ROADEF 2010 Challenge

A large scale energy optimization problem

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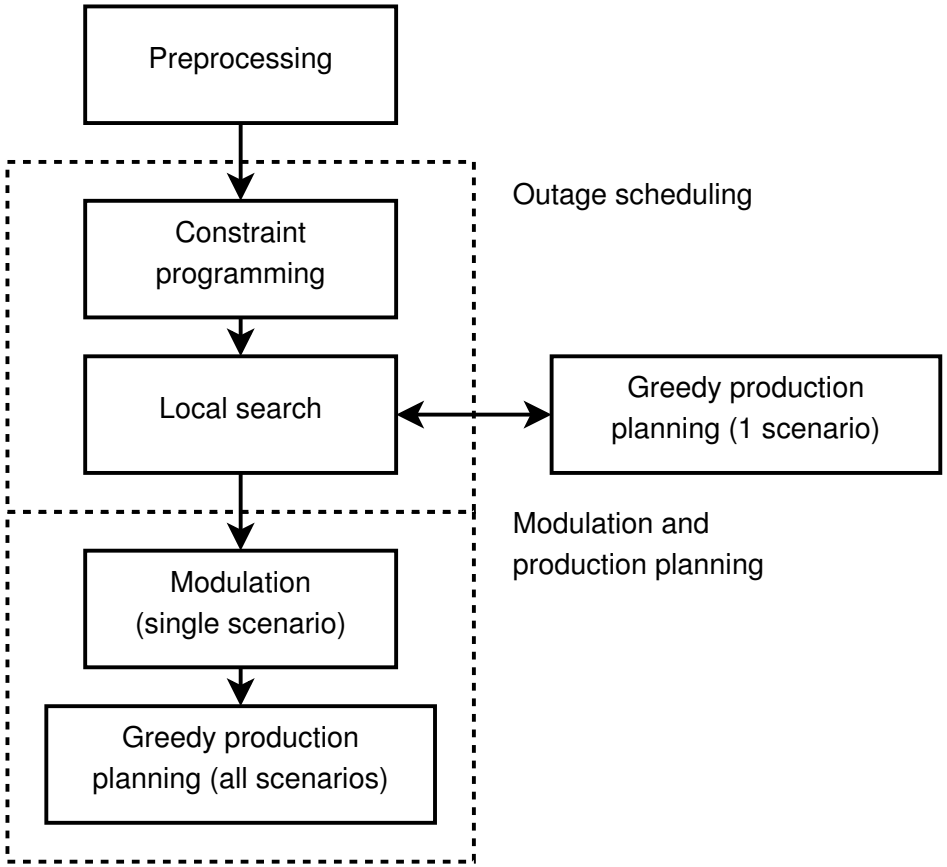
Problem introduction

We consider the problem in two parts:

- The outage scheduling part includes:
  - Scheduling constraints (CT13 to CT21) and refueling and fuel level constraints
  - Deciding the number of outages for each type 2 plant
- The production planning part includes:
  - Setting production levels for all scenarios
  - Scenario demand and modulation constraints

Solution approach



Constraint programming

The CP-solver (made with the Gecode library) is used to find a feasible starting solution for the outage scheduling part.

- Objective: Maximize average online type 2 capacity
- No demand constraints, no scenarios
- Feasible only with respect to scheduling and fuel constraints
- Output: the number of outages, outage start weeks and refueling amounts

Note: in the qualification round we used the ILOG CP-solver, but for the B-instances we had difficulties finding feasible solutions.

Constraint programming, cont.

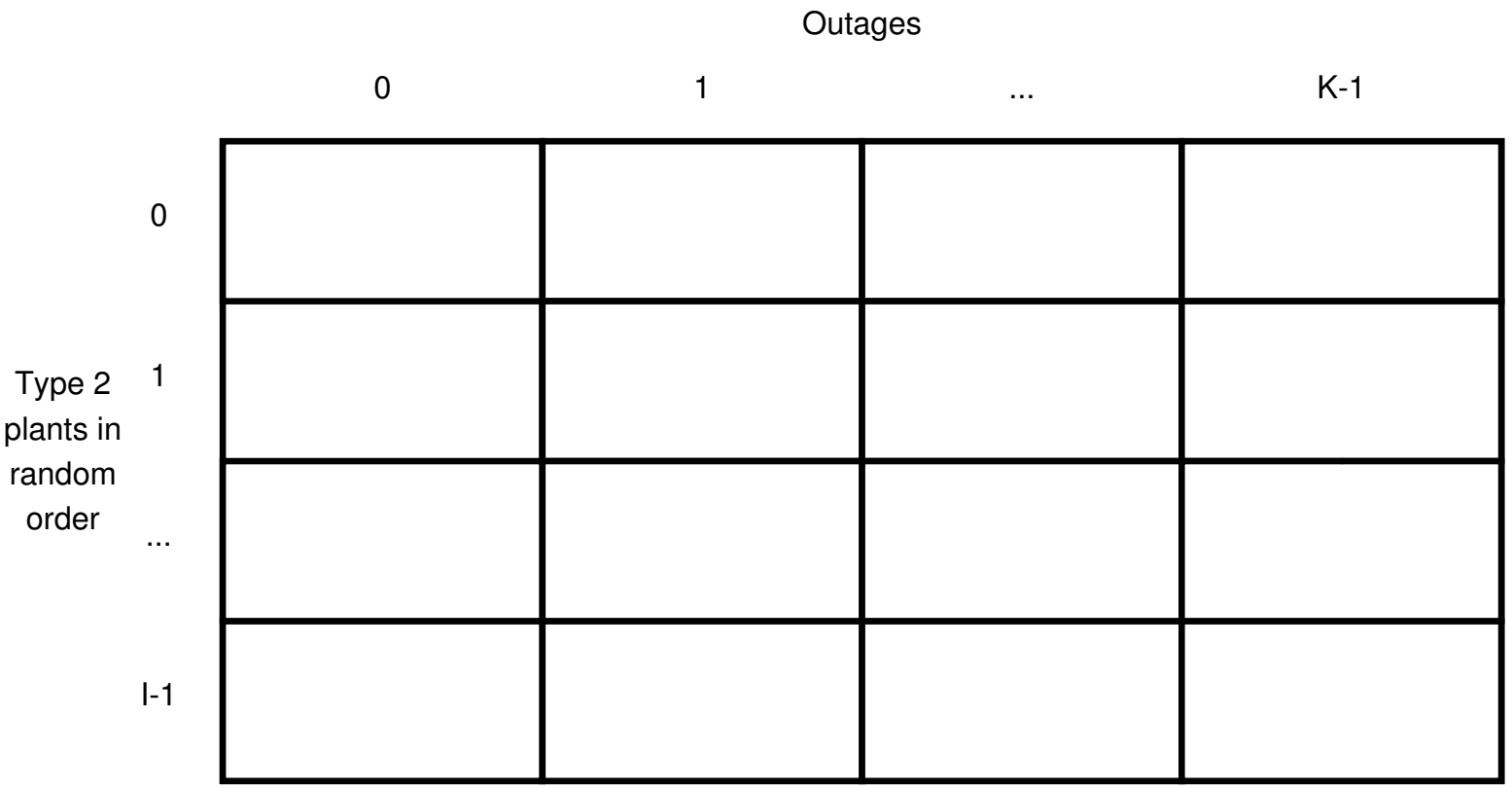
Variables:

- Outage scheduled, $\{0, 1\}$
- Outage start week, $\{0, \ldots, H-1\}$
- Refueling amounts, $\{R_{min}, \ldots, R_{max}\}$

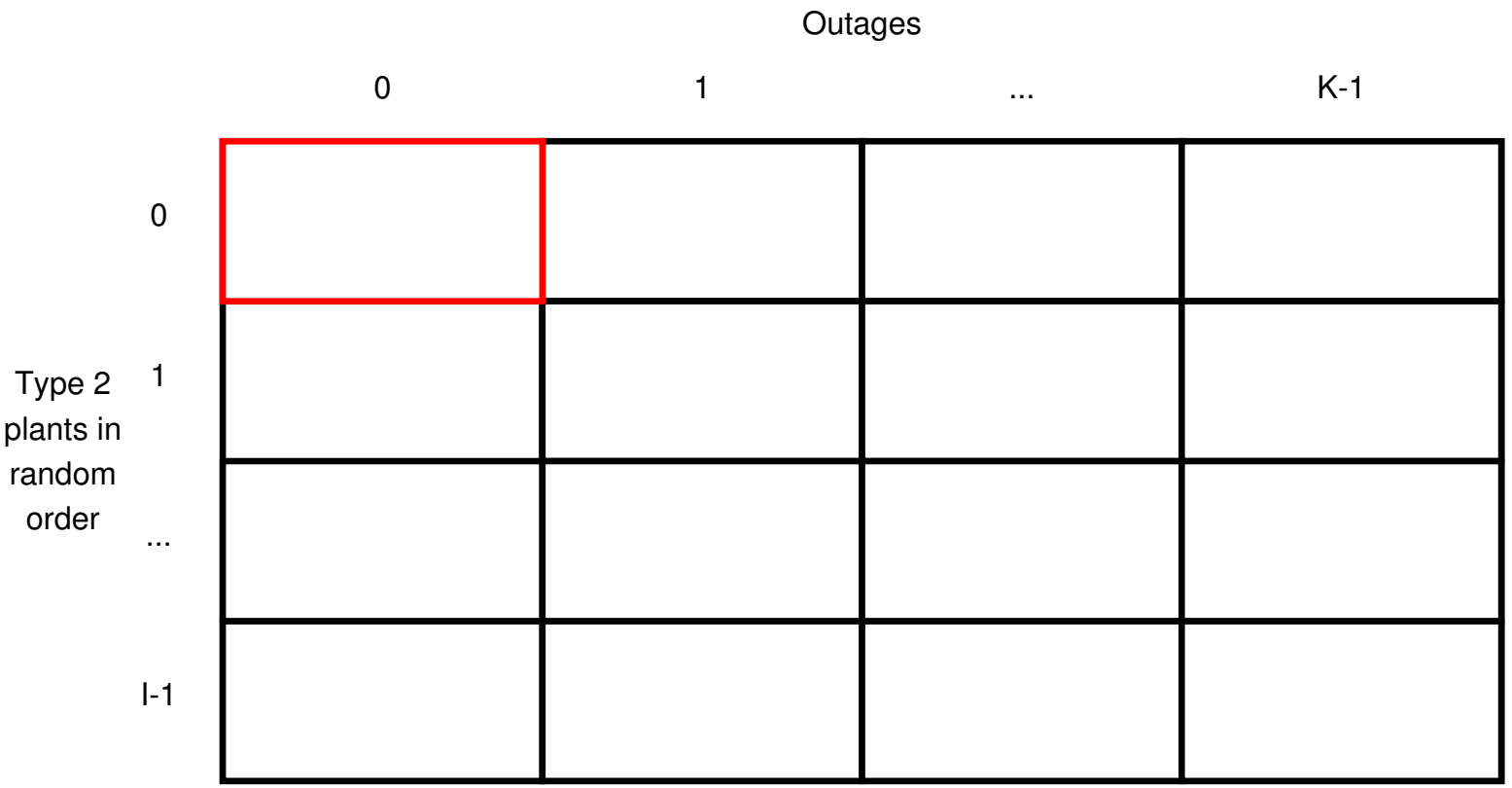
Constraints:

- CT13 to CT21
- Minimum spacing constraints to ensure existence of a feasible refueling schedule

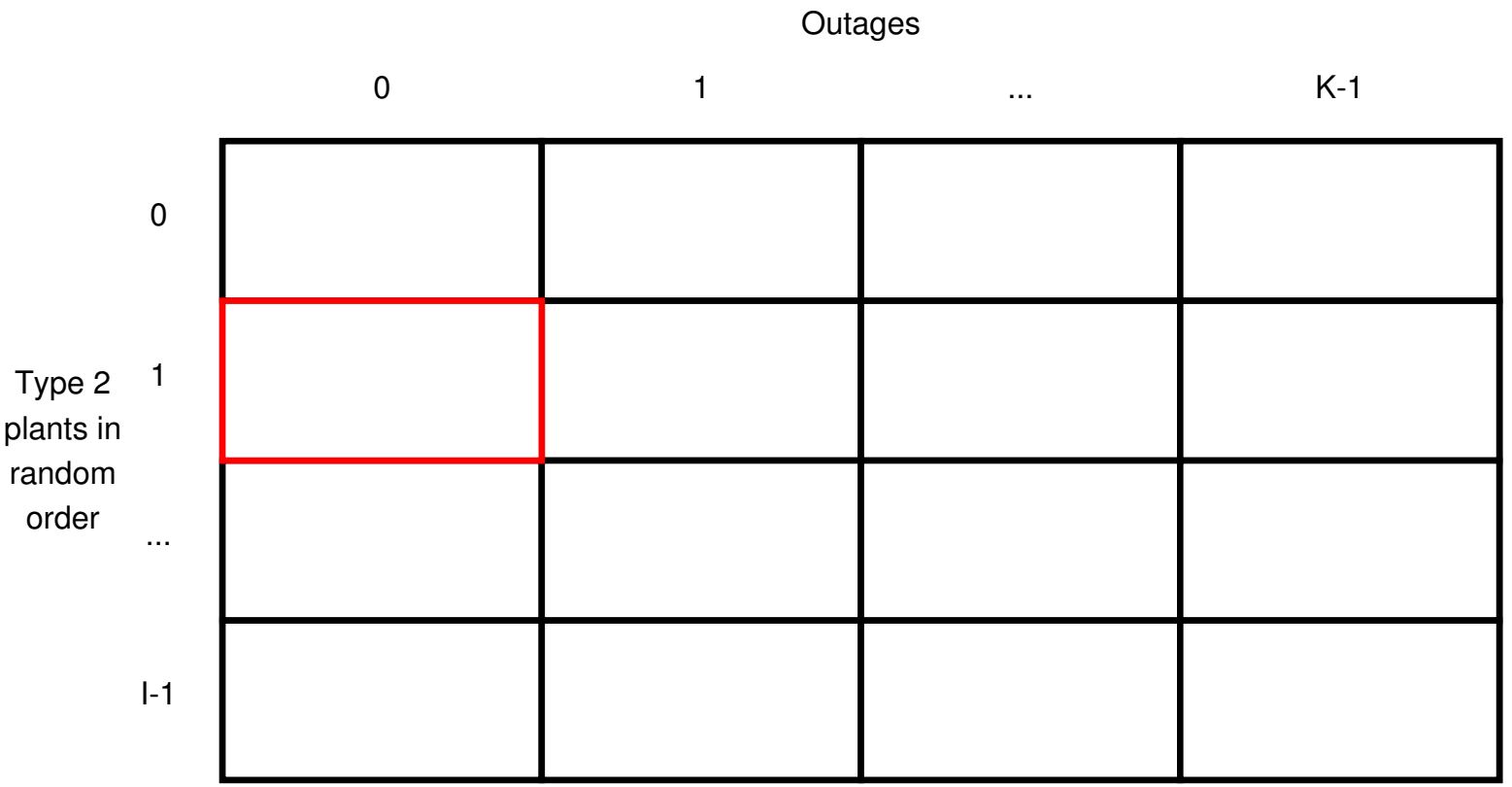
Branching strategy



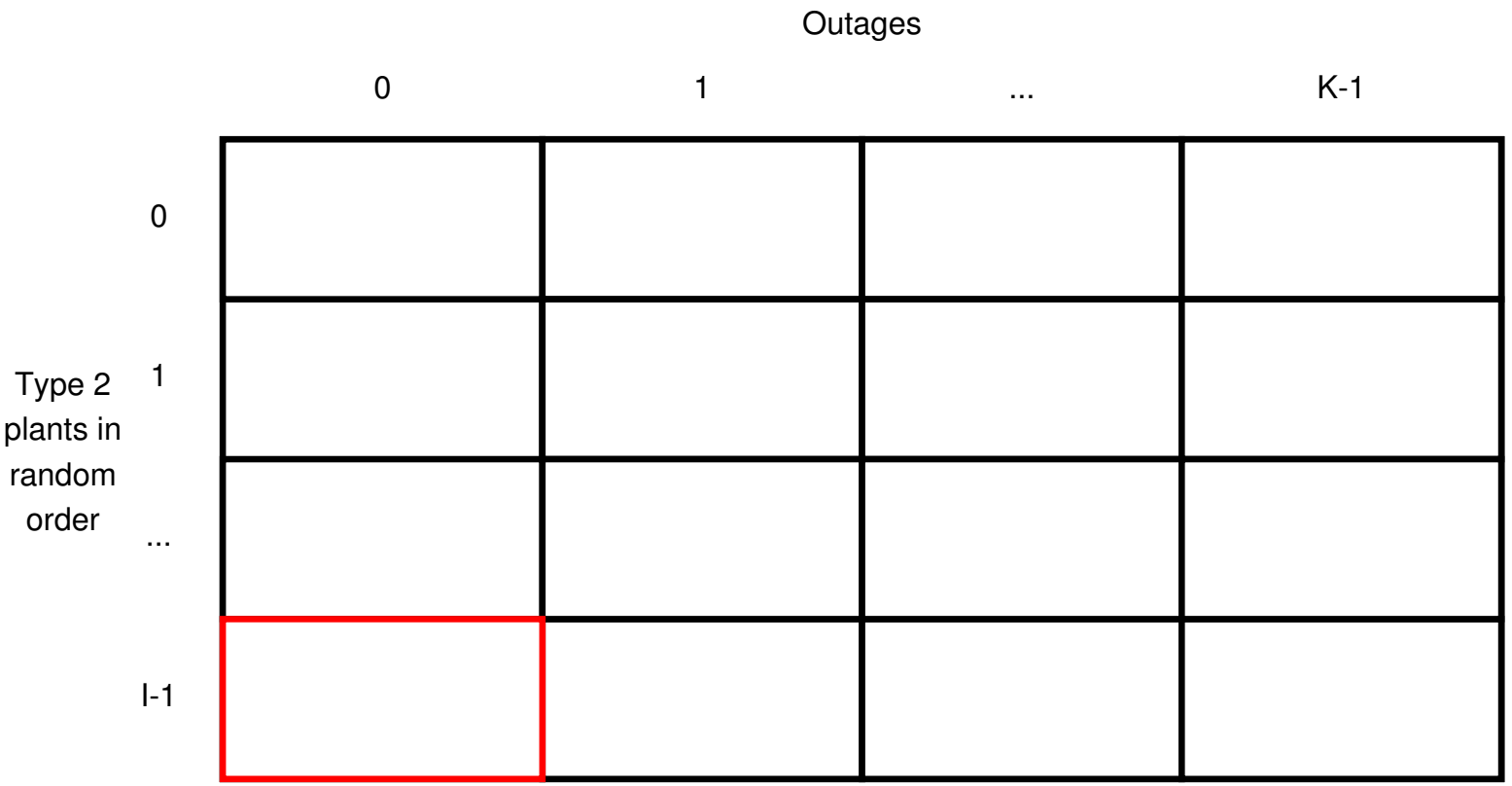
Branching strategy, cont'd.



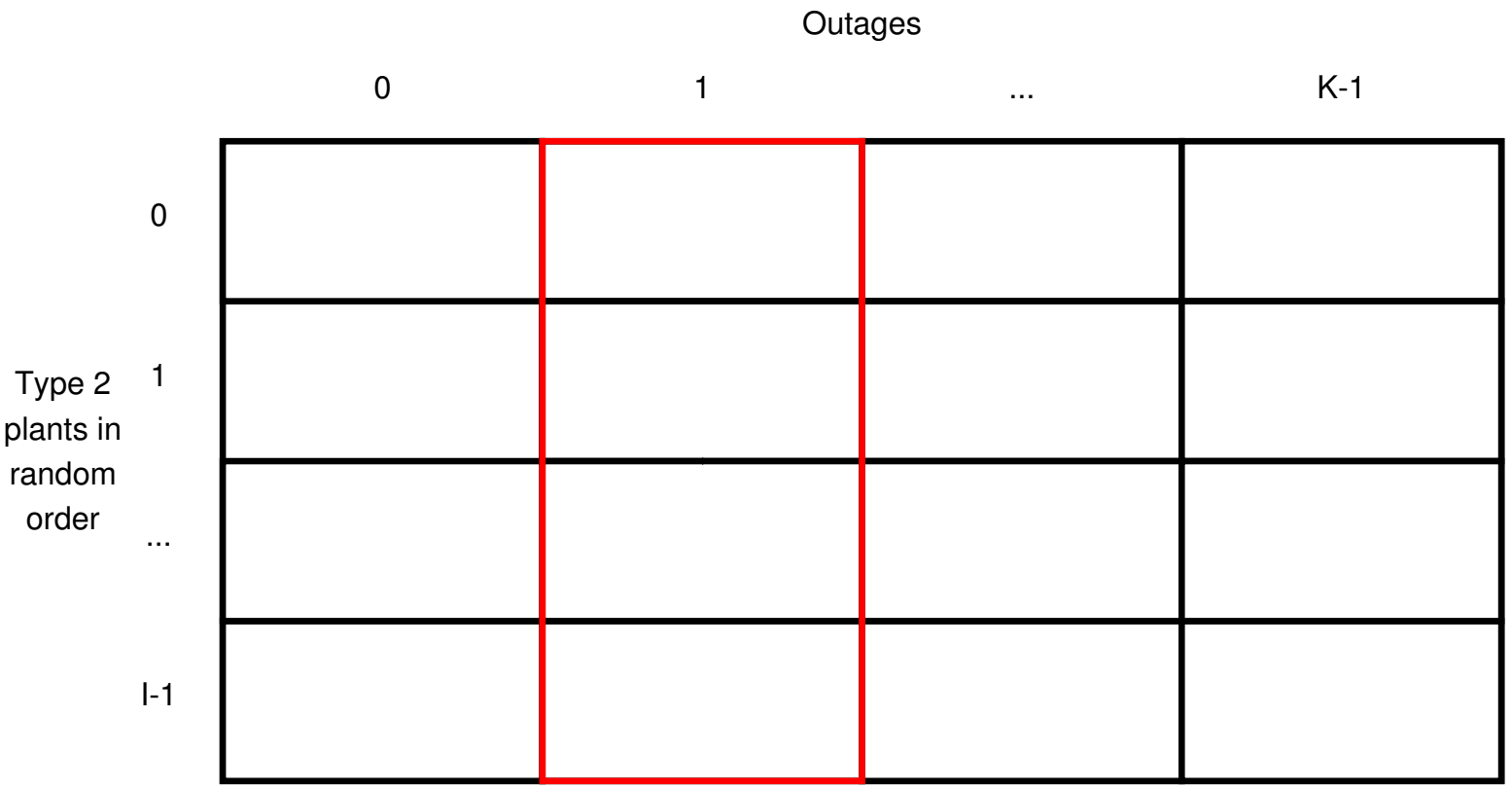
Branching strategy, cont'd.



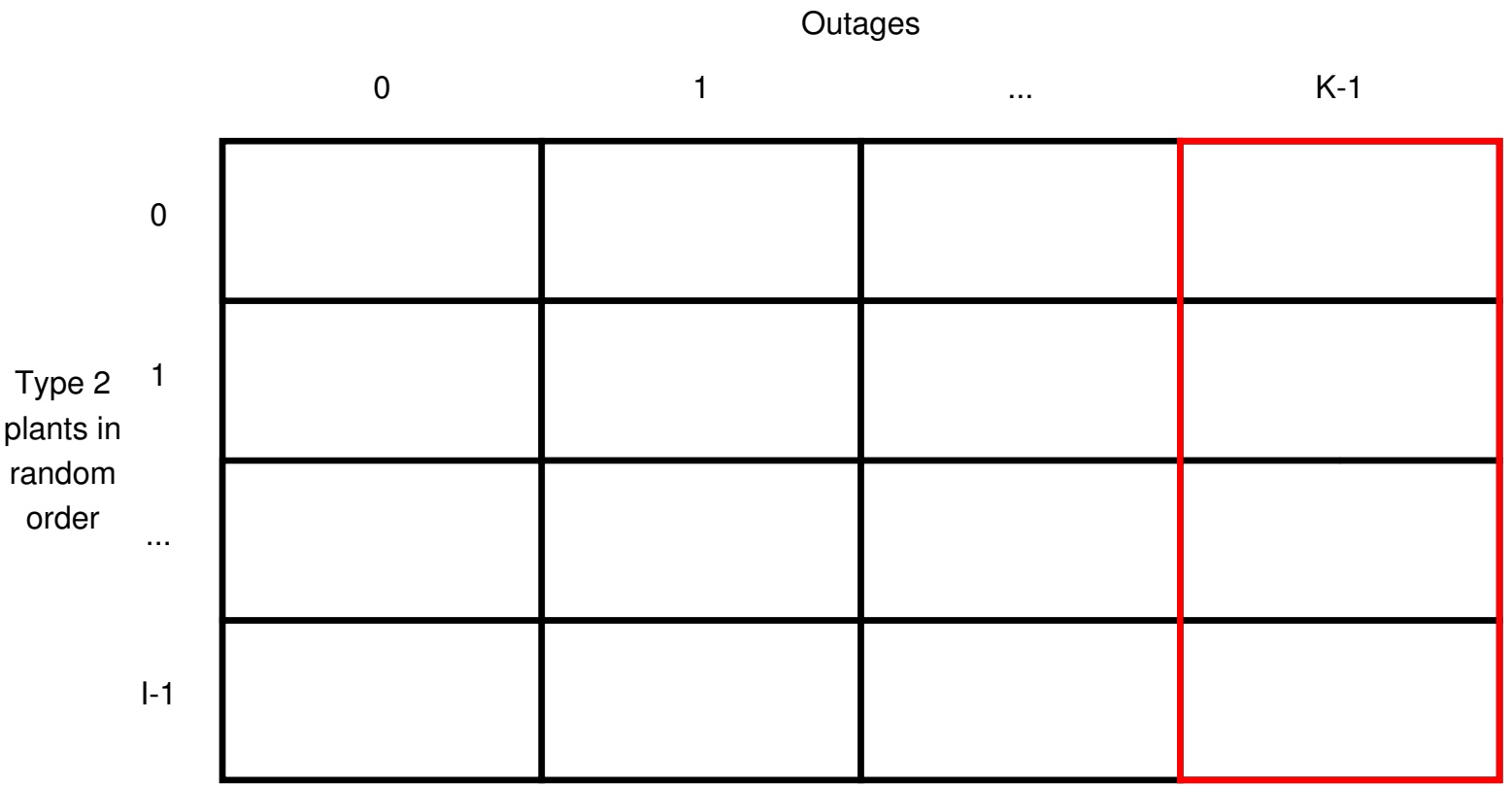
Branching strategy, cont'd.



Branching strategy, cont'd.



Branching strategy, cont'd.



Branching strategy, cont'd.

1. Outages scheduled: First branch is on *scheduled*
2. Start week: First branch is on *earliest week*
3. Refuel amount: First branch is on *maximal refuel amount*

Greedy production planning

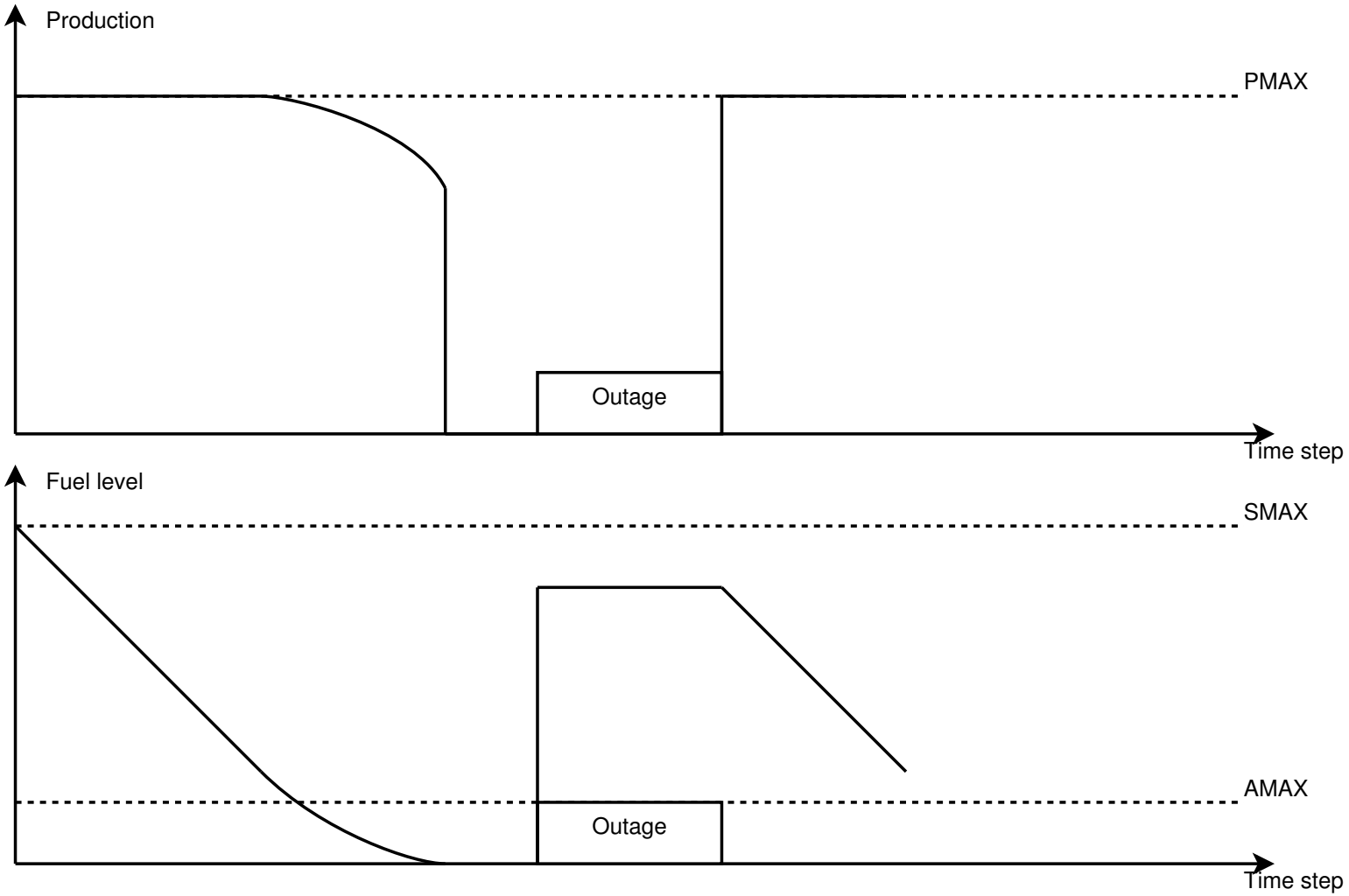
For type 2 plants

- Find feasible production levels
- Increasing refueling amounts

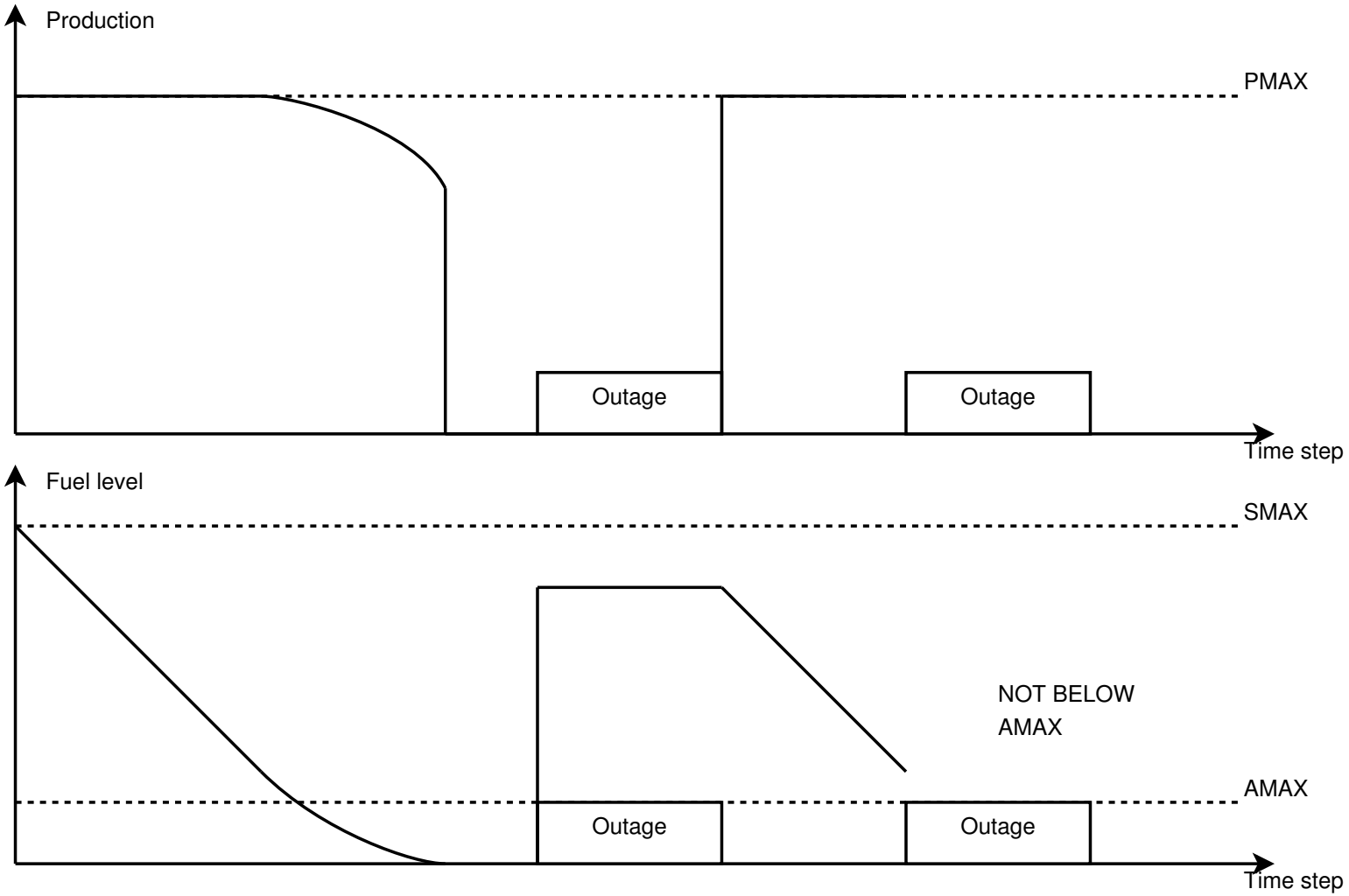
For type 1 plants

- Cheapest type 1 plant is used first
- Production levels are only set after modulation have been performed and just before writing the final solution

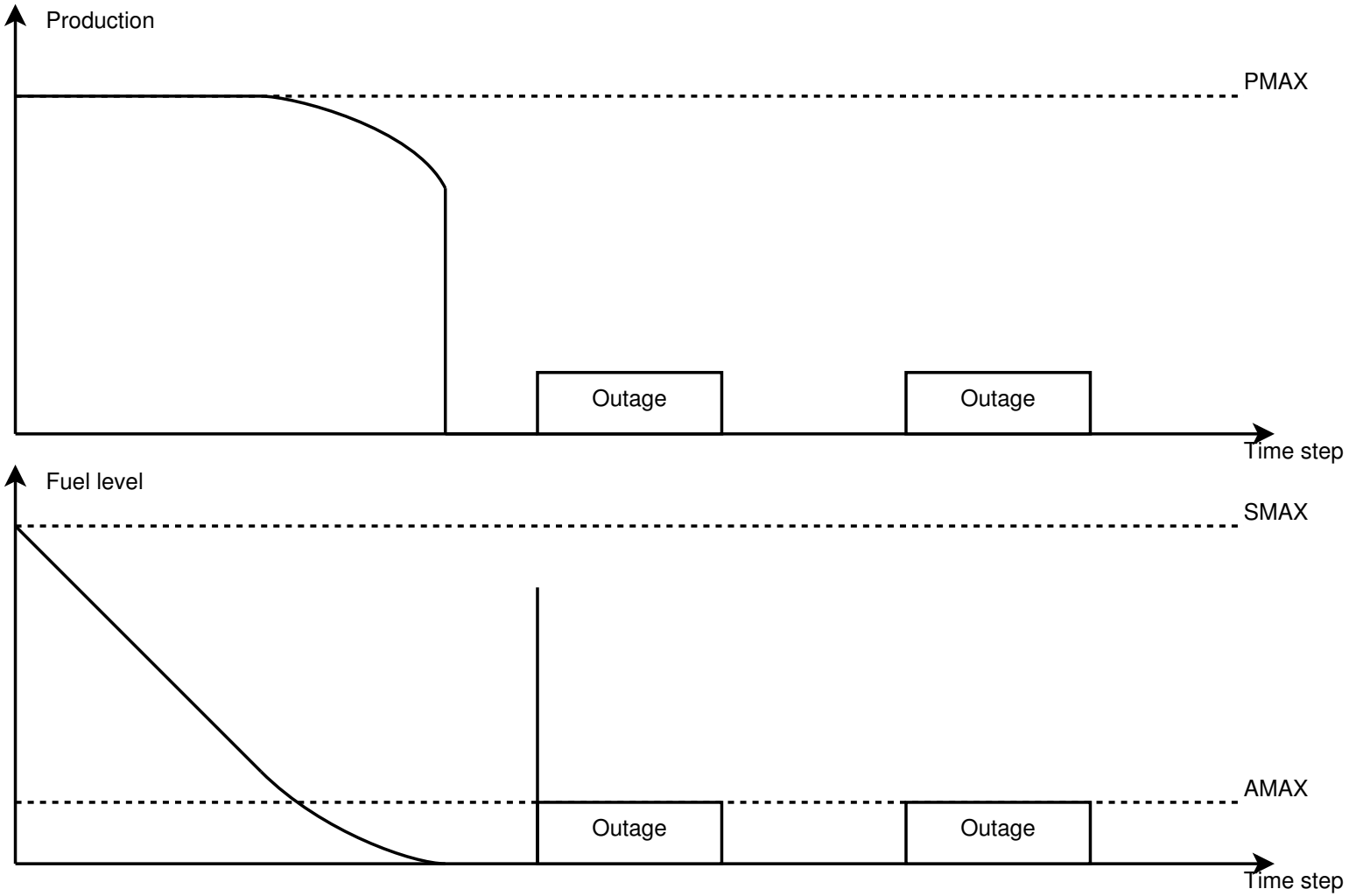
Greedy production planning, cont'd



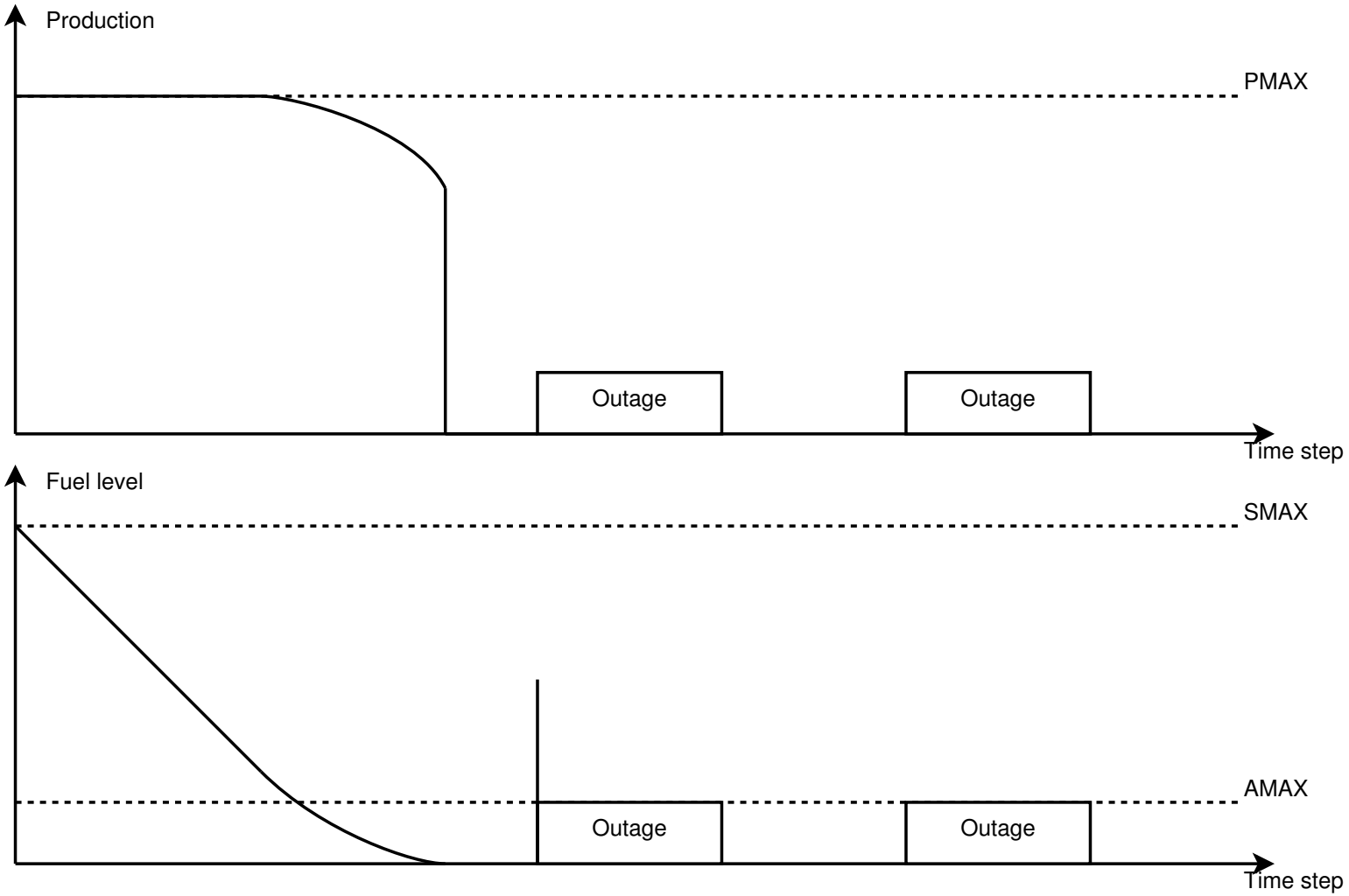
Greedy production planning, cont'd



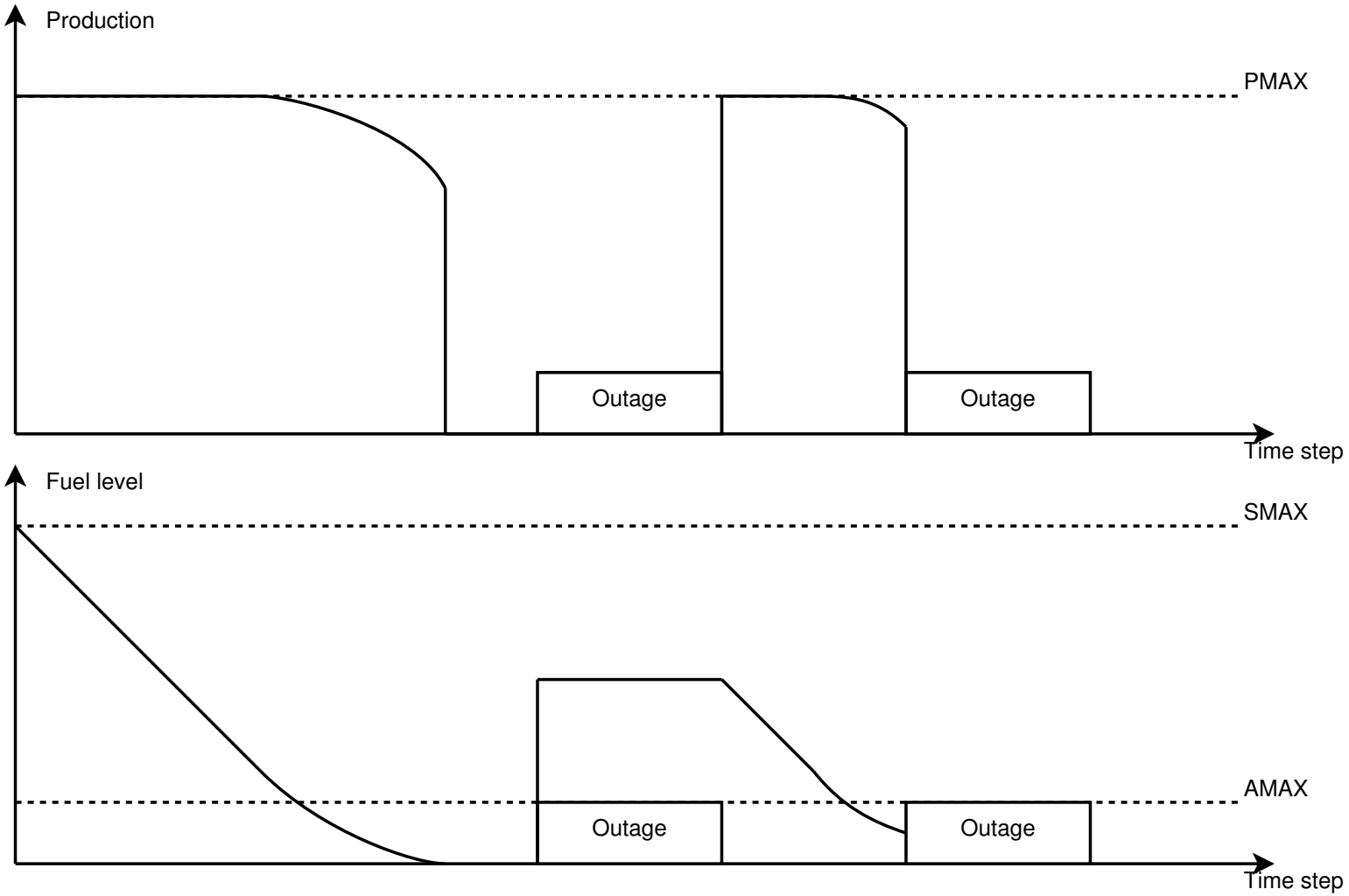
Greedy production planning, cont'd



Greedy production planning, cont'd



Greedy production planning, cont'd

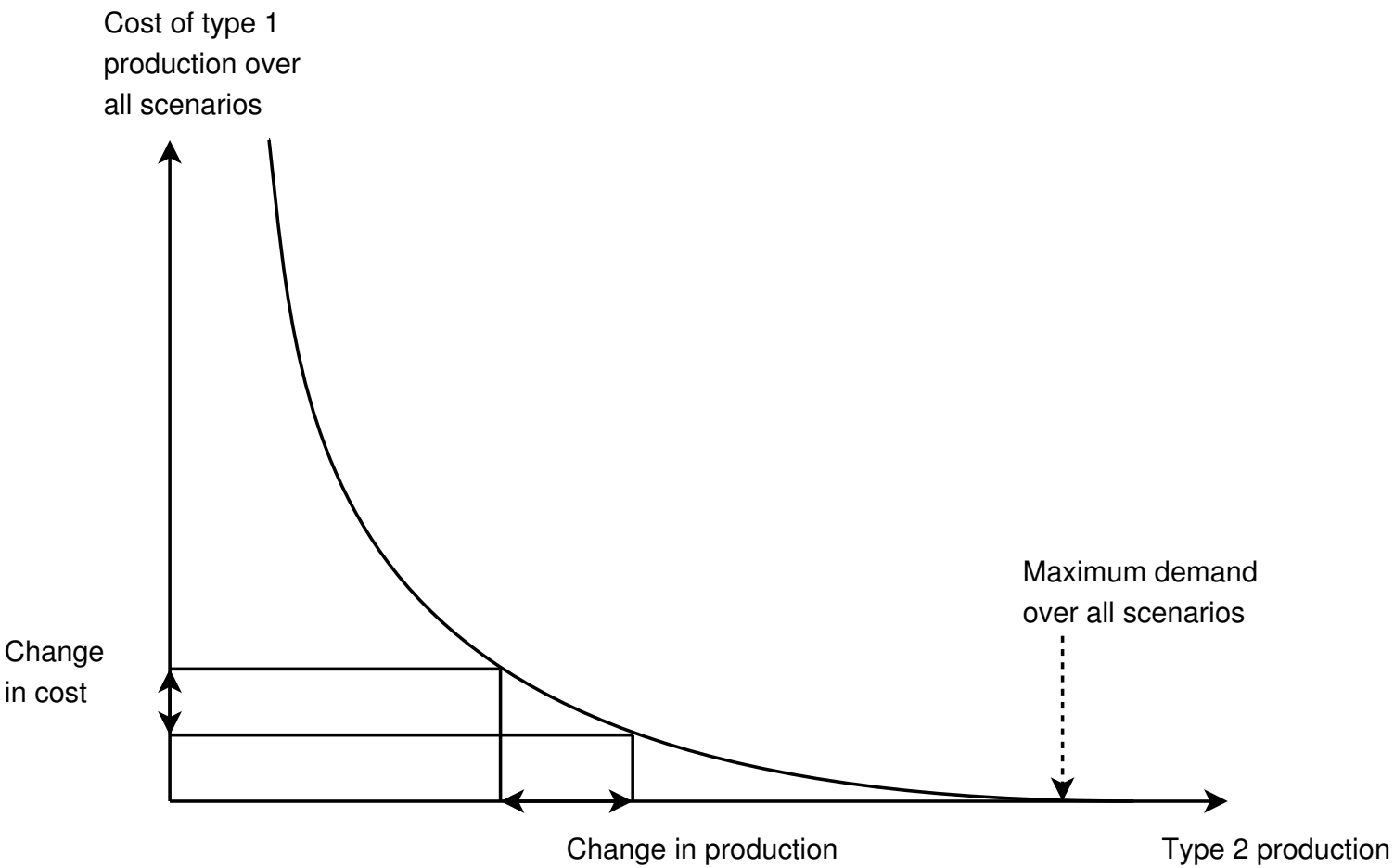


Local search

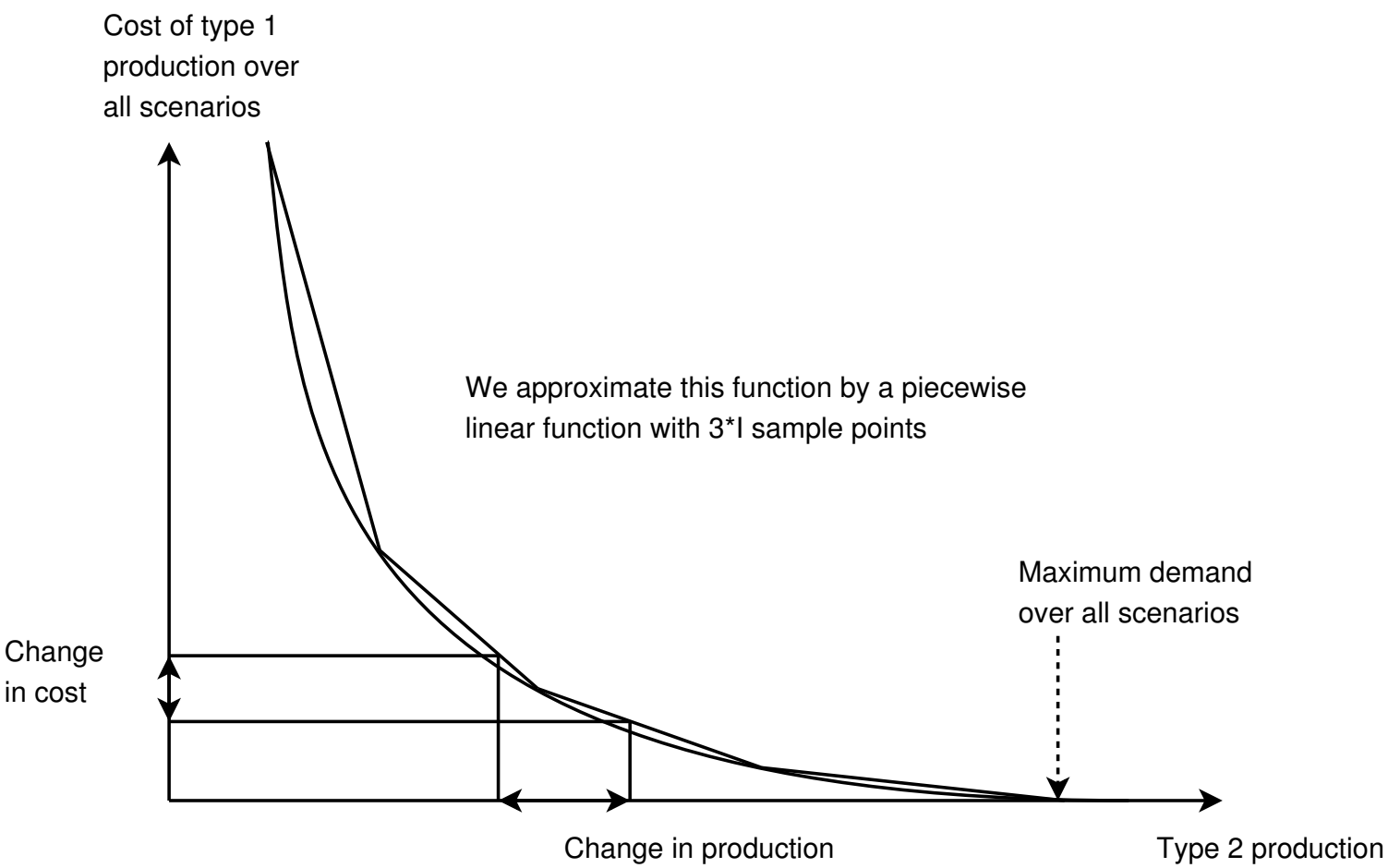
We try to improve on the outage schedule by local search

- Initial solution: We start from the CP-solution
- The neighborhood consist of all possibilities of moving a single outage a few weeks forwards or backwards
  - We only consider moves that are feasible wrt. CT13 to CT21
  - We only consider moving outages less than m weeks
- Evaluation: A move is evaluated by the estimated change in production cost. The change consists of changes in
  - Type 2 costs for the affected plant: Re plan production and refuel amounts
  - Type 1 costs: Estimation of the effect over all scenarios.

Estimating the change in type 1 cost



Estimating the change in type 1 cost



This approximation to type 1 costs is relatively good:

- In our experience it is correct up to 3 or 4 significant digits
- Evaluating the approximation is a constant time operation, since we maintain the total type 2 production for every time step

But somewhat memory expensive:

- Need to store an approximation for each time step

Meta heuristic, simulated annealing

To guide the local search we use a simple simulated annealing procedure

- Start temperature that gives an acceptance ratio of approximately 0.5
- Exponential cooling with plateaus
- Restart after n idle iterations

Modulation strategy

To make the solution feasible we modulate the type 2 power plants according to the minimum demand scenario.

- Idea: Modulate on the type 2 plant which has the shortest time to the next outage.

It is better to modulation per scenario, as we will see now.

Results

Instance	Results (competition)	Results (per sc. mod.)
dataB6.txt	$8.5511 \cdot 10^{10}$	$8.5544 \cdot 10^{10}$
dataB7.txt	$8.1900 \cdot 10^{10}$	$8.1912 \cdot 10^{10}$
dataB8.txt	$8.3469 \cdot 10^{10}$	$8.2810 \cdot 10^{10}$
dataB9.txt	$8.3487 \cdot 10^{10}$	$8.2851 \cdot 10^{10}$
dataB10.txt	$8.0185 \cdot 10^{10}$	$7.9150 \cdot 10^{10}$

Table: Computational results

The per scenario results are for instances B8, B9 and B10 about 0.8%, 0.8% and 1.2% better respectively.

Thank you for your attention!

Questions?