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A Route Planner for Gas Transport through the Netherlands

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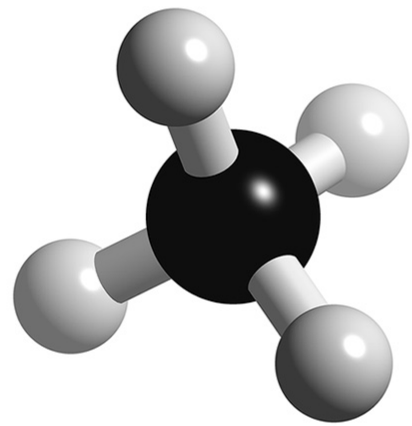
We change the world of energy

I: GAS

History of Gas in the Netherlands - I

1579 – 1644: Jan van Helmont invents the concept of "gas"



(actually, he discovered CO_2, not methane)

History of Gas in the Netherlands - II

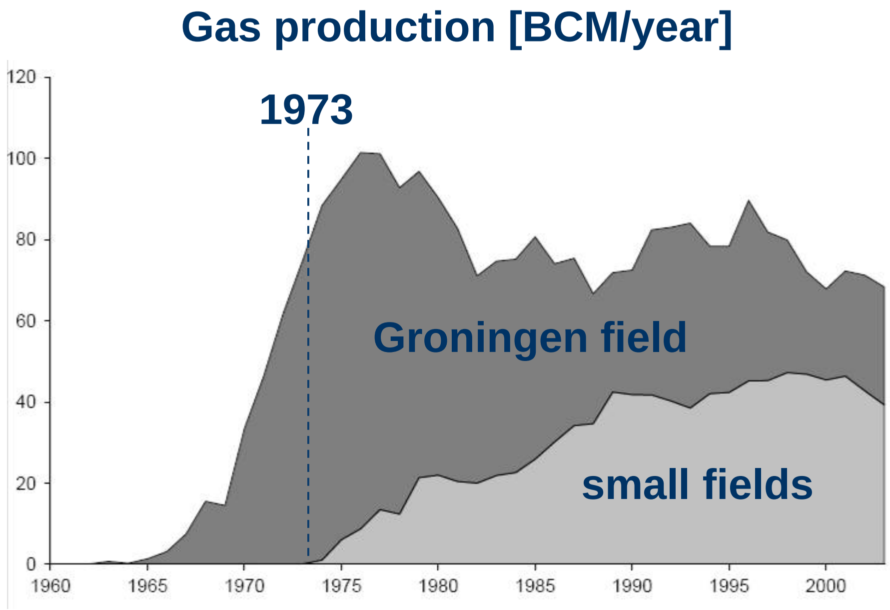
1959: Discovery of the huge Groningen gas field

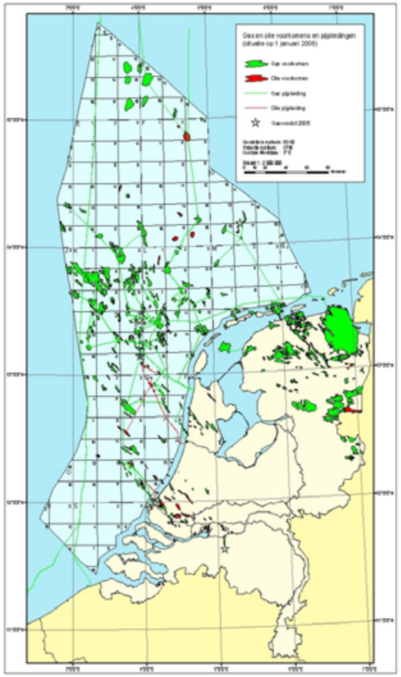
1963: foundation of the integrated company Gasunie

- ►~99,8 % of Dutch buildings connected to gas
- ►gas ~50 % of the Dutch primary energy mix

History of Gas in the Netherlands - III

1973: Policy of small fields secures long-term gas production of ~80 BCM/year





- Export of ~40 BCM/year to large parts of Western Europe (D, B, LUX, F, CH, I)

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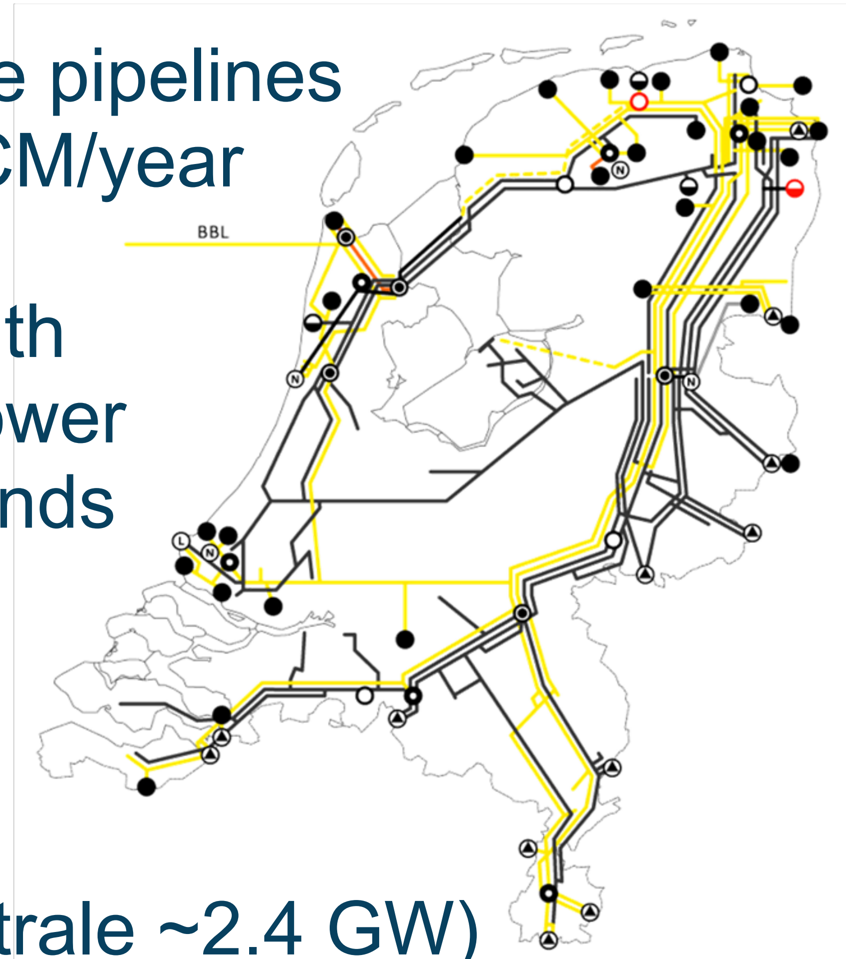
Dutch Gas Transport Network (July 1st, 2005)



- ►~11000 km high pressure pipelines
- ►gas transported ~100 BCM/year
- ►exit capacity ~300 GW
- ►8 compressor stations with ~ 800 MW of installed power
- ►5 different gas quality bands
- ►third-party storage

- ►centralized planning

(for comparison: Eemscentrale ~2.4 GW)

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History of Gas in the Netherlands - IV

European integration

Liberalization of the gas market:

► entry-exit system
► capacity booking and nomination (~ "check-in")

2005 – 2009: unbundling of the gas industry:

► gas trading company GasTerra
► gas transport company gasunie
► KEMA gas consulting & services

Vision of Gasunie as the Gas Roundabout of Northwest Europe

Vision of Gas as the Backbone of a Renewable Energy Infrastructure

- Use the flexibility of gas-fired power as back-up for wind and solar power

- Make natural gas, itself, renewable: certification and injection of green gas

Challenges of Gas Transport

- Entry-exit system driven by market parties
- Shorter lead times down to 1 – 2 hours ahead
- Structural changes in direction of gas supply
- Higher volatility due to intermittency of renewable power

- Concerns about security of supply
- Increased regulatory pressure on cost

Challenges of gas transport: "provide <u>safe</u> and <u>reliable</u> gas transport against <u>minimal cost</u>, <u>environmentally friendly</u>"

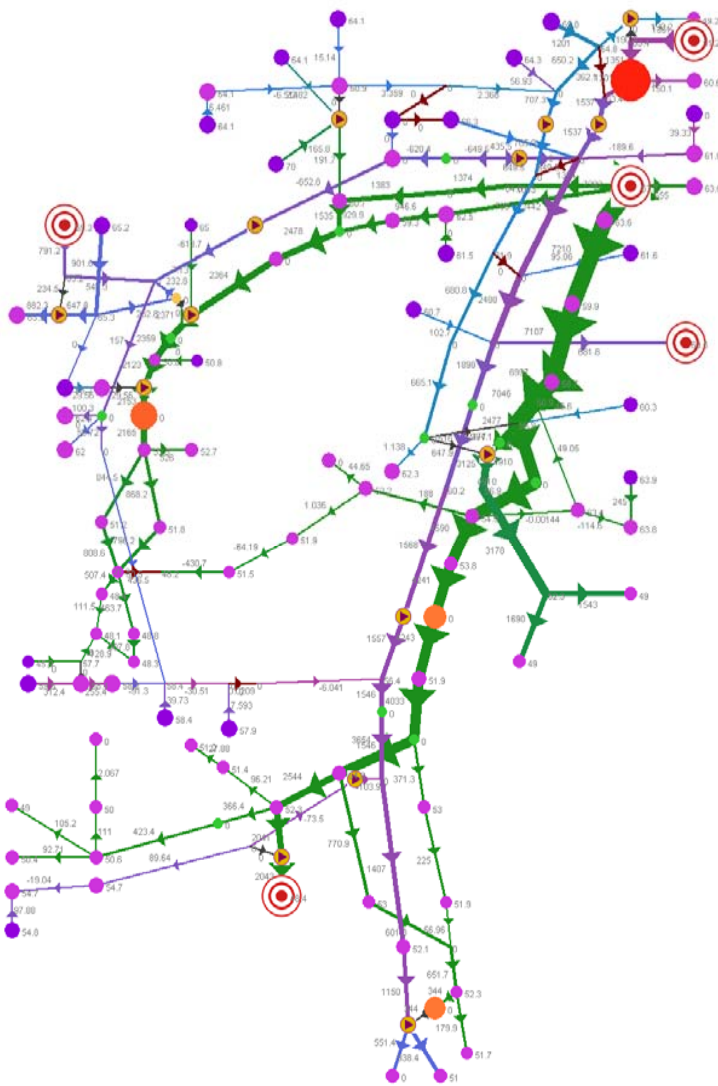
II: OPERATIONS RESEARCH

(ref: T. van der Hoeven,
Math in Gas and the Art of Linearization)

Route Planner for Gas Transport

- Run autonomously in the background
- Find a feasible gas transport plan 24 hours ahead at all times
- Optimize the operational cost of gas transport
  - compressor fuel
  - nitrogen for blending
  - flexibility

  based on nominations by market parties and own predictions of gas demand



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Background: Gas Transport Simulator (GUS - Gasunie simulator)

- State estimation of the gas transport network
- Interpolation of field measurements
- Quality and consistency checks on field measurements
- Checking the feasibility of gas transport plans

Optimization with the simulator:

- Trial-and-error
- Rules-of-thumb
- Full integration of the simulator with an optimizer is not feasible

Operations Research Challenges

- ~100 entry points, ~1000 exit points, thousands of pipeline segments
- nonlinear relation between pressure drop and flow, depending on gas quality
- nonlinear compressor performance curves, depending on gas quality
- compressible line pack
- interchangeability between gas blending and compression
- loops in the network

"more like a weather model than a typical supply chain optimization problem"

Operations Research Strategy - I

- ❶ Starting with the simulation model, reduce the number of variables by creating pseudo pipelines, pseudo compressors, pseudo entry points, pseudo exit points, etc.

- ► Routine for automatic network reduction on the basis of valve positions

Operations Research Strategy - II

❷ "Econometric approach to physical modelling": Tune the pressure drop equations and the compressor performance curves to actual field data

- Routine for automatic (re-)calibration of model parameters on the basis of realizations
  - Pseudo-pipelines 24 hours
  - Pseudo-compressors 1 year

Operations Research Strategy - III

❸ Convert the problem into a linear program (LP)

- ►Linearize the pressure drop equations in the current point
- ►Linearize the compressor performance curves in the current point

Operations Research Strategy – IV

❹ Actually, use sequential linear programming (SLP)

❺ Use more than one model

- ► Initially, do the calculations without pressure
- ► Then include the pressure variables, but keep the quality constant
- ► Finally, use the full model

❻ Gradually increase model stiffness

❼ Introduce flow stabilizers

Result I: Security of Supply

☺ Find a feasible, day-ahead gas transport plan at all times, based on nominations by market parties and predictions for gas demand in the public market

- ► Currently: robust within pressure margins
- ► In the future: robust against alternative scenarios

Result II: Minimal Cost

- Dispatchers configure certain set points and ranges prior to optimization
- ► The route planner runs in the background, autonomously producing "optimal" gas transport plans
- ► After optimization, plans are fed into the simulator for manual fine tuning

☺ Determine day-ahead, cost-optimal gas transport plans, based on nominations by market parties and predictions for gas demand in the public market

Result III: new intuition for gas transport in the new world

- ☒ Dispatchers are living in a "pressure" world, not a "flow" world
- ☒ Ageing human assets

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- ☑ Develop awareness of the operational cost of gas transport
- ☑ Develop intuition and new rules-of-thumb
- ☑ Train new operators

Key findings and new insights

- Different order of preference of compressors
- Flexible use of blending stations
- Extensive use of the flexibility offered by contractual means and line pack
- The main instabilities are caused by the blending stations
- Inaccuracies resulting from automatic network reduction are exploited, and lead to unrealistic plans
- The optimizer outsmarts the dispatcher time and again, but does not explain how

Result IV: Energy Management of Electric Compressors

- ► The advent of electric compression creates opportunities for trade-off between line pack in the gas network and imbalance of the electric grid through the spot market for power production ramp-up/ramp-down

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- ☺ Current trials with an integrated energy management system for fuel gas and electricity show promising results

III: DEMONSTRATION

Concluding remarks I: GAS

- The route planner has run without problems for more than one year
- The route planner is capable of finding optimal day-ahead plans in a highly complex gas transport network
- The resulting plans must be read as providing directions and not details
- The route planner is a powerful tool for developing insight in the changing gas transport landscape

Concluding remarks II: OR

- Since most algorithms are loops around linear programs, why not design your own loop around linear programs?
- Very good results with an econometric approach to physical modeling
- "anything goes": use all the tricks you know
- Spend 50 % of your time on the relationship with the client, 40 % on the problem formulation, and 10 % on modeling and optimization

Thank you for your attention

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