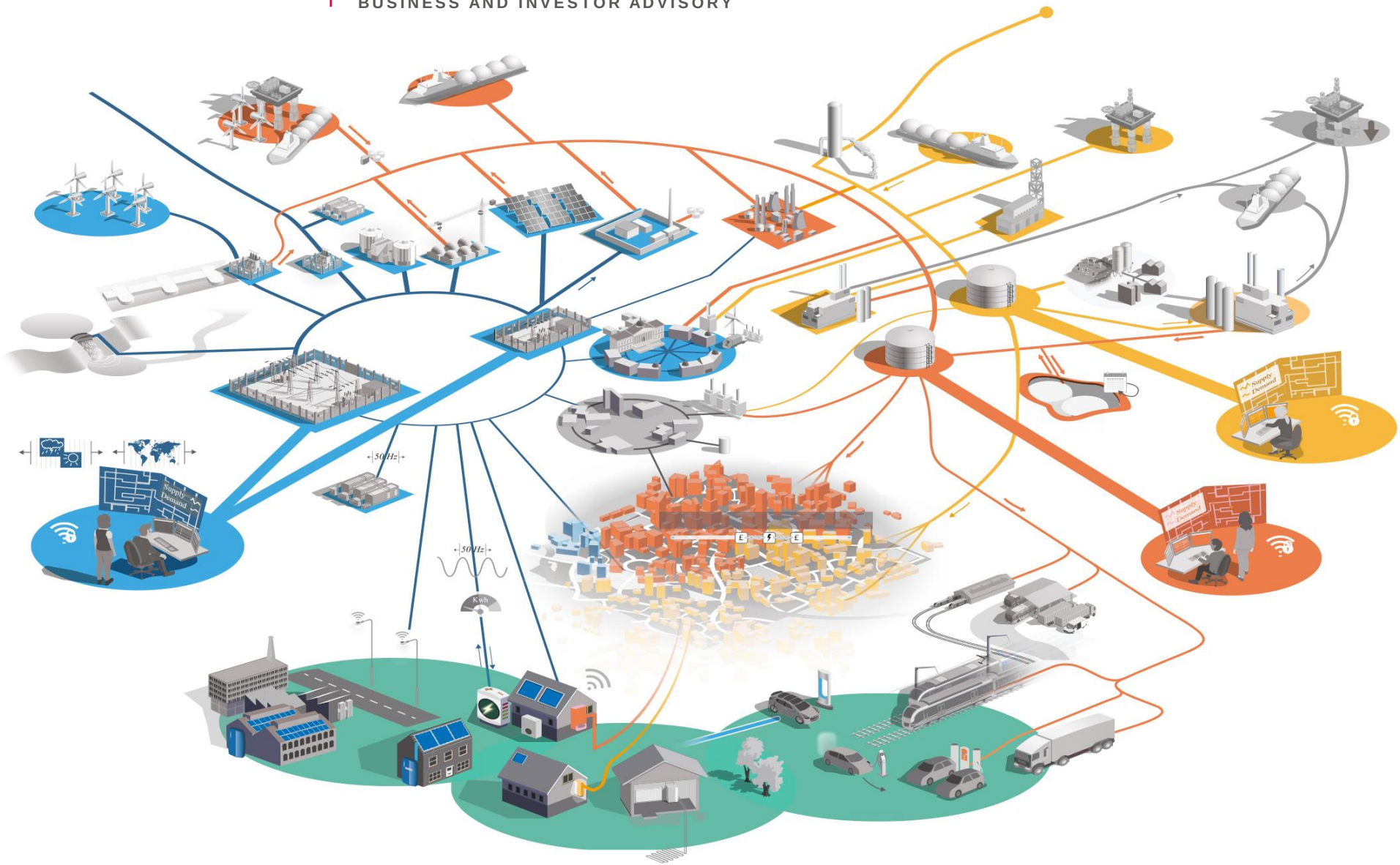
THE DEPLOYMENT OF BATTERY STORAGE IN GB AND EUROPE

JANUARY 2021

WORKSHOP PRESENTATION

BUSINESS AND INVESTOR ADVISORY



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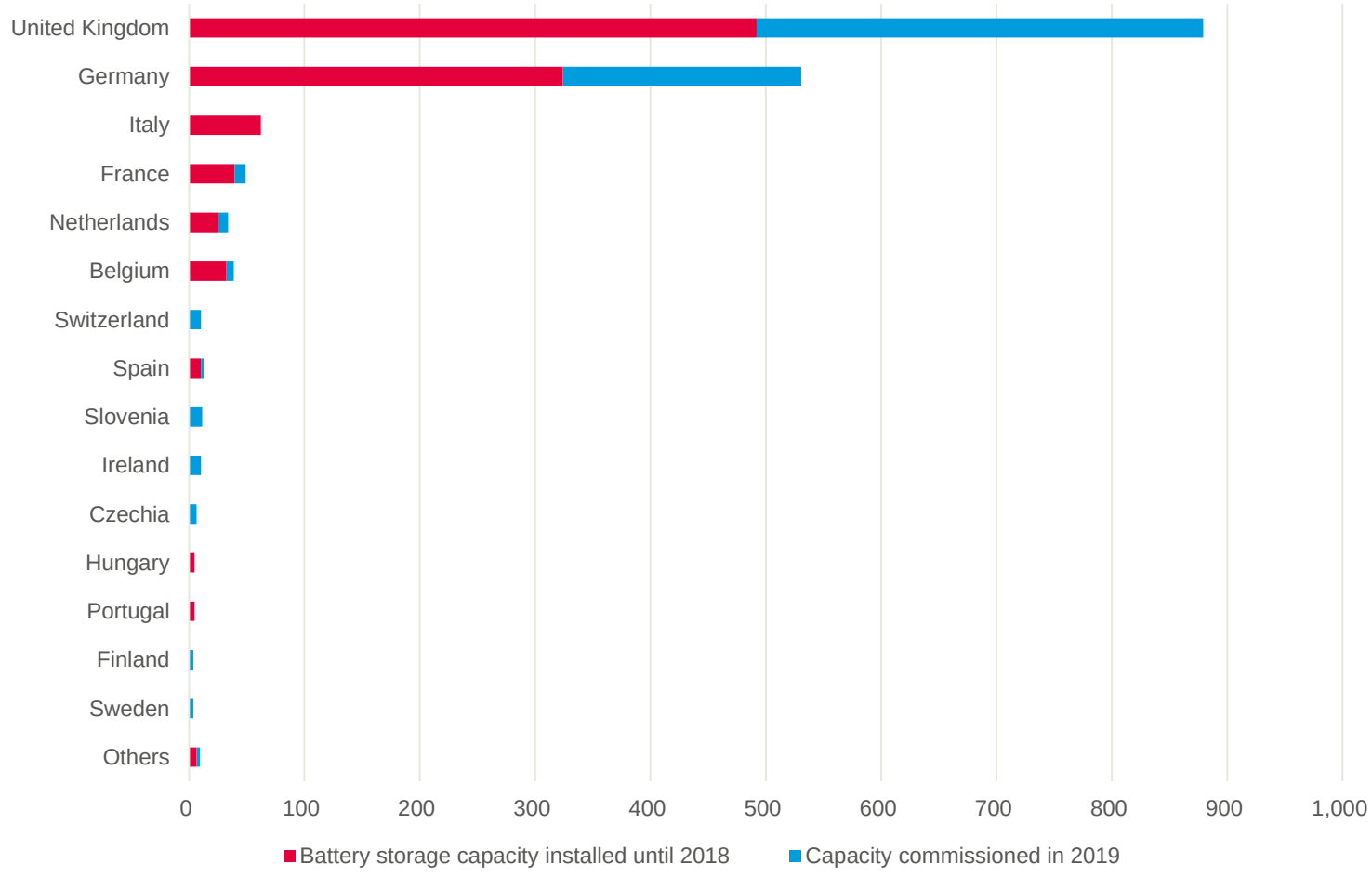
The deployment of Battery Storage in GB and Europe

European Installed utility scale battery storage capacity

The United Kingdom leads the way in the deployment of utility-scale battery storage in Europe with Germany second

FAST PACED GROWTH IN BATTERY STORAGE

Batteries are the fastest growing large energy storage form, favoured by developers and investors ahead of pumped hydro energy storage.



SOURCE: QUARTERLY REPORT ON EUROPEAN ELECTRICITY MARKETS (Q4 2019), EUROPEAN COMMISSION

The deployment of Battery Storage in GB and Europe

Location of Batteries in Electricity/Energy Systems

In GB and in Europe more generally, well before 2035, we are already seeing battery storage routinely deployed at multiple places in the electricity system

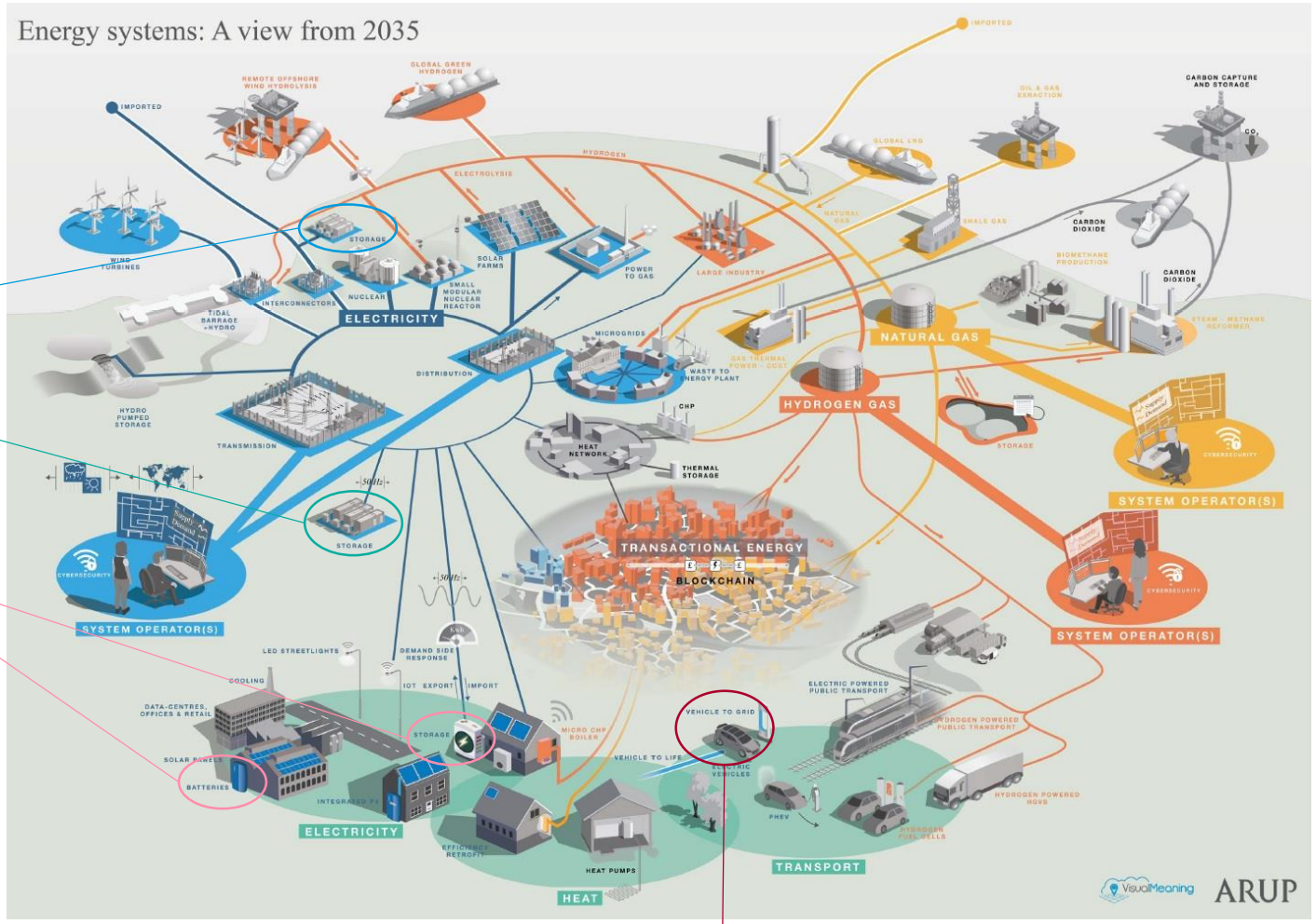
LOCATION OF BATTERIES IN ELECTRICITY / ENERGY SYSTEM

Transmission: Grid-scale batteries connected to the transmission network (400 kV).

Distribution: Grid-scale batteries connected to the distribution network (<33, 132 & 275 kV).

Behind the Meter: we have seen batteries deployed in businesses, the industrial and commercial (I&C) segment as well as in homes, the residential segment. In businesses/I&C batteries have been deployed to reduce network charges related to peak.

Vehicle to Grid (V2G): Plug-in electric vehicles, such as battery electric vehicles (BEV), plug-in hybrids (PHEV) or hydrogen fuel cell electric vehicles (FCEV), communicate with the power grid to sell demand response services by either returning electricity to the grid or by throttling their charging rate.

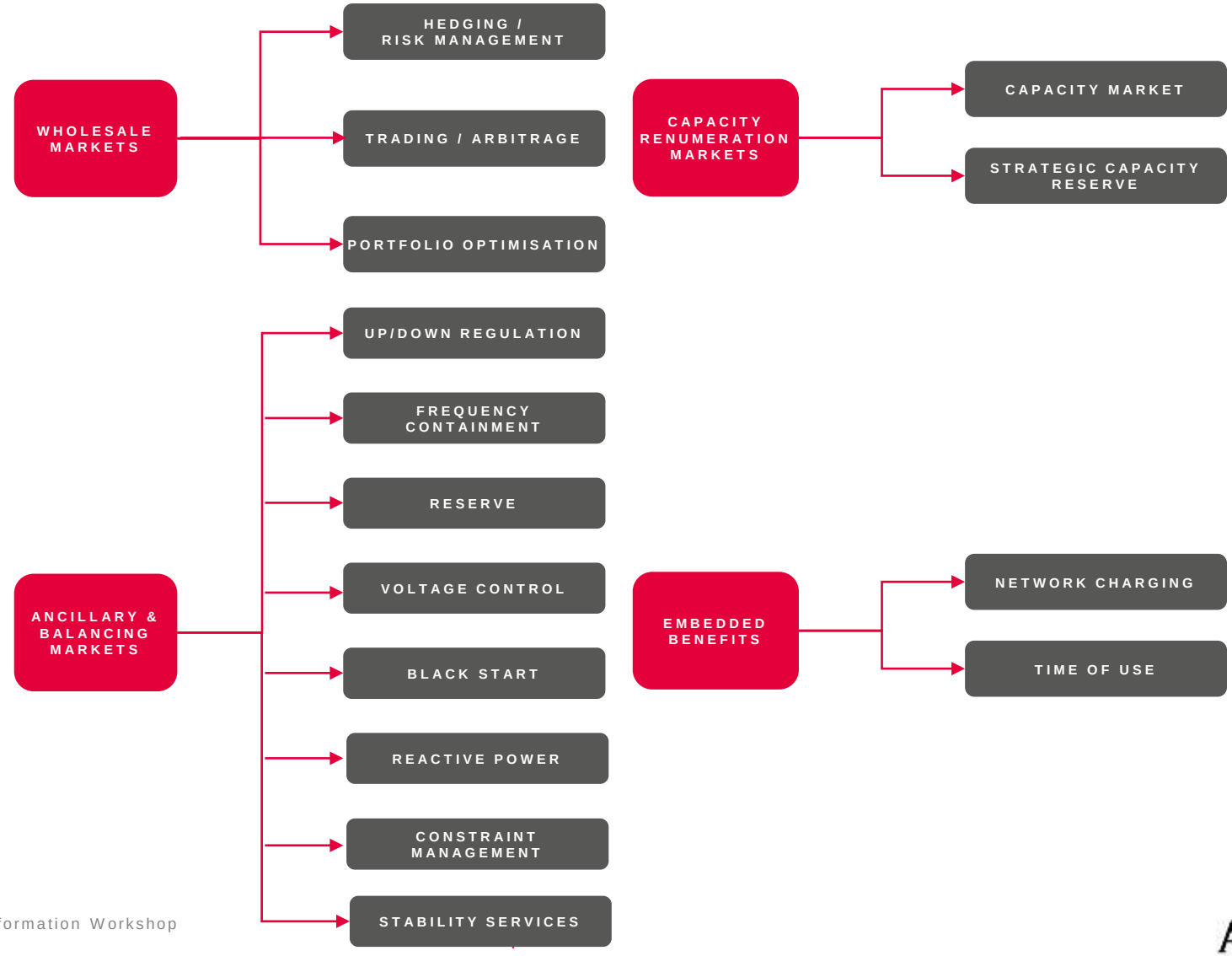


SOURCE: ENERGY SYSTEMS: A VIEW FROM 2035, ARUP, 2017

The deployment of Battery Storage in GB and Europe

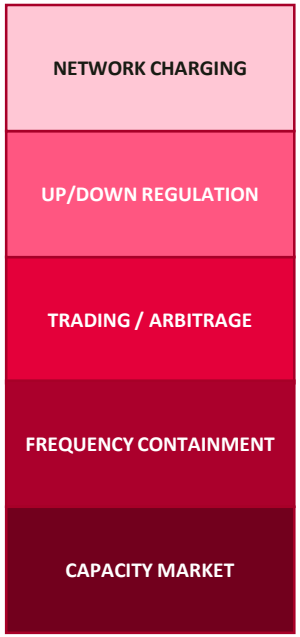
Battery Storage revenue streams

Battery Storage can provide valuable services to a number of different market players including generators, utilities, system operators and traders, capturing a number of revenue opportunities



REVENUE STACKING

Illustration of how revenues from different markets are stacked to deliver returns to investors:



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The deployment of Battery Storage in GB and Europe

Competitor Technologies: Wholesale & Imbalance Markets

Battery Storage is well placed to compete in Wholesale and Imbalance markets which are bigger and growing at a faster rate than Control Power markets where it competes across all of the control power markets

LEGEND

- Capable of providing the service
- ✓ Providing the service
- Not capable of providing the service
- × Not Providing the service

WHOLESALE & IMBALANCE

- **Day-Ahead Market (DAM)** – Generators (typically sellers) and Suppliers (typically buyers), voluntarily trade electricity, traditionally for hourly strips of electricity, a day before delivery.
- **Intra-Day Market** – Once again, Generators and Suppliers, voluntarily trade electricity up to an hour ahead of delivery, taking the opportunity to adjusting their in response to closer to real-time information.
- **Imbalance Market & Voluntary Balancing** – The System Operator accepts Bids to reduce generation / increase consumption and Offers to increase generation / reduce consumption.

	DAM	IDM	IM/VB	PC	SC	TC	Comments
Battery Storage	✓	✓	✓	✓	✓	×	Battery storage as we saw on our first slide has been deployed across the main geographical markets in Europe and is active across DAM, IDM and IM/VB in GB and Germany in particular
Compressed Air Energy Storage (CAES)	×	×	×	✓	×	×	Currently there is only one operational CAES in Europe, at Huntorf in Germany, but CAES could have a broad role across multiple markets
Conventional	✓	✓	✓	✓	✓	✓	Conventional generators are relatively high priced providers of ancillary services given the missed revenue from wholesale market needs to be recovered in ancillary services. Conventional generators such as: gas turbines (OCGT, CCGT) or Combined Heat and Power (CHP) systems
Demand Side Response (DSR)	✓	✓	✓	✓	✓	✓	Aggregators pool DSR from Industrial and Commercial (I&C) and take them to the markets
Hydro	✓	✓	✓	✓	✓	✓	Run-of-River and Seasonal-storage hydro across Europe compete in these markets
Flywheels	×	×	×	×	×	×	There is very limited operational flywheel capacity in Europe, it is expected to focus on the Primary Control market
Interconnectors	✓	✓	×	×	×	×	Day-ahead and intra-day market coupling is in operation across Europe (except GB, following Brexit), seeing interconnection competing with other forms of flexibility
Nuclear	×	×	×	✓	✓	×	Except in France, where nuclear power plants are operated flexibly. Nuclear power generation is generally sold out in the forwards/futures markets with DAM and IDM trading only used occasionally to manage planned and enforced outages
Peaking plant	✓	✓	✓	×	✓	✓	Expect the majority of trading to be in these markets given that they will largely be out-of-the-money in forward/futures market and will only come into-the-market during some peak hours. Given flexibility can support Voluntary Balancing Contribution in the Imbalance Market
Pumped Storage	✓	✓	✓	✓	✓	✓	There is significant pumped storage hydro capacity in Southern Europe and Central Western Europe
Wind and Solar	✓	✓	✓	×	×	✓	Although the generation output will be forward sold in the forward/futures market, price shape available in the DAM and IDM will be necessary to ensure a sculpted market output profile

BALANCING SERVICES

- **Primary Control (PC)** – Generator/demand side response within seconds either due to a deviation in the system frequency or a signal from the system operator.
- **Secondary Control (SC)** – An automatic centralised or decentralised service provided by the generator or a demand side responder to adjust the output of a unit if frequency deviation lasts for a longer period.
- **Tertiary Control (TC)** – An automatic or manual change of generator output, in order to restore reserve within minutes.

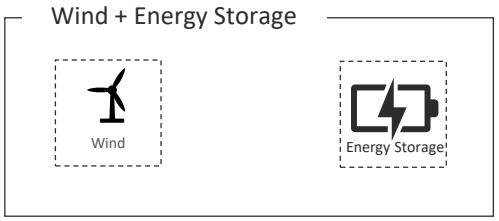
The deployment of Battery Storage in GB and Europe

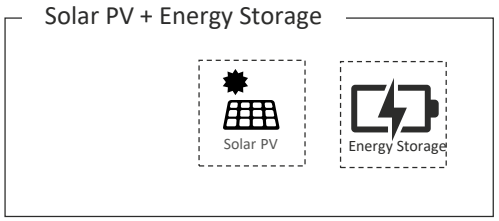
Hybridisation of Renewables with Energy Storage

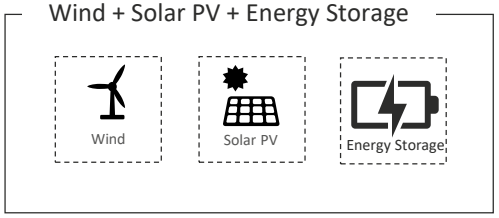
Both Hybrid Renewables + Storage and Hybrid Energy Storage Systems (HESS) can unlock additional value and reduce system integration costs.

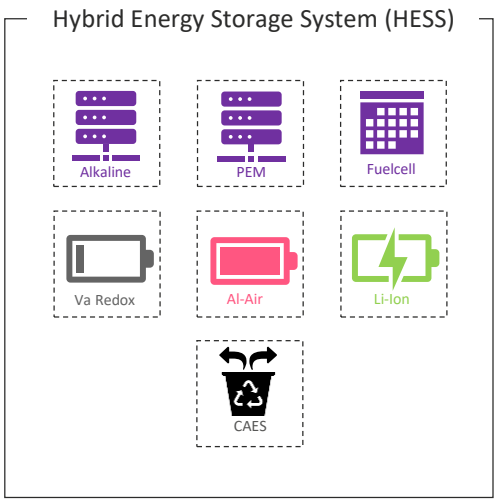
HYBRIDISATION UNLOCKED ADDITIONAL VALUE

- In GB and Europe battery storage development has largely been in response to a lack of system flexibility exposed by increased intermittent generation.
- We haven't yet seen significant examples of hybrid systems where renewables is paired with energy storage.
- Renewables and energy storage generation hybrid systems support the delivery of 'near firm' renewable generation. Regularising the output and therefore reducing the system integration costs.
- Hybrid Energy Storage Systems (HESS) typically combine fast-acting with slower-acting storage solutions. Enabling them to combined frequency response with energy arbitrage









The deployment of Battery Storage in GB and Europe

Key points

There are a umber of lessons which can be learned from the deployment of Battery Storage in GB and Europe

KEY CONSIDERATIONS

The creation of flexibility markets, for wholesale, imbalance and control power, will give developers, investors and lenders the confidence to invest to support the deployment of battery storage.

Procurement of flexibility needs to evolve in order to ensure consumers are getting value for money. Start with longer duration products before moving procurement closer to real time.

Assuming that there isn't further deregulation and unbundling, moving to 'near firm' renewables / low carbon generation procurement should encourage developers to hybridise renewables with battery storage and other electricity storage forms.

SOURCE: ARUP ANALYSIS

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