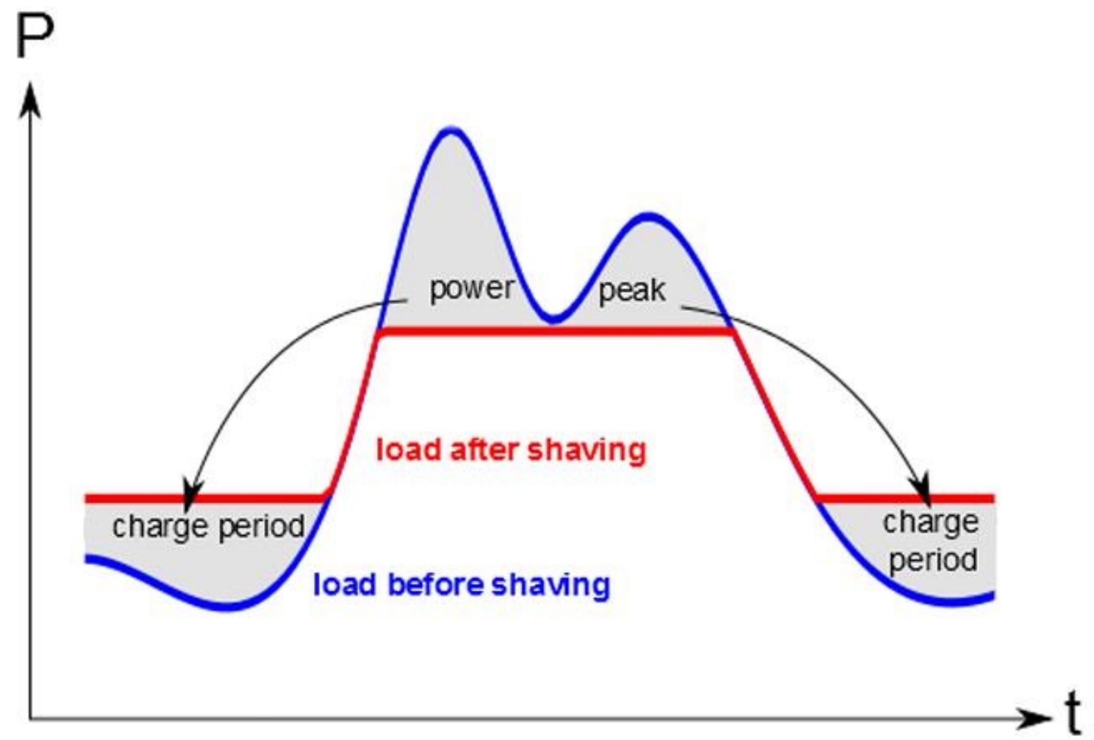
CONTENT



BACKGROUND

Introduction to energy storage and power systems

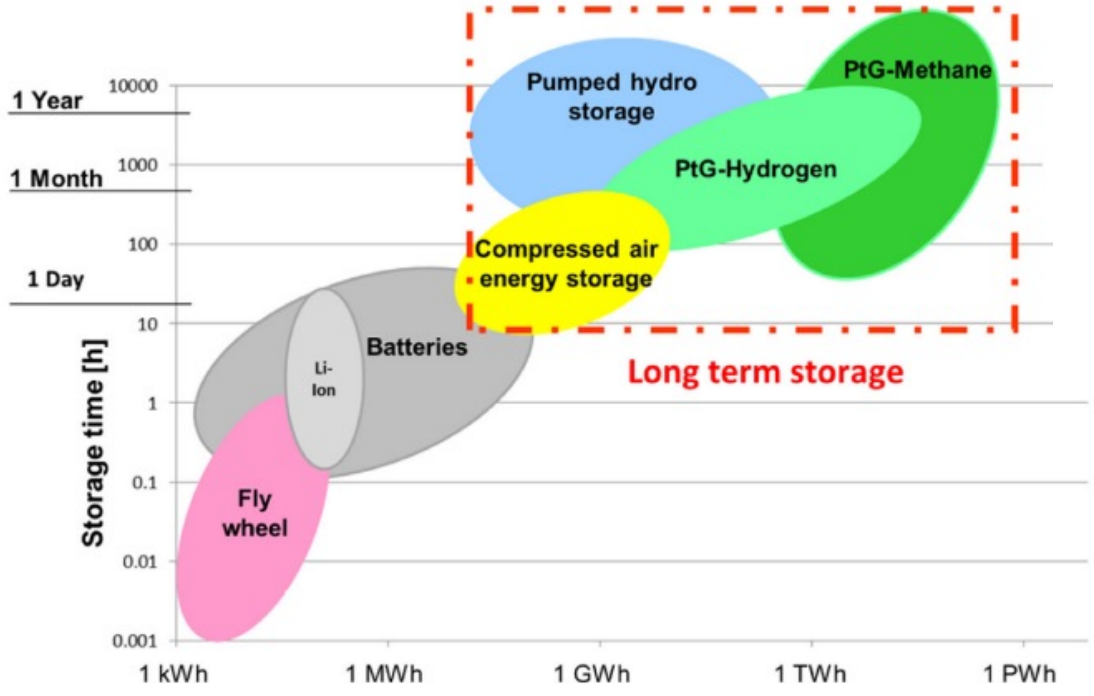
WHY DO WE NEED ENERGY STORAGE

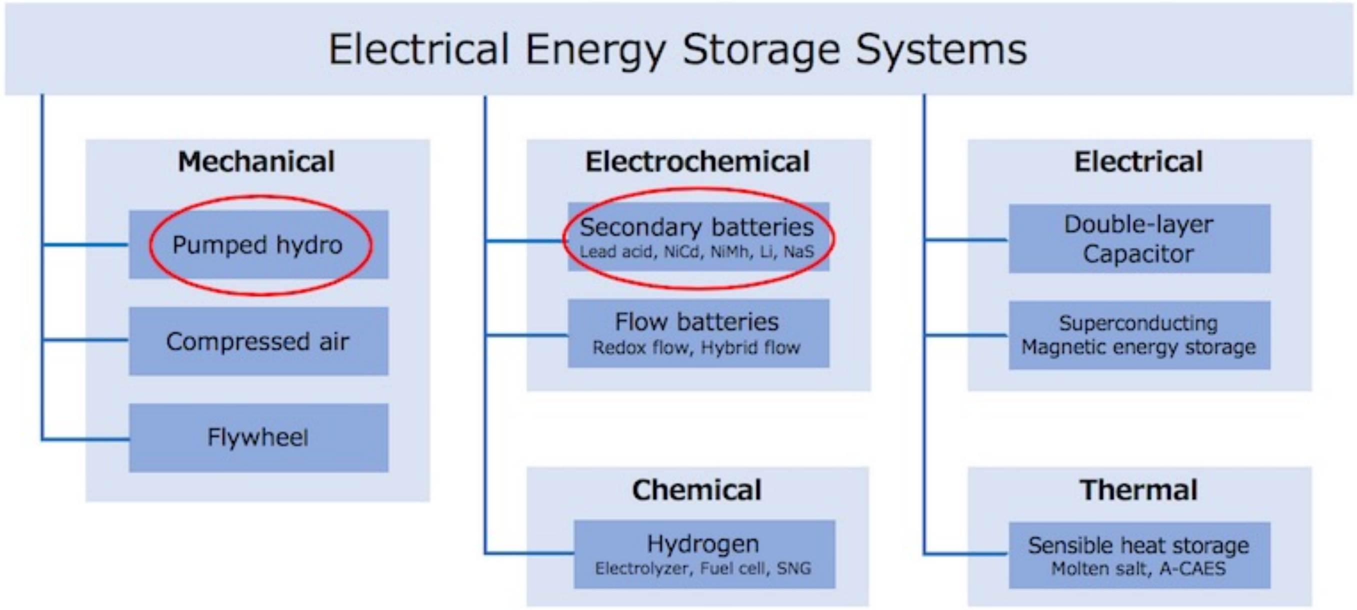


- **Peak shaving** refers to the practice of shaving off the peaks of electricity usage during periods of high demand by shifting non-essential loads to off-peak hours

Source: batteryblokk; Beuse et al. (2021)

ENERGY STORAGE TYPES





Source: Ajanovic et al. (2020)

STATUS QUO OF ENERGY STORAGE DEVELOPMENT

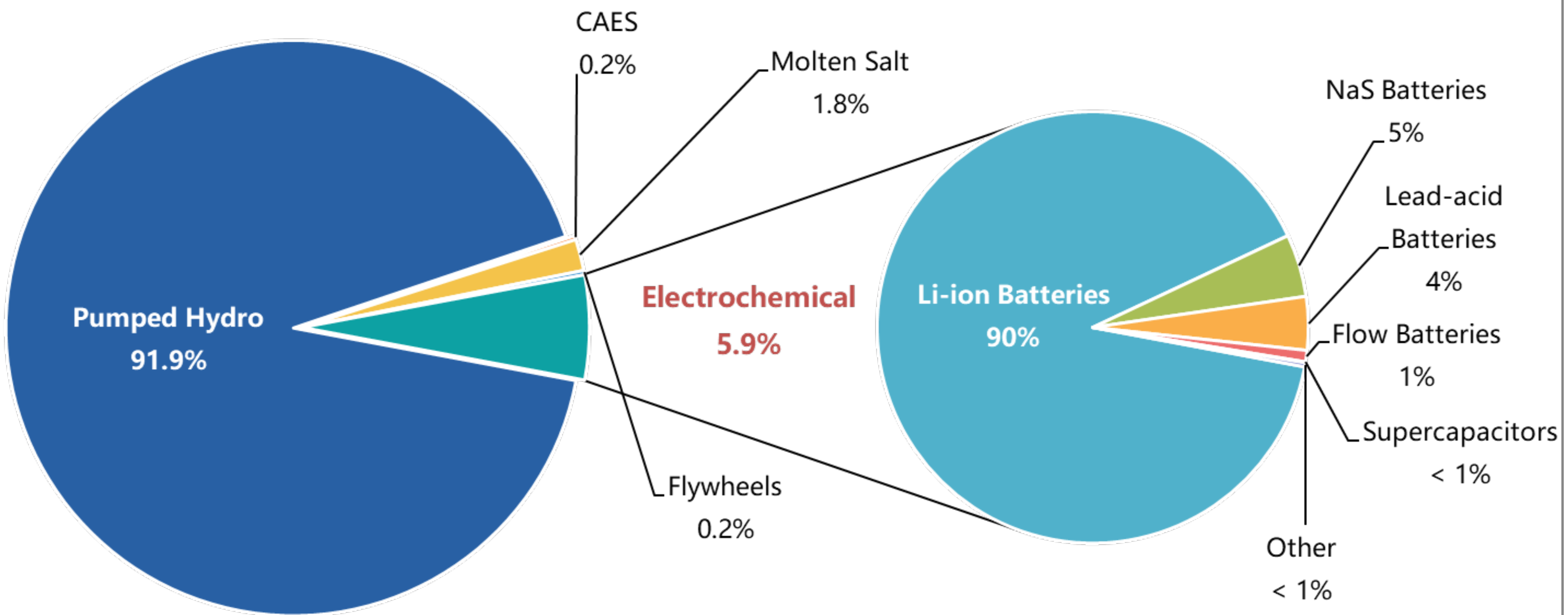
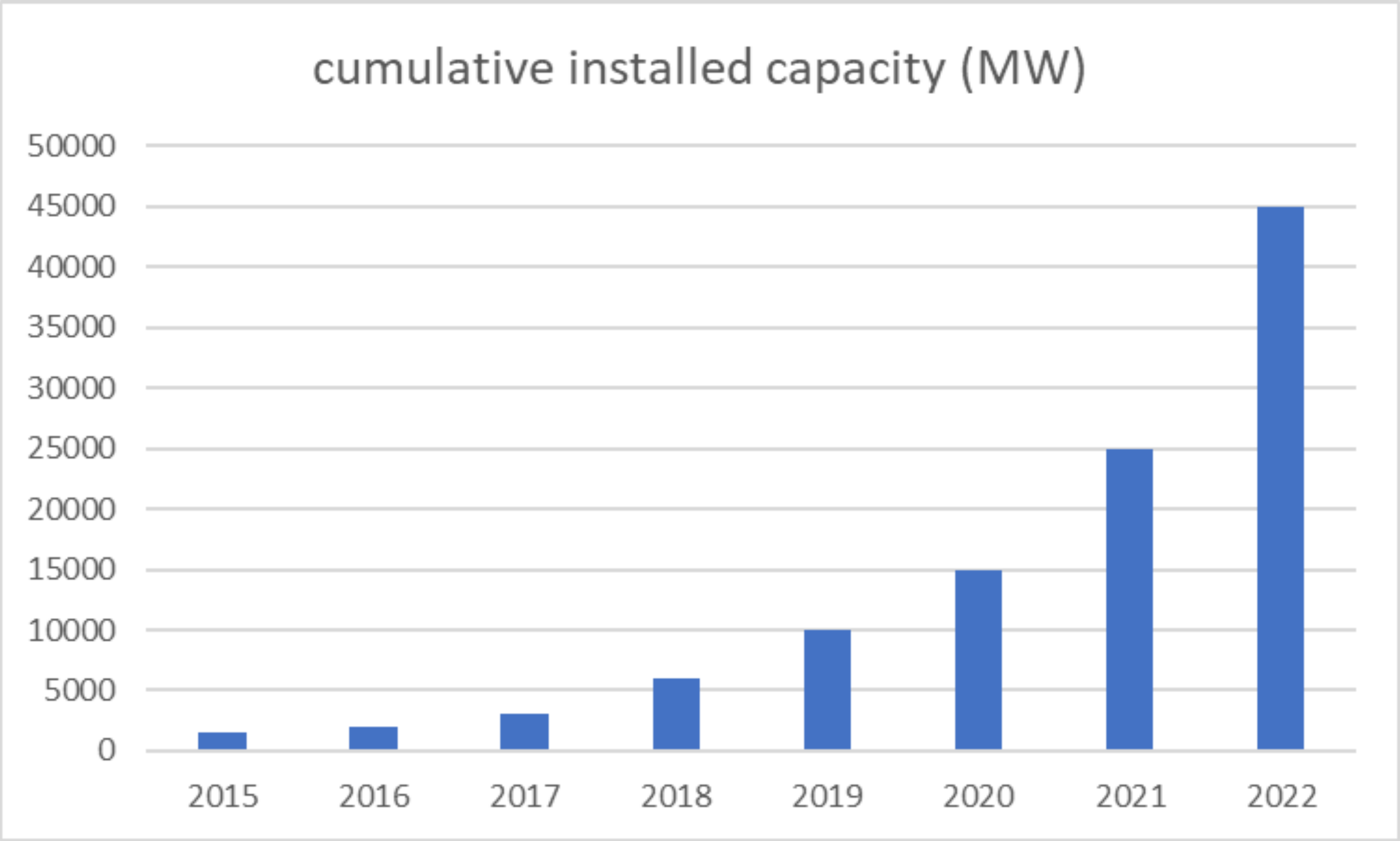


Figure1. Global Electrical energy storage market cumulative installed capacity (MW%, 2000-2020)

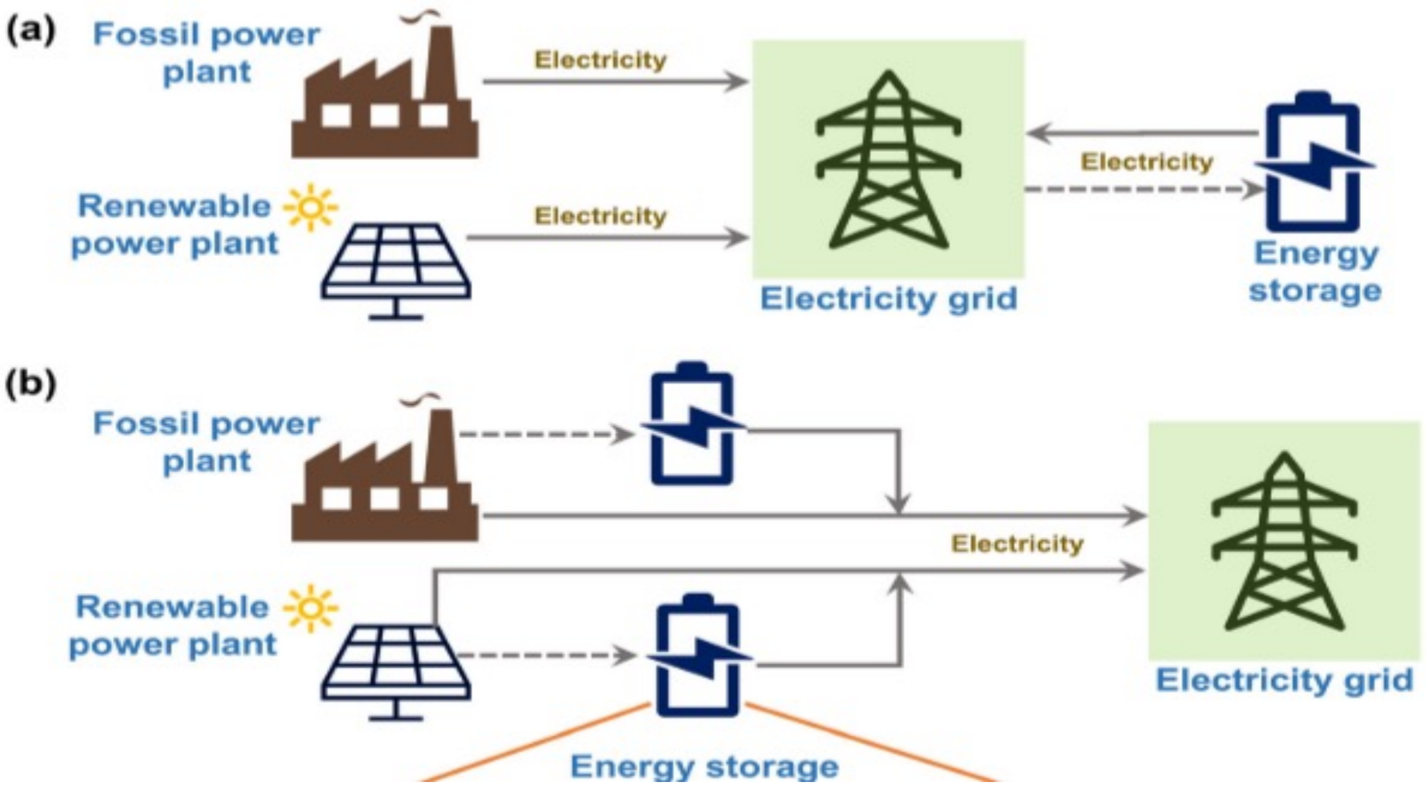
Source: CNESA Energy Storage Industry White Paper 2021

BATTERY STORAGE DEVELOPMENT



Source: CNESA Energy Storage Industry White Paper 2023;

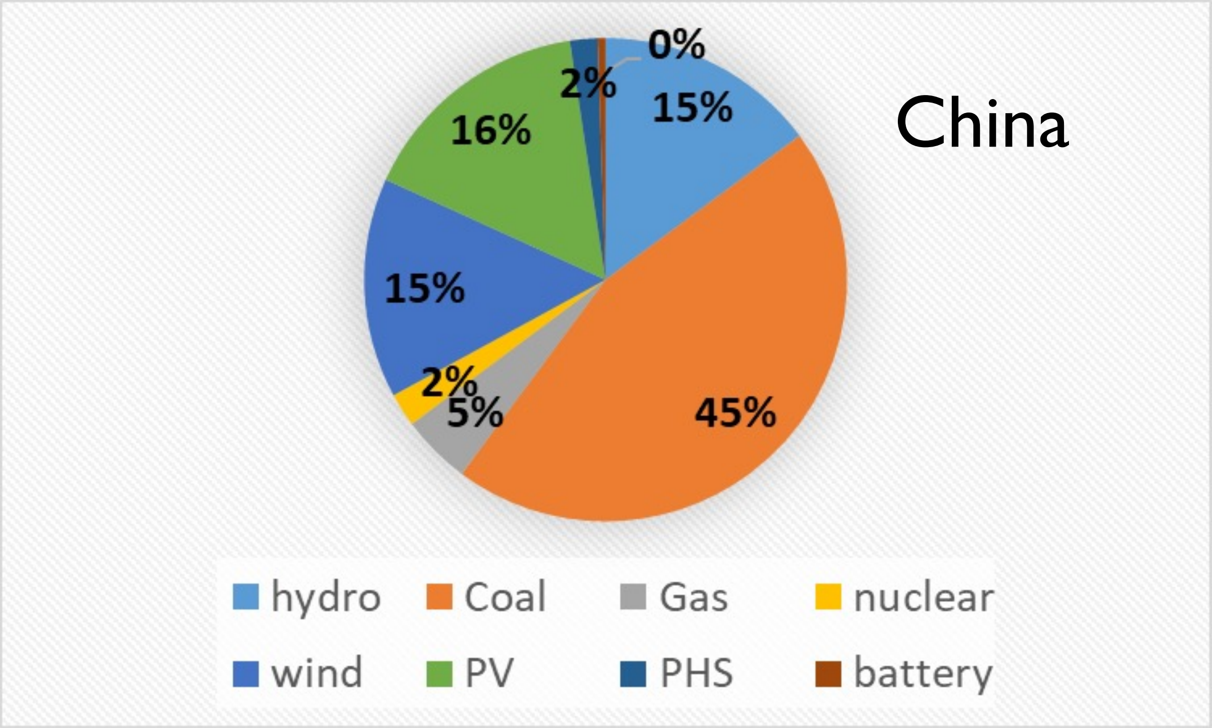
TWO CONFIGURATIONS OF POWER GENERATION SYSTEMS AND ENERGY STORAGE

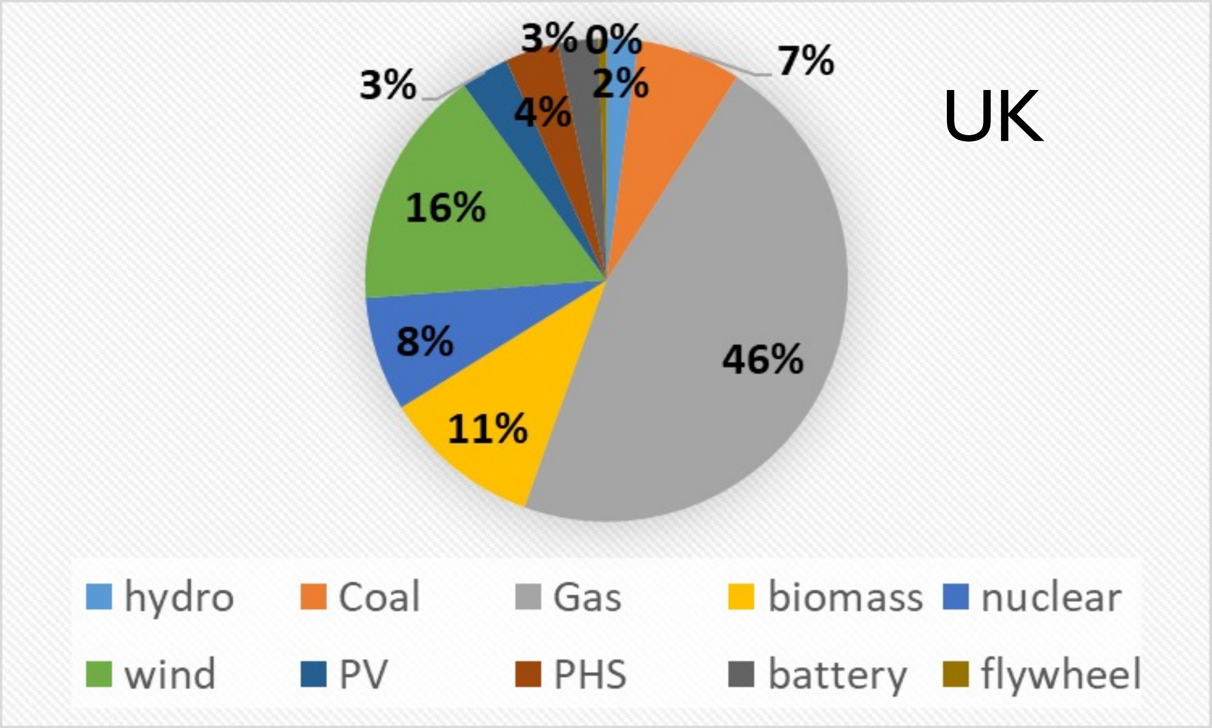


Source: Zantye et al. (2022)

DIFFERENT POWER SYSTEMS

Installed capacity mix of **different** power system in 2022



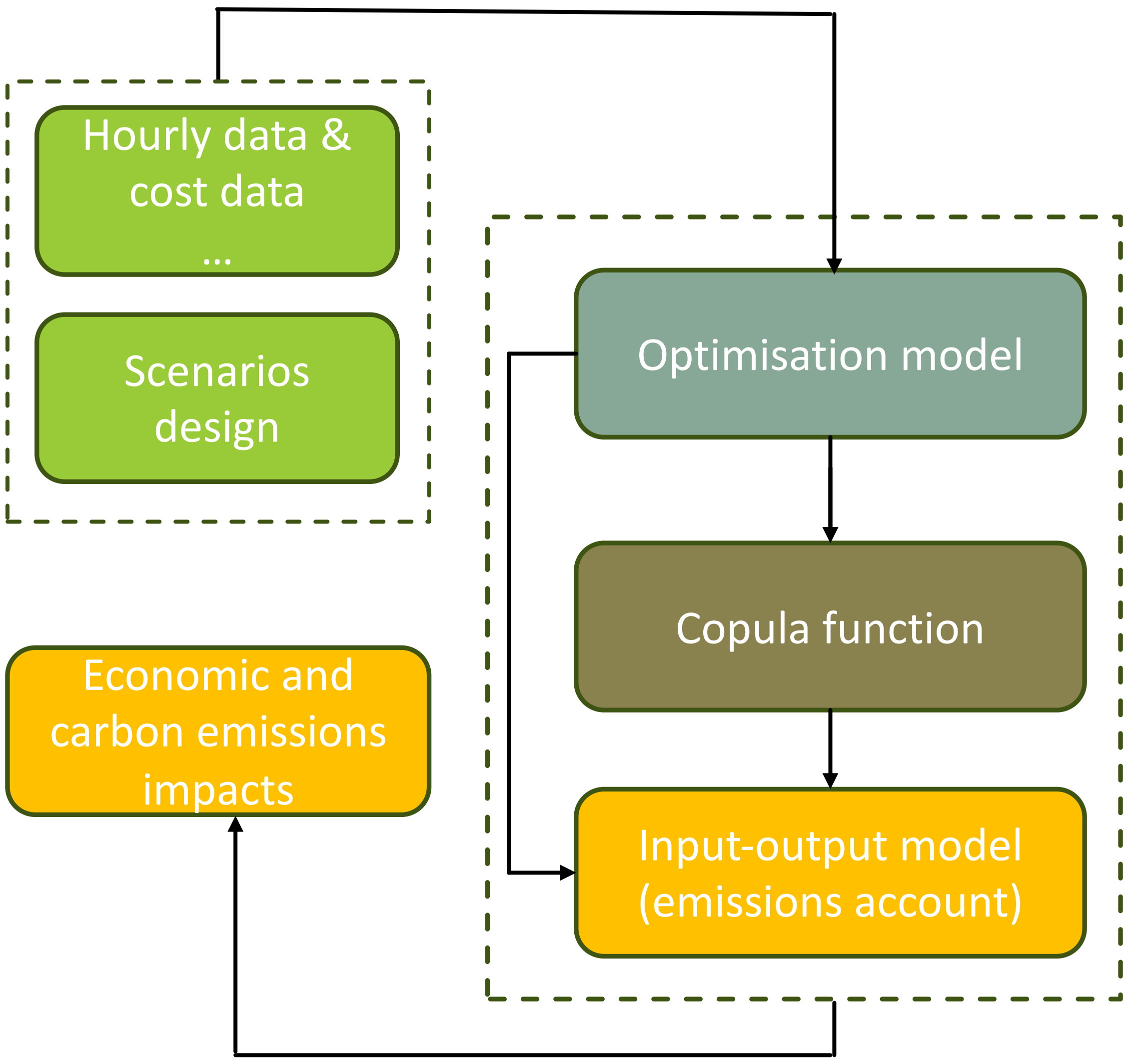


Source: collected from public data

METHODOLOGY

FRAMEWORK

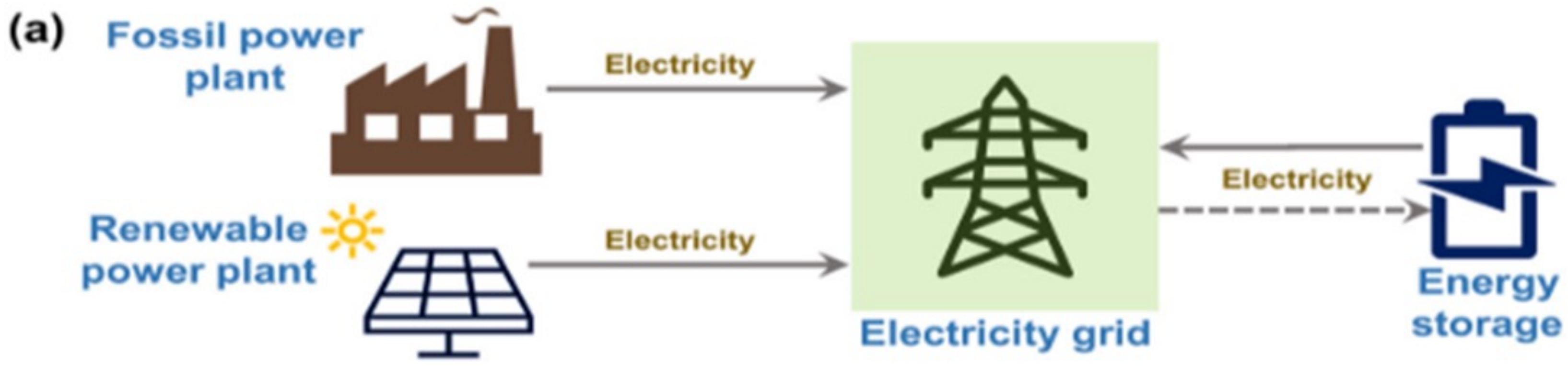
Aim: To explore the direct and indirect economic and environmental impacts of energy storage on decarbonisation of power systems



POWER SYSTEM OPTIMISATION MODEL

Objective function:

Minimise **operating costs and investment costs of capacity expansion** of power system



POWER SYSTEM OPTIMISATION MODEL

Constraints:

Power output
Power balance
Energy storage
Carbon limits

Variables:

Planning installed capacity; hourly power output; hourly charging and discharging power; hourly energy storage

POWER SYSTEM OPTIMISATION MODEL

China's power system

- hydro generation
- coal-fired generation
- gas-fired generation
- nuclear power generation
- wind power generation
- solar power generation
- pumped hydro storage (PSH)
- battery storage (BESS)

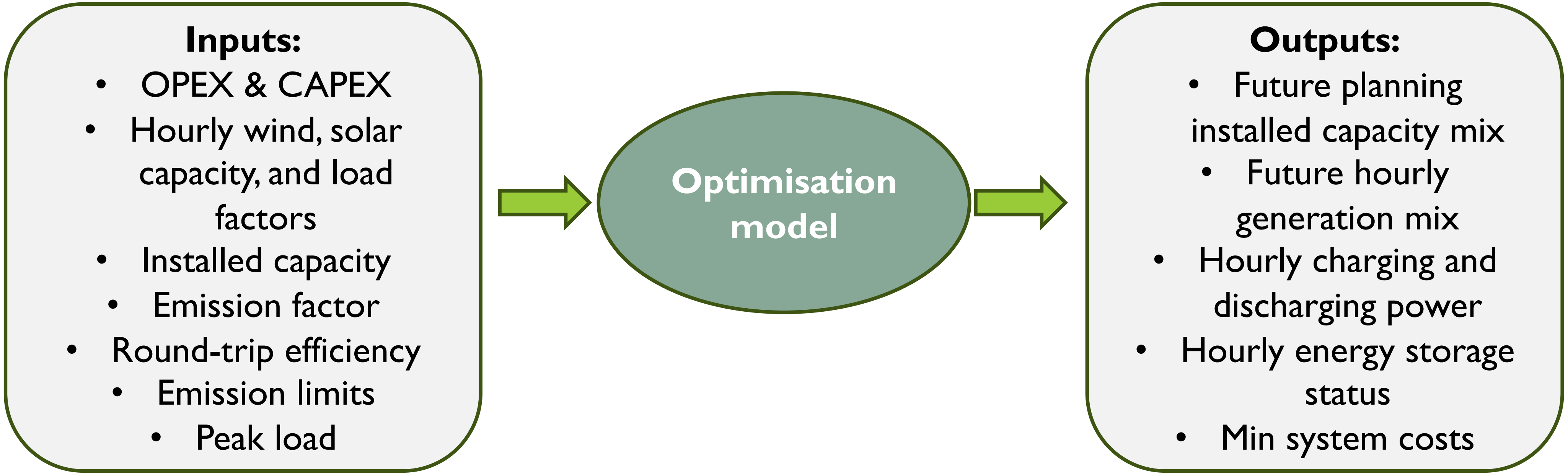
The UK's power system

- hydro generation
- coal-fired generation
- gas-fired generation
- Biomass generation
- nuclear power generation
- wind power generation
- solar power generation
- pumped hydro storage (PSH)
- battery storage (BESS)
- flywheels storage

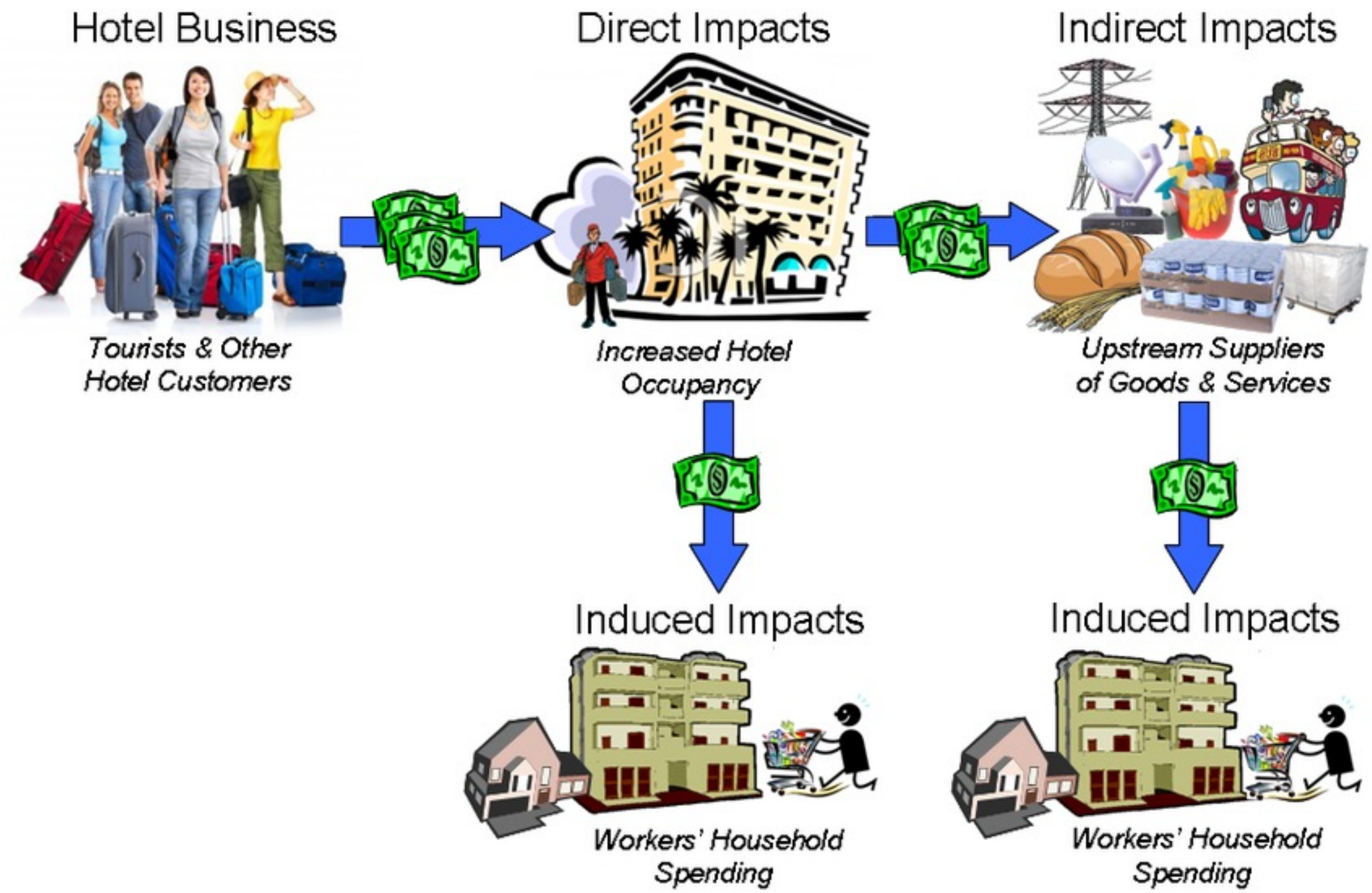
SCENARIO DESIGN

	Description	Capacity in 2025 (MW)
China	Base	PSH: 62000 BESS: 30000
	Medium-growth capacity: 20% higher than BAU for PSH; 50% higher than BAU for BESS	PSH: 74400 BESS: 45000
	High-growth capacity: 40% higher than BAU for PSH; 100% higher than BAU for BESS	PSH: 86800 BESS: 60000
UK	Base	PSH: 2800 BESS: 10000 Flywheels: 400
	Medium-growth capacity: 20% higher than BAU for PSH; 50% higher than BAU for BESS and Flywheels	PSH: 3360 BESS: 15000 Flywheels: 600
	High-growth capacity: 40% higher than BAU for PSH; 100% higher than BAU for BESS and Flywheels	PSH: 3920 BESS: 20000 Flywheels: 800

POWER SYSTEM OPTIMISATION MODEL



INPUT-OUTPUT MODEL EXAMPLE



INPUT-OUTPUT MODEL

$$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{F}$$

where

X represents the total outputs by sector after changes
I is a unit matrix
A is the matrix of direct input coefficients of domestic products in original IO tables, $a_{ij}=z_{ij}/x_j$
F represents the final demand by sector after changes

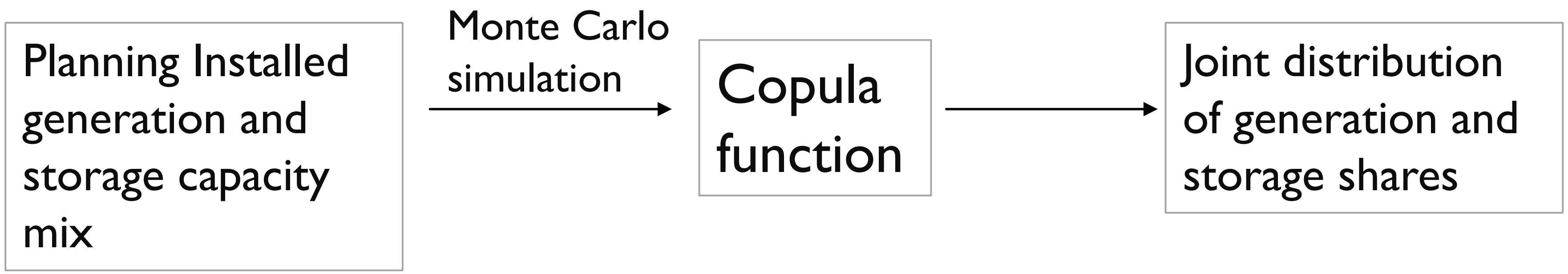
INPUT-OUTPUT TABLE

		sectors				FD	TO
		I	…	N	n		
sectors	I	**Z**				**F**	**X**
	⋮						
	N						
	n						
TVA		**V**					
TTI		**Y**					

		sectors						FD	TO
		I	…	N	n	…	n+k		
sectors	I	$\mathbf{Z}^{N}$			$\mathbf{Z}^{Ne}$			$\mathbf{F}^{N}$	$\mathbf{X}^{N}$
	⋮								
	N								
	n	$\mathbf{Z}^{eN}$			$\mathbf{Z}^{e}$			$\mathbf{F}^{e}$	$\mathbf{X}^{e}$
	⋮								
	n+k								
TVA		$\mathbf{V}^{N}$			$\mathbf{V}^{e}$				
TTI		$\mathbf{Y}^{N}$			$\mathbf{Y}^{e}$				

COPULA FUNCTION

A good tool to solve joint distribution problems between multiple correlated variables



INPUT-OUTPUT MODEL

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="6">sectors</td><td rowspan="2">FD</td><td rowspan="2">TO</td></tr>
<tr><td>I</td><td>…</td><td>N</td><td>n</td><td>…</td><td>n+k</td></tr>
<tr><td rowspan="6">sectors</td><td>I</td><td colspan="3" rowspan="3">$\mathbf{Z}^{\mathbf{N}}$</td><td colspan="3" rowspan="3">$\mathbf{Z}^{\mathbf{Ne}}$</td><td rowspan="3">$\mathbf{F}$
$\mathbf{N}$</td><td rowspan="3">$\mathbf{X}$
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<tr><td>⋮</td></tr>
<tr><td>n+k</td></tr>
<tr><td colspan="2">TVA</td><td colspan="3">$\mathbf{V}^{\mathbf{N}}$</td><td colspan="3">$\mathbf{V}^{\mathbf{e}}$</td><td colspan="2" rowspan="2"></td></tr>
<tr><td colspan="2">TTI</td><td colspan="3">$\mathbf{Y}^{\mathbf{N}}$</td><td colspan="3">$\mathbf{Y}^{\mathbf{e}}$</td></tr>
<tr><td colspan="2"></td><td colspan="6">Emission account</td></tr>
</table>

$$B = \mathbf{E}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{F}$$

where

B represents the total the carbon emissions;
E represents the carbon emissions per unit of output of each sector

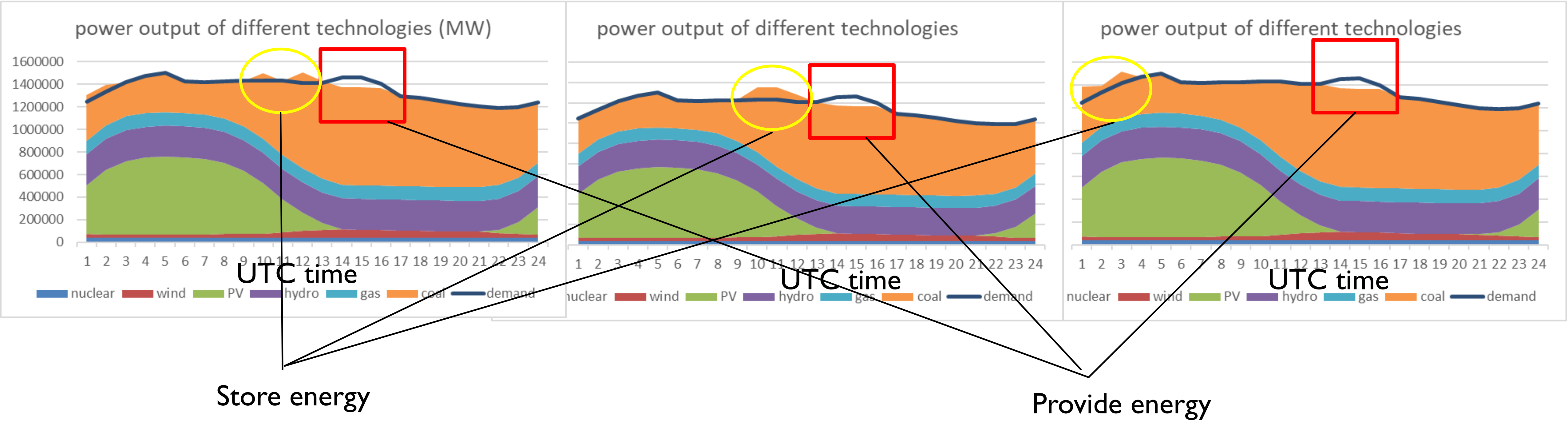
RESULTS

OPTIMISATION MODEL RESULTS FOR CHINA

Scenario:
PSH: 62000 MW
BESS: 30000 MW

Scenario:
PSH: 74400 MW
BESS: 45000 MW

Scenario:
PSH: 86800 MW
BESS: 60000 MW

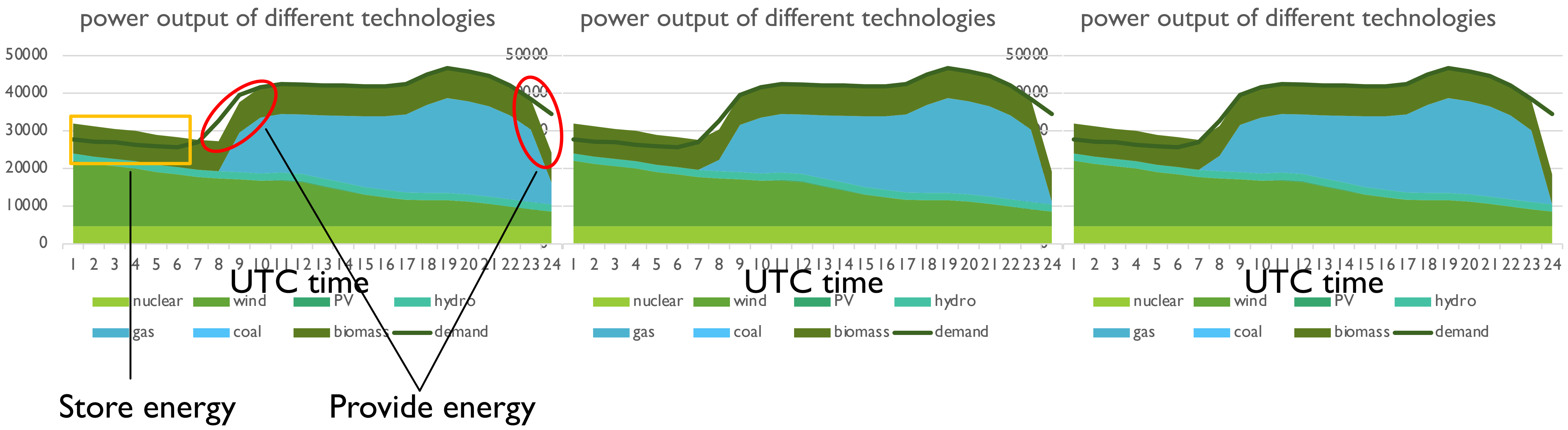


OPTIMISATION MODEL RESULTS FOR UK

Scenario:
PSH: 2800 MW
BESS: 10000 MW
Flywheels: 400 MW

Scenario:
PSH: 3360 MW
BESS: 15000 MW
Flywheels: 600 MW

Scenario:
PSH: 3920 MW
BESS: 20000 MW
Flywheels: 800 MW

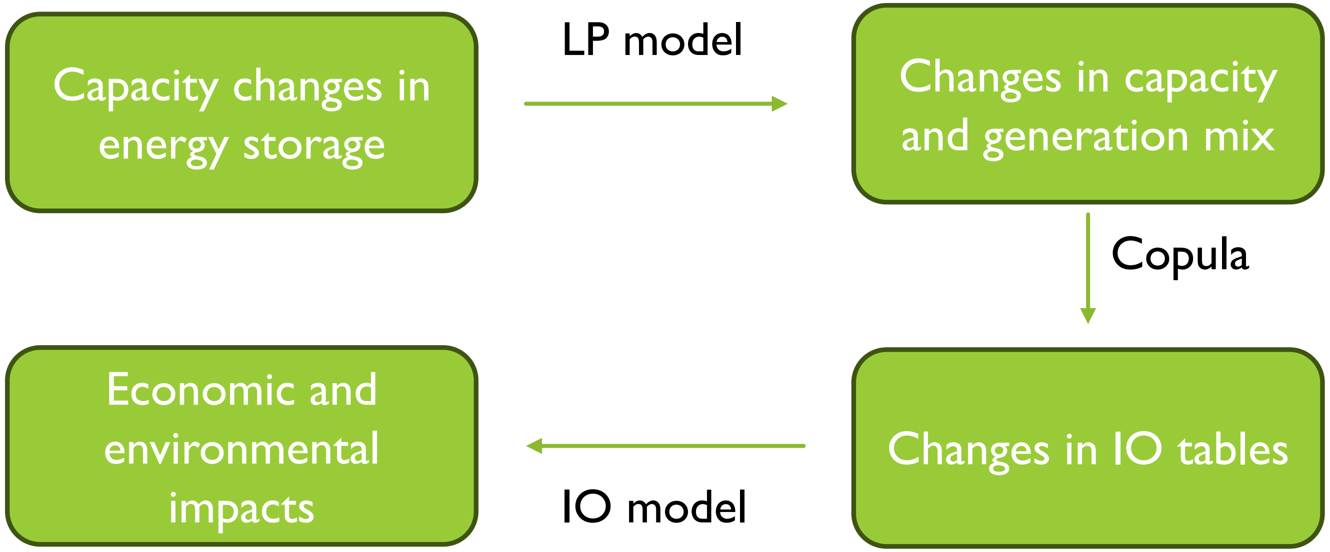


SUMMARY

SUMMARY

The most important role of energy storage is peak shaving

Impacts mechanism:



THANK YOU

Q & A

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