Integrated Resource Planning Training for Decision Makers

Day 6, Session 11 Optimisation of dispatch and of investment

15 March 2021

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- What is dispatch?
- Analysing thermal generators in an IRP
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- Analysing Storage in an IRP

Electricity’s unique properties as a commodity

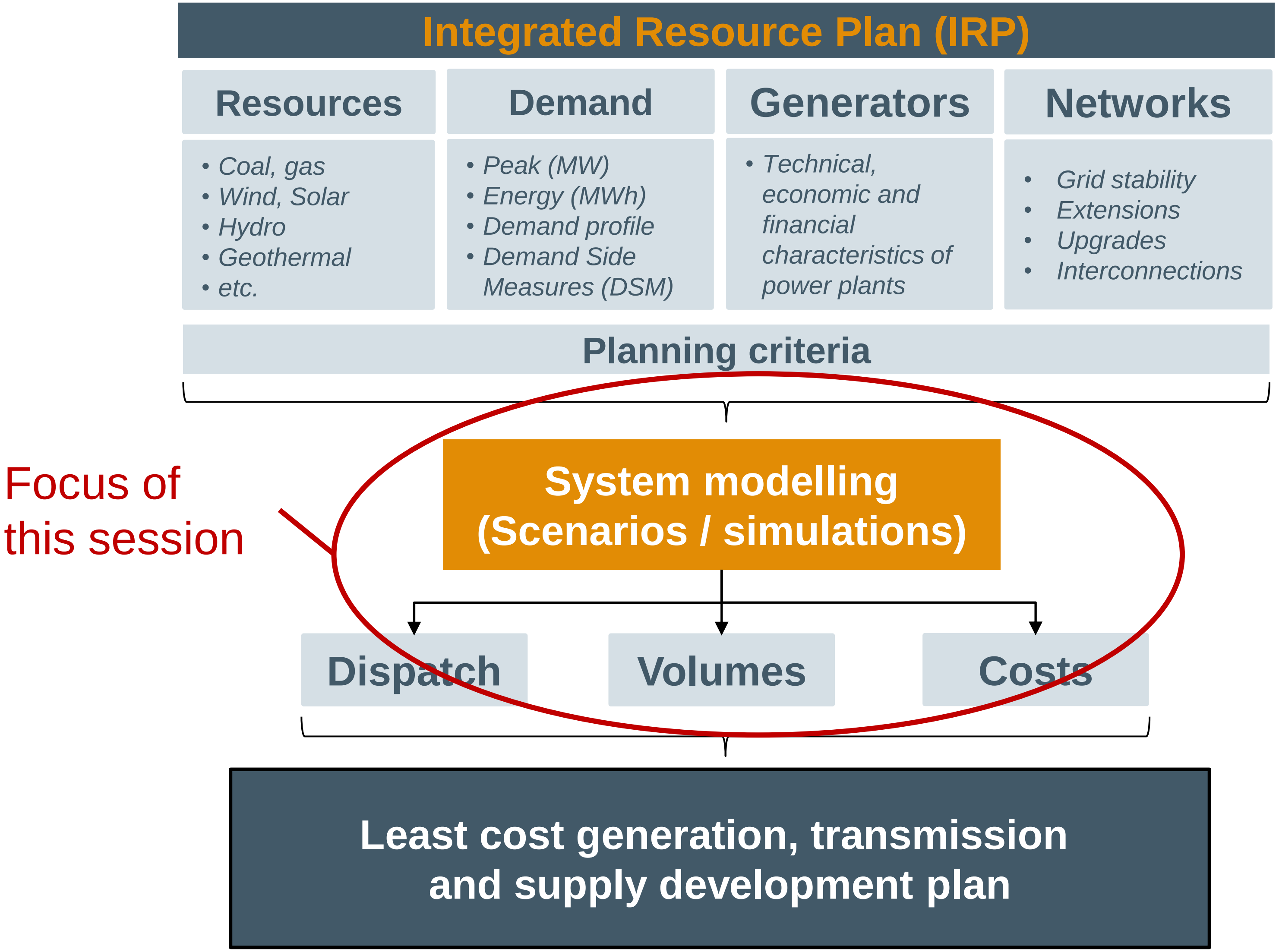
- There are high fixed-costs to build the necessary infrastructure to transmit and distribute the electricity to end-users.
  - It requires planning looking at the sector in the long run
  - Asset lives more than 20 years
- It cannot be stored as electricity
  - It must be created to be used immediately and the demands varies over short intervals
  - Fly wheels, batteries, pumped storage all convert electricity into other forms of energy and then convert the energy back to electricity
  - There is a cost to storage
- Once electricity is produced, it is impossible to tell which generator produced which electrons once it is pooled in the network.

Why least cost planning?

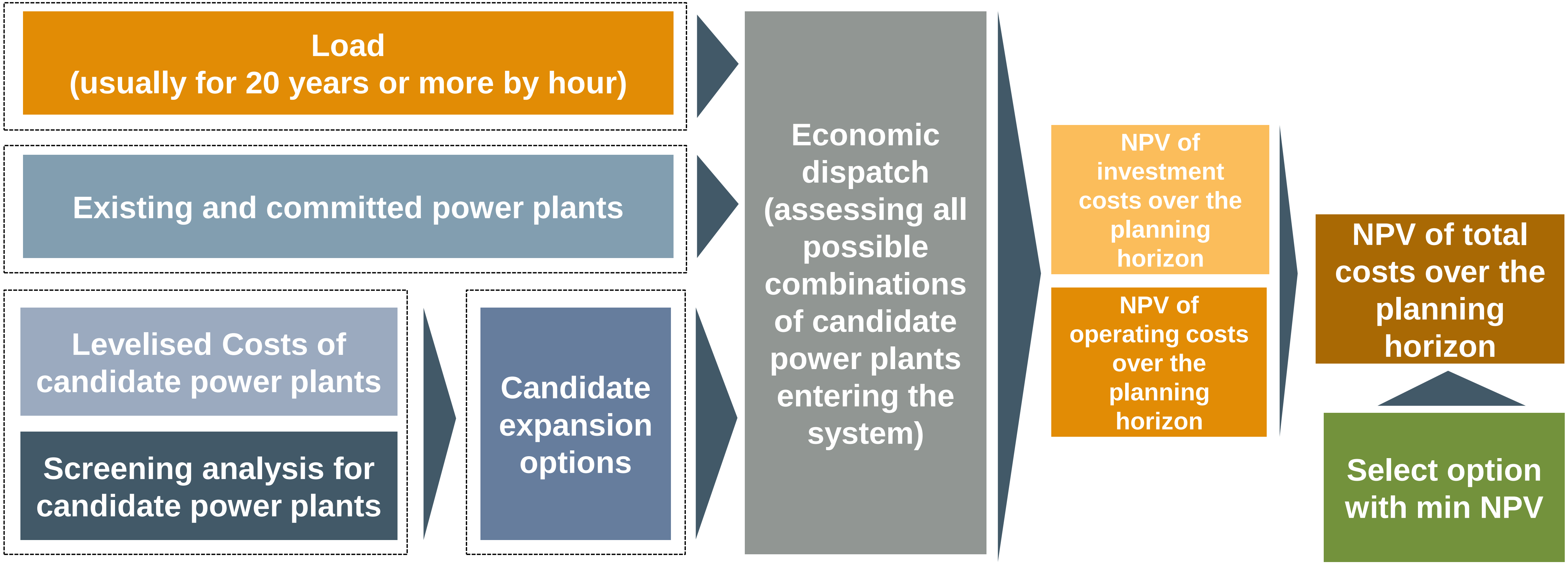
- Least cost planning is a method to evaluate alternatives in terms of both costs and reliability
  - Estimates full costs of providing a given amount of electricity
    - Direct costs – construction, planning, operation, etc.
    - Externalities – environmental costs, loss of habitat, etc.
  - Take into consideration technical constraints
    - Generators constraints
    - Grid constraints
  - Wide variety of generation facilities with costs and technical characteristics changing over time
  - Compare, rank and select portfolio that minimizes cost given the uncertainty on demand and cost estimates

Overview of an IRP

- The objective of the IRP is to establish the
  - long term generation and transmission plan
  - that meets the forecast electricity demand
  - at the lowest **economic** cost
  - given policy and reliability targets.
- The plan establishes the mix of
  - import contracts and new generation capacity and transmission projects
  - that results in the lowest cost in present value, real terms.



Selecting the least cost generation plan



Analysis to eliminate options that are clearly uneconomic

Analysis to determine candidate options

To simulate the operation of the power sector sophisticated modelling is typically required

- Large datasets
  - One year has 8,760h and the analysis has to be done typically for 20 years
- Multiple candidate options
  - Several possible options have to be assessed
- Dynamic analysis is needed for hydro, RES and storage
- There are many factors to consider
  - Changing costs
  - Technical constraints
  - Reliability standards
  - Policy and renewable energy targets

Inputs

All inputs, some of which are constant and, others that vary by period.

- General inputs
- Demand forecast inputs
- Power plant inputs
- Fuel price inputs
- Network inputs

Calculations

Simulation of system's operation

Hydro/Storage representation

Renewables' generation by period

Merit order dispatch

Outputs

Compiles outputs for each period across the whole timeframe

Market outcomes

Investment decision

Cross border constraints

Policy and planning

What is economic dispatch?

- Economic dispatch is the balance of supply (generation) and load using the least cost option subject to technical constraints

Load forecast

- System load in each period (half hour/hour)

Available generating units

- Available capacity each period

Cost of generating:

- variable O&M
- fuel costs
- heat rate
- startup costs

Generator operating limits:

- ramp rate
- min and max gen levels
- min running time
- min time must stay off when turned off
- Intermittency of RES generation

Economic dispatch

Balance supply and load using the least cost option subject to technical constraints

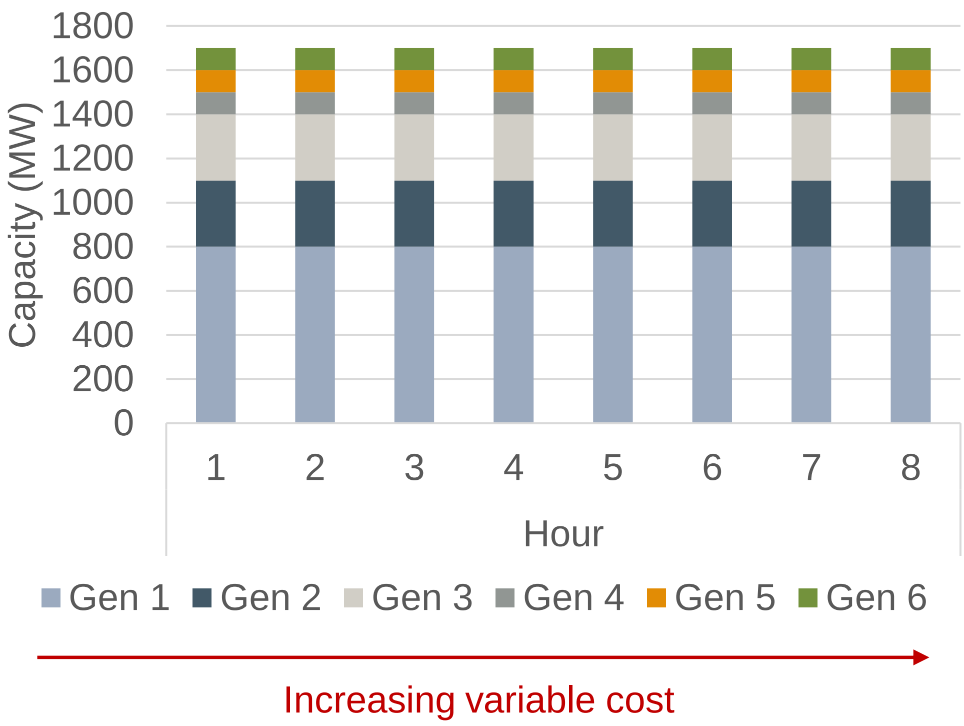
Why dispatch is needed?

- Demand changes at each hour
- Technologies are not the same
  - They have different technical characteristic
  - They have different costs
  - They may not be available at all times
    - Maintenance schedules, Forced outages, Availability of resources for RES
- A power plant can also provide other services
  - Ancillary services
    - Reactive power
    - Inertia
    - Frequency control
    - Spinning reserves
    - Non-spinning reserves

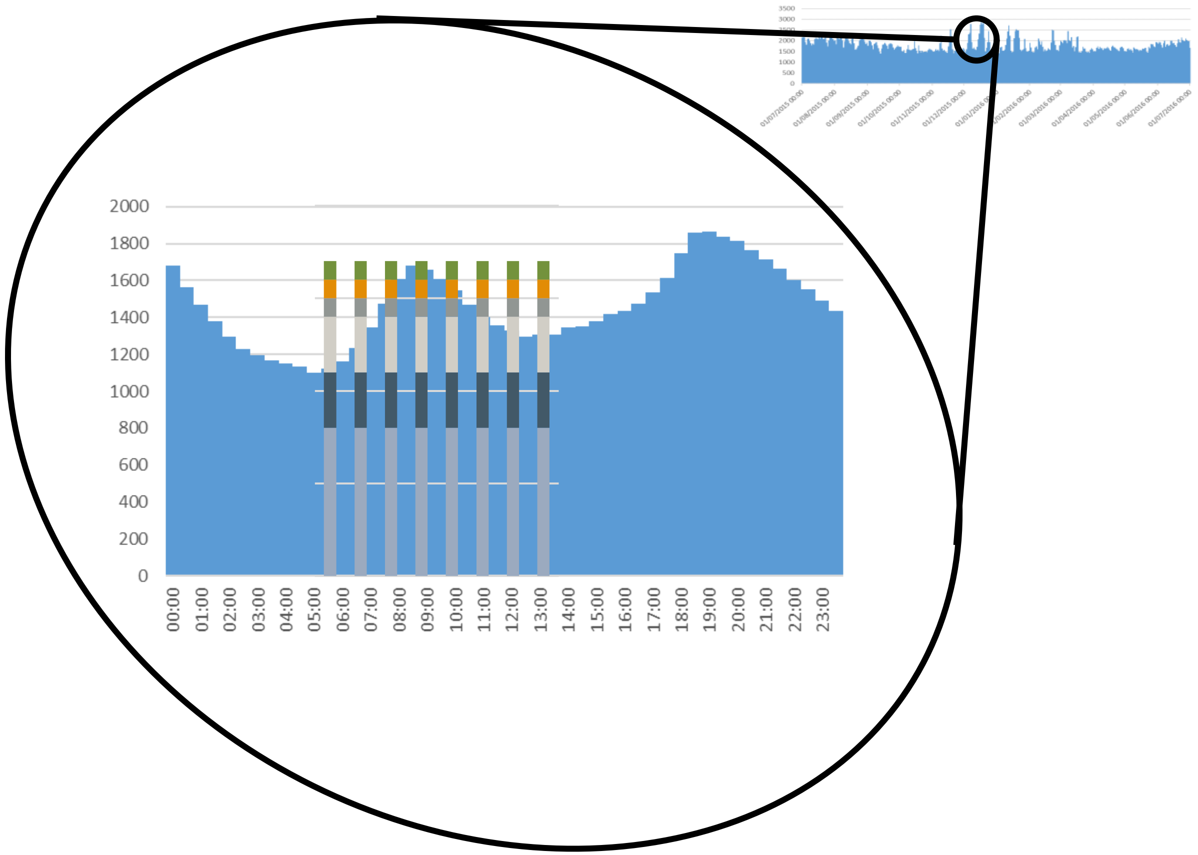
- Dynamic dispatch decisions are also necessary to assess hydro, pumped storage and batteries
  - It is uncertain when and whether RES will be available for dispatch
  - Storage optimasation is a dynamic problem that requires cyclical modelling
  - Hydro generation is constrained by the amount of water that is available
    - The decision of when and how much hydro energy should be dispatched significantly affects system costs

What gets dispatched? Merit order and load

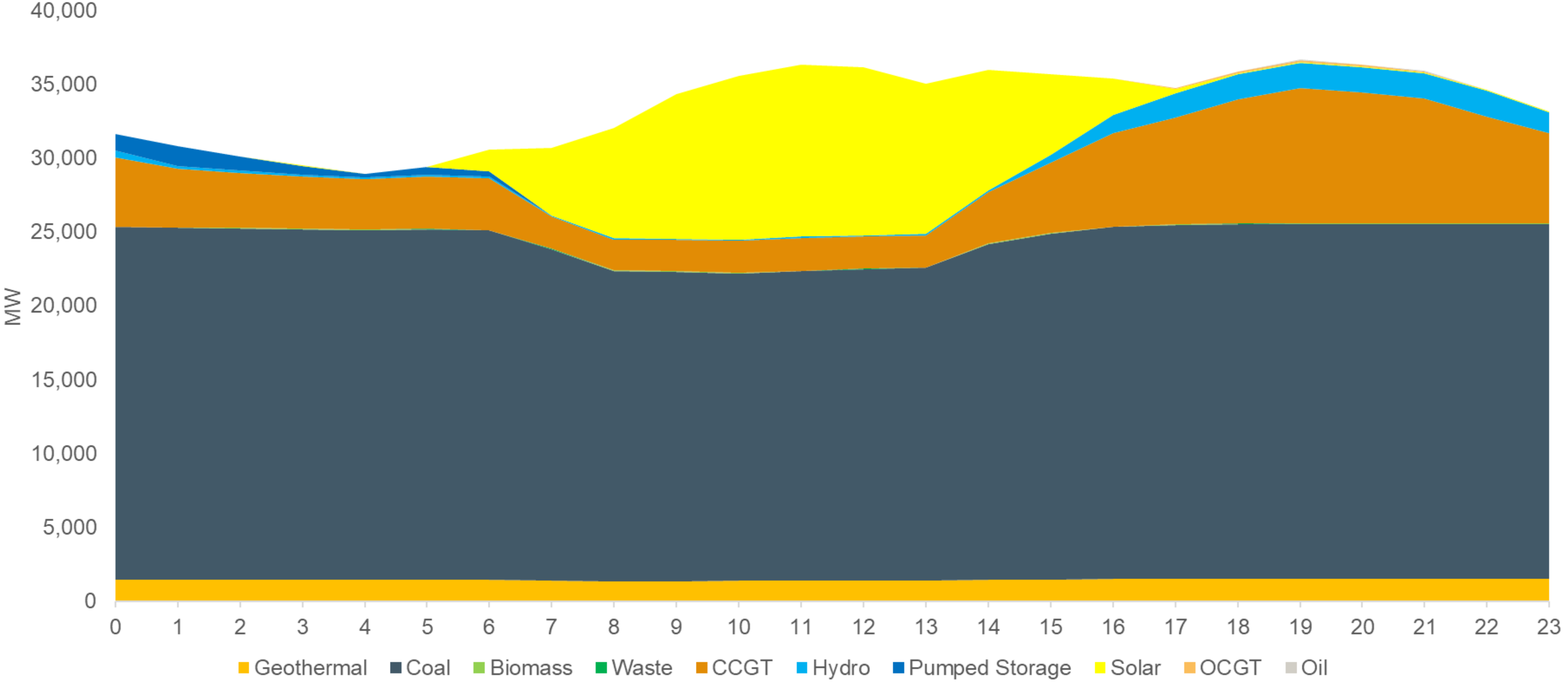
- Sort available generators by their **variable costs** and stack



- Overlay on load for dispatch



Dispatch for an average day in a coal dependant system in Asia



Key planning inputs

- The forecast electricity demand (MW and GWh)
  - The forecast load shape (i.e. the MW demand in each hour of the year)
- The costs and technical characteristics of existing, committed and candidate generating plants
- The available power and energy of renewable energy power plants
- Cost of imports
- The security standards
  - Reserves margin or accepted LOLP/EENS
- The projections of fuel prices
- Scenarios and sensitivities
- The discount rate

Power plant information typically required for existing, committed and candidate power plants

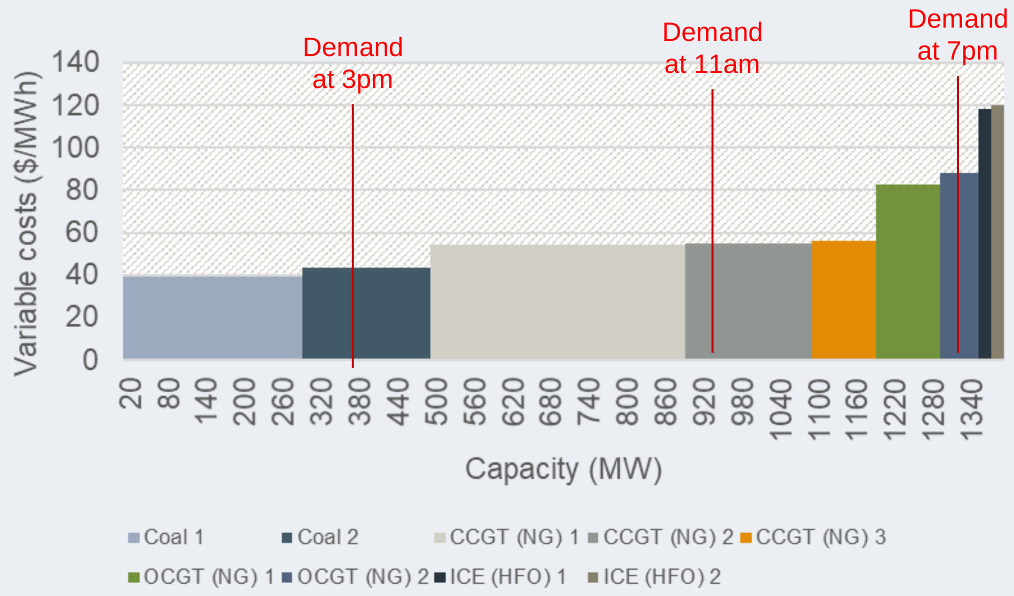
Plant Name	Status	Type	Fuel	Installed capacity (MW)	Grid Available Capacity (MW)	Available genera-tion (GWh)	Capital costs (US$/kW)	Variable O&M (US$/MWh)	Fixed O&M (US$/kW/yr)	Heat rate (GJ/MWh)	Lifetime	FOR (%)	MOR (days)	Year avail.
Hydro 1	Existing	Hydro Dam	Hydro	19.8	19.8	85	-	1.07	10.1	-	50	2%	21	2005
Hydro 2	Existing	Hydro Dam	Hydro	5.6	5.6	28	-	1.07	10.1	-	50	2%	21	1990
Hydro 3	Existing	Hydro Dam	Hydro	20	20	50	-	1.07	10.1	-	50	2%	21	1990
Hydro 4	Existing	Hydro Dam	Hydro	15	15	70	-	1.07	10.1	-	50	2%	21	1990
Bagasse 1	Existing	Subcritical Steam	Bagasse	65.5	0	n/a	-	4.1	80	17.049	25	4%	30	2012
Bagasse 2	Existing	Subcritical Steam	Bagasse	41.5	12	n/a	-	4.1	80	17.049	25	4%	30	2010
Coal 1	Existing	Subcritical Steam	Coal	2.2	0	n/a	-	2.2	48.4	10.970	30	4%	21	2010
Solar 1	Existing	Solar PV	Solar	0.1	0.1	Generation profile	-	0	10.5	-	25	0%	4	2016
Hydro 5	Committed	Hydro	Hydro	13.6	13.6	71.0	-	1.05	10.0	-	50	2%	21	2021
Hydro 6	Candidate	Hydro	Hydro	120	120	275.6	4,328	0.5	5.8	-	50	2%	21	2026
Coal 2	Candidate	Subcritical Steam	Coal	6 x 50	6 x 42.5	-	2,100	2.2	48.4	10.790	30	4%	21	2025
Bagasse 3	Candidate	Subcritical Steam	Bagasse	50	42.5	-	2,342	2.2	80.2	17.049	30	4%	21	2026
Biomass 1	Candidate	Subcritical Steam	Woodchips	50	42.5	-	2,242	2.2	135.3	14.234	30	4%	21	2027
Solar 2	Candidate	Solar PV	Solar	50	22	Generation profile	950	0.3	27.5	-	25	4%	30	2024
OCGT 1	Candidate	OCGT	HFO	30	30	-	848	13.0	21	10.666	25	3%	15	2020
Imports	Candidate	Imports	-	-	50	30		Import price		-	5	-	-	2023
Wind 1	Candidate	Onshore	Wind	30	30	Generation profile	1,264	7.0	13.0	-	25	4%	1%	2024
Battery 1	Candidate	Li-on	-	4	4	4h	1,395	efficiency	34.2	-	15	-	-	2023

Dispatching thermal power plants

- **The dispatch decision for thermal power plants depends on**
  - Variable costs
    - Variable O&M costs
    - Emission costs
    - Fuel costs (power plants efficiency / heat rates, fuel price)
    - Start up / Shut down costs
  - Technical constraints
    - Available capacity
    - Rump up/down rates
    - Min stable load
    - Maintenance schedules
    - Forced Outages

Constructing the merit order curve:

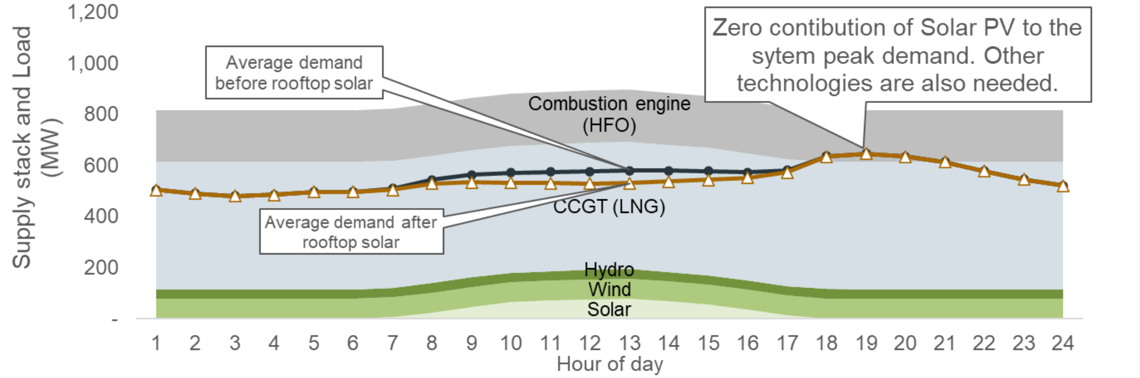
- Step 1 – Calculate power plant variable costs
  - Variable O&M + Heat rate x Fuel price + emission cost + (start up / shut down cost)
- Step 2 – Stack available capacity by least cost
- Step 3 – Technical constraints



Analysing Solar Photovoltaic (PV) generation in an IRP

- **Solar PV generation is intermittent**
  - Sometimes Solar PV produces electricity and sometime not
  - And it produces only at certain times
- **Solar PV has essentially zero variable costs**
  - When energy is available it is dispatched first
- **Solar PV generation may not match the system load profile**
  - Solar PV may not be able to contribute to capacity requirements in systems with an evening peak
- **Fast response reserves may be necessary**
- **Solar PV has to be assessed in combination with other technologies and at a granularity that can capture its intermittent nature**

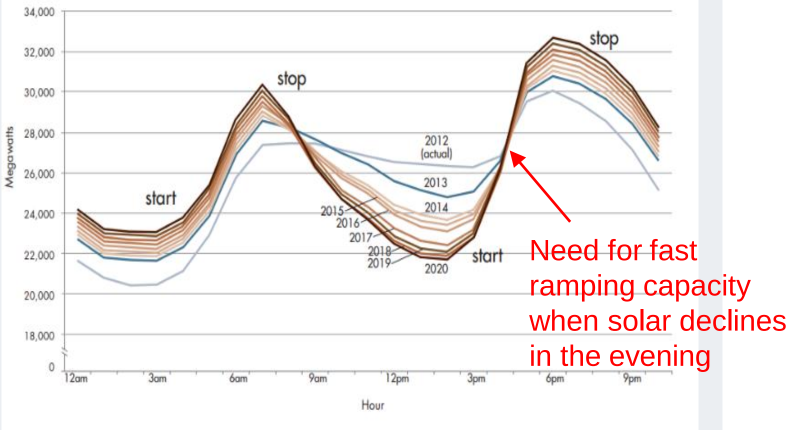
Solar PV in Jamaica does not provide peak capacity



Source: Economic Consulting Associates (ECA) analysis, 2018

California's changing load curve from 2012 to 2020

- Increased solar penetration contributes to 'duck curve' effect on daily load curve
- Need for fast ramp up capacity to meet evening peak as solar declines



Source: California ISO, What the duck curve tells us about managing a green grid, 2013

Analysing Wind generation in an IRP

Need to model variability of wind

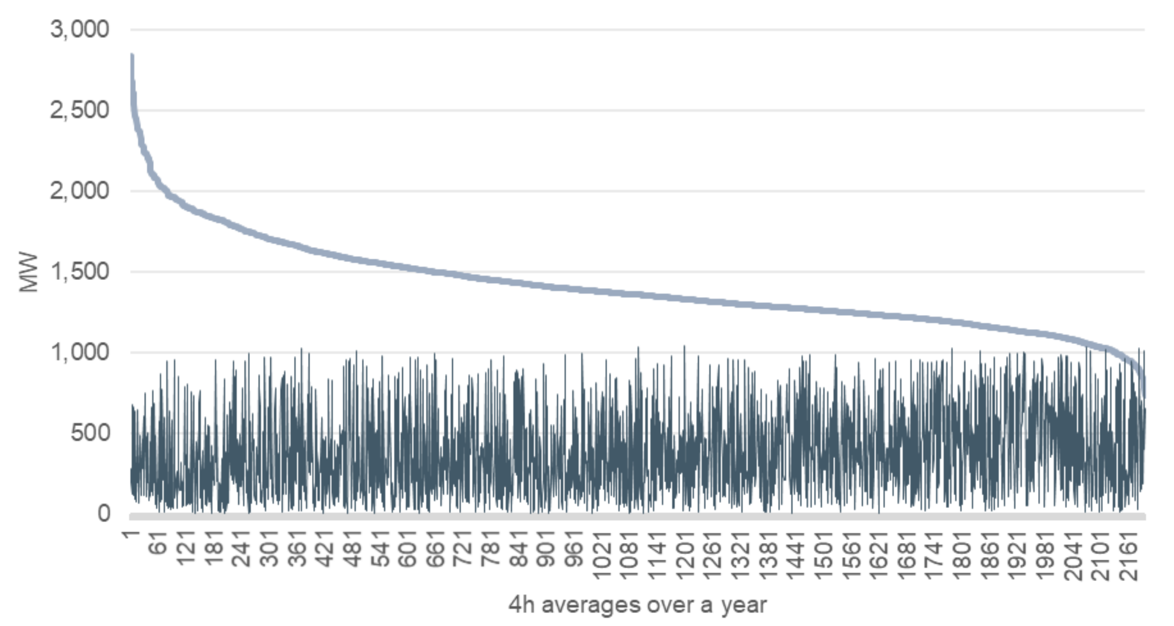
- Wind generation is generally characterised by volatility
  - For long-term planning, it is uncertain whether it will be windy at the time of the system peak on a Wednesday evening in June for example.
- Balancing wind power with other forms of generators is complex and is necessary to determine the least cost generation mix for planning.

Stochastic wind modelling

- Gives better indication of how much and what type of capacity is needed
- Can assess the reduction in energy costs against the need for additional capacity and fast response generation

Example of wind dispatch and the load duration curve in South Australia

- Wind does not correlate with load
  - Simulating wind will help determine the reduction in energy costs against the need for additional capacity and fast response generation
  - It can also assess what backup capacity may be needed



Source: Economic Consulting Associates (ECA) analysis, 2017

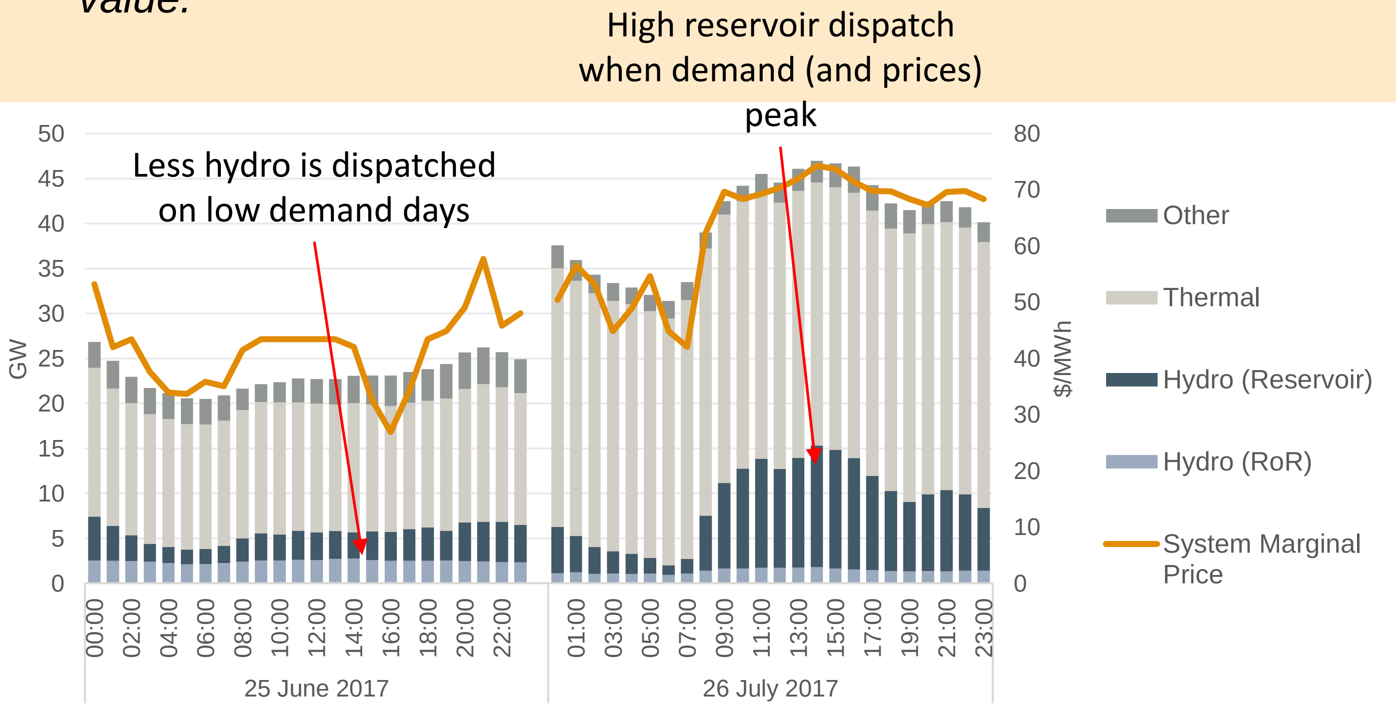
Analysing hydro (with or without reservoir?) in an IRP

The decision of when and how much hydro energy should be dispatched significantly affects system costs

- Hydro generation is constrained by the amount of water that is available
- Hydro power plants cannot operate at full capacity throughout a year; it depends on water availability
- Dispatch behaviour is typically determined by the 'marginal value of water' or its 'opportunity cost'
  - Variable cost is essentially zero
- The objective is to concentrate dispatch around peak period first
  - Subject to storage levels
- Hydro can also contribute to ancillary services

Example: Turkey summer 2017

- Less hydro is dispatched on low demand June day *despite more favourable hydrological conditions to save energy for hours with higher value.*

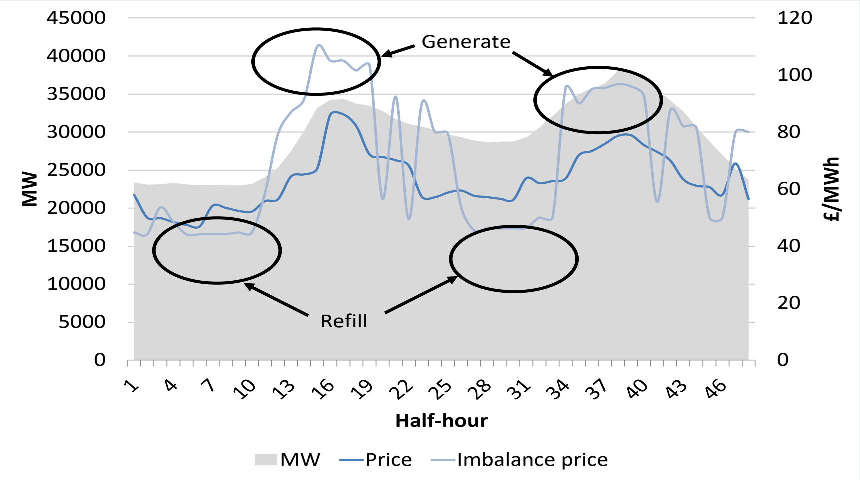


Source: Economic Consulting Associates (ECA) analysis, 2018

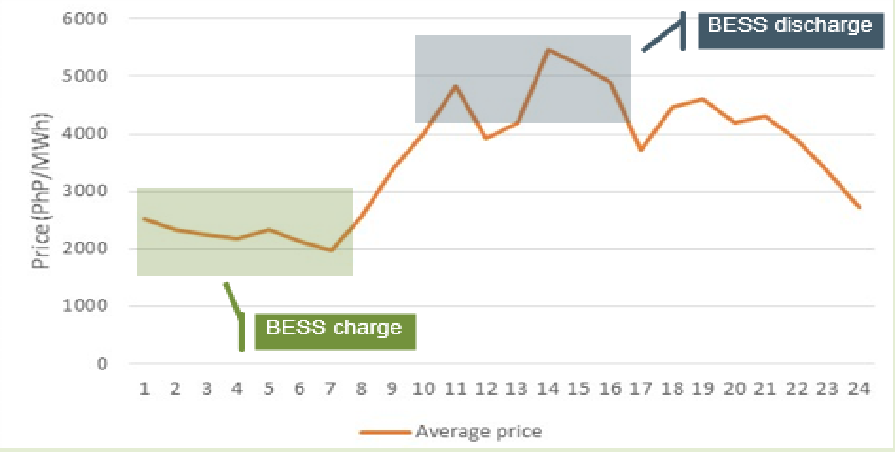
Analysing storage in an IRP (pumped-storage, battery storage)

- Pumped storage and batteries have similar characteristics to hydro with storage
  - Except that they have additional costs from storing
- The objective is to pump / charge in low-price periods for discharge in high-price periods
  - E.g. charge overnight; discharge at evening peak
- How can pumped storage and batteries be best utilised to minimise costs? Used for fast reserve service or peak energy?
  - **Dynamic problem** that requires cyclical modelling
    - A static view is insufficient
    - Requires analysis of expected price curves
    - On a cyclical basis, need to model whether a generator chooses to pump / charge or generate across rolling timeframes

- Cyclically refill and generate in response to prices (UK)



- Price curve for the Philippines in 2017 illustrating arbitrage opportunity for Battery Energy Storage Systems (BESS)



Source: Economic Consulting Associates (ECA) analysis, 2019

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