EMP-E

Energy Modelling Platform for Europe

EMP-E 2021: Re-Energising Sustainable Transitions in Europe

Energy System Modelling, Methods & Results to support the European Green Deal

26th to 28th October · online

plan4res SMS++, an open modelling library for evaluating long term electricity system costs and flexibilities

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hosted in cooperation with the European Commission

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The plan4EU model (from plan4res project)

plan4res: Synergistic approach of Multi-Energy Models for a European Optimal Energy System Management Tool

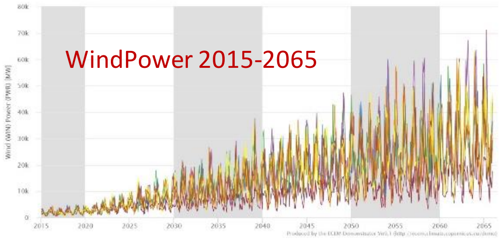
<u>Implement models and tools</u> that provide

an integrated energy system representation able to optimize and simulate expansion and operation with a high share of Renewable Energy

For contributing to European targets for reduction of emissions while maintaining high quality of supply at lowest cost

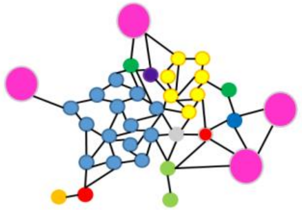
The plan4EU model in short

- **Focus on electricity system simulation and optimisation**
  - Including multi-energy assets bringing flexibility to the electricity system
- **Adaptable Geography perimeter**
  - Europe or lower perimeter
  - Subcountry representation
- **Uncertainties:**
  - Electricity demand
  - RES profiles (PV, Wind, RoR…)
  - Inflows
  - Failures



Source: C3S Energy/ECEM demonstrator

- **Modular Time horizon and granularity**
  - Typically 1 yr. with hourly granularity
- **Simplified modular Grid**



- **Power plants**
  - Operational decision of power plants based on their specific fuel costs
  - Technical constraints (ramping, min up-/downtimes,…)
- **Storages**
  - Hydro storages including complex cascaded systems
  - Battery storages
- **Intermittent generation**
  - Generation of wind, solar, run of river based on meteorological profiles
- **E-mobility**
  - Storage capability of electric vehicles (vehicle-to-grid, power-to-vehicle)
  - Limitation of storage availability by driving profiles
- **Load management**
  - Load shifting of a given energy consumption during a sub-period
  - Load curtailment based on a given potential (e.g. during one year)

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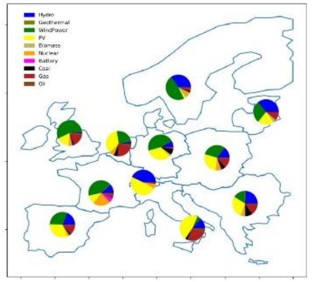
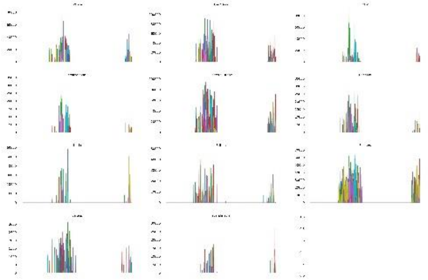
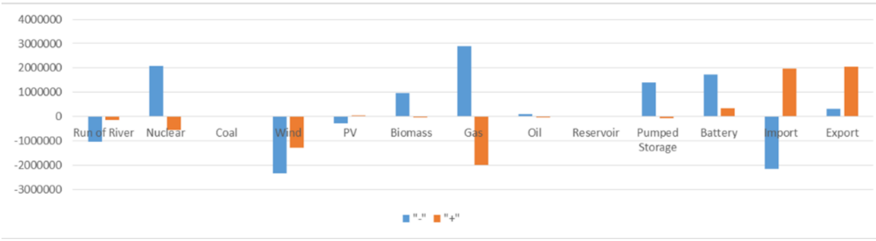
Examples of Use Cases



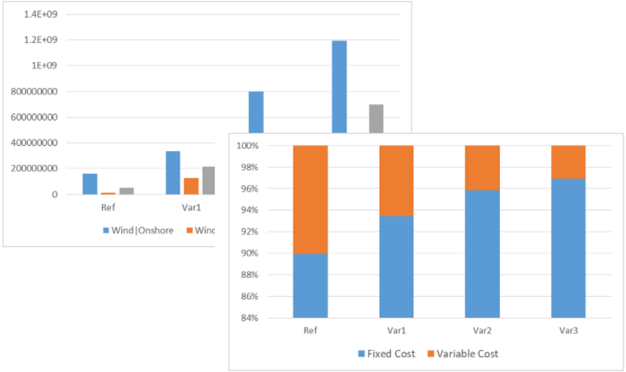


- **Scenario Assessment:**
  - ➢ Is a given scenario feasible?
  - ➢ What is the cost of electricity operation?



- **Impact (Value) of using flexibility from:**
  - ➢ Individual Load Management (openEntrance Case Study 1)
  - ➢ e-Mobility (openEntrance Case Study 2)
  - ➢ existing power plants (plan4res Case Study 3)

- **What Impact different levels of RES integration have on system operation and costs?**
  - ➢ Electricity generation cost
  - ➢ Cost to ensure the dynamic robustness of the system (Reserves, Inertia)



- **Impacts of climate change**

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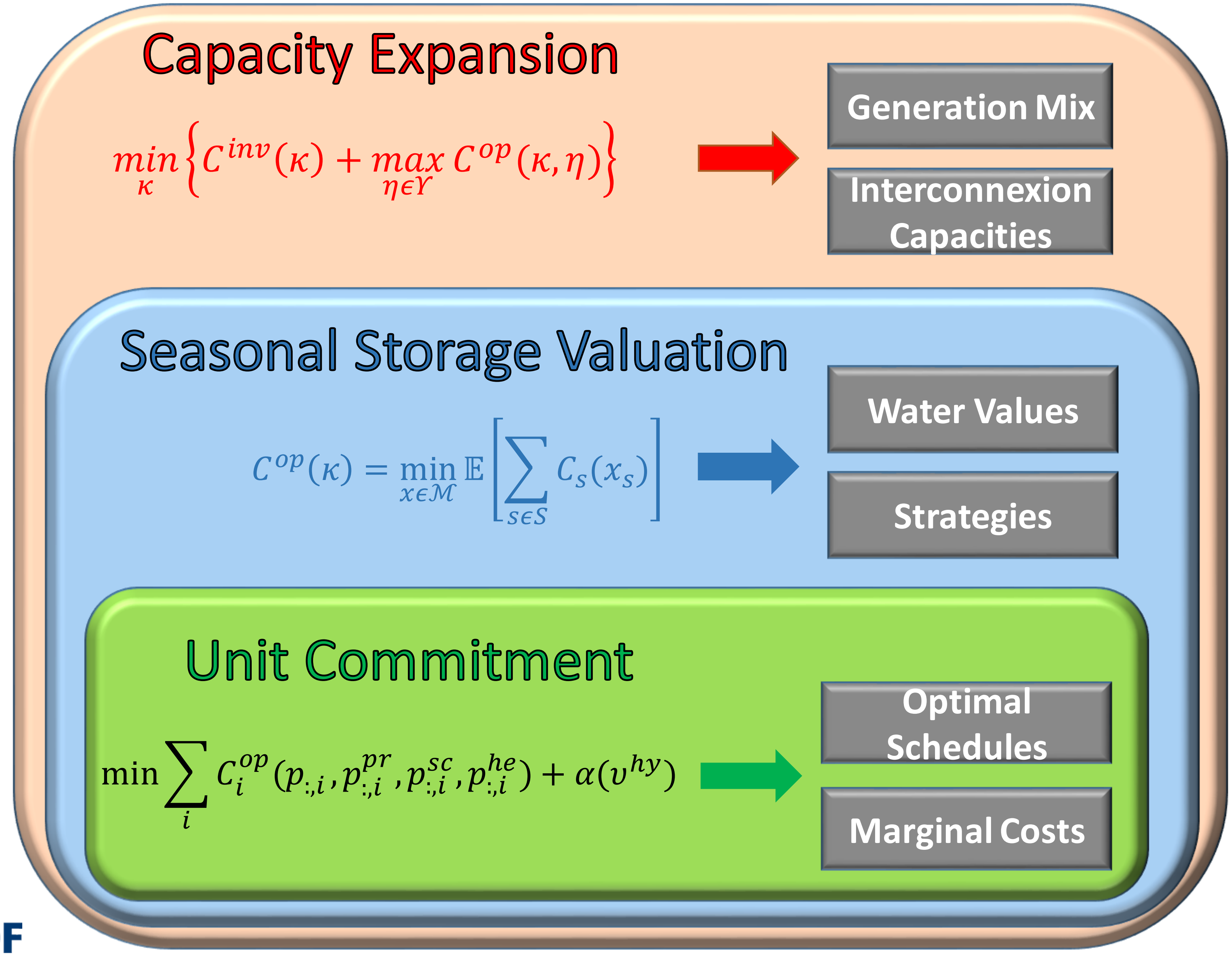
The plan4EU model

- **The Capacity expansion model** computes the optimal mix:
  - ✓ *electric generation plants,*
  - ✓ *storages,*
  - ✓ *interconnection capacities between clusters*
  - ✓ *distribution grid capacities,*
- **The seasonal storage valuation model** computes the operation strategies for seasonal storages:
  - ✓ *For Hydro reservoirs*
  - ✓ *And also all other 'seasonal' flexibilities such as Demand response*
- **The European unit commitment model** computes the optimal operation schedule for all the assets dealing with constraints:
  - ✓ *Supply power demand and ancillary services*
  - ✓ *Minimal inertia in the system*
  - ✓ *Maximum transmission and distribution capacities between clusters*
  - ✓ *Technical constraints of all assets*



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2

Modelling and solving with SMS++

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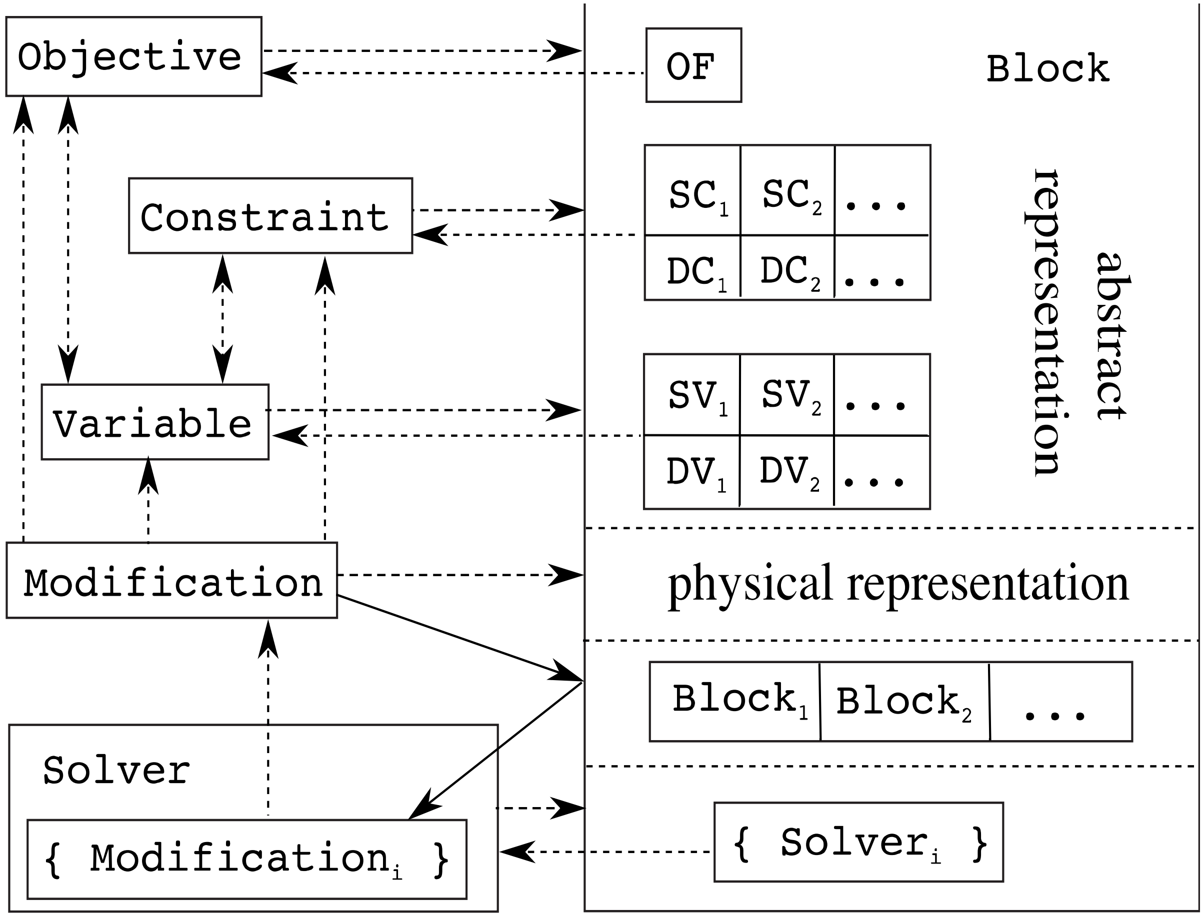
It’s a bird, it’s a plane, it’s …

SMS++ is a set of C++ classes implementing a modelling system that:

- is explicitly geared towards large-scale structured problems
- allows exploiting specialised solvers (decomposition, DP, SDDP, …)
- manages all types of dynamic changes in the model
- explicitly handles reformulation/restriction/relaxation
- does parallel from the start
- ***is community-oriented, extendible to almost any problem class, open***
- ***encourages code sharing and re-use for specific applications***



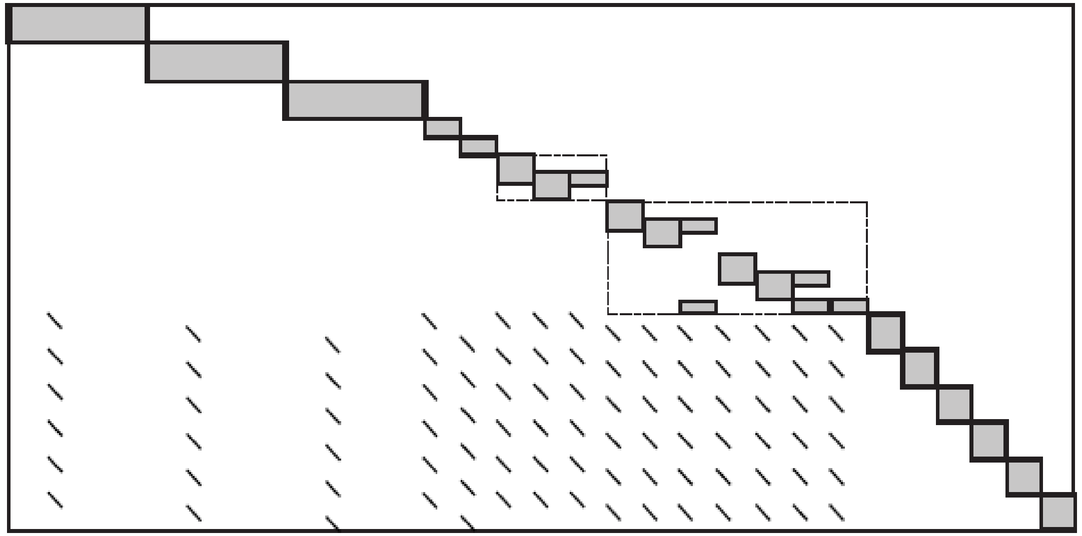
Modelling with SMS++

- « core » SMS++ is available at https://gitlab.com/smspp/smspp
- « umbrella » repository https://gitlab.com/smspp/smspp-project to host and integrate separate repos for different problems/solvers
- currently 10+ repos for « leaf » problems (MCF, Knapsack, ...), interfaces with existing solvers (Cplex, SCIP, SDDP) and native solvers (BundleSolver, LagrangianDualSolver)
- specific repo for energy problems https://gitlab.com/smspp/ucblock
- repos for stochastic problems https://gitlab.com/smspp/stochasticblock and solvers https://gitlab.com/smspp/sddpblock
- inclusive approach where all contributions are welcome and supported
- aiming at a vibrant community of developers and users
- need to use C++ (interfaces with other systems possible but not there yet)
- a lot of code documentation (https://smspp.gitlab.io) but no user manual or implementation guidelines (except frangio@di.unipi.it)

Curent Energy models in SMS++

Nested decompositions at different time horizons

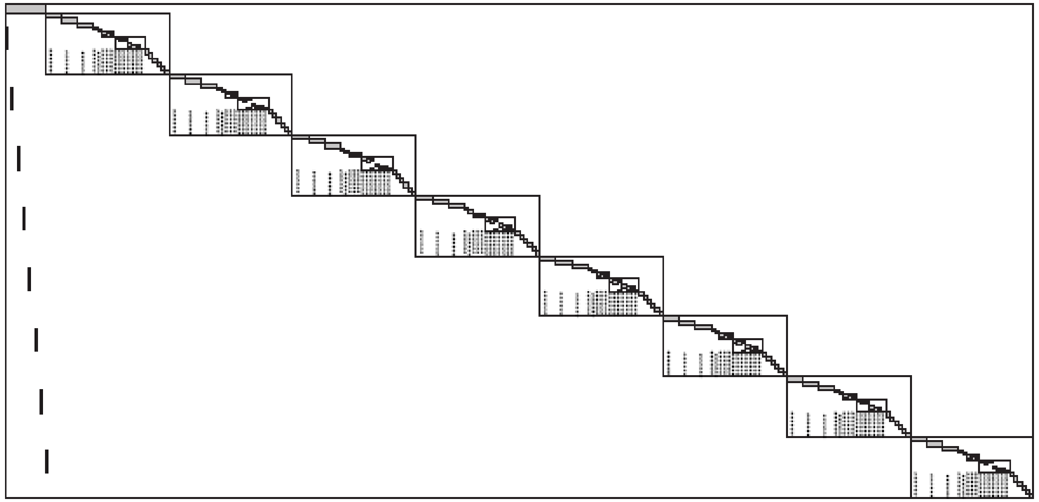
- Schedule a set of generating units to satisfy the demand at each node of the transmission network at each time instant of the horizon (24h)



- Several types of almost independent blocks + linking constraints
- Perfect structure for Lagrangian relaxation[1,2]

[1] Borghetti, F., Lacalandra, Nucci "Lagrangian Heuristics Based on Disaggregated Bundle Methods [...]", *IEEE TPWRS*, 2003
[2] Scuzziato, Finardi, F. "Comparing Spatial and Scenario Decomposition for Stochastic [...]" *IEEE Trans. Sust. En.*, 2018

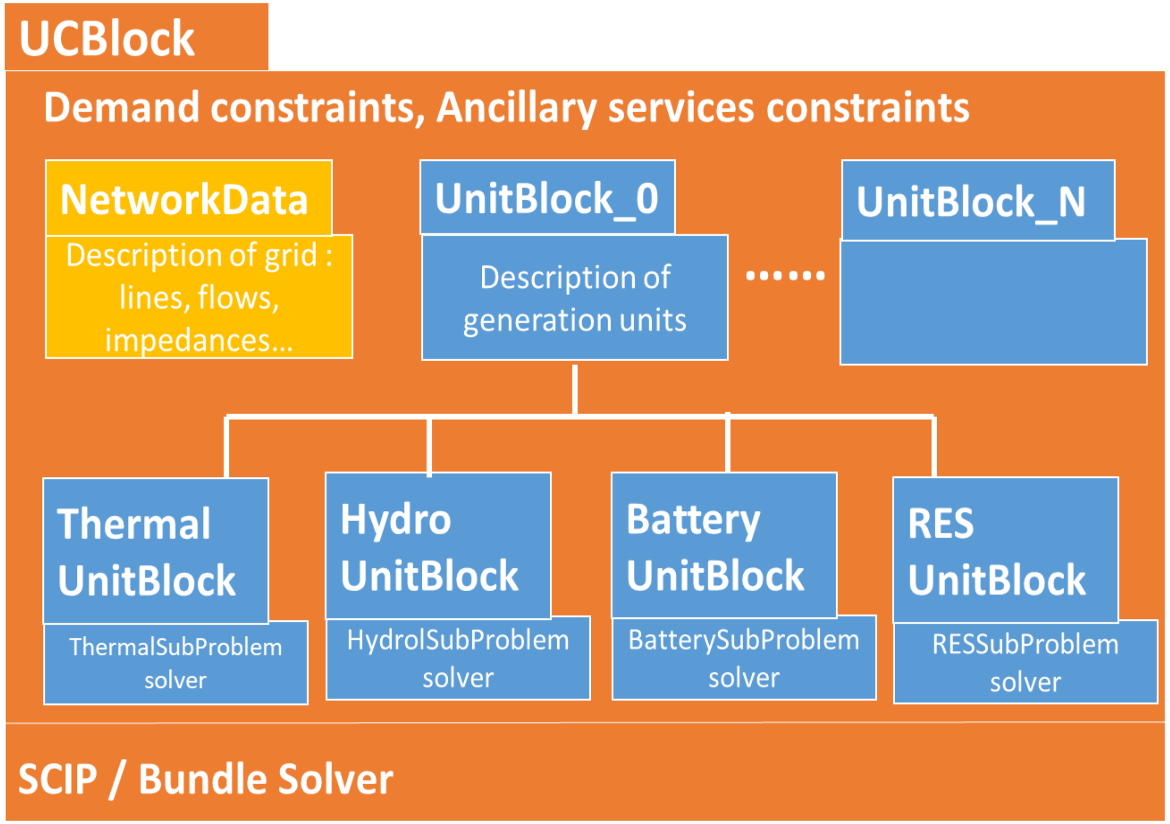
- Manage water levels in reservoirs considering uncertainties (inflows, temperatures, demands, ...) to minimize costs over the time horizon (1y)

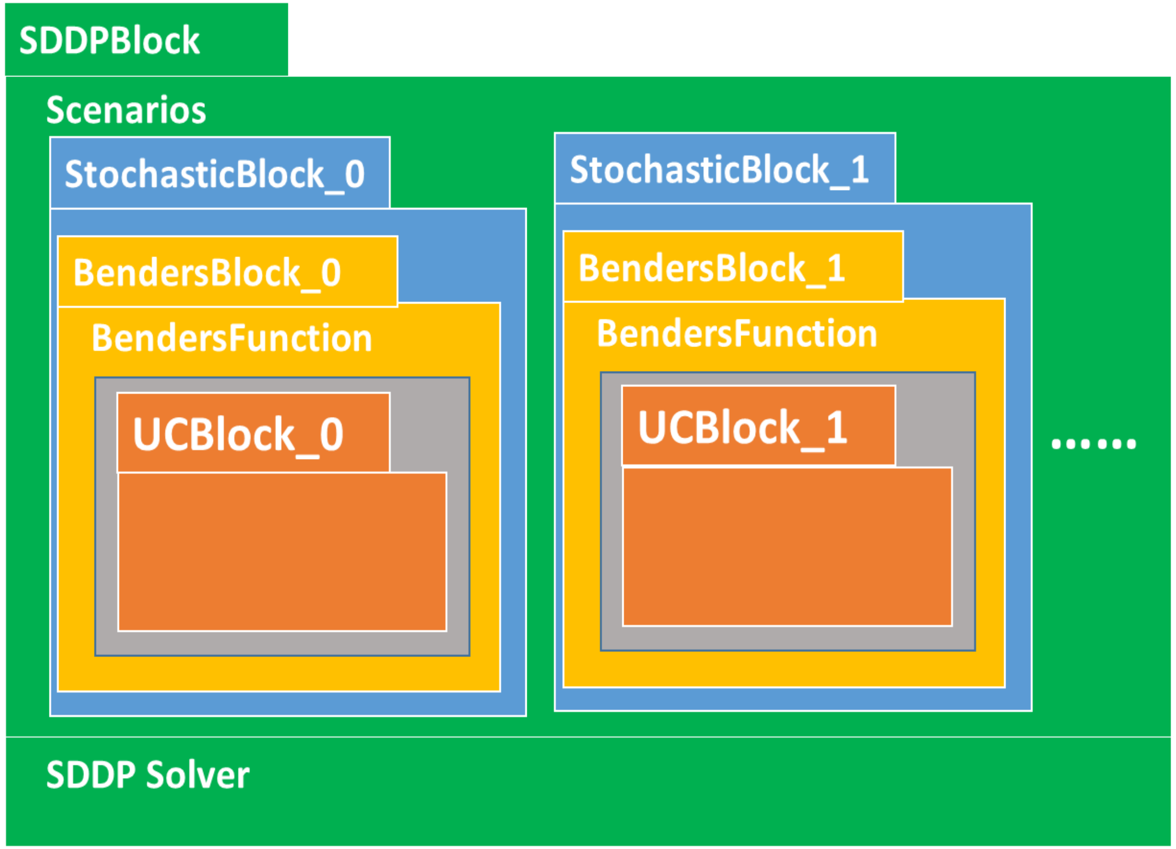


- Very large size, nested structure
- Perfect structure for Stochastic Dual Dynamic Programming[3,4] with multiple EUC inside

[3] Pereira, Pinto "Multi-stage stochastic optimization applied to energy planning" *Math. Prog.*, 1991
[4] van-Ackooij, Warin "On conditional cuts for Stochastic Dual Dynamic Programming" arXiv:1704.06205, 2017

Seasonal Storage Valuation and Unit Commitment in SMS++





- currently extending it to strategic, 30-years (stochastic) capacity expansion problem
- "just another level" over existing ones

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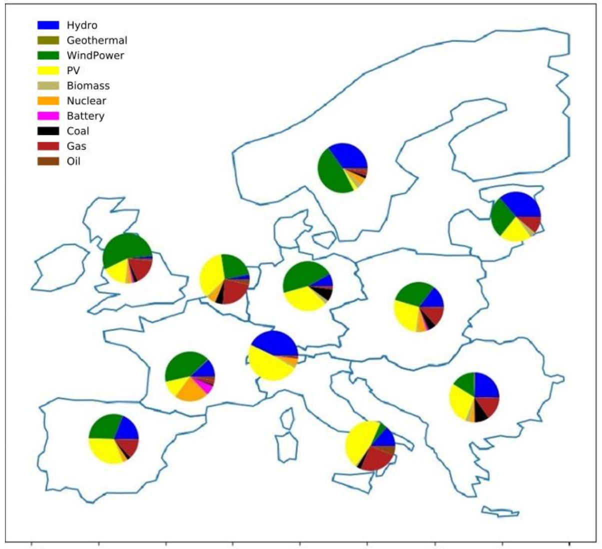
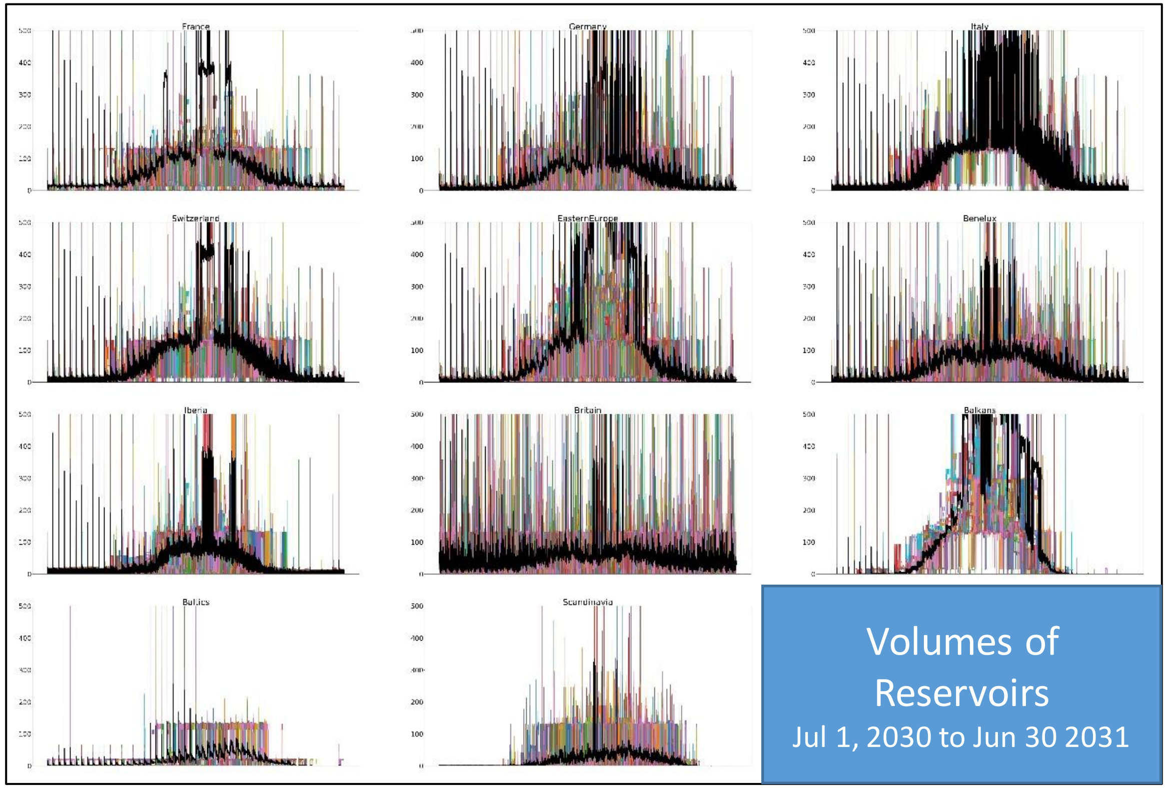
Case Study example: Assessment of openEntrance Scenario Techno friendly 2030 for the electricity mix

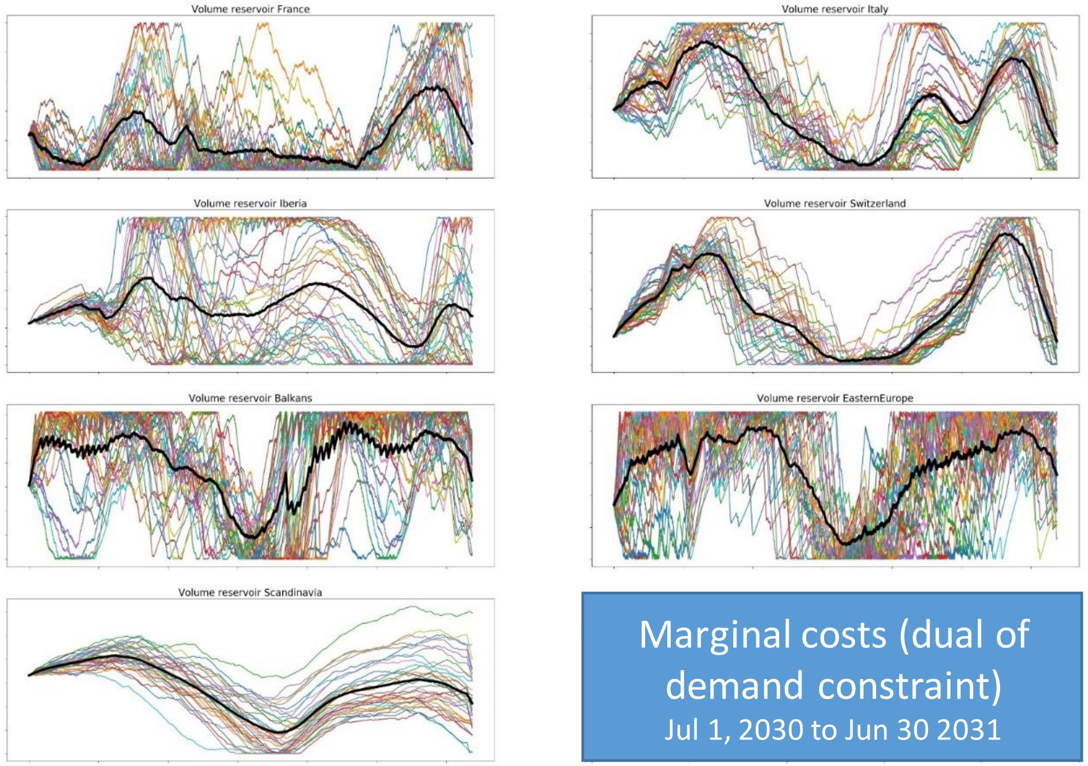
Marginal Costs of Electricity, Volumes of Seasonal Storages



Installed electricity Generation mix

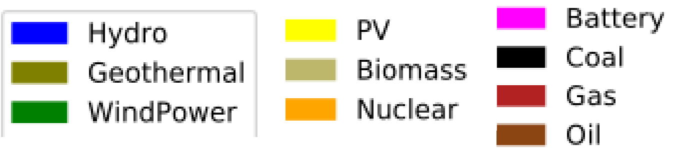


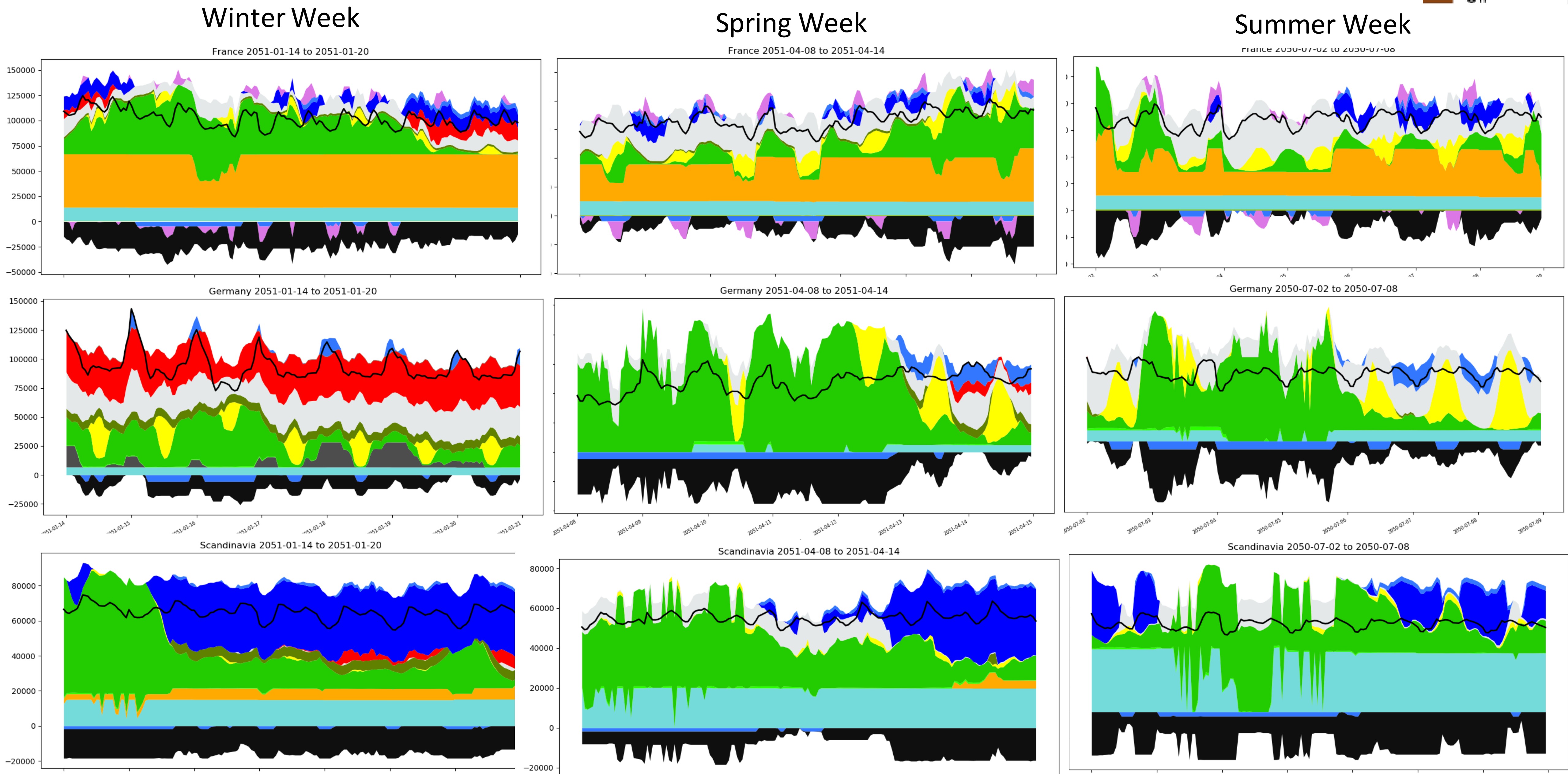
Volumes of Reservoirs
Jul 1, 2030 to Jun 30 2031



Marginal costs (dual of demand constraint)
Jul 1, 2030 to Jun 30 2031

Hourly Profiles for specific weeks





www.plan4res.eu

Main results are available:

❑ Reports and data:

- https://zenodo.org/communities/plan4res

❑ Solvers:

- SCIP: https://www.scipopt.org/
- StOpt: https://gitlab.com/stochastic-control/StOpt
- NDOSolver/FiOracle: https://gitlab.com/frangio68/ndosolver_fioracle_project

❑ Modelling Library:

- SMS++: https://gitlab.com/smspp/smspp-project

❑ Environment:

- Container: https://gitlab.com/cerl/plan4res/p4r-env
- CI/CD platform: https://gitlab.com/cerl/plan4res/p4r-exec-singularity

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