BEST

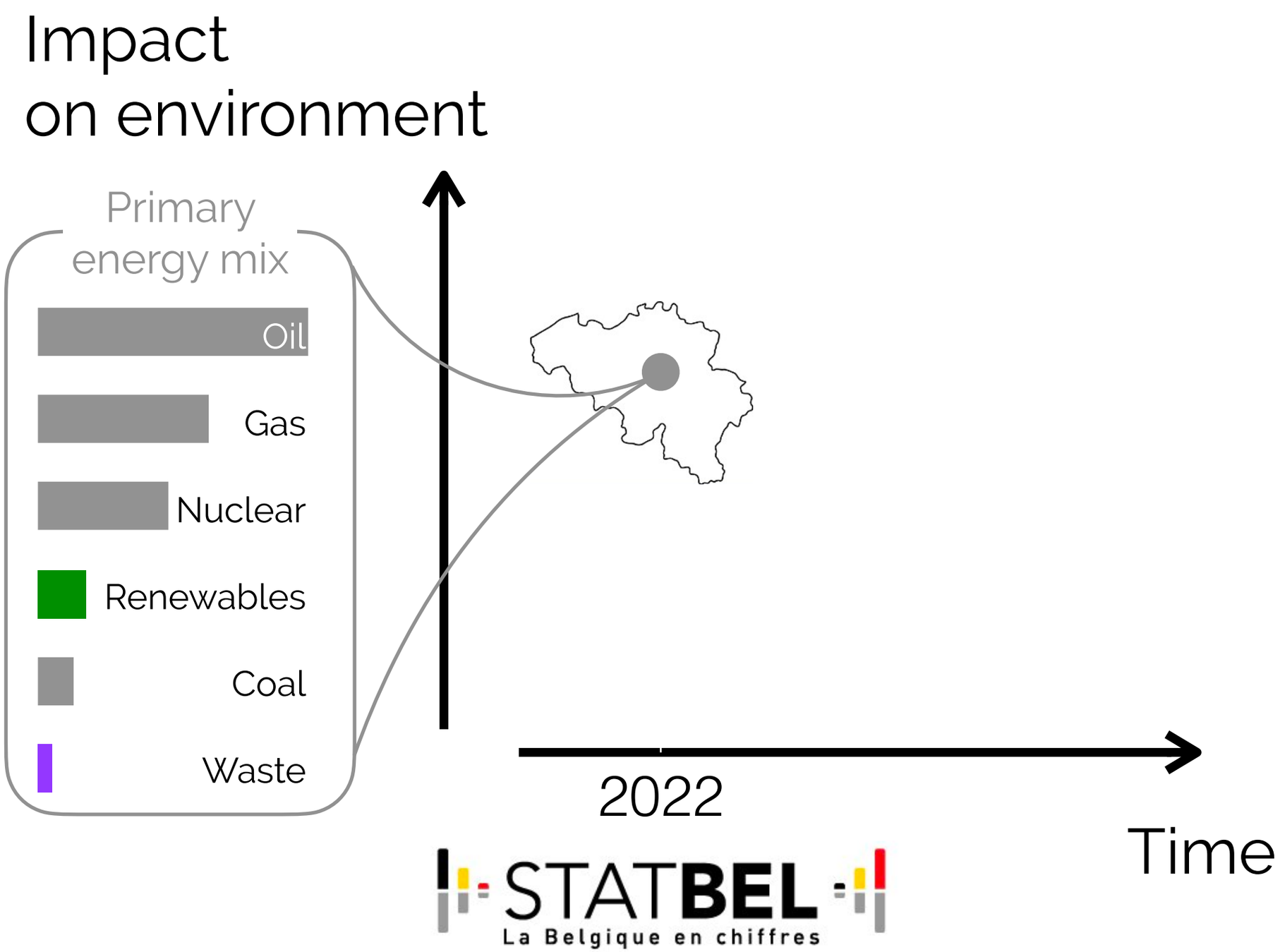
Belgian Energy System

A hierarchical multi-objective reinforcement-learning based optimisation

Xavier RIXHON
xavier.rixhon@uclouvain.be

BEST - 5th Consortium meeting - May 23rd, 2022
https://best-energy.be/

From where we are...



STATBEL
La Belgique en chiffres

… to where we want to go

FUELS

Import of electro- and bio-fuels

EFFICIENCY

Towards **smaller energy consumption**

DEMANDS

Towards **sobriety**?

Impact on environment

Primary energy mix

Oil

Gas

Nuclear

Renewables

Coal

Waste

Sustainability ~~target~~ wall

2022

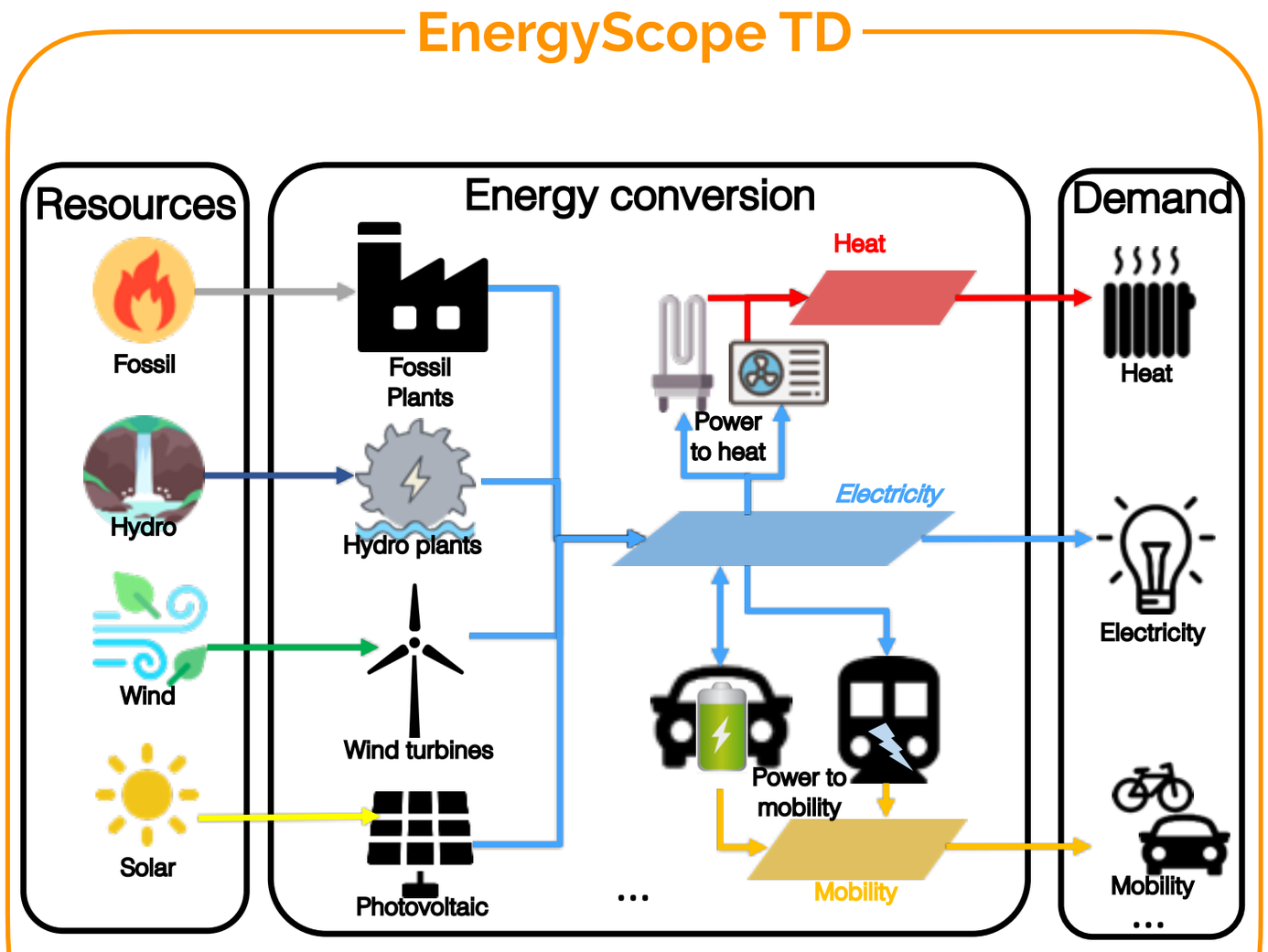
2050

Time

EnergyScope TD

EnergyScope TD: a whole-energy system model to minimize the total cost (Limpens et al., 2019)

UCLouvain
EPFL



Linear programming (LP)

Multi-**sector** and multi-**carrier**

Optimization of **investment & operation** strategies

Snapshot modeling approach

optimisation of a target future year

Hourly resolution

required by high integration of renewables and storage

Tractable formulation

suitable for uncertainty quantification

What is the **most cost efficient pathway** to get there?

From EnergyScope TD to EnergyScope Pathway (G. Limpens' thesis)

Perfect foresight

Representative years

EnergyScope TD constraints

2020 2025 2030 2035 2040 2045 2050

2020-2025 2025-2030 2030-2035 2035-2040 2040-2045 2045-2050

Phases

Additional constraints
(e.g. no sharp complete shift of tech.)

2020 2025 2030 2035 2040 2045 2050

Implementation of different pathway methodologies

Perfect foresight

Complete knowledge on the whole horizon

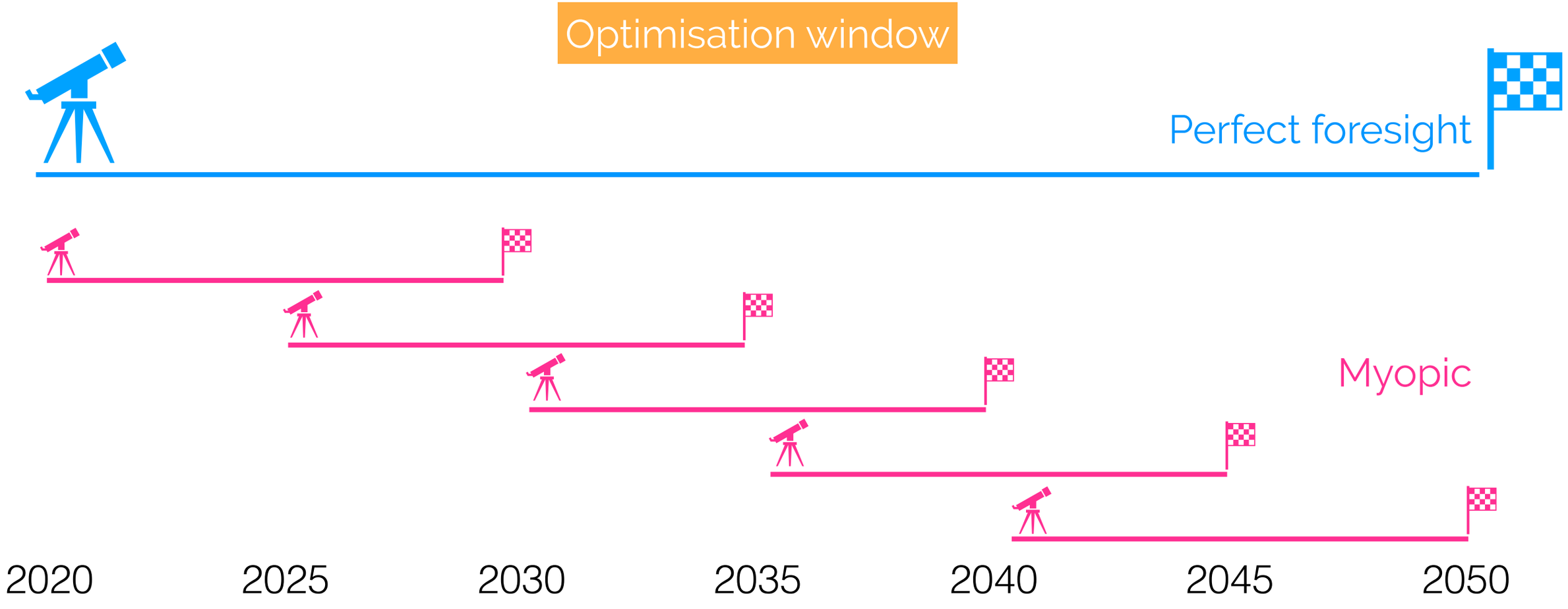
Global optimisation of all the time-periods

VS

Myopic

Limited knowledge on the whole horizon

Step-by-step optimisation



Myopic: limited vision with immutable decisions

1st phase optimisation

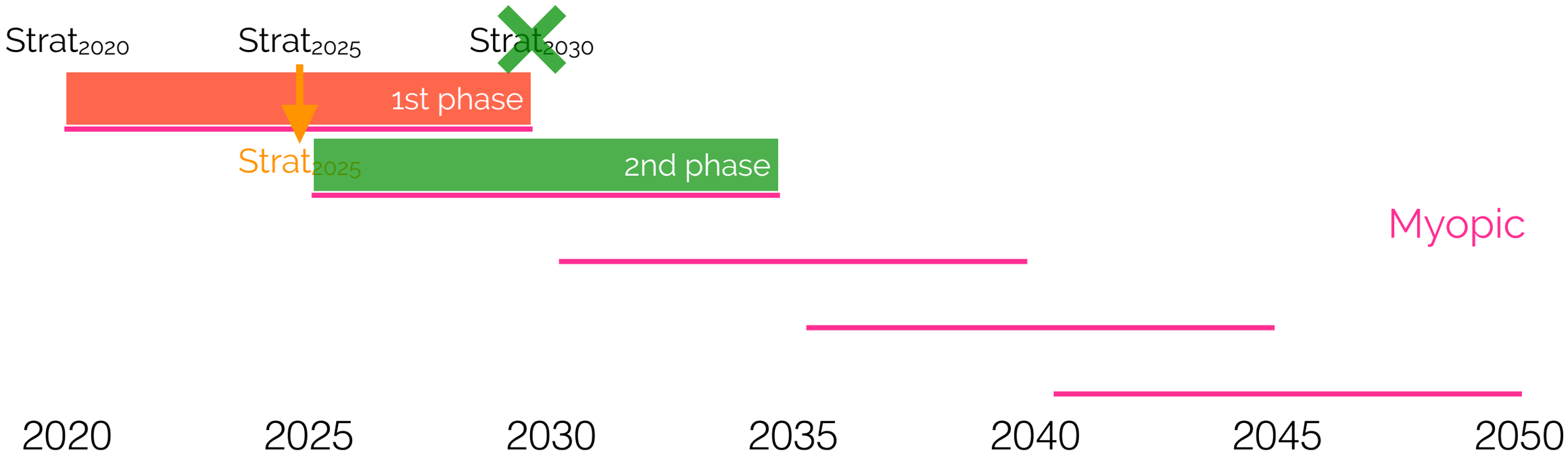
1. Optimisation of the pathway over the first phase
   => Strategy (i.e. design and operation) over the whole phase (e.g. 2020, 2025 and 2030)

Set strategy for start of 2nd phase

2. Strategy is set until the start of the second phase: **immutable decisions** as initialisation

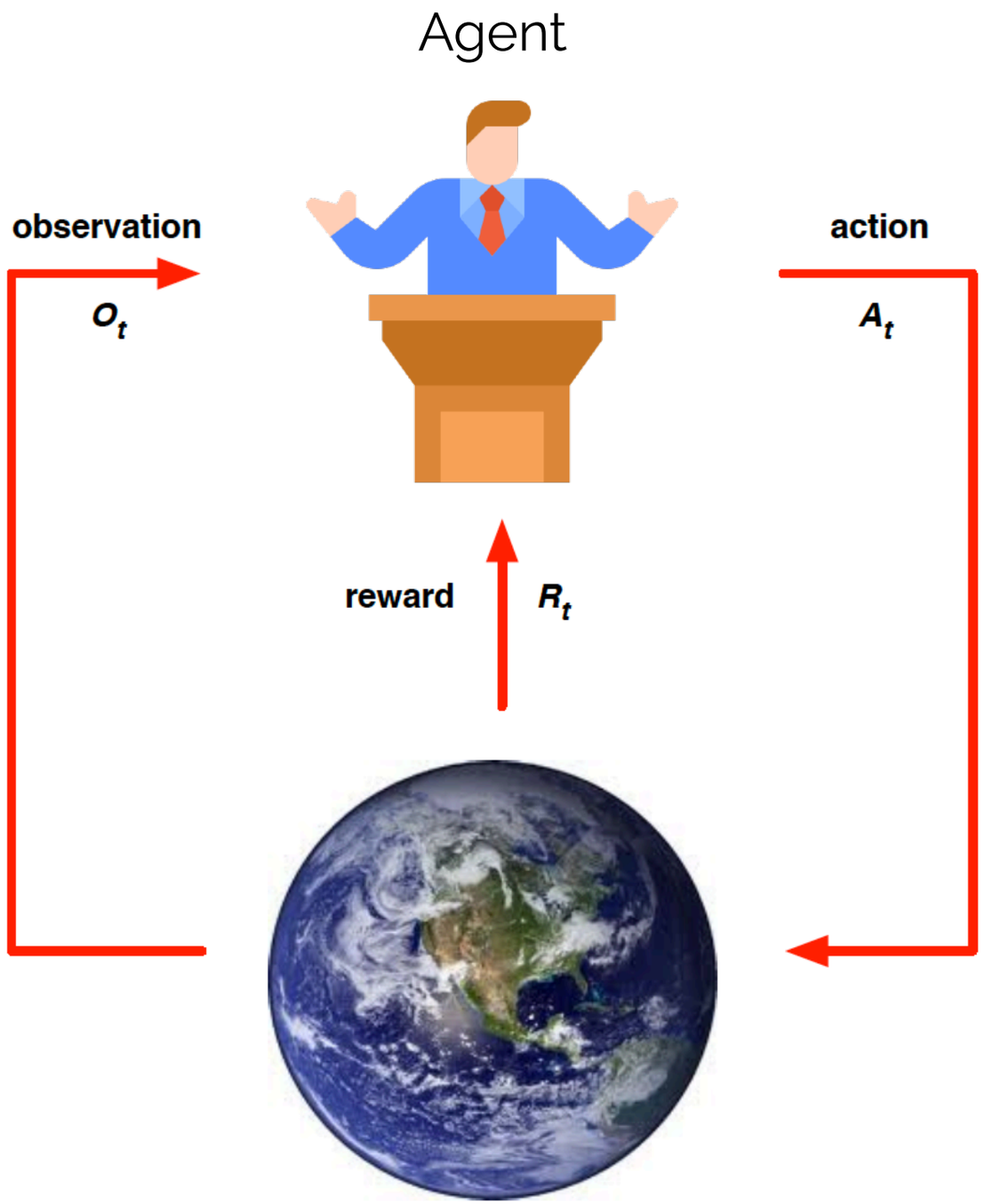
2nd phase optimisation

3. Optimisation of the pathway over the second phase with set strategy at start and discarding the rest of the already optimised future

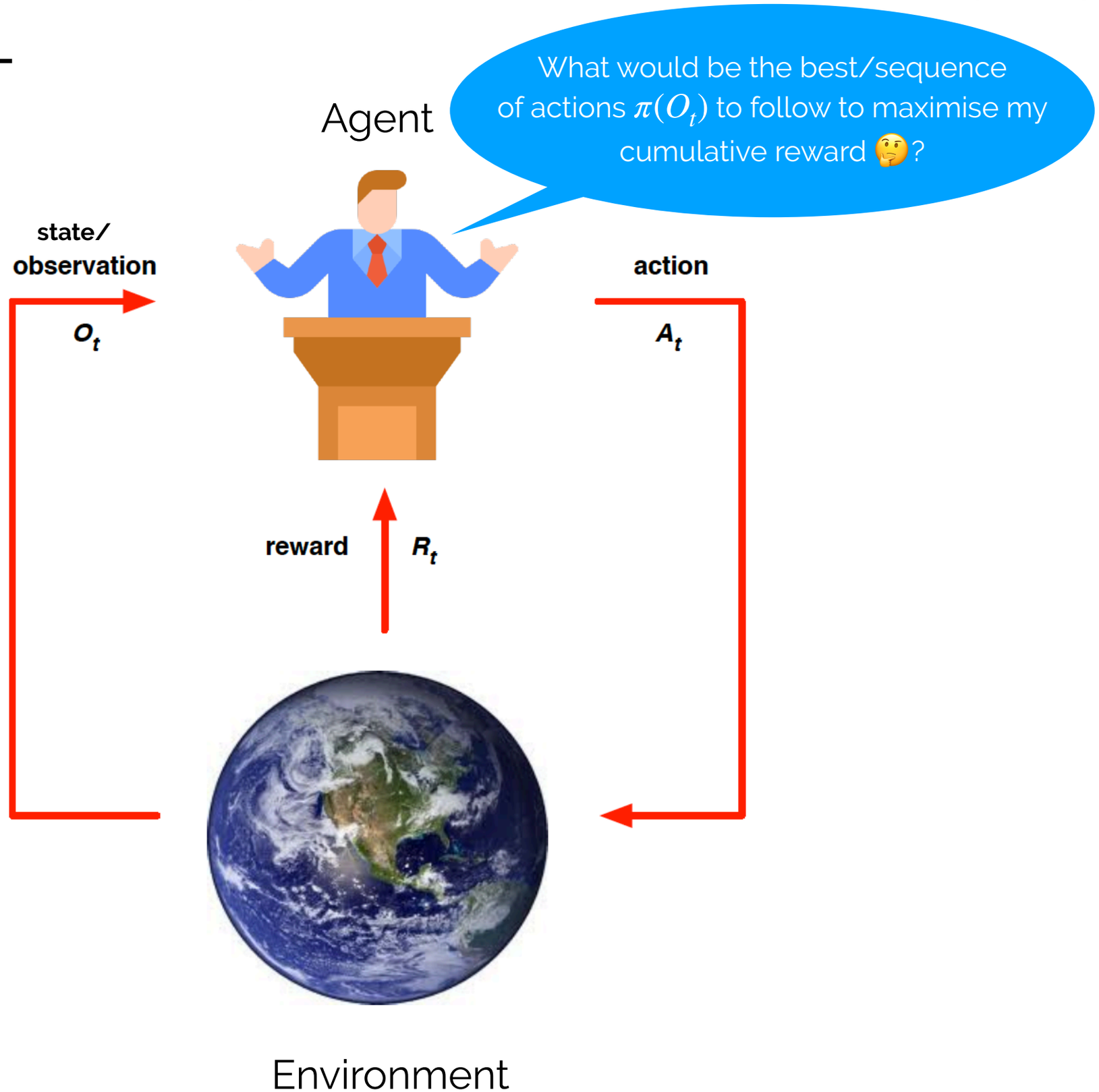


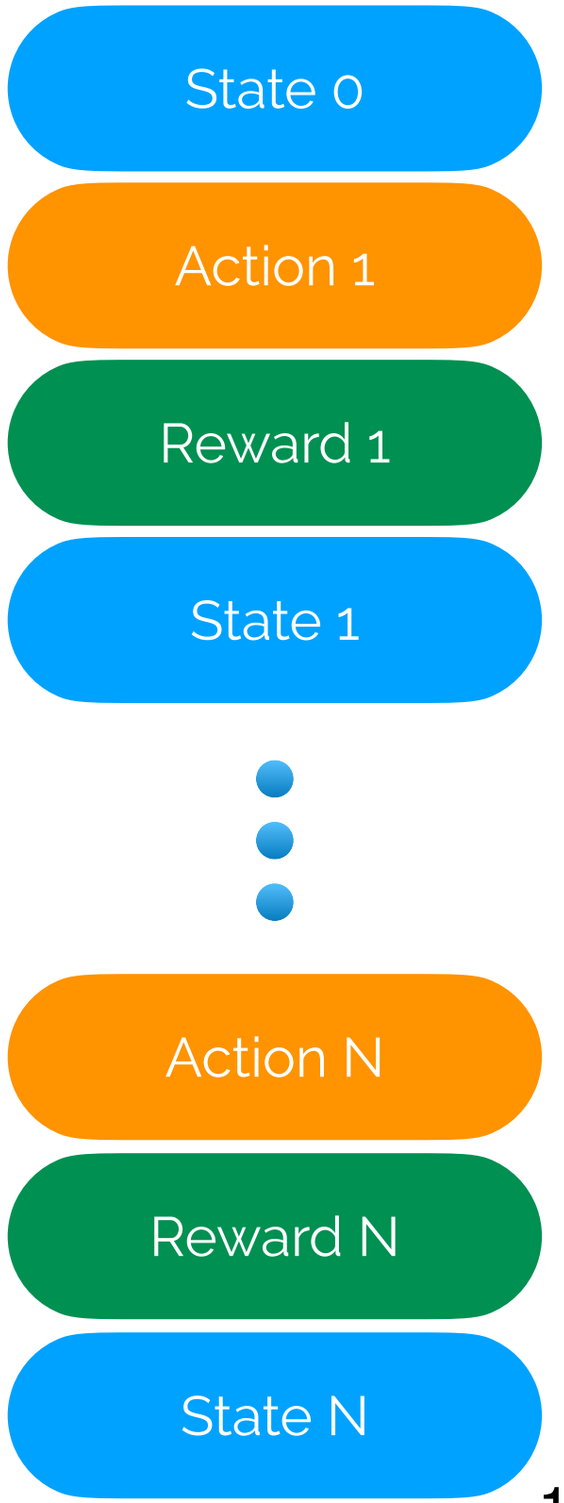
What is the **most robust policy** to meet our climate target(s)?

Artificial agent will learn this policy, by himself - Reinforcement learning

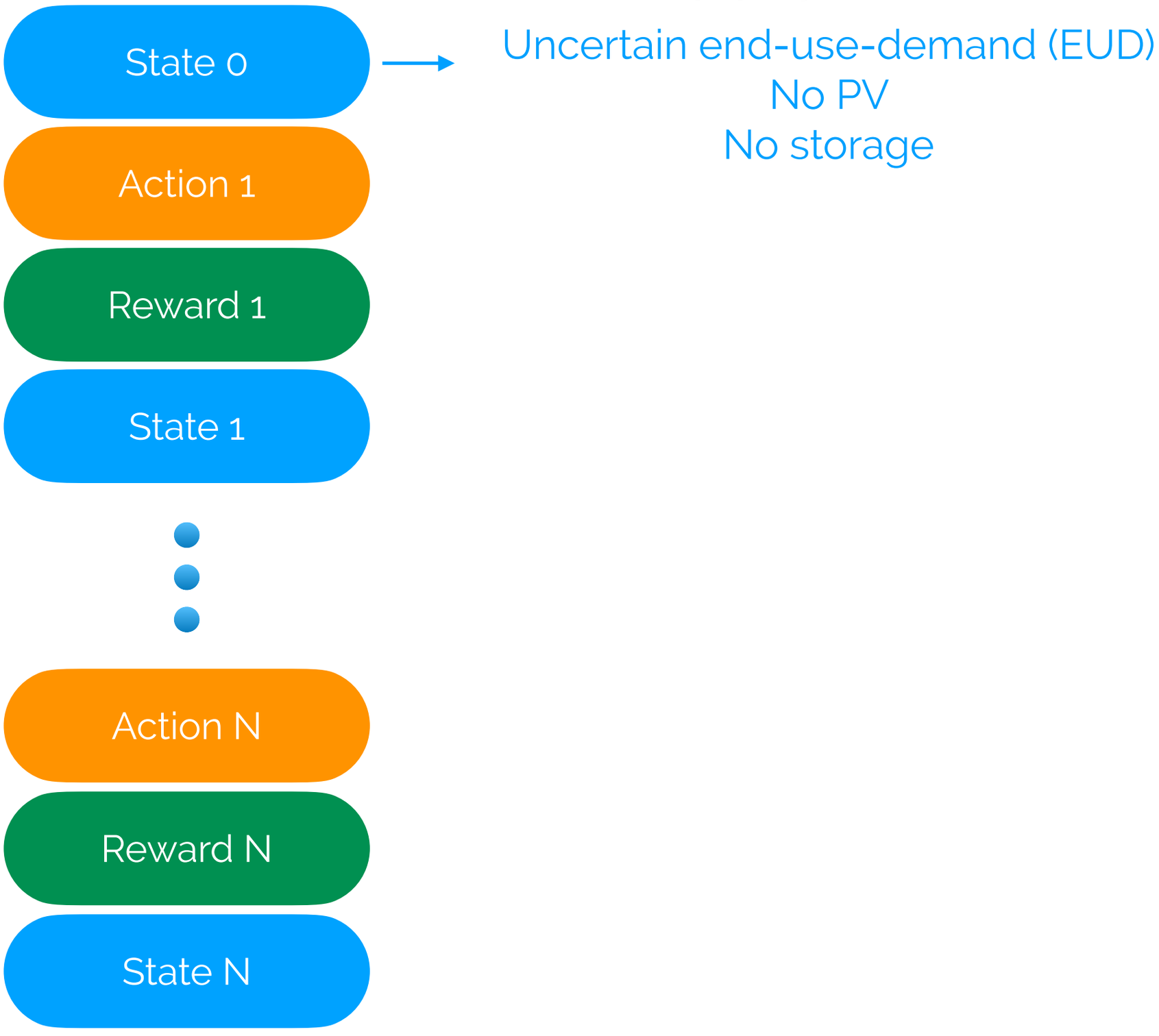


Artificial agent will learn this policy, by himself - RL



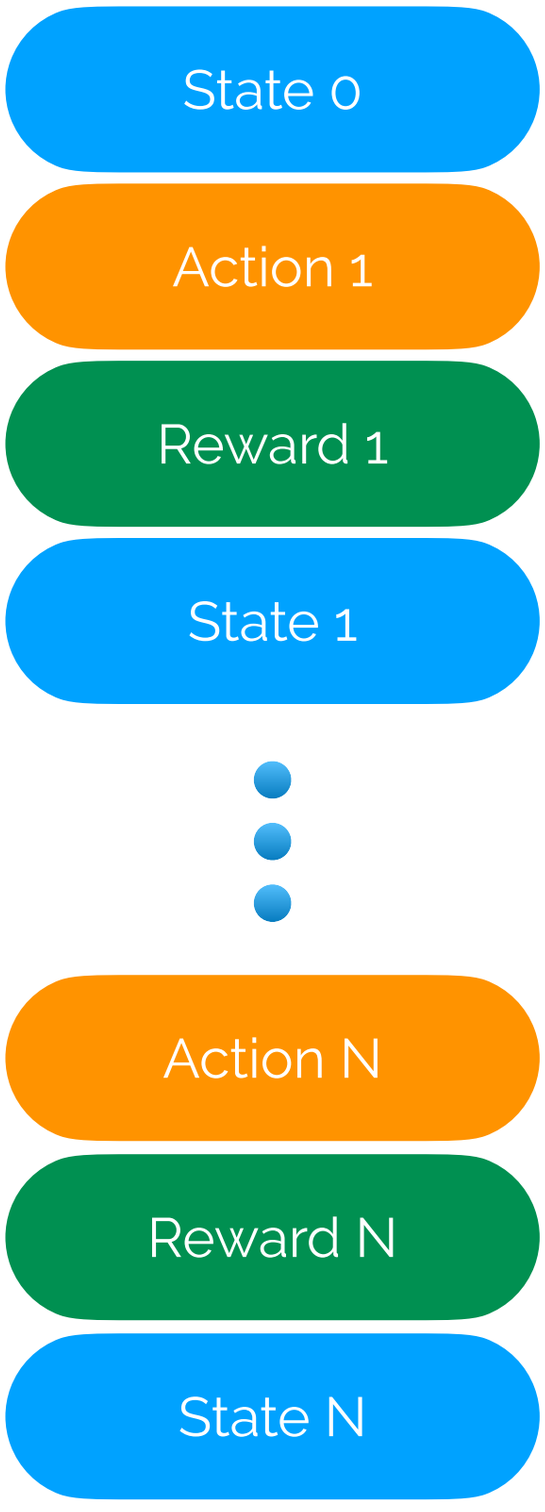


Sand pit case study
From fossil to solar supply



Uncertain end-use-demand (EUD)
No PV
No storage

Sand pit case study
From fossil to solar supply



0 - Increase the amount of PV by 10 **OR**
1 - Increase the amount of PV and storage by 5 **OR**
2 - Increase the amount of storage by 10

Sand pit case study
From fossil to solar supply

State 0

Action 1

Reward 1

State 1

Action N

Reward N

State N

-10 if exceeded installation of PV or storage **OR**

+10 if $prod_{PV} \geq EUD$ **OR**

$1/(EUD - prod_{PV})$

Sand pit case study
From fossil to solar supply

State 0

Action 1

Reward 1

State 1

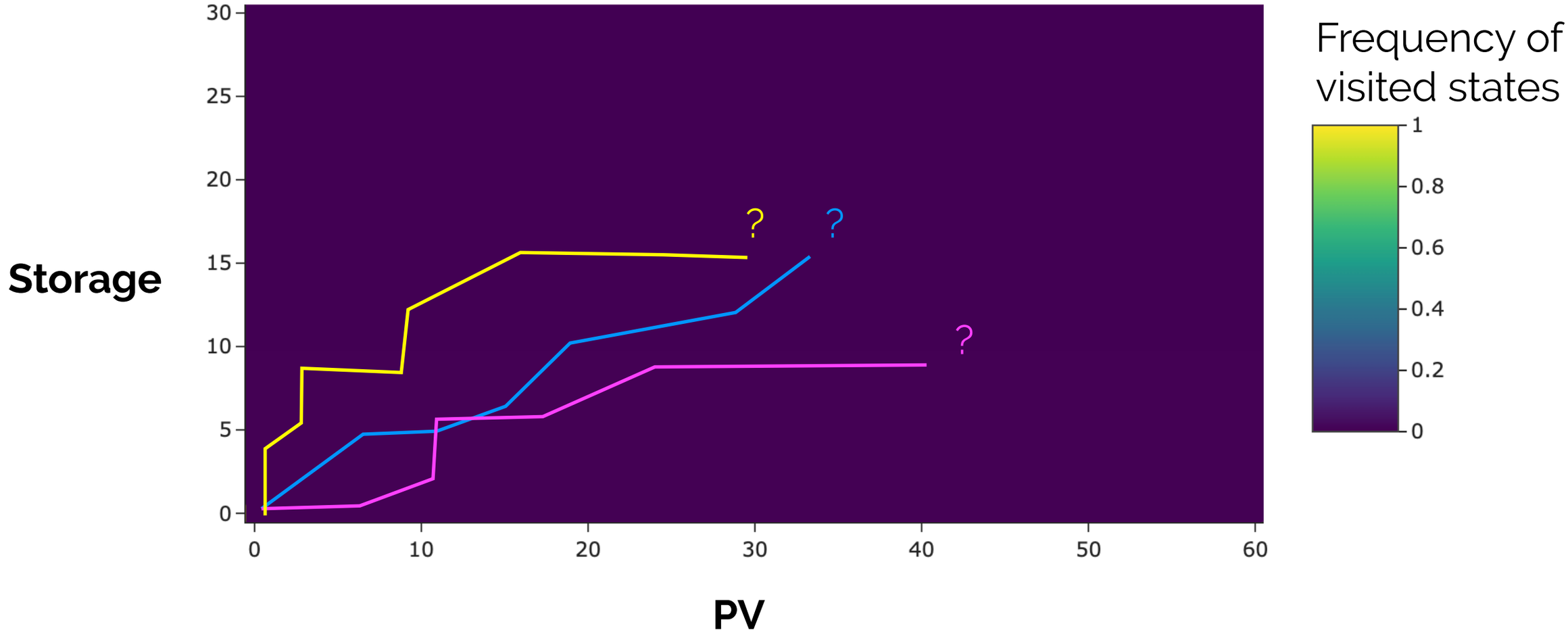
Amount of PV
Amount of storage

Action N

Reward N

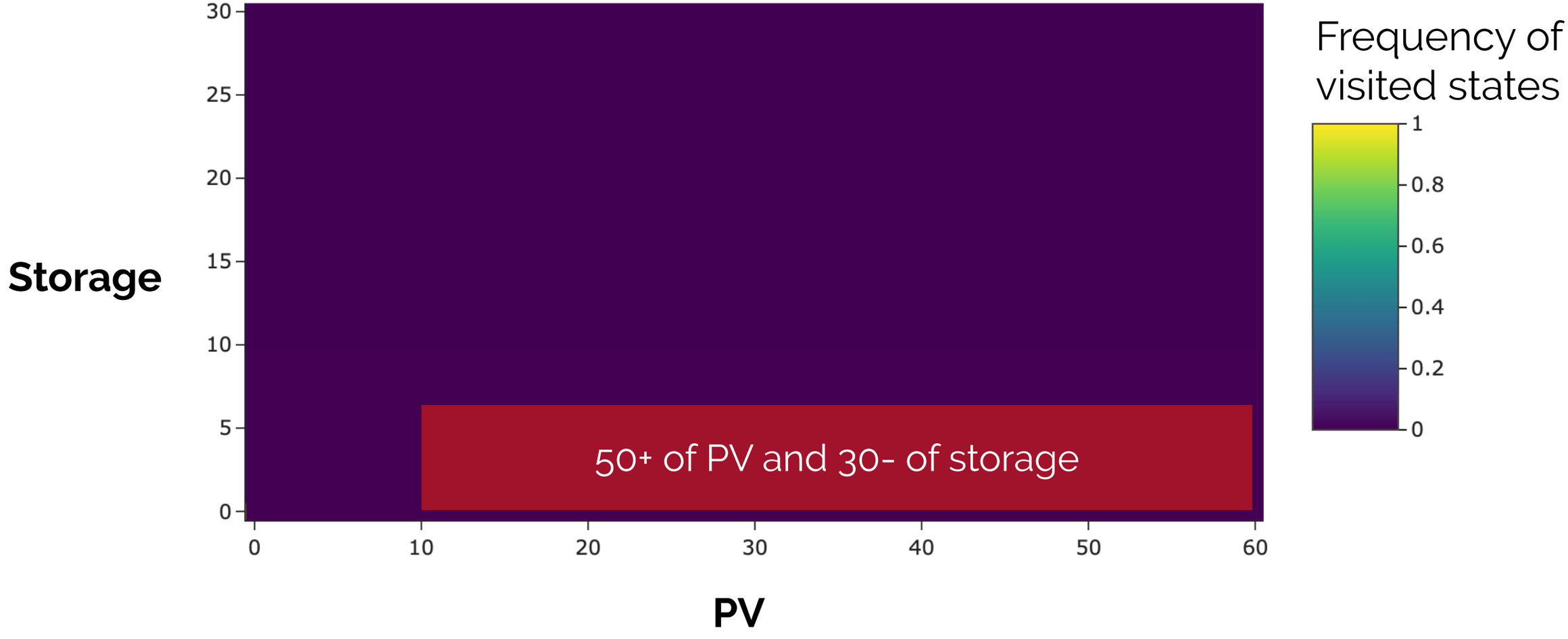
State N

What policy does the agent learn?

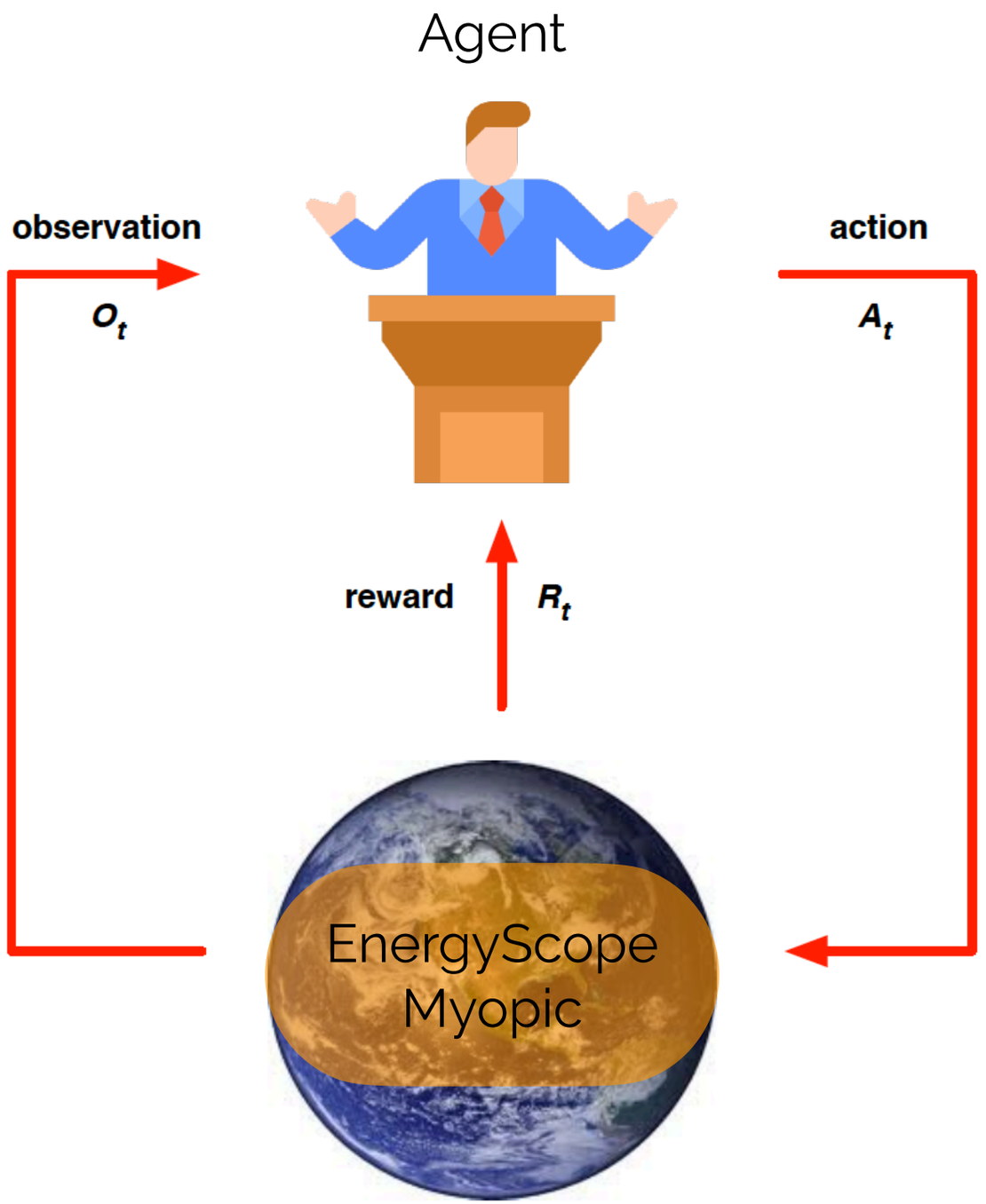


What if there is a risk of black-out?

At the beginning of the episode, there is a **5% risk** of black-out.
Although, if we stay in this black-out-risky area, the risk
increases by 2% at every iteration.

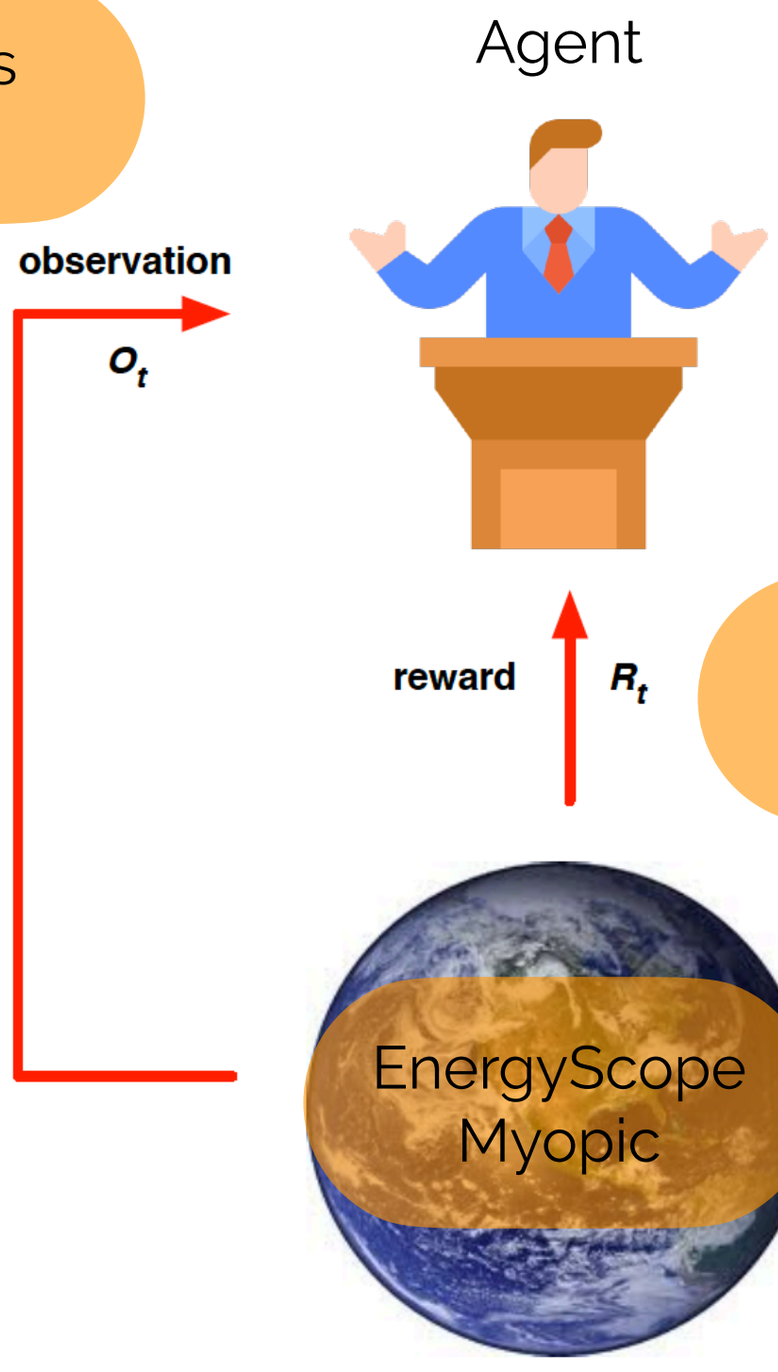


Artificial political agent - Reinforcement learning



Artificial political agent - Reinforcement learning

Installed capacities
Amount of CO2



???????

???????

Probability of a shock

Uncertain
Environment

Actions

Cost

Incentives/Taxes on technologies

Investment

Limit the investment in tech./res.

Availability

Limit/Increase the availability of resources

Demand

Capping the demand (at which cost?)

Change

Inc./Dec. change in phase Willingness

Rewards

Emissions

Cumulative CO2 emissions over the transition

Net-zero target reached (yes?/no?)

Stochastic events

Cost

Rise of cost of imported resources

Change

Decrease in willingness to change

Availability

Limitation of import capacity

A hierarchical multi-objective reinforcement-learning based optimisation

Novelty is multi-scale… to help the government in policy decisions

Case study:

- Apply a reinforcement learning approach to draw a robust policy in the uncertain transition of a whole-energy system

Methodology:

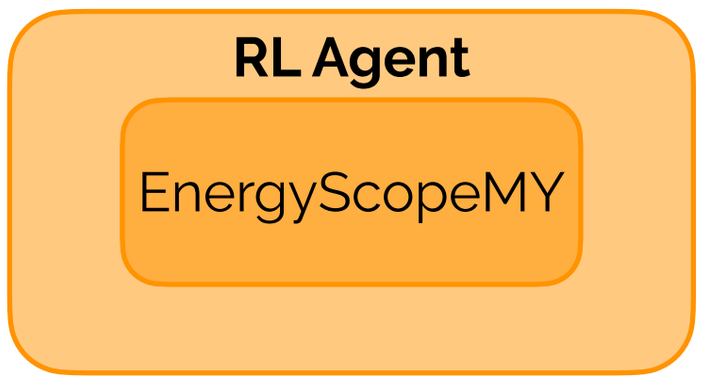
- Apply a reinforcement learning approach to an optimisation environment (rather than to a simulation environment)
- Build a hierarchical multi-objective optimisation framework, using RL

EnergyScopeMY

Minimise the cost for each time window, given immutable decisions

RL Agent

Minimise the emissions to maximise its reward



« As for the future, our task is not to foresee it, but to enable it »

Antoine de Saint-Exupéry, *Citadelle*, 1948