PSR

Simulating Power Systems by Solving Millions of MIPs

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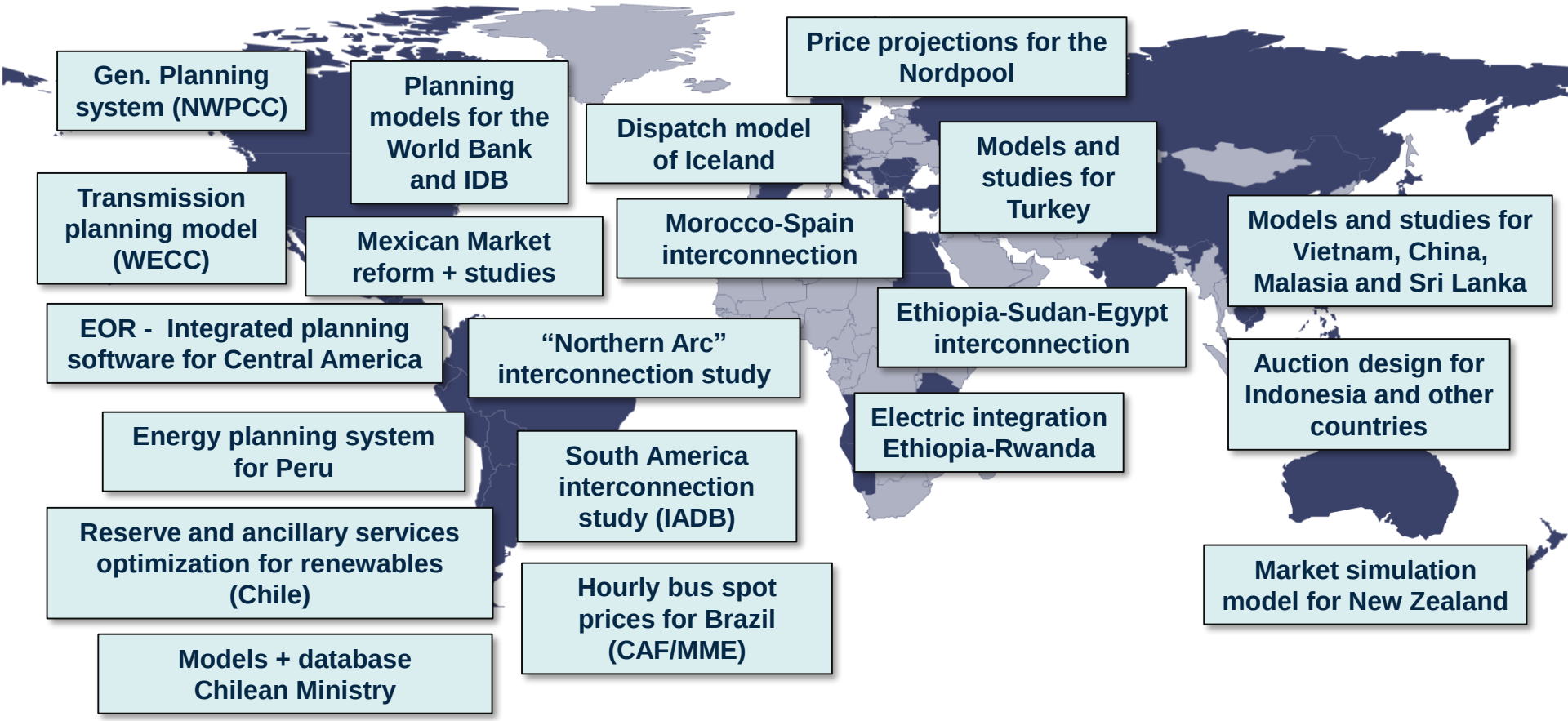
PSR

Provider of analytical solutions and consulting services (economic, regulatory, financial and technological) in electricity and gas since 1987

Our team has 58 experts (17 PhDs, 31 MSc) in engineering, optimization, energy systems, statistics, finance, regulation, IT and environment analysis

We work in more than 70 countries in all continents

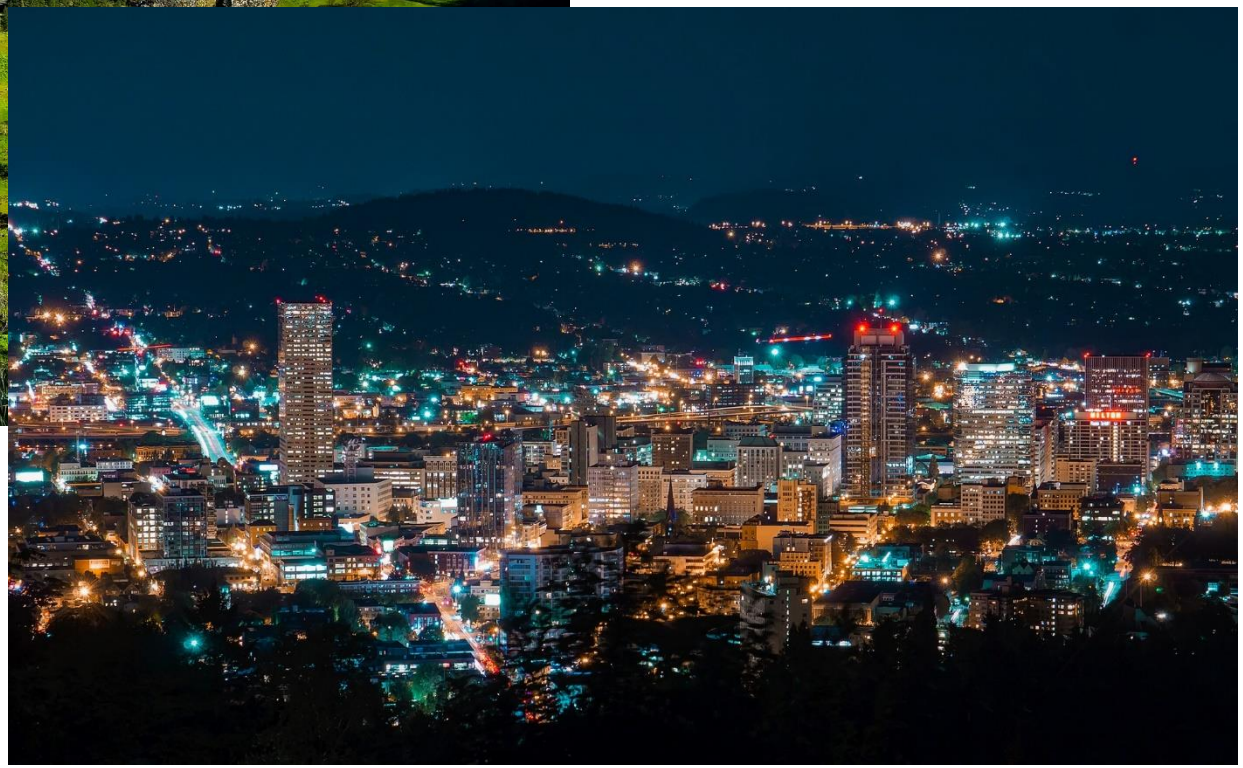


300+ active licenses

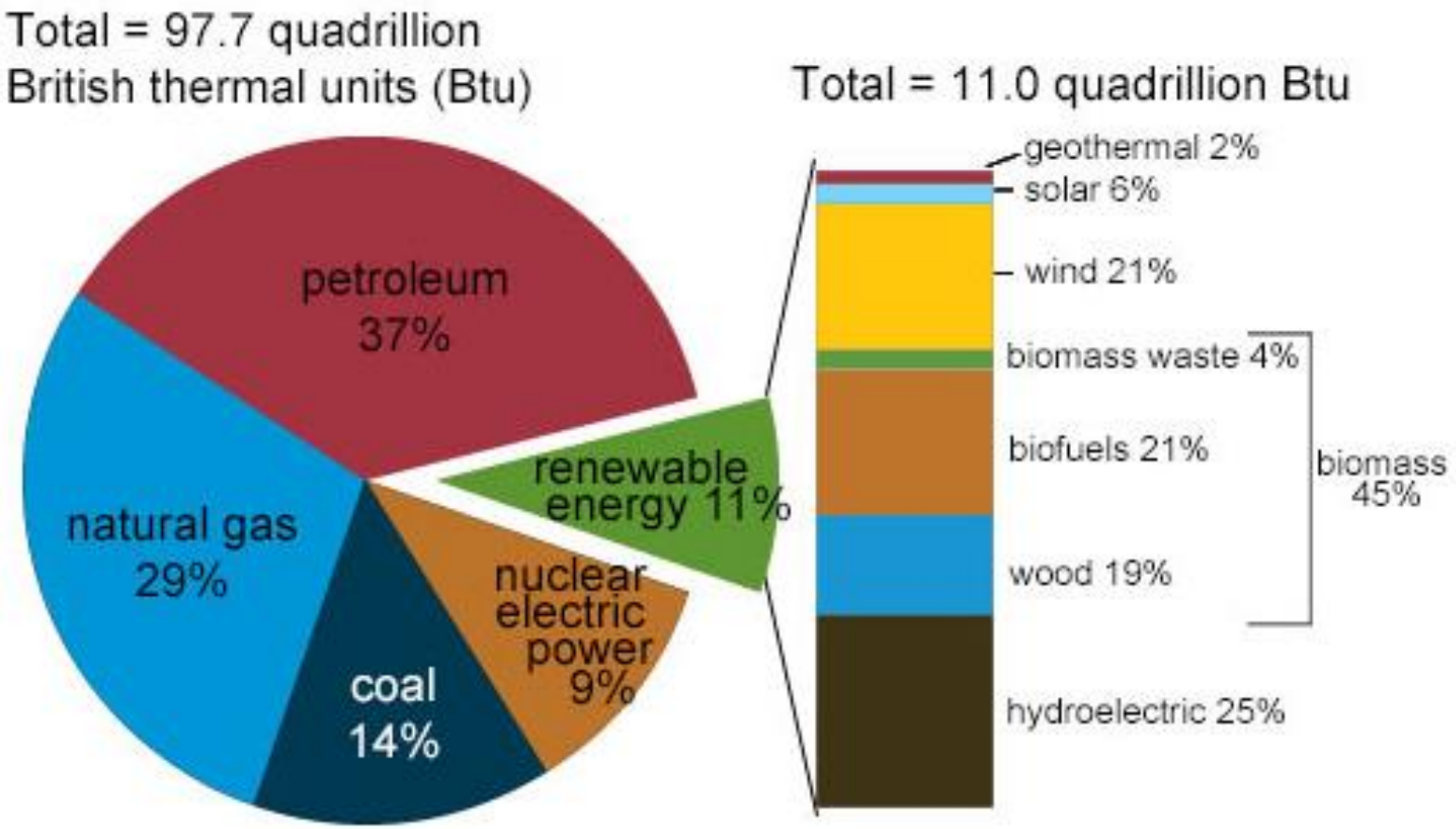
70+ countries

The US Pacific Northwest

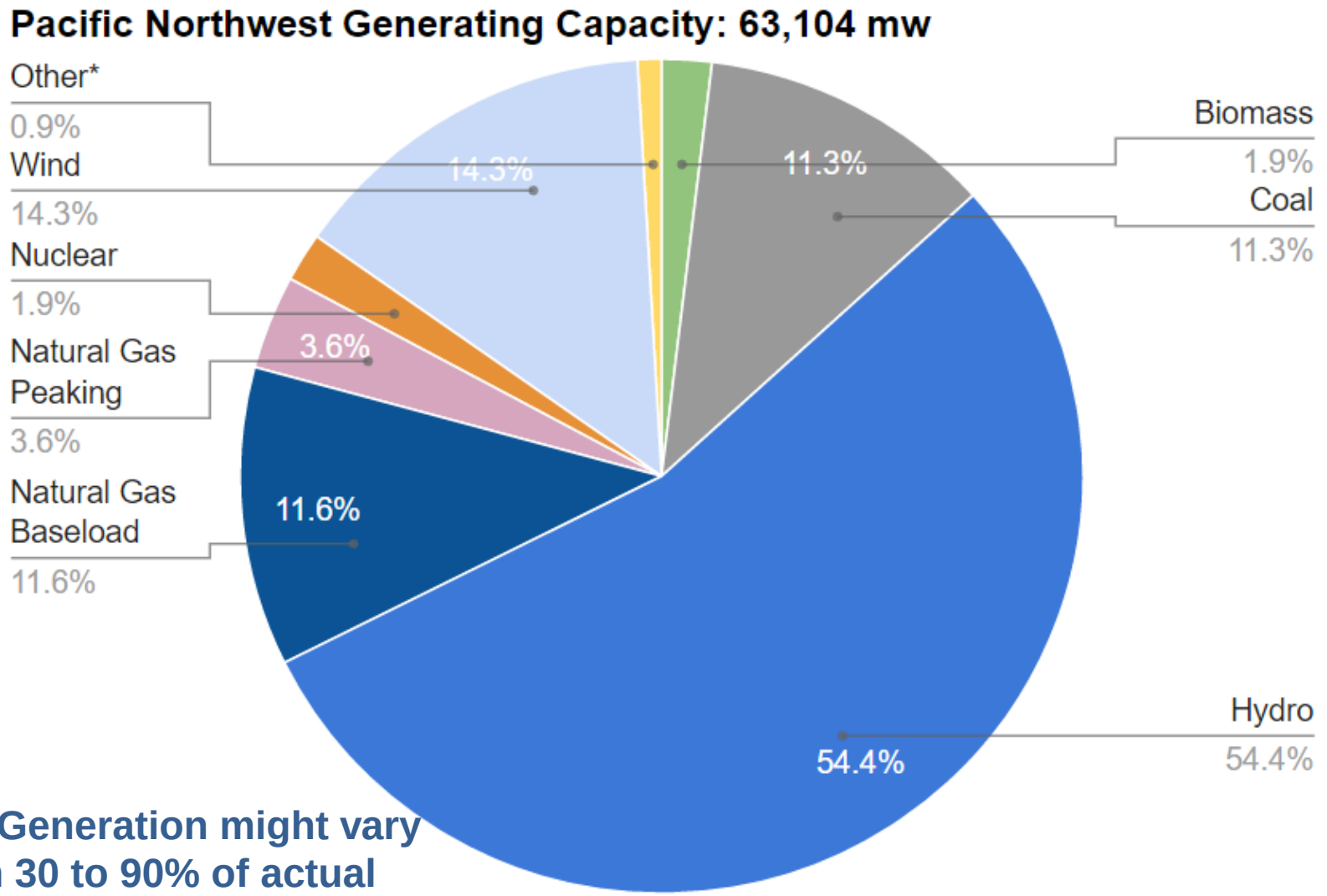
The US Pacific Northwest



The US


Total = 97.7 quadrillion
British thermal units (Btu)
petroleum 37%
natural gas 29%
coal 14%
nuclear electric power 9%
renewable energy 11%
Total = 11.0 quadrillion Btu
geothermal 2%
solar 6%
wind 21%
biomass waste 4%
biofuels 21%
wood 19%
biomass 45%
hydroelectric 25%

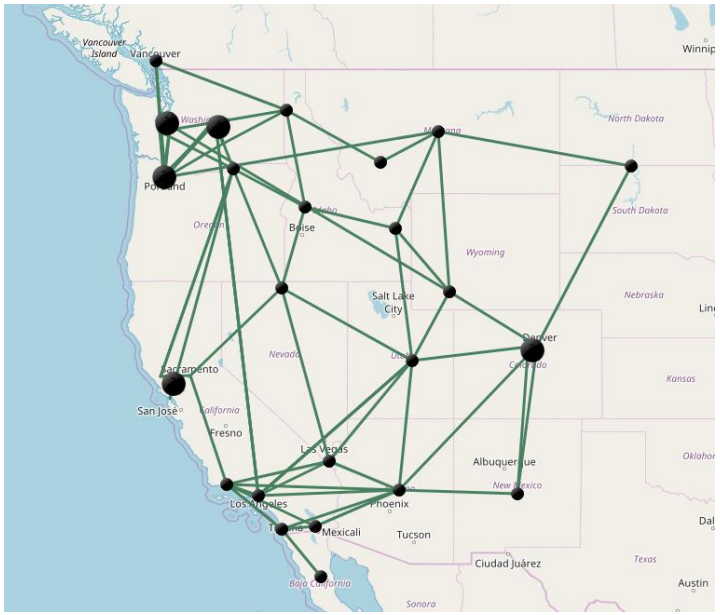
The US Pacific Northwest



Hydro Generation might vary from 30 to 90% of actual generation in a year

The US Pacific Northwest

- Plants to be represented
  - 76 hydros (38 reservoirs)
  - 133 thermals
  - 339 non-dipatchable plants (including renewables)
- Network
  - DC optimal power flow
  - 34 nodes
  - 74 circuits



The US Pacific Northwest – some details

- Large share of hydro generation

  With detailed operation (irrigation, topology, Canada)

- Renewable generation (15% of capacity)

  Solar and Wind

- Fuel contracts

  Set on a daily basis

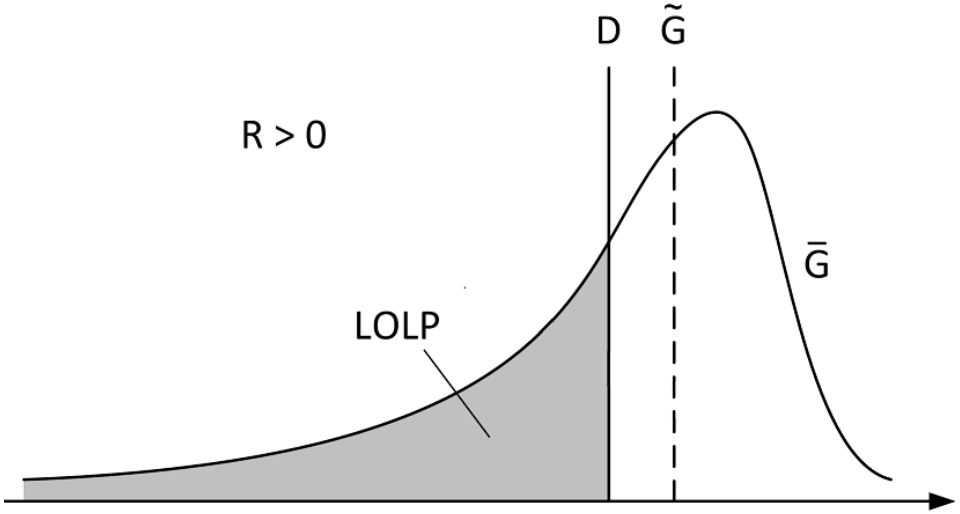
- Redispatch with limited resources

  not all resources are available to all loads

Main Goal

- Mimic the real-life operation with as many details as possible

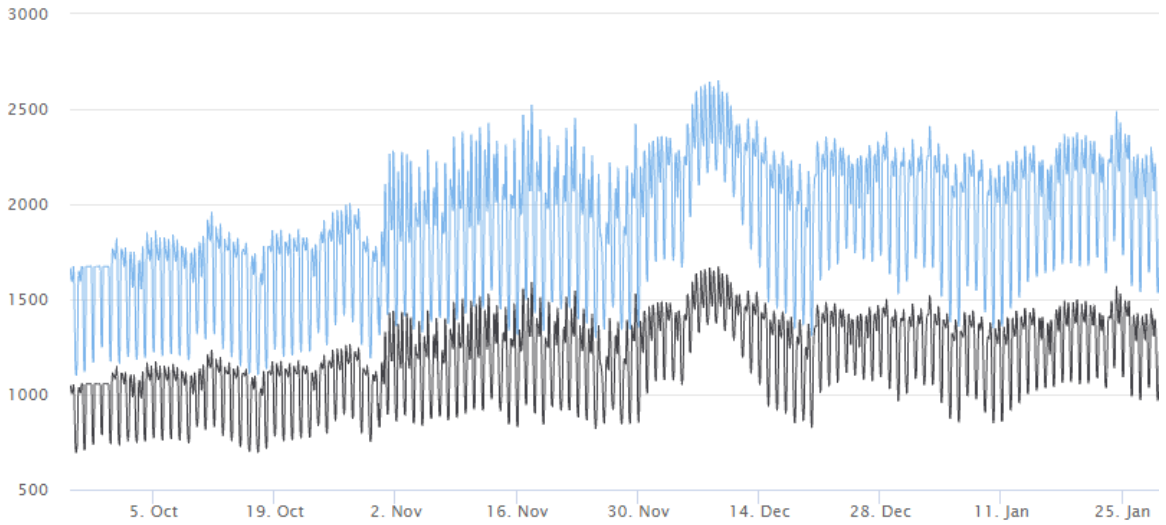
- Evaluate system reliability, compute Loss Of Load Probability
  - Other results like generation, marginal costs...



Main Goal

- Uncertainty on:

  Load



  Renewable Generation

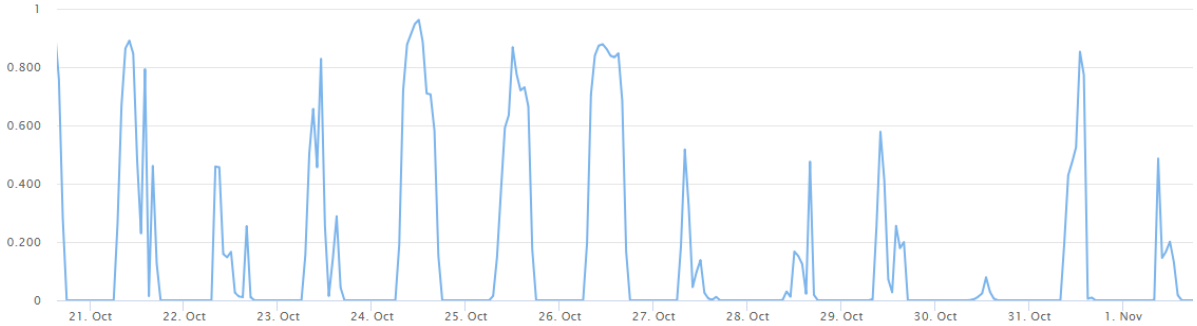
  Inflows

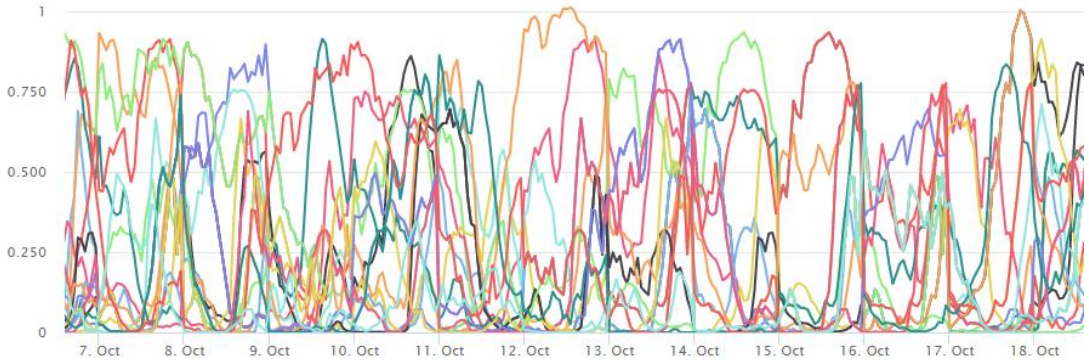
Main Goal

- Uncertainty on:

  Load

  Renewable Generation





  Inflows

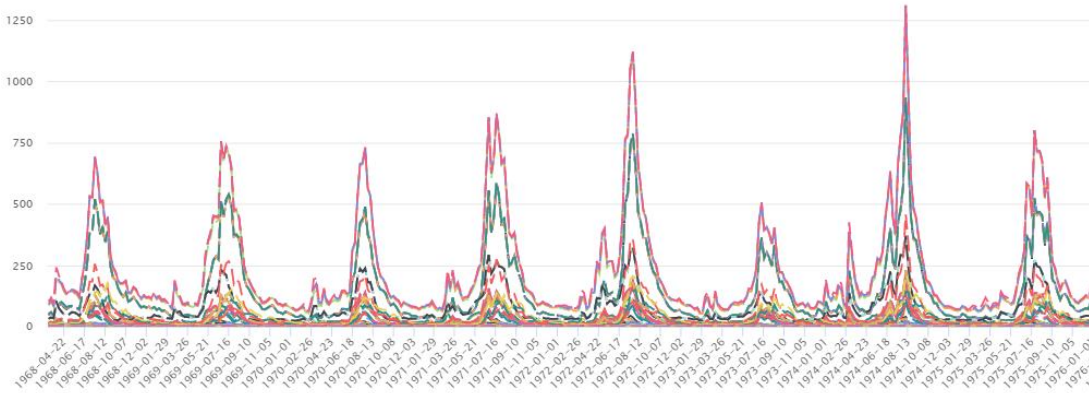
Main Goal

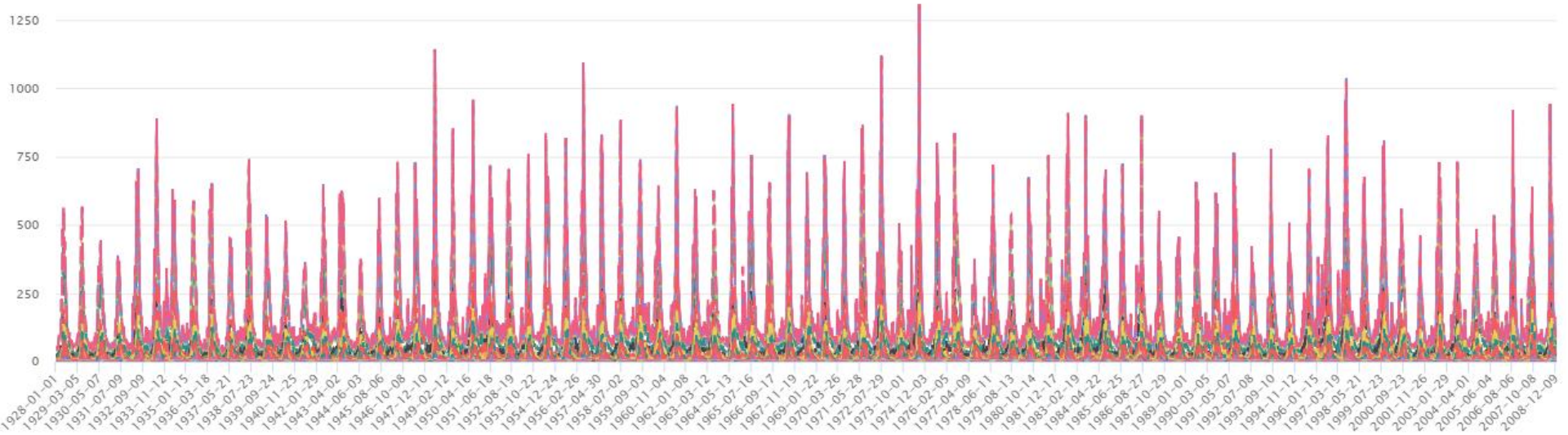
- Uncertainty on:

  Load

  Renewable Generation

  Inflows





Main Goal

- Uncertainty on:

  Load

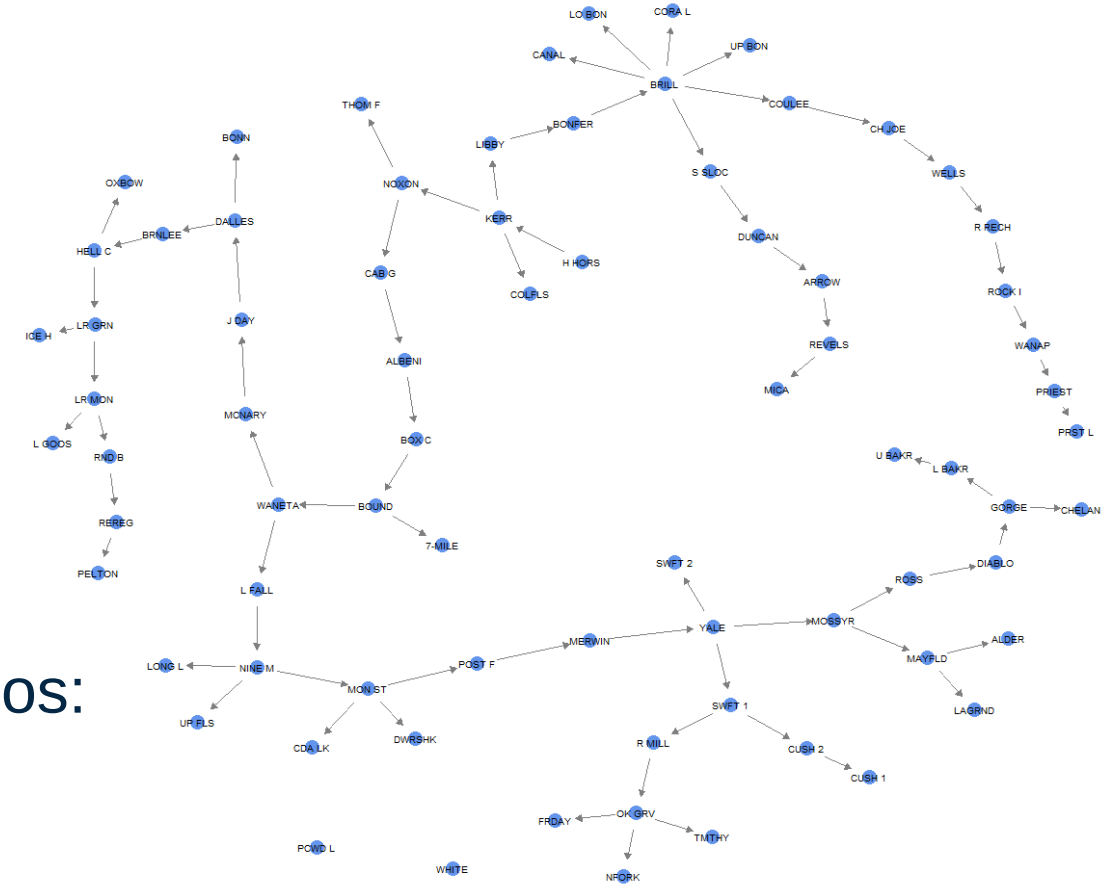
  Renewable Generation

  Inflows

- Dependency on scenarios:

  Baysian network

- Followed by monte-carlo simulation



Big Challenges

- Detailed modelling of the system

- Good representation of uncertainty
- These combinations lead to:

  Challenging optimization and computation solutions

  Involving parallel processing and Big Data

Big Challenges

- 54 milllion MIPs problems

  Daily/weekly operation with hourly resolution

- 6000 scenarios (8760 hours each)

- Distributed processing

  (≈ 500 servers)

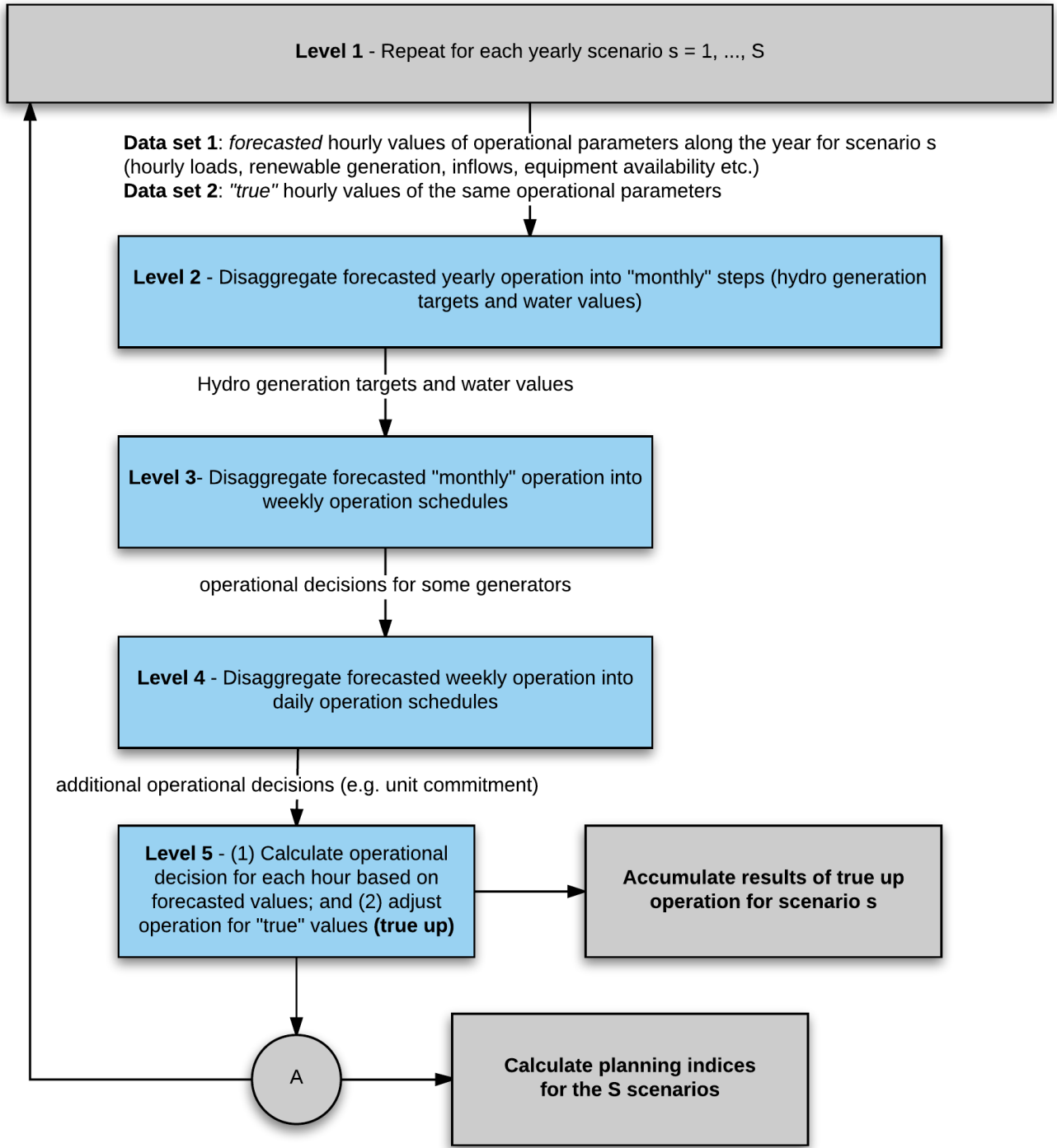
- Distributed storage

  (10 Tbytes for results and statistics)

- In 8 hours!

Multi layer model

- Medium term planning (weeks ahead)
  - Water values
  - Slow commitments
- Day ahead operation
  - Fuel contracts
  - Market trading
- Hour ahead operation
  - Detailed hydro-thermal operation
- Real time generation control
  - Redispatch under uncertainty with limited resources


Level 1 - Repeat for each yearly scenario s = 1, ..., S
Data set 1: *forecasted* hourly values of operational parameters along the year for scenario s (hourly loads, renewable generation, inflows, equipment availability etc.)
Data set 2: *"true"* hourly values of the same operational parameters
Level 2 - Disaggregate forecasted yearly operation into "monthly" steps (hydro generation targets and water values)
Hydro generation targets and water values
Level 3- Disaggregate forecasted "monthly" operation into weekly operation schedules
operational decisions for some generators
Level 4 - Disaggregate forecasted weekly operation into daily operation schedules
additional operational decisions (e.g. unit commitment)
Level 5 - (1) Calculate operational decision for each hour based on forecasted values; and (2) adjust operation for "true" values **(true up)**
Accumulate results of true up operation for scenario s
A
Calculate planning indices for the S scenarios

Medium term modelling

- High inflow variability
- Hydro share of generation varies from 30 to 90%
- Classic problem of hydro systems with relevant storage:

  Valuing water throughout time!
- Multi-stage stochastic optimization

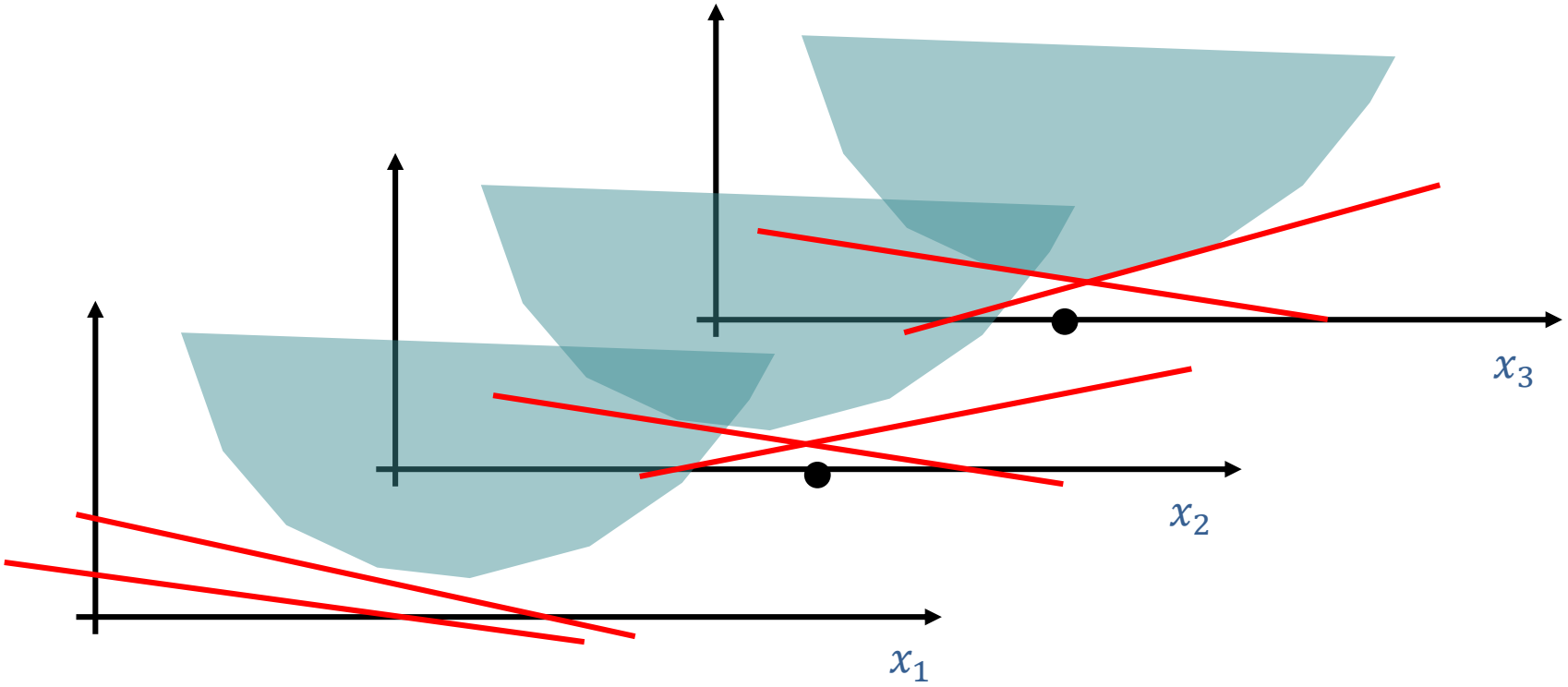
The US Pacific Northwest

- Complex cascades

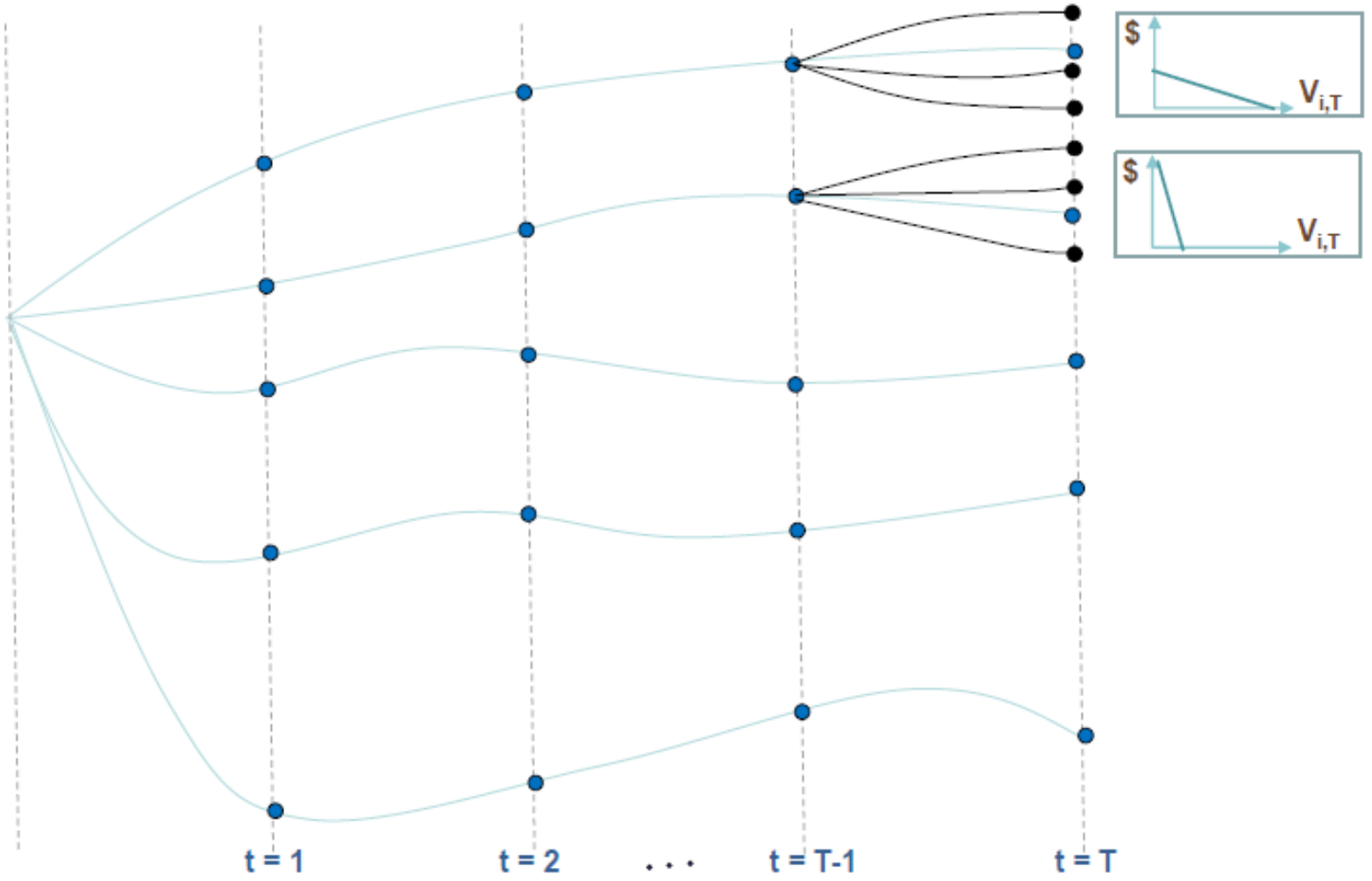
Stochastic Dual Dynamic Programming

- Best of breed method to overcome the curse of dimensionality
  - Many coupled stages and scenarios lead to intractable deterministic equivalents
- Highly paralelizable
- Detailed representation of hydro operation
  - Multiple constraints
  - Complex topology

SDDP – iteratively construct a policy

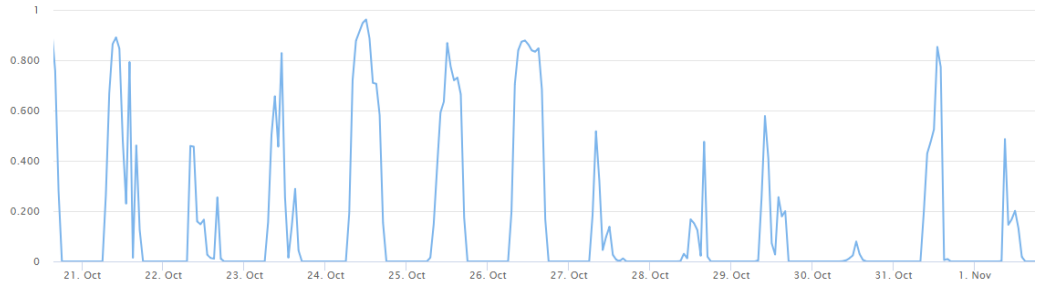


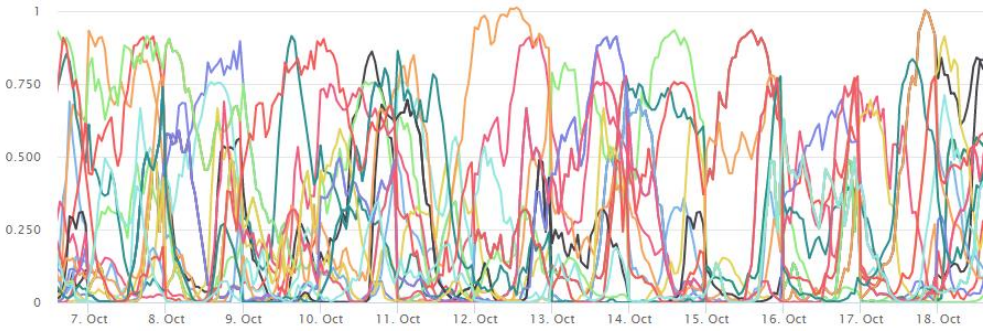
SDDP – Parallelizable



Short term operation (dayand hour ahead)

- Non-convex hydro modelling
- Integrality contraints
  - Thermal unit commitment
- Hourly representation

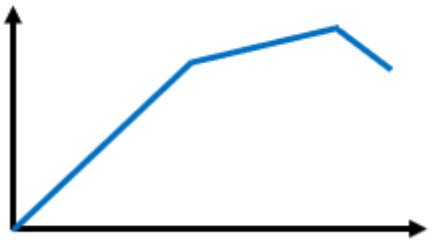




Mixed Integer Programming

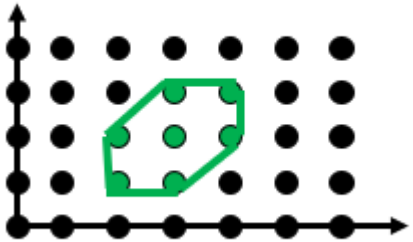
- Detailed representation of non-convexities

  non-linear hydro production -> SOS



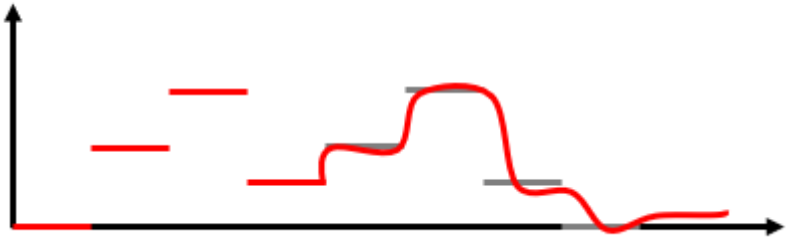
- Strong formulations

  Unit commitment



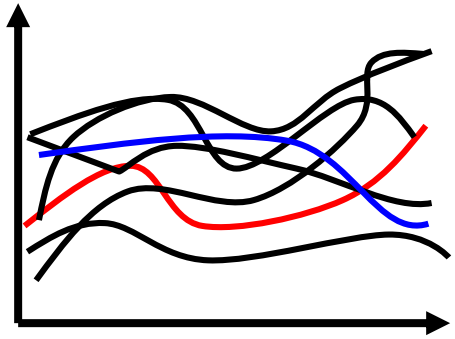
- Relaxation of end-of-horizons

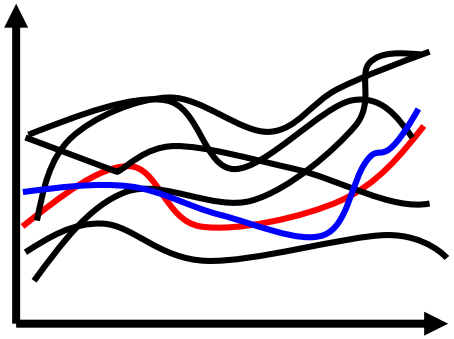
  otherwise solution is too myopic

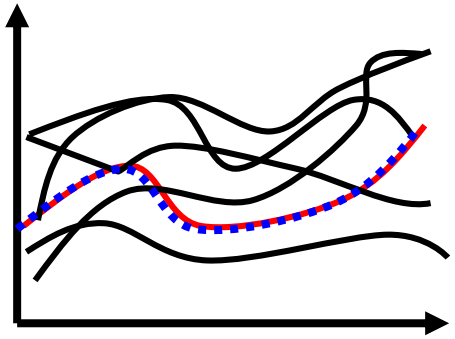


Real time redispatch (“true up”)

- Load and renewable generation forecasts become reality
  - “Forecasts” as convex combinations





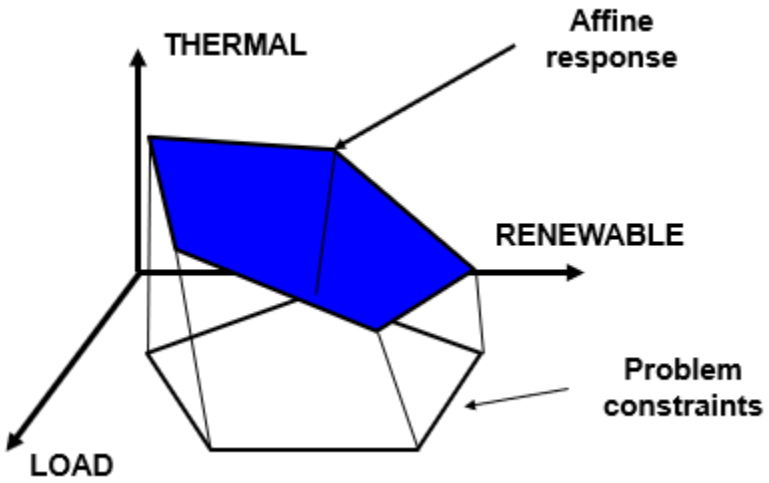


- More:
- Contracts must be settled
- Redispatch thermal and hydro plants
  - Only some plants can perform corrective action for some loads

Linear Decision Rules

- Stochastic program to optimize the redispatch operation
- Affine generation control

  Thermal and hydro (commited) generation as linear functions of Load and Renewable Generation Variation



Problem dimensions

- Weekly/Monthly (2 millions LPs + 5,000 MIPs)
  - Variables: >30,000 ; Constraints: >50,000 ; Integers: >2,000
  - Not 100% paralellizable (SDDP is an iterative method)
  - 1 hour on 40 servers
- Daily (6000*(8760+360) = 54 millions MIPs)
  - Variables: > 50,000 ; Constraints: > 70,000 ; Integers: > 5,000
  - Avg time 80s per 720 problems (1month) = 3.3 hours (using 500 servers)
- Hourly (6000*8760 = 52 millions MIPs)
  - Variables: Constraints:
  - Avg time 70s per 720 problems (1month) = 2.9 hours (using 500 servers)

Highly paralelized execution

- IO – Input & Output (Read and Write)
  - Using multi-server elastic data-bases running Cassadra

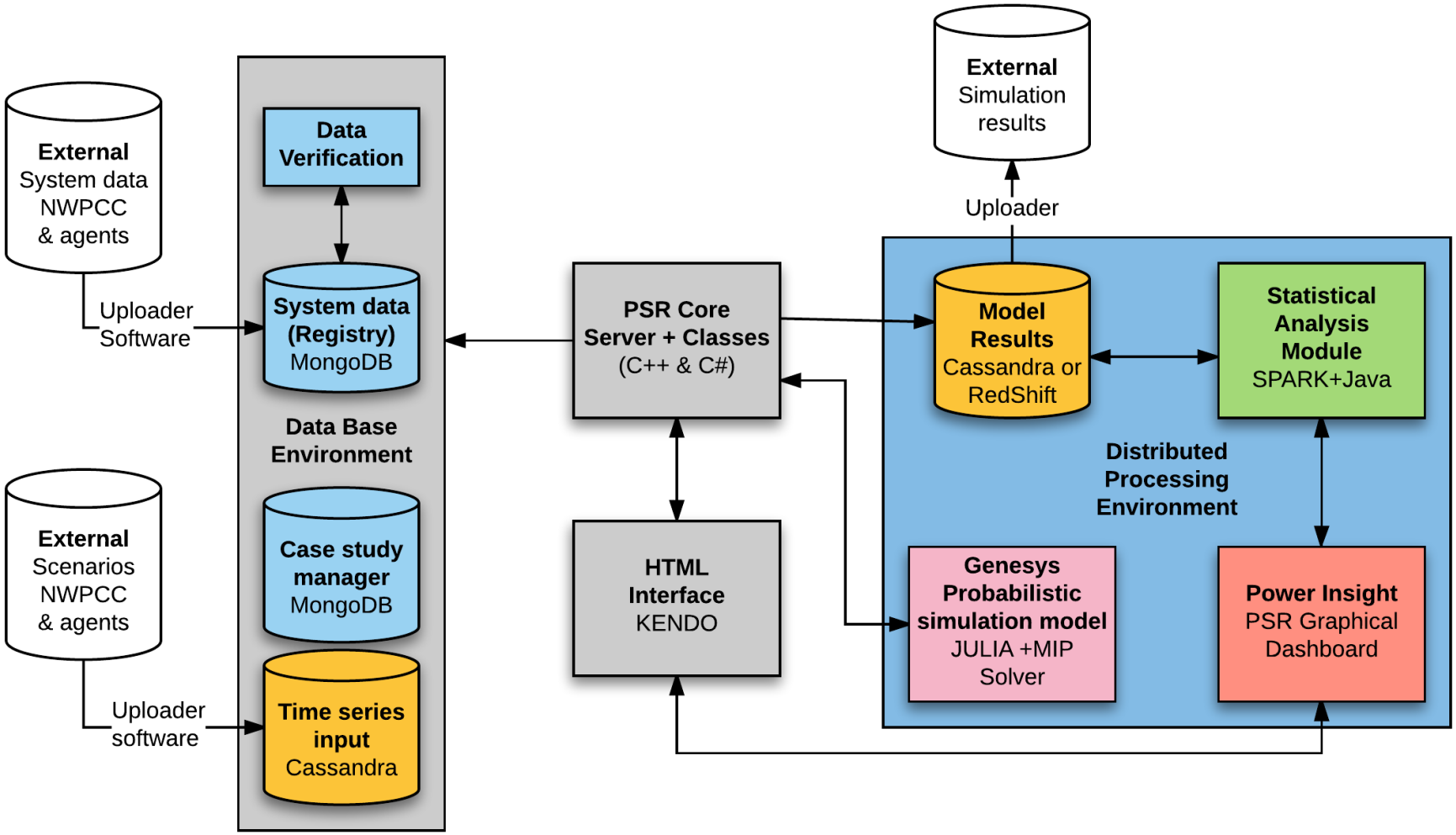
- Execution
  - Initialized from web interface
  - Remote execution
  - AWS server
  - 500 servers with 32 cores each = 16.000 cores

Querying results

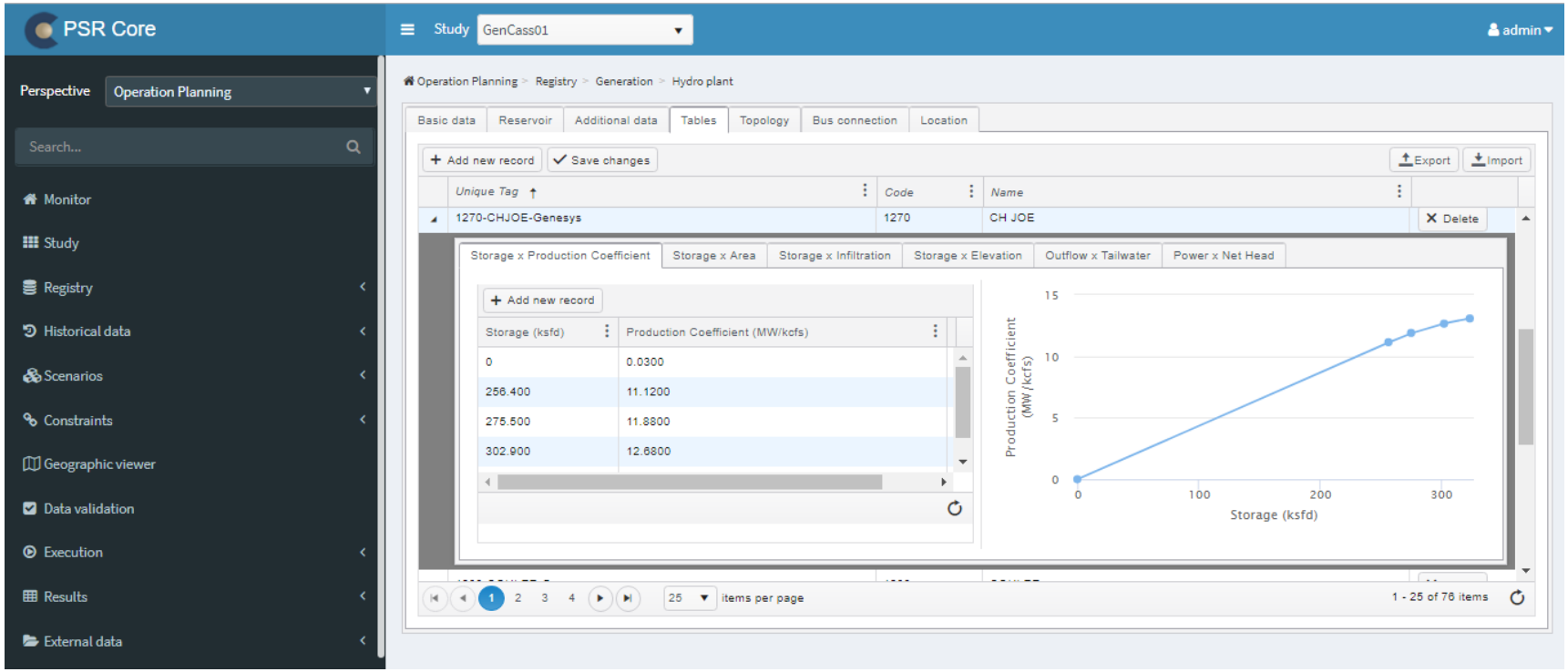
- Need to query results in 10Tb results pool
- Can’t do it from my pc
- But I can do it from my phone/tablet!
- Multiple servers

  Spark performs computations

Genesys architecture



Web Platform



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Thanks