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WHEN TRUST MATTERS

Renewable energy balancing non-liberalized electricity markets

DNV Energy Systems

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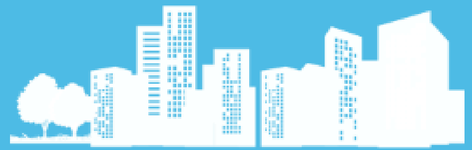
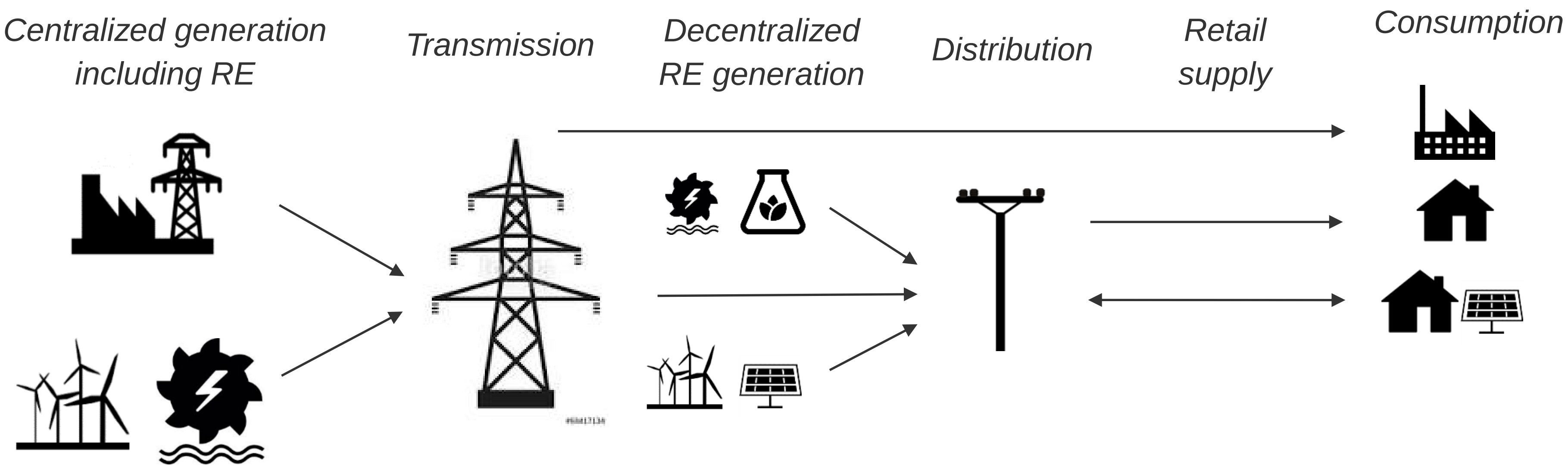


VRE integration in electricity systems

Renewable generation in the electricity system

As part of a world-wide trend, more and more renewable energy based generation is integrated in energy supply industries (ESI).

- Large-scale RE installations feed-in into high-voltage grid
  - ➢ Need for accommodation of consequences on system & transmission level
- Small-scale RE installations feed-in into mid / low voltage grid
  - ➢ Need for accommodation of consequences on system & distribution level

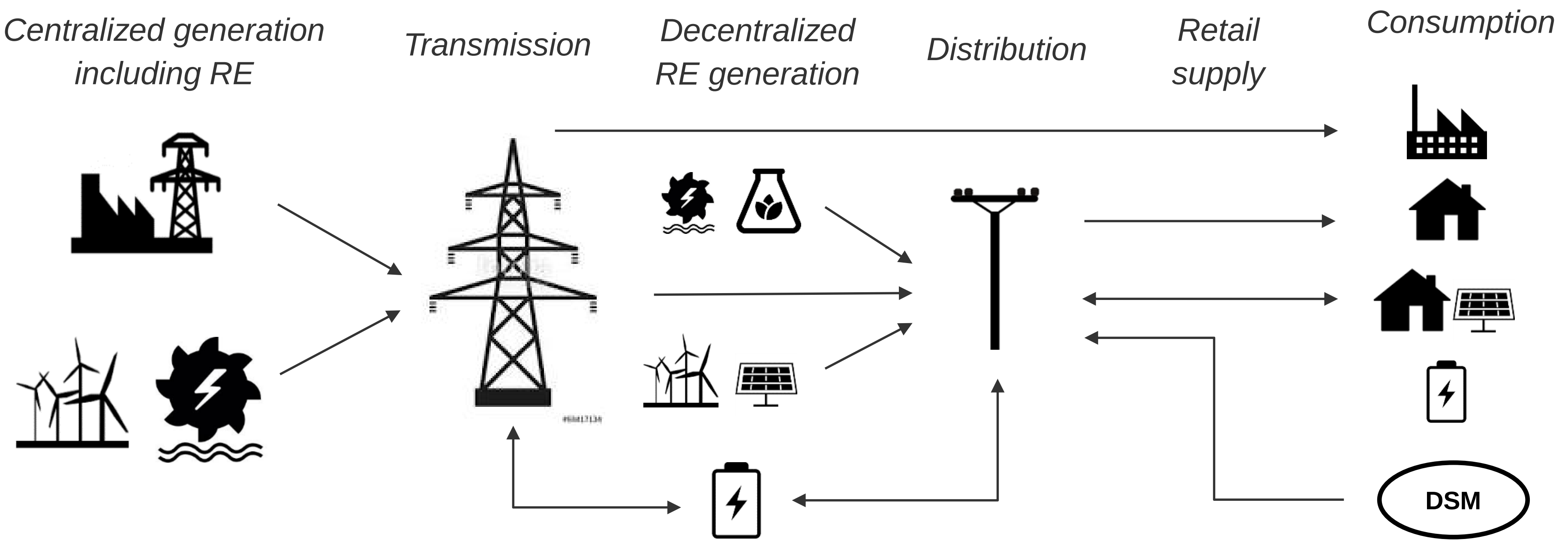


Source: DNV

Flexibility in the electricity system

The electricity system disposes of several sources of flexibility that can be harnessed to meet challenges arising from renewable energy generation.

- Flexible generation assets, incl. gas-fired power plants and biomass
- Storage can provide storage services on transmission & distribution level
- Demand side management (DSM): demand is reduced to resell electricity
- Self-consumption by prosumers provides additional flexibility

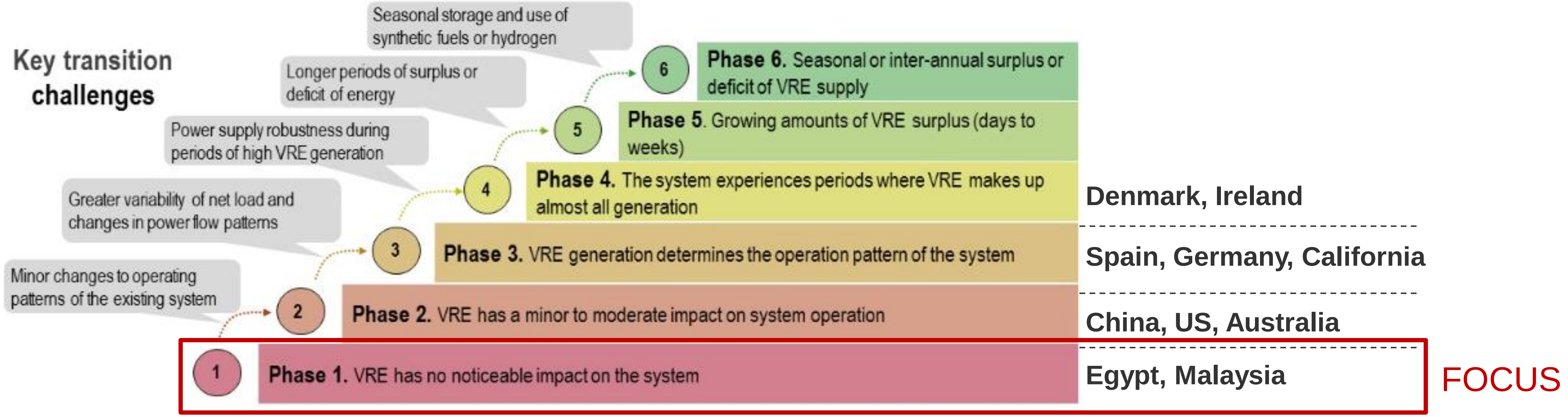


Source: DNV

VRE integration in electricity systems

Ambitious renewable-energy targets make it necessary to rethink the design of the electricity system and increase flexibility.

- IEA categorized integration of VRE into 6 different phases depending on the share of VRE in total generation
- RES progress has not been homogenous across countries (liberalized markets leading)
- No one-fits-all solution: different power sector structures, liberalization level and VRES integration challenges



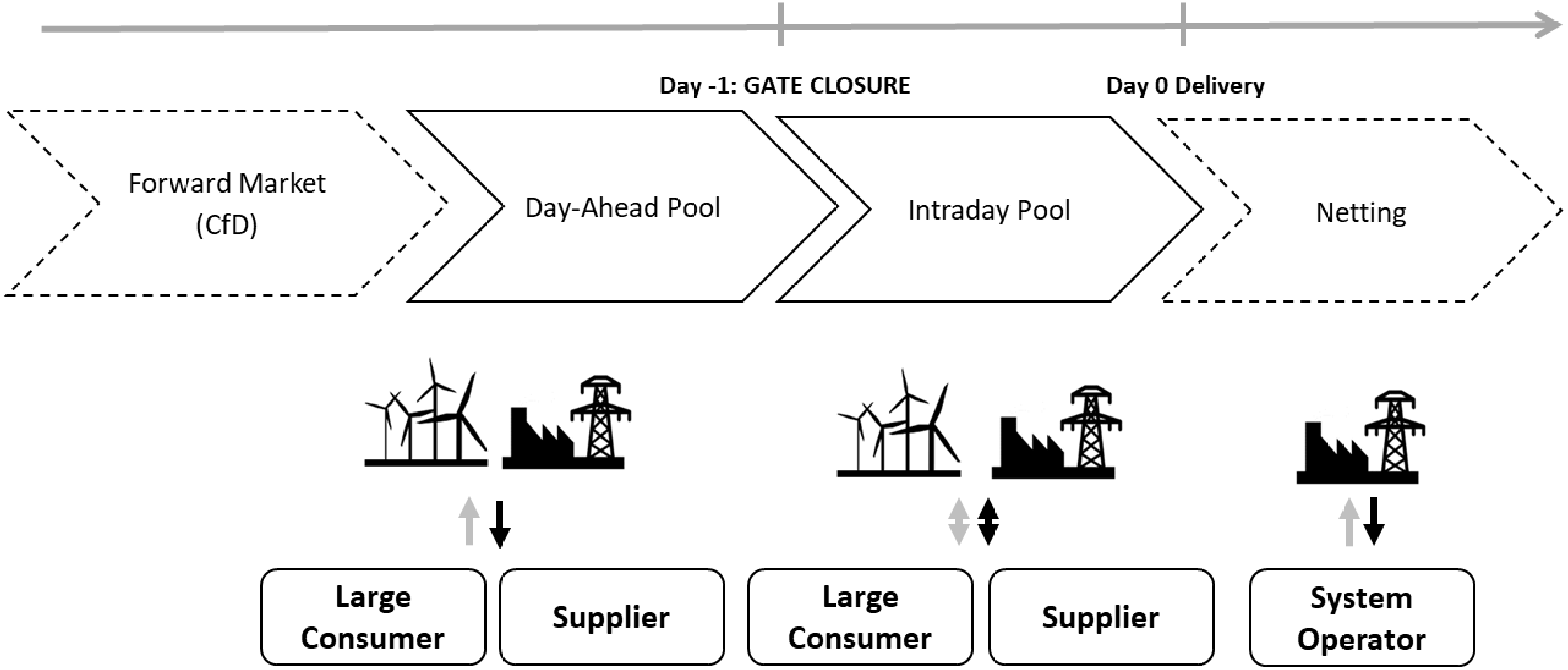
Source: IEA 2018

VRE in liberalized electricity systems

Large-scale RE electricity - Centralized market (power pool)

In centralized market VRE generated electricity typically sold in the DA market, ID is used to clear imbalances before delivery, remaining imbalances cleared via balancing markets.

Spanish example

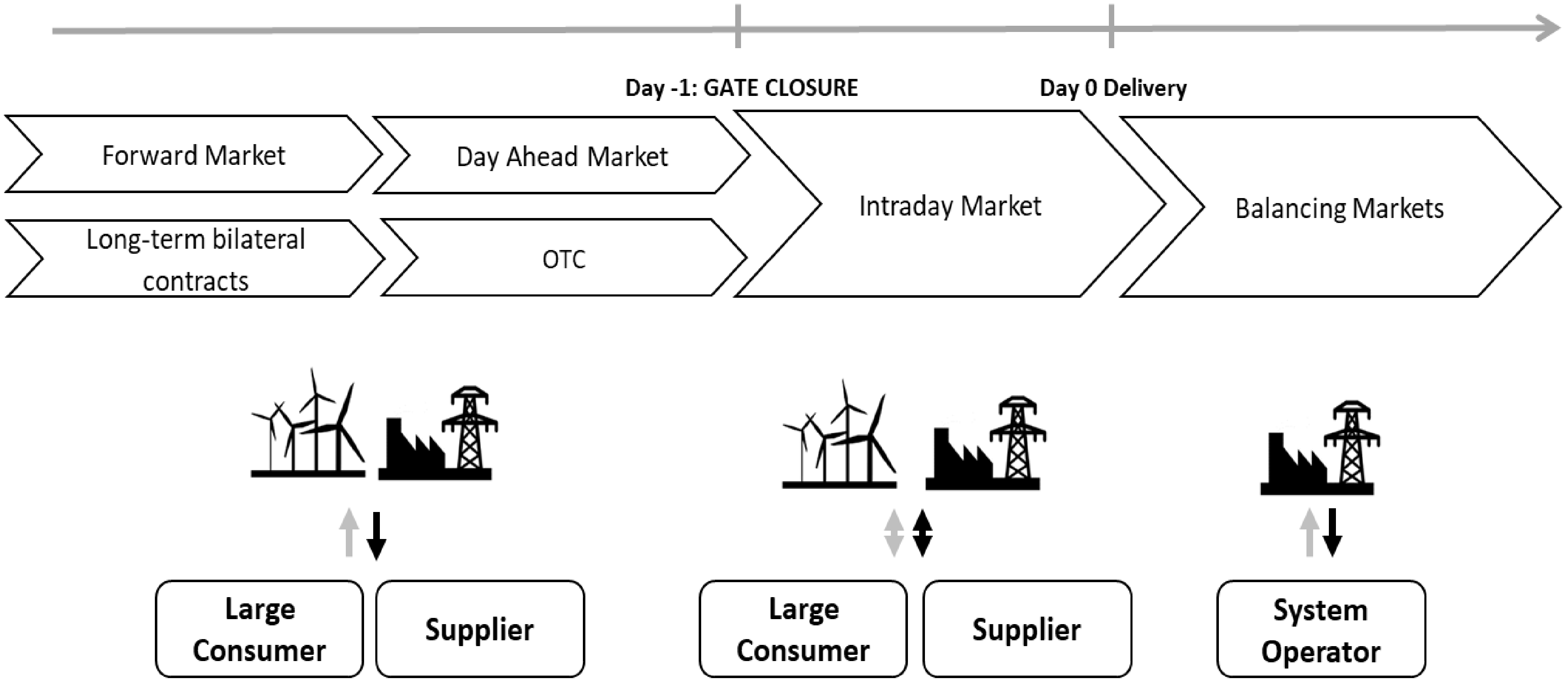


Source: DNV

Large-scale RE electricity - Decentralized markets

In decentralized markets, (large-scale) renewable energy assets sell their generation output into the DA, ID is used to clear imbalances before delivery. VRE installations take full balancing responsibility.

German example



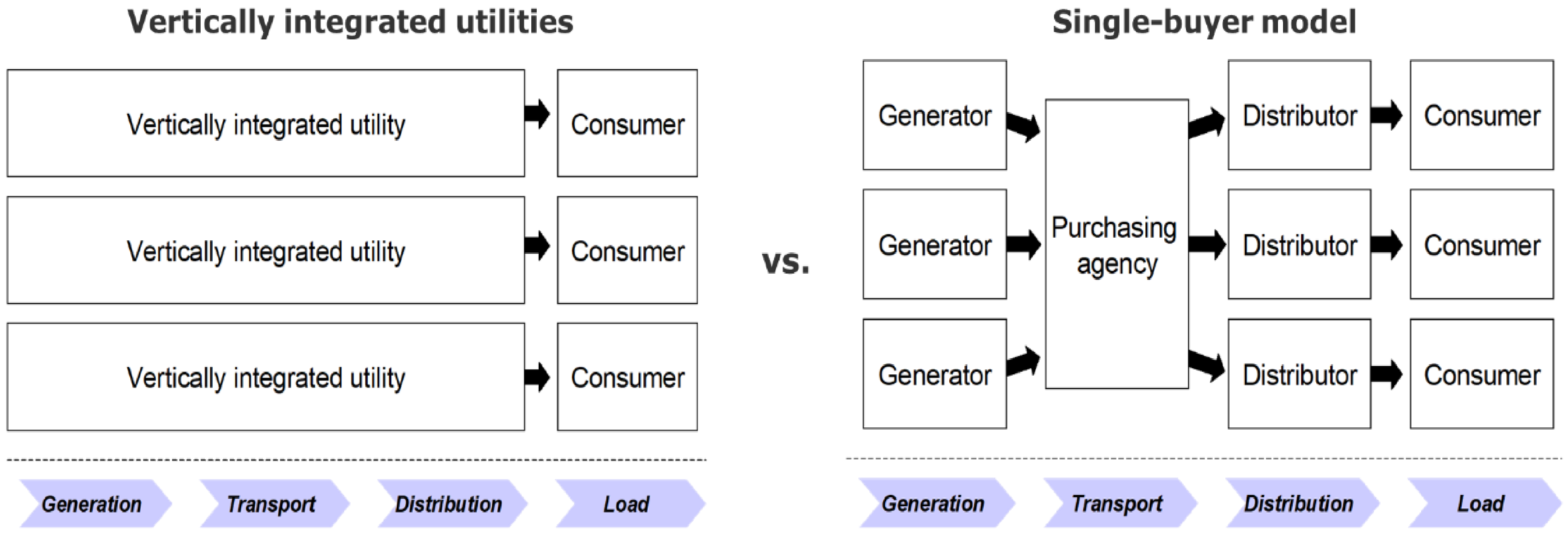
VRE in non-liberalized electricity system

Electricity supply traditional structure vs. single buyer model

Traditionally all business areas integrated within a single company / entity, while in the SB model competition between generation plants is introduced (promoting cost efficiency) and attracting private investment (IPPs).

In vertically integrated systems, **no regulatory** tools for VRE integration exist

In SB model **some regulatory** tools for VRE integration exist



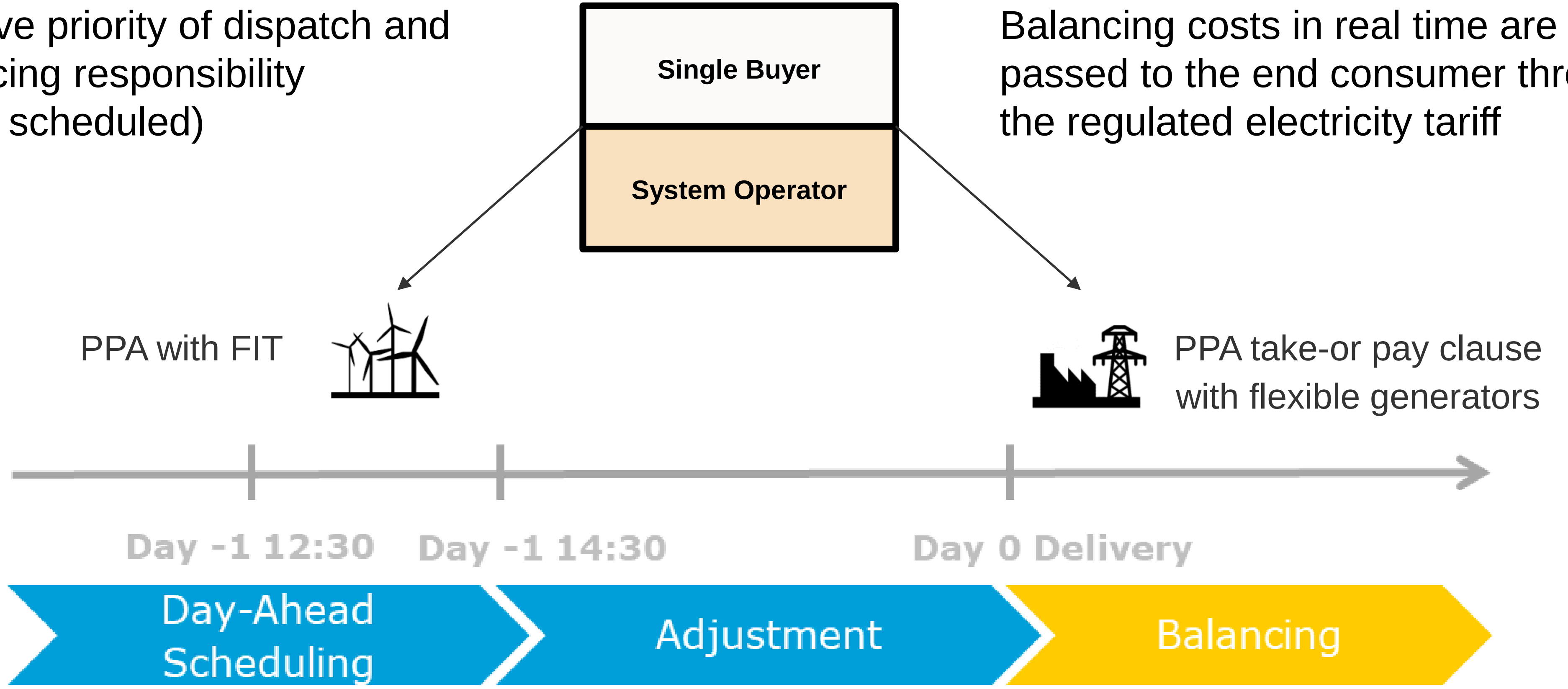
Source: DNV

Challenge RE system - Scheduling VRE and other generation

Single buyer / System Operator bears responsibility for stable delivery.

VREs have priority of dispatch and no balancing responsibility (centrally scheduled)

Balancing costs in real time are passed to the end consumer through the regulated electricity tariff

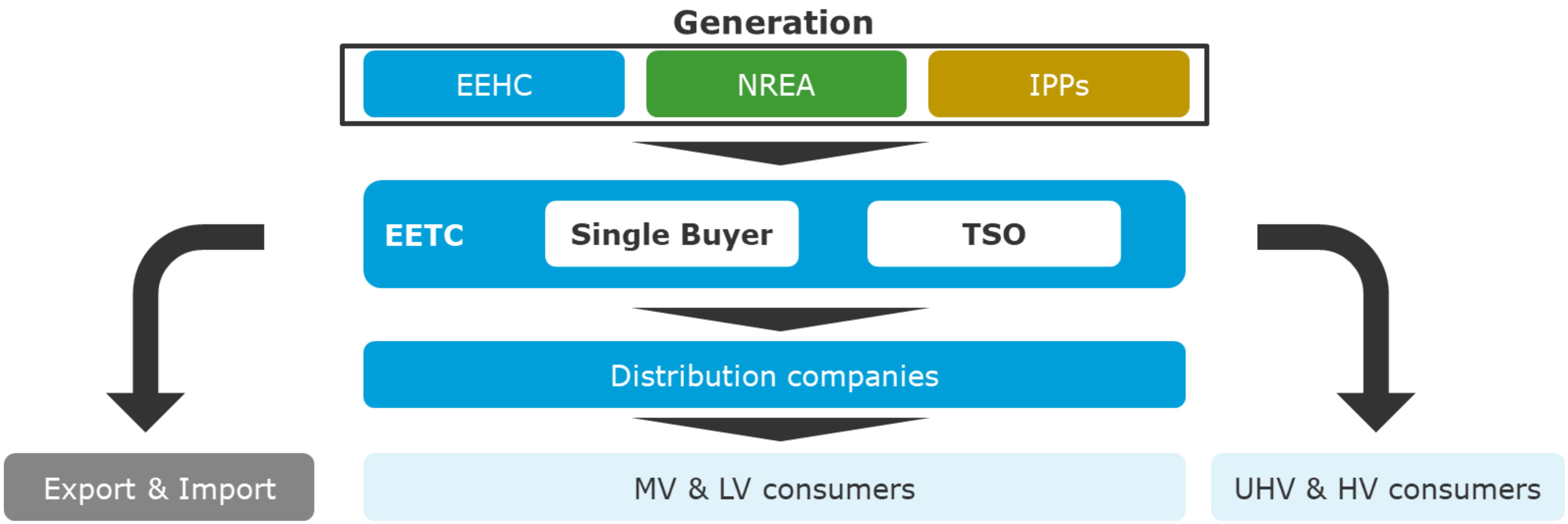


Source: DNV

Electricity supply with single buyer – Egypt

For scheduling generation costs are calculated per power plant and the schedule is determined centrally according to actual availability of the most efficient generation plant as well as considering special PPA clauses.

Egypt electricity system structure

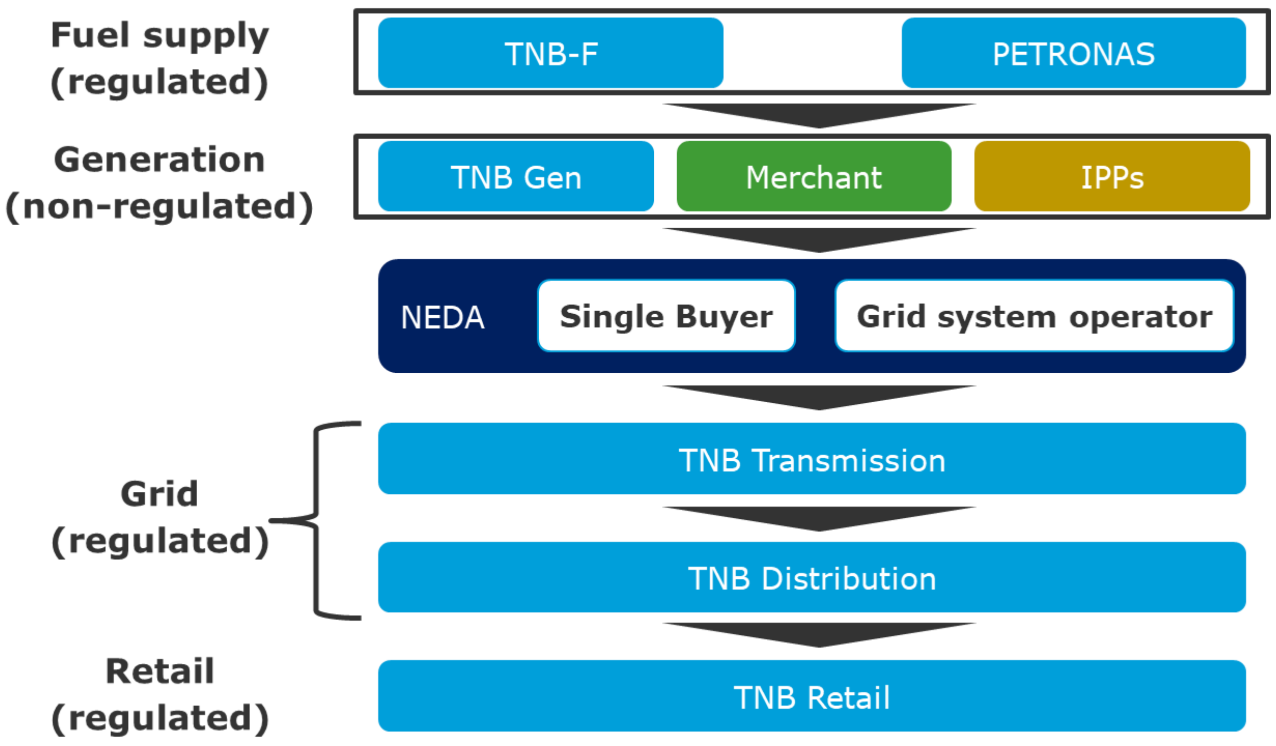


Source: DNV

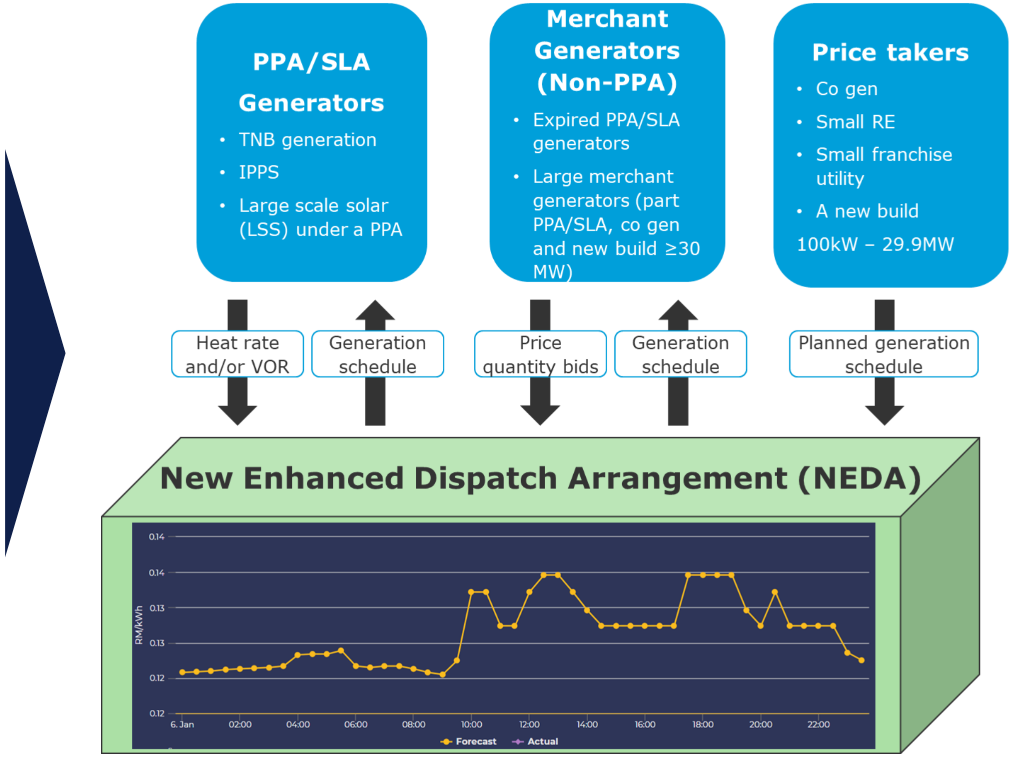
Electricity supply with single buyer - Peninsular Malaysia

Generators have a PPA with the SB or are merchant plants. Scheduling process is performed by the SB, which uses the PPA prices and merchant bids to set the Day-Ahead schedule. GSO issues real-time dispatch instructions.

Peninsular Malaysia electricity system structure



Day-Ahead schedule



Source: DNV

Options for balancing improvement of VRE in non-liberalized electricity system

Assumptions on SB model

- From an economic perspective, the Single Buyer model should allow optimal dispatch of VRE (holistic approach)
- The single-buyer model is often used as transitional arrangement before introduction of competitive wholesale market

However,…

- due to political motives and defined PPA preferences intervention of day-ahead schedule might lead to suboptimal resource allocation
- the SB has not a strong profit motive and therefore no incentive for innovation in flexibility options
- it is common to see delays toward liberalized electricity markets due to investment, knowledge and political reasons

Options to enhance flexibility in a SB system rely on following assumptions:

- A balancing mechanism could incentivise additional flexibility from market players besides obligations set in the PPAs
- A price signal could encourage better forecasting of new VRES capacity (e.g. in form of a balancing penalty)
- Market players are interested in signing contractual arrangements (e.g. between VRE generators and flexible generators/consumers) to improve economic performance

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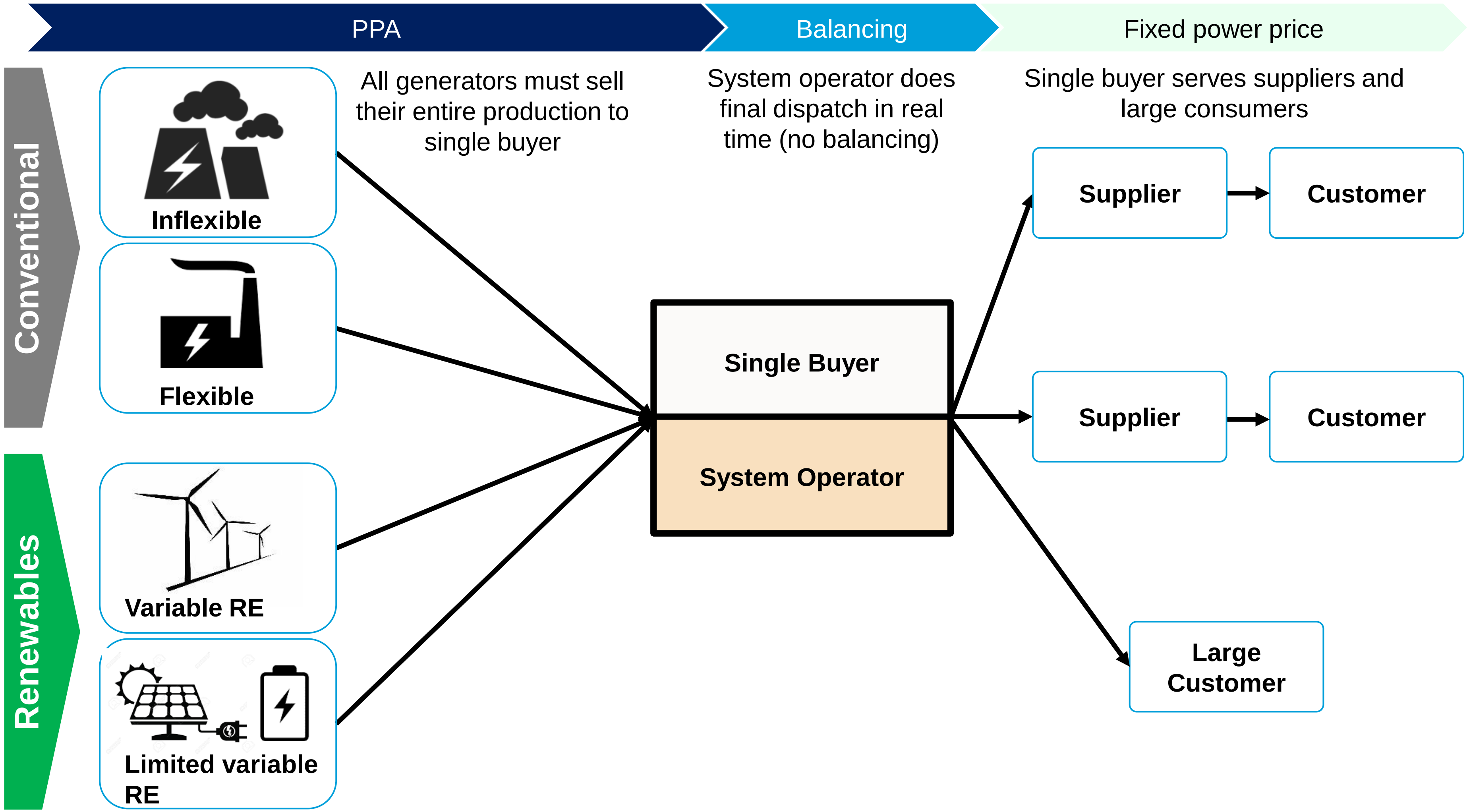
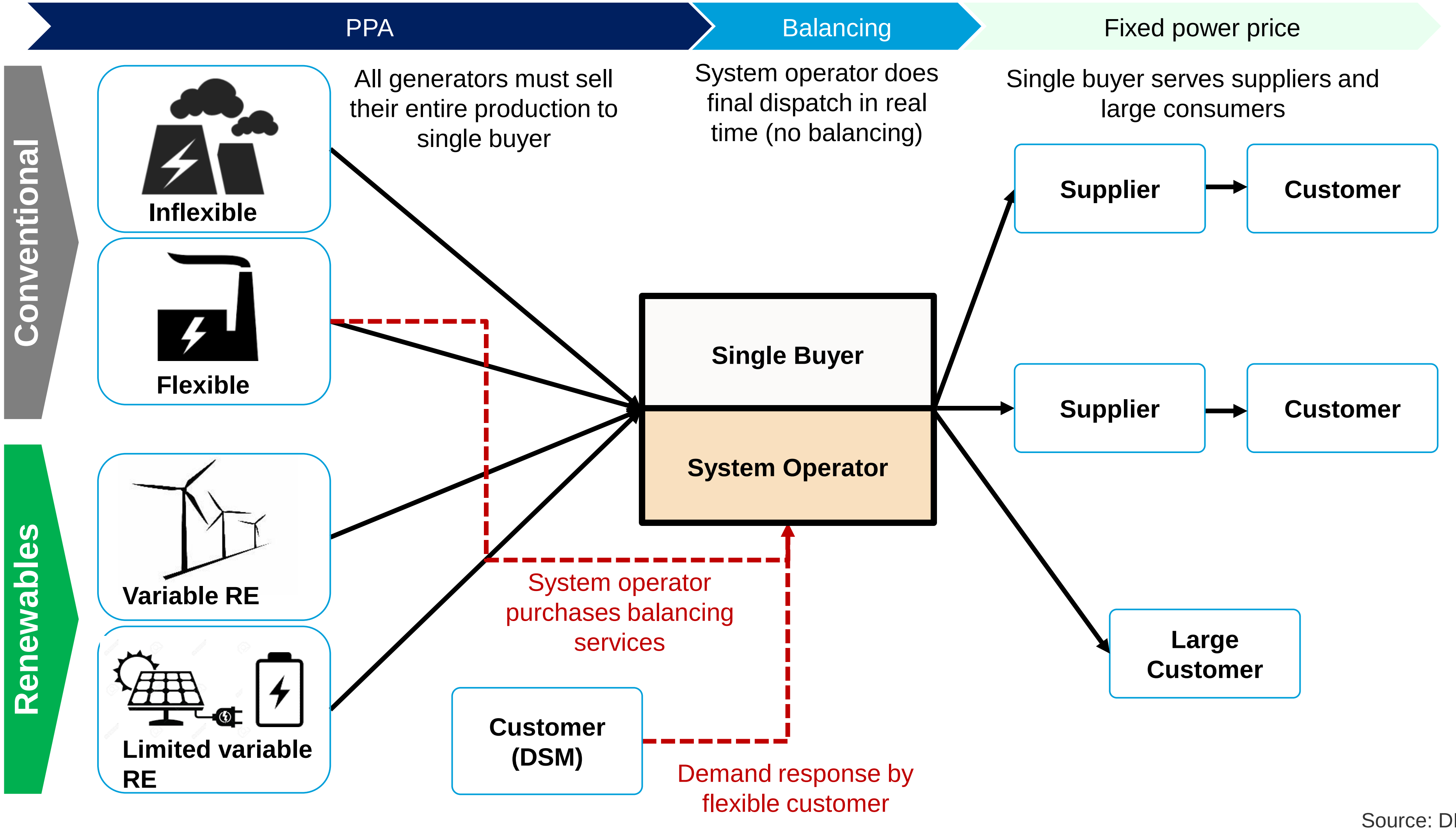
Status Quo: Technical balancing
SO is responsible for balancing



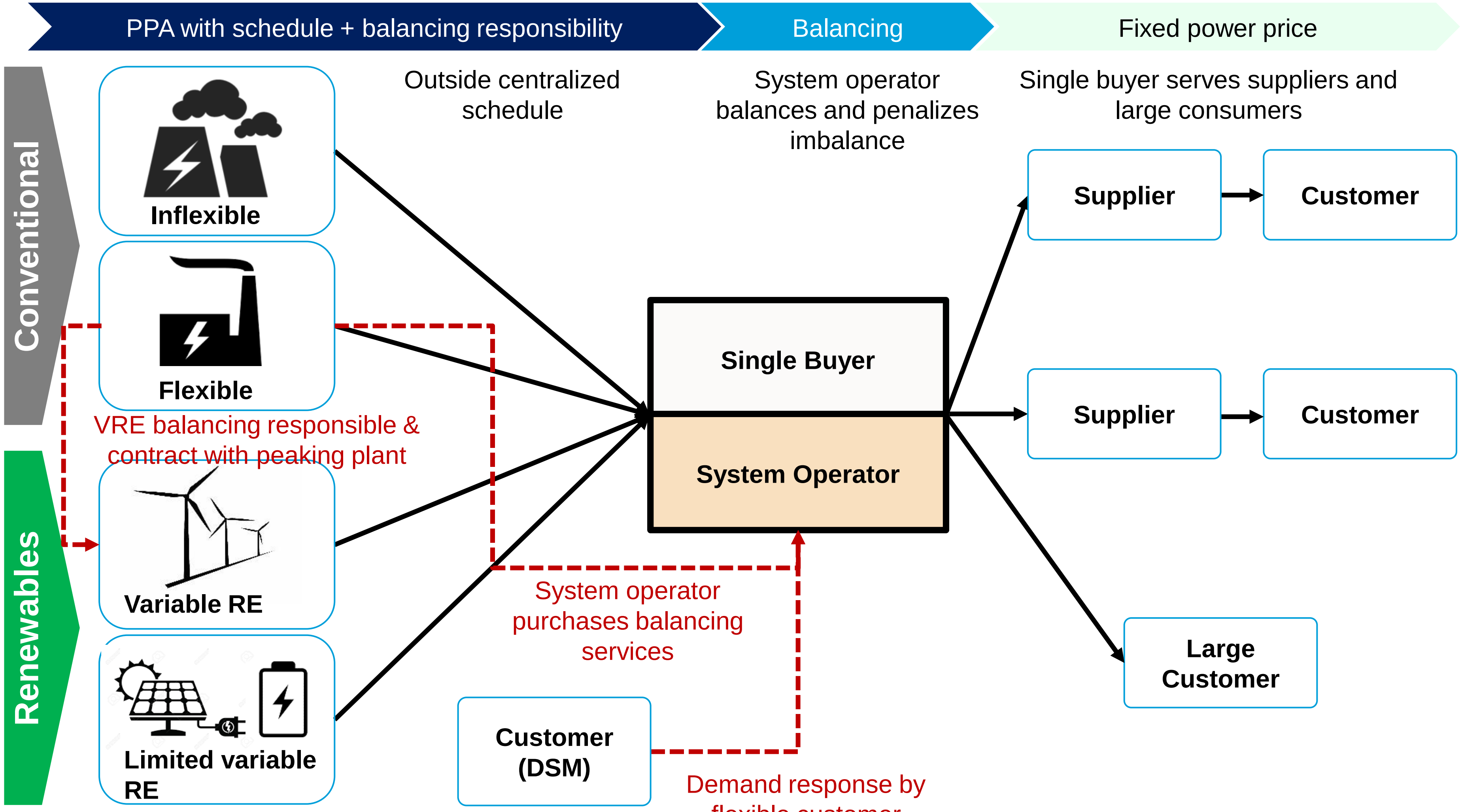
Source: DNV

Balancing model 1: Commercial balancing
SO purchases balancing services



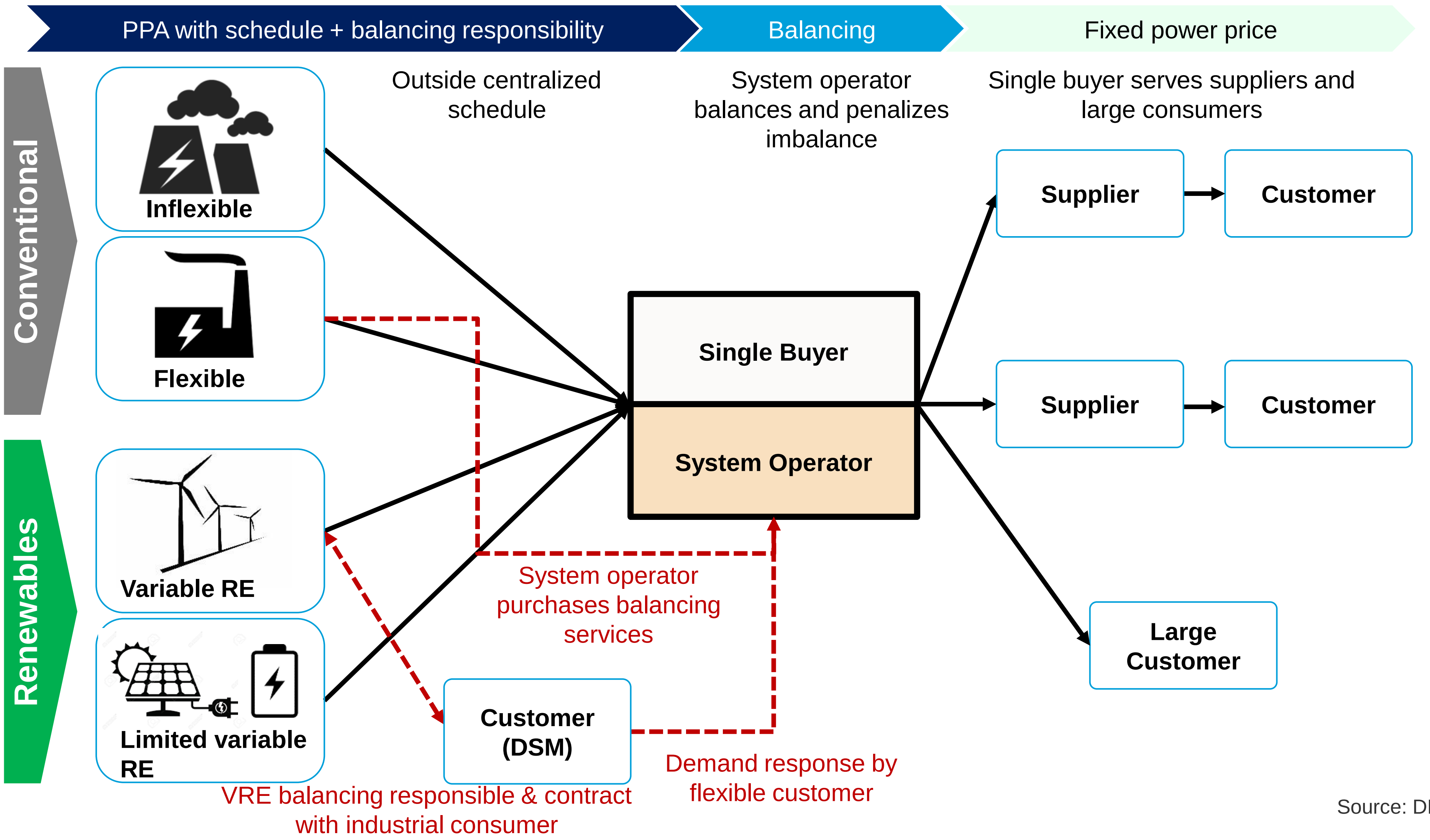
Source: DNV

Balancing model 2a: VRE balancing responsible Contract with flexible power producer



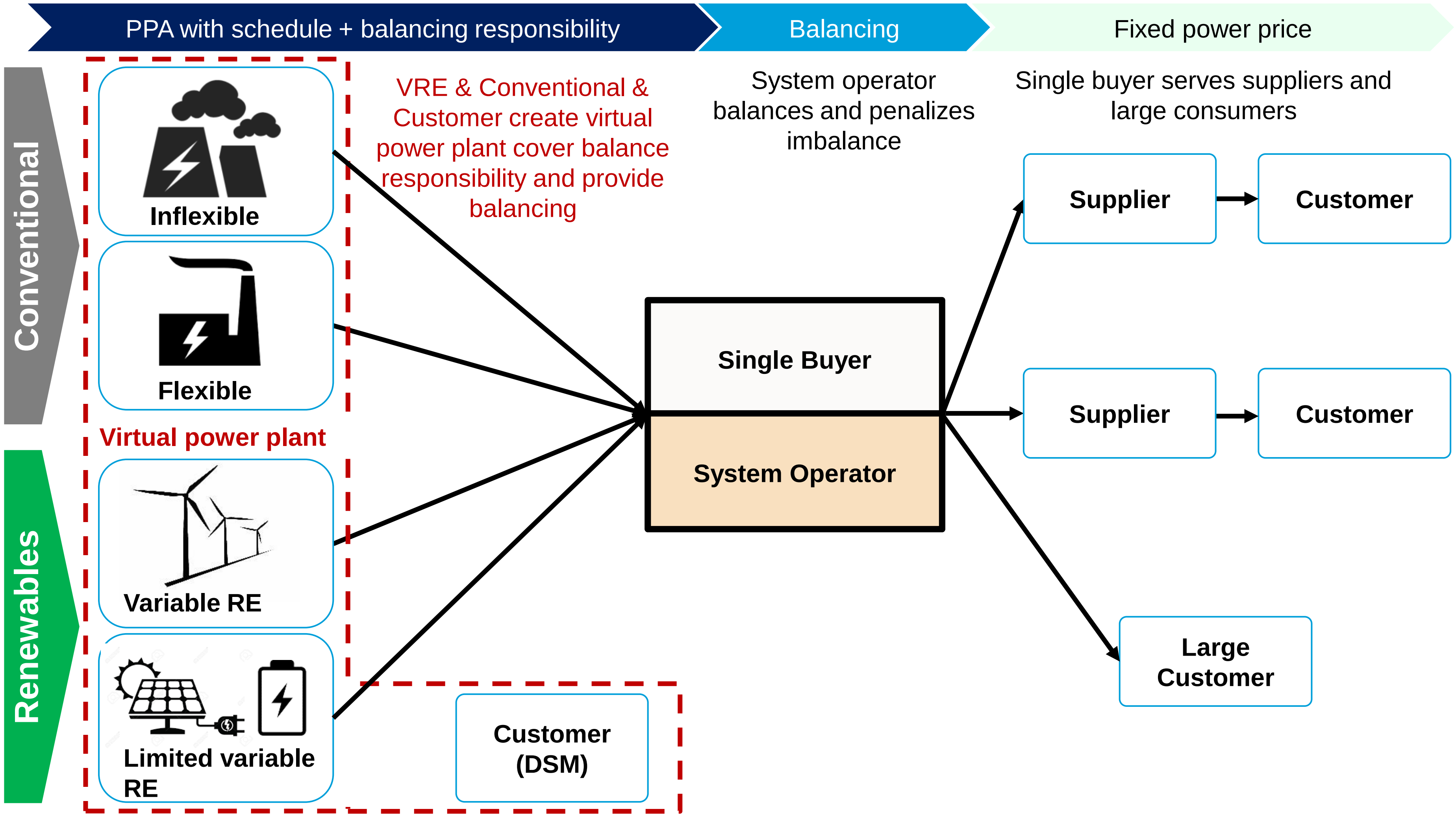
Source: DNV

Balancing model 2b: VRE balancing responsible Contract with large & flexible consumer



Source: DNV

Balancing model 2c: VRE balancing responsible Virtual power plant



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Thank you for your attention

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