# The effect of high-resolution modelling on renewable energy optimal portfolios

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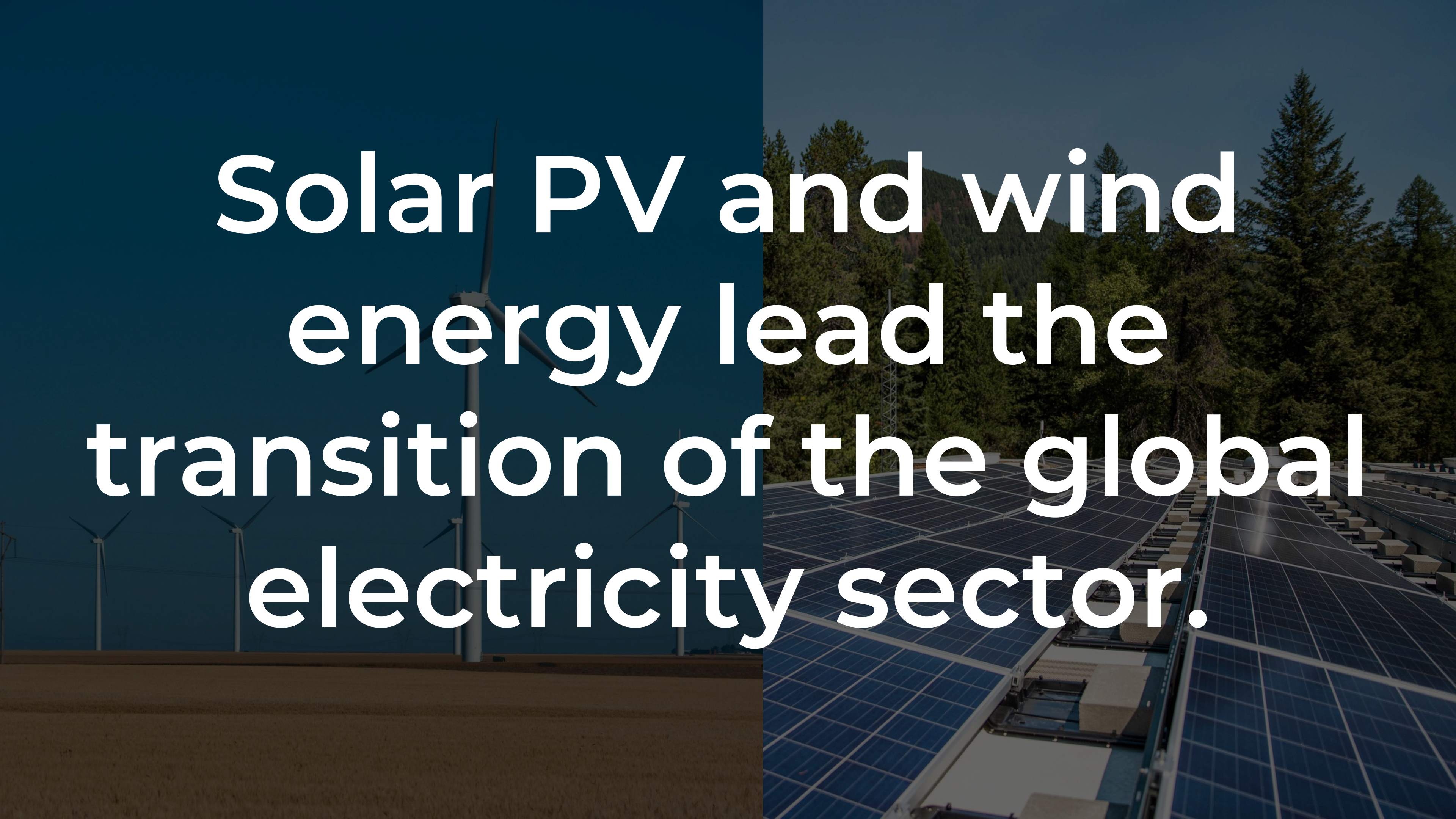
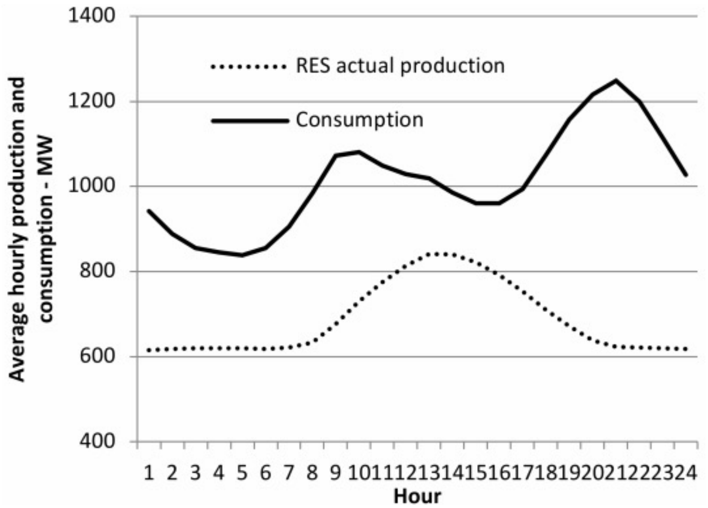

Solar PV and wind energy lead the transition of the global electricity sector.

# THE PROBLEM

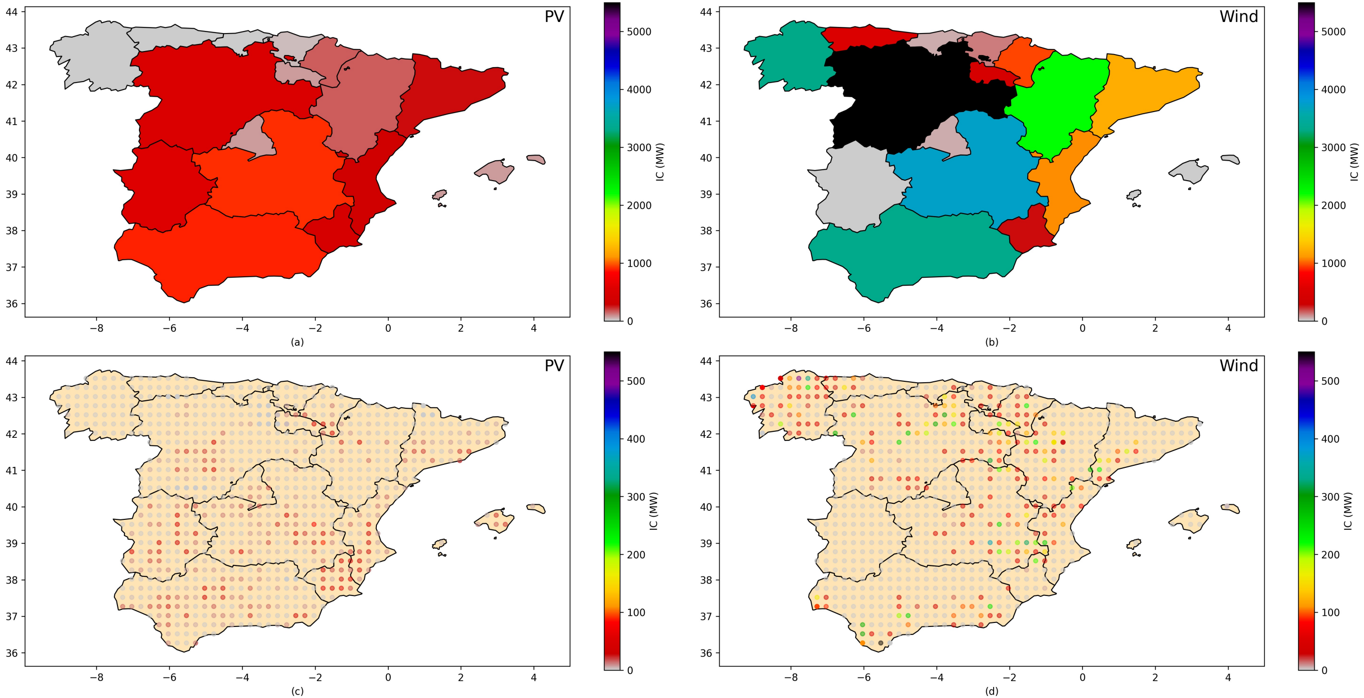



Illustrative example for three Sardinia wind plants.
From Zedda (2019)

## COMPLEMENTARITY

Generation and
demand curves
do not match!

# THE 2020 DISTRIBUTION



# HOW A REGION APPEARS TO BEHAVE

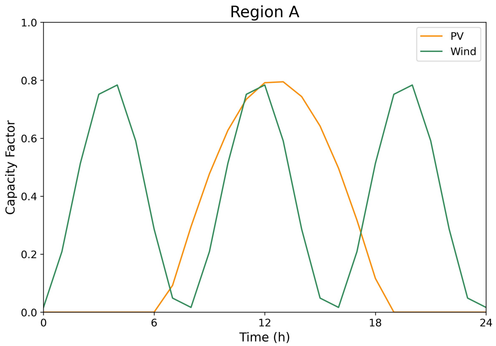
# HOW A POINTS IN A REGION ACTUALLY BEHAVE

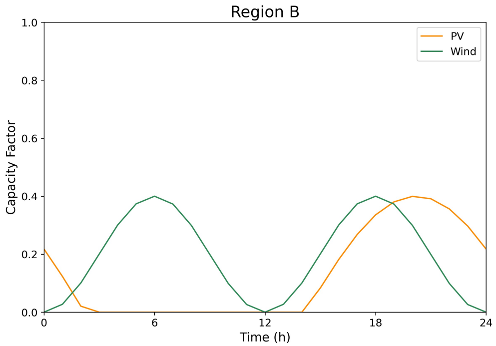
# THE APPROACH

Apply portfolio theory from climatic to hourly time scales, using a high-resolution grid and aggregated regions, to:

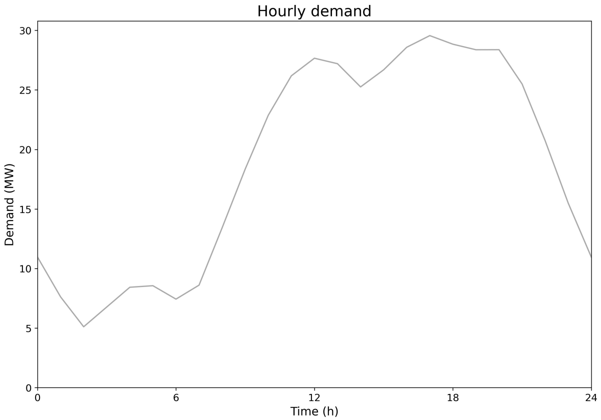
1. Cover a percentage of the hourly demand
2. Avoid exceedance and shortage
3. Geographically distribute renewable capacity to minimize risk at a given penetration level

# AN ILLUSTRATIVE EXAMPLE



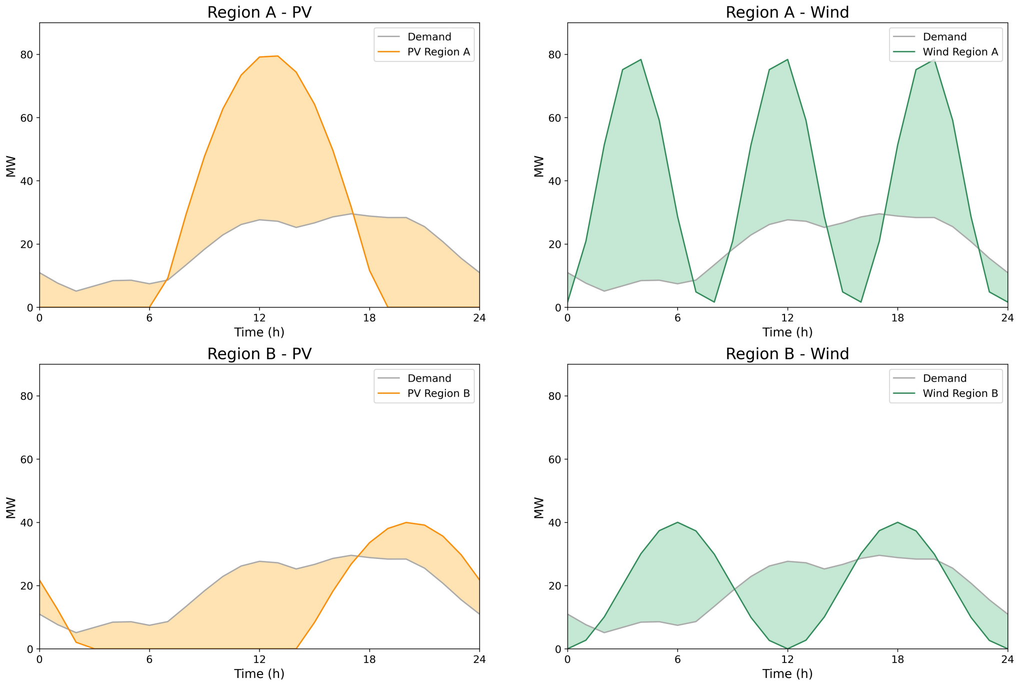




100 MW available



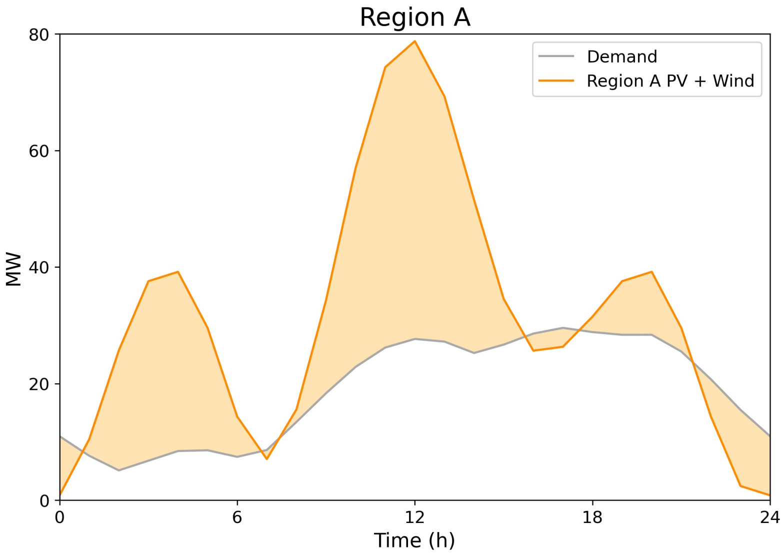
# AN ILLUSTRATIVE EXAMPLE

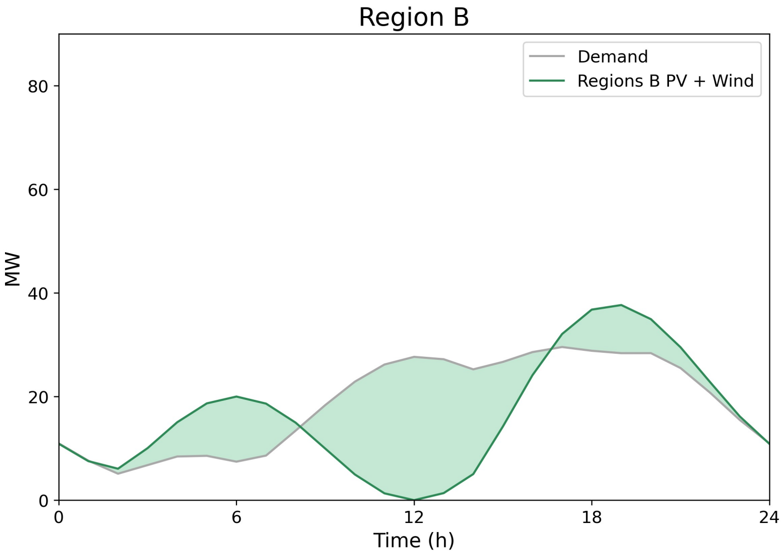
## 100 MW all at only one region and technology



# AN ILLUSTRATIVE EXAMPLE

## 100 MW split evenly between technologies, one region



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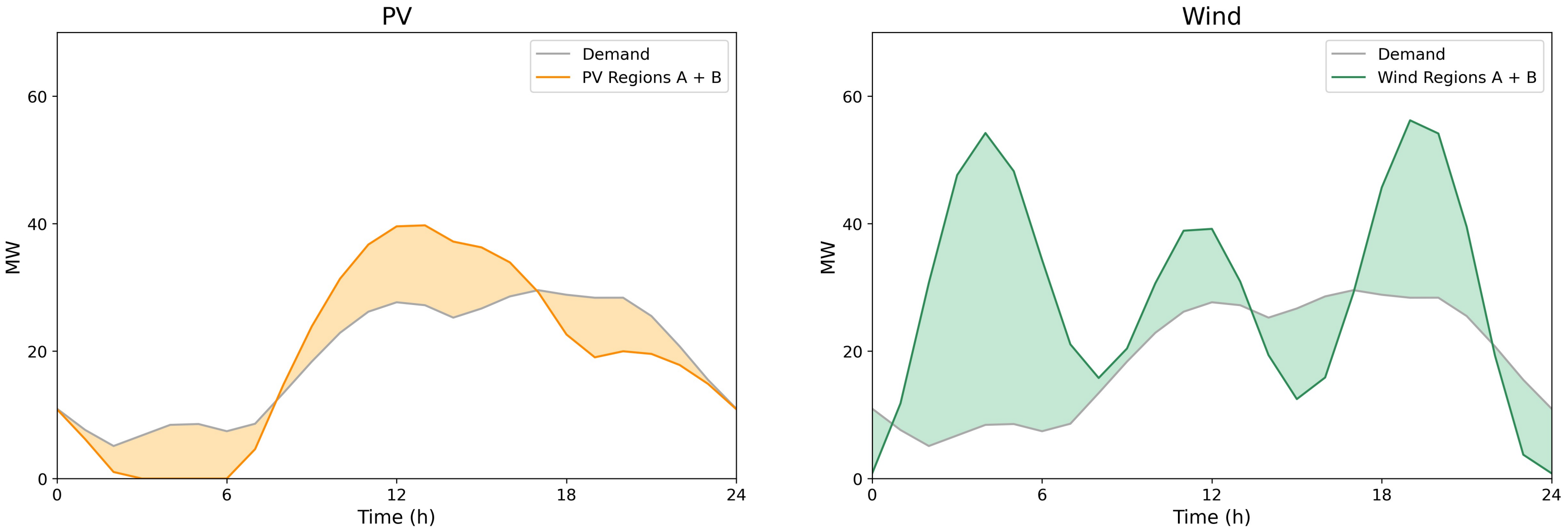
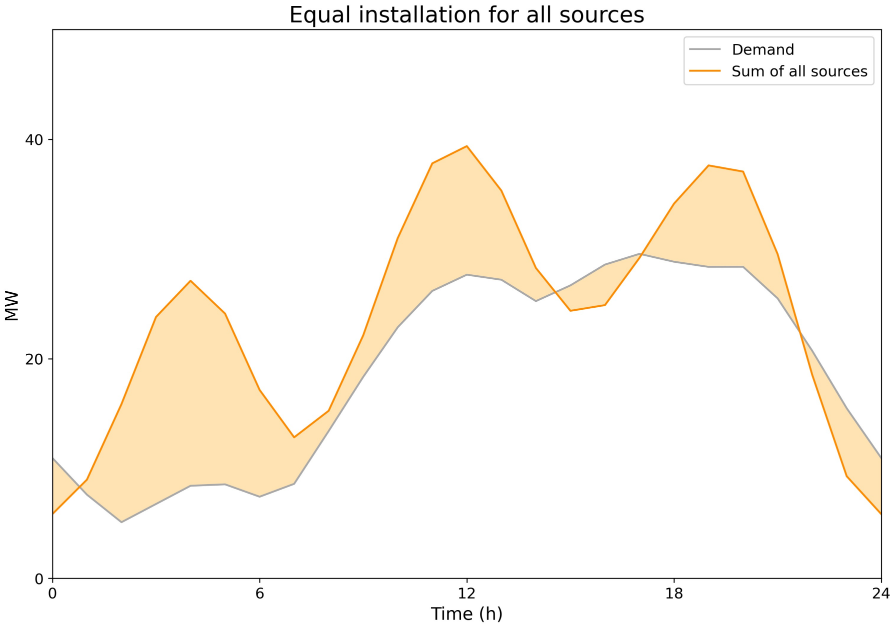


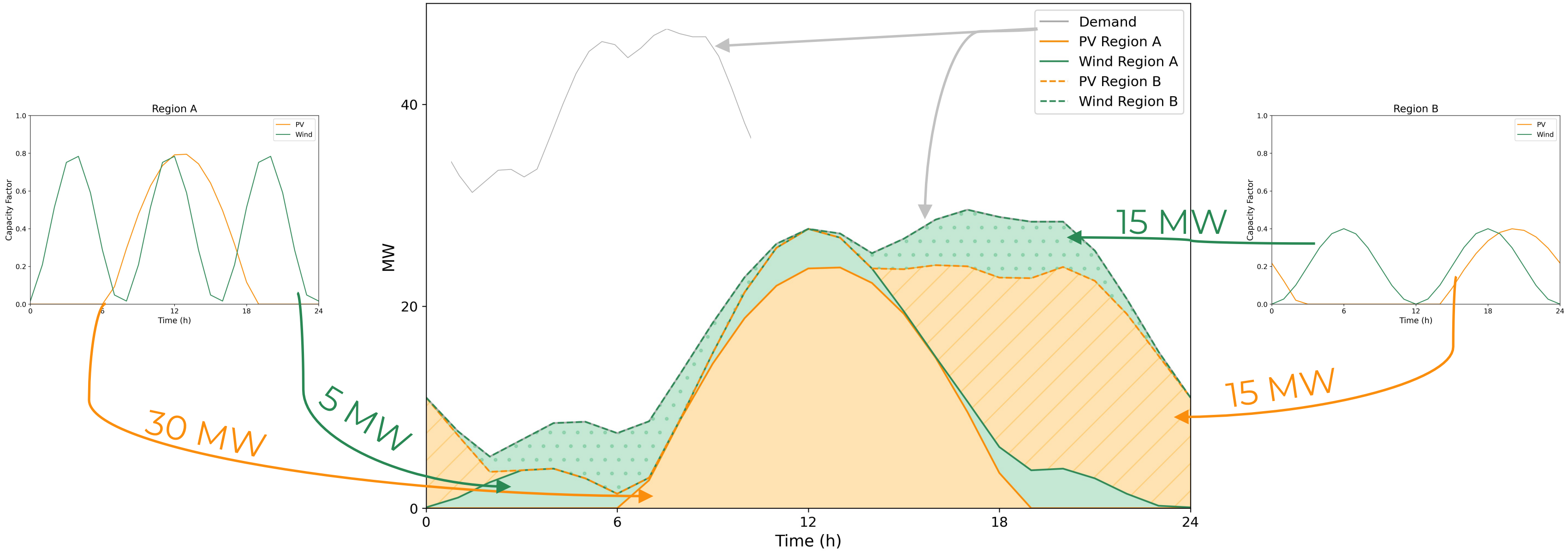
# AN ILLUSTRATIVE EXAMPLE

100 MW evenly split between all regions and technologies



# AN ILLUSTRATIVE EXAMPLE

100 MW **selectively** split between all regions and technologies



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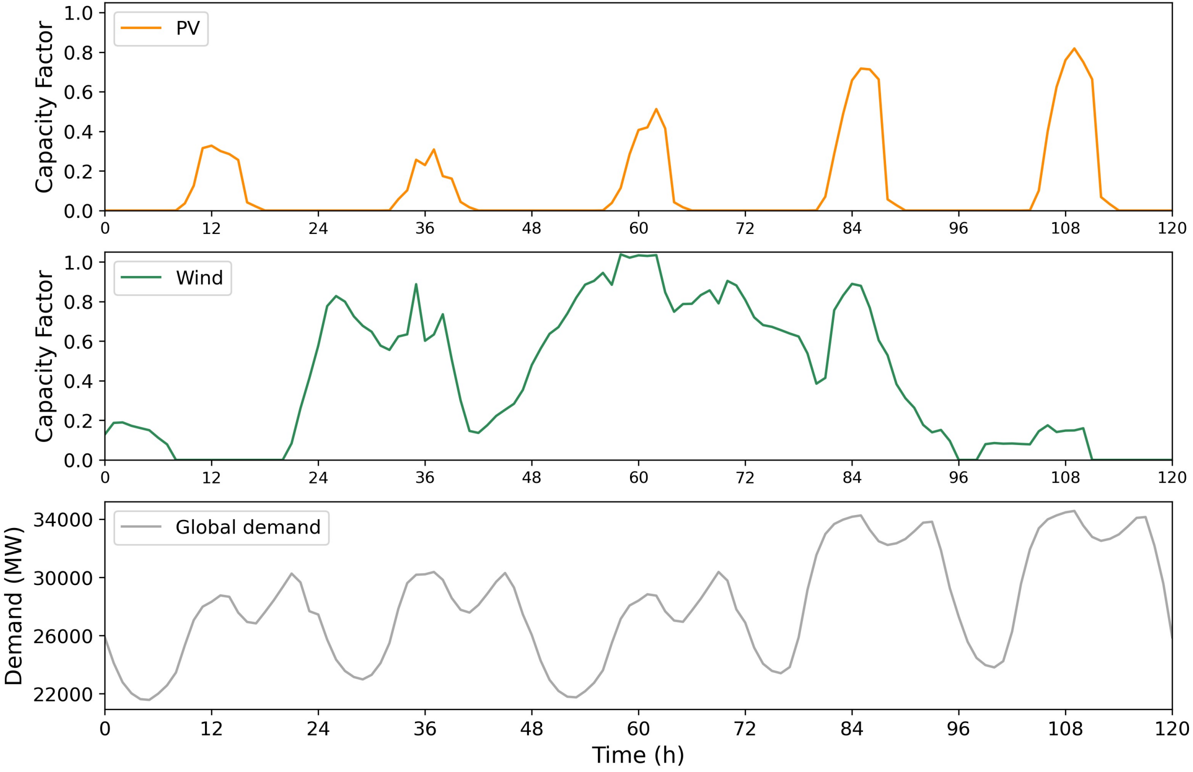
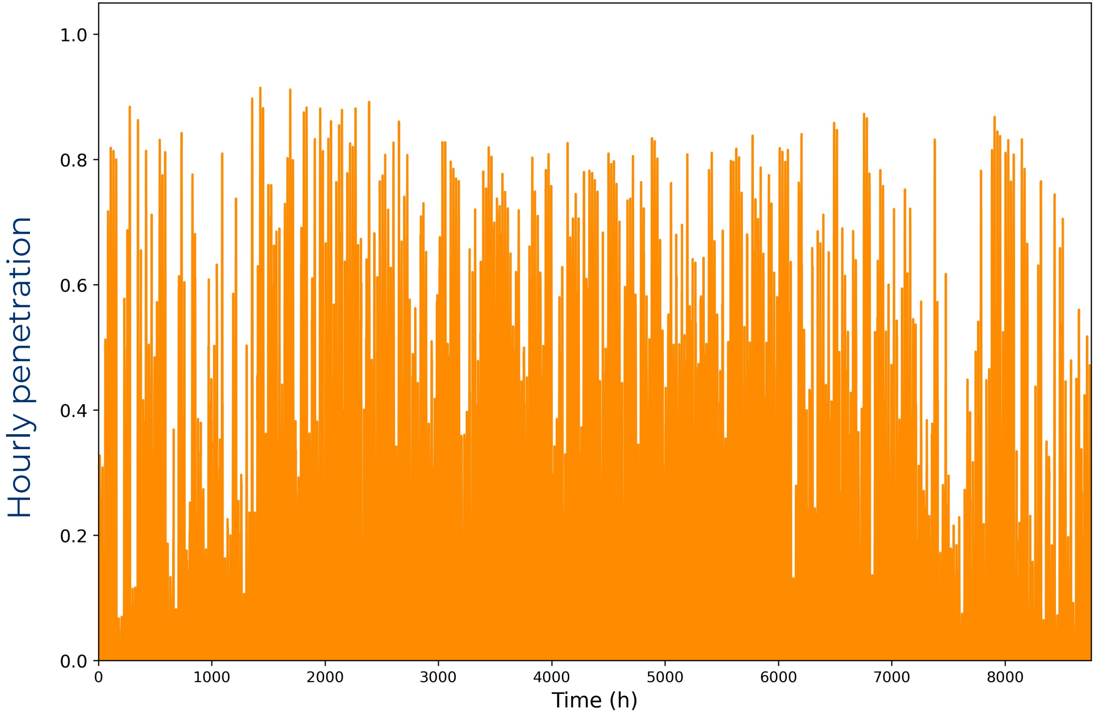



x 829

x 829

# AN ILLUSTRATIVE EXAMPLE

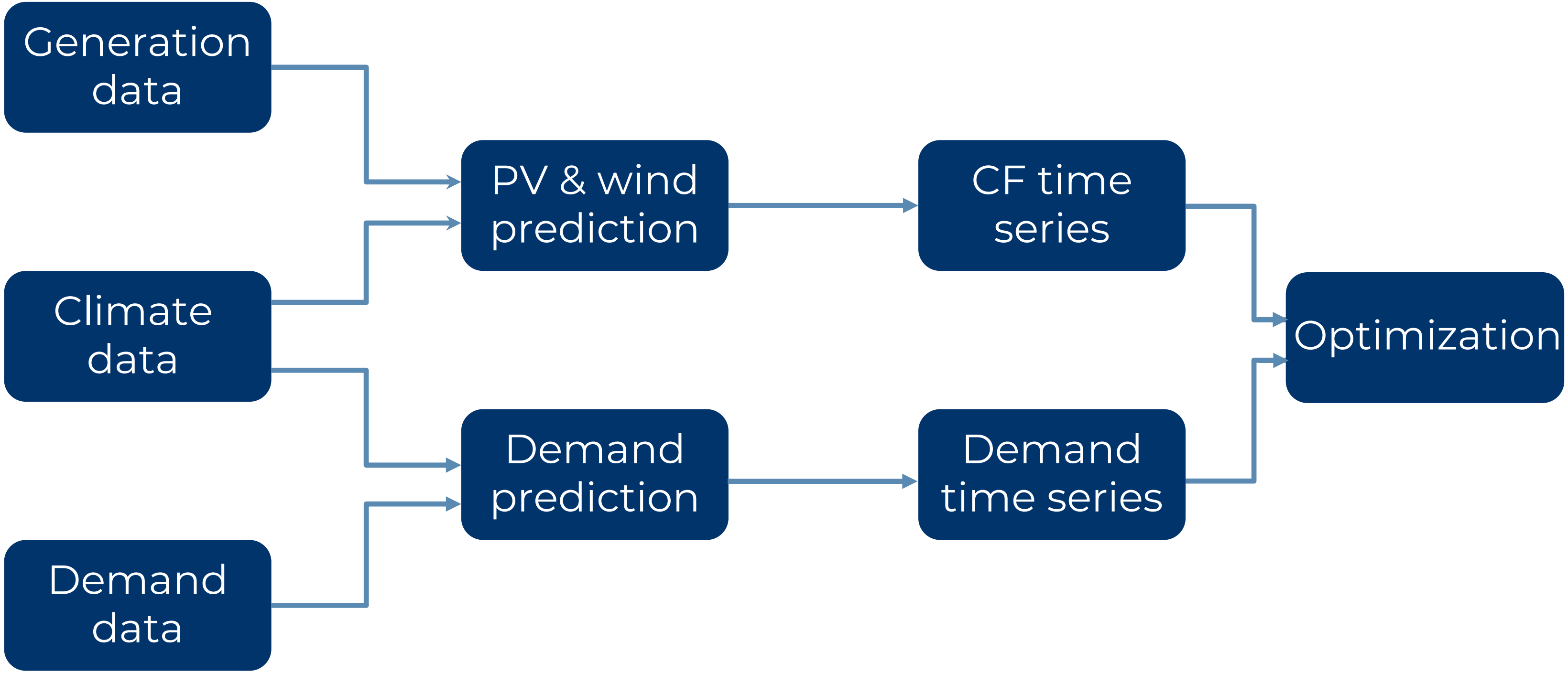



Global penetration
→ Mean

Risk
→ Variance

# The e4clim model

# THE E4CLIM MODEL



# THE E4CLIM MODEL

Generation data

Climate data

Demand data

## Climate data: ERA5

2m temperature

10 m wind components

Mean sea level pressure

Surface pressure

Mean surface downward radiation flux

Mean surface downward radiation clear sky

## Electricity data

**REE**

CCAA monthly generation

CCAA monthly demand

National hourly demand

CCAA yearly installed capacity

**Ministerio**

Local "daily" installed capacity

# THE E4CLIM MODEL

PV & wind prediction

Demand prediction

## Generation

Solar PV panel model

Wind energy generator model

## Demand

Dependent on temperature and type of day

Fitted to national hourly series scaled by regional monthly

# THE E4CLIM MODEL

## Generation to capacity factor

Simulated: how much of the potential generation the climatic conditions produce.

Observed: how much production is reported compared to the potential generation from the installed capacity

CF time series

Demand time series

## Calibration

Generation: CF is calibrated nationally to observations to reach realistic values

# THE E4CLIM MODEL

## Change the installed capacities to:

Maximize penetration (percentage of demand covered by renewable generation)

Minimize supply risks (variance as proxy, predictability of PV is considered)

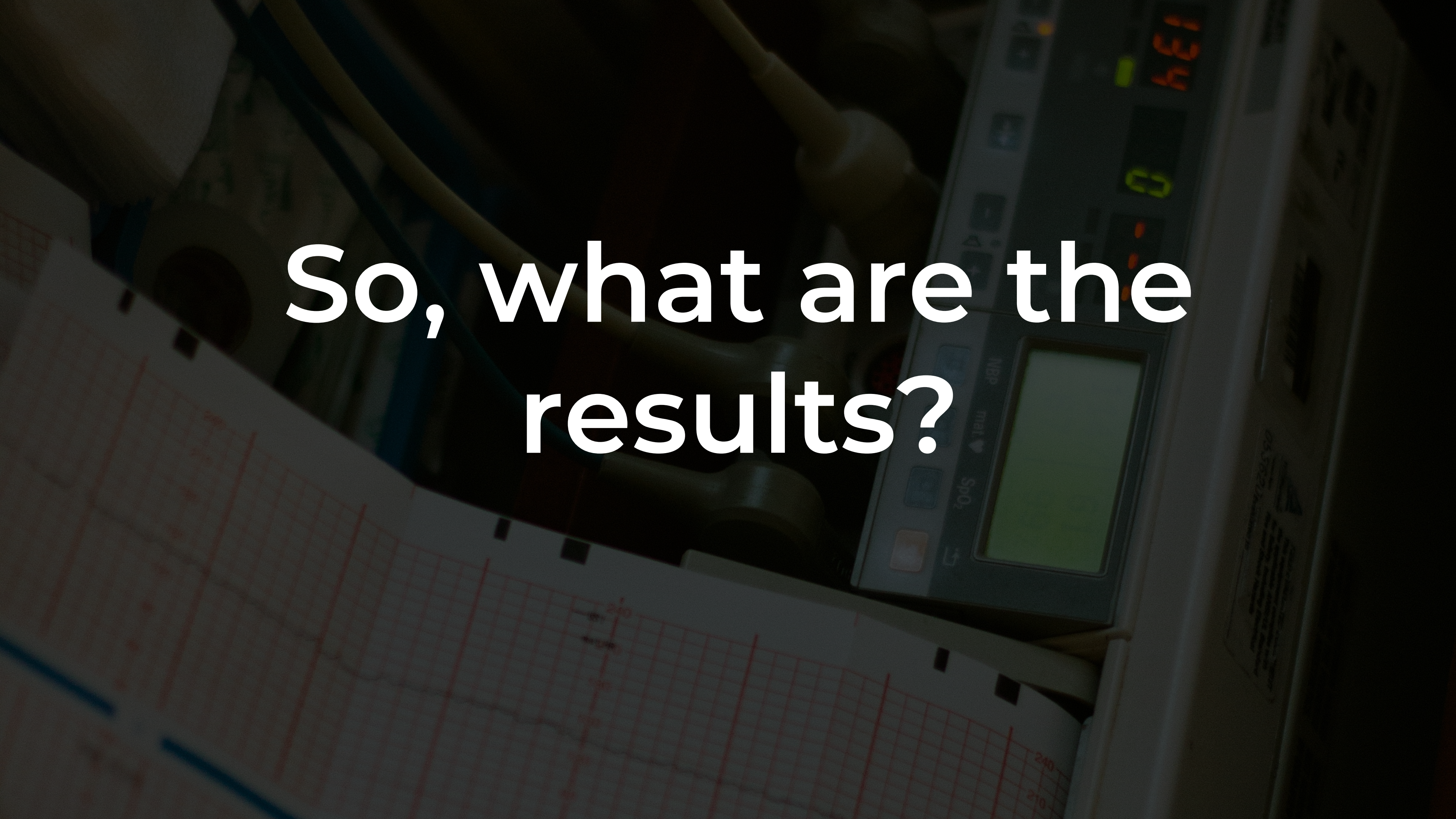
Optimization

## Constrained to:

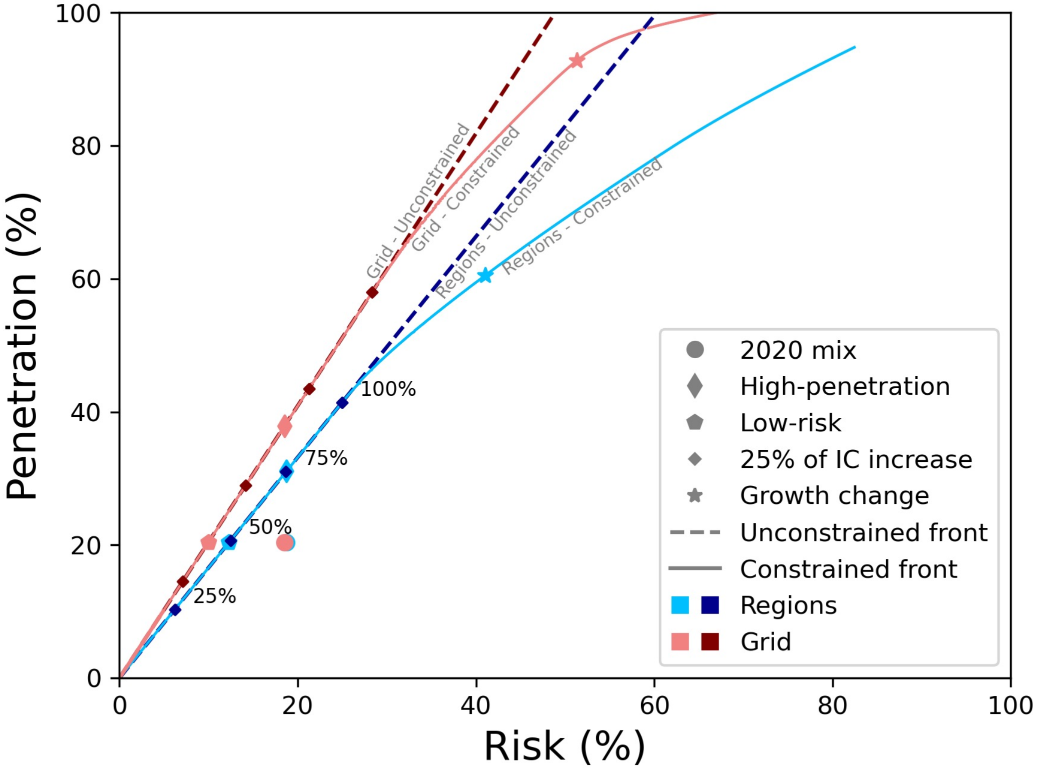
Capacities are non-negative

Total capacity can not exceed the 2020 mix

# So, what are the results?



# PARETO FRONT



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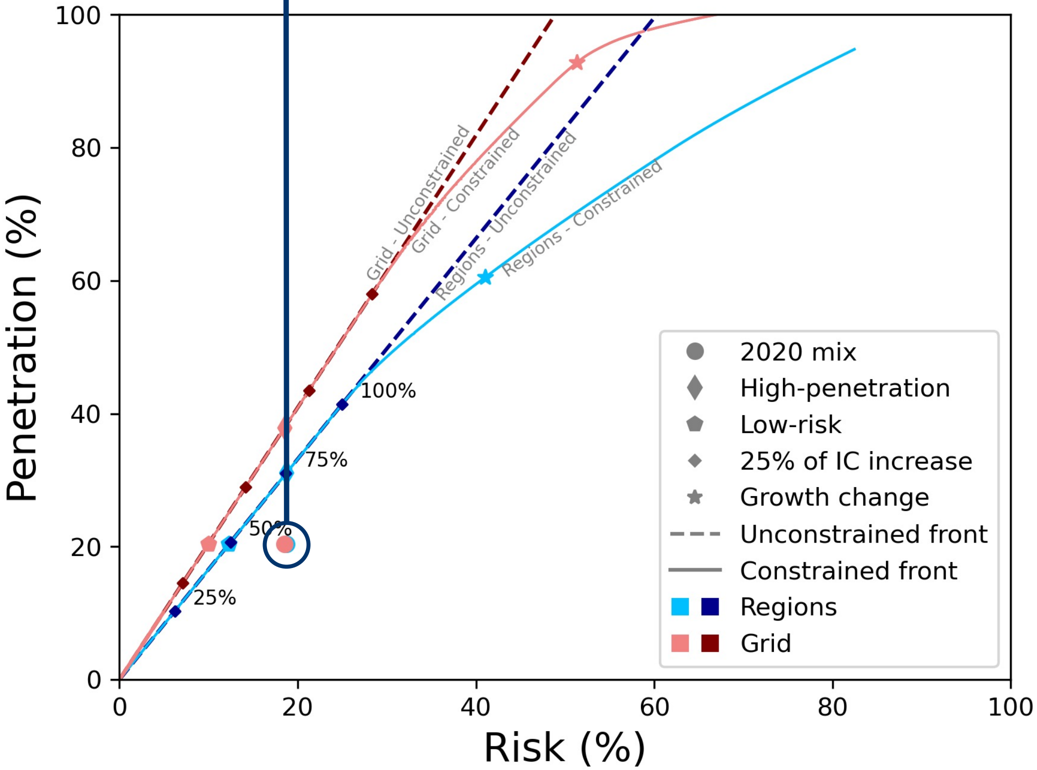
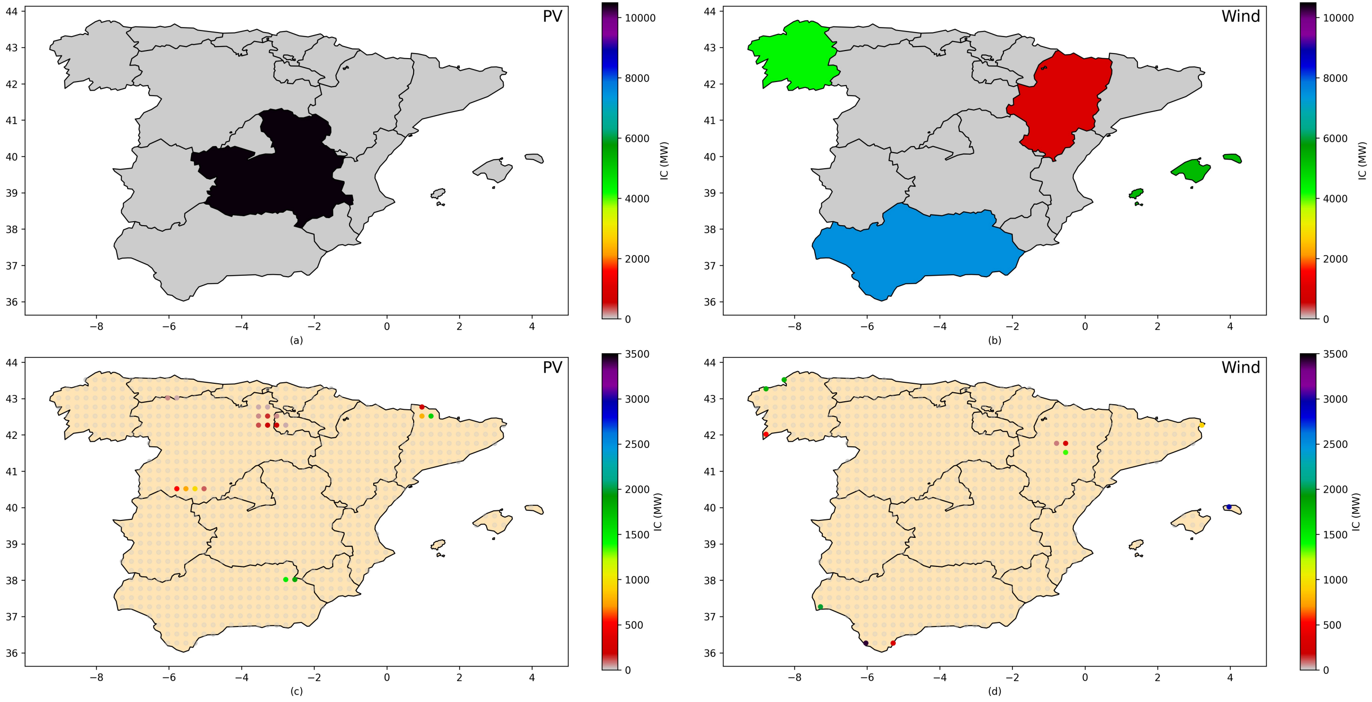


# THE HIGH PENETRATION DISTRIBUTION



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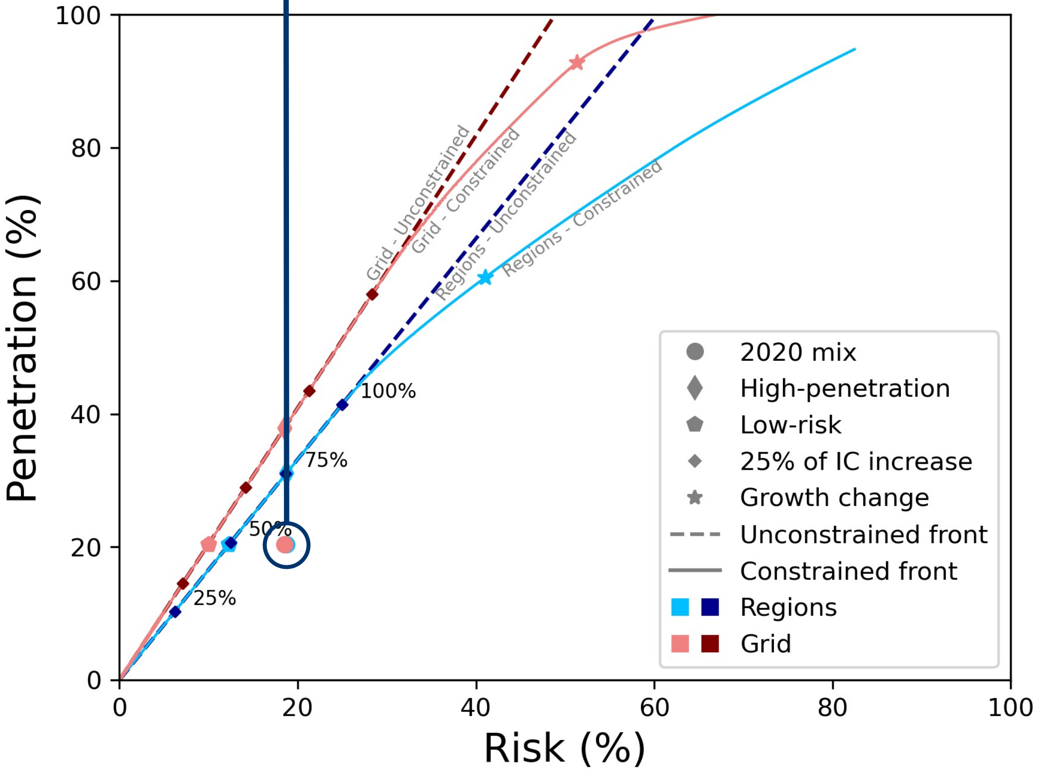

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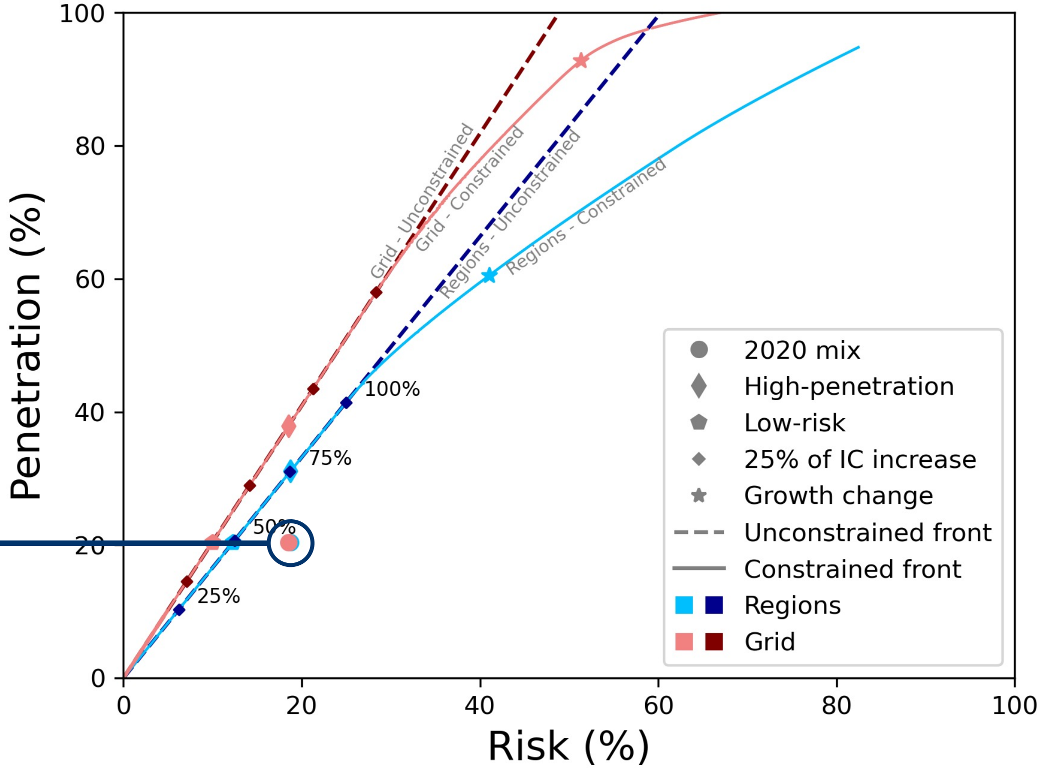
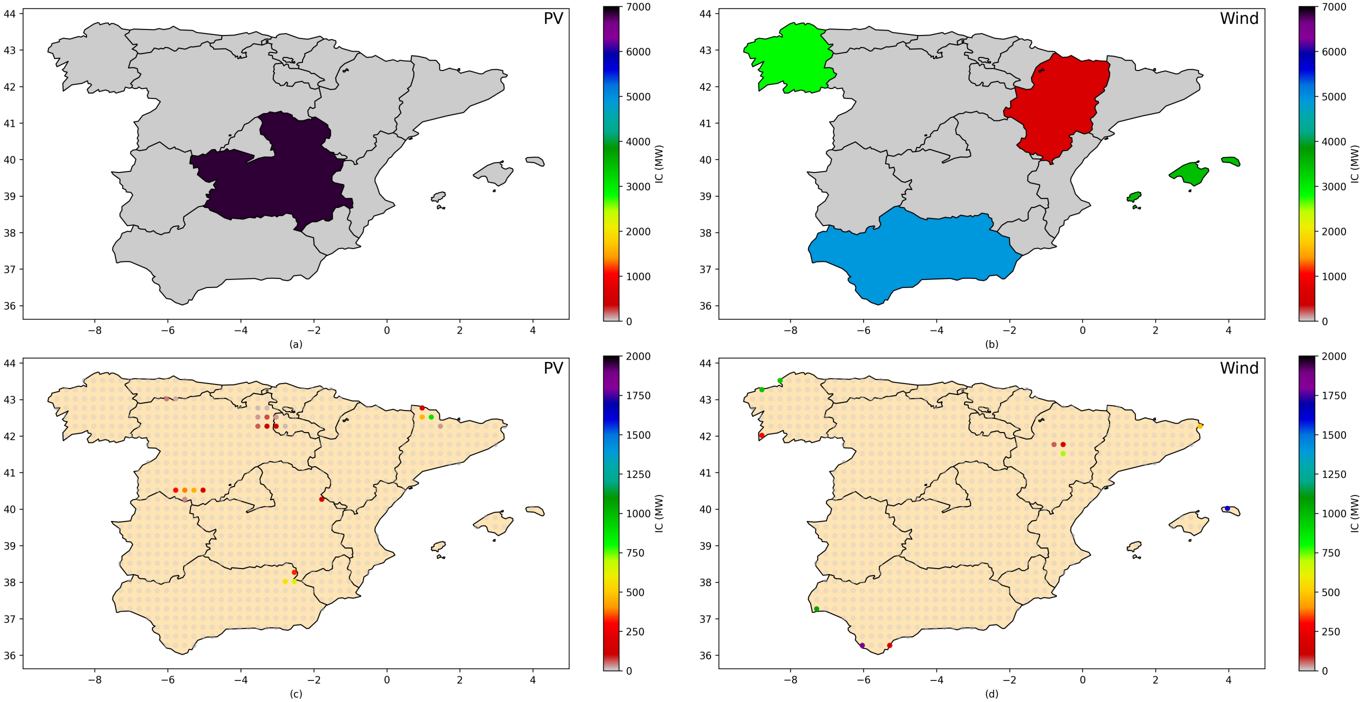


# THE LOW RISK DISTRIBUTION



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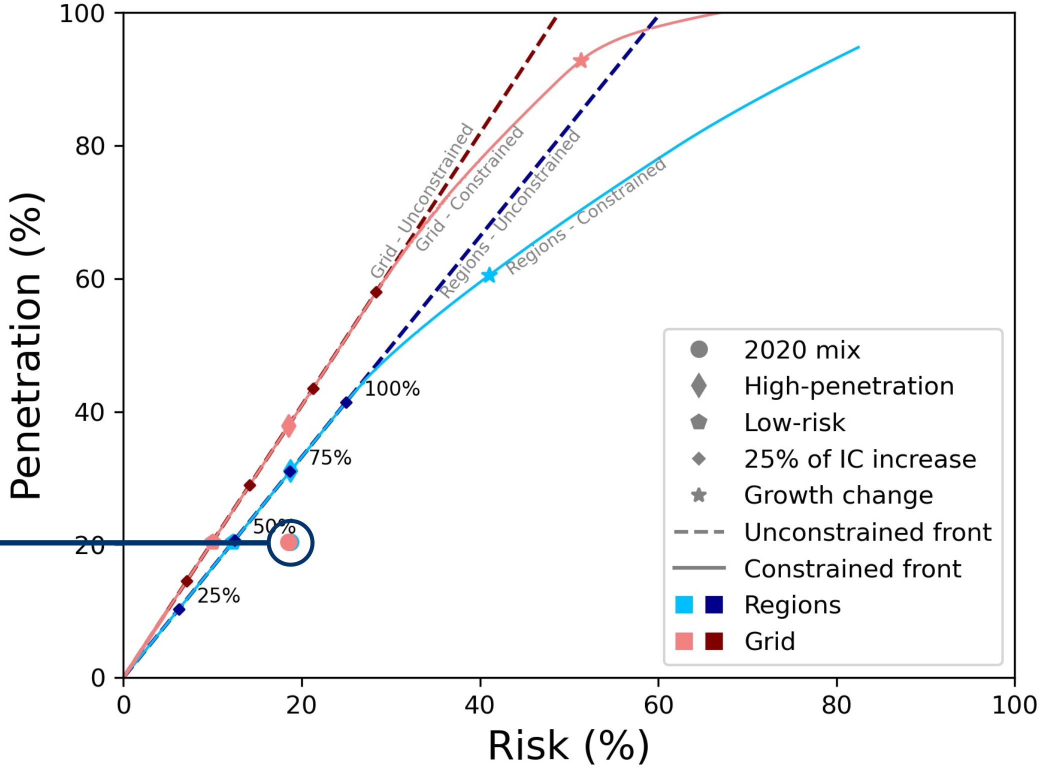
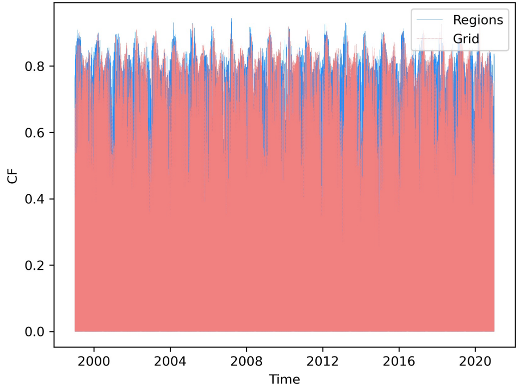


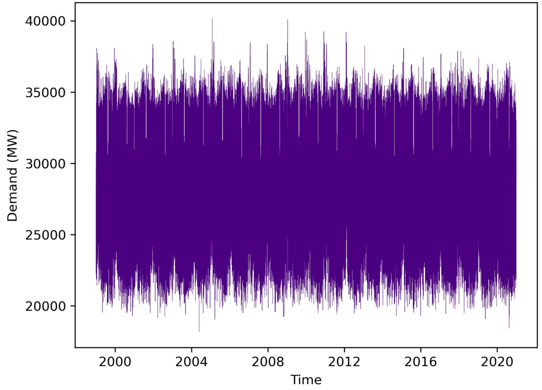
# Analyzing the time series

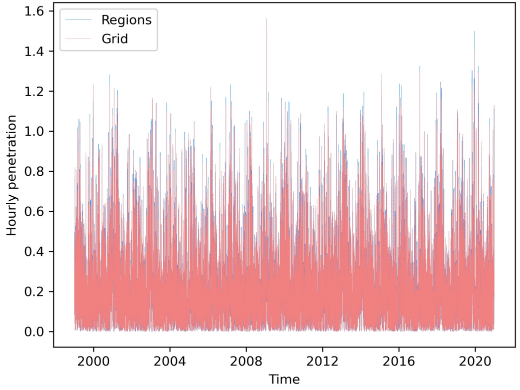
# HOURLY PENETRATION SERIES

CF series(t, x) x IC(x) / Demand series(t) = $\boxed{\text{Penetration series(t)}}$



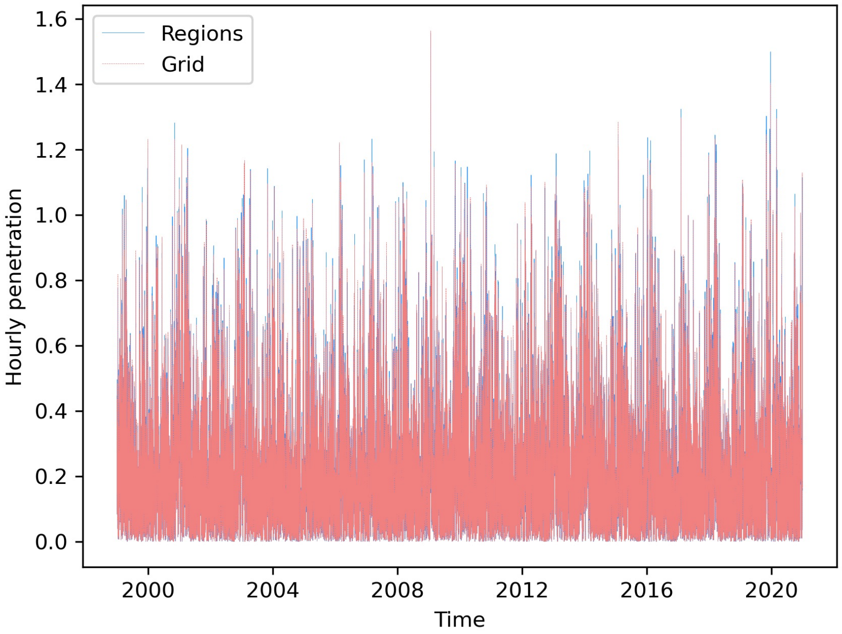

Example: PV in Andalucia




Example: 2020 mix

# HOURLY PENETRATION SERIES

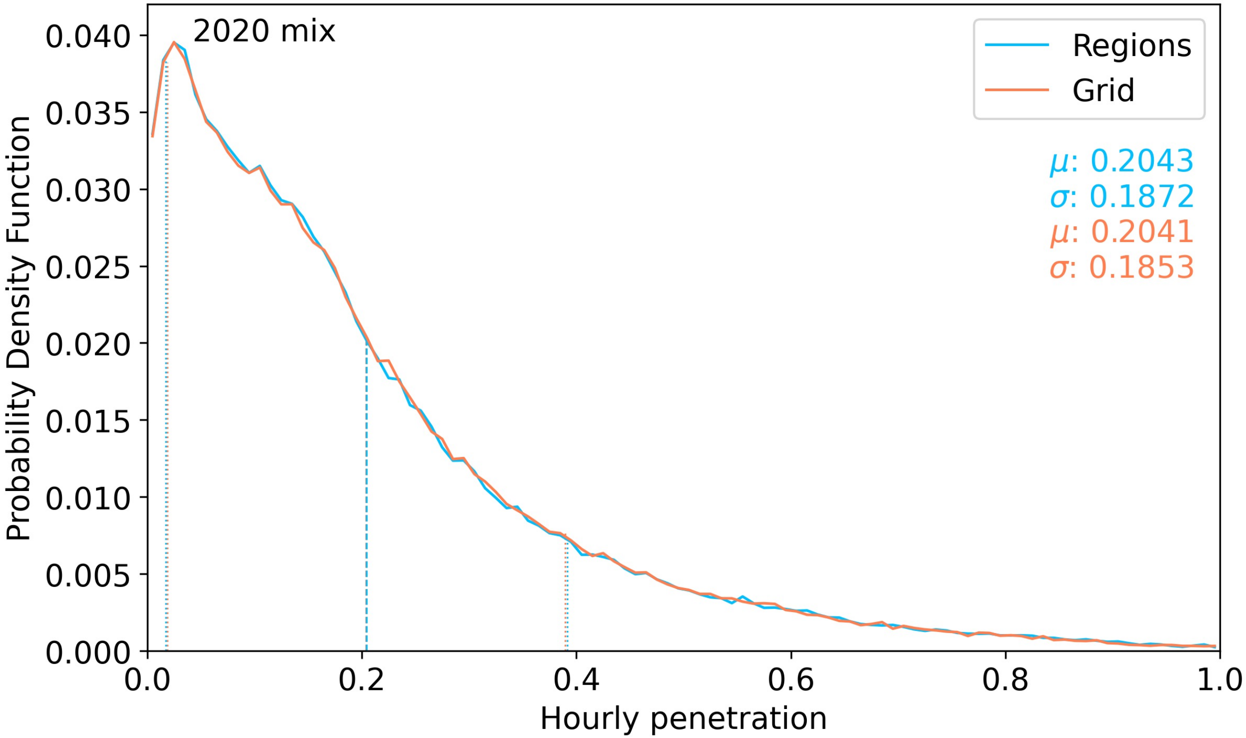



Example: 2020 mix

→ Probability density function

→ Fast Fourier Transform

# THE PROBABILITY DENSITY FUNCTIONS



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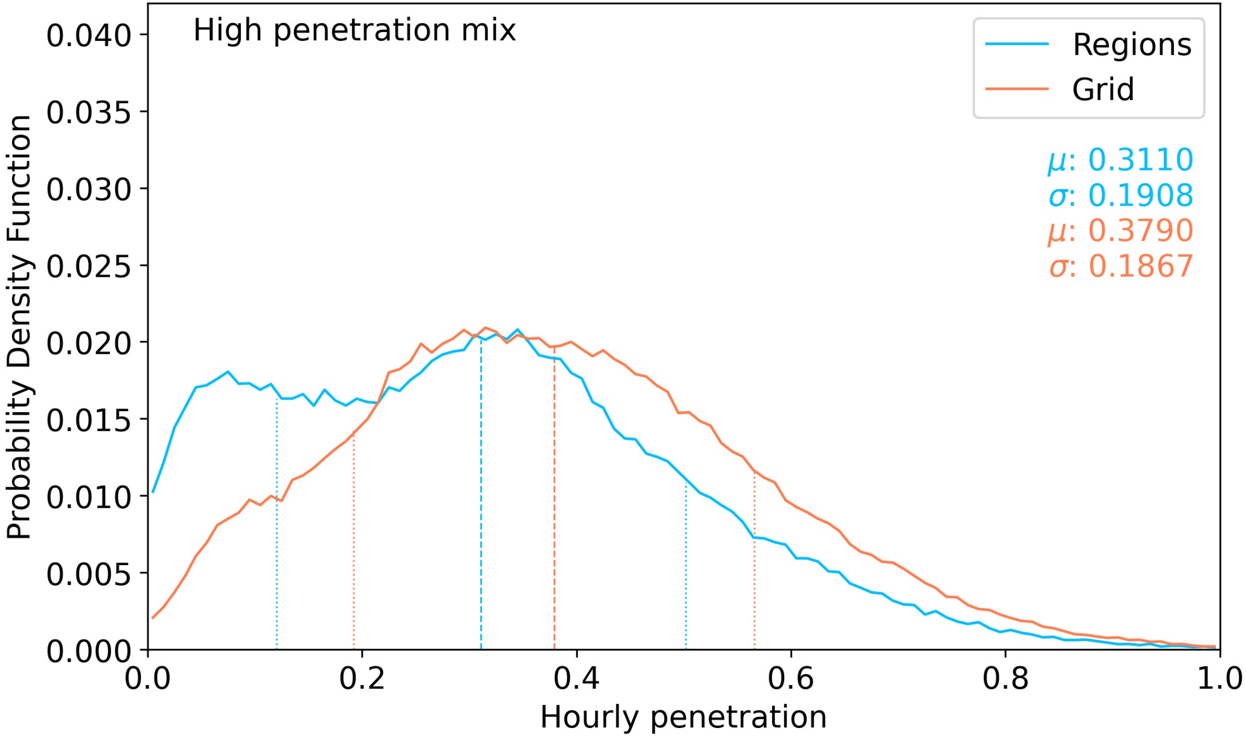

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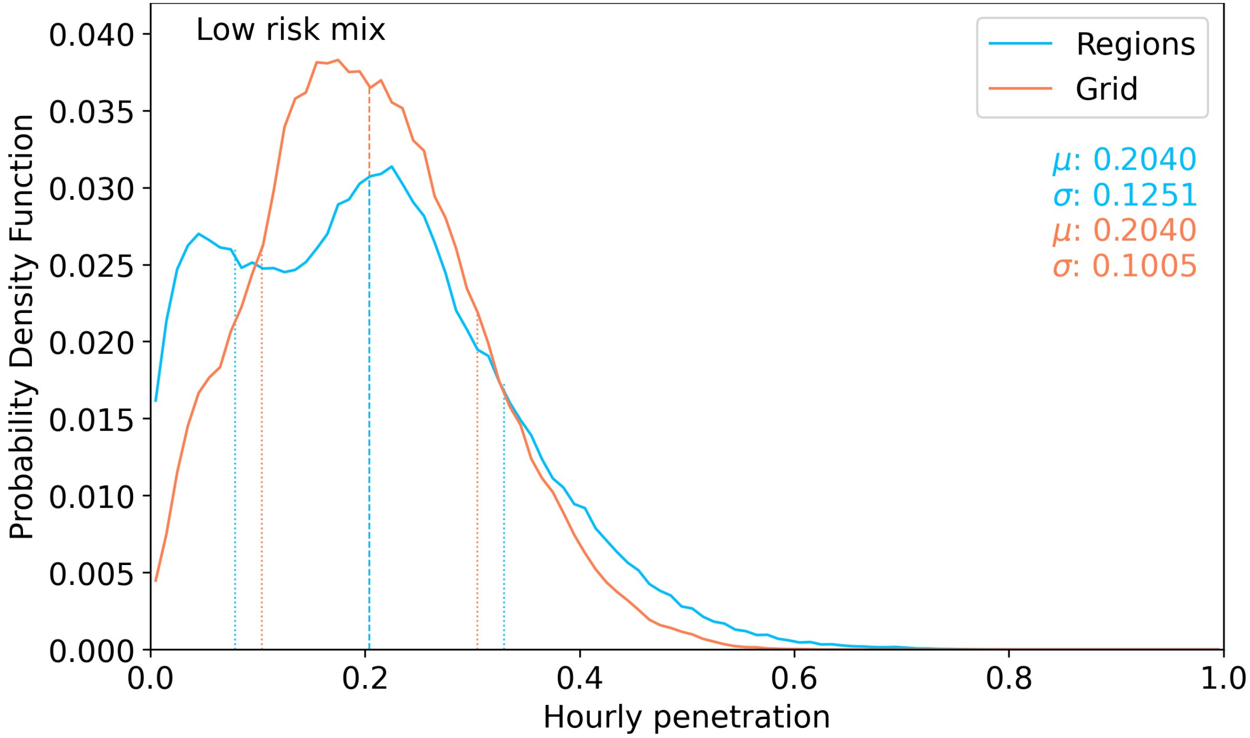
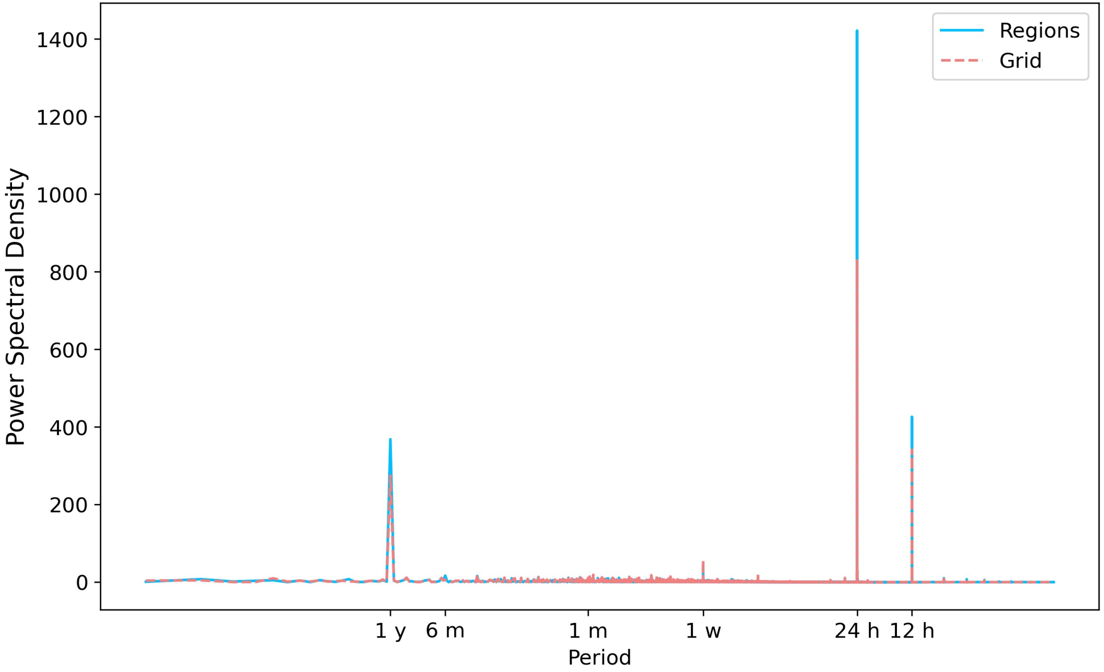


# THE FOURIER SPECTRA

## For the high penetration scenario



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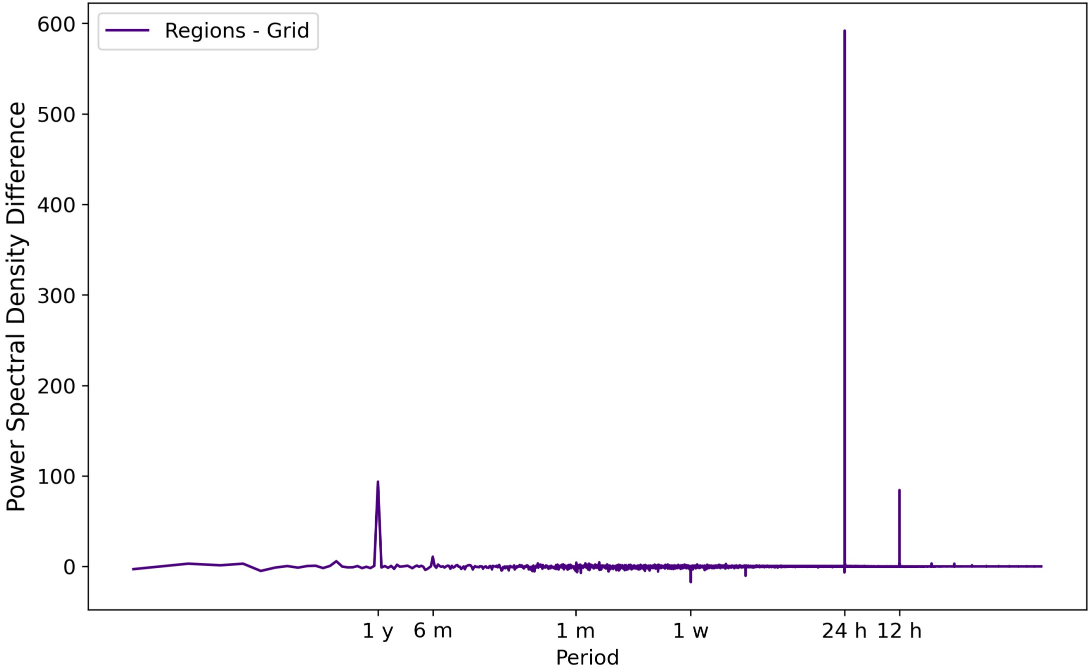
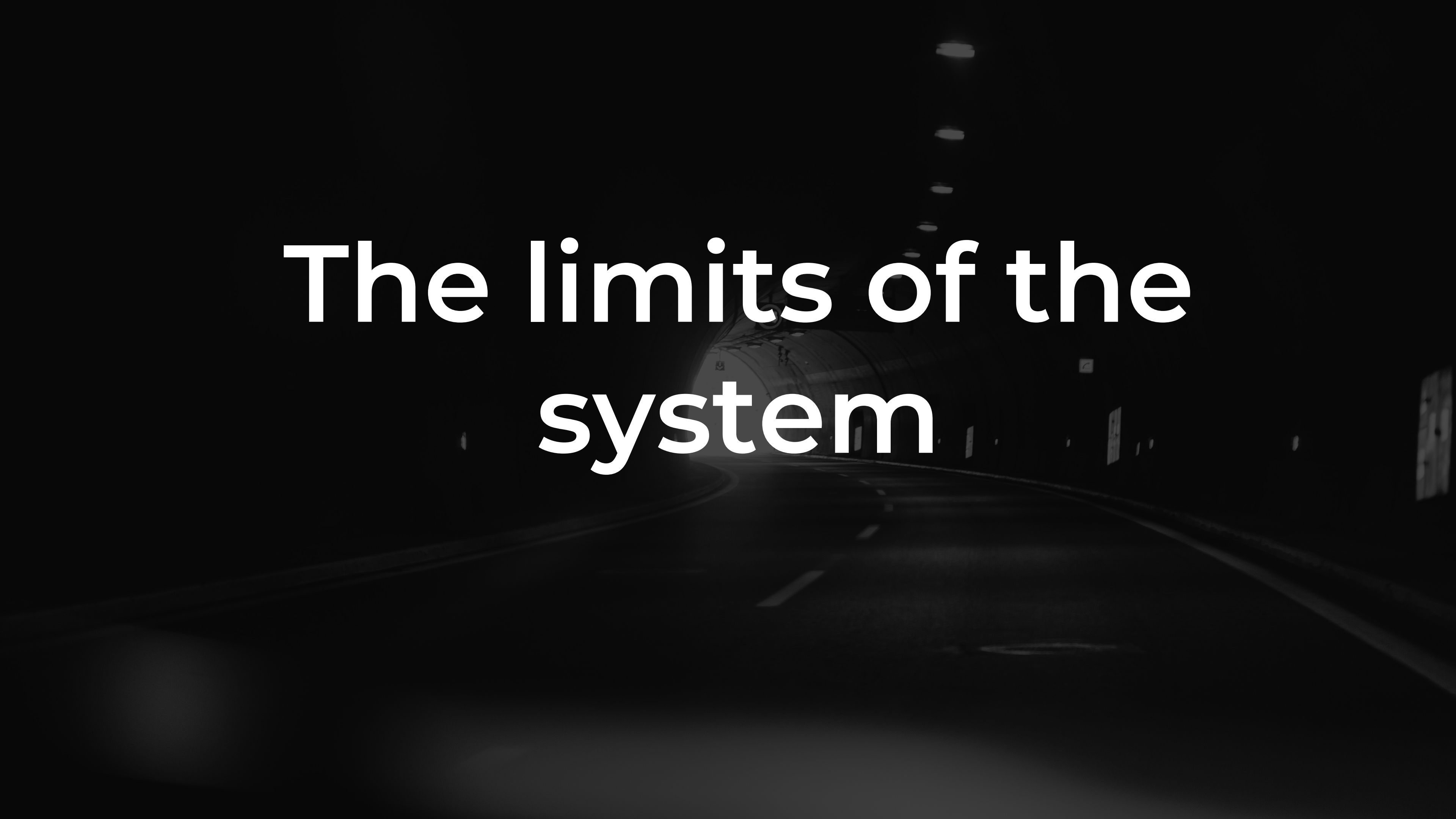
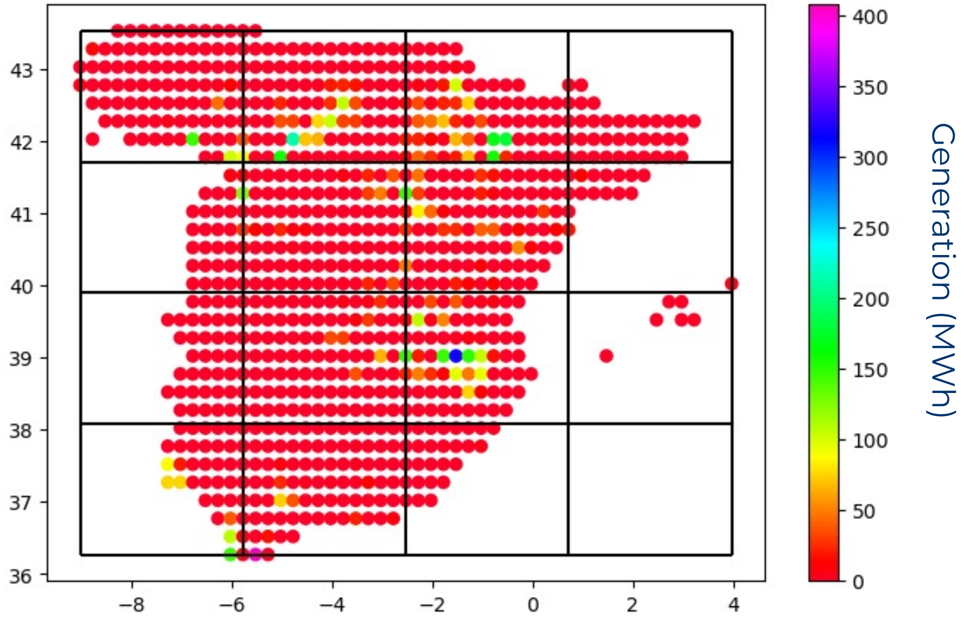




# The limits of the system

# THE DIVISION INTO REGIONS

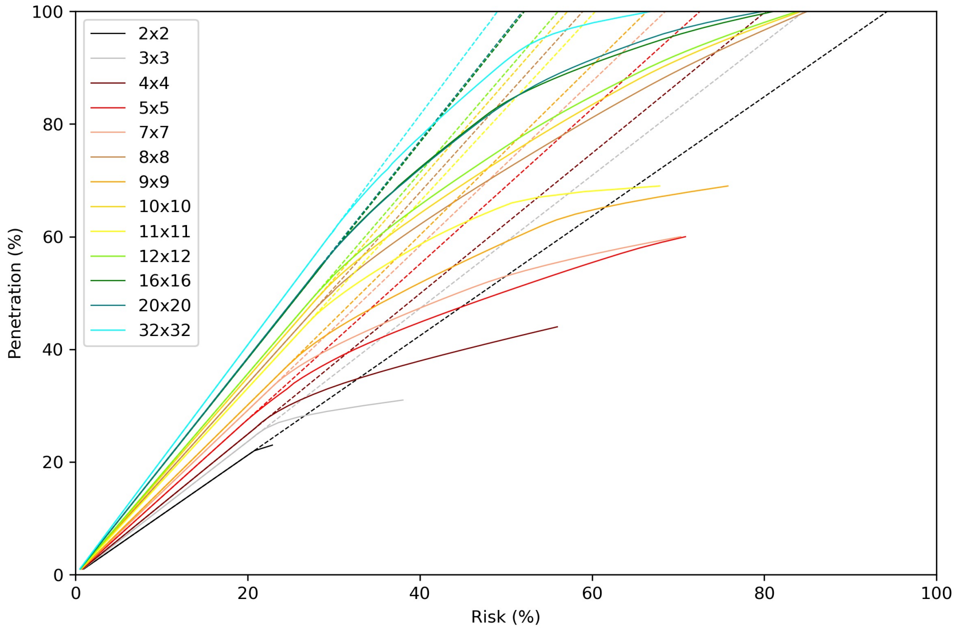
Split the grid into subsequent regions defined by a mesh




Example of the 4x4 mesh, with 15 non-null regions

# THE OPTIMIZATION FOR EACH GRID RESOLUTION

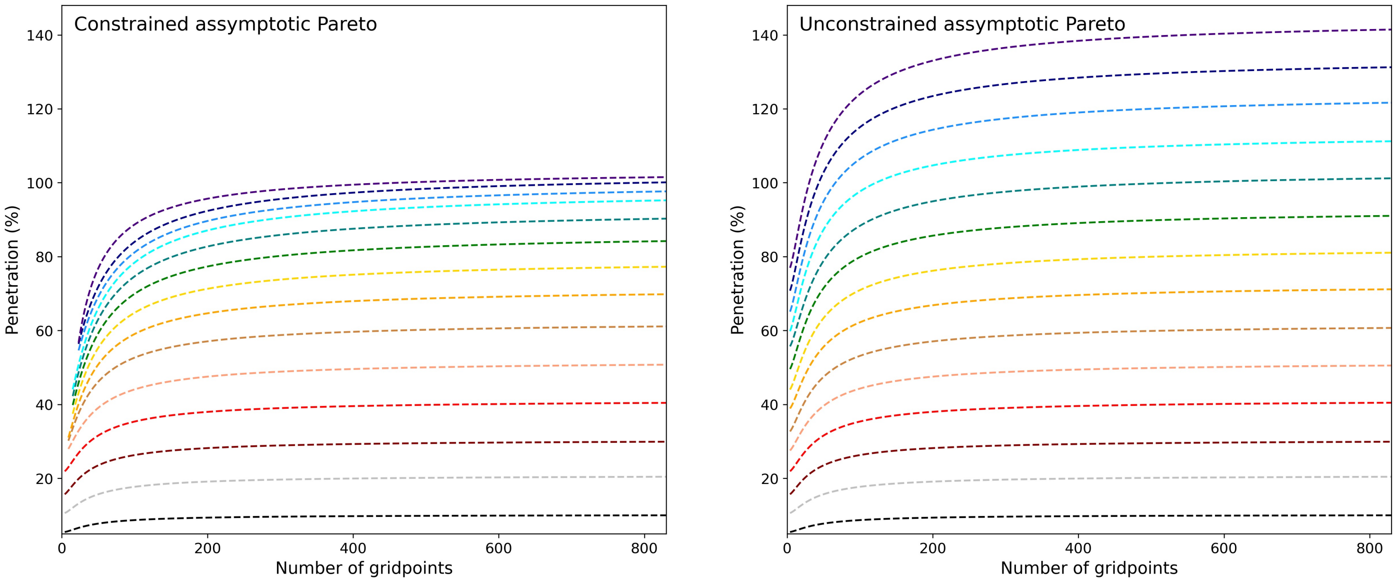
And optimize the IC for each grid resolution



# THE PURSUIT OF THE RESOLUTION-INDEPENDENT PARETO FRONT

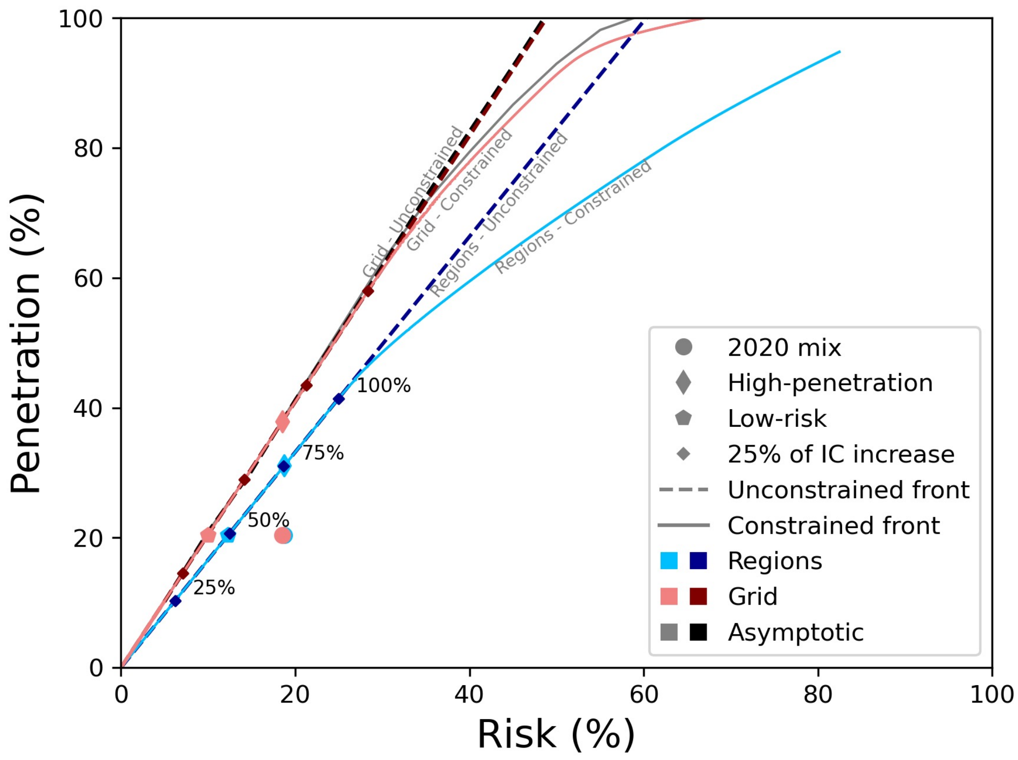
$$a\left(1+\frac{b}{x}\right)^{x}+c$$

$$\lim_{x\to\infty} = ae^{b}+c$$

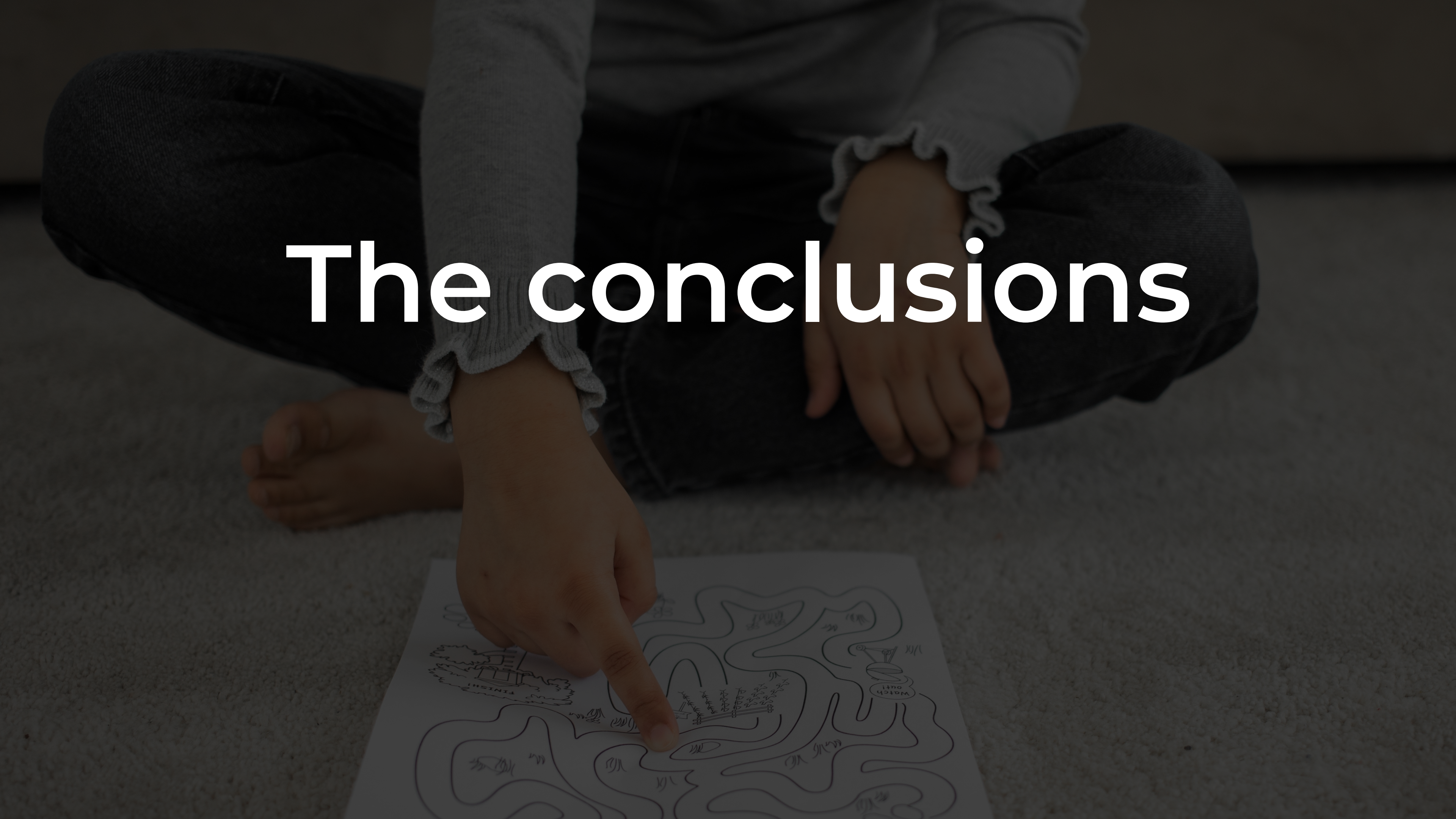



Risk from 5% to 70% in 5% intervals

# THE ASYMPTOTIC PARETO



# The conclusions



# CONCLUSIONS

The grid allows for a **more accurate** representation of reality.

The grid also returns **more optimal** scenarios.

The role of **covariances** is key to the difference in optimal mixes.

There is an **intrinsic system limit** to optimal scenarios.


# ACKNOWLEDGEMENTS

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