Ramona Infrastructure
A multi horizon stochastic programming investment model

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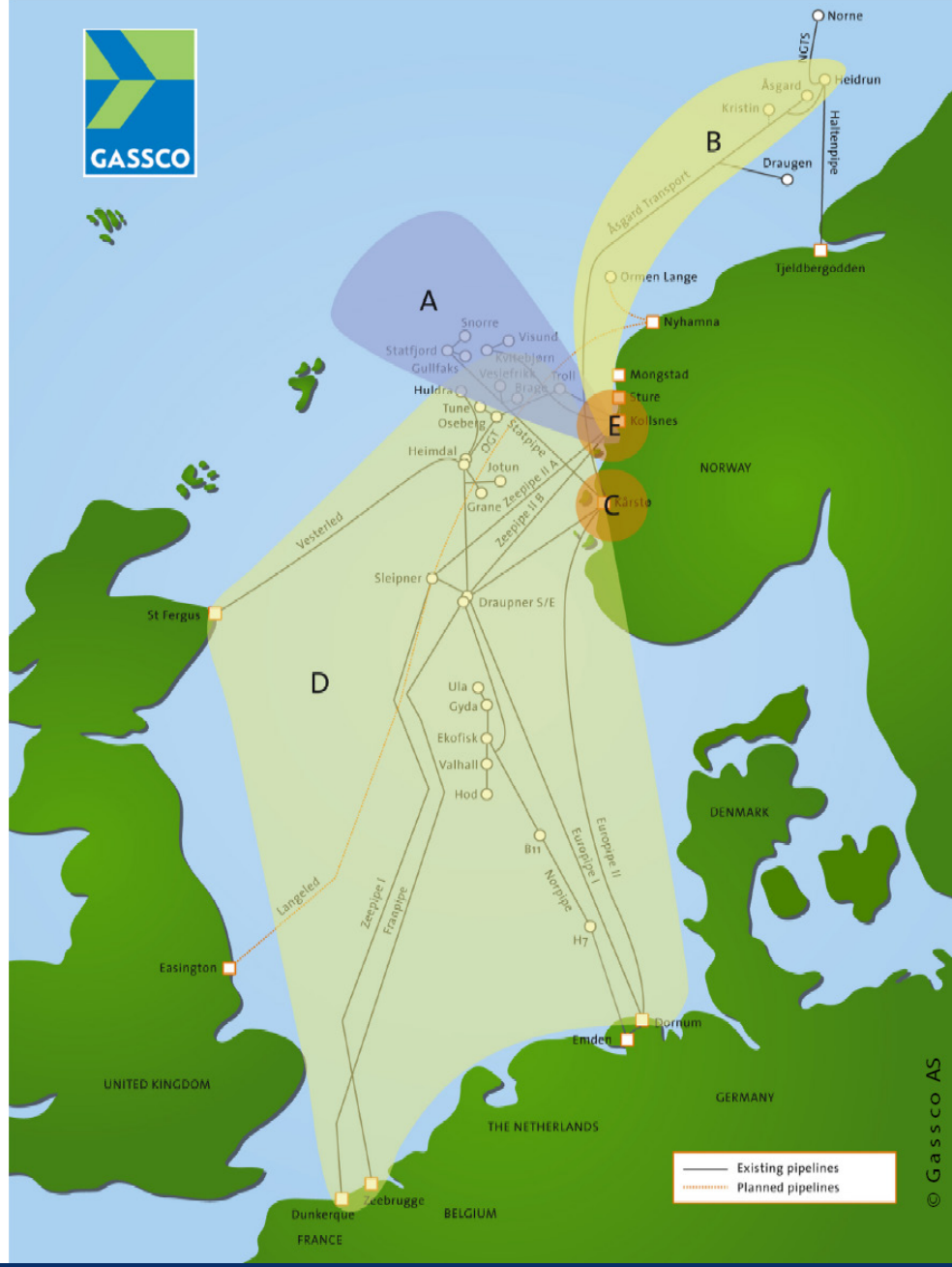
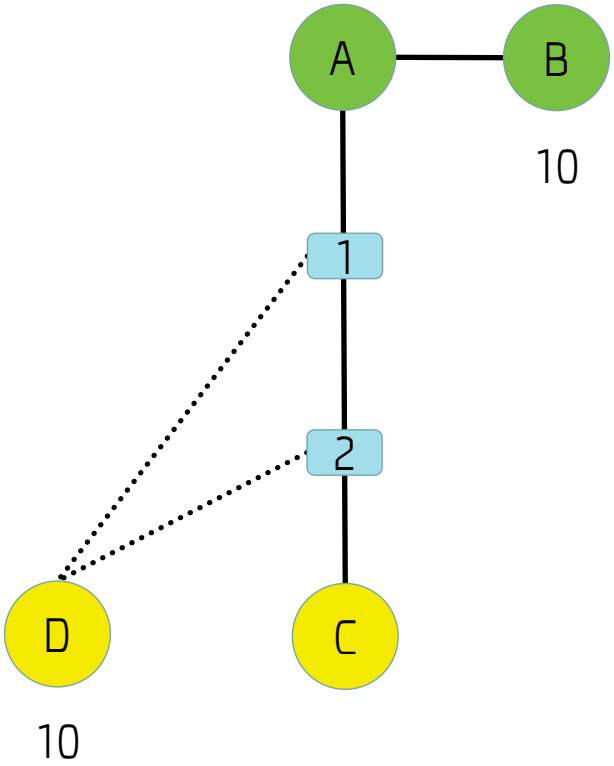
Background

- World's largest subsea gas transport system,7800 km
- Liberalized markets
- Ageing infrastructure
- Gas quality issues
- System effects



Investments and system effects

- The capacity in the initial system is 51.3 MSm^3/d
- We want to extend the system with a new field and a new market (B&D)
- Two possible connection points: CP1 & CP2
  - With CP1 the capacity between A&C is: 47.5 MSm^3/d
  - While with CP2 the capacity between A&C is: 44.1 MSm^3/d



Uncertainty & Operational variability

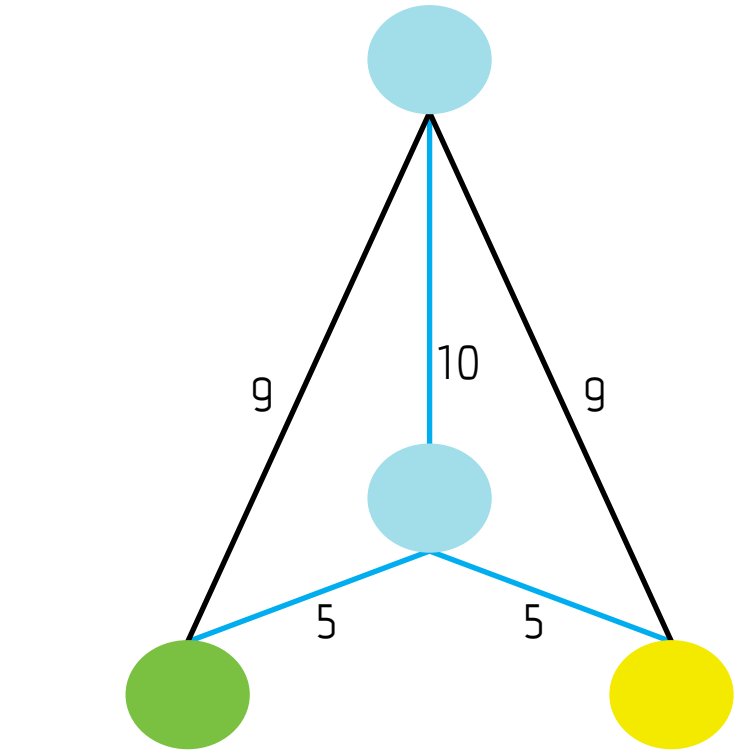
- A common approach is to replace uncertain parameters by mean value
- Such **deterministic** models fail to account for deviating values and don't produce robust solutions

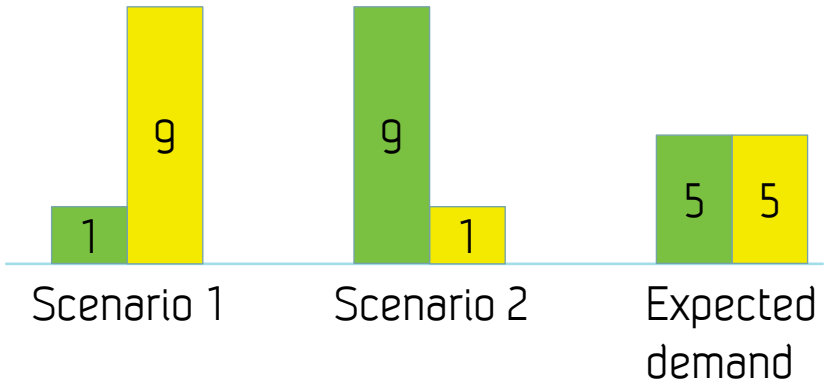
- Common to **aggregate** data for strategic analysis
- Aggregation may hide important detail
- Analogous to deterministic vs. stochastic
- Performance in peak load situations or low load situations may be important

Example design & operation

- Stochastic daily demand
- Project Blue: – designed for expected value

- When will Black be better than Blue?
  - Depends on probabilities and outcomes of scenarios!





Framework

- Optimization
- Stochastic programming
- MILP
- Commercial solver+modeling environment (XpressMP/Mosel)

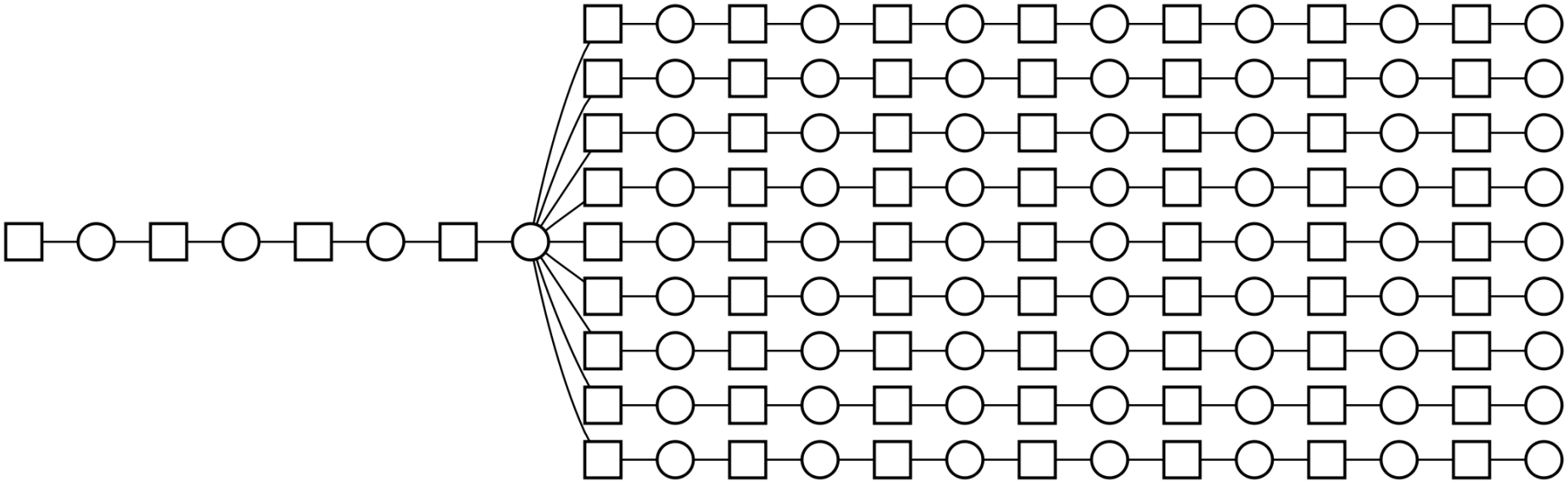
- Build on experience from previous models
  - Deterministic strategic model
  - Deterministic operational model
  - Stochastic tactical model
  - Stochastic operational model

- Challenge: find a sufficient level of detail

Mathematical formulation

- **Maximize expected net present value**
  - Market price * volume sold
  - Less Investment costs
  - Less Operational costs
- Such that security of supply / production assurance is kept at a high level
- **Subject to:**
  - Production limits
  - Market demand
  - Mass balance
  - Flow/pressure relationship
  - Investment enables capacity
  - Mutually exclusive projects
  - Etc…

A two-stage scenario tree



Computational results

- The case we have run so far has a realistic number of investment possibilities
  - But a relatively short time horizon (15 years),
  - And a small scenario tree
    - Two stages
    - 9 scenarios
- To solve large scale cases / problems we are working on solution algorithms
  - Divide the large problem into sub problems and utilize parallelization techniques

Case	#rows	#cols	#integer	Solution time
Deterministic	37 045	15 236	9 724	7s
Stochastic	233 549	95 428	61 860	126s

Conclusions

- The analysis tool handles
  - Investment analysis (fields, branch-offs, compressors, etc)
  - System effects
  - Gas quality
  - Operational decisions and the influence on design
  - Uncertainty
    - Short-term (prices, demand, events)
    - Long-term (prices, demand, gas quality, reservoir volumes, new discoveries, etc)

- Status for the model
  - Implemented the model presented here 2 years ago
  - Solved the first realistic scale problem instances
  - Discussing implementation for production