SOVN - NEW MARKET MODEL

EXPERIENCE AND RESULTS

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Agenda

- Introduction
- Base method
- Results
- Challenges
- Conclusion

Introduction

- SOVN

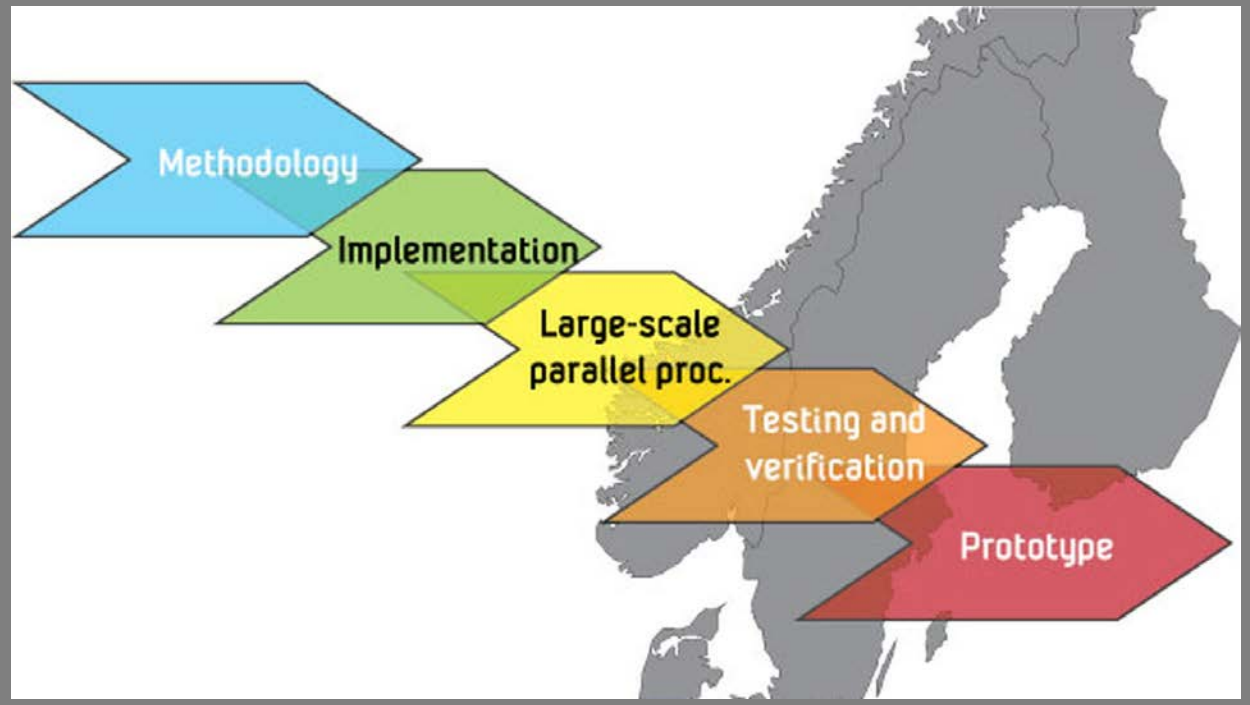
  Stochastic **O**ptimization with individual water **V**alues and grid restrictions for **N**ordic power system

- 2013 to mars 2017

- 14.8 mill NOK

Project goal

- Multi-stage stochastic optimization
- Large-scale (Europe)
- Detailed description of hydropower
- No calibration and no heuristic



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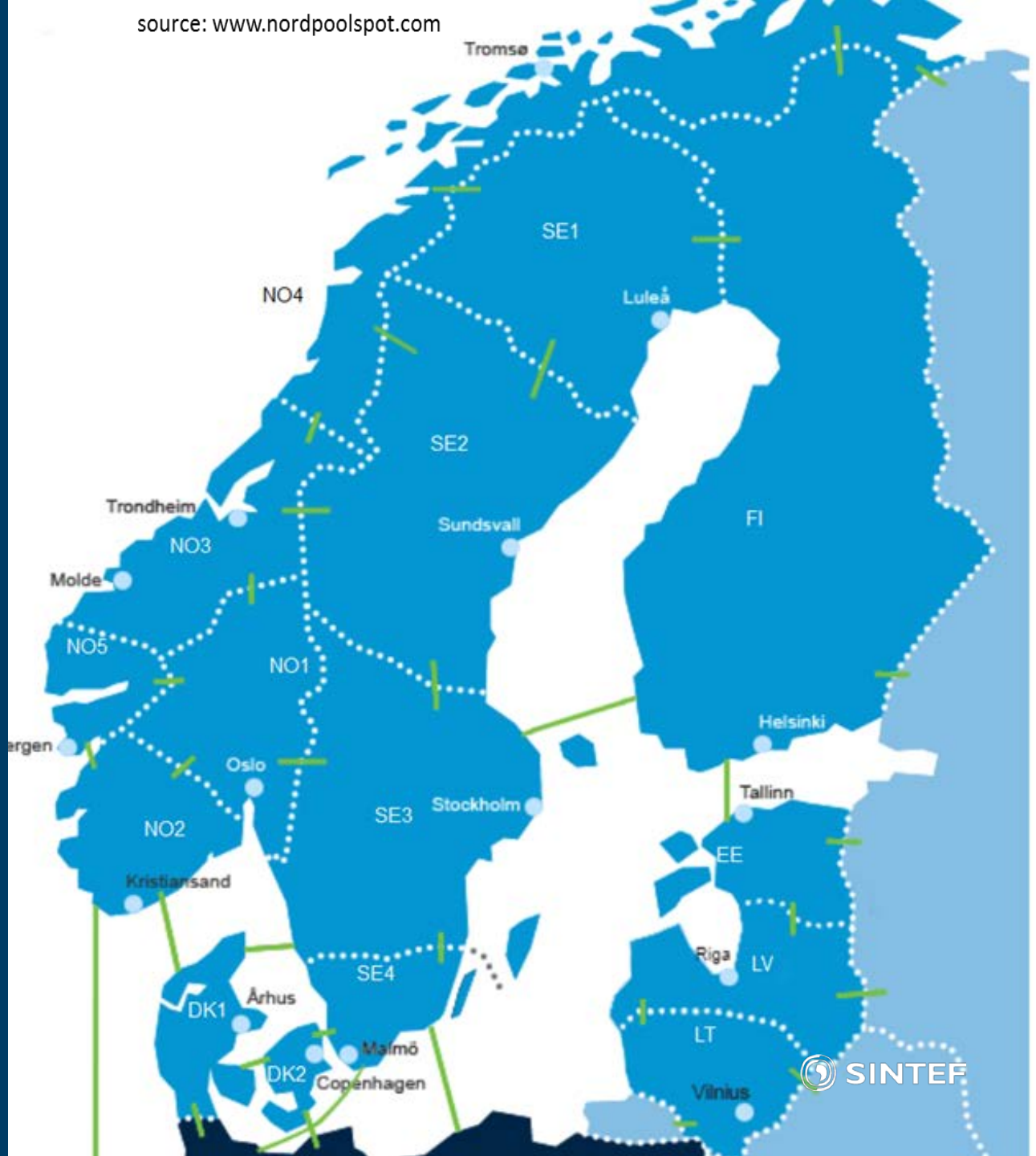
Motivation

- Mixture of generation
  - Higher variations (wind, sun)
- More interconnectors

- Hydropower
  - Balancing the high variation
    - 50 % of total storage capacity in Europe
    - Quick to change
  - Environment
  - Individual water values (marginal cost)
- Optimization with regard to physical details more important

Applications

- Price forecast
- Long-term operation of hydro power
- Investment decisions
  - Production and transmission



Functionality

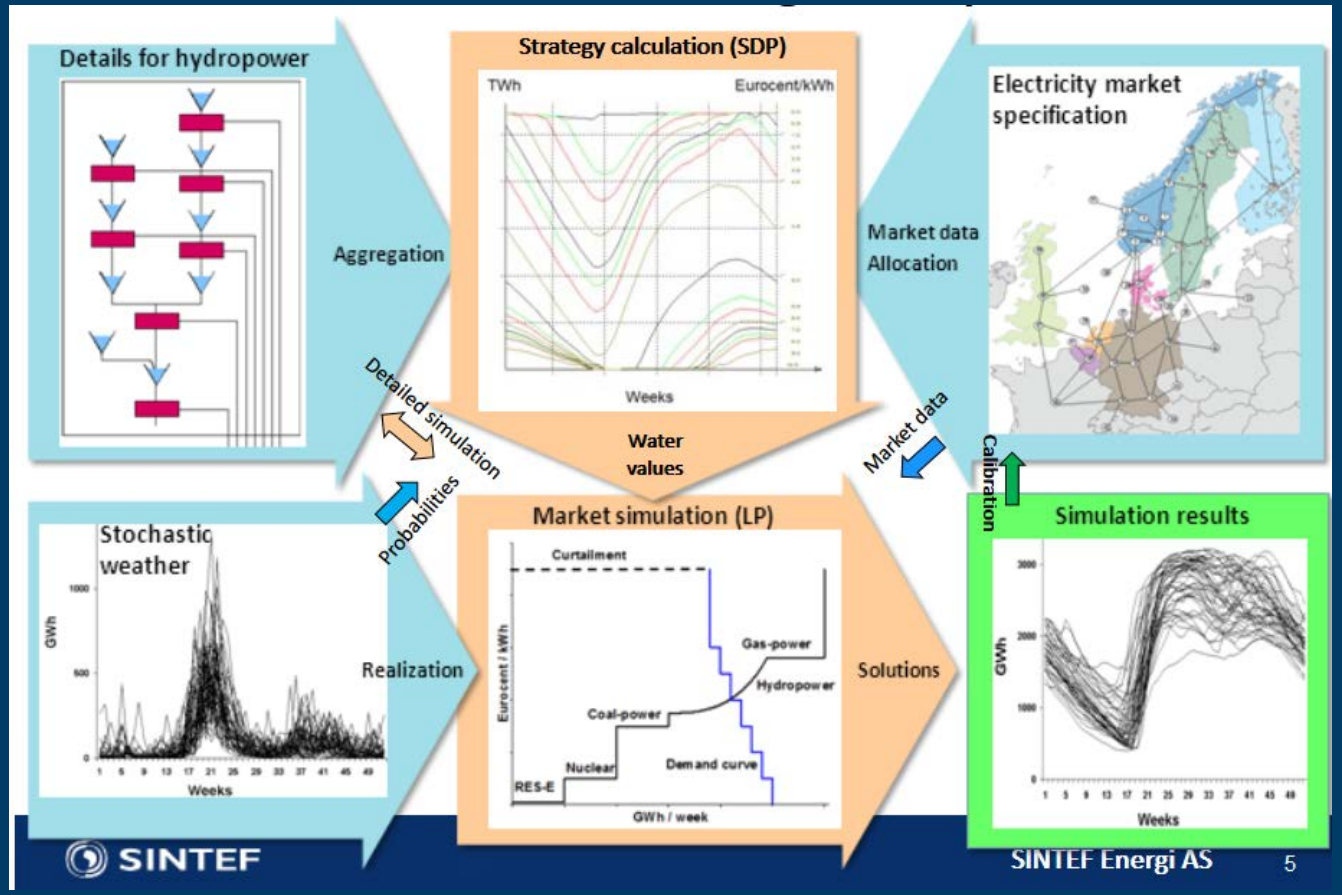
- All EMPS functionality
- Additional hydro modelling:
  - Head correction in strategy
  - Time delay on flows
  - Ramping on production
- Grid:
  - Transmission constraints between areas
  - Physical flow at area levels (PTDF)
  - Physical flow at area levels calculated from detailed flow (PTDF)
  - Ramping on cable/line
- Reservation of capacity: up and down

Method

- Solve the same problem as EMPS, Samtap, Samnett, ReOpt

- Maximize socioeconomic surplus

Overview of EMPS concept



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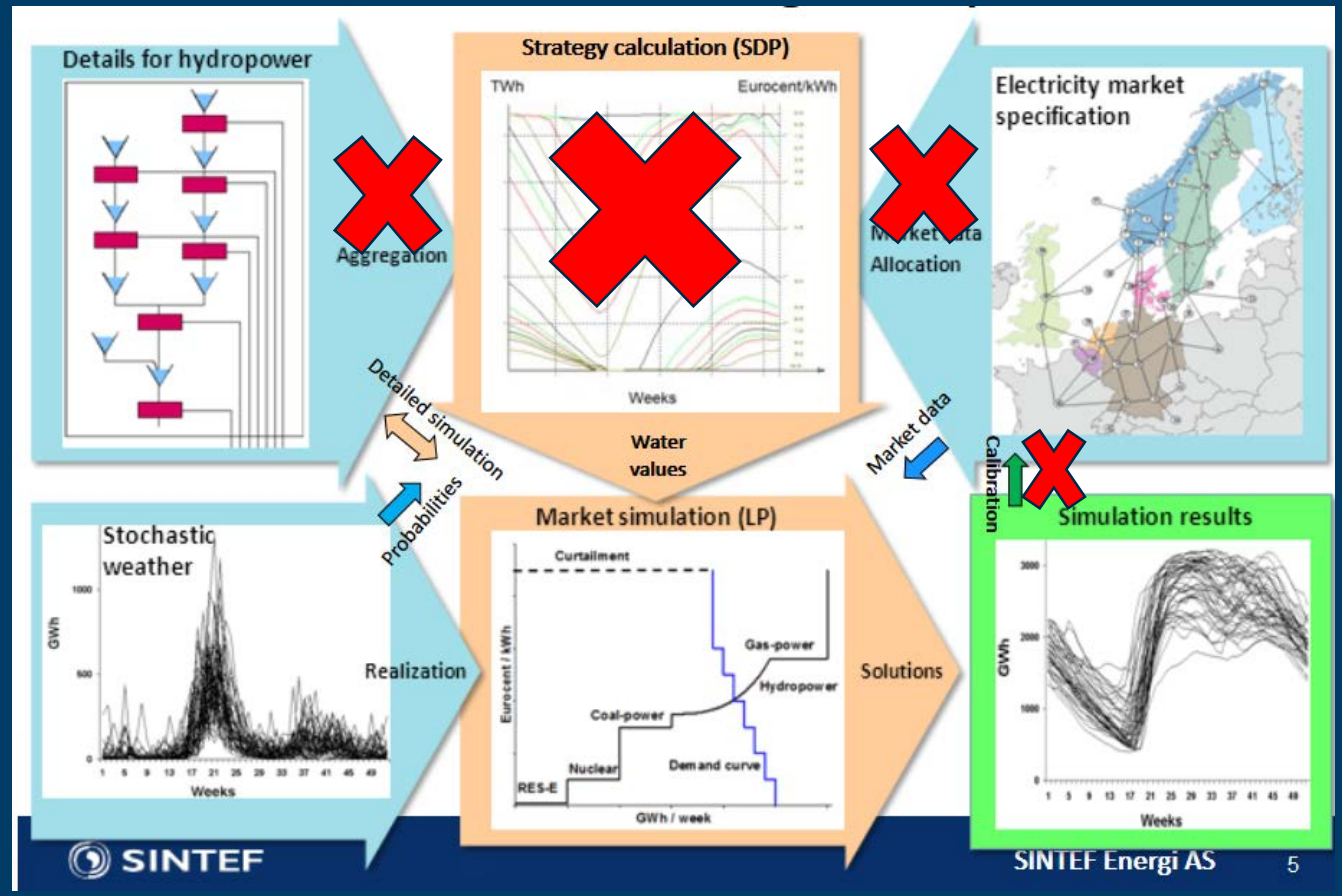
Method

- Strategy in combination with market simulation
- Formal optimization
  - No heuristics
  - No aggregation and disaggregation
- No need for calibration

Overview of EMPS concept



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Method

- 2 stage stochastic optimization problem
- Deterministic first stage (week)

- Scenario fan (second stage)
  - Uncertainty in:
    - Inflow, temperature, wind, solar, snow
    - Exogenous prices
  - Scenarios from historical data
    - Correlations in time and space

Scenarios

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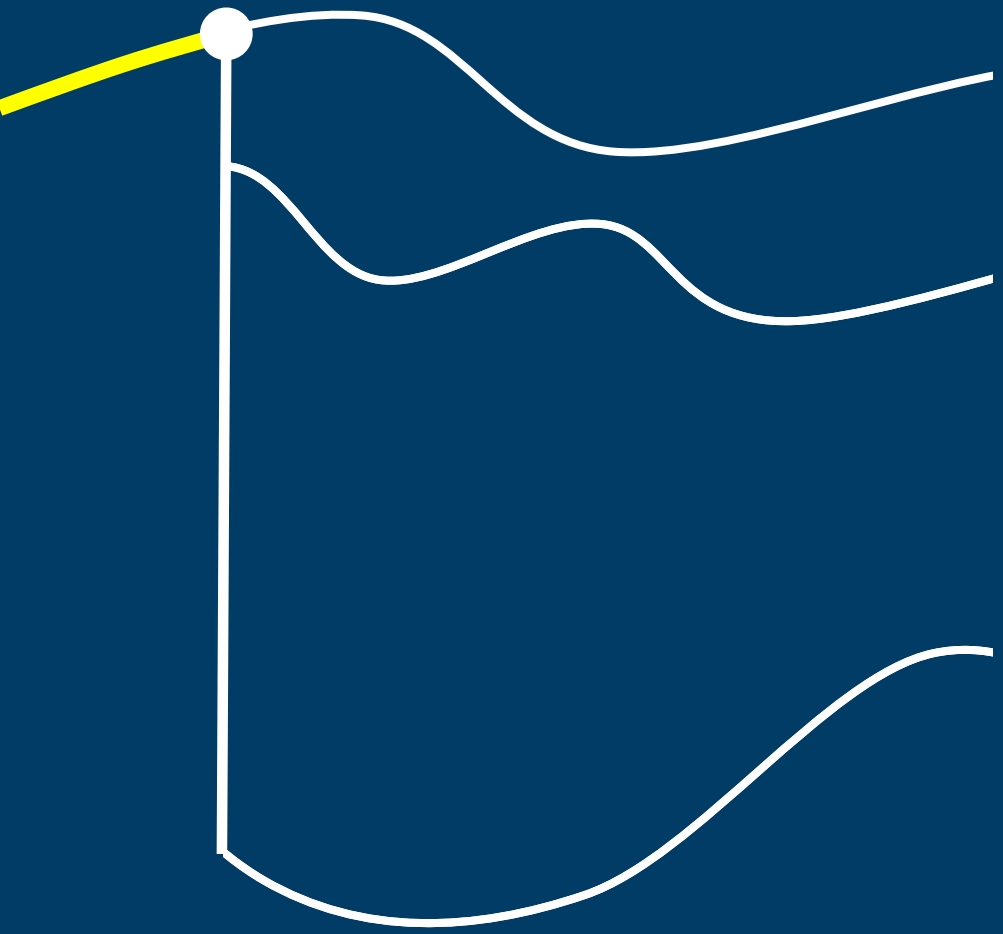
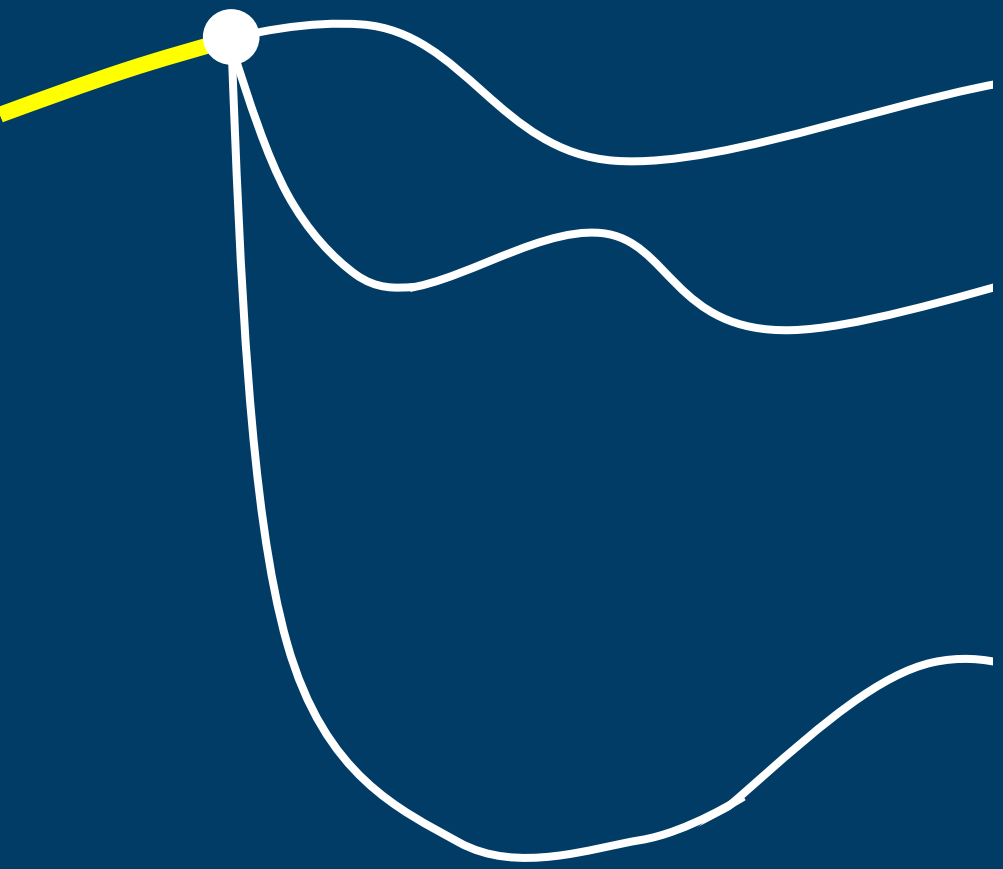
Solving first scenario

Two stage problem

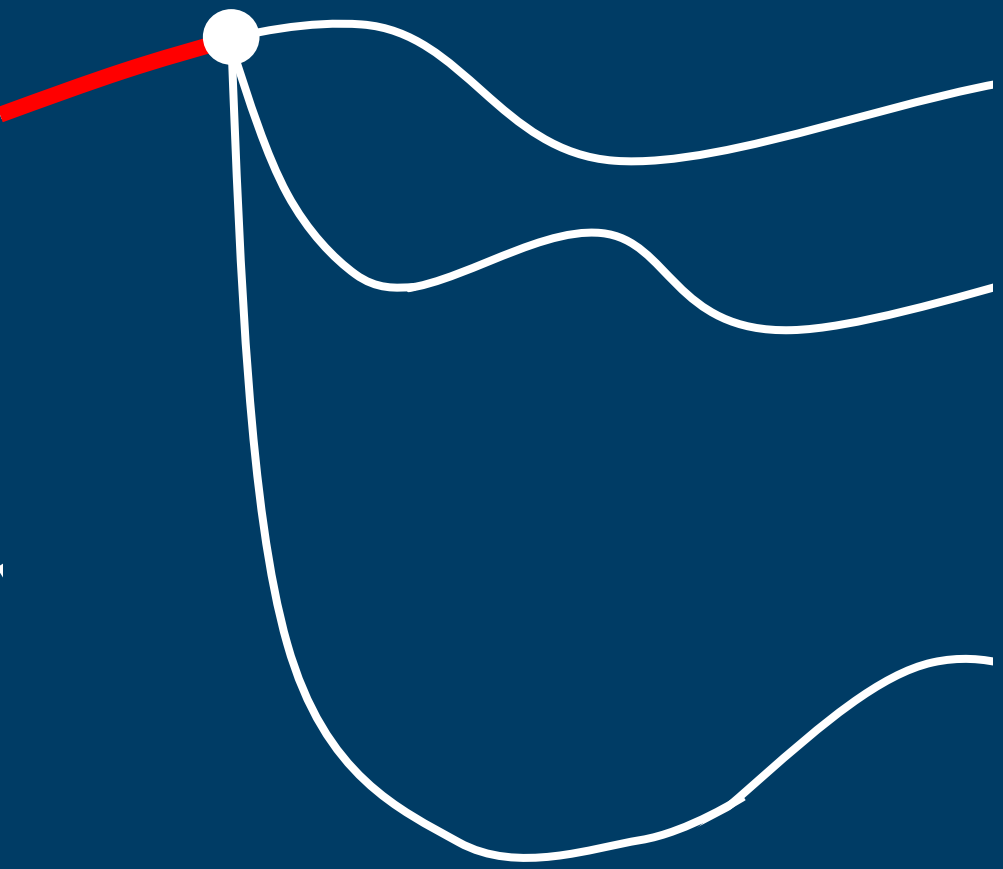
Scenario reduction



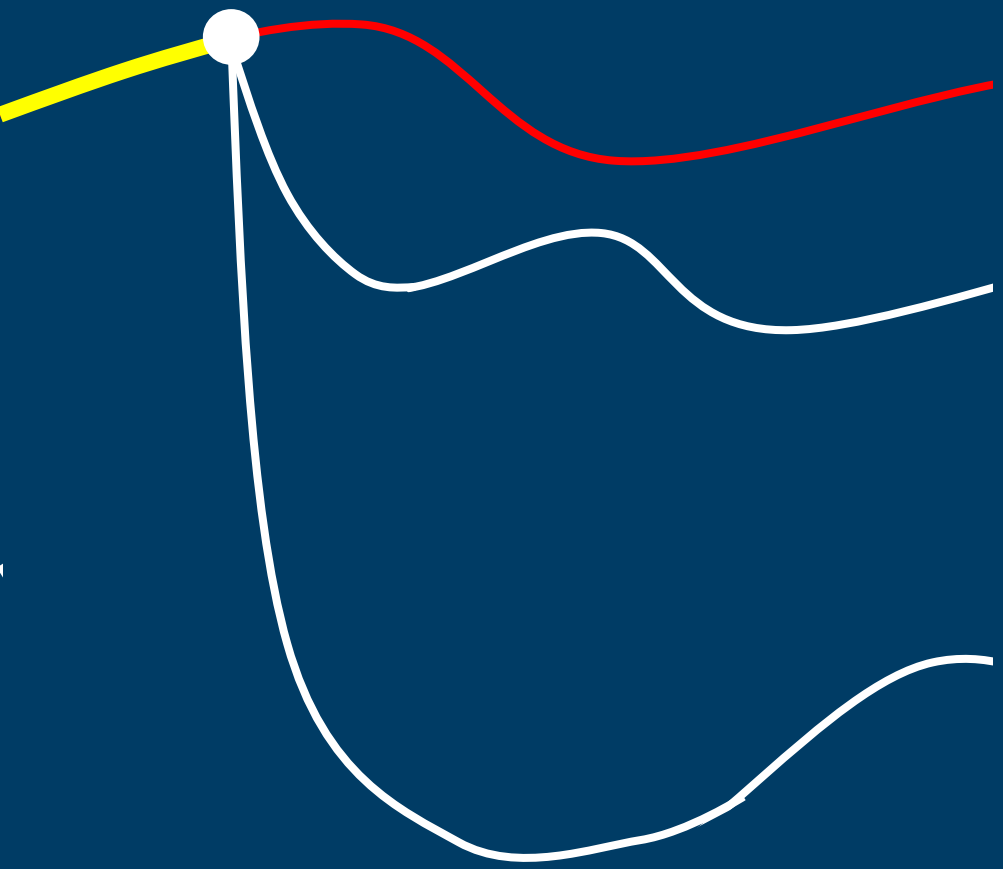
Smoothing

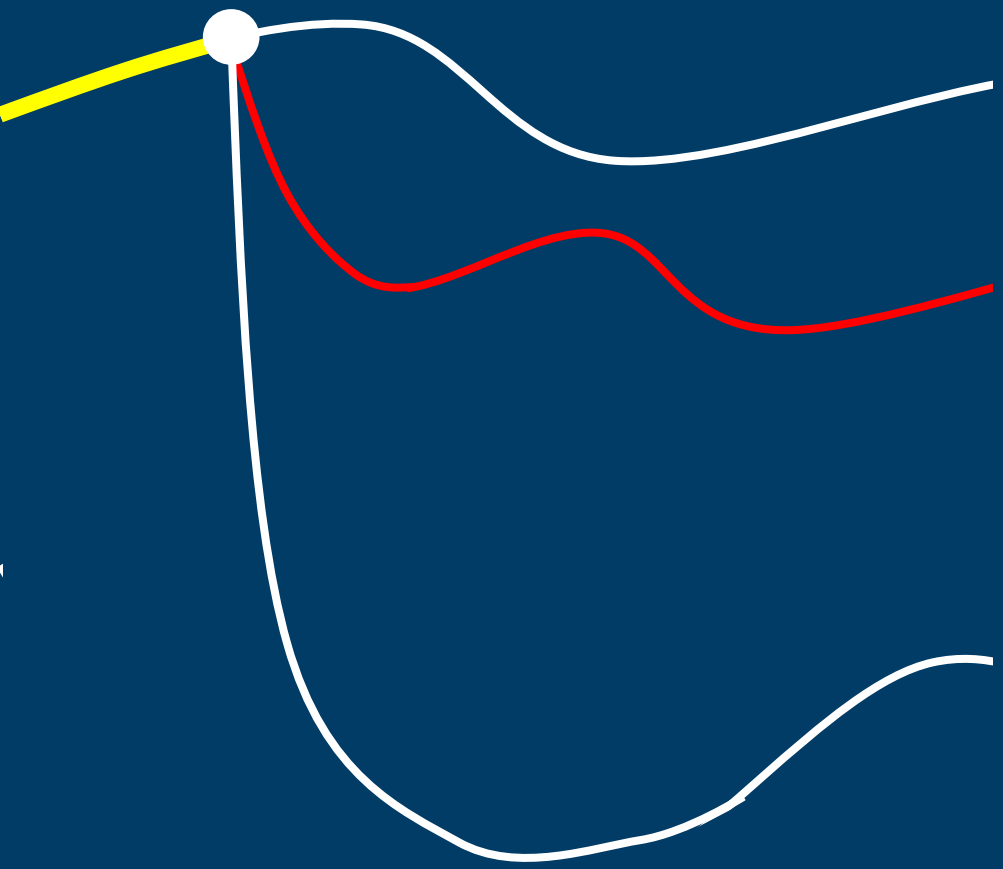


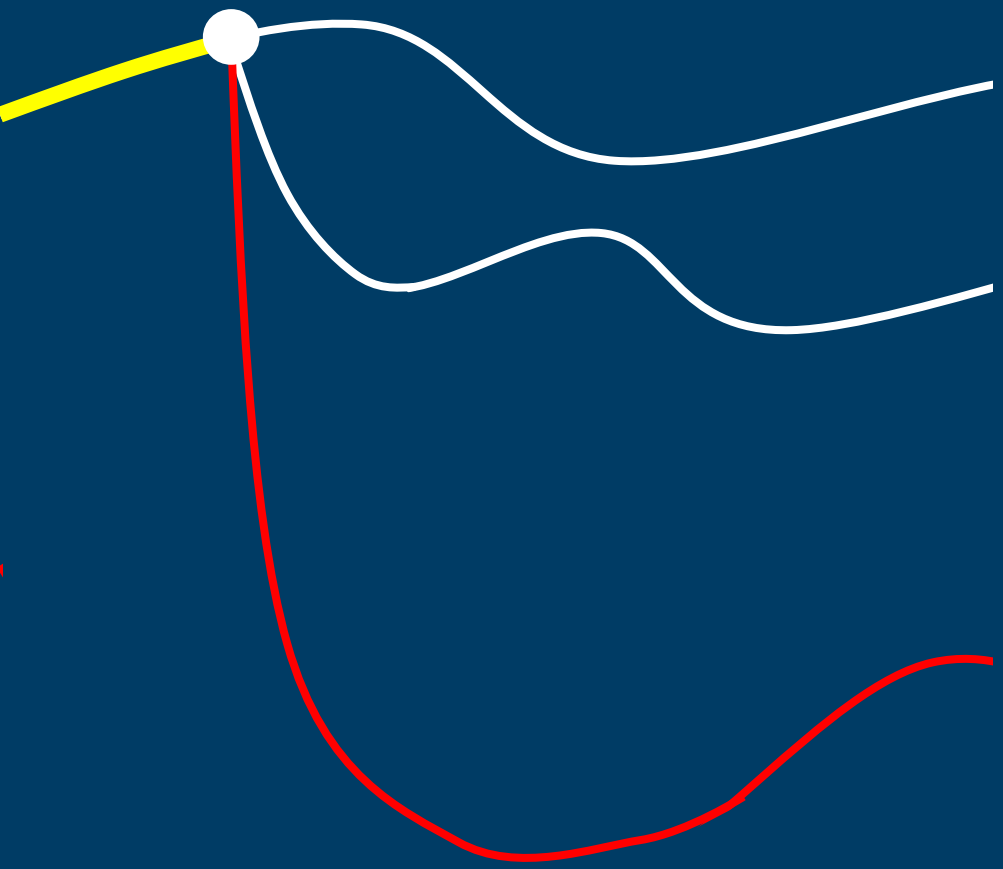
Solving first stage problem

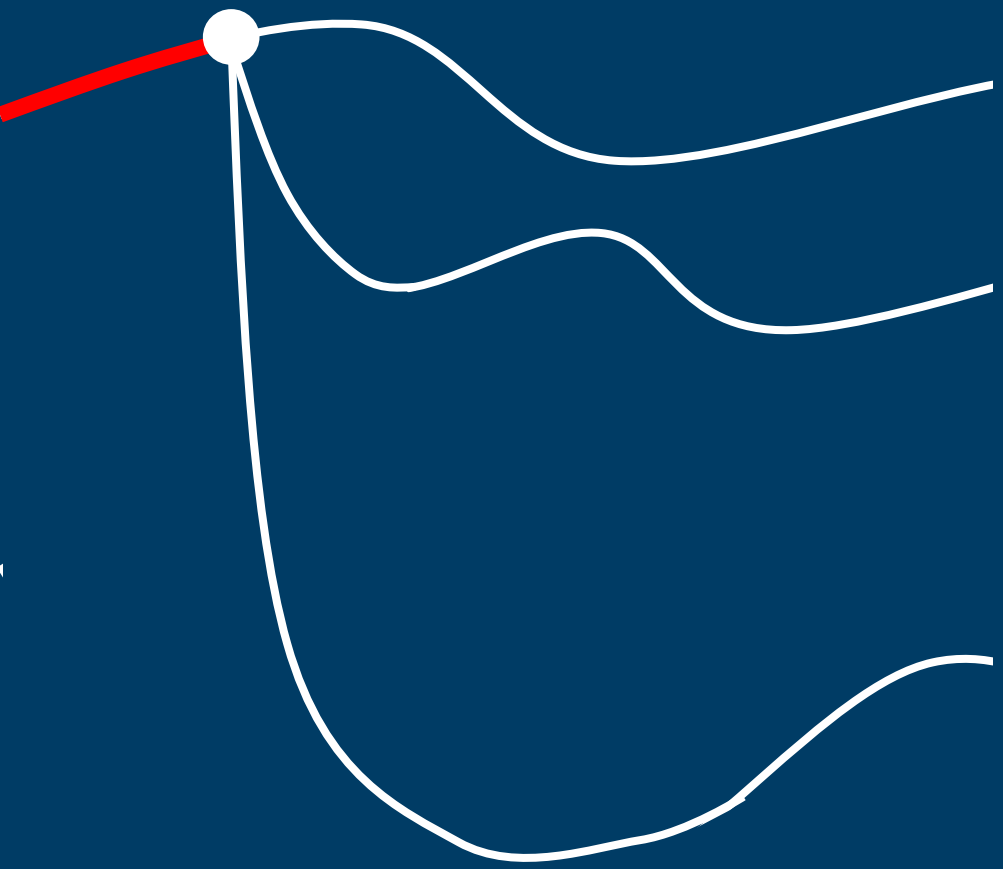


Solving second stage problem

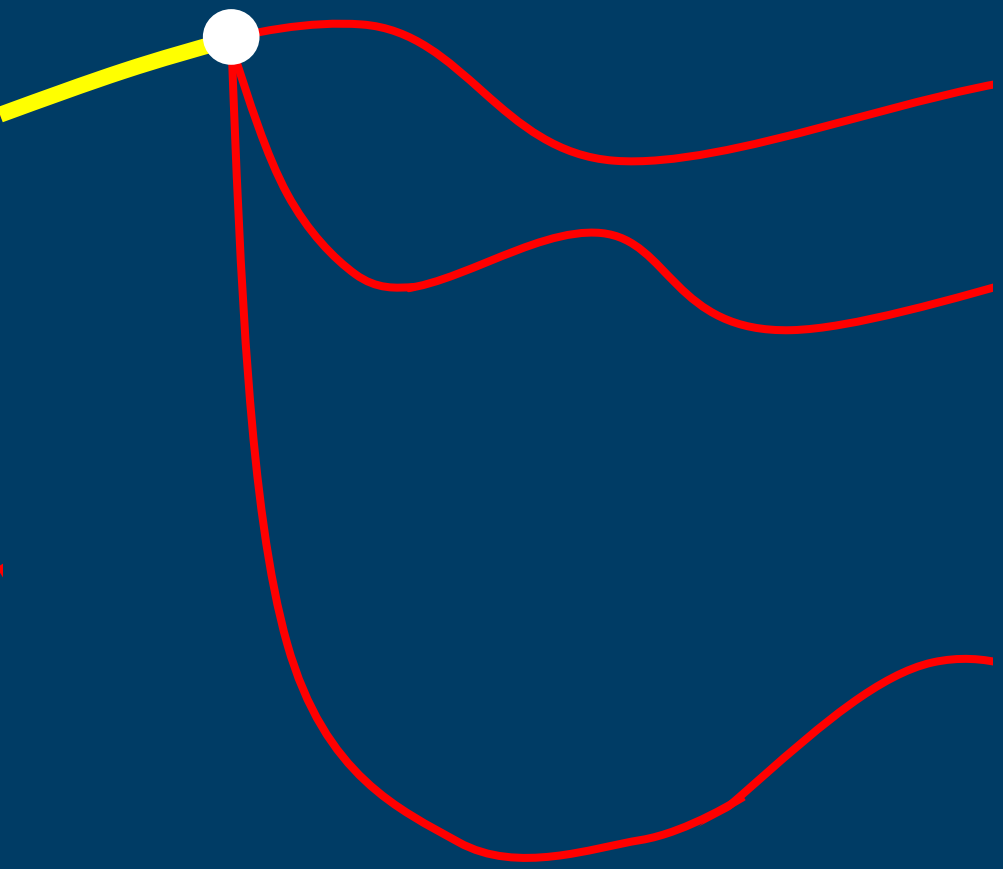


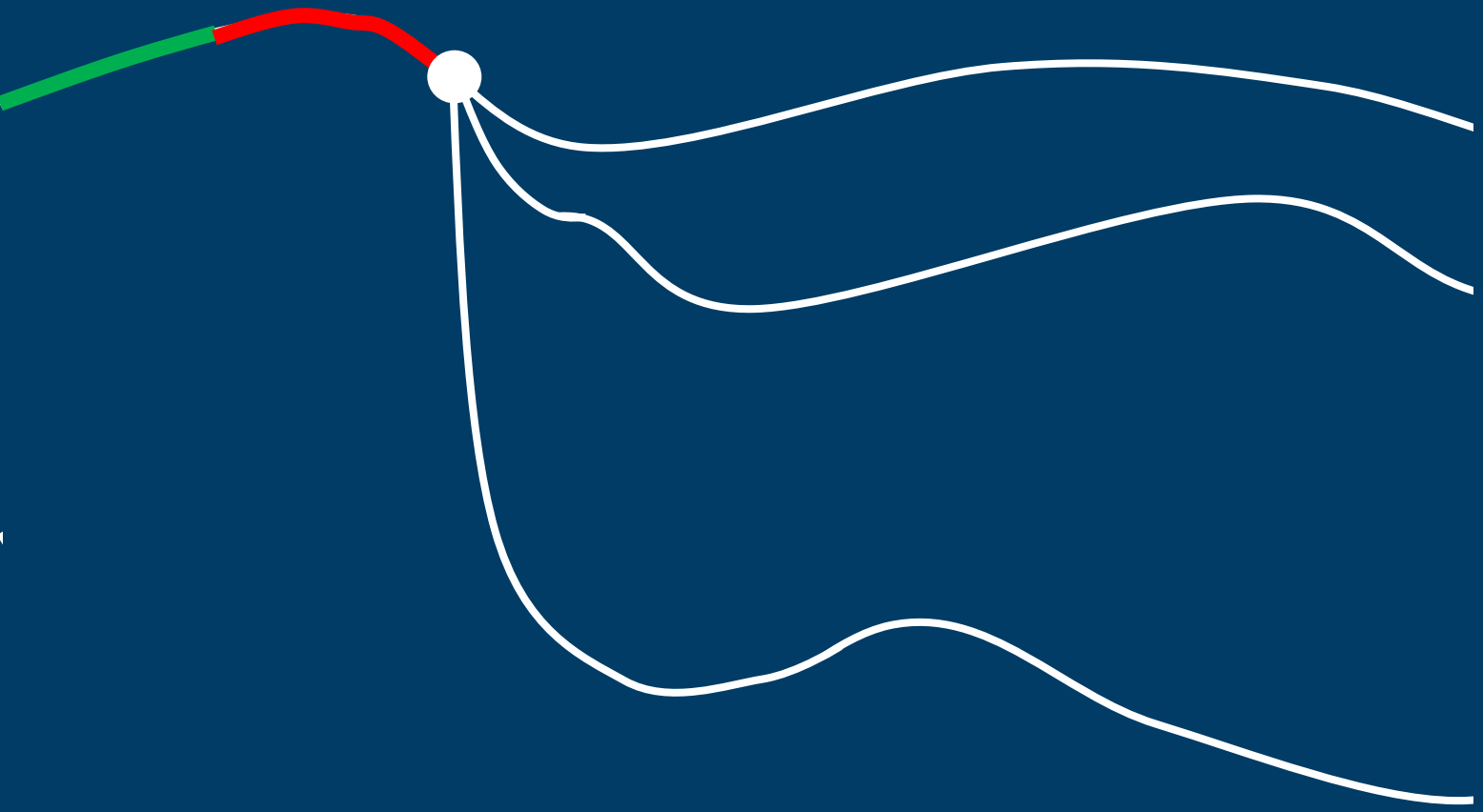


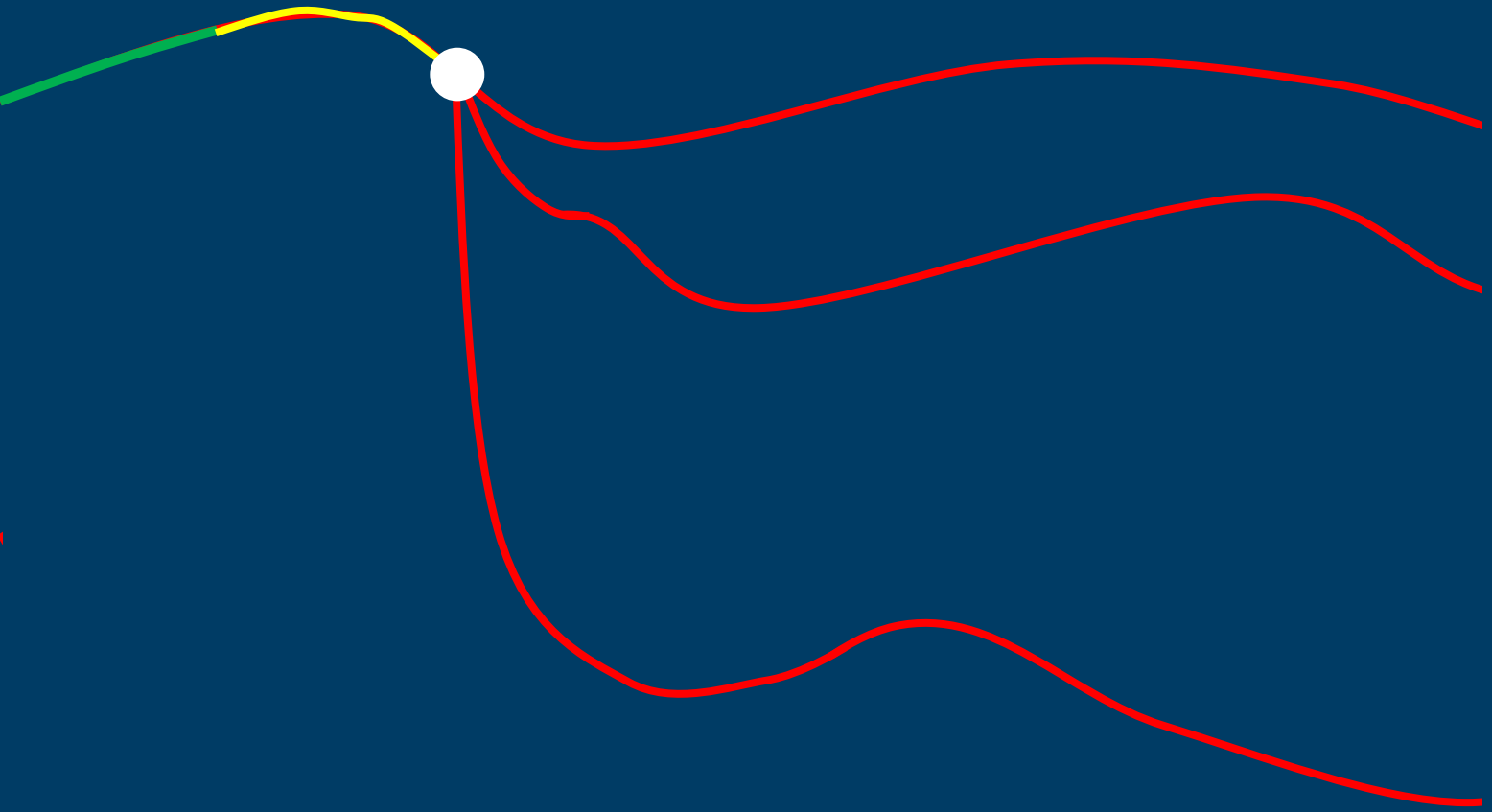


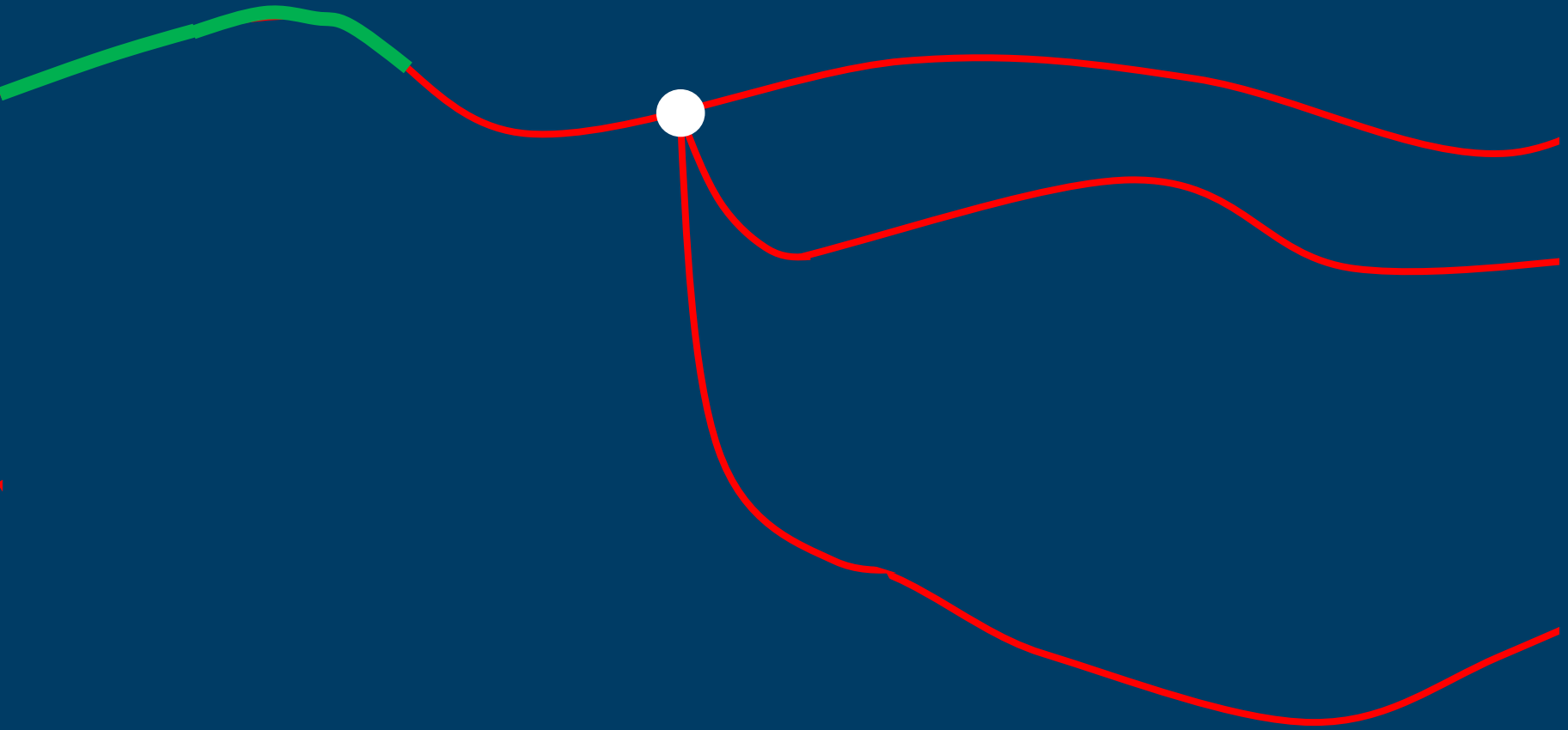


Parallelization of scenario fan









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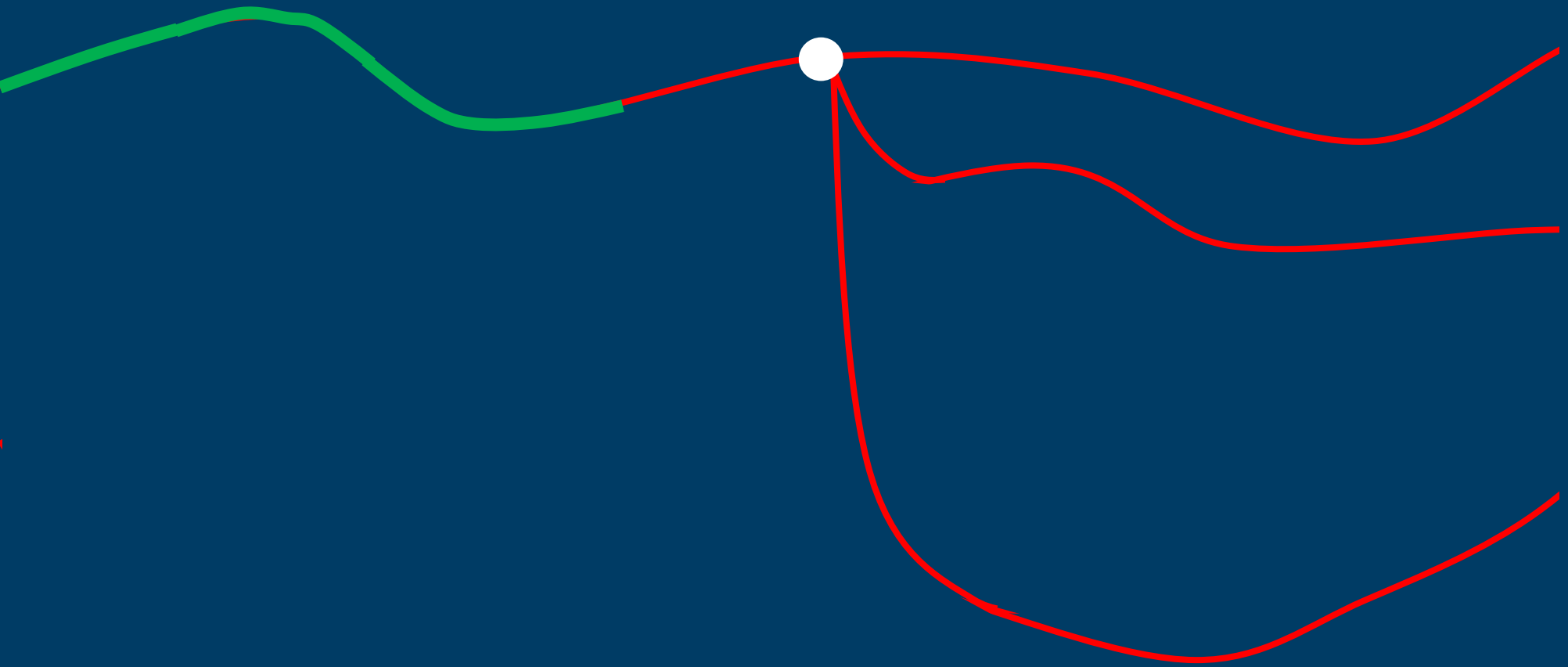

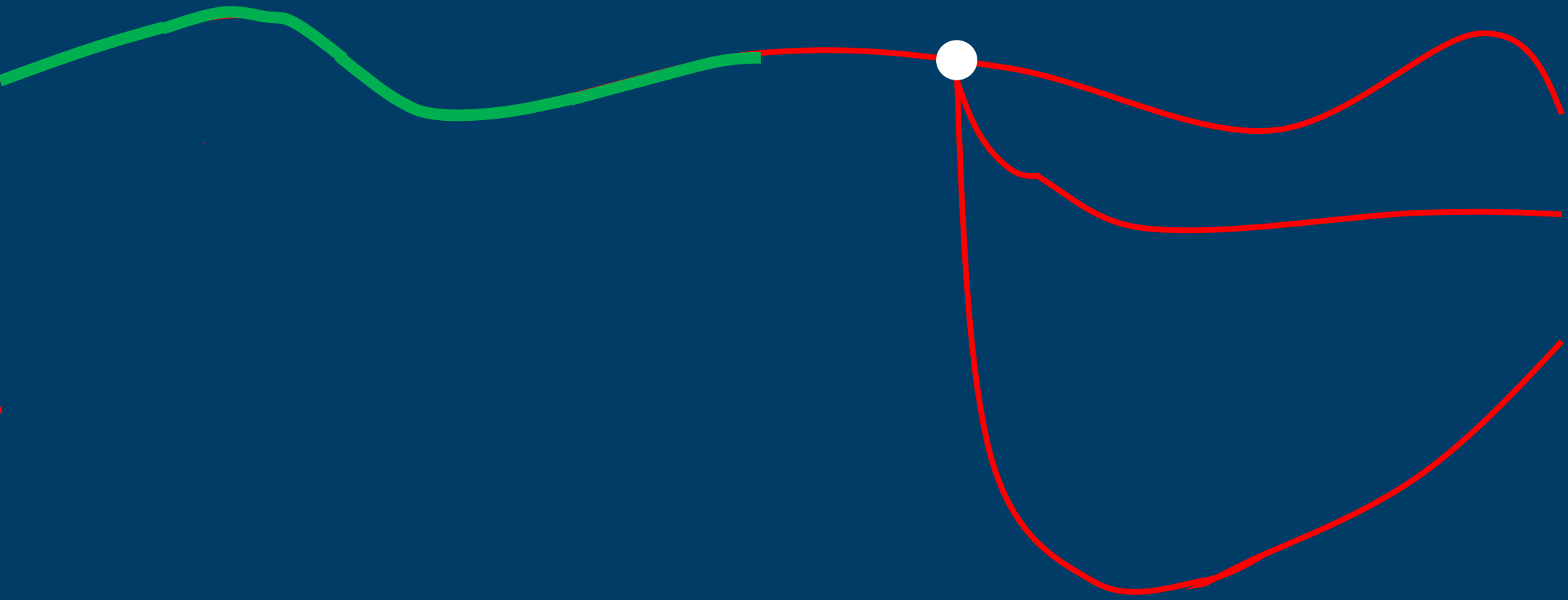

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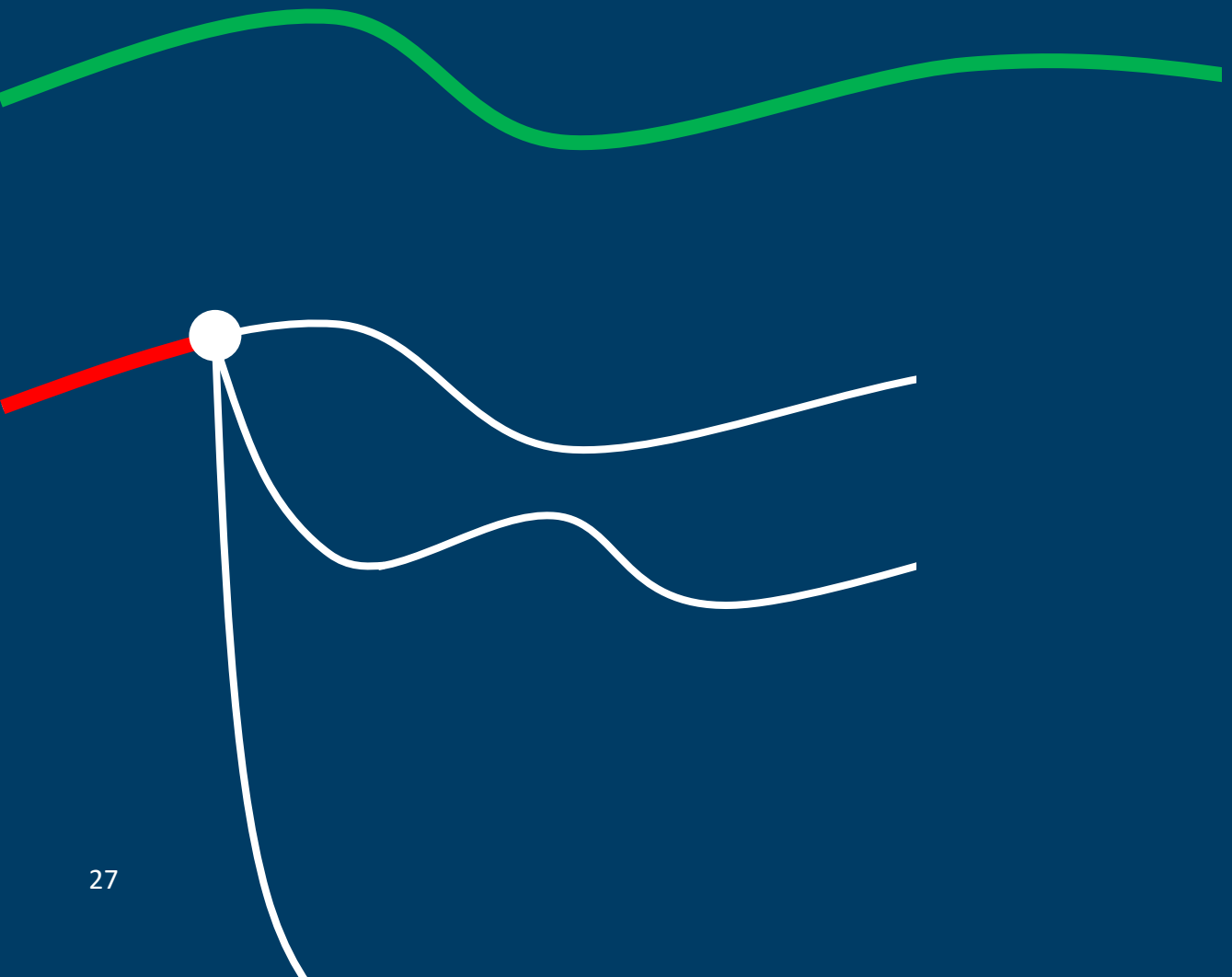
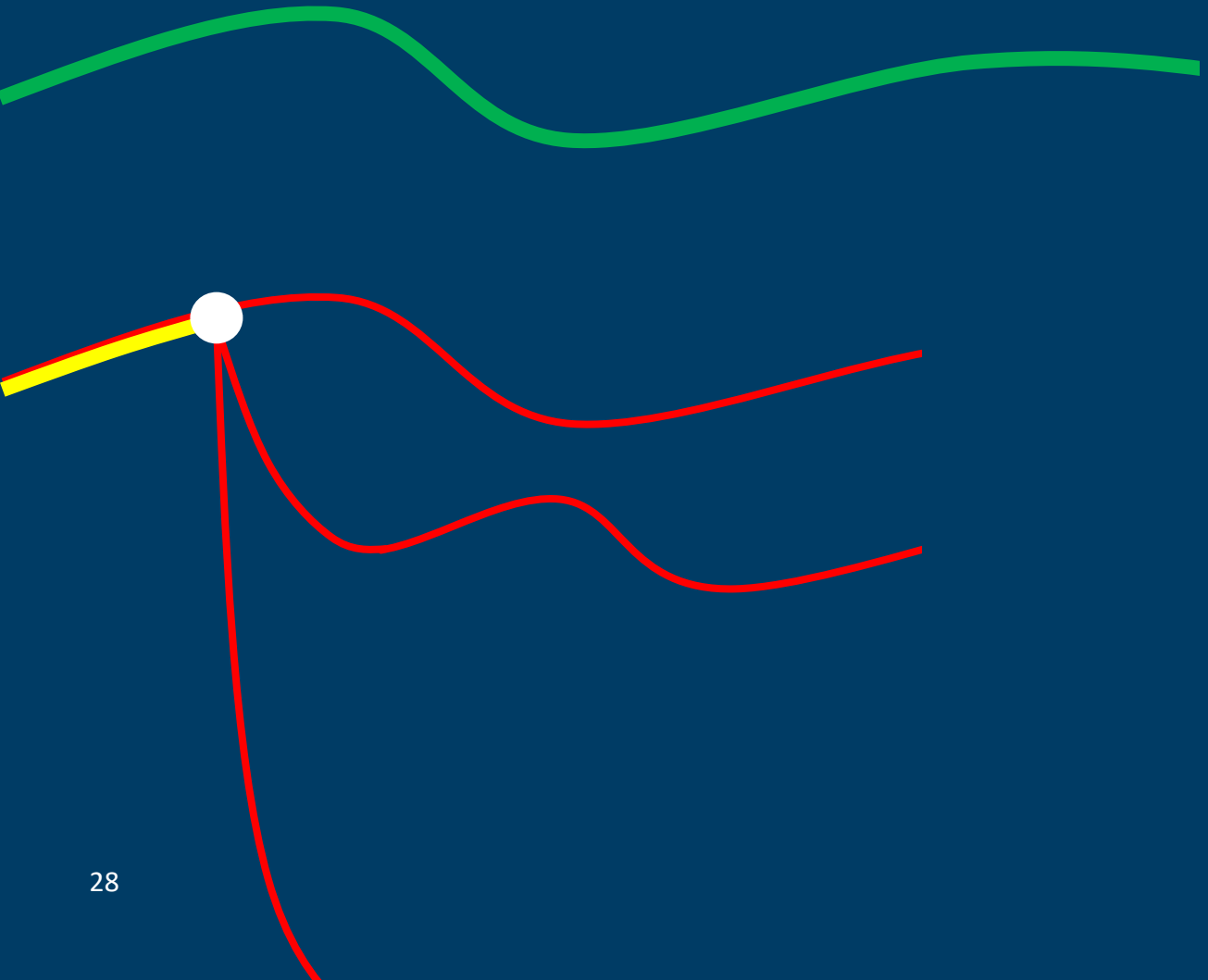
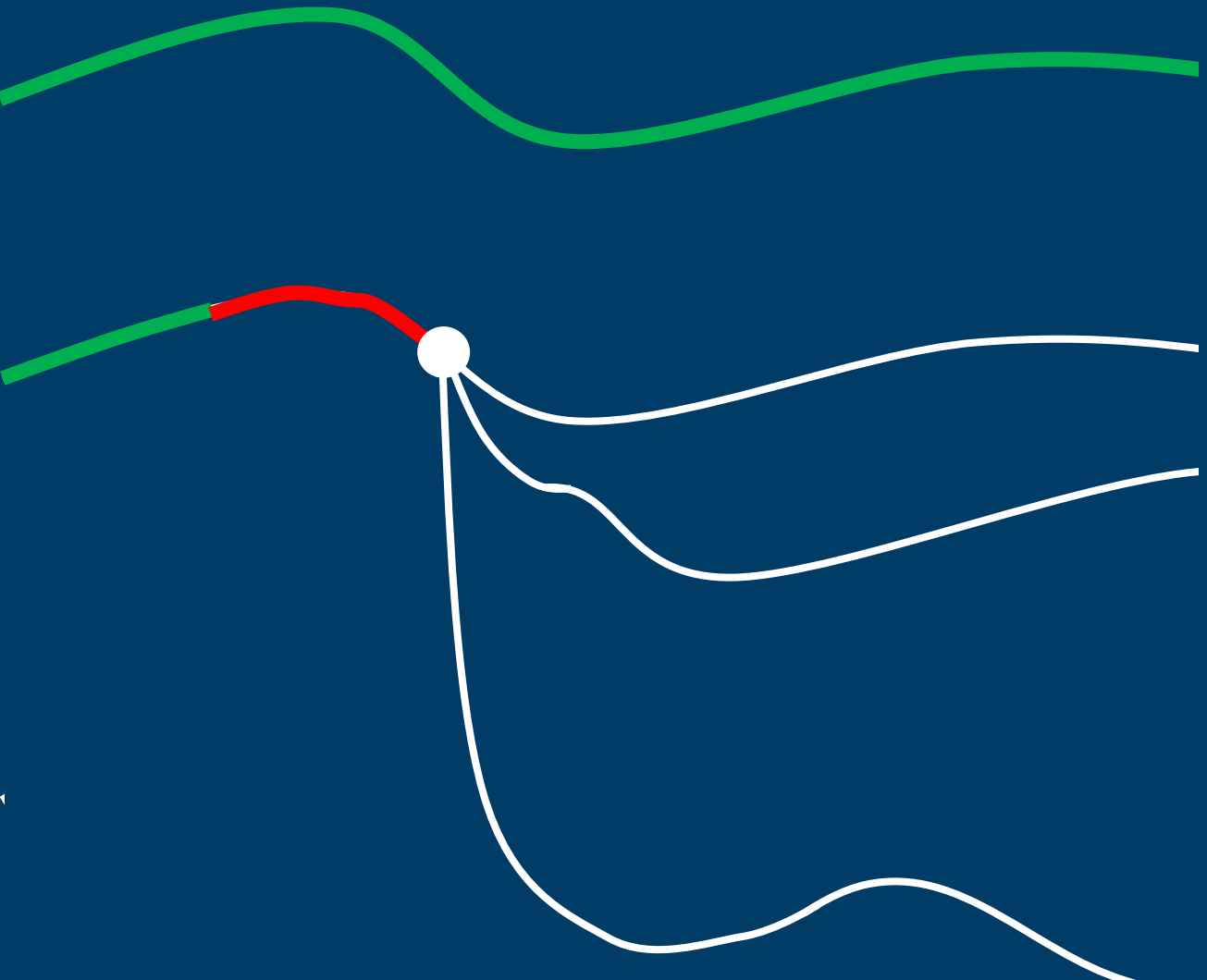
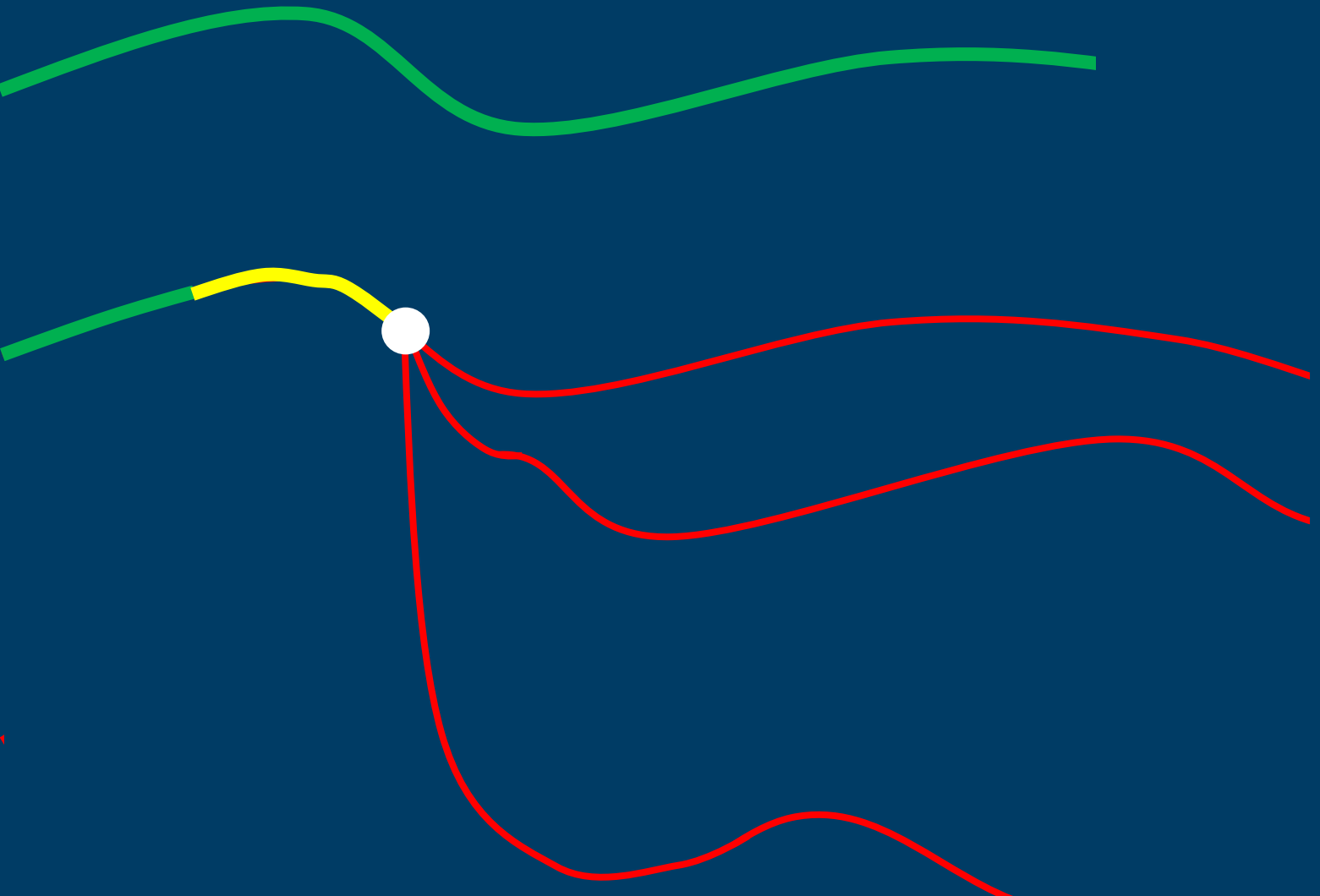
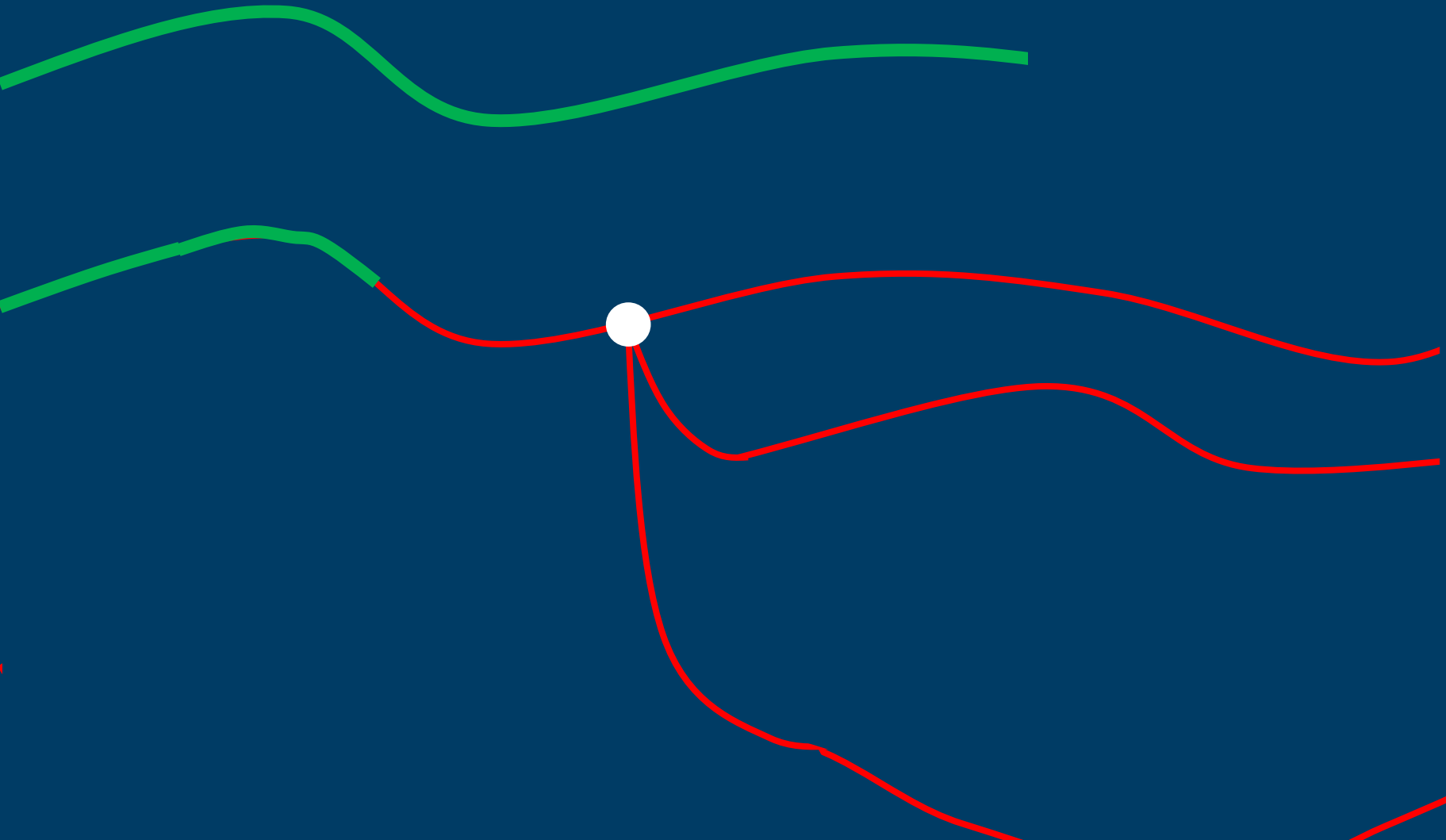
Solving second scenario

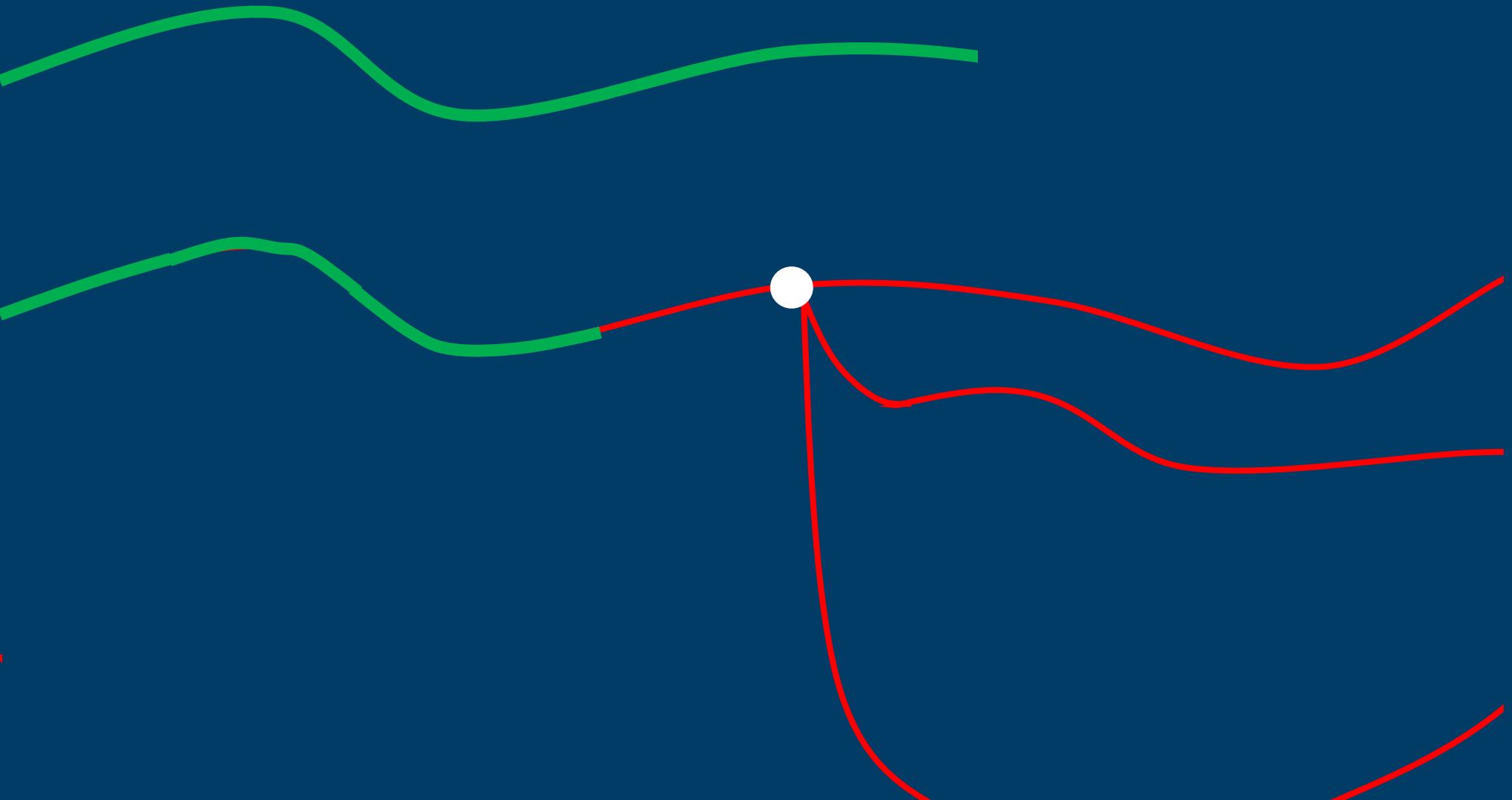


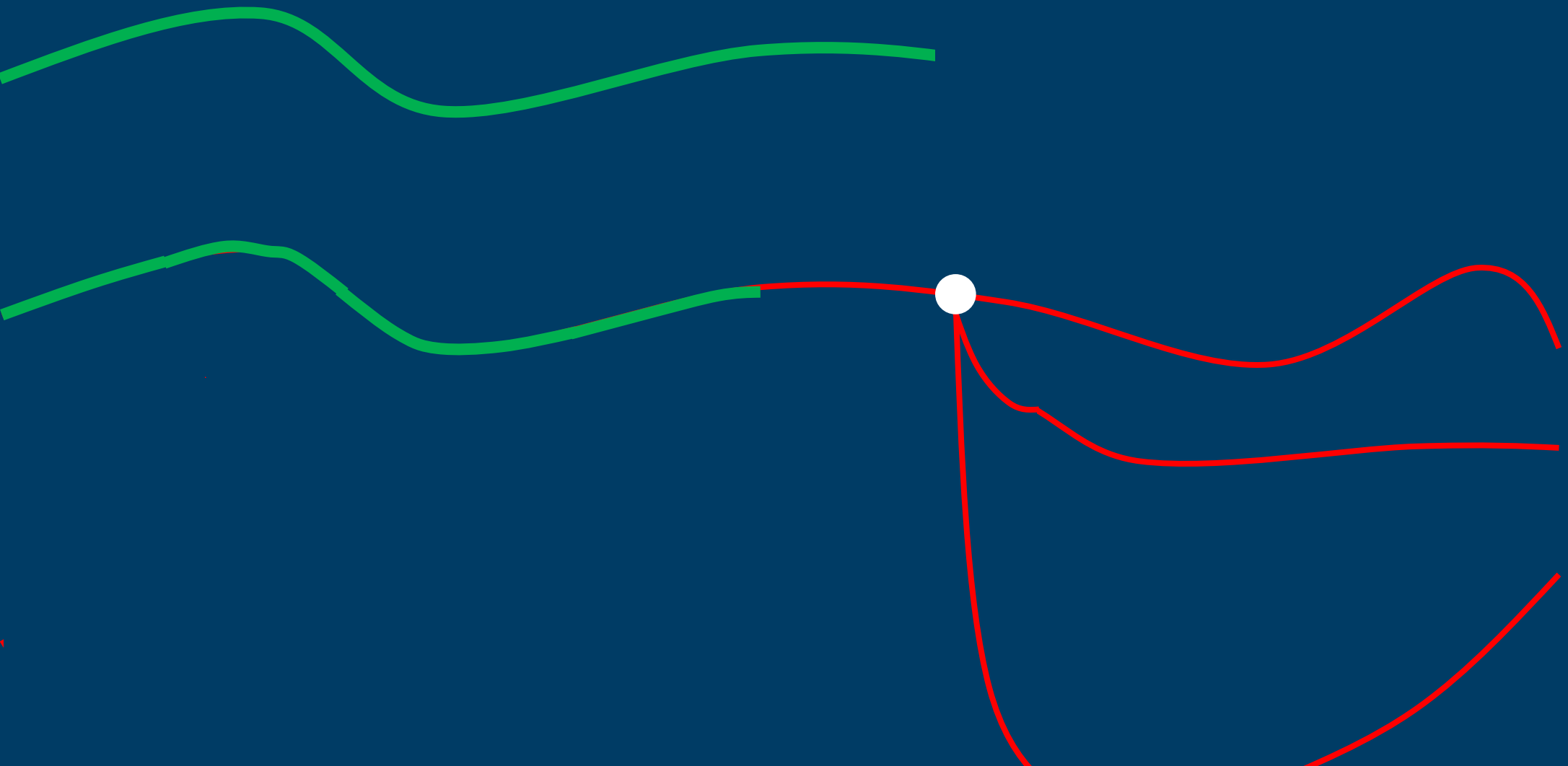












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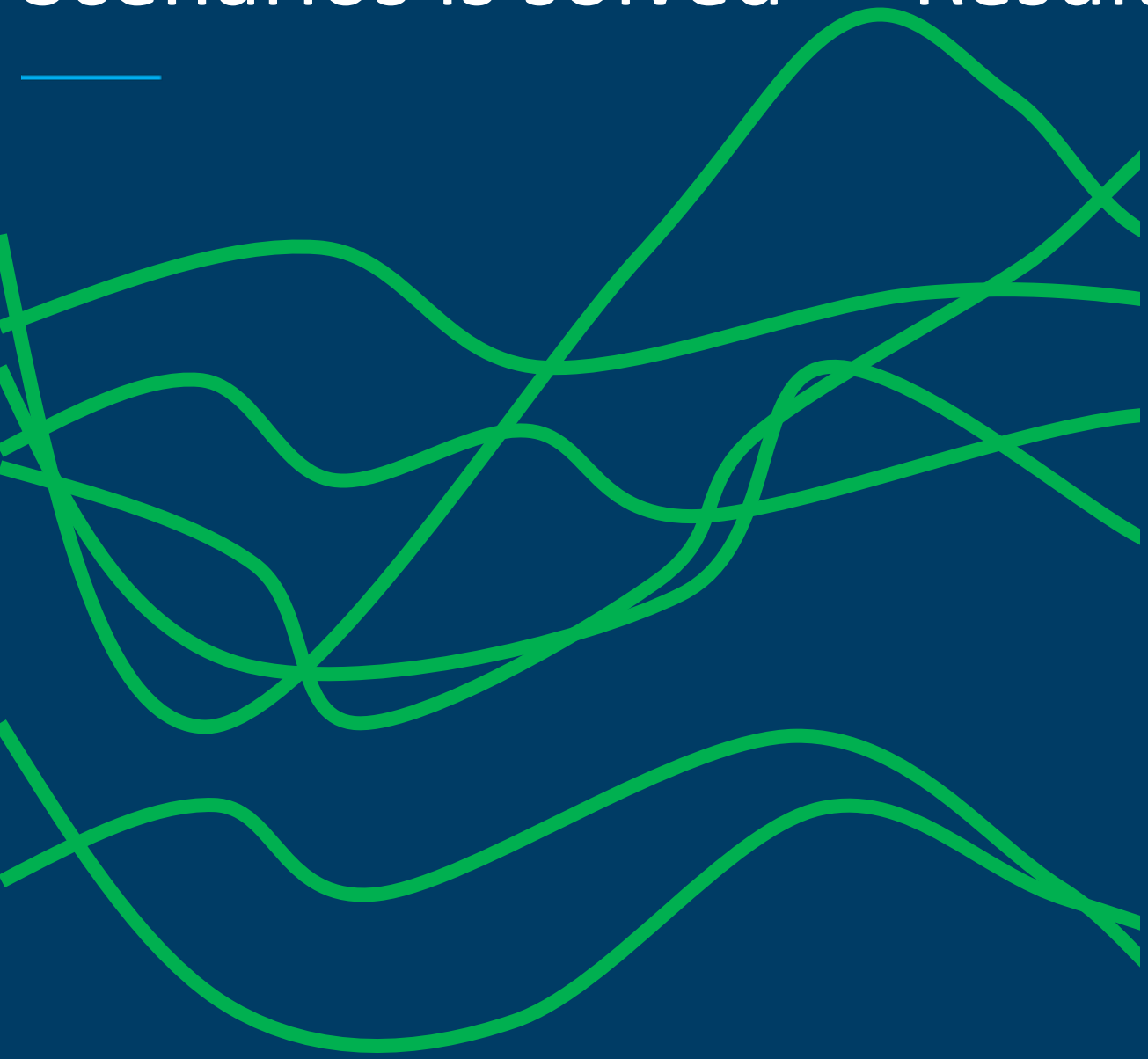
Scenarios is solved -> Results



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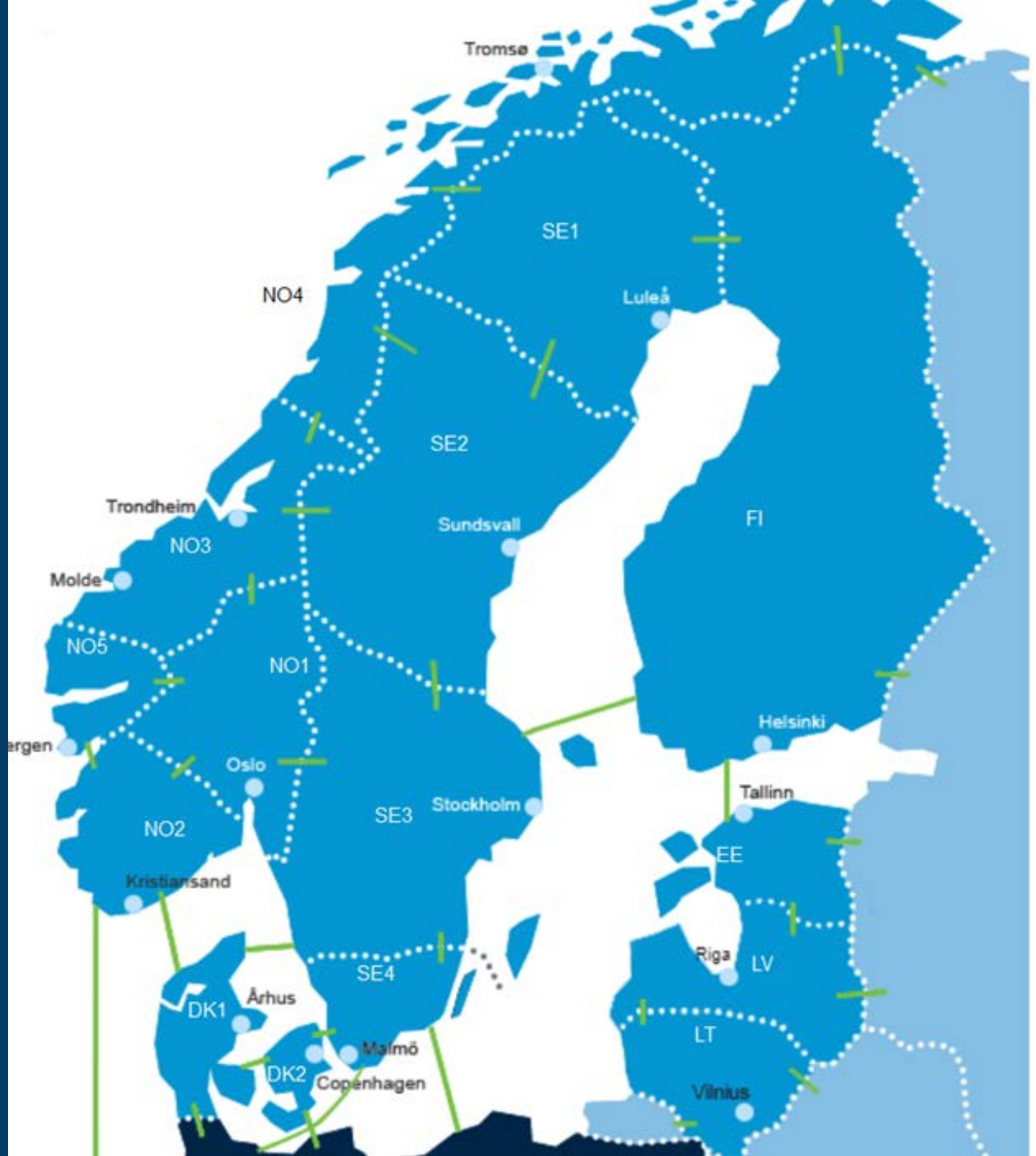
Statnett data

- Detailed description of Nordic + Baltic
- Interconnected countries is represent with exogenous prices

- 1265 hydro power modules
  - 228 inflow series
- 85 wind series
- 15 temperature series



Simulation

- 5 load periods in a week
- 51 scenario (1962-2012) in serie
- 19 scenario in scenario fan
- 52 weeks in scenario fan
  - Weekly time resolution

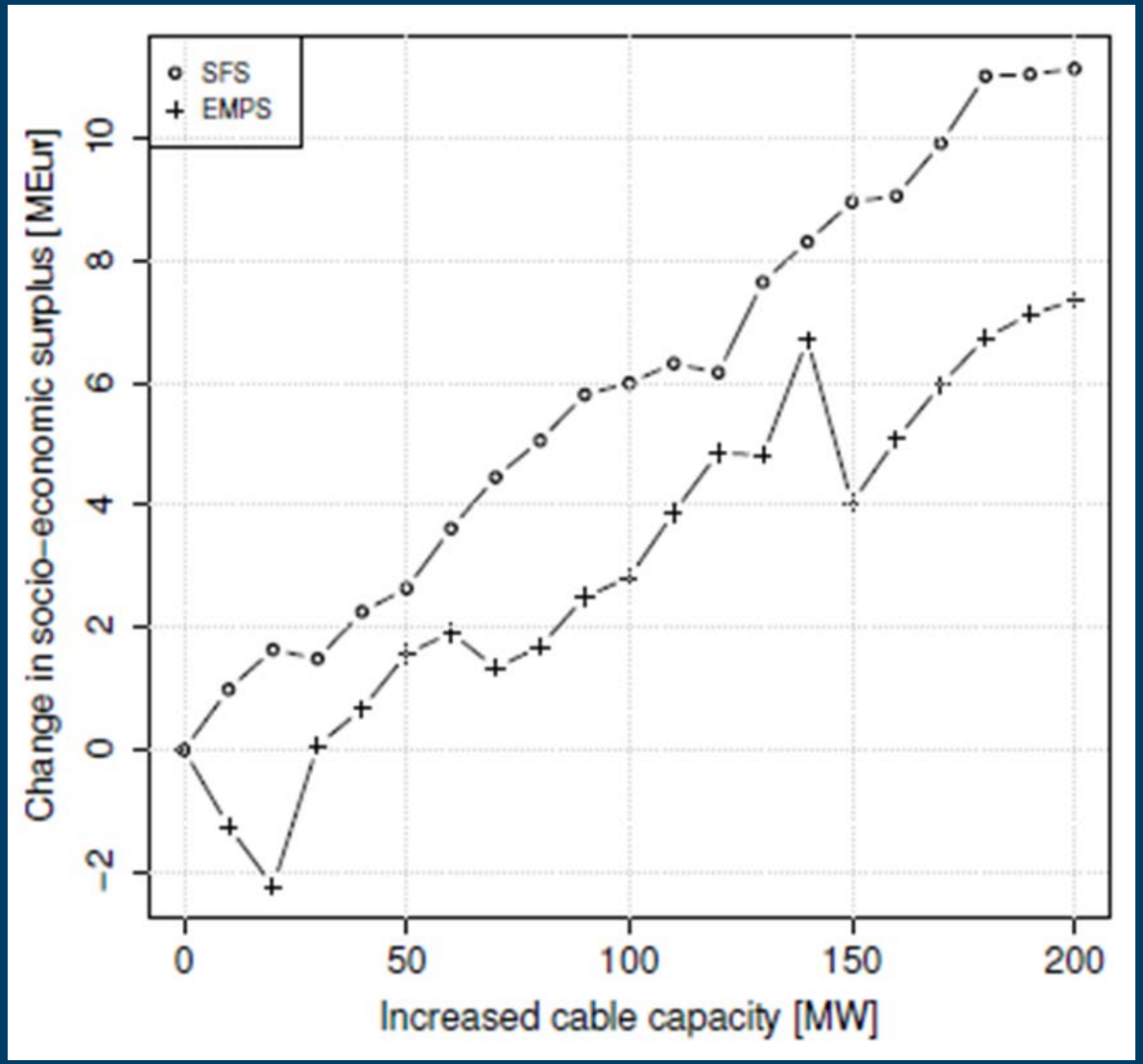
Tested case

- Cable
  - German and Southern Norway
- Pump storage plant
  - Duge – Sira-Kvina
- Snow
  - With and without

Results – Cable

- +277 M€/year for socioeconomic surplus in Nordic

- Consistent results



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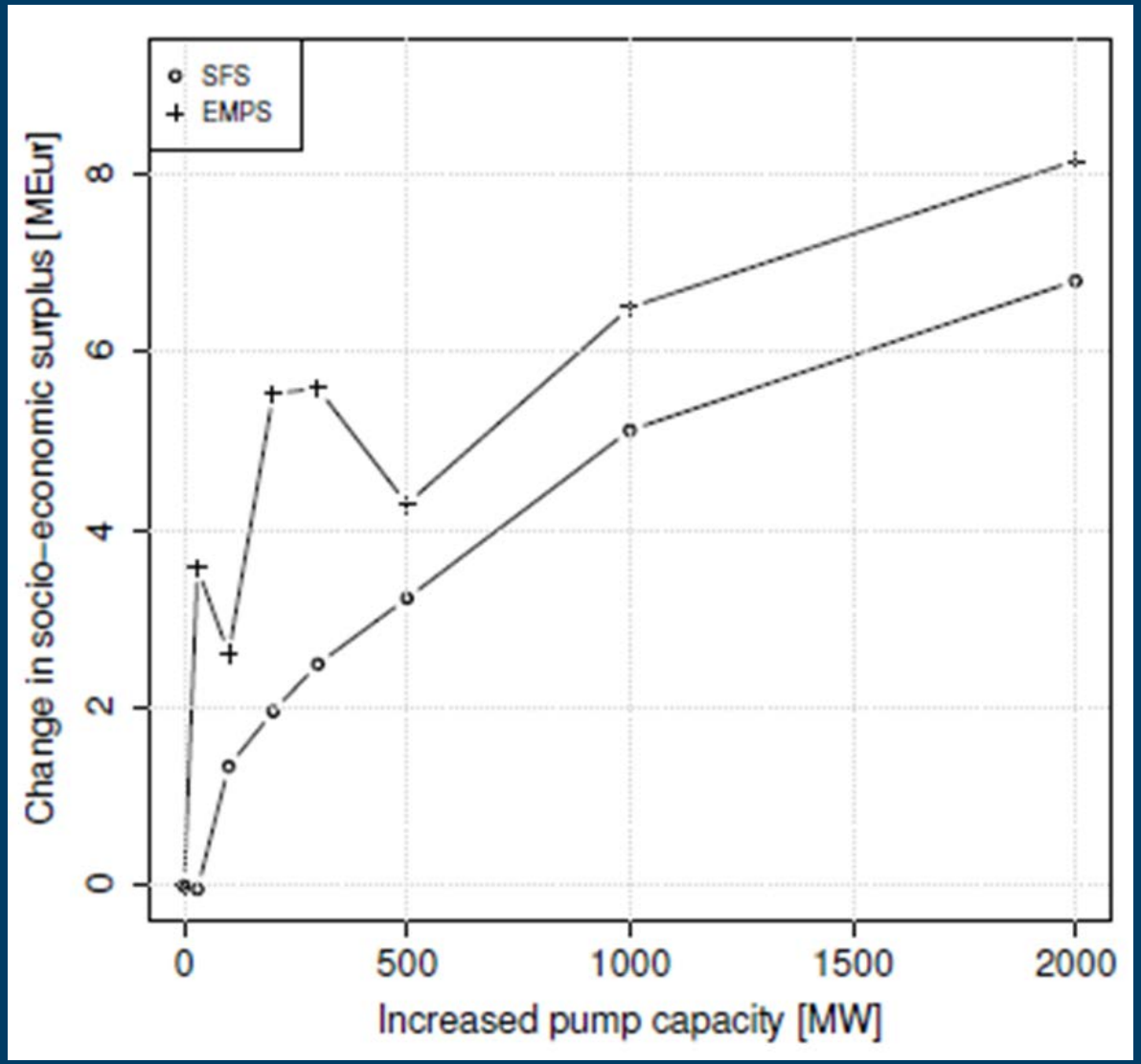
Results – pump

- +345 M€/year for socioeconomic surplus in Nordic
- Consistent results
- 5000MW cable from Norway to Germany



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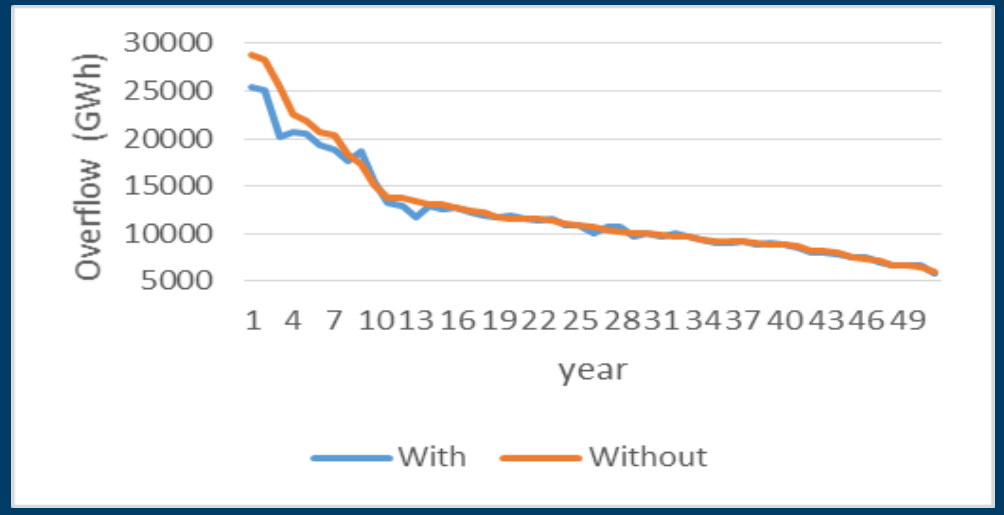
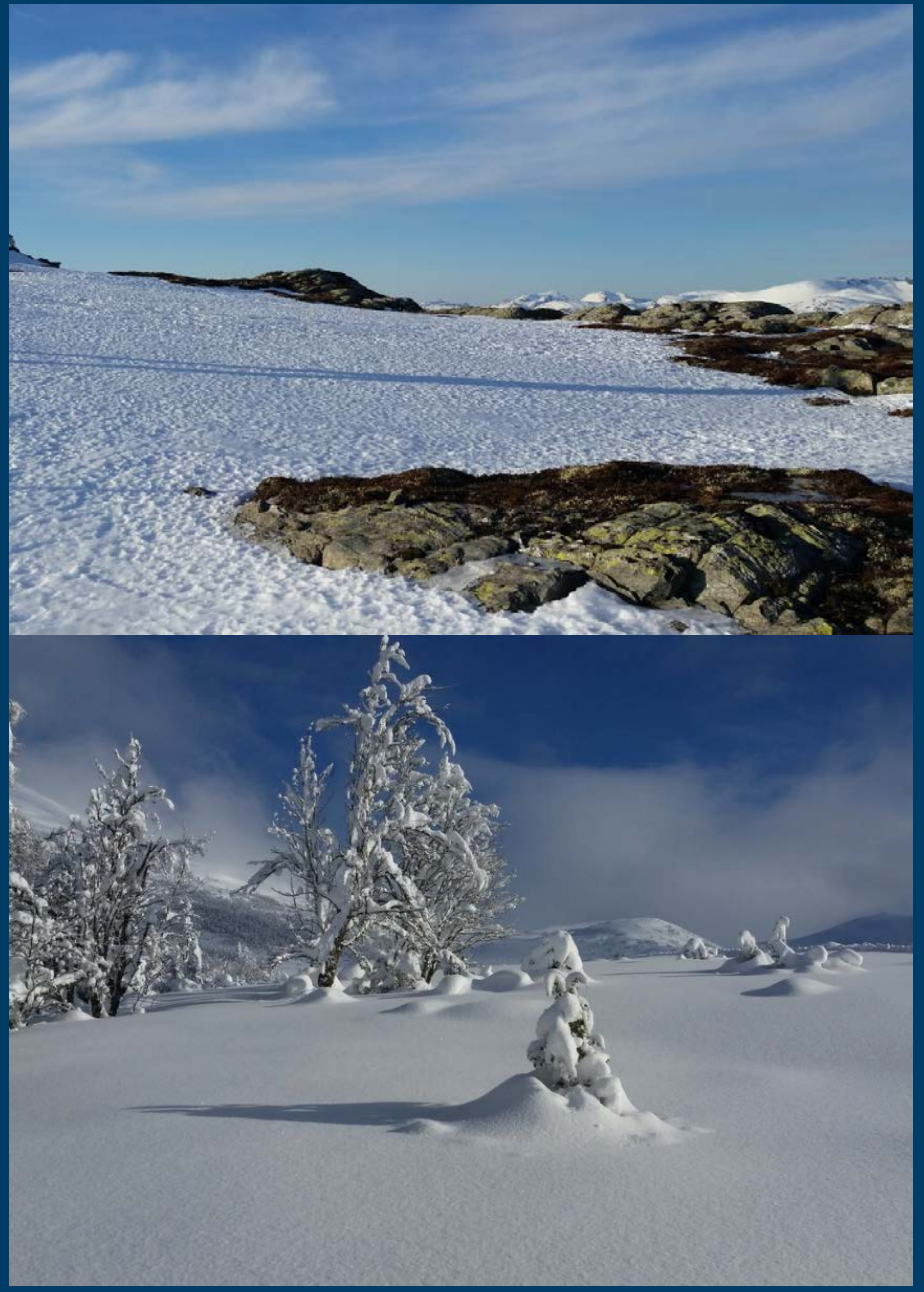
Results - Snow

- +9.4 M€/year in socioeconomic surplus in Nordic
- In Norway
  - +440 GWh/year production
  - 5.2 TWh in maximum reduction of overflow
  - 0.0014 TWh in maximum increase of overflow





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Experience

Detailed description of system

- Price variation
- High curtailment risk
- Water value

Formal optimization

- Easy to expand
- Easier to find errors and non-logical results

Challenges

Get all extra information

- E.g. time delay, node description and PTDF matrix

Calculation time

- Parallelized
- Flexible time resolution
- Commercial solvers for large optimization problem, e.g. CPLEX, Gurobi, Express
- No calibration

Challenges

- Calculation time
  - 50 hours on test case
    - EMPS 10 min without calibration
  - 156 hours with finer time resolution
    - 56 time step in week problem
    - 92 time step in scenario fan

- Depend on time resolution, detailed description and size of power system
- Increases with more restrictions
  - Not head correction, time delay and snow

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Conclusions

- No calibration

- Individual water values
- Important to include details

- Better investment decisions
- Consistent results

Conclusions

- Prototype
- Work well

- Easy to include more restrictions
- Seasonal model (individual water values)

Future

- Work well for further research
  - Integrate several of market
  - State dependent constraints
- More users

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Teknologi for et bedre samfunn