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Natural Gas Infrastructure Design

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SINTEF Applied Economics

Background/Objective

- Design or Redesign of NG Infrastructure:
  - Field Development, topside/subsea
  - Processing Facilities, onshore/offshore
  - Compression Facilities, onshore/offshore
  - Pipelines
- When and Where
  - Which fields at what time
  - Dimensioning (pipeline, processing)

Input data

- **Fields**:
  - CAPEX
  - OPEX
  - Production profile
  - Distances
  - Time window
- **Pipelines:**
  - CAPEX
  - OPEX
  - Length
  - Capacity
- **Processing facilities**
  - CAPEX
  - OPEX
  - Capacity
- **Markets:**
  - Price
  - Demand

Complexity

- Combinatorial explosion:
  - 1 field : 40
    - 4 technologies
    - 10-years start window
  - 2 fields: 1600
  - 10 fields: 40^10 ~= 10^16
- Production from fields is flexible
- Trade-Off:
  - Increase capacity vs. delay production

Optimization Model

General Mixed Integer Linear Program:

$$\min c^\top x + d^\top y$$
$$\text{s.t.} Ax + By \leq b$$
$$x \in \mathbb{R}_+^{n_x}$$
$$y \in \mathbb{Z}_+^{n_y}$$

Solve using commercial software or specialized algorithms

Optimization Model

Maximize (expected) NPV:

$$NPV = \sum_{s \in \mathcal{S}} \sum_{t \in \mathcal{T}} Prob_{ts} \delta_t (Rev_{ts} - Cost_{ts})$$

New projects may be started (once) during defined time windows:

$$\sum_{t=Start_p^e \ldots Start_p^l} start_{pts} \leq 1$$

Etc..

Main constraints

- Costs incurred from
  - Investments (CAPEX)
  - Production (OPEX)
- Revenue stems from sales/delivery to Market
  - Price
  - Demand
- Satisfy physical and logical constraints:
  - Production capacity
  - May only transport using links that are in production

Novelty/Improvement

- Improved model formulation
  - Continuous Capacity Selection
  - Tighter Formulation
  - Use fewer (costly) binary variables
- GUI Prototype (covering subset of model)
  - Excel Interface for input/output

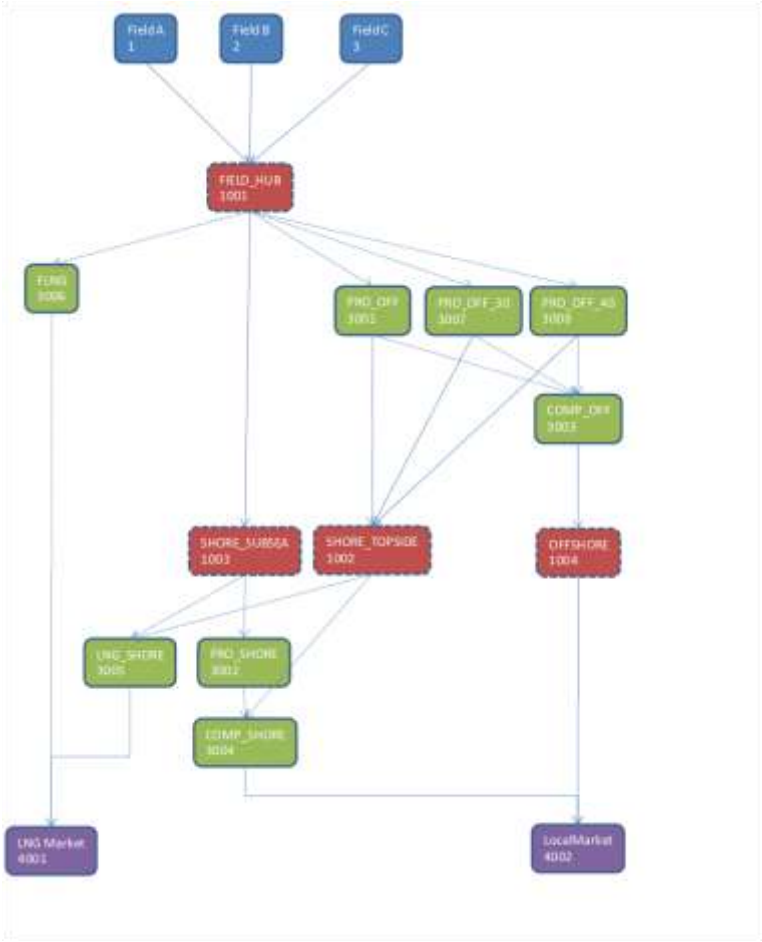
Continuous Capacity Selection

- Continuous scaling, see e.g. Moore (1959)

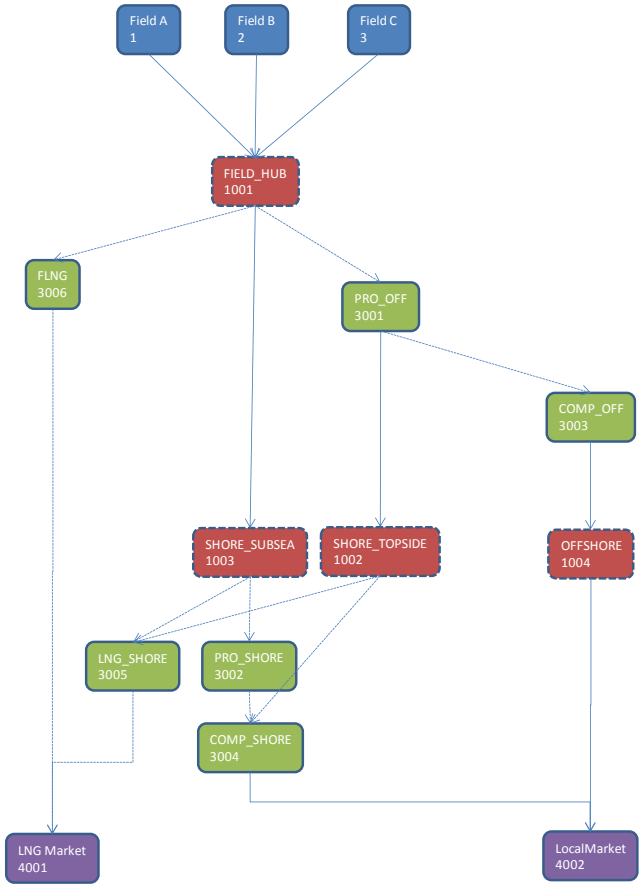
$$C_1 = C_0 \left(\frac{X_1}{X_0} \right)^{2/3}$$

- Fewer binary variables
- Practical advantages
  - easier to set up
  - less need to anticipate solutions
- Matching capacities

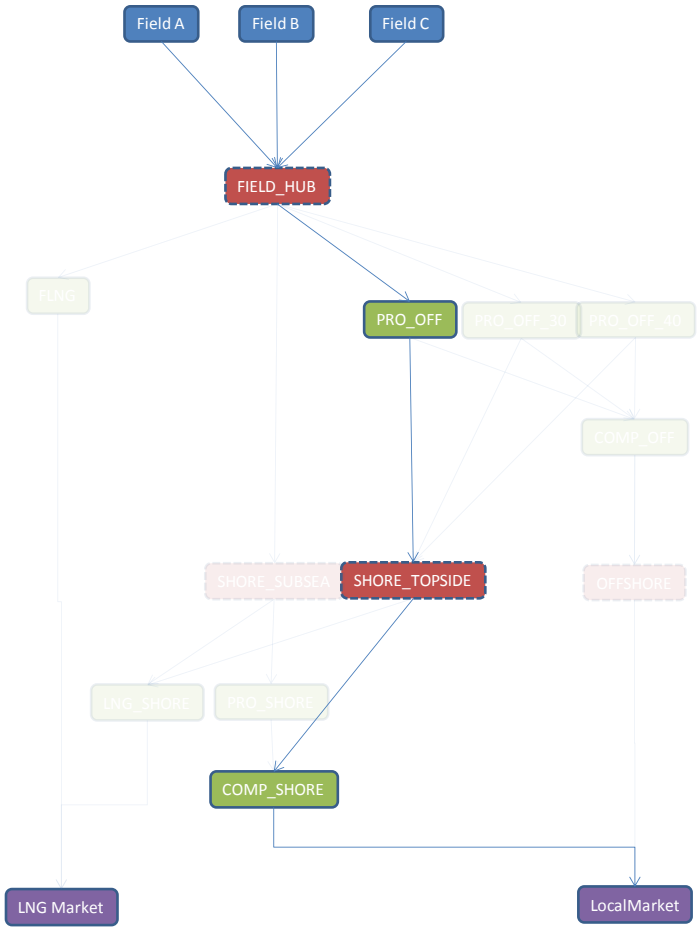
Example


Field A
1
Field B
2
Field C
3
FELD_HUB
1001
FLNG
3006
PRO_OFF
3001
PRO_OFF_30
3007
PRO_OFF_40
3009
COMP_OFF
3003
SHORE_SUBSEA
1003
SHORE_TOPSIDE
1002
OFFSHORE
1004
LNG_SHORE
3005
PRO_SHORE
3002
COMP_SHORE
3004
LNG Market
4001
LocalMarket
4002

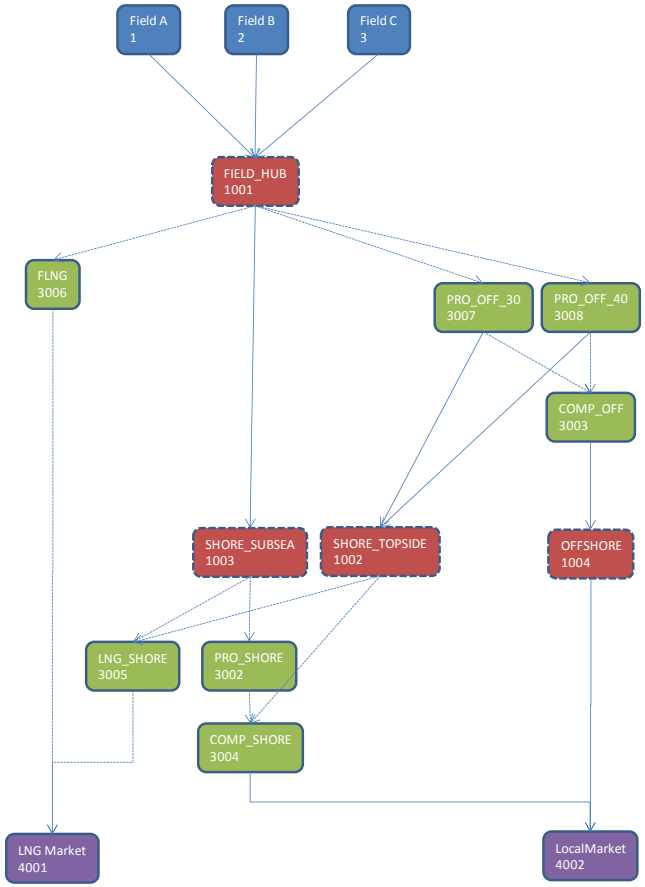
Candidate Projects: Continuous Offshore Capacity



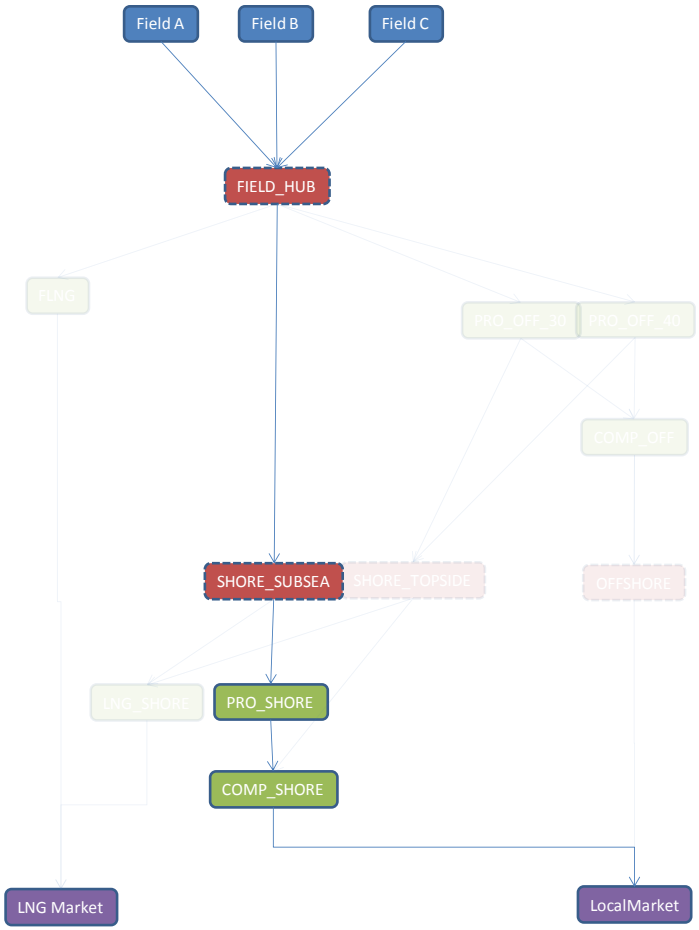
Continuous Offshore Capacity

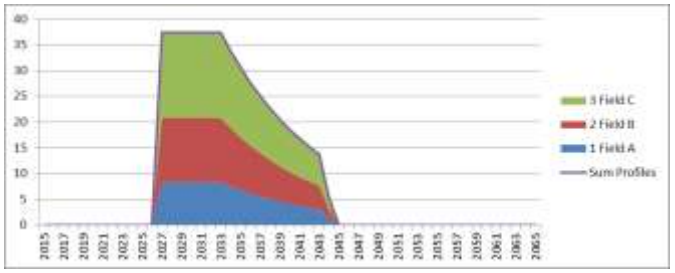


Candidate Projects: Fixed Offshore Production

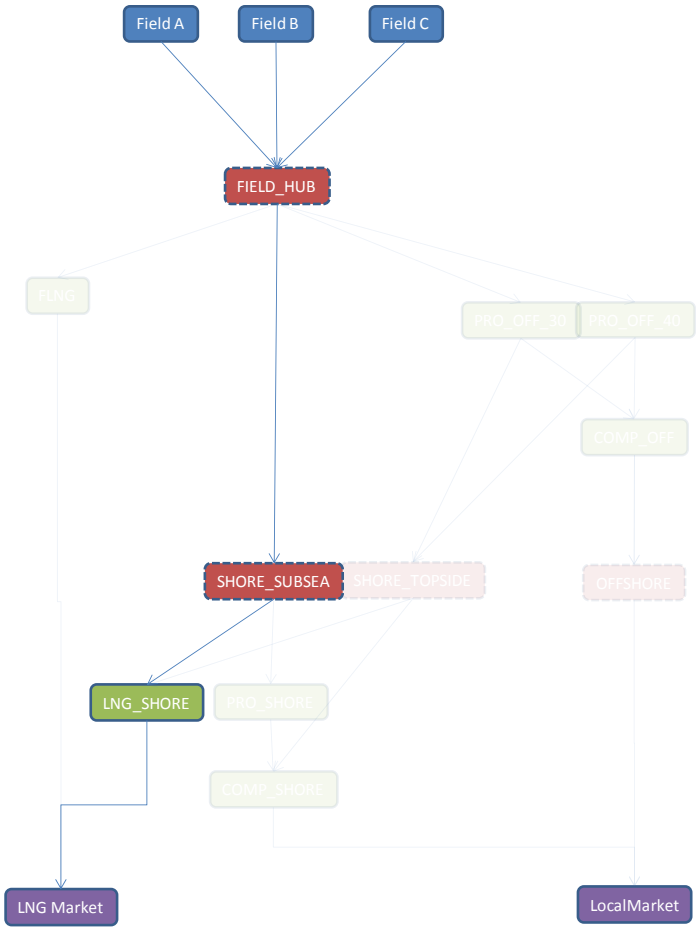


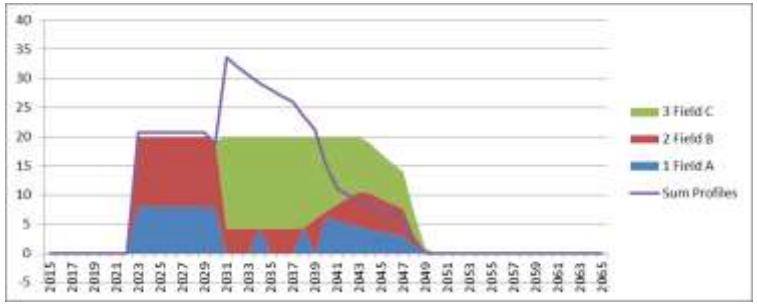
Fixed Offshore Capacity





LNG | Premium 0.75 NOK/SM3





Experience From Analyses

- More thorough and consistent analysis
- Explore solutions to understand problem
- Sensitivities
- Difficult/Impossible to perform manually/spreadsheet
- Manage level of detail