Plan4res is an electricity system optimisation and simulation tool, composed of the 3 following models :

* A Capacity expansion model (CEM) aimed at adapting the electricity mix,
* A seasonal storage valuation model (SSV) aimed at optimizing the management of seasonal storages
* A simulation tool, based on a Unit Commitment model (EUC), aimed at optimizing the short term operation of the system.

**Those 3 models cannot be described independently as:**

* The Seasonal Storage Valuation Model itself uses the European Unit Commitment Model for solving its inner transition problem.
* The Capacity Expansion Model uses the Unit Commitment model alone, or the Seasonal Storage Valuation Model (and the Unit Commitment model) for the evaluation of its operation cost function.

This means that CEM cannot be ran without EUC, or SSV and EUC, and SSV cannot be ran without EUC, while EUC can be ran alone, and SSV-EUC can be ran without CEM.

Both 3 models share the exact same set of data.

## Capacity Expansion Model

The capacity expansion model is concerned with finding a (better) or ideally optimal set of assets including generation plants, interconnection capacities between clusters and distribution grid capacities, for the considered time horizon. Here optimal means, providing the least-cost set of assets, while accounting at best for the modelled constraints.

The objective is thus to design the optimal generation mix with the optimal transmission and distribution grid capacities for a given long-term horizon (e.g. 2050). The problem then consists in minimizing the sum of two terms:

(5)

Where:

(a) κ denotes a vector containing the investment capacities either on generation technologies at each node of the network or on some lines of the transmission or distribution grid;

(b) U is the distinct and ﬁnite set of “meta-scenarios” (e.g., some choice of climate-change trajectory);

(c) denotes the annualized investment cost induced by installing the ca-pacity κ in the electrical system;

(d) denotes the expected operation cost of the system with the given installed capacity κ on the typical time horizon (for instance the typical year 2050), under the assumption of the meta-scenario η.

Additionnal constraints can be included :

1. Each region is able to produce the amount of energy required to meet the demand

For each Region z :

 : Demand of region Z, at time t for scenario j

: RES load factor of technology i at time t for scenario j, with

 : maximum power of technology i , at time t, scenario j

 : number of units of techno i in region z

1. Each region has to reach a target in terms of RES share (including hydro)

 : share of Renewable energy for zone Z with

The 2 constraints are not to be used together.

## Seasonal Storage Model

The Seasonal Storage Model solves a mid-term problem, where mid-terms stands usually for annual. This problem consists in evaluating an approximation of the expected operation cost, , for a given vector of installed capacity, κ, under the assumption of the meta-scenario η.

The mid-term horizon is a set of stages (eg. weeks), subdividing the typical period (eg 1 year) on which operation costs are evaluated. Each stage is divided in time steps (eg. Hours).

Note that uncertainties (such as reservoir inflows, demand, outages or intermittent generation) are impacting operation decisions which are made dynamically along the mid-term horizon, while those uncertainties are progressively revealed and the forecasts are accordingly updated. Hence, the SSV model consists of a multi-stage stochastic optimization problem, aiming at minimizing the sum of operation costs on each stage s:

Where:

• x = is the sequence of operation decisions taken at the beginning of each stage. These decisions are supposed to be non-anticipative, in the sense that decisions made at stage s should only depend on the past realizations of uncertainties.

X is the feasible set associated with operation decisions. In particular, it includes the already invoked non-anticipativity constraint relating decisions to observed uncertainties. We also emphasize the presence of dynamical constraints (relating reservoir levels between two stages, ramping rates or any other conditions that involves linking adjacent time steps). This prevents us from taking decisions independently between two stages.

• represents the operational cost on the stage s as a function of decisions . Notice that depends implicitly on the installed capacity κ and on uncertainties revealed at stage s (demand, inﬂows, intermittent generation) so that the expectation appearing in (6) is related to the probability distribution of those implicit uncertainties. Furthermore, the expectation is not to be taken over the set of meta-scenarios U, since these are assumed to be given without a (probability) distribution: they represent plausible futures against which we want to hedge, but which cannot be reasonably equipped with a distribution.

This problem is solved by time decomposition using stochastic dynamic programming. At each stage s, a transition problem is solved, involving operational cost of stage s and the cost-to go function giving the minimum future operational expected cost. The transition cost is evaluated by the EUC Model (see below).

## Simulation

The European unit commitment problem (EUC) solves the short-term horizon problem (short-term meaning daily or weekly), where operational decisions are provided at one stage s ∈ S, in a deterministic setting, taking into account the “value” that seasonal storage units can bring to the system via the cost-to-go function. The EUC occurs in two ways.

(a) The EUC optimization mode solves the transition problem of SSV with a convexification of the operational constraints. In fact, it is intended to provide cutting plane approximations of cost-2-go functions. Notice that the associated operational decisions may be infeasible since non-convex technical constraints have been convexiﬁed. The advantage is that the EUC optimization mode should run reasonably fast.

(b) The EUC simulation mode solves the transition problem, without any convexiﬁcation of technical constraints. This mode is intended to provide a feasible generation dispatch, on a given sub-period. It uses the cutting plane approximations of the cost-2-go functions provided by SSV and is based on a feasible recovery heuristic ensuring the feasibility of operation decisions. The computing time required to run the EUC simulation mode could be signiﬁcantly greater than that to run the EUC optimization mode.

However, in simulation mode, both investment capacities κ and approximations of the cost-to-go functions remain ﬁxed. Therefore in total, likely, the simulation model will be faster than the optimization mode.

To compute the expected cost, post-optimization, it is more relevant to rely on feasible decisions and consequently to use the EUC simulation mode implemented sequentially for each stage s ∈ S and averaged over Monte Carlo simulations of the random vector ξ. In this fashion we can compute a stochastic upper bound on the actual optimal cost of operation for the current investment capacity κ.

Various kinds of flexibilities involving both generation, storage and consumption are dealt with:

* Dynamic operation constraints of power plants (ramping constraints, minimum shut-down duration, …)
* Dynamic operation of storage (including battery-like storages and complex hydro-valleys modelling)
* Demand-Response (including eg. household dynamic consumption load-shifting or load curtailment)

The EUC can also account for both transmission and distribution networks:

* Transmission Network representation: from a copper plate approach to a ‘clustered’ approach with limited transport capacities.
* Electricity distribution limited capacities and reinforcement costs

The simulation runs in sequence the EUC at all stages of the period (usually weeks).