A Decision Support System for Coordinating Vessel Routing, Inventories and Trade in the LNG Supply Chain

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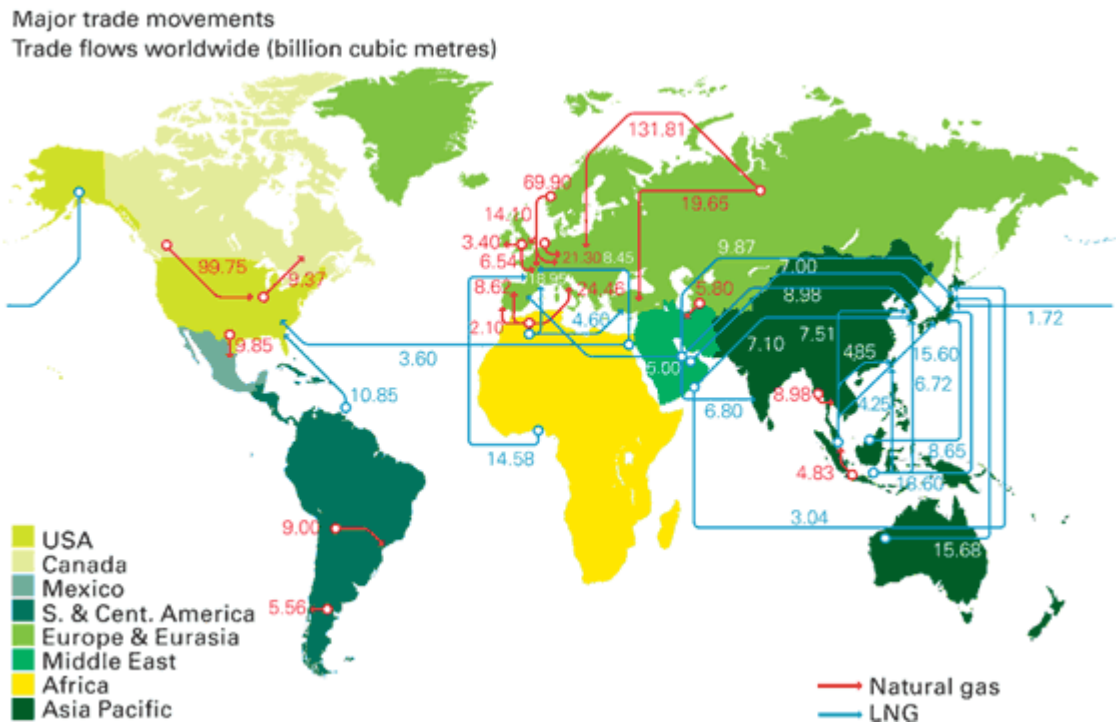
The project

- Goal: Develop a decision support tool for tactical planning for the LNG value chain
- How: Close cooperation
  - Industrial partners knows the business needs and possibilities
  - SINTEF knows the methodology
- Main result: The software “LNGScheduler”

The LNG Business - geography

- Main regional markets
  - North America
  - Europe
  - Asia
- Accounts for 28% of the natural gas trade between countries
- Heading against natural gas as a global commodity

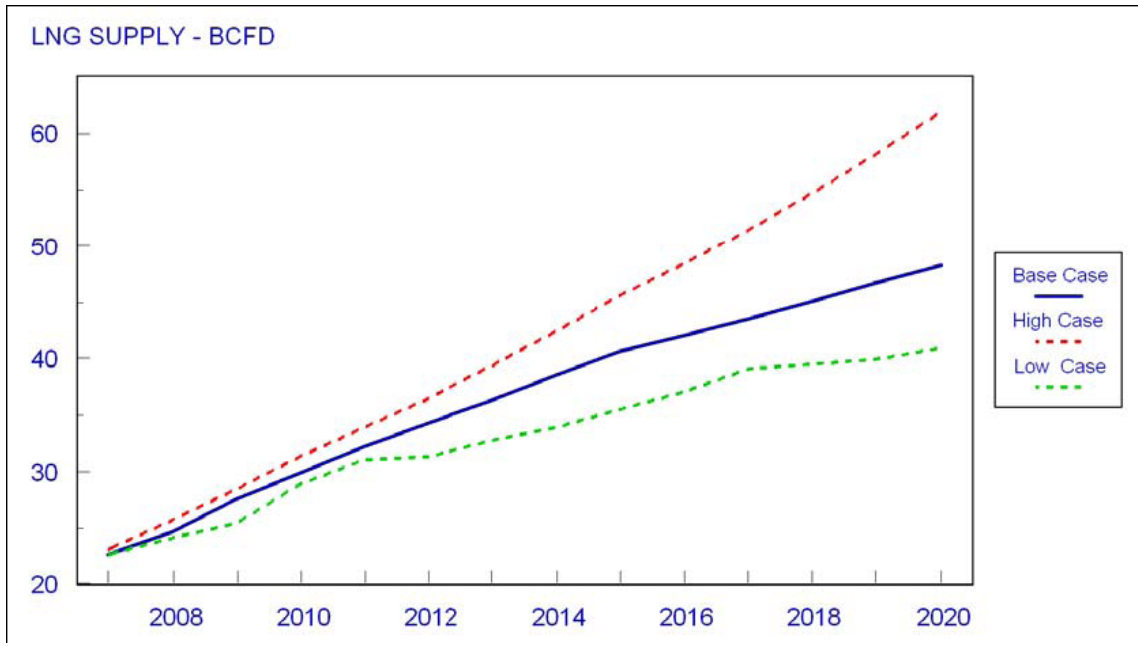


Source: bp.com

The LNG Business - growth

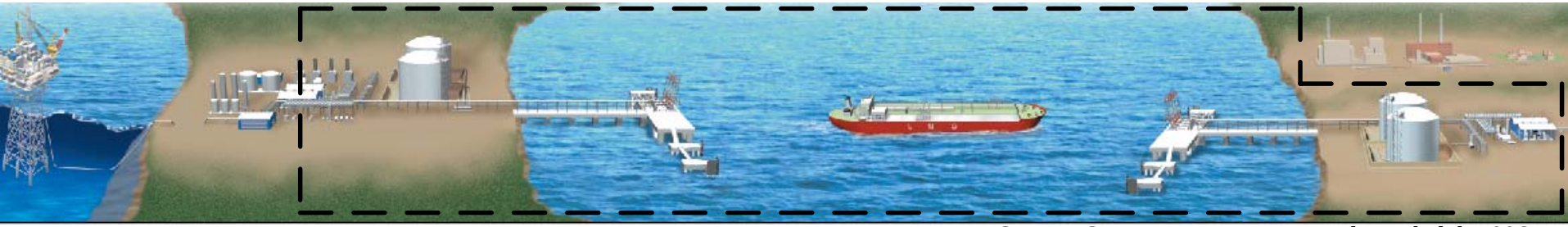
- Fast growing business
  - Around 8% annual growth expected
- 224 LNG tankers operating in March 2007, 145 new tankers ordered
- Increasing use of short term contracts (spot)

Three LNG Growth Scenarios:



Source: Jensen Associates

Tactical value chain planning



Source: Suez Energy International, Michalek 2006

- Main decisions: Production rate, regasification rate, routing and scheduling of vessels, loading/unloading volume, spot vs contract sales
- Traditionally
  - Manual planning in spread sheets and the like
  - Split planning in sub tasks
    - Terminal management, fleet management, contract management
    - Regional planning

Consequences for tactical planning

- Increasing number of vessels and terminals
  - => combinatorics make problem intractable for manual planning
- Increasing flexibility and dynamics in the value chain
  - => making rules of thumb for planning harder
  - => the risk of sub optimization because of split planning increases
  - => increased need for frequent replanning

Methodology

- Mathematical programming / Operations research / Optimization
- Makes the analytical core of a optimization based decision support software

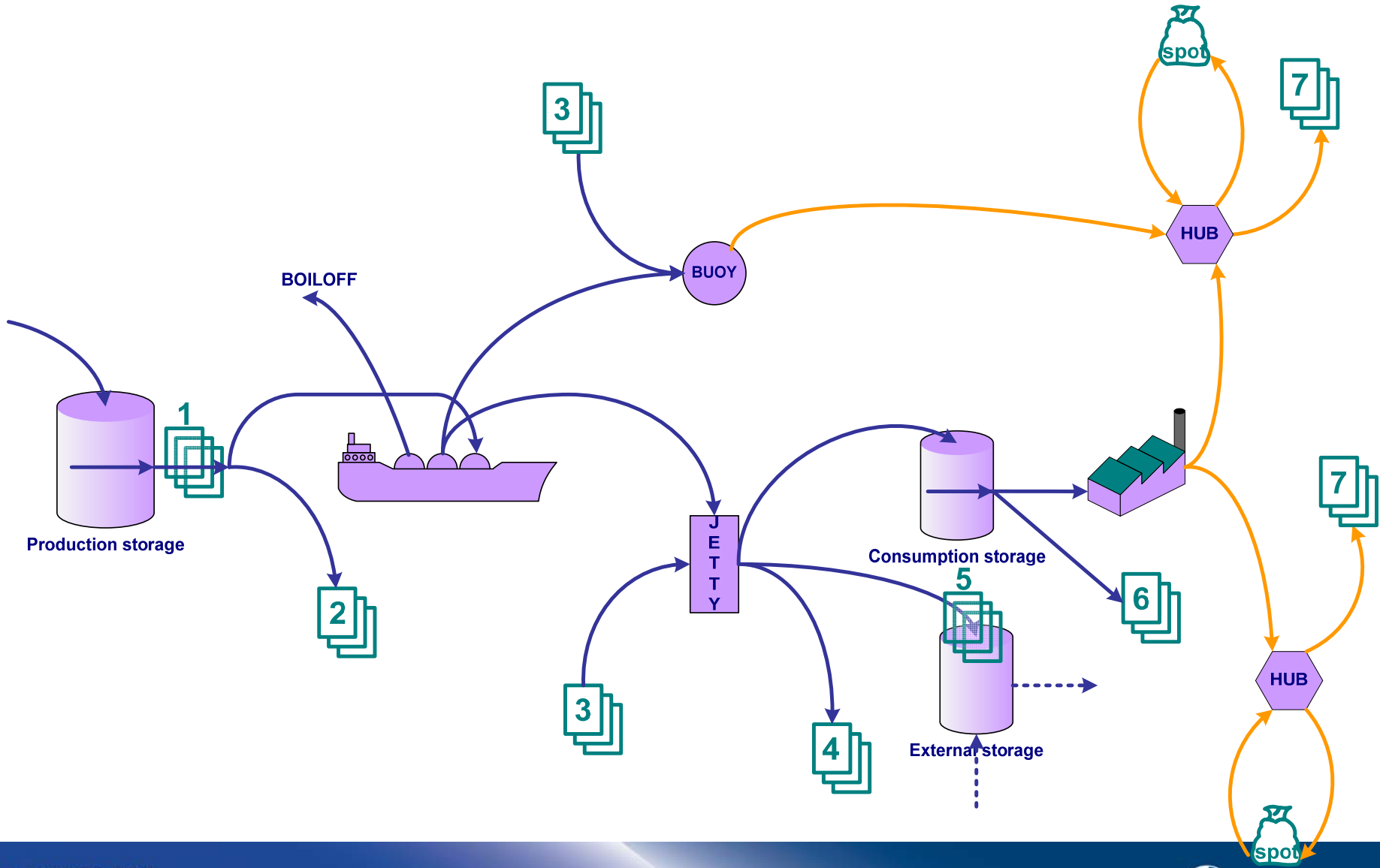
Properties of an optimization model

- Gives solutions (plans) based on the problem description
  - Not an evaluation of suggested solutions or policies
  - Treats the whole picture simultaneously

The model

- Extended inventory routing problem
  - Routing of vessels
  - Inventory management
  - Extension: contract management and NG markets
- Maximize profit
  - LNG/NG purchase and sales
  - Operation costs
    - Fuel costs, port costs, channel costs, charter cost
- Contains linear and discrete elements => mixed integer linear problem (MILP)

The LNG Value Chain – as we model it



Contract structures

- Given, but time varying price
- Upper and lower limit on purchase and sales within day or period
- Destination clauses
  - Limited possibility to deliver gas outside the contracted destinations
- Destination dependent pricing
  - Net back pricing
  - Profit sharing
- Limits on number of visits and frequency of visits in a port
- Etc…

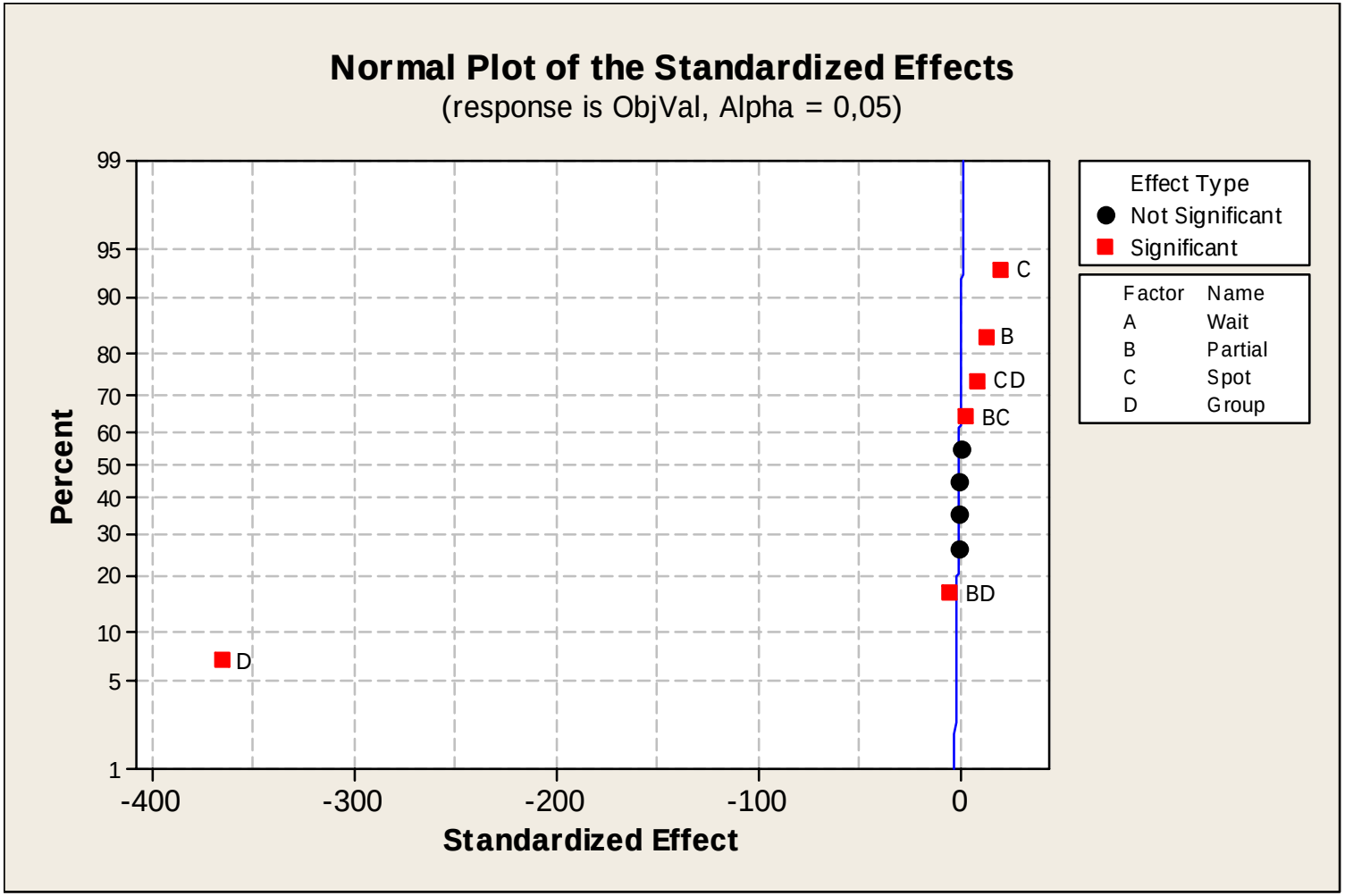
Computational challenges

- Vessel routing is a classical optimization problem known to be computationally hard
- Our model extends the routing with terminals, contracts and markets

- We try different solution strategies using commercial optimization software and tailor-made solvers

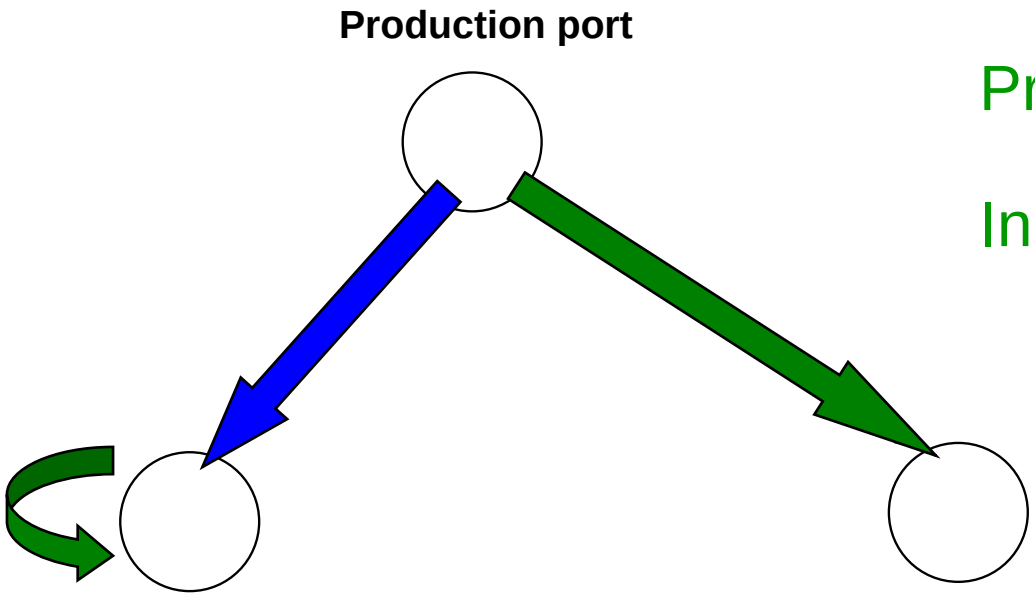
- State-of-the art algorithmic work:
  - Solution times very case dependent
  - 0,5-1 year horizon cases solved to near optimal solutions within 10 hours, first solution typically within an hour
  - More research needed

Some results



Including spot markets

- Example: geographical swap



Consumption port 1

Obligation: 130.000 m^3
Contract price: 70 $/m^3$
Spot price: 72 $/m^3$

Consumption port 2

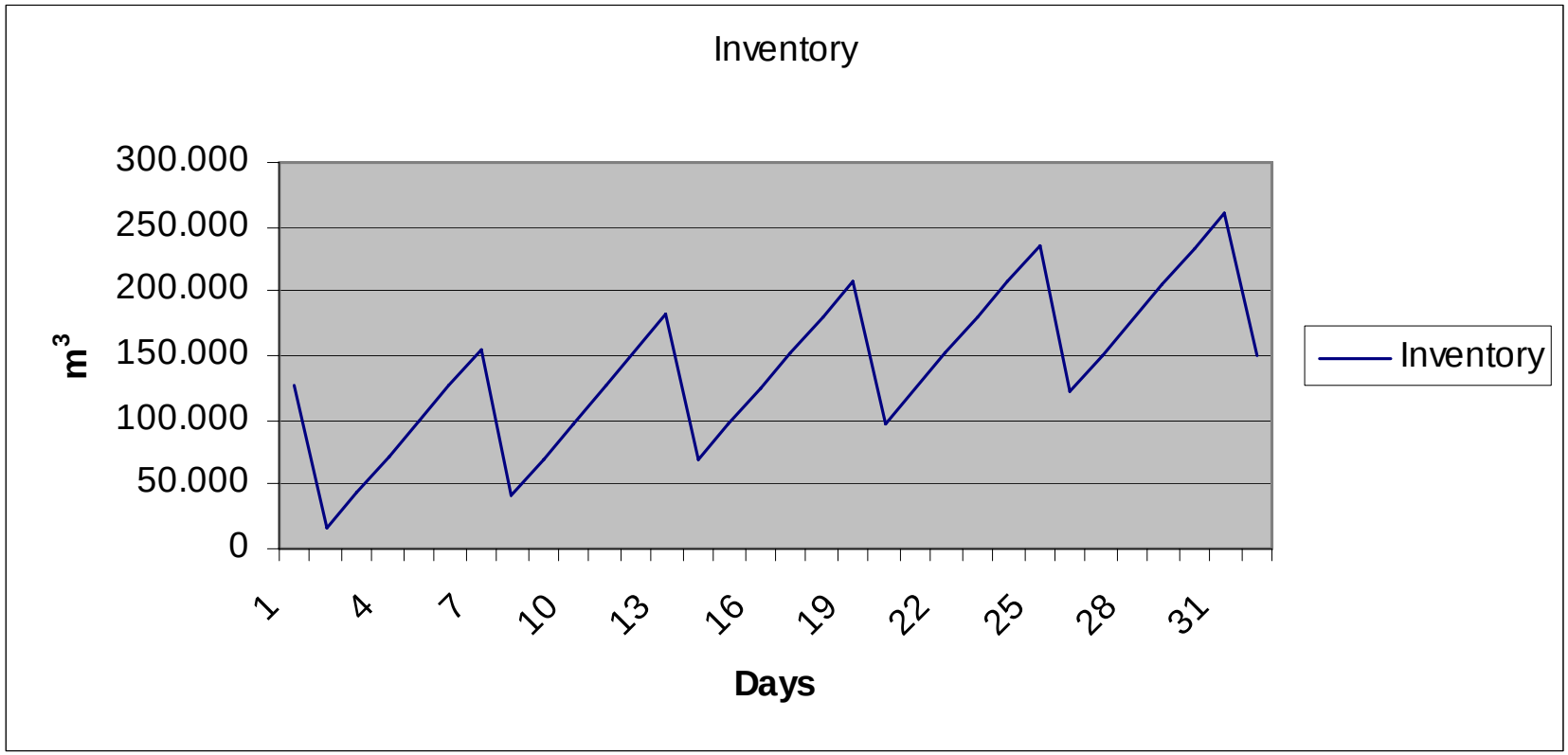
Spot price: 85 $/m^3$

Profit: 9,1 mill $

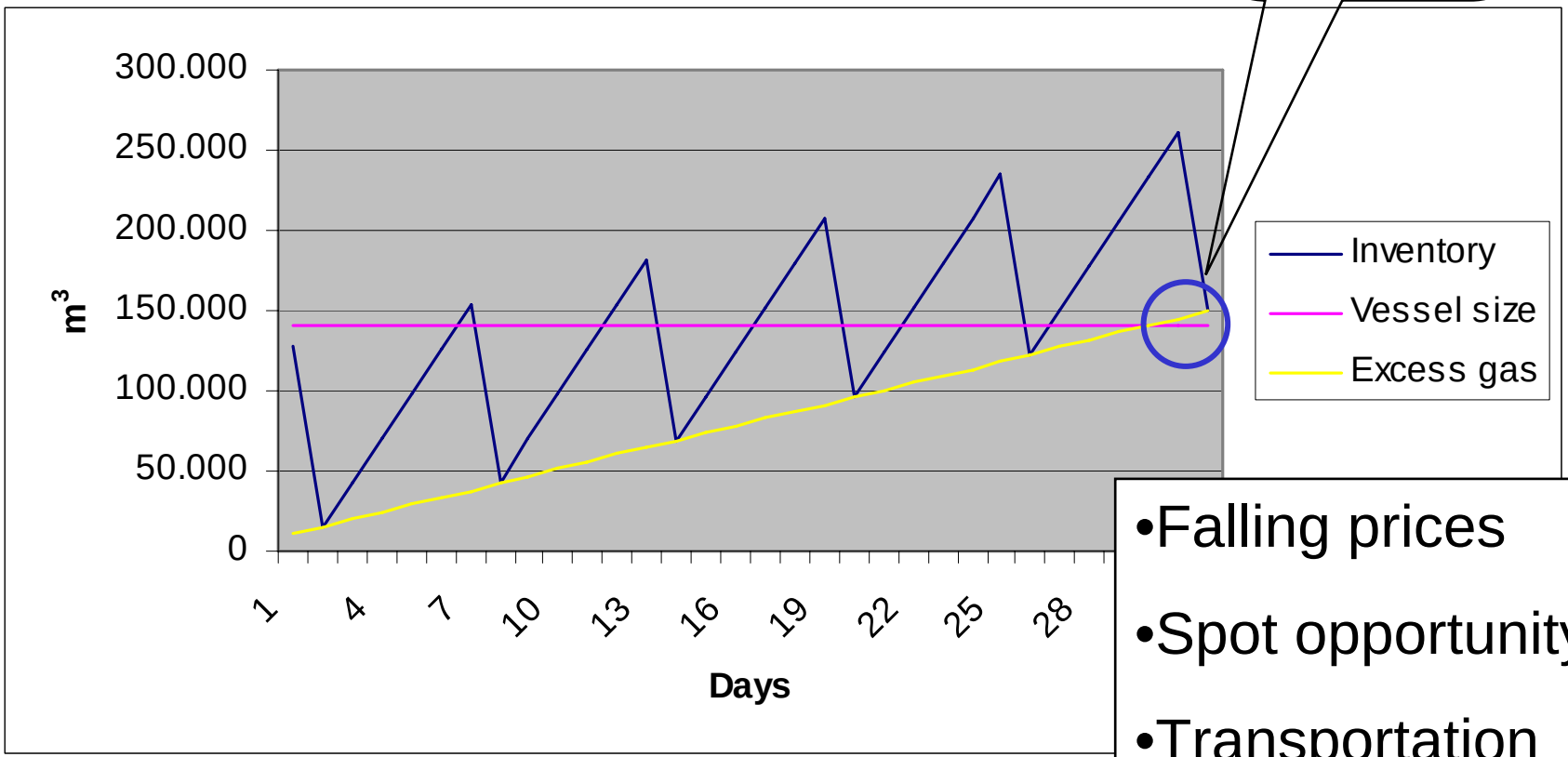
Profit: 10,79 mill $

Increase: 1,69 mill $

Partial loading/unloading



Partial loading/unloading



- Falling prices
- Spot opportunity
- Transportation capacity window

Areas of use

- Develop yearly main plan
- Terminal meetings with negotiations for slots
- Respond on spot opportunities
- Fleet evaluation

- The tool is currently being tested on real planning situations by our industrial partners

Summary

- Development in the LNG/NG business gives new possibilities but makes planning more challenging
- An extended inventory routing problem seems like a good way of modeling the LNG value chain
- Business partners are doing initial tests in real decision processes
- Small real life cases can be solved with existing algorithms, but more research is needed to treat larger problems

The end…

Thank you