Annex 1: DISC model documentation

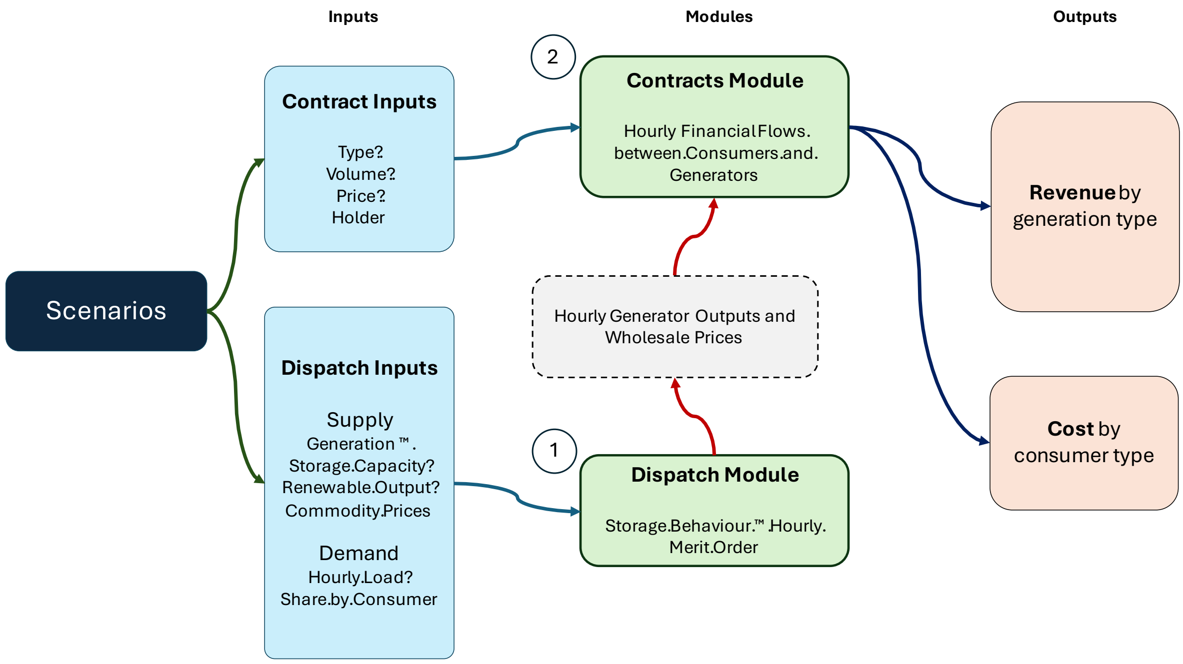
The Dispatch and Contracts (DISC) model combines a stylised representation of the electricity system dispatch with the financial layer of electricity markets. By combining these essential features of the techno-economic electricity market system, DISC seeks to provide insights about the relationship between the physical electricity system and the associated financial flows through electricity markets. The framework was initially developed to deliver a scenario analysis in a report for the Industry, Research and Energy (ITRE) committee of the European Parliament (Zachmann et al, 2023). DISC is implemented in Python.

Figure 11 is a schematic overview of DISC, covering the modelling process from scenario design, model inputs, modelling steps, to model outputs. The framework can represent a single integrated system (typically a country or region) and does not account for the effect of interconnection constraints on dispatch and prices. Two core assumptions are underlying the DISC framework:

1. **Efficient dispatch of the electricity system.** In every hour, the DISC framework uses the cheapest available resources to meet demand. This is equivalent to assuming that the short-term wholesale electricity market operates as a perfectly competitive hourly auction in which different generation types compete based on variable costs.
2. **Dispatch is independent of contracts.** DISC first optimises the dispatch of electricity generation to meet demand, then calculates the associated financial flows between generators and consumers. The holding of contracts by different parties does not affect their dispatch outcomes.

The second assumption is critically important, as much of the policy discussion related to long-term contracts focuses on their incentives for short-term operational decisions. The DISC framework abstracts from such considerations and focuses on the relationship between the physical system, the holdings of contracts and financial flows between market participants.

Figure 11: Dispatch and Contracts (DISC) model structure



Source: Bruegel

DISC requires a set of data inputs, categorised by dispatch and contract. On the supply side, the inputs include:

- Capacity by generation type (Solar PV, Gas CCGT, etc);
- Cost by generation type, determined by:
  - Technical assumptions (efficiency, emissions factor, etc);
  - Commodity prices: gas, coal, oil, and carbon;
- Capacity by storage type (Battery and Pumped Hydro);
- Hourly renewable output (Solar, Wind, and Hydro).

The demand side inputs are:

- Hourly load;
- Share of load by consumer type (Household, SME and Industry).

The dispatch module of DISC then operates as follows. First, the storage technologies are modelled heuristically, like Zerrahn et al (2018). Beginning with the first hour of the year, surplus renewable output is stored in the batteries and pumped hydro units, and then dispatched in hours in which fossil fuel generation would otherwise be needed to meet demand. In this way, the storage technologies shift additional clean electricity over time. Second, in hourly increments over a given time horizon (typically one year), the model optimises the dispatch to meet the demand with the cheapest available resources, based on the merit order model of ranking resources by their variable costs. The input from the storage technologies and the renewable capacity is assumed to be always dispatched when available. The output of other generation types in each hour is determined by the available renewable generation, the demand, and the other dispatchable resources. The variable costs of the generator needed to add one more unit of supply in every hour determines the hourly wholesale prices, based on the principle of marginal pricing.

The contract inputs are determined by assumptions regarding the contract stack in electricity markets. For different contract types (eg CfD, PPA, Futures), the model takes inputs on:

- Contract type (physical or financial);
- Contract price;
- Contract holder (generation type on supply side and consumer type on demand side);
- Contract volume.

The contracts module then arithmetically calculates the financial flows between generators and consumers, based on the outputs from the dispatch module and the contracts inputs. The final outputs are the revenue of different generation types by contract (wholesale market, CfD, etc) and the cost paid by consumers by contract type.

Annex 2: Scenario design

Three distinct scenarios are used in the analysis for this policy brief: Baseline, 20% Less Demand, and Fossil Fuel Shock. The essential differences between each scenario are provided in Table 1. To summarise, the 20% Less Demand is the same as the Baseline scenario, expect with a 20% demand reduction in every hour. The Fossil Fuel Shock scenario is the same as the Baseline scenario, except each commodity price (apart from carbon) is three times higher (see Table 3).

Dispatch Inputs

ENTSO-E's European Resource Adequacy Assessment 2023 is used as the basis for many of the dispatch inputs underlying the scenario design for this analysis. In particular, the installed capacity by generation type (Table 2), as well as the hourly demand and renewable output time series are based on ERAA numbers.

Table 2: 2030 Generation Capacity Inputs by Country

Generation Type	DE [GW]	FR [GW]	IT [GW]	ES [GW]	PL [GW]
Solar (PV)	215	42.3	74.6	64.8	21.7
Onshore Wind	115	31.3	18.4	48.3	13.8
Offshore Wind	30.5	3.9	8.5	2.8	9.6

Hydro – Run of River	3.9	13.6	7	3.4	0.4
Hydro – Reservoir	0.8	9.8	8.8	11.4	0.4
Biomass & Waste	0	0	0	0	0.7
Other Renewable	13.1	2.4	4.4	1.7	2.2
Solar (CSP)	0	0	0.9	3.8	0
Nuclear	0	61.8	0	5.1	0
Gas CCGT	24.9	7.2	42.6	24.5	5.8
Gas OCGT	10.7	0	0	0	0
Hard Coal	0	0	0	0	11.6
Lignite	0	0	0	0	6.5
Oil	1.9	1	0	0	0
Other Non-Renewable	7.3	4.4	8.6	4	5.6
Demand Side Response	5	5	2.2	1	0

Source: Bruegel based on ENTSO-E's European Resource Adequacy Assessment (ERAA).

The commodity prices assumed for the dispatch module determine the variable costs of fossil fuel generators.

Table 3: Commodity Price Assumptions

Commodity	Baseline	Fossil Fuel Shock	Unit
Gas	30	90	€/MWh
Oil	30	90	€/MWh
Coal	35	105	€/tonne
Lignite	5	15	€/MWh
Nuclear Fuel	15	15	€/MWh
Carbon	150	150	€/tonne

Source: Bruegel based on European Commission's electricity market reports and EWI's Merit Order Tool estimations.

Contract Assumptions

The assumptions about the contract volumes are based on the IEA's Renewable Energy Market update (IEA, 2023) which provides the share of renewable capacity covered by state-support schemes, PPAs and merchant for new capacity in 2023 and 2024. The scenario design assumes that the output of renewables in 2030 follows a similar ratio of contracts. The assumed volumes (which constitute the percentage of the total output of the renewable asset over the time horizon of the model run) are provided in Table 4.

Table 4: 2030 Contract Volume as a share of Total Renewable Output

Contract	DE	FR	IT	ES	PL
CfD	94%	98%	90%	29%	100%
PPA	6%	2%	10%	67%	0%
Merchant	0%	0%	0%	4%	0%

Source: Bruegel based on IEA (2023).

The contract price assumptions are primarily based on Morawiecka and Scott (2024) and the author's own estimations where data was not available.

Table 5: 2030 Contract Strike Prices

Contract	DE	FR	IT	ES	PL
Solar CfD [€/MWh]	65	65	60	35	50
Onshore Wind CfD [€/MWh]	65	65	65	35	50
Offshore Wind CfD [€/MWh]	75	75	75	70	70
Solar PPA [€/MWh]	75	75	75	75	75
Onshore Wind PPA [€/MWh]	70	70	70	70	70
Offshore Wind PPA [€/MWh]	80	80	80	80	80

Source: Bruegel based on Morawiecka and Scott (2024).

The share of demand by consumer type determines how much each type pays to the generation type and in this analysis is based on Eurostat. The SME category is based on services and other parts of the economy not covered by industry or households.

Table 6: 2030 Share of Demand by Consumer Type

Consumer	DE	FR	IT	ES	PL
Household	28%	37%	23%	33%	21%
SME	29%	37%	38%	35%	41%
Industry	43%	26%	39%	32%	38%

Source: Bruegel based on Eurostat.