Mathematics of Gas Transport – Let‘s talk about data

Janina Zittel and the Energy Network Optimization Team

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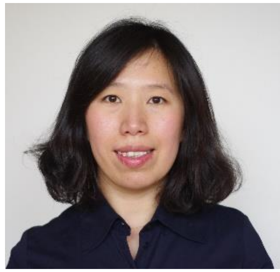
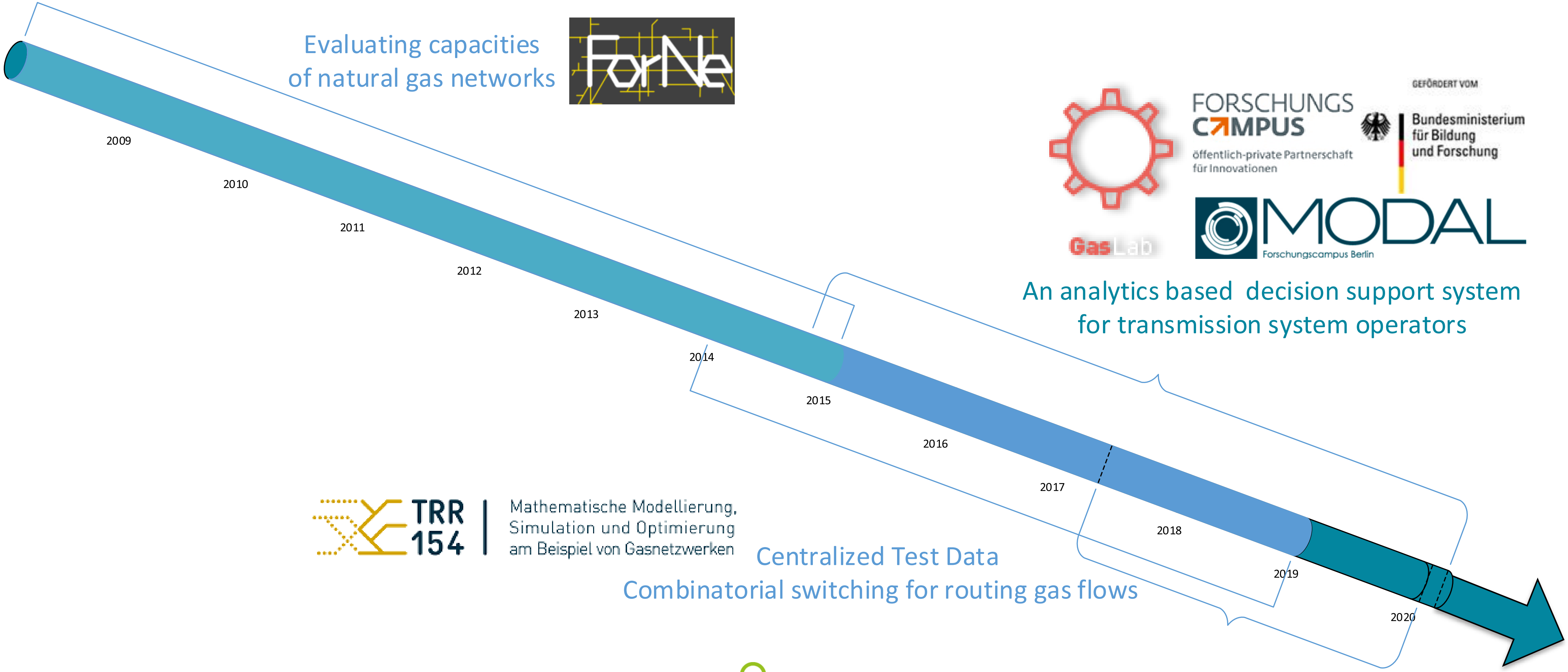


Solving problems of TSOs using mathematical optimization – our journey



Evaluating capacities of natural gas networks

ForNe

GasLab

FORSCHUNGS CAMPUS
öffentlich-private Partnerschaft für Innovationen

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

MODAL
Forschungscampus Berlin

An analytics based decision support system for transmission system operators

TRR 154 | Mathematische Modellierung, Simulation und Optimierung am Beispiel von Gasnetzwerken

Centralized Test Data

Combinatorial switching for routing gas flows

plan4res

Synergestic Approach of Multi-Energy Models for an European Optimal Energy System Management Tool

With our Project Partners from Research and Industry

The ForNe Team

With the industry partner Open Grid Europe GmbH,
The research partners from WIAS Berlin, HU Berlin, TU Darmstadt, U Duisburg-Essen, FAU Erlangen-Nürnberg, Leibniz-U Hannover
And the software companies atesio and develOPT

The plan4res Team

With the research partners from Electricitè de France, Cray Computer GbmH, RWTH Aachen, Imperial College London, Uni Pisa, Uni Modena e Reggio Emilia, Siemens AG

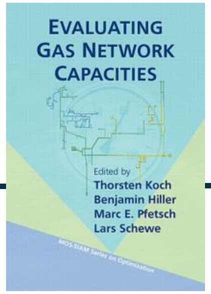
2nd Conference on Mathematics of Gas Transport

With experts from industry and science

The MODAL GasLab team

With the industry partners from Open Grid Europe GmbH and Soptim

ForNe Nomination Validation

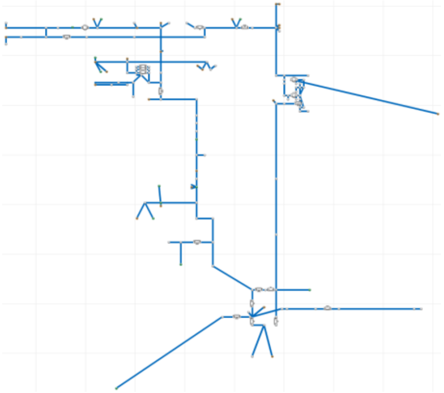


- Given
  - ➢ a detailed description of a gas network
  - ➢ a nomination specifying amounts of gas
  - ➢ flow at entries and exits
- Find
  1. settings for the active devices (valves, control valves, compressors)
  2. values for the physical parameters of the network that comply with gas physics and legal and technical limitations

? How to decide whether a given nomination is technically feasible

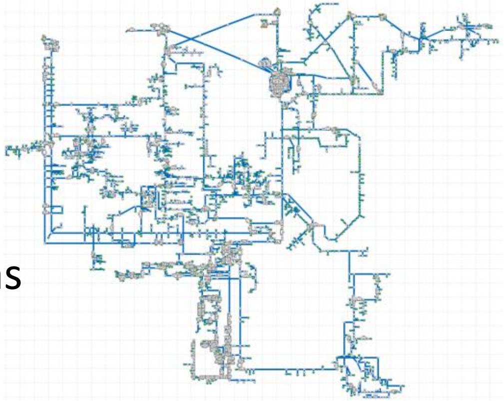
From

Simplified subnetwork



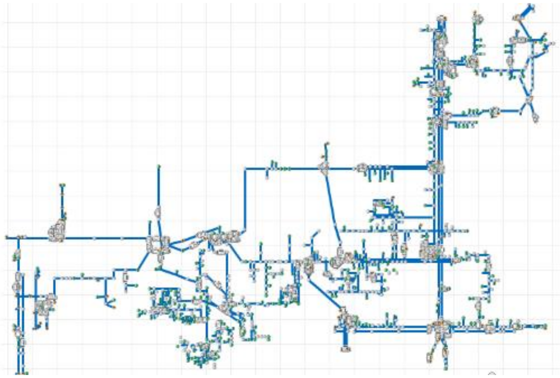
Over

Entire l-gas network

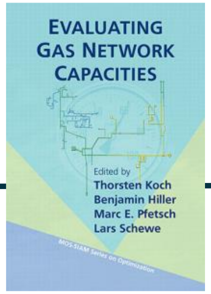


To

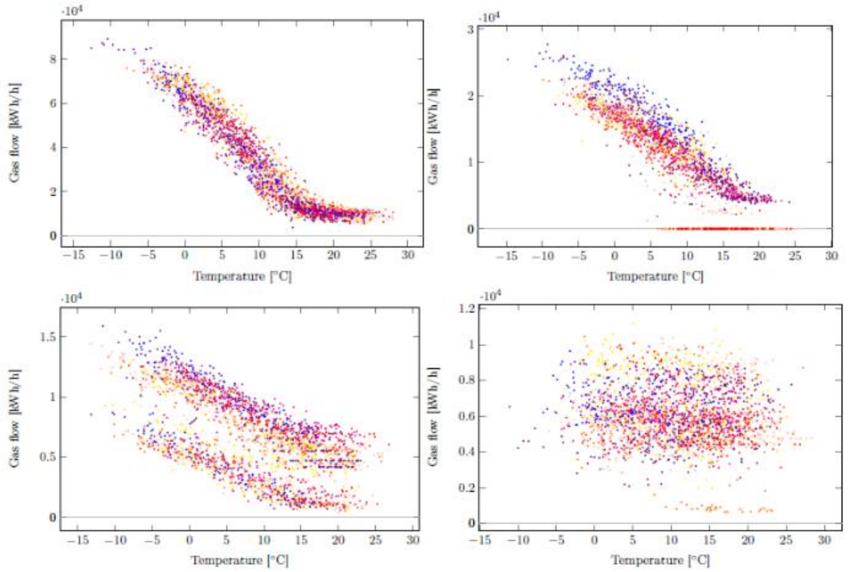
Entire h-gas network



ForNe Booking Validation



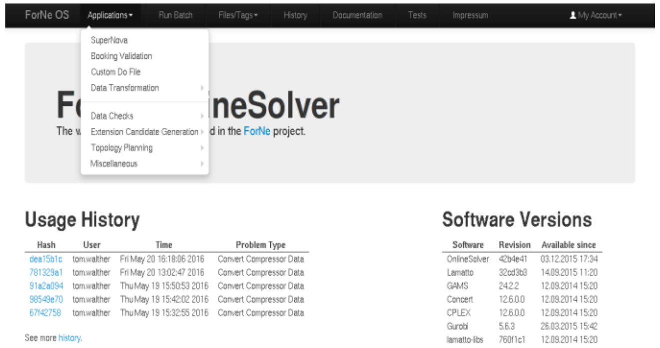
? How to decide whether adding another capacity product delivers feasible nominations



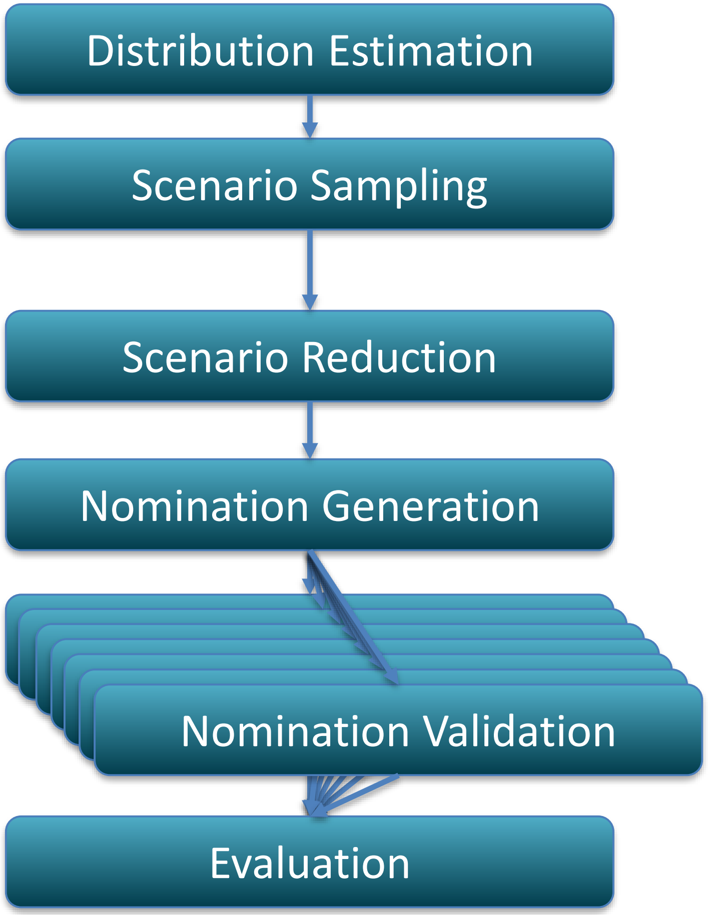
A typical run combines

- 20 datasets

(10 temperature classes, workday/weekend)



- with 6 periods for contracts
- to get 1,000 nominations each
- total of 120,000
- on a network of 4,000 arcs and
- 450 switching elements



and takes two weeks on a cluster of 256 cores, with < 1 h / nomination

Input Data - The GasLib Format

Network Topology - .net

```
<source geoWGS84Long="10.0667004121" alias="" y="6691.6" x="12108"
        geoWGS84Lat="48.448723929" id="source_1">
  <height unit="m" value="7"/>
  <pressureMin unit="bar" value="1.01325"/>
  <pressureMax unit="bar" value="121.01325"/>
  <flowMin unit="1000m_cube_per_hour" value="0"/>
  <flowMax unit="1000m_cube_per_hour" value="10000"/>
  <gasTemperature unit="Celsius" value="15"/>
  <calorificValue unit="MJ_per_m_cube" value="41.342270292"/>
  <normDensity unit="kg_per_m_cube" value="0.82"/>
  <coefficient-A-heatCapacity value="31.61010551"/>
  <coefficient-B-heatCapacity value="-0.004284754861"/>
  <coefficient-C-heatCapacity value="8.019089e-05"/>
  <molarMass unit="kg_per_kmol" value="18.0488790169"/>
  <pseudocriticalPressure unit="bar" value="46.7020607"/>
  <pseudocriticalTemperature unit="K" value="202.4395142"/>
</source>
<sink geoWGS84Long="10.0667004121" alias="" y="6794.3" x="12090"
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  <pressureMin unit="bar" value="1.01325"/>
  <pressureMax unit="bar" value="121.01325"/>
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  <flowMax unit="1000m_cube_per_hour" value="10000"/>
</sink>
<innode geoWGS84Long="7.92474003681" alias="" y="6324.6" x="5389.9"
        geoWGS84Lat="48.3578033109" id="innode_1">
  <height unit="m" value="77"/>
  <pressureMin unit="bar" value="2.01325"/>
  <pressureMax unit="bar" value="86.01325"/>
</innode>
```

Scenario - .scn

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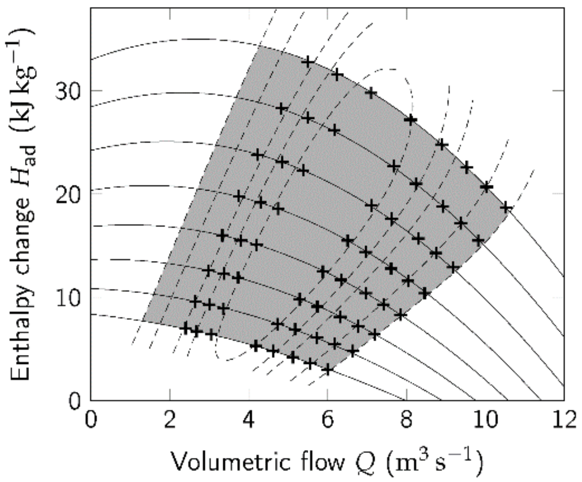
<node type="entry" id="source_1">
  <pressure unit="bar" bound="lower" value="2.0133"/>
  <pressure unit="bar" bound="upper" value="86.013"/>
  <flow unit="1000m_cube_per_hour" bound="both" value="472.636"/>
</node>
```

Compressor station data - .cs

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  <height unit="m" value="77"/>
  <pressureMin unit="bar" value="2.01325"/>
  <pressureMax unit="bar" value="86.01325"/>
</innode>
```


Please checkout our website: http://gaslib.zib.de
For a full documentation

Schmidt, M.; Aßmann, D.; Burlacu, R.; Humpola, J.; Joormann, I.; Kanelakis, N.; Koch, T.; Oucherif, D.; Pfetsch, M.E.; Schewe, L.; Schwarz, R.; Sirvent, M. **GasLib—A Library of Gas Network Instances**. *Data* **2017**, *2*, 40.

The MODAL GasLab – The Goal

Building the future decision support system for nationwide gas transmission system operations

From

- Network evaluation / control operation is based on individual experiences
- Variety of historically learned control options
- Predictive control required due to network inertia

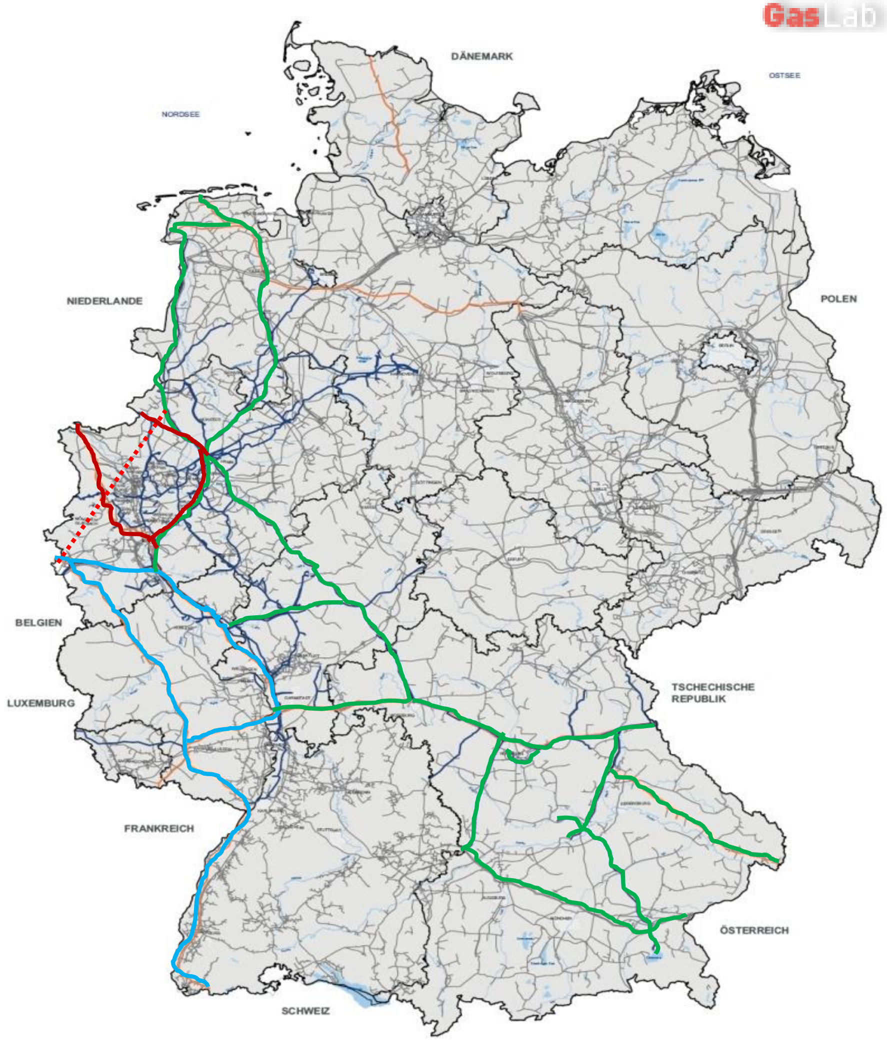
To

- Specific, standardized recommendations for network operations
- Modern forecasting and optimization methods allow a predictive and stable network operation that detects and prevents the occurrence of problems

The MODAL GasLab – The Approach

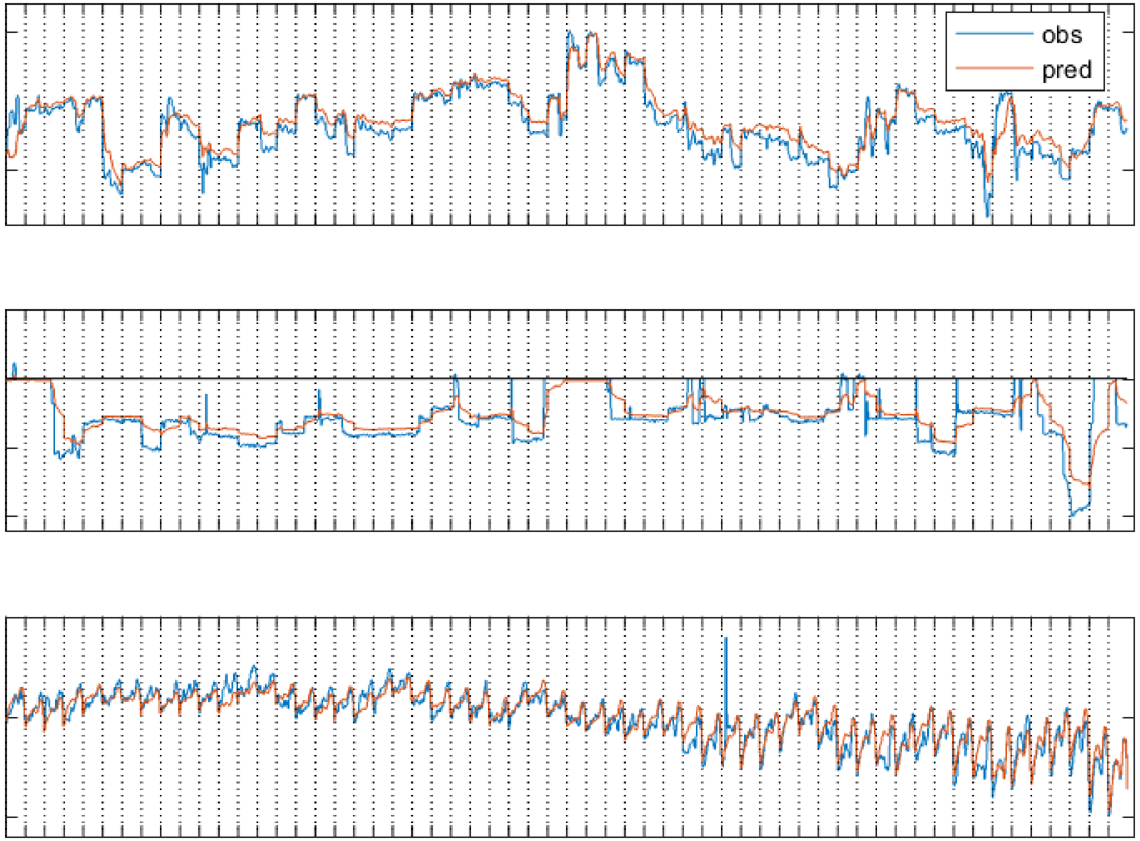
The three types of analytics for a foresighted decision support system for gas grid operation

- **Descriptive** analytics: modeling and simulating the gas flow in the network
- **Predictive** analytics: predicting future gas supply and demand at the entries and exits of the network
- **Prescriptive** analytics: recommending network control measures to ensure safe and efficient operation of the network.

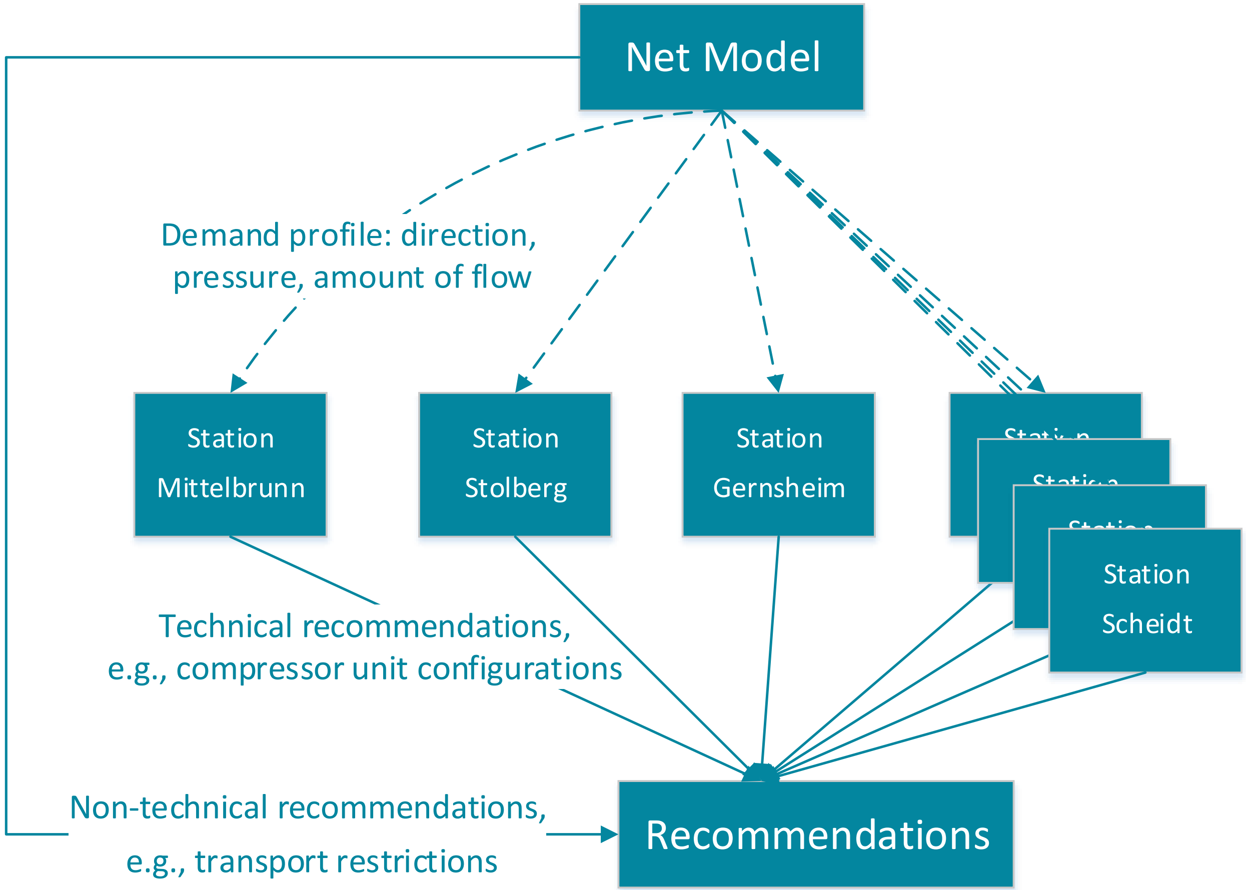


Components of the GasLab Solution

The GasLab GasFlow Forecasting System



The GasLab Navi

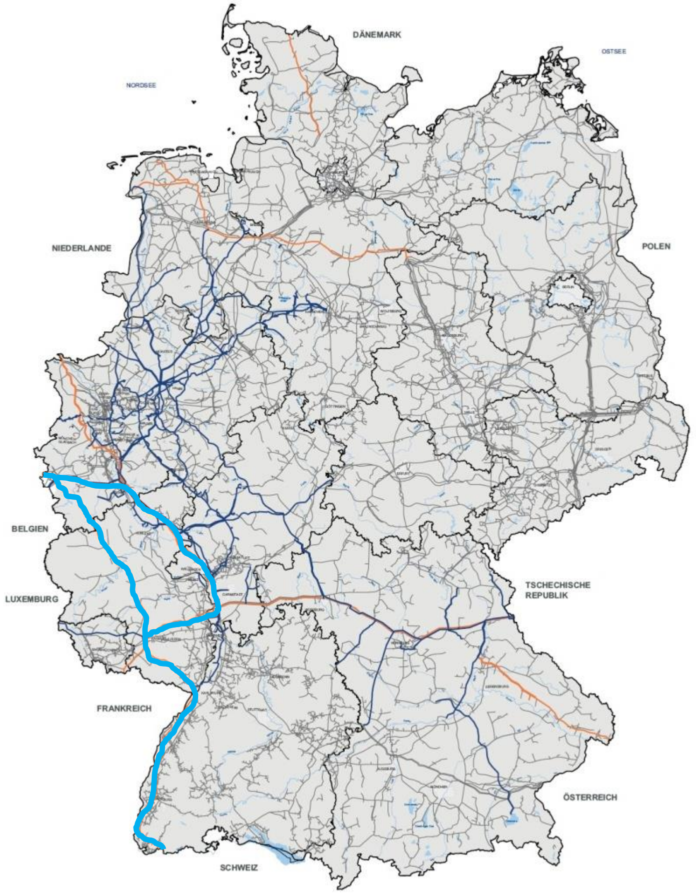


Data

- 1 Transmission System Operator

- Interfaces to several source systems
  - measurements
  - simulations
  - nominations
  - state of active elements
  - maintenance schedules
  - …

- 2 **tailored models** for the individual **stations** (a coarse model and a detailed model)



Gas Network Modelling in plan4res

Multimodal Investment Model

Scenario framework per year
Trajectory of technology mix/capacities

Disaggregation and European Unit Commitment Model

Schedules

Transmission Grid Operation Model

Re-dispatched schedules for GPPs and P2G

Allowable limits on gas supply from P2G and gas demand of GPPs (electricity induced nomination)

Schedules for GPPs and P2G (electricity induced nomination)

Nomination Validation (NoVa)

Model Extension - 1

Compute the limit values for electricity induced supply and demand

Model Extension - 2

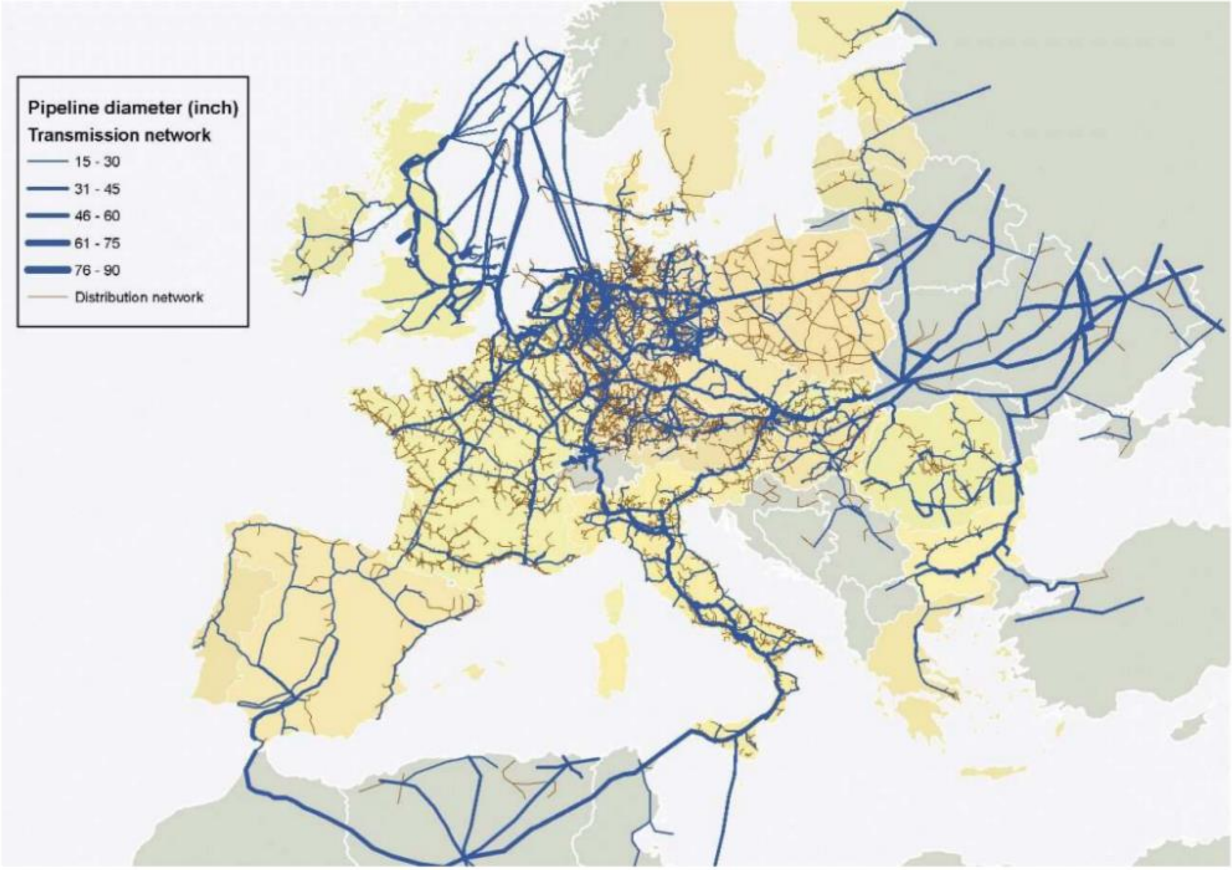
Re-dispatches nomination at P2G and GPPs if not feasible, minimizing re-dispatching costs

Plan4res – Data

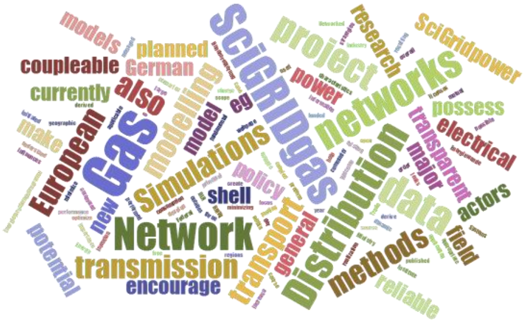
- Public Data Sources
  - TSO Transparency Platforms, TSO Web Sites; Organizations, i.e., ENTSOG, GIE, GSE, FNB; Bidding platforms, i.e., PRISMA; Open dataset provided by Electricity, Heat, and Gas Sector Data for Modeling the German System Project[1]
- Nominations
  - Electricity induced supply and demand: supply from P2G, demand of GPPs
  - Non-electricity induced supply and demand: Imported gas, gas from storages, LNG, production, cross-border demand, household usage, industry
- Gas Network Description
  - Nodes: X,Y, height, types, flow bounds
  - Pipelines: End nodes, length, diameter, roughness Control valves: End nodes, other technical data
  - Compressor stat.: End nodes, other technical data

[1] Kunz, F. ; Weibezahn, J.; Hauser, P.; Heidari, S.; Schill, W.-P.; Felten, B.; Weber, C. (2017).
Reference Data Set: Electricity, Heat, and Gas Sector Data for Modeling the German System (Version 1.0.0)
[Data set]. Zenodo. http://doi.org/10.5281/zenodo.1044463

But software solutions for Europe need open data for Europe



Carvalho, Rui et al. (2009). **Robustness of Trans-European Gas Networks**. *Physical Review E 80.1*



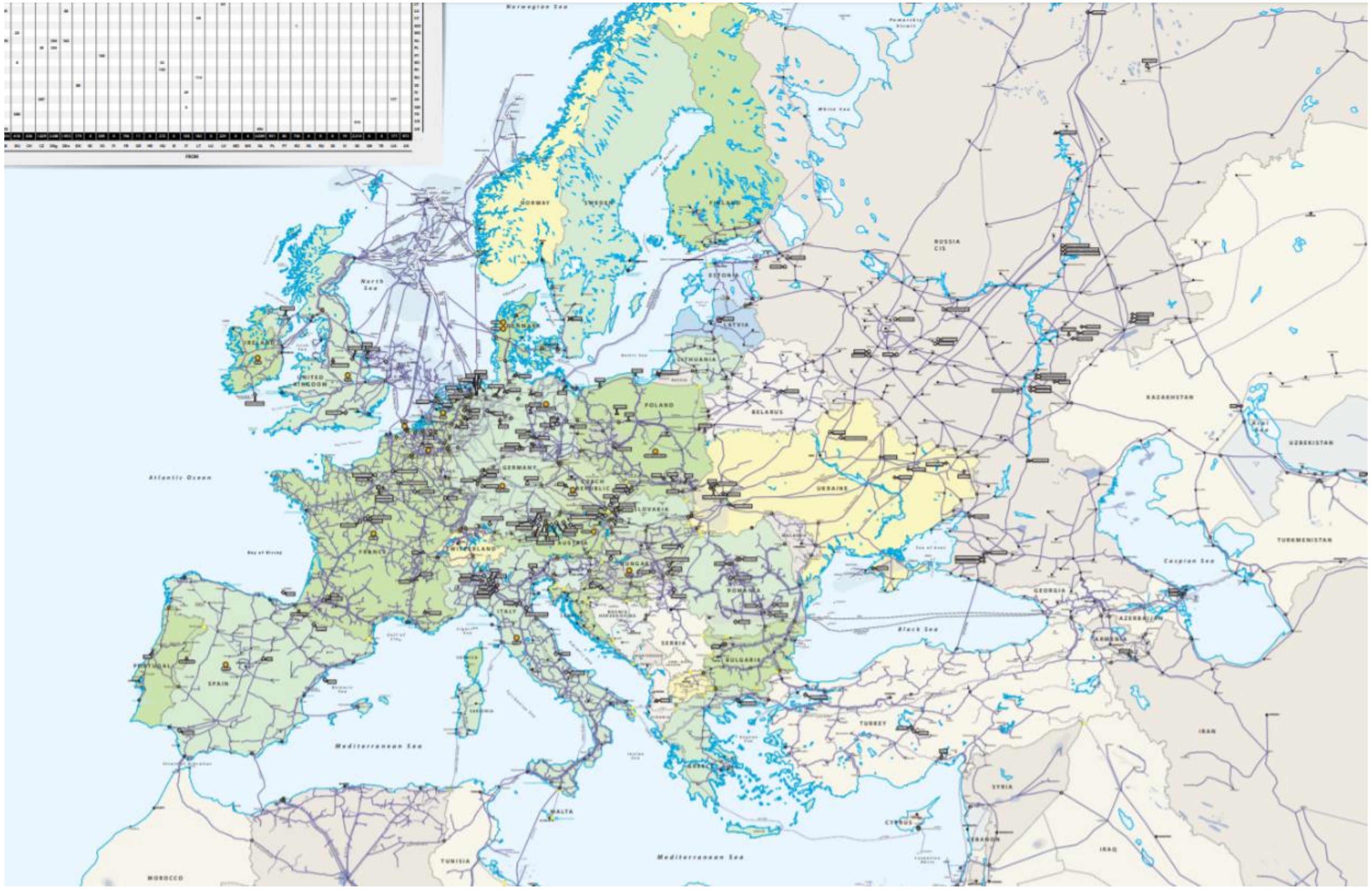
SciGRID Gas

Ongoing project at DLR Institute for Networked Energy Systems – that aims to deliver a European data set for scientific purposes funded by the German Ministry of Economic Affairs and Energy

We could do so much more, if only …

Data available at TSOs, DSOs and organizations like ENTSOG

could be shared **open access** (for academic purposes)



Screenshot of https://www.entsog.eu/sites/default/files/2018-12/ENTSOG_GIE_SYSDEV_2017-2018_1600x1200_FULL.pdf ENTSOG