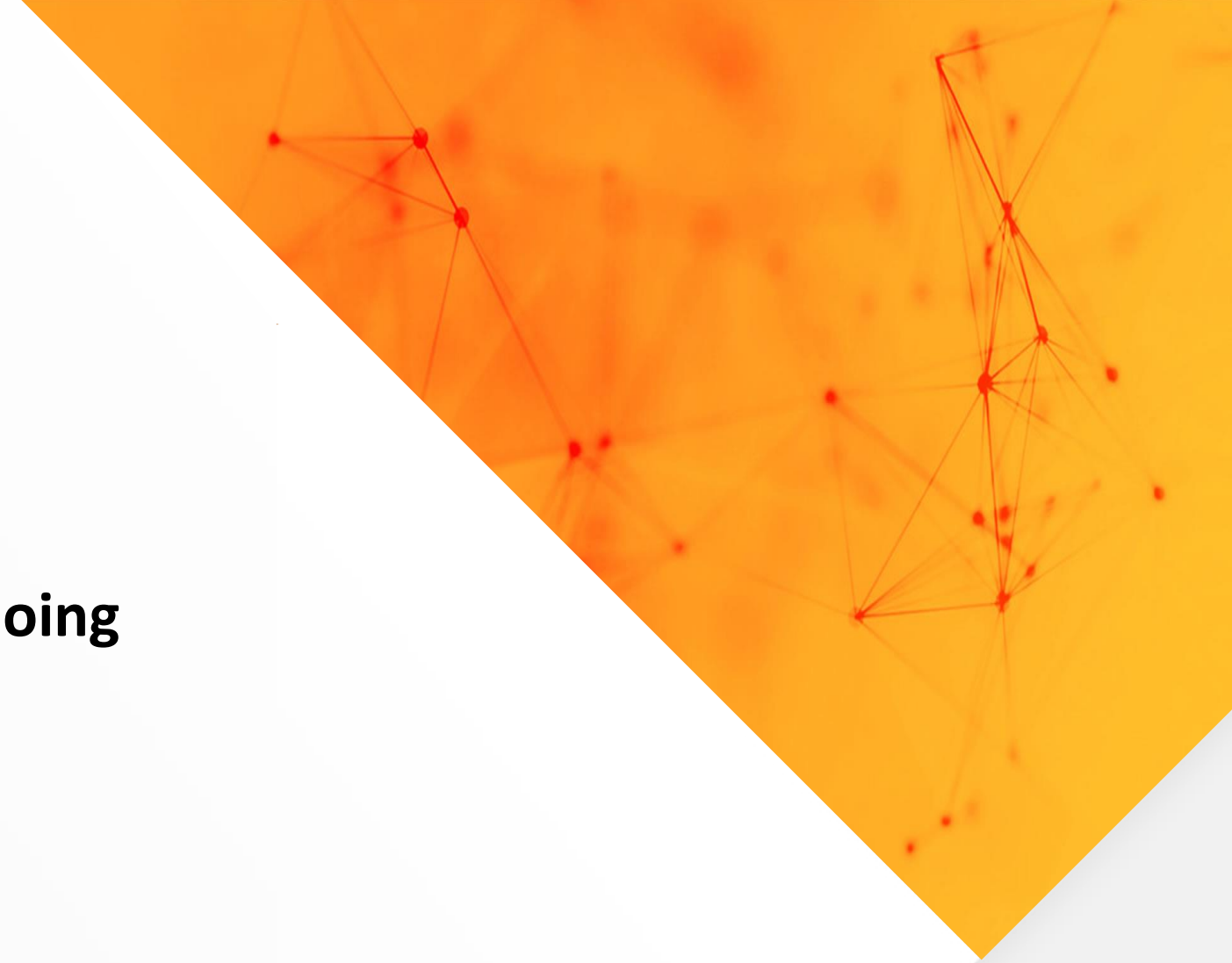
Hydrothermal Scheduling: Simulation and coupling between long- and short-term models

Vitor de Matos

Workshop "Stochastic Programming models and algorithms for energy planning"

Understanding what we are doing



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Multistage Stochastic Linear Programming

- What is the problem to be solved and how to evaluate the quality of a solution?

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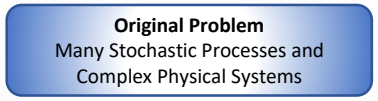

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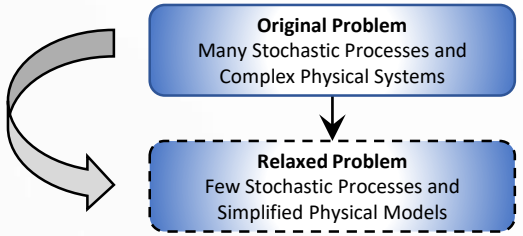
Multistage Stochastic Linear Programming

- What is the problem to be solved and how to evaluate the quality of a solution?

1st Approximation:

- Only the most important stochastic processes are selected to reduce the sample space.
- Simplified physical models are formulated to ensure convexity and to reduce the state space.



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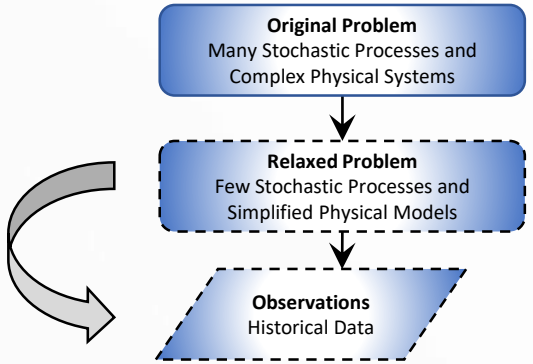
Multistage Stochastic Linear Programming

- What is the problem to be solved and how to evaluate the quality of a solution?

2nd Approximation:
The historical data usually are the only information about the stochastic process behavior. The data may not be reliable.



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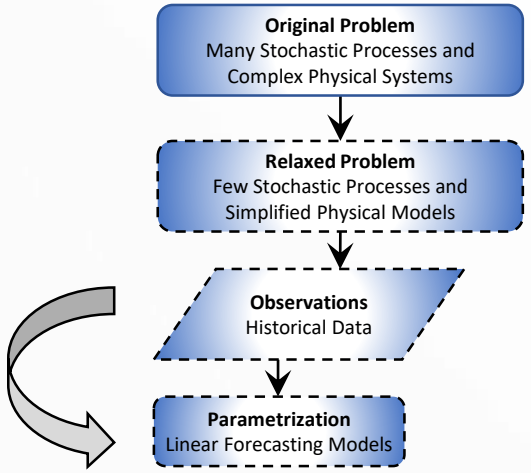
Multistage Stochastic Linear Programming

- What is the problem to be solved and how to evaluate the quality of a solution?

3rd Approximation:
Linear forecasting models are designed to represent the stochastic processes behavior.



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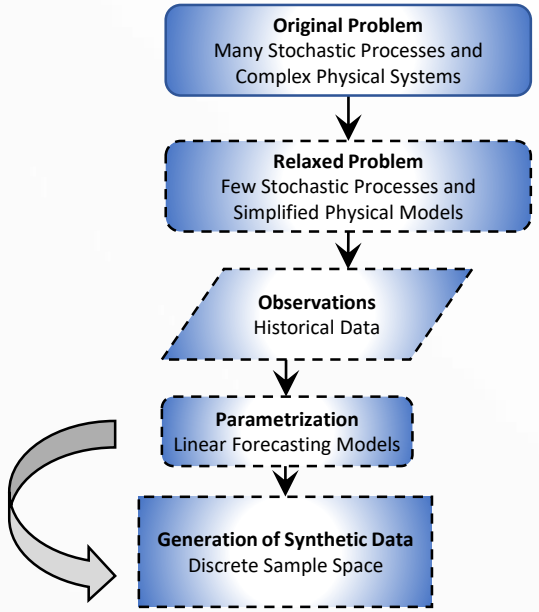
Multistage Stochastic Linear Programming

- What is the problem to be solved and how to evaluate the quality of a solution?

4th Approximation:
The discrete sample space is ready to be generated with the forecasting models and a random sampling process.



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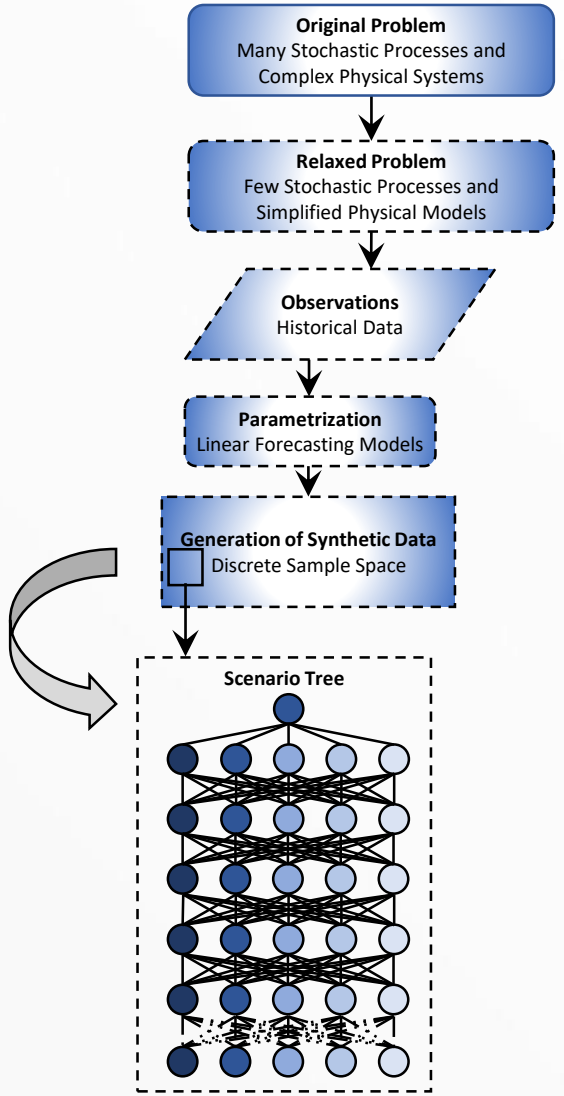
Multistage Stochastic Linear Programming

- What is the problem to be solved and how to evaluate the quality of a solution?



5th Approximation:

- The finite-horizon optimization problem is defined by a sample of the sample space (scenario tree).
- The size and the structure of a proper scenario tree may be computationally prohibitive for certain types of problems.

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Multistage Stochastic Linear Programming

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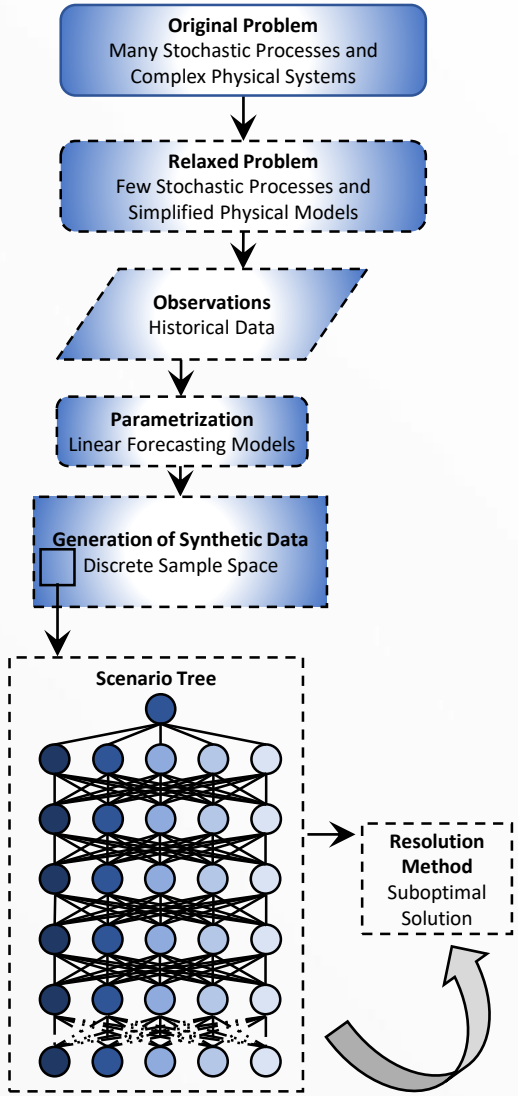

6th Approximation:
Depending on the resolution method and the stopping criteria, the result is a suboptimal solution.

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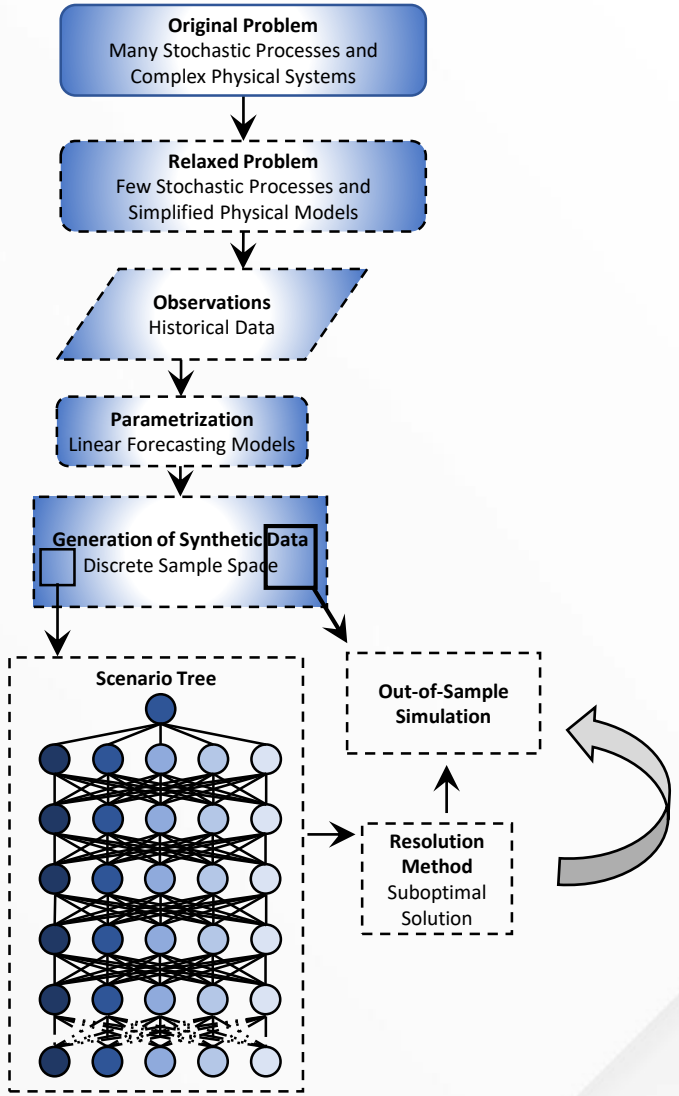
Multistage Stochastic Linear Programming

- What is the problem to be solved and how to evaluate the quality of a solution?



Solution Evaluation:
A proper solution evaluation may be computationally expensive.
Sometimes out-of-sample and historical simulations are used.

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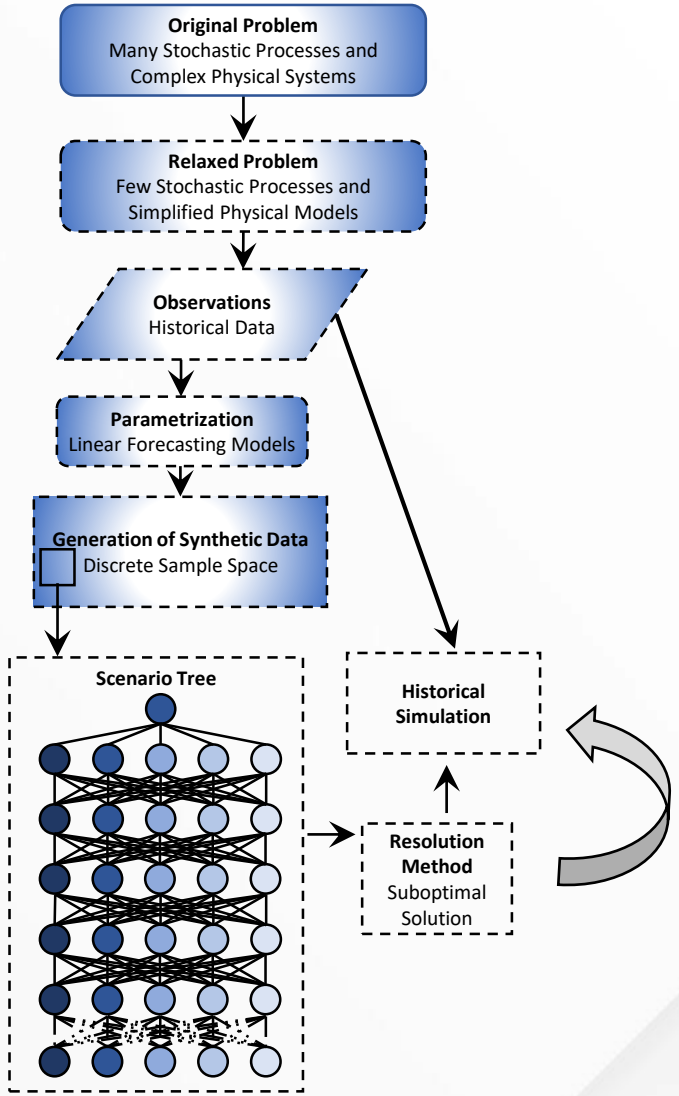
Multistage Stochastic Linear Programming

- What is the problem to be solved and how to evaluate the quality of a solution?



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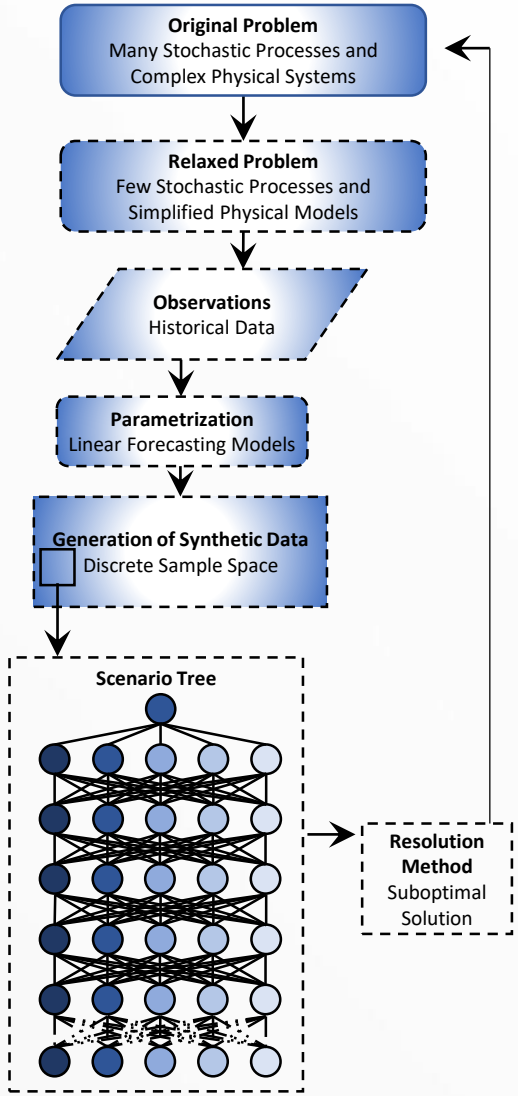
Multistage Stochastic Linear Programming

- What is the problem to be solved and how to evaluate the quality of a solution?

At the end of the process the suboptimal solution is applied to the original (real-life) problem



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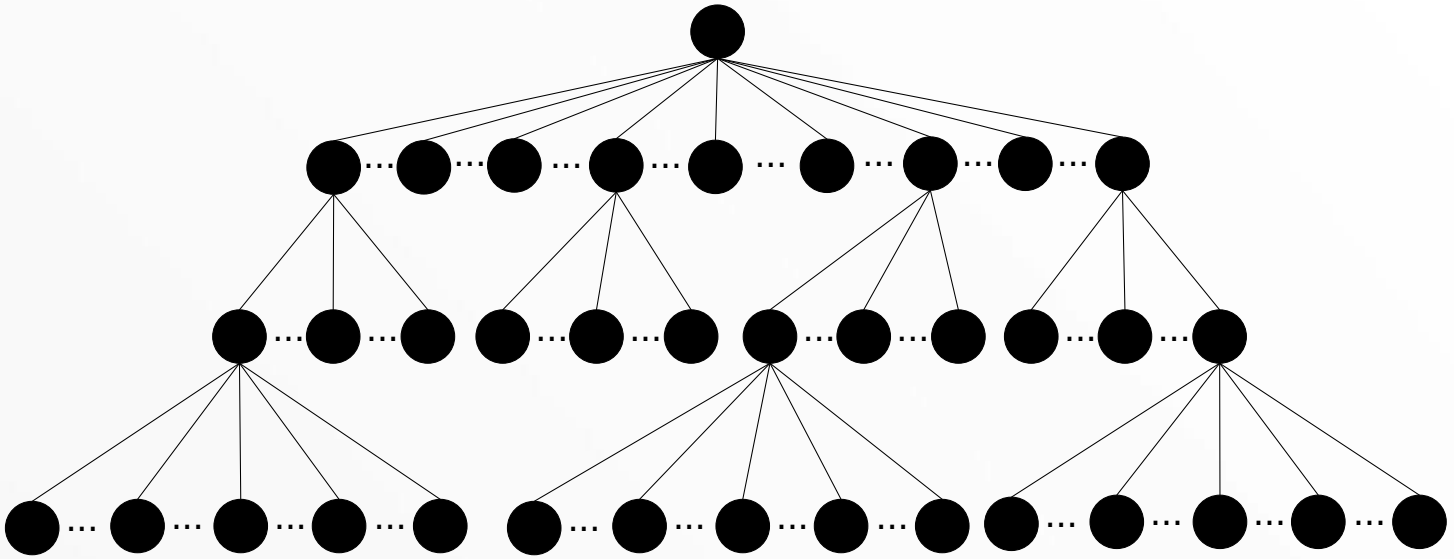
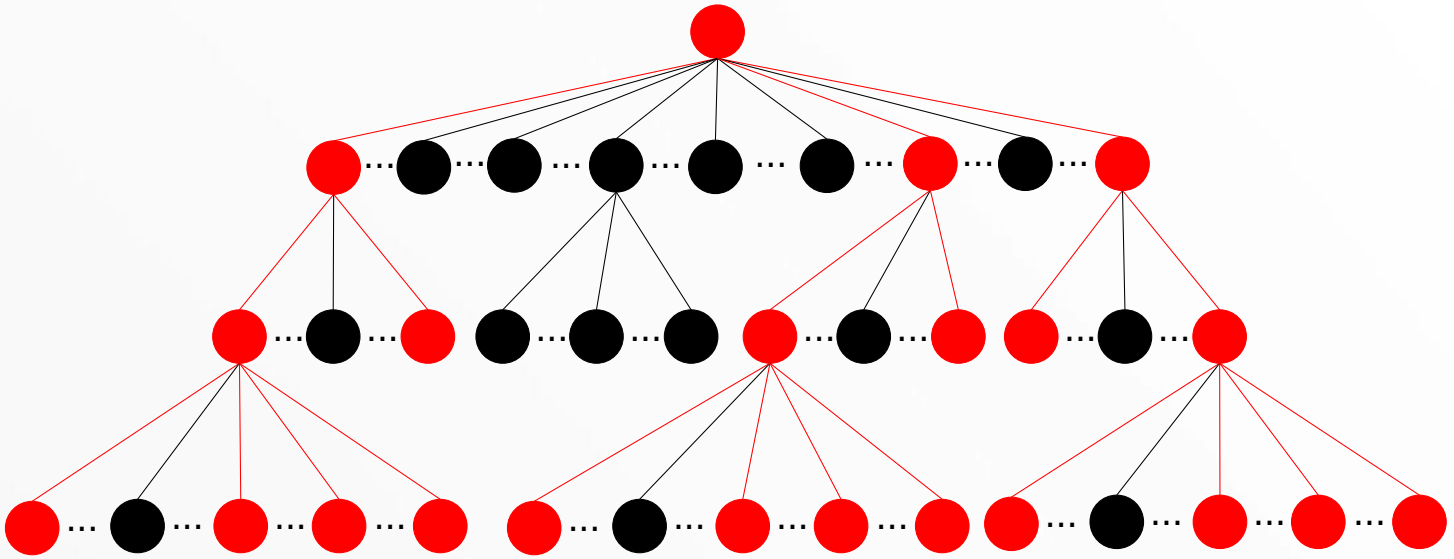
Stochastic Programming

- Scenario Tree



Stochastic Programming

- Scenario Tree



- Sampling Strategy → Monte Carlo (MC), Selective Sampling, Latin Hypercube Sampling, ...
- Reduces the original tree into a small sample of it

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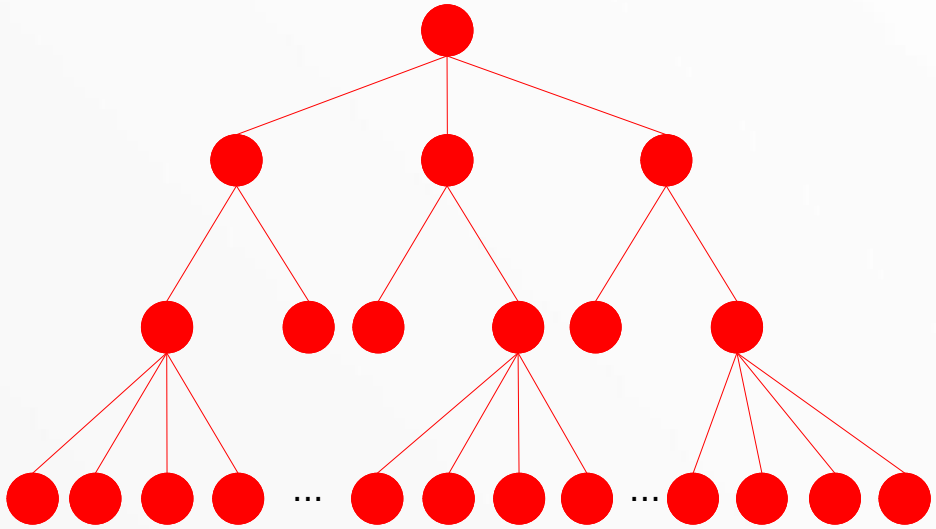
Stochastic Programming

- Even than, it is not possible to find the solution for the scenario tree



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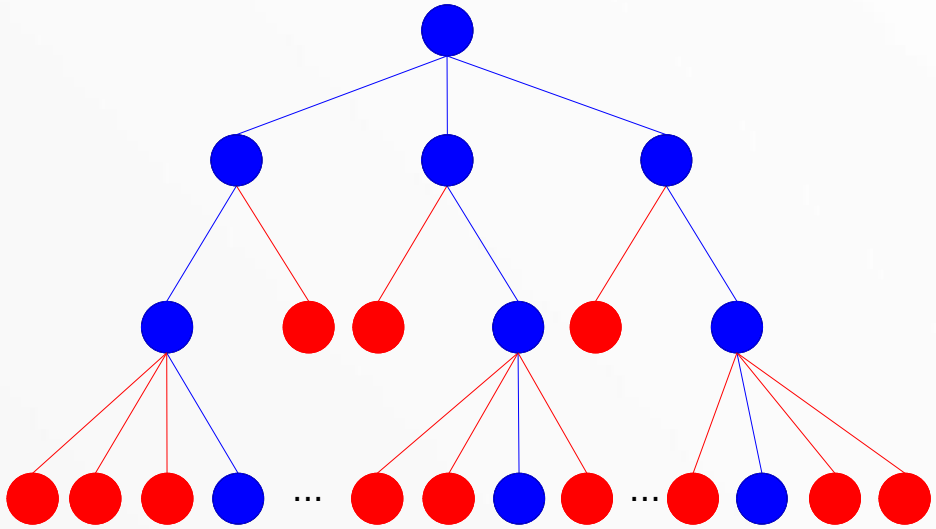
Stochastic Programming

- Even than, it is not possible to find the solution for the scenario tree
- Stochastic Dual Dynamic Programming -> SDDP
- Sampling strategy -> Monte Carlo



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Rolling Horizon vs Simulation
Data from 2016 – Expectation – 1954

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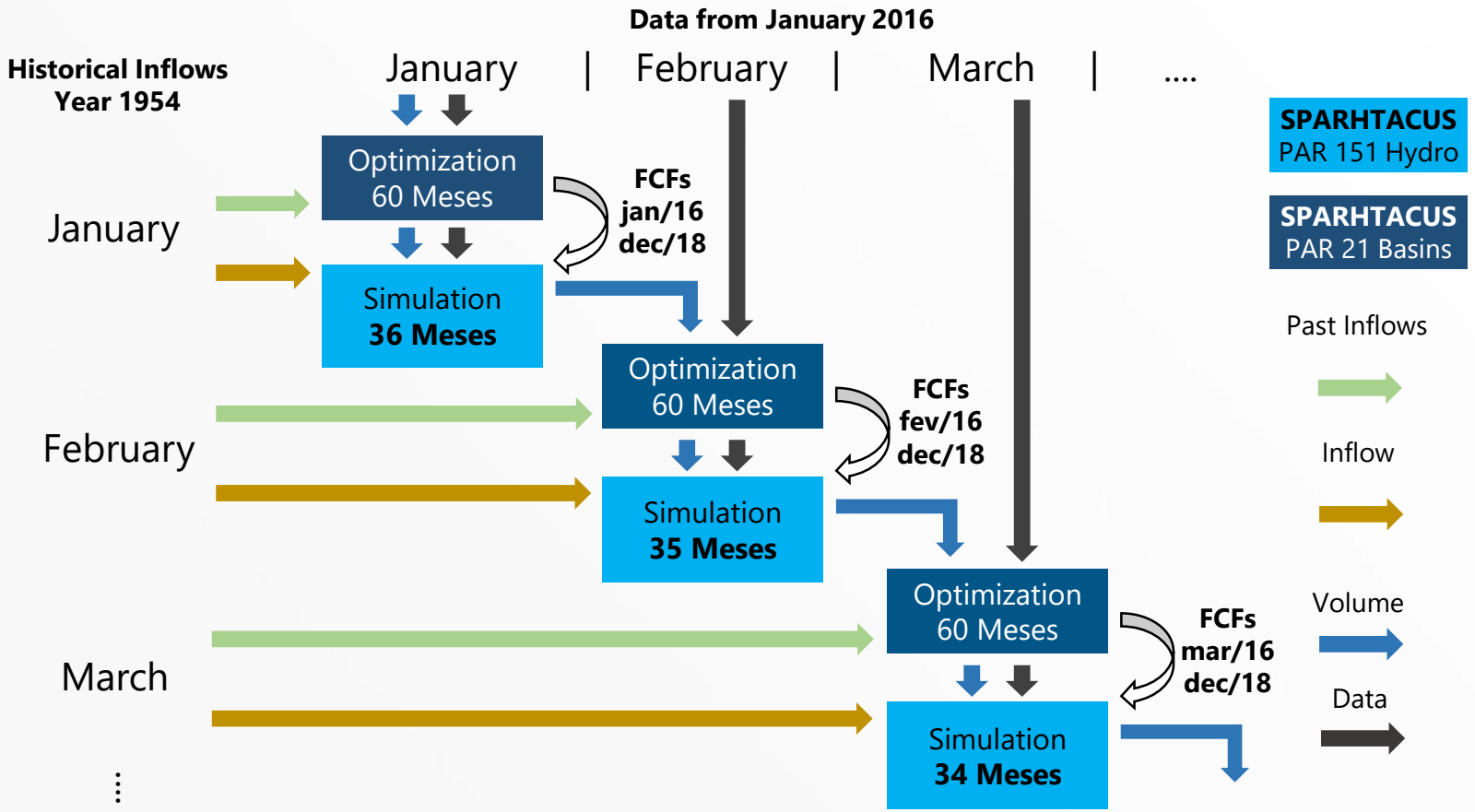
ANEEL R&D Project - SPARHTACUS

- ANEEL R&D Project
  - Developed by: UFSC/LabPlan e Plan4 (nowadays Norus)
  - Proposed by: Engie
  - In cooperation with: Brookfield, CEMIG, COPEL, CPFL, DUKE, Neoenergia
  - Ended in November/2016

- Objective
  - Develop a computational to solve the long- and short-term problem at the same time with individual hydro and thermal power plants

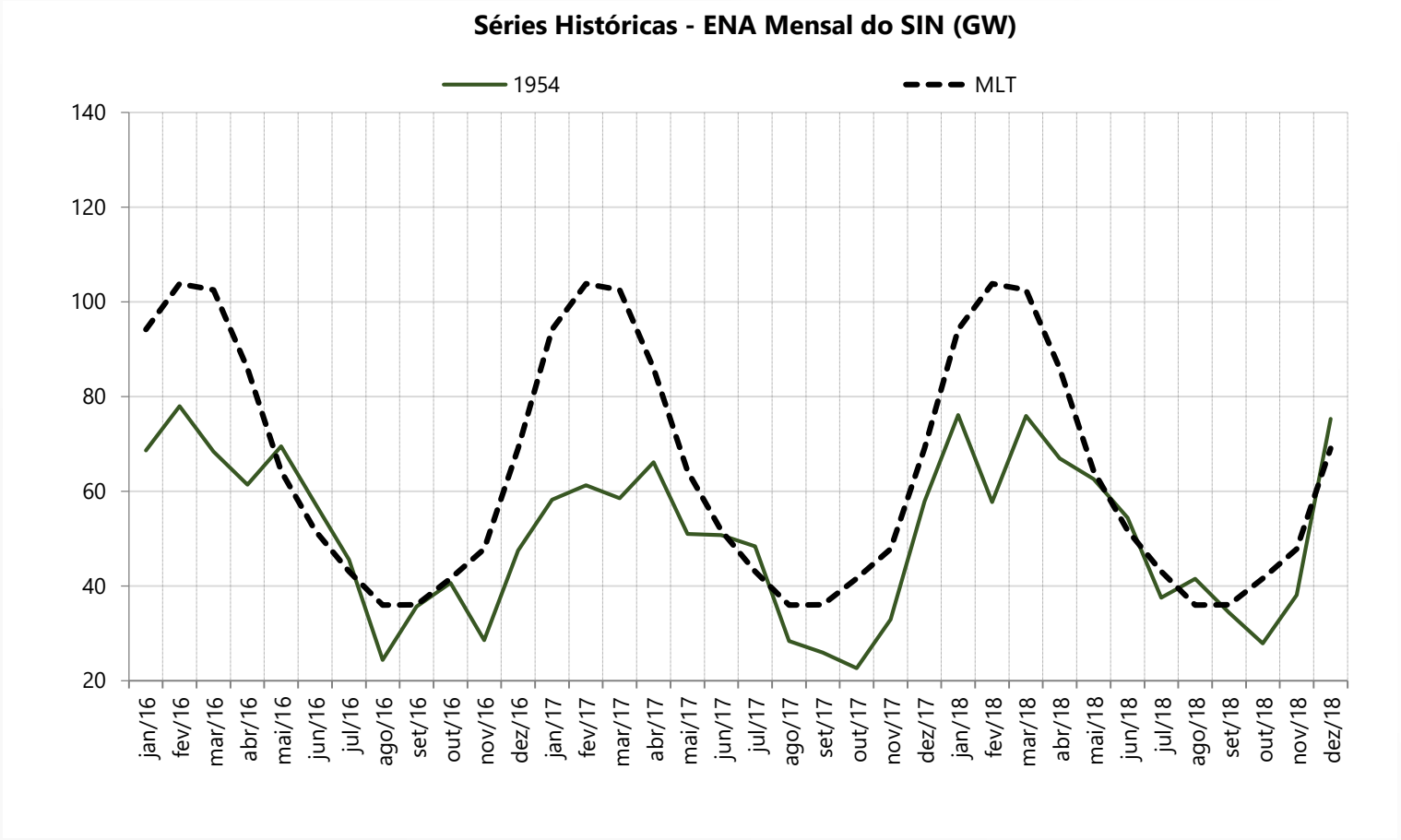
- All results and analysis presented in this talk are a result from this R&D Project

Rolling Horizon vs Simulation



Rolling Horizon vs Simulation

- Historical Inflow



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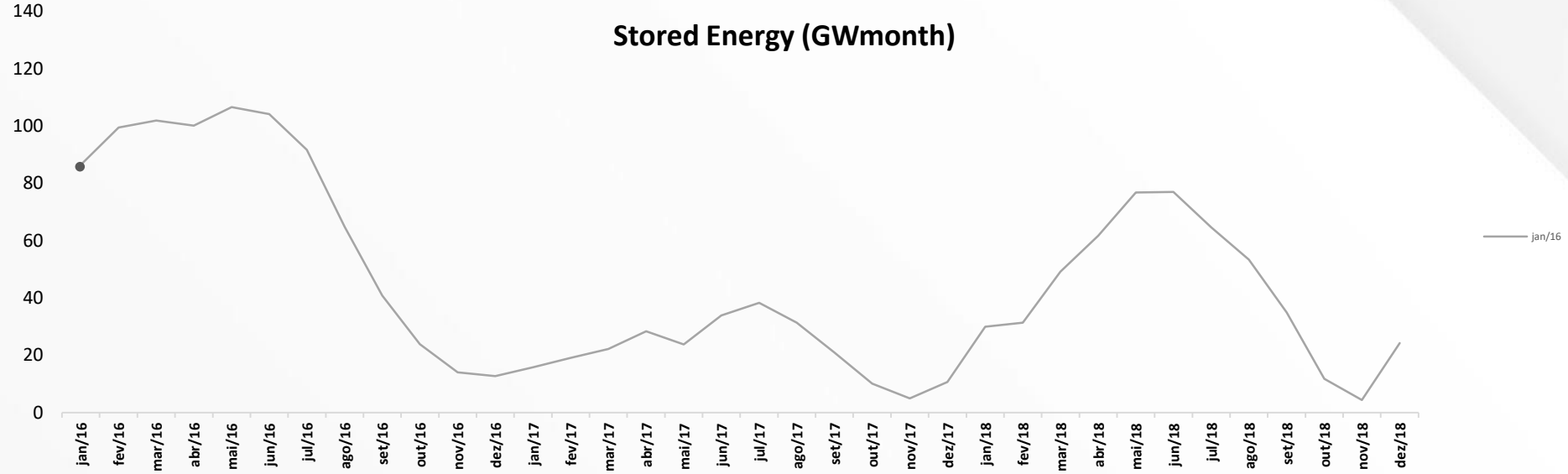

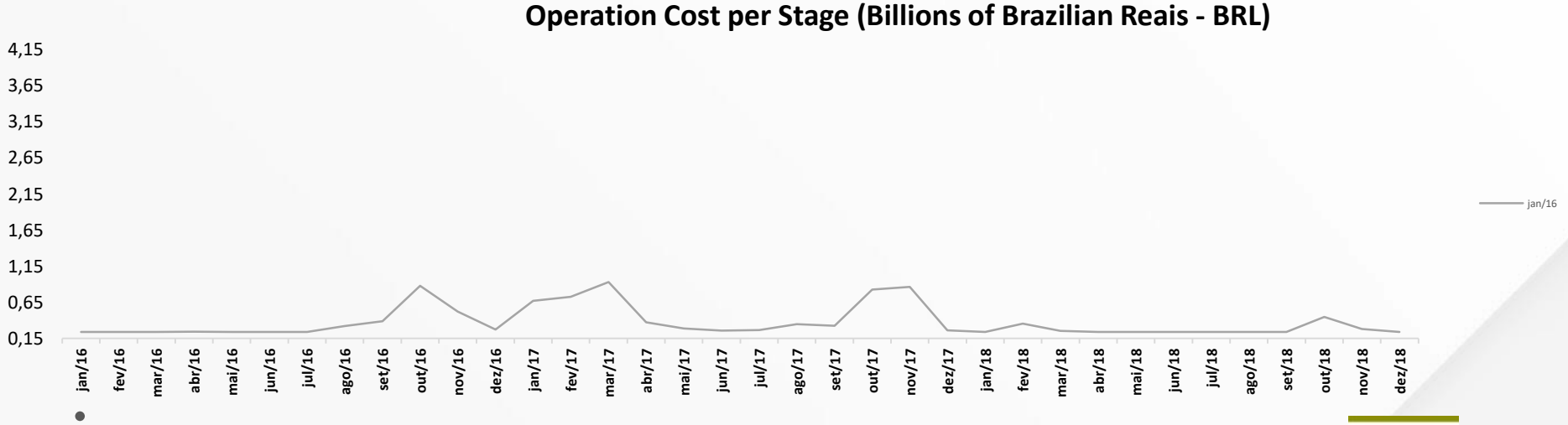

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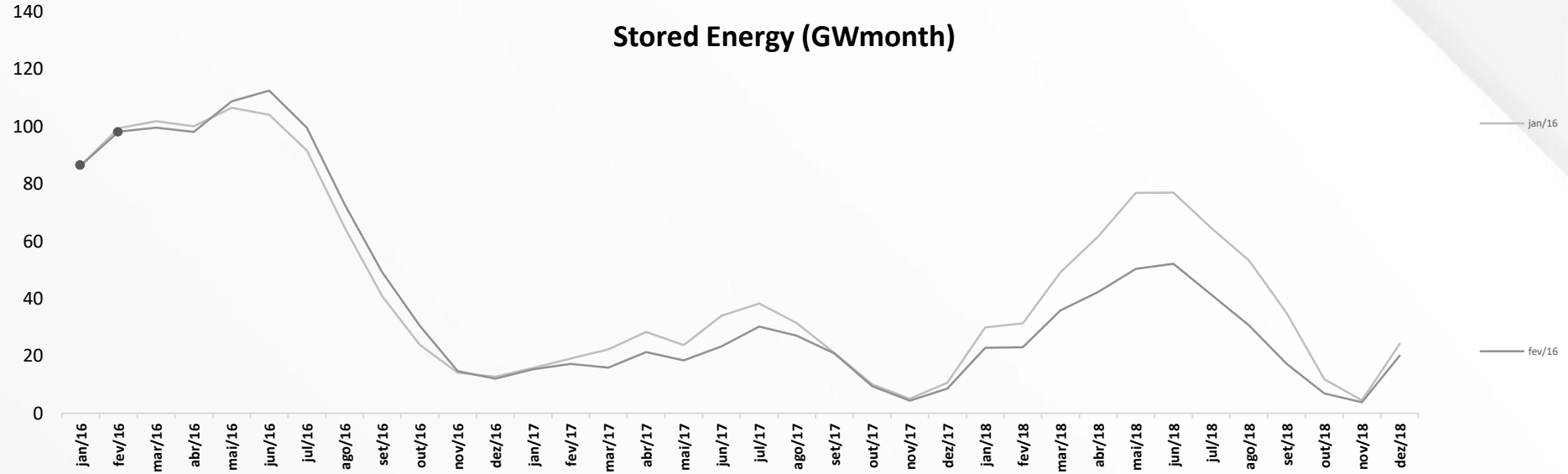

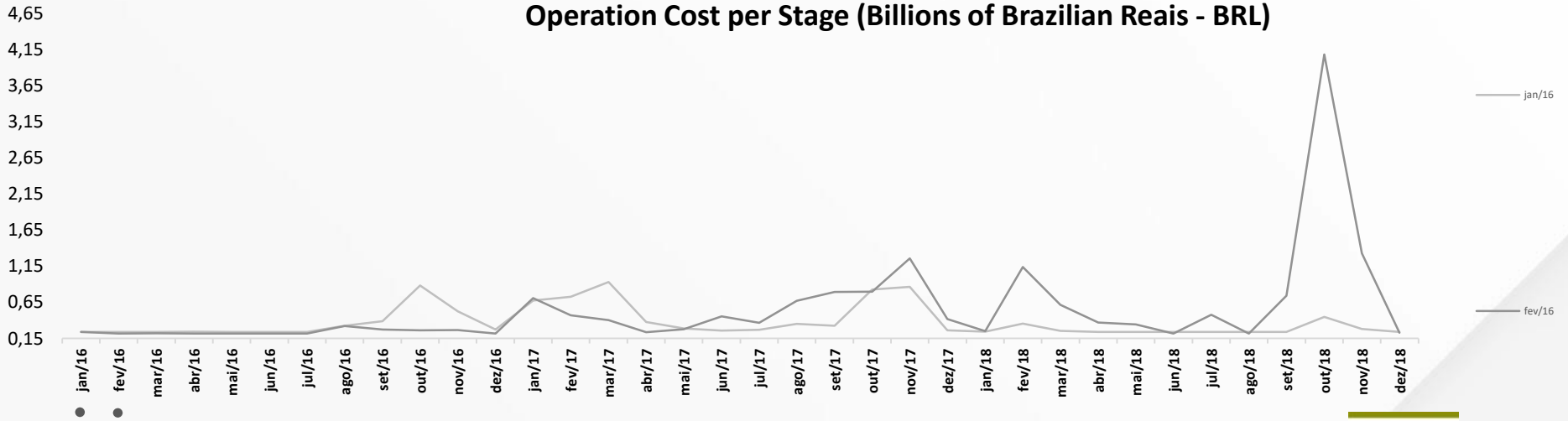

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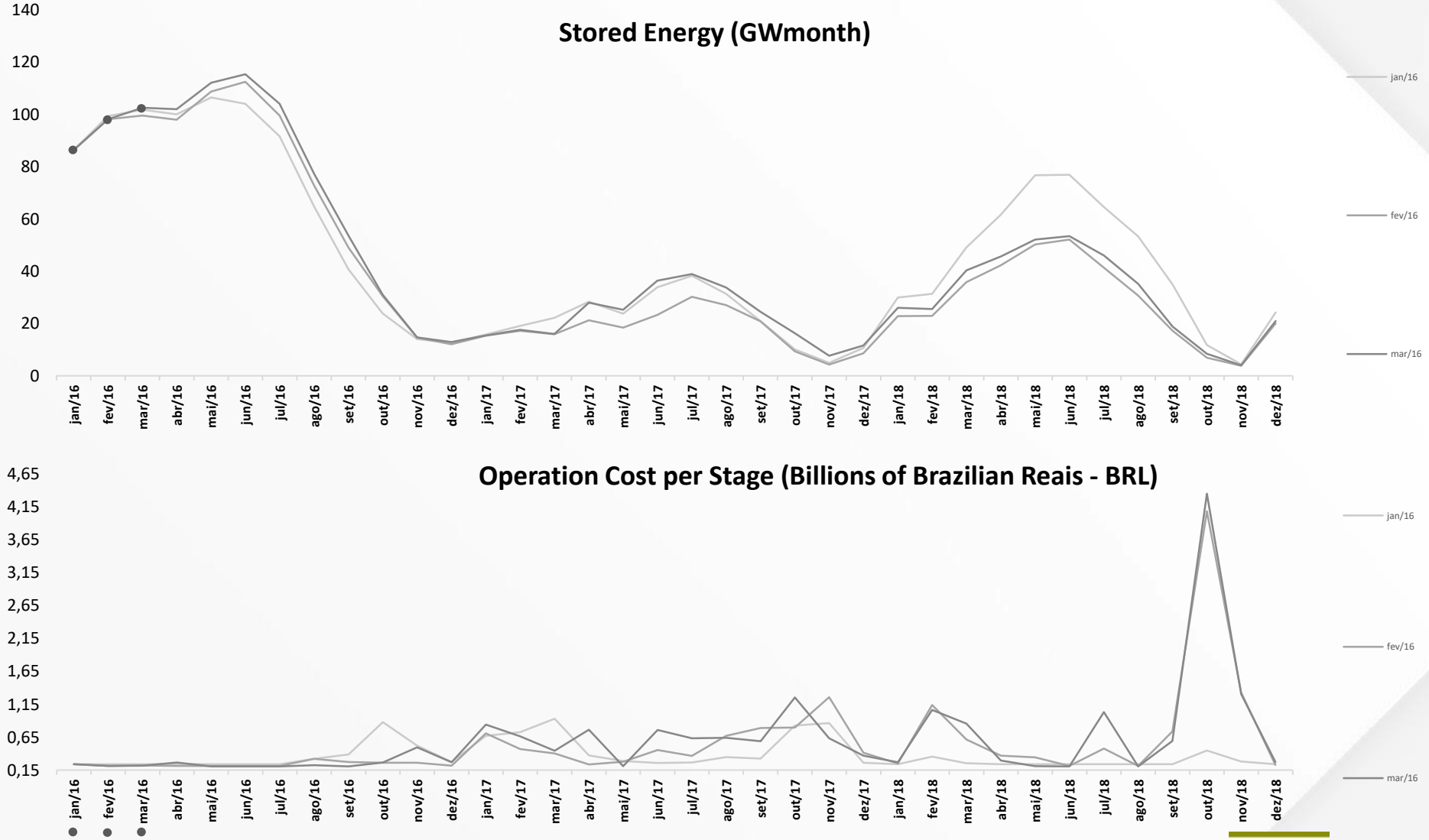

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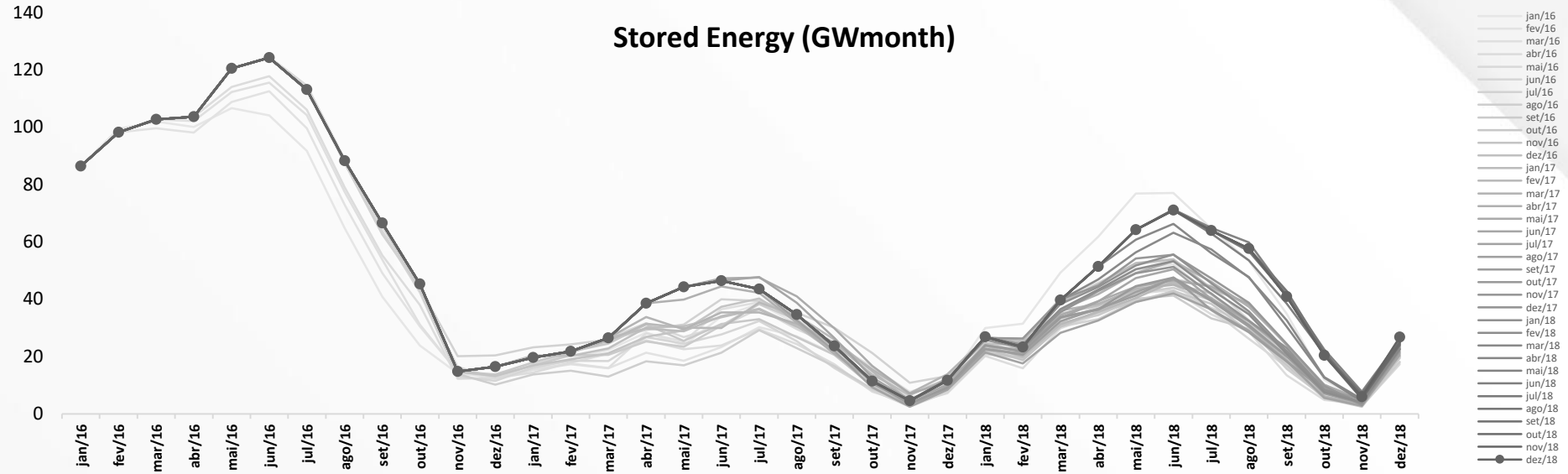

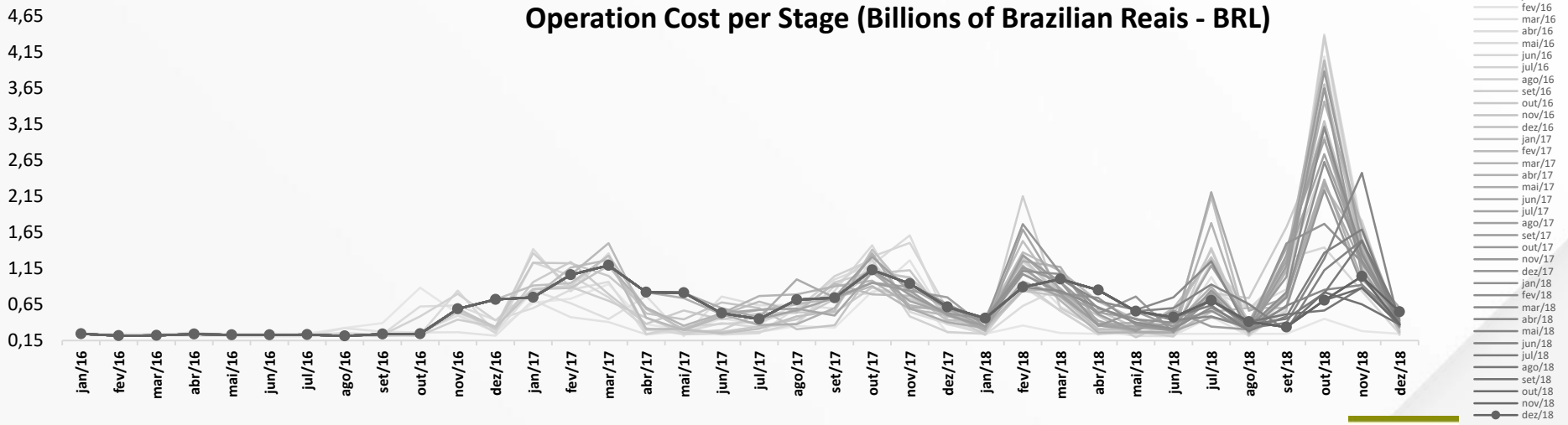

Hydrothermal Scheduling in Brazil

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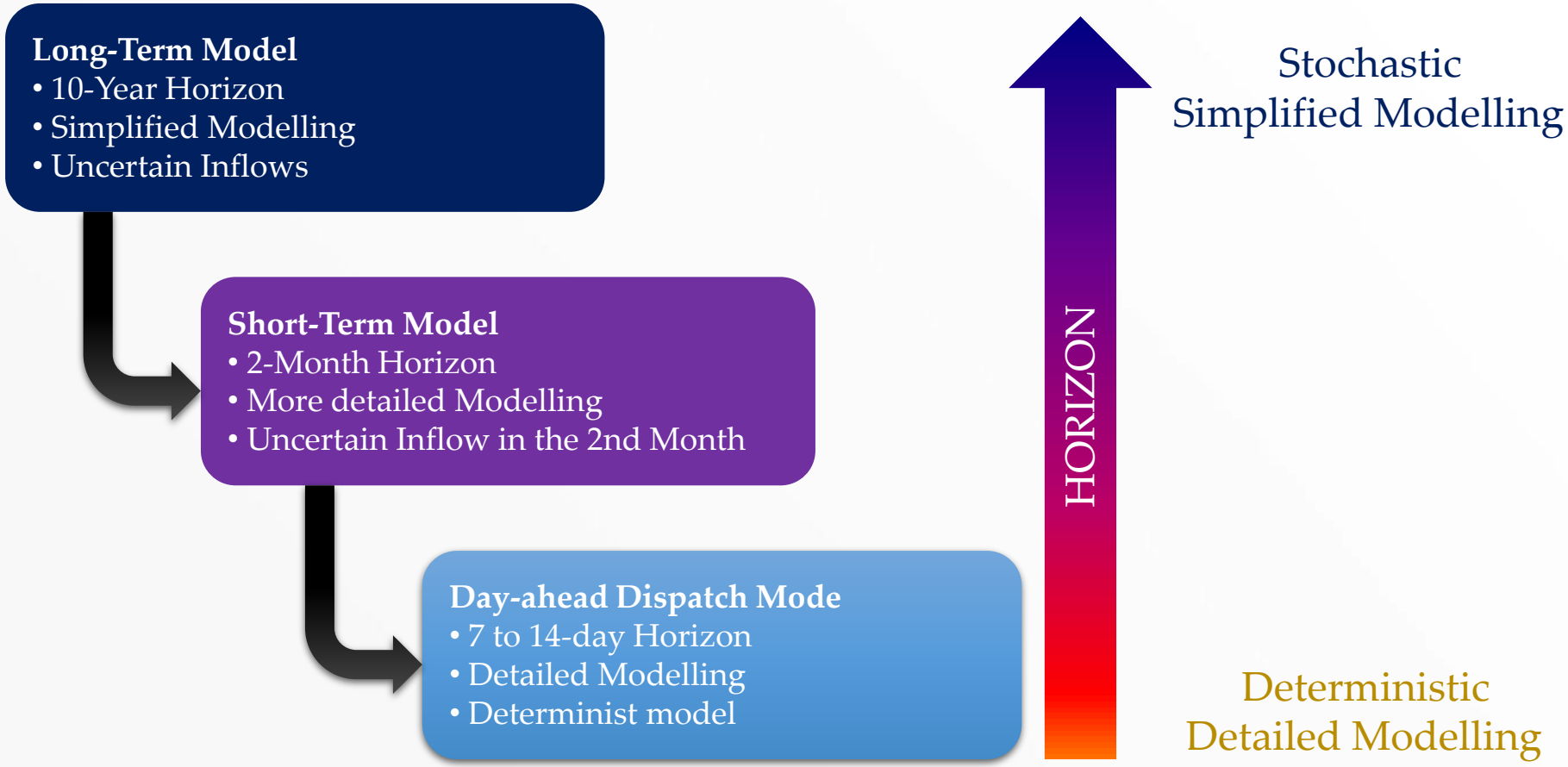
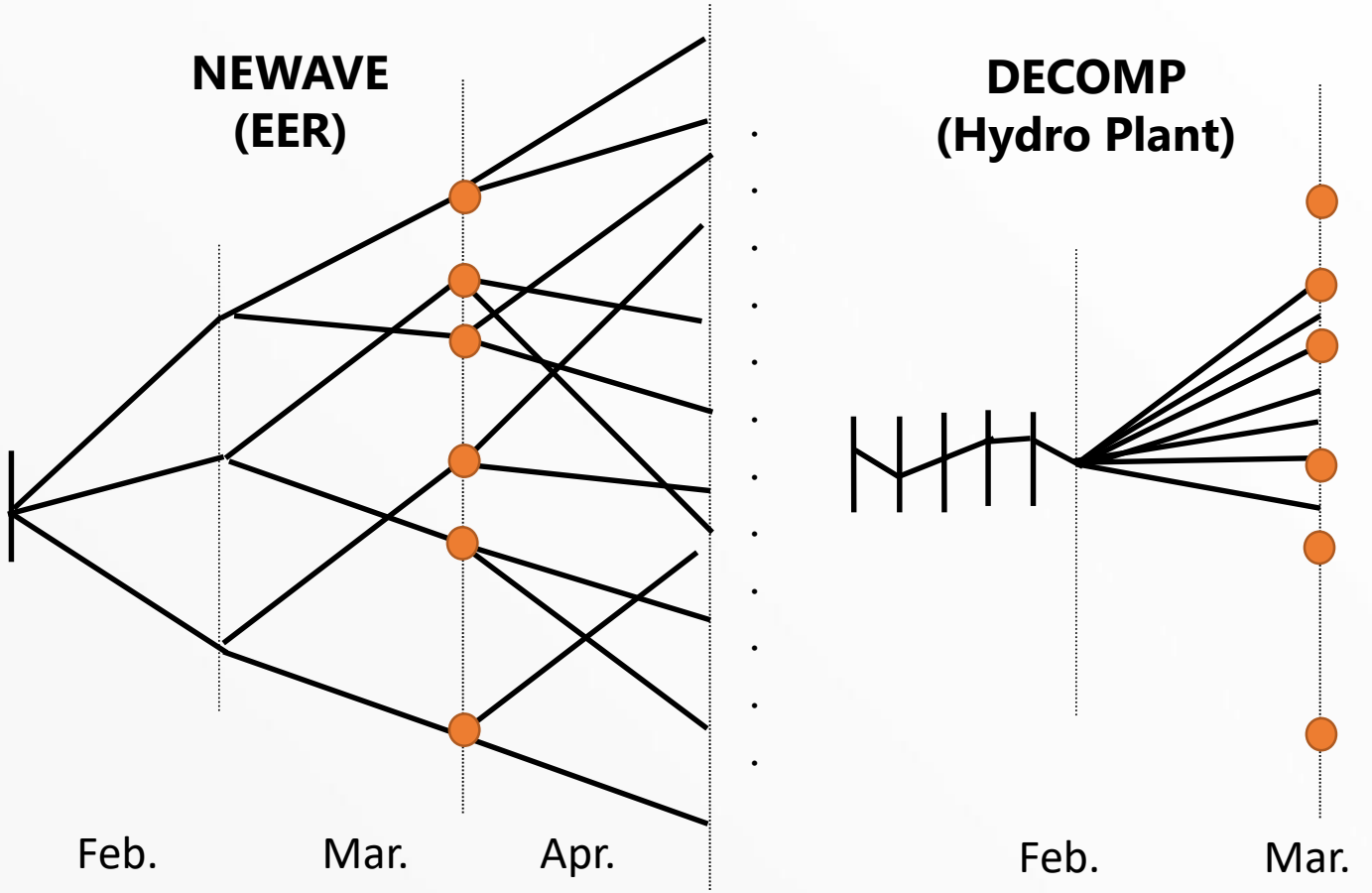
Scheduling in 3 steps



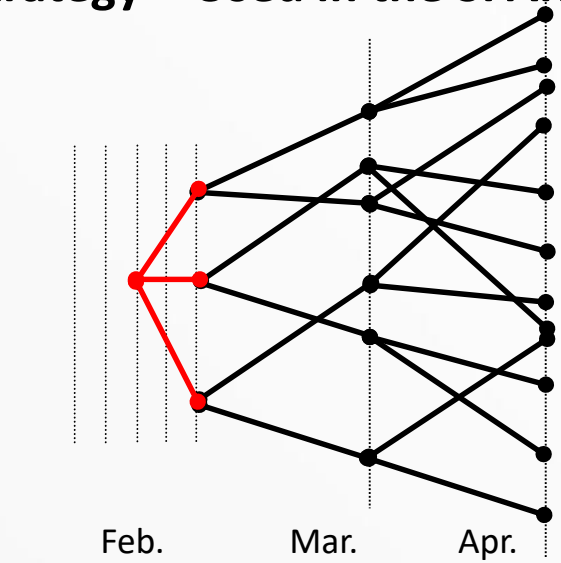
Coupling Long-Term and Short-Term Models

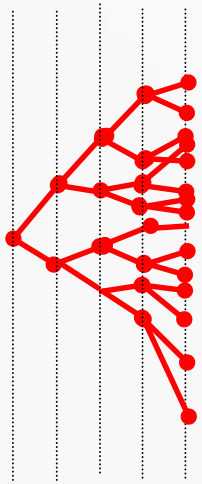


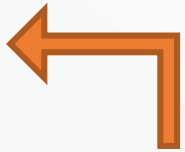
- **We need to desaggregate policies**
  - From Energy into Volume
- **States of interest may not be the same**
  - Volumes and Past Inflows

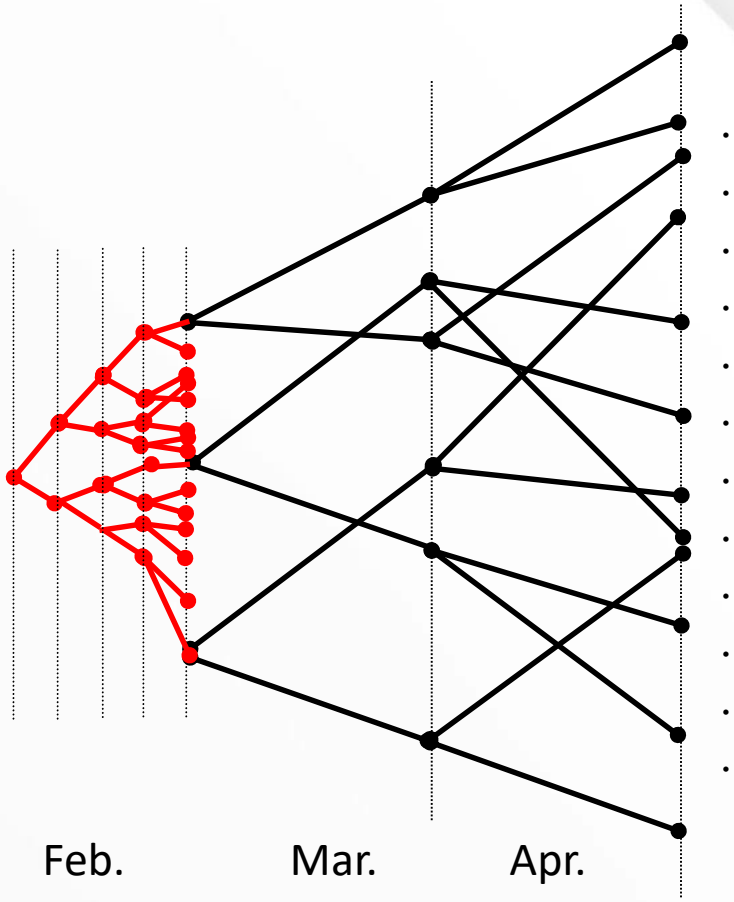
Future Cost Function

Possible Strategy – Used in the SPARHTACUS Model









Future Cost Function

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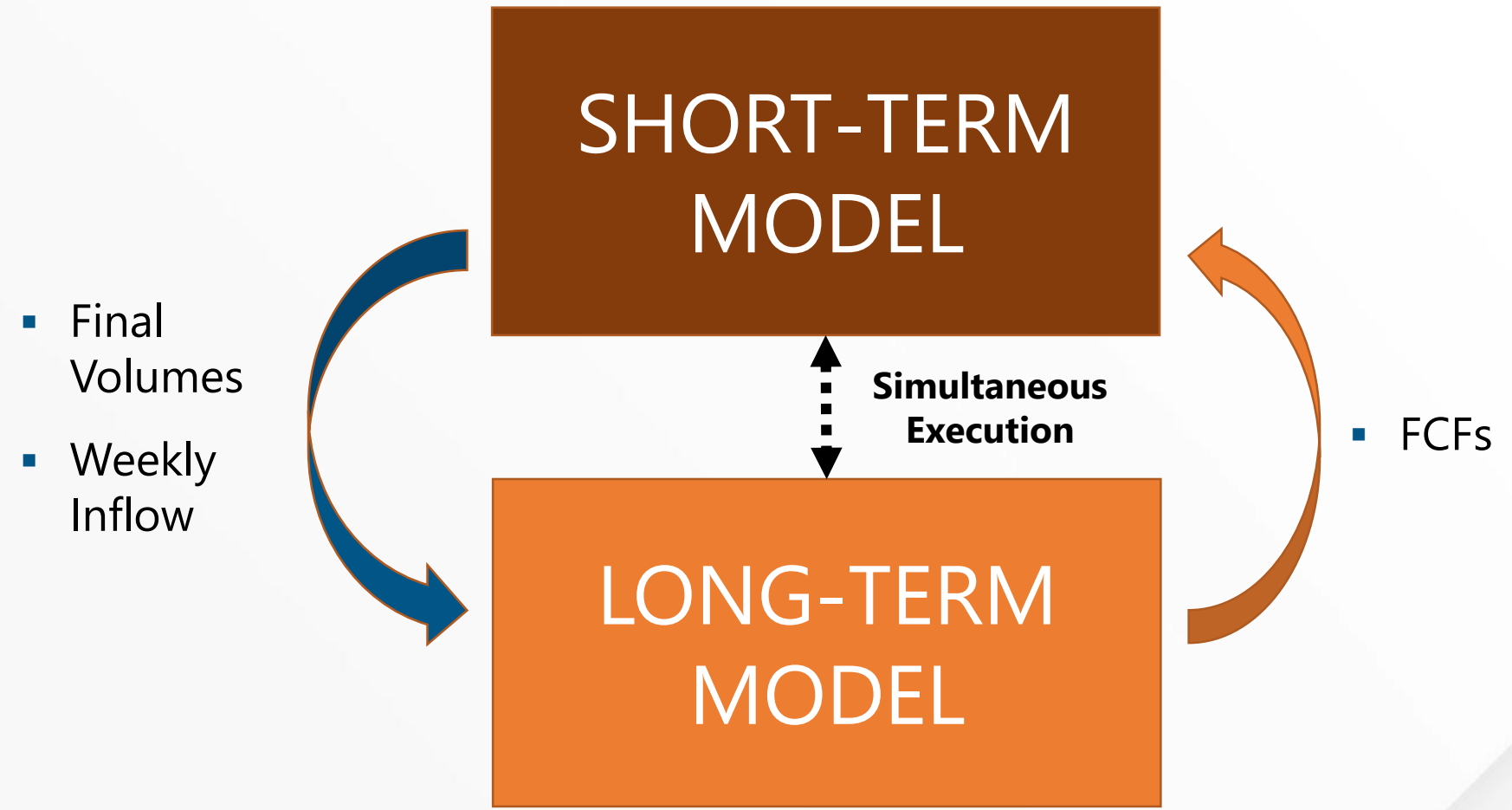
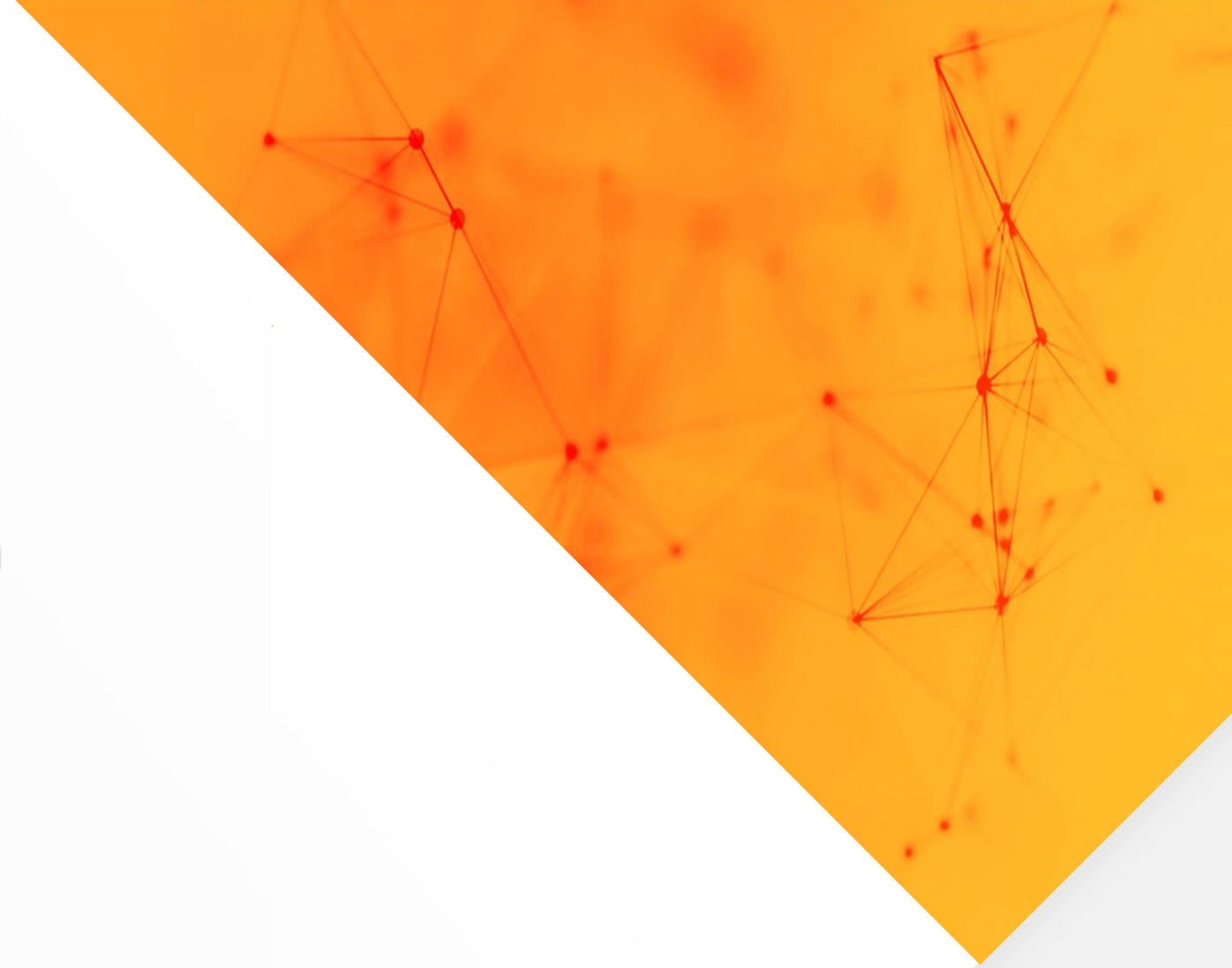


Coupling Long and Short term models



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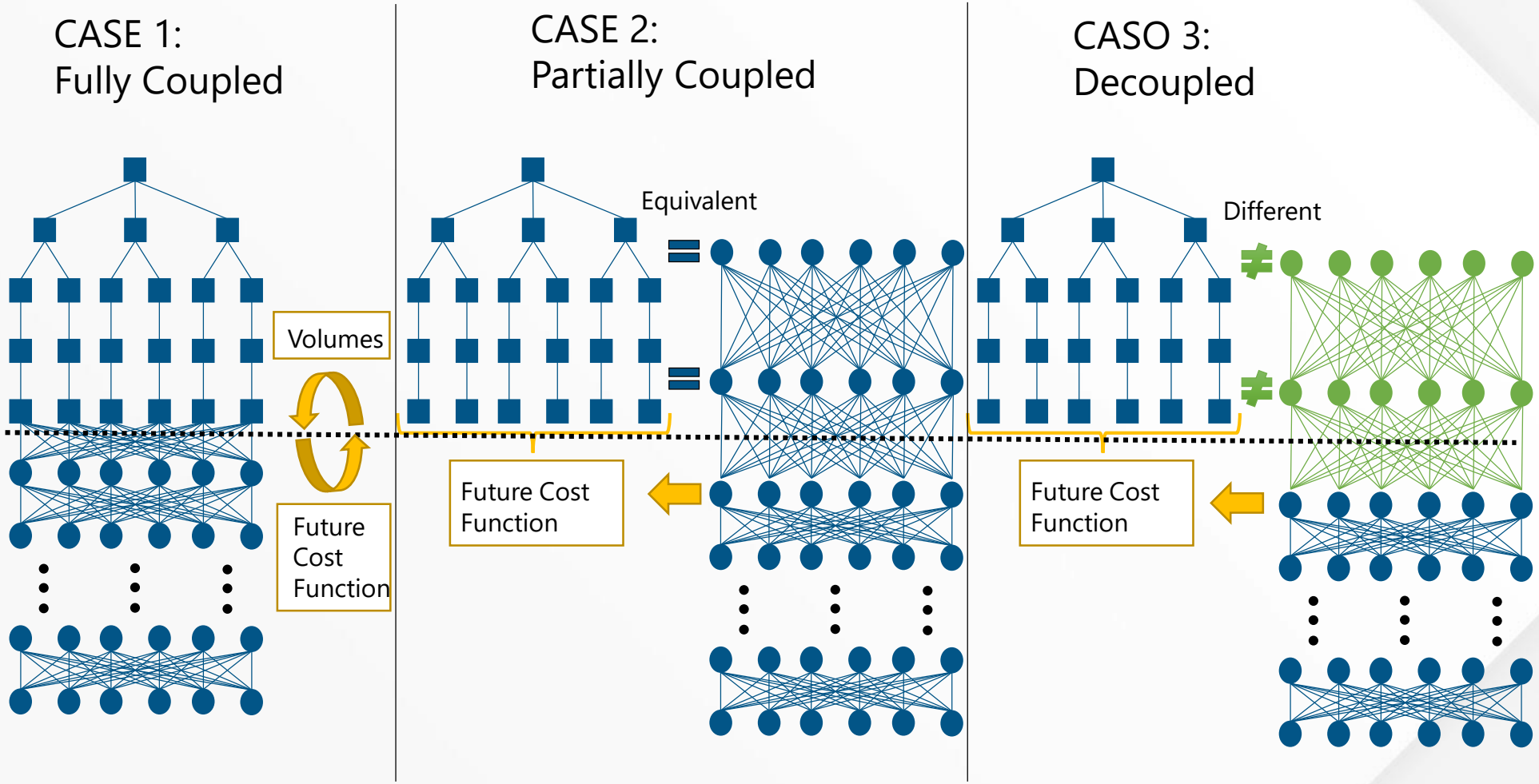
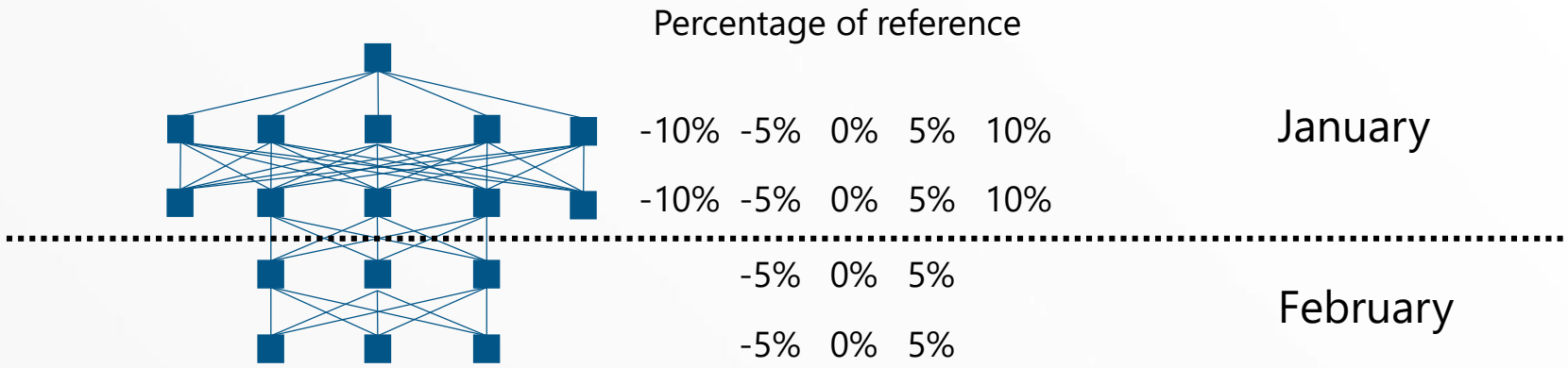
Coupling Long and Short term models



Coupling Long and Short term models

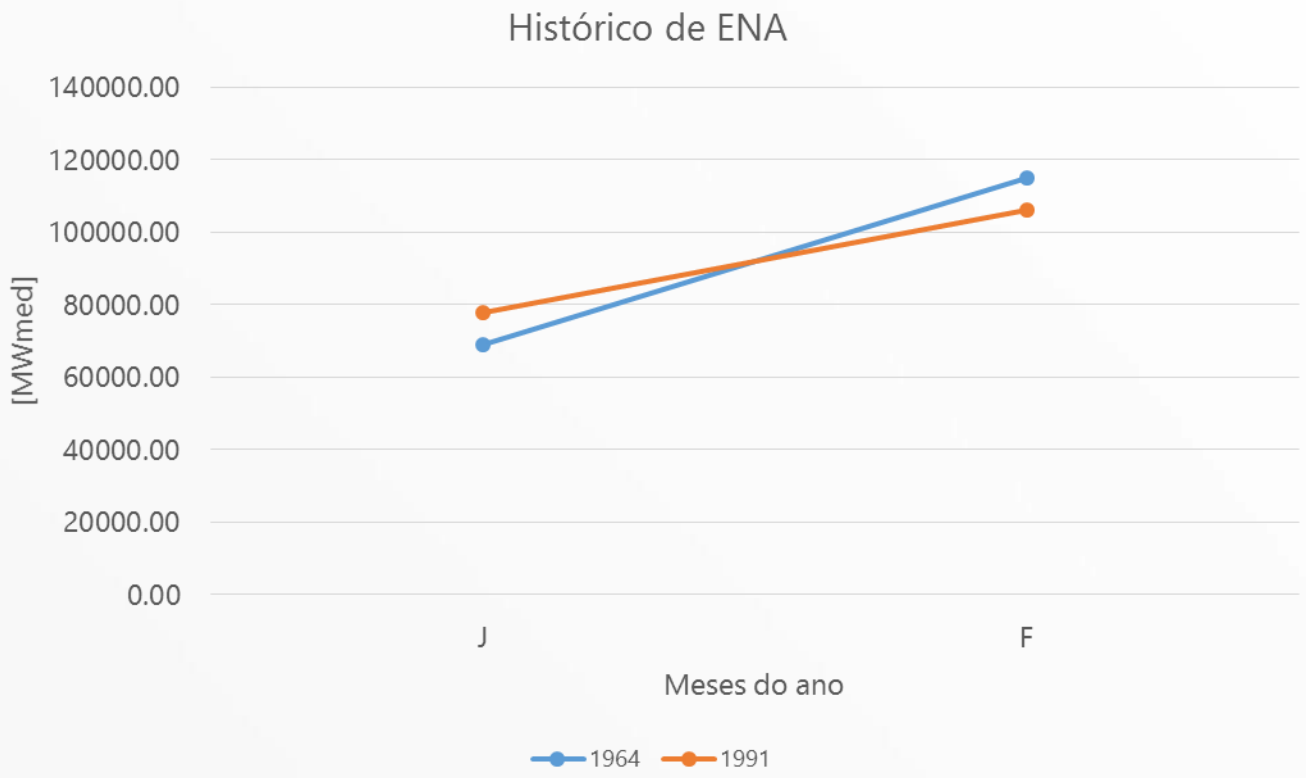
- Building scenario tree using inflows from **1964** as reference;



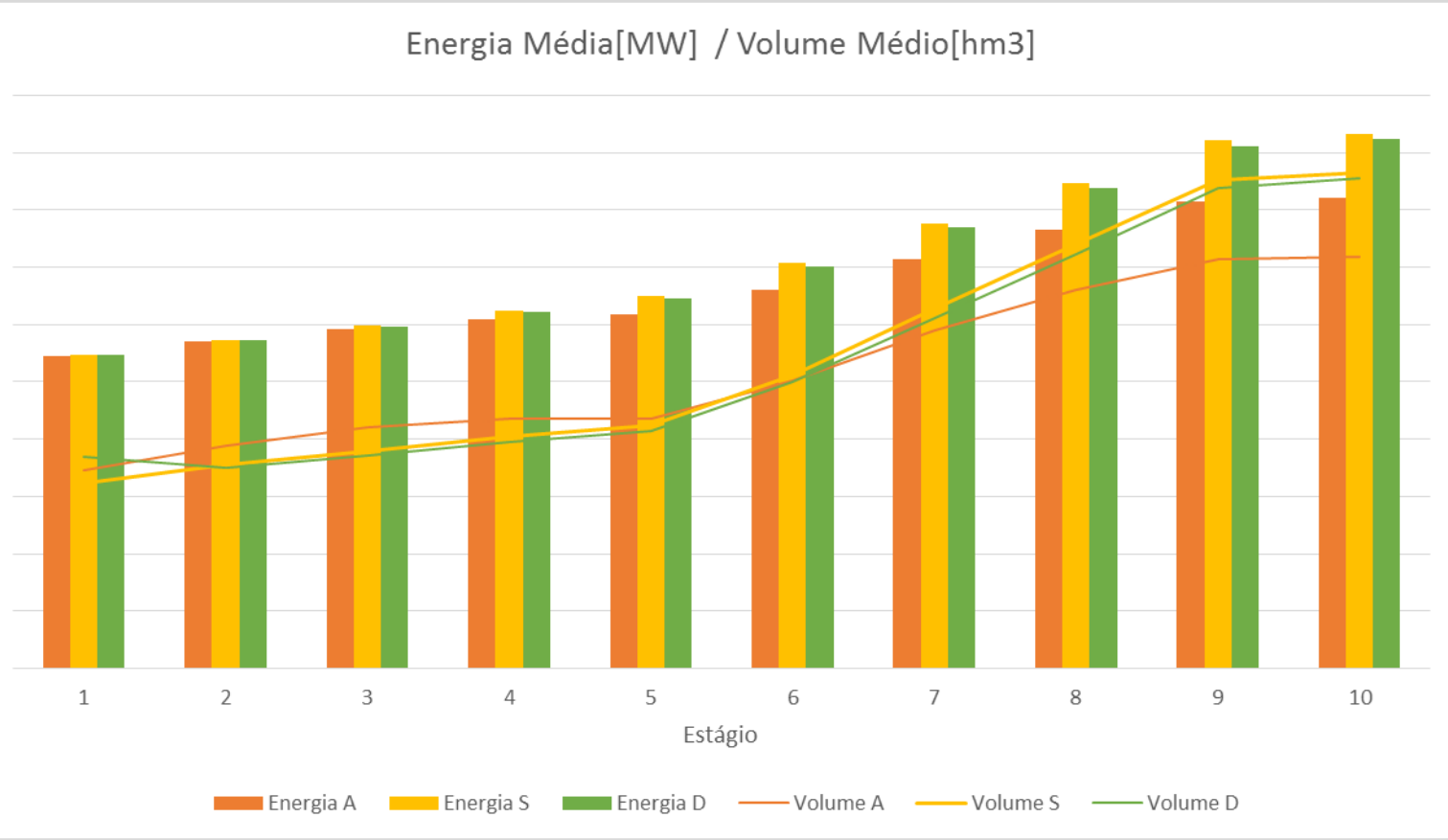
- Decoupled: inflows from year **1991**.

Coupling Long and Short term models

- Historical Inflows from years **1964 and 1991**;



Coupling Long and Short term models



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Thank you!

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