HOW TWO GAS NETWORK OPERATORS PREPARED FOR THE ENERGY TRANSITION BY AUTOMATING KEY NETWORK ANALYSIS FUNCTIONS

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ABSTRACT

The energy transition presents challenges and opportunities to (gas) distribution network operators. As gas network operators adjust to the changing energy mix, they will start distributing alternative, more sustainable gasses through their networks, such as biomethane and hydrogen, possibly mixed with natural gas. Given the added complexity introduced by these additional gas sources and blends, they will need to carry out feasibility and impact assessments studies, as well as perform ongoing analysis of the network operation, to ensure safe and reliable operation. This puts a high reliance on the ability to build accurate and consistent flow models of the gas network, as well as integrate data from sources such as GIS, and SCADA or possibly edge monitoring devices. Given the pace of change, and the requirements to provide ever more data for analysis and insights, gas network operators are looking to ways of automating key processes within their business. This paper will present two real world case study examples of how data from GIS, SCADA & edge devices have been used to create high reliability models, reducing data errors, automating previously manual processes, and allowing network analysts to focus on value adding activities. With the integration of field data, the network modelling is moved closer to ‘real time’ by automatically updating the models with live data. Scenarios are set up to run automatically or on demand/by event providing reports that are published across the business on company dashboards.

1. INTRODUCTION AND BACKGROUND

Our future energy system will be different to the system of the past. Electricity demand will grow strongly, driven by the adoption of electric vehicles and heat pumps, and potentially production of hydrogen. Most of this demand will be met by cheap renewables which will transform the economics of the sector, delivering plentiful electricity when the wind is blowing and sun is shining, alongside higher cost reliable low carbon power such as nuclear, hydrogen power plants, and gas plants with carbon capture and storage to fill the gaps, with fossil fuels playing a diminishing role over the long term.

The unprecedented rise in gas prices over the last twelve months has delivered a major shock to the energy system across Europe in particular. There is a need to strengthen the resilience of the sector to better cope with volatility and to make the sector fit for the longer term, bridging to a future market that is less subject to volatile natural gas prices, and makes efficient use of cleaner, greener, secure home-grown energy.

In this rapidly evolving energy market, utilities are ever more dependent on highly accurate and fully up-to-date models of their networks to make critical timely decisions based on the most accurate data available, and we are seeing a move towards real-time operations.

2. ENERGY TRANSITION (SOUTH AMERICA AND EUROPE)

The energy transition and the transformation of the energy / gas system is taking shape across the world. We zoom into several regions, as they are relevant to the customer use-cases described later in the document.

2.1. Brazil

Brazil's energy policies measure up well against the world's most urgent energy challenges. Access to electricity across the country is almost universal and renewables meet almost 45% of primary energy demand, making Brazil's energy sector one of the least carbon-intensive in the world. Total primary energy demand has doubled in Brazil since 1990, led by strong growth in electricity consumption and in demand for transport fuels on the back of robust economic growth and a burgeoning middle class.

Large hydropower plants account for around 80% of domestic electricity generation, making the Brazilian electricity mix one of the cleanest in the world. Continued expansion of hydropower is increasingly constrained by the remoteness and environmental sensitivity of a large part of the remaining resource. PV projects (utility scale and distributed) will represent nearly 70% of all additions in the coming years. Reliance on other sources for power generation is also growing, notably natural gas, wind (on-shore and off-shore) and bioenergy. Brazil is a global leader in second generation biofuels and flex-fuel cars provide a large domestic market. Ethanol supply is set to average 660 kb/d in 2026, up 90 kb/d compared with 2020 and 35 kb/d higher than in 2019. A system of contract auctions provides a mechanism to bring forward investment in new generation and transmission capacity, as well as to diversify the power mix.

Large offshore oil and gas discoveries have confirmed Brazil's status as one of the world's foremost oil and gas provinces. Pre-salt discoveries also prompted a change in upstream regulation, granting Petrobras – the national oil company – a strengthened role in areas deemed strategic. Production from the deep-water pre-salt fields in the Santos basin has gained considerable momentum in recent years, offsetting declining output from mature fields elsewhere. Thanks to such successful developments in deep-water production, Brazil turned into a net oil exporter in 2017. As a result, total oil supply is expected to grow by 1.2 mb/d to 4.2 mb/d in 2026, according to IEA forecasts.

At COP26 where Brazil announced a long-term objective to reach net-zero emissions by 2050 and a 50% carbon emissions reduction plan coupled with a zero illegal deforestation target by 2030. This is supported by an announced 2030 climate action plan and a hydrogen national strategy which is being developed.

Currently Brazil, Mexico, Venezuela, and Argentina are responsible for 80% of regional GHG emissions. Reducing unabated fossil-fuel use in industry, greening road transport, and improving energy efficiency are key transition challenges.

Brazil aims to maintain hydropower and boost solar and offshore wind output. Yet it wants oil and gas production to almost double by 2030. Land-intensive production of liquid biofuels challenges the forest fuel-food balance. Incipient, but lacking a regulatory framework, hydrogen is set to become part of the Brazilian energy strategy (National Energy Plan 2050, December 2020). Brazil has also indicated/adopted a target for carbon neutrality by 2050.

2.2. Europe

Transition policies, European Green Deal and 'Fit for 55' aim at a net zero greenhouse gas emission economy by 2050, which is forecast not to be met. Nearly decarbonized electricity grid by 2050; < 5% generation by coal and natural gas. The high carbon price could spur CCS uptake, but lukewarm support and a decarbonized power system ensure low implementation. Europe will lead the transition to hydrogen production and use, alongside China. By 2050, hydrogen will meet 12% (4.5 EJ) of Europe's final energy demand, representing 20% of the world hydrogen energy use. Uptake of Hydrogen in Europe will be policy driven, given Hydrogen is not economical compared to conventional fossil fuels.

2.2.1. The Netherlands

Natural gas and oil are still the dominant sources of energy in the Dutch energy supply. In 2018, Total Primary Energy Supply (TPES) came from natural gas (42%), oil (37%), coal (11%), biofuels and waste (5%), and small shares from nuclear, wind, solar, hydropower and geothermal.

The Groningen gas field, located in the northeast of the Netherlands, is one of the largest gas fields in the world and was historically the main source of domestic gas production. However, natural gas production activities in the Groningen field have caused earthquakes that damaged over 10 000 buildings and resulted in strong public and political pressure to end gas production from Groningen as soon as possible. As a result, gas production from Groningen will end by mid-2022, while ensuring security of gas supply by reducing gas demand and increasing the availability of gas from other sources.

As a result, the Netherlands became a net gas importer.

The Netherlands is aiming for a rapid transition to a low-carbon economy and has placed ambitious greenhouse gas (GHG) reduction targets at the centre of energy and climate policy. The 2019 Climate Act sets targets to reduce GHG emissions by 49% by 2030 and by 95% by 2050 (versus 1990 levels). The Netherlands has developed a detailed policy framework to drive the achievement of these targets. The core of this framework is the 2019 Climate Agreement, which was developed using the collaborative Dutch Polder system. Over 100 stakeholders from across society contributed to developing the 2019 Climate Agreement, which contains emissions reductions targets and measures in five sectors: electricity, industry, the built environment, mobility, and agriculture and the natural environment.

The Netherlands is an important transit and trade hub for natural gas, oil, electricity, and coal and has extensive cross-border and subsea oil and gas pipelines and electrical interconnections. Dutch ports play a key role in global and regional energy trade and have one of the largest concentrations of oil refining and marine bunkering fuels in Europe and a major liquefied natural gas (LNG) terminal.

2.2.2. Realtime Time Network Study – UK

The RTN project is a bottom-up approach to modelling gas networks in the UK to gain better insights to customer behaviours affecting demand, and an understanding of the impact of different gas supplies with varying energy content.

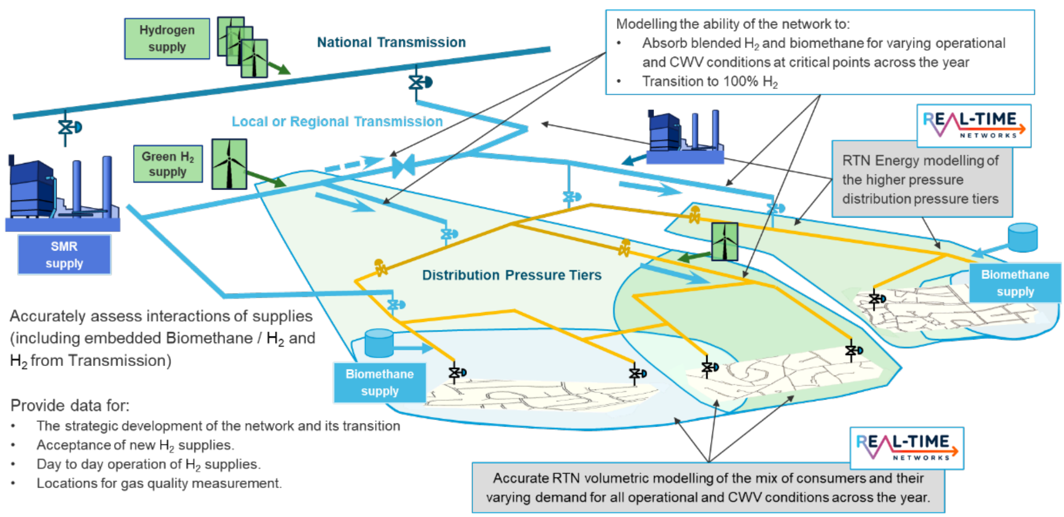

Figure 1- RTN network diagram showing new supply sources

The RTN Project developed a consumer demand model for application in below 7 bar networks. The RTN Demand Model can be applied at Peak condition, for design of networks, and at all off-peak conditions, for operational analyses. Whilst the RTN Demand Model is a bottom-up approach, the ability to model flows through the networks supports peak and off-peak modelling in the MPIP system and in the LTS. The RTN Demand Model is based on the collection of data for 1200 sites across SGN's SE LDZ, over a 2-year period at a 6-minute granularity. The resulting demand model reflects the behaviour of 10 domestic and 9 non-domestic consumer types. Testing has shown that the resulting demand model is highly accurate over a wide range of consumer numbers and for the range of expected weather conditions. To categorise any consumers into their demand model classification the Demand Model uses socio-economic data as well as customer data.

The Demand Model uses the Annual Quantity of gas used by each individual consumer as a factor to reflect each consumers' use of gas. The peak demand model can be applied to network modelling using a technique called "variable diversity". This technique considers the behavioural diversity in demand expected in consumers of the same and of different types, i.e., reflecting that not all consumers use the same level of gas in the same period.

The variable diversity approach determines the tree structure for the flow of gas in a network, even where loops of pipe are present, and applies the diversity in demand variably across the network as the number of consumers fed by a pipe change from extremities (low diversity) to supplies (high diversity). This approach ensures that appropriate peak demand is applied across the network, resulting in reduced demand away from the extremities, compared the current approach, Off-peak demand modelling will provide profiles of demand across any selected day or days to reflect the weather conditions (CWV) and factors for the day of week and month. Confidence intervals for the demand are also available to be used in modelling. Whilst the RTN Demand Model generated through the project is based on data for the SE LDZ its use for other LDZs represents a significant improvement in accuracy.

The RTN project highlighted several challenges with the way in which current networks are modelled.

Some Selected conclusions from the RTN report are highlighted below specifically relating to the topic in this presentation.

- Distribution networks have already changed in fundamental ways and will pose increasing challenges. Key Areas include:
  - Biomethane
  - Gas Quality Standards as they develop
  - Hydrogen blending and 100% hydrogen
  - Complexity of consumer behaviour
  - Complexity of Consumer Billing
- Digitalisation in the context of the RTN project, means bringing together the right data to provide solutions for designing and operating gas networks and providing processes to make best use of this data in modelling. This includes use of Smart Meter data, sensor data and the provision of Software as a Service.
- An effective Real-Time Model has been developed, which improves the off-peak output from the Demand Model on a site-by-site basis, for situations where a live data stream is available for any given site. Where such a data stream is available, this allows more detailed and accurate information for the site to be provided to the network model up to the end of D+1 (i.e. the day after the analysis is being run)
- The Real-Time Model, which allows raw Demand Model output to be tailored to the demand pattern at an individual site, for sites with a live data feed, has been shown to work effectively on a site-by-site basis. It can identify where a site has a profile consistently different to the expected one for that site type, and to successfully adjust the Demand Model output in line with this. A prototype Real-Time Model has been developed as part of the RTN system.

3. CHALLENGES AND THE TECHNICAL SOLUTION

System planning and maintenance is an intense and complicated process. Gas network operators need to anticipate and apply variables over short- and long-term planning periods. In both gas distribution and -transmission networks, advanced hydraulic analysis is needed for decision support to attain optimal operational efficiency.

Simulation provides a mechanism to essentially create a view into the future. It is aimed at taking the guesswork out of system planning and maintenance. Traditionally, capacity planning has been done over 5 years periods, reviewed annually, and the operational aspects have been on a set and forget approach. However, with the energy transition and the potential for introduction of new gas sources at different levels in the gas supply network, it is essential to have a more dynamic approach over shorter time periods.

The following sections describe the generic technical approaches to solving the challenges in gas network operation created by the energy transition in both South America and Europe, with Section 4 describing the specific use cases (COMGAS and Enexis), where DNV has helped in establishing a more coordinated and dynamic approach to managing gas networks as part of a wider digital transformation initiative.

3.1. Automatic Model Building

The solution proposed uses DNV network modelling software (Synergi Gas) that supports network analysts make daily operating decisions for load approval and operational support, size main extensions and replacements for economy and performance and create long-term strategic plans that maximize operational use of gas network infrastructure.

This modelling tool helps companies leverage the link between planning, maintenance, and operations through a robust hydraulic analysis tool. Some features of the tool include:

- Models in steady-state and transient modes
- Capable of modelling large (> 1 000 000 node) systems
- Hydraulic analysis in gas gathering, transmission, and distribution systems, as well as industrial gas applications
- Handles a wide range of gases due to expansive equation of state capabilities, including CO_2, N_2, H_2, H_2S, etc. User can specify incoming gas streams compositionally
- Has full heat transfer calculations
- Provides detailed modelling of compressor and regulator stations
- Has optimization tools for fuel minimization, throughput maximization, or contract maximization

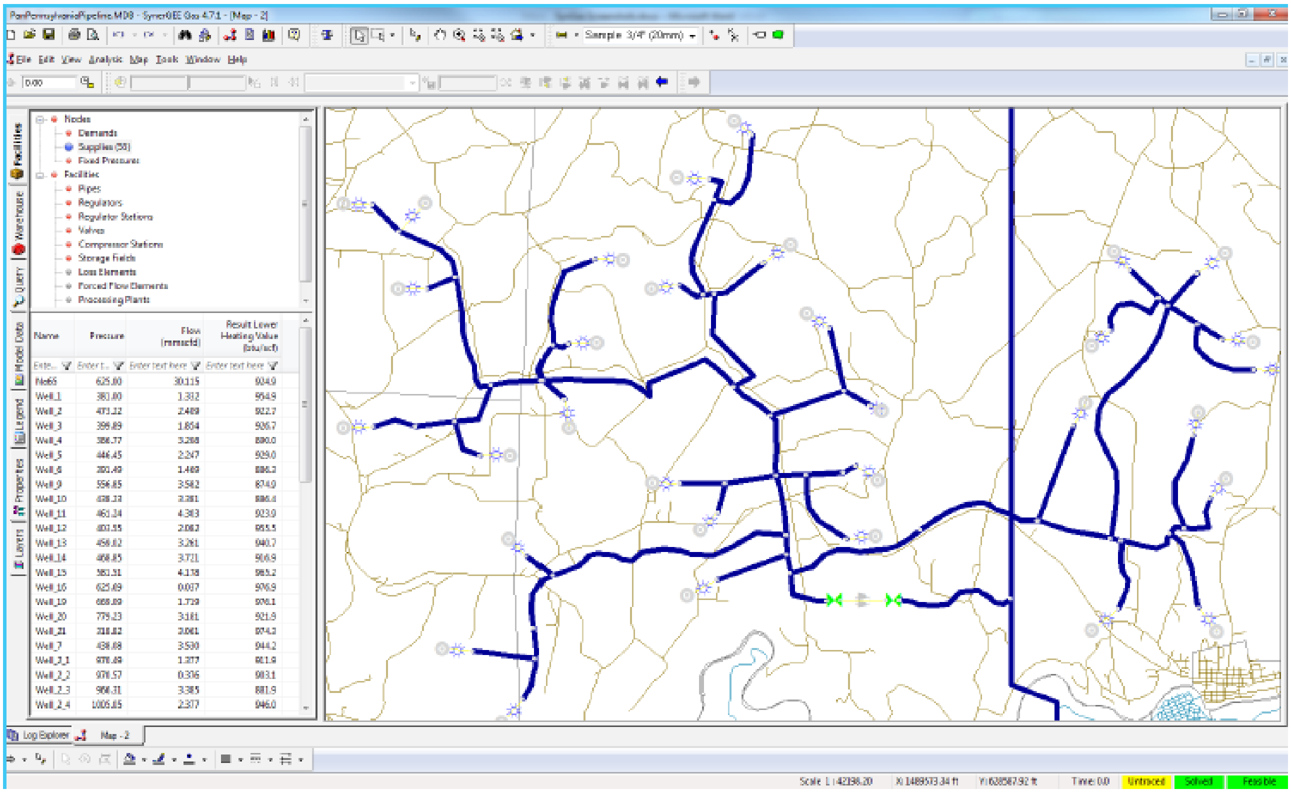

Figure 2 DNV's Gas modelling tool - Synergi Gas

DNV has now added a new solution to this tool, called *Automatic Model Build*, which will fully automate the model build process using a combination of the Synergi Gas Hydraulic Model (Solver), Network Modelling and Customization and configuration. The business drivers for developing this module are:

- To enable operators to automate near-real-time generation of network models
- To automate the updating of network model demands
- To replace in-house custom components

The Automatic Model Build solution is shown in Figure 1.

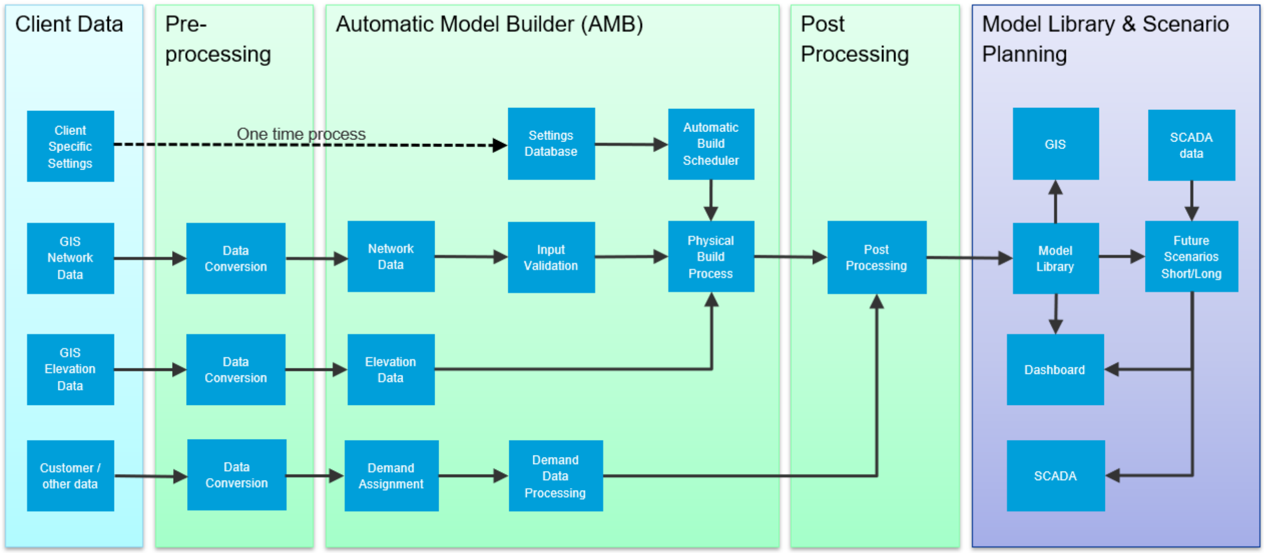

Figure 3 Generic Automatic Model Build processes

The solution is composed of several standard software components that are configured and made customer specific where needed. The standard software components are:

- Modelling Tool User Interface
- Modelling Tool Solver
- Model Builder
- Automatic Model Builder Controller

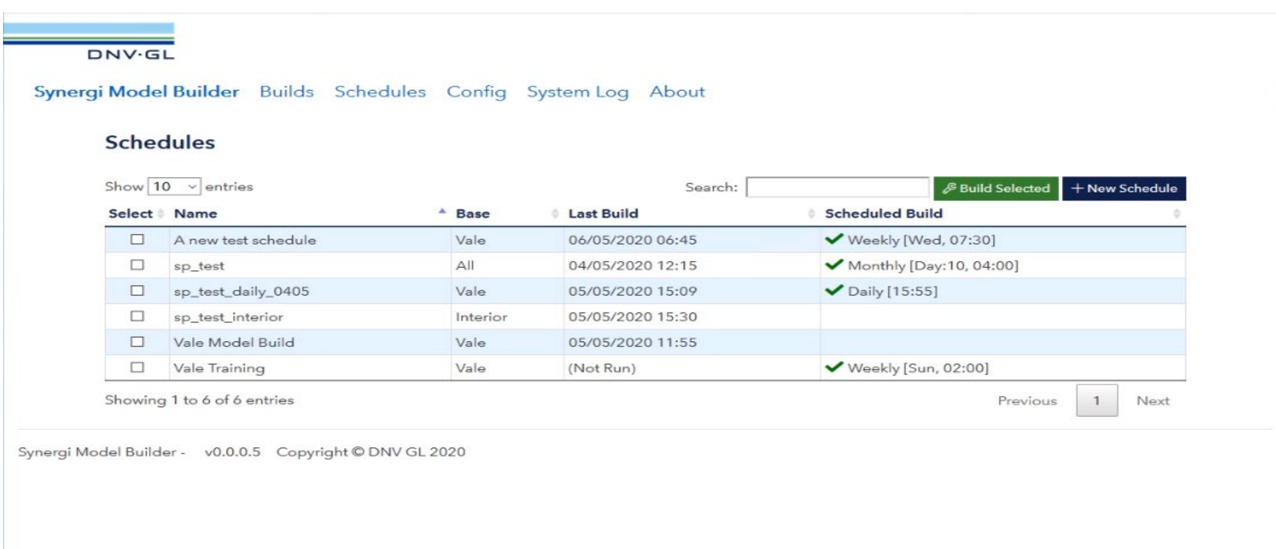

Figure 4- Model Builder Schedule Manager

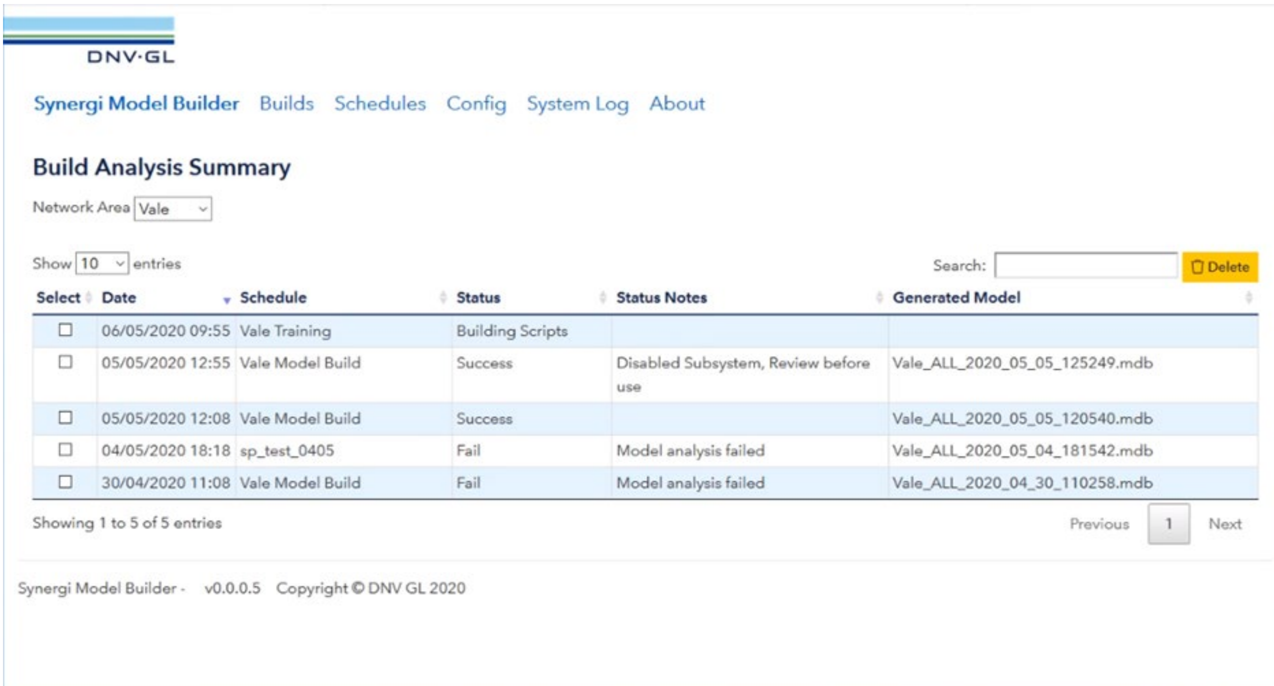

Figure 5- Build Analysis Summary Screen

Initially, the solution loads MiddleLink files (.NODE, .PIPE, .GNODE, .REG, .VALVE, .DESC) into the modelling tool. There are no settings for these as they are processed in a set way and on mass but roughly in the order above. Then .CSV files (including Demand) are processed using the exchange file format to add them to the model built by Model Builder. This model is then saved before passing to the Post processing and the Validator. The model built by the first steps and then loaded into the AMB validator (which uses the Model Solver)

The AMB Validator:

- Moves the “Dummy” pipe to Model top right corner
- Valve downstream node are renamed
- Isolated sub-systems are disabled
- Final Model classification (Valid, Warnings, Error)
- Post processing Synergi Scripts:
- Zero out demands

3.2. Operational Benefits

The benefits of DNV’s Automated Model Builder solution are summarized as follows:

- Delivers more up to date models.
- Repeatable process that delivers consistent model builds.
- Reduces manual input and time, freeing modelers time for other analyses.
- Increases model build frequency daily/weekly/monthly.
- Models align with the GIS.

- Optimization of the model build process by DNV's expert Network Analysis & IT consultants.
- Tried & tested, low risk solution.
- Comprehensive ongoing support and maintenance, including access to experts if future enhancements are required (subject to Service Level Agreement)
- Identifies GIS errors.
- Improves model accuracy and source data quality.
- Includes other data such as demand, valve position, equipment status.

3.3. Edge devices and IOT

To further enable network operations to happen closer to real-time, operators can make use of Edge devices. IOT connectivity ensures that these devices can be connected and that data can be transferred very cost effectively nowadays.

Monitoring devices placed at strategic locations in the network can be used to collect operational data that can be used to align models closer to real time. When used with a tool that can be used to schedule and manage scenario analysis, they can be based on a much more accurate representation of the current state of the network and this can provide detailed insights into pipeline and network operations leading to improved decision-making. Scenario schedules can be created that perform network analysis automatically, highlighting exceptions relating to the operations such as pressure issues, gas quality or even alarm imbalances such as leaks.

3.4. Gas Quality Tracking

Gas Quality Tracking (GQT) is a system to enable the user to model accurately model and predict the gas calorific value (CV) of gas at every node in a network. This data is especially important when a network contains hydrogen and biomethane blends. Operators need to know what CV they are delivering to their customers and whether that value will meet their contractual obligations to a particular customer.

The GQT system takes data from SCADA, flow meters, CIS and GIS; runs it through validation and then through models in order to output CV, line pack and various other information about the network.

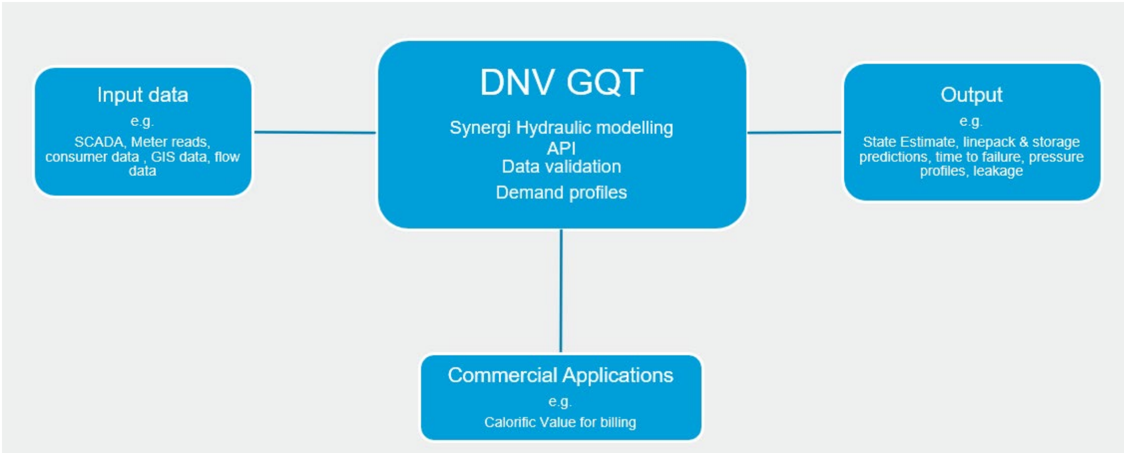

Figure 6- Data for GQT

3.5. Transitioning to Hydrogen

There are several considerations to be aware of when modelling hydrogen and hydrogen blends. Hydrogen has approximately one third the calorific value of natural gas. This means that around three times the volume of hydrogen is required to satisfy the same demand.

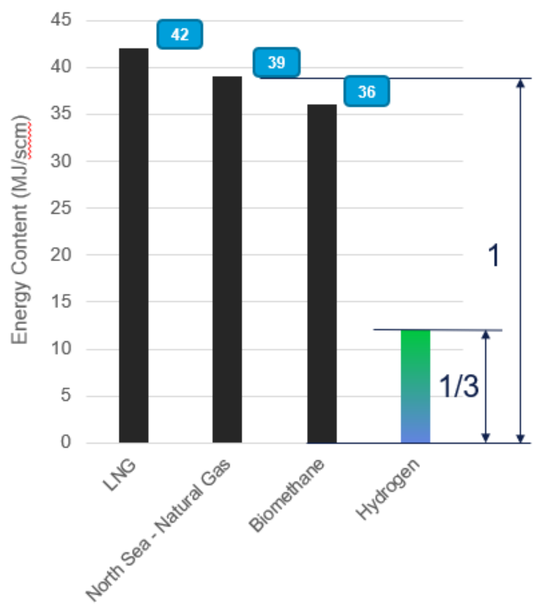

Figure 7 Energy Content of various Gas Sources

The flow rate is directly related to the gas velocity, so as the flow rate increases by 3 times, hydrogen velocities will also increase by 3 times the natural gas velocity.

If hydrogen velocity is 3 times the natural gas velocity when pressures are the same, because you've got additional pressure drop from the additional flow, you will have lower pressures with hydrogen. This means that the hydrogen velocity could be significantly more than the 3 times what is normally quoted.

Although the volumetric flow rate is 3 times higher with hydrogen for the same energy content the pressure losses are only 50-70% higher (depending on the network).

For the same volumetric flow rate, the pressure losses are lower with hydrogen due to the lower viscosity and specific gravity.

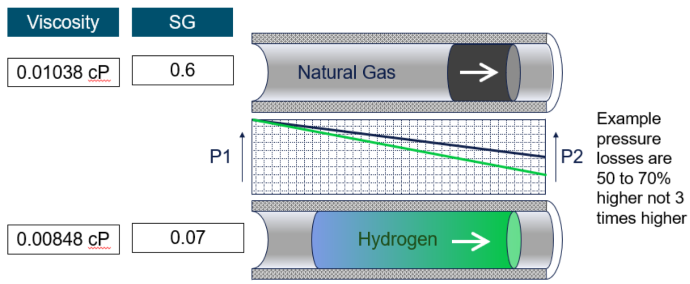

Figure 8 - Comparison of Pressure losses NG vs Hydrogen

Ultimately this means that network modelling must be performed prior to adding hydrogen in order to determine whether the network can deliver the required energy to customers without violating pipeline pressure and flow constraints.

3.6. Future Vision - Generic Scenario Planning tool

DNV envisage a future solution where a completely integrated scenario planning tool could be used to create and schedule scenarios, where results can be easily interrogated using standard Web style displays.

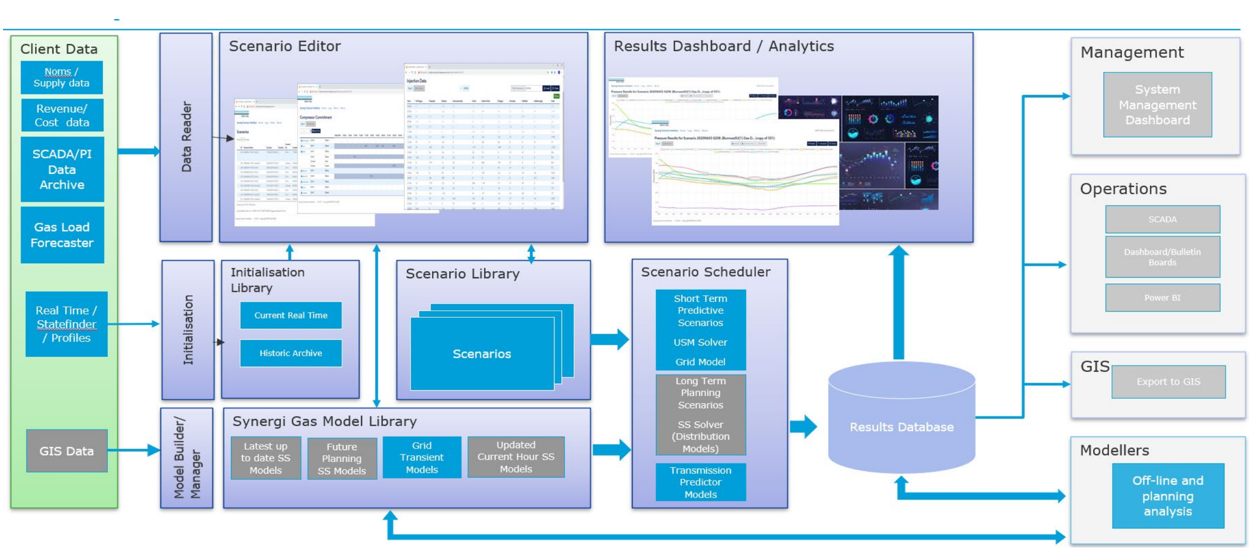

Figure 9- Future Vision for Grid Operations

The complexity of the network configuration, whether it be transmission or distribution would be hidden from the user. Models will be initialized from various available sources and run using a variety of appropriate solving techniques e.g. realtime – Statefinding, Time Varying or Steady state. Results and exceptions will be served to client business specific dashboards, bulletin boards or even back to operational GIS solutions.

This will allow network analysts to focus on dealing with exceptions or undertaking more detailed value added analysis, rather than serving data that can now be automated.

4. CUSTOMER CASES

4.1. COMGÁS Network Operations

COMGÁS is the biggest natural gas distributor in Brazil, serving more than 1.7 million clients in São Paulo state. It provides natural gas to households, businesses, industries and vehicles, using pioneering technological resources on the development of distribution networks and service expansion.

COMGÁS connects big gas supplies with the country's biggest consumer market: São Paulo Metropolitan Area, Campinas Administrative Region, Part of the cost of São Paulo and Paraiba Valley. Its concession area covers 177 cities of São Paulo state, currently representing approximately 27% of Brazil's GDP and more than 35% of the country's energy consumption. Currently, the company holds 16,000 kilometers of distribution network and serves clients from 80 different cities, on the industrial, commercial and residential sectors, it also provides vehicular natural gas and it enables cogeneration and climatization projects.

COMGAS already utilized hydraulic modelling and the network was broken into 3 Main models. These were operated and analysed independently.

As the physical networks were expending at pace, network analysts were spending time on building and validating isolated network models, from GIS that contained many errors. This meant that much time was wasted on correcting connectivity issues, incorrect customer assignments, lack of node consistency and other general modelling issues. As a result, models were not being built as often as they should. Hence, they were not closely aligned to the physical network and contained various inaccuracies.

To address this, COMGAS launched a project to implement the Gas Management System (GMS) as part of a company-wide development and digital transformation of their operations. The key objectives were to improve the Gas Operations management, not only to improve their operational efficiency but also to ready themselves for the energy transition by being able to improve responsiveness both in terms of demand response and also projected changes in supply that could potentially arise through the introduction of Hydrogen and bio gas into the network. This Gas Management System project was implemented in 2 Phases.

Phase 1 – Automated Model Building with Scheduler and Integration to GIS.

This initial phase provides a mechanism to enable the models to be built automatically from the GIS, using a tool that would provide the capability to configure schedules for the models to be built, and provide a framework for managing issues during the build.

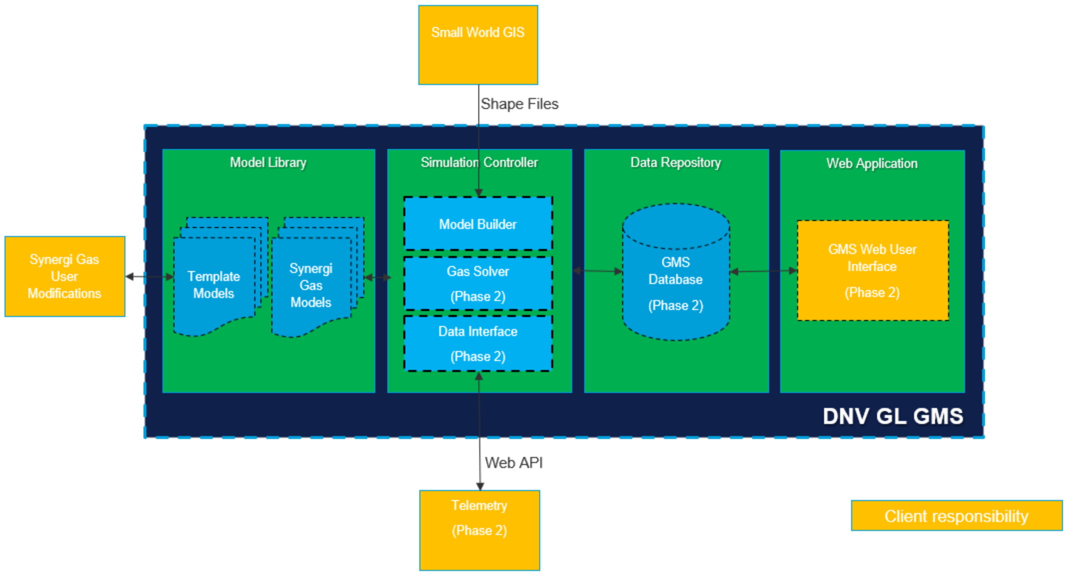

Figure 10 COMGAS process

- Phase 2: Telemetry Integration and Automated Scenario analysis

  This phase develops the work from phase 1 by providing additional functionality as listed below.

  1. Network model integration with the Telemetry system to provide near real time data for accurate simulations across all pressure tiers.
  2. Transient modelling of the 7bar and above networks to enable accurate simulation of Line-Pack.
  3. Time Varying Steady State models for 4bar and below.
  4. Automatic generation of gas demand profiles using the latest Telemetry and short-term future prediction using historical data.
  5. Scenario analysis for simulating both high and low short-term future predicted demands.
  6. Scenario analysis for simulating the impact of maintenance events upon network performance.
  7. A repository of network simulation results accessible for third party reporting using a published API.

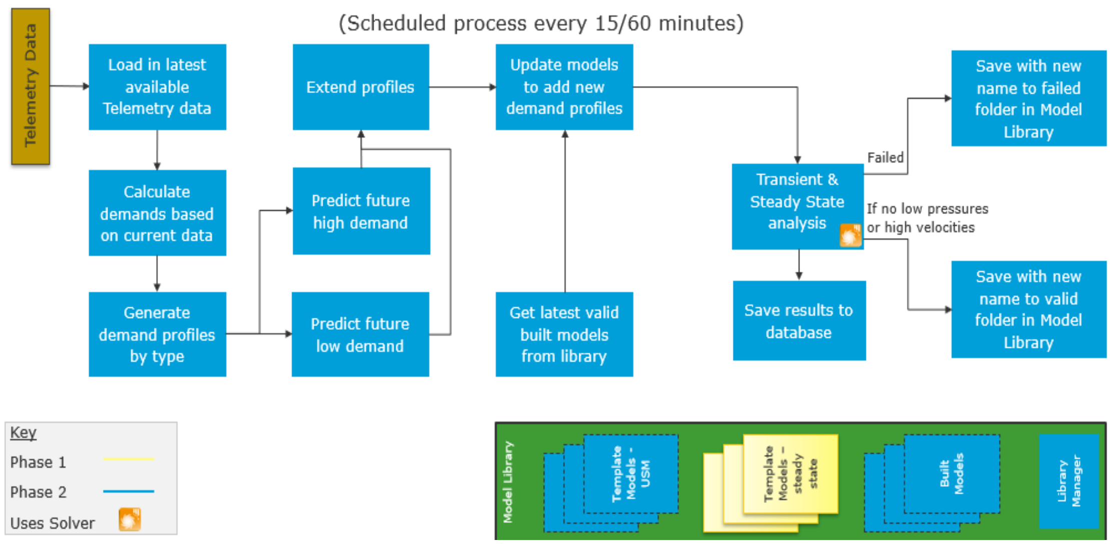

Figure 11 GMS Telemetry data and model process with high/low scenarios

4.2. Enexis – Gas distribution network operator in the Netherlands

Enexis Group in the Netherlands, with 4,500 employees, is one of the three largest grid operators in the Netherlands, delivering gas to 2.3 million customers and electricity to 2.8 million customers. Enexis works to ensure stable and reliable grids and to secure the future of the energy supply. The company coordinates and funds initiatives to boost the energy transition to make sustainable energy possible.

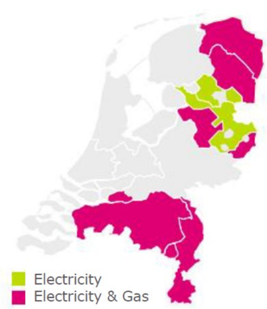

Figure 12 Enexis Gas distribution network operator - the Netherlands

Enexis is a long-time user of DNV's hydraulic modelling and simulation software - Synergi Gas. In response to the constantly changing utility market, especially related to the energy transition, the engineers at Enexis saw the need to become more agile with accurate models of their gas pipeline grids based on the most current information. Due to various factors impacting demand, such as pandemic isolation, use of hybrid heating pumps and higher market prices, there has been a very different usage pattern, with very little stability. The pandemic and the new way of working that it brought about, has resulted in changes in customer consumption patterns. The escalating gas prices drive more and more households to change from gas to electric heating, resulting in connections being rapidly removed from the grid and a quickly evolving gas network.

Therefore, Enexis has chosen to upgrade to DNV's Synergi Gas Automated Model Builder, to carry out feasibility and impact assessment studies to ensure safe and reliable operations as they distribute alternative gasses such as biomethane and hydrogen through their networks.

Previously, their models for carrying out feasibility and impact assessments had been updated on an annual basis, and any new modelling, done intermittently, had to be completed using manual updates. Also, the in-house software did not have the capability for accurate modelling of the most complex situations.

Now, with the Automated Model Builder, grid architects are given a near real-time network model for transient and time-varying analysis, with more accurate results and better support for critical decisions. As part of the process, the automatic model builder looks for isolated pipes and automatically disables them to make a valid model. These decisions can now be based on near-live information, giving additional insights, and enabling improved reporting. Alerts and messages can be quickly configured in the tool.

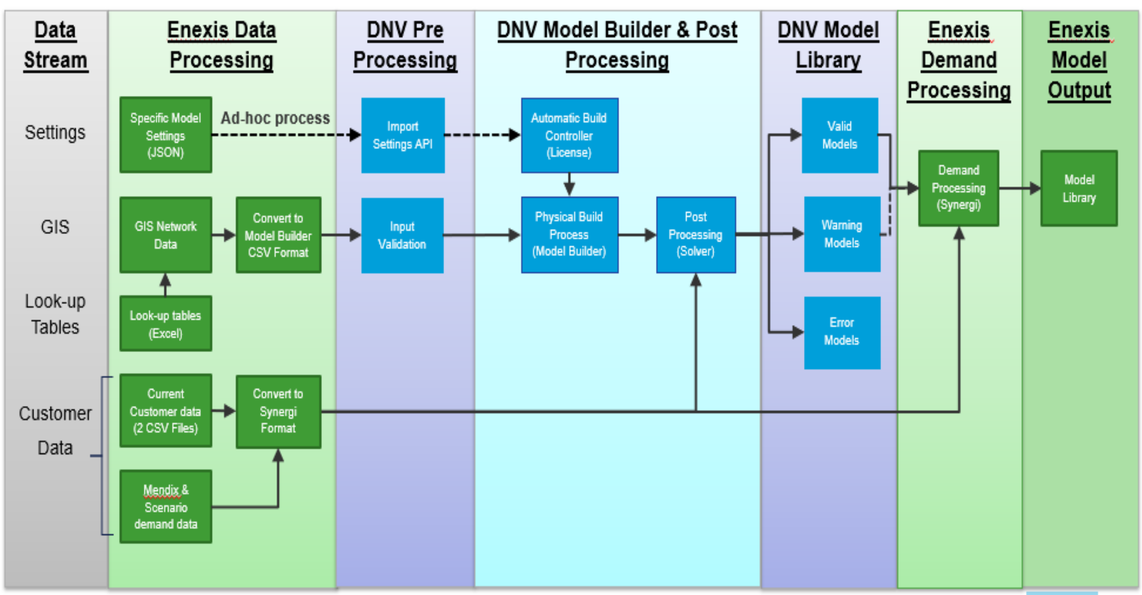

Figure 13 AMB process for Enexis

The way the Automated Model Builder is being set up, the system automatically updates every model once a week and runs checks to ensure the models are good and valid, based on correct data. This eliminates the need for manual updates.

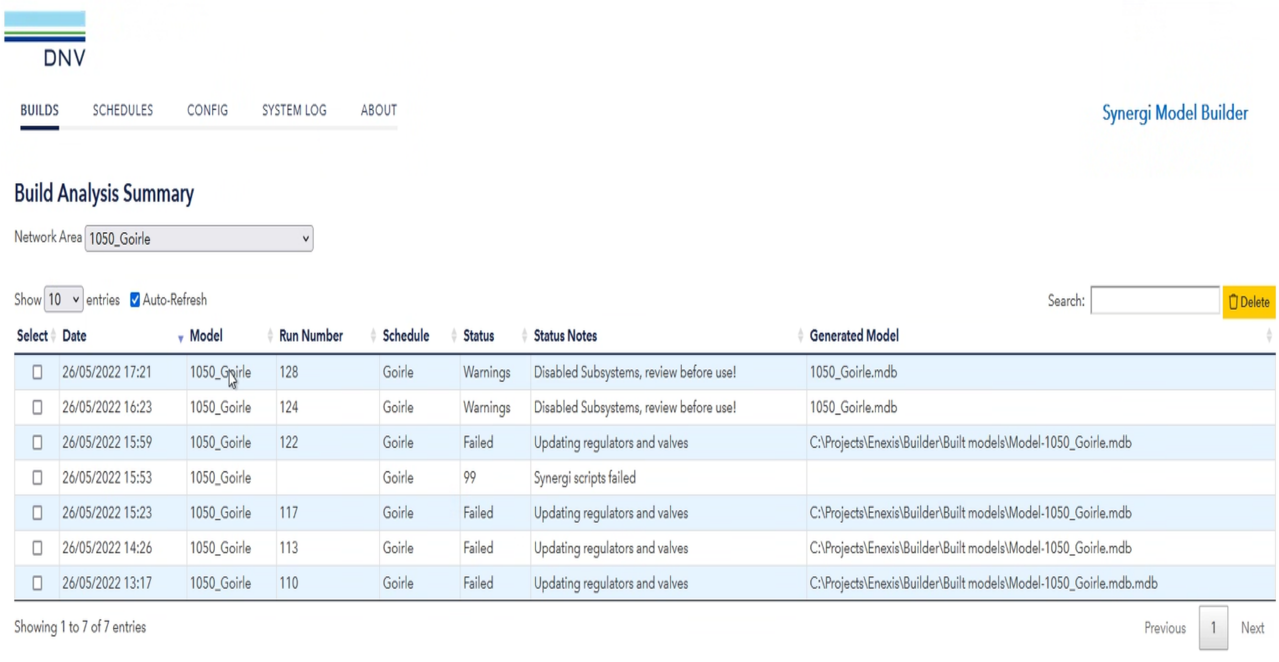

Figure 14 AMB - Build Analysis

Enexis chose to run the tool in their private cloud environment, to protect the privacy of their customers. Since Enexis has already extensive experience using hydraulic modelling software for managing and optimising various assets in their network, the Automated Model Builder pulls together all the assets to provide a comprehensive view to Enexis. Having an accurate and up-to-date digital representation of the physical network is essential for carrying out feasibility and impact assessments with the introduction of novel gases such as hydrogen and biomethane.

The benefits of the AMB solution for Enexis are:

- Delivers more up-to-date and consistent models through implementing a repeatable process thus reducing manual input and time
- Identifies GIS errors and improves model accuracy and source data quality.
- Analyses the built model and automatically disables data issues. Automated issue of logs which can be used to improve data quality.
- Ongoing support and maintenance by DNV experts on operational issues, optimisation of the model build process and on future enhancements.

Enexis is currently finalizing the testing phase of the software, which will run live for all users later in the year.

5. CONCLUSIONS

The changing energy supply mix and the general drive to Net Zero is driving network operators to change and improve how they manage existing transmission and distribution assets, to be able to adapt to the new supply and demand requirements for their networks, including the introduction of Hydrogen and bio Methane.

Because of the potential introduction of both hydrogen biogas supplies at different levels in the networks, this drives a need for greater awareness of both the operational pressure management, but also the ability to model the gas compositions across all levels in the network. This impacts both operations and maintenance.

Further, development of digital tools, provides opportunities the establish more efficient operations, and to support the maximization of the investment in that infrastructure.

Operators need to design and develop efficient and cost-effective networks and pipeline systems capable of delivering to anticipated demand levels where time periods are much reduced based on changing environmental or supply conditions.

Integration to GeoSpatial solutions and the ability to automate model builds, aligning the physical, geospatial and hydraulic model, greatly improves modelling accuracy and longer term reduces time spent in correcting modelling errors.

Effective model management greatly improves operational decision making by providing more accurate analysis on which to base decisions for feasibility study and impact assessment of network infrastructure changes. Automatic model builds helps to deliver more up to date models and a repeatable process that delivers consistent model builds.

The ability to introduce low-cost edge/telemetry devices across the networks provides an opportunity through integration to move distribution networks closer to real-time operations with more up to date network analysis results that can be delivered automatically through scheduled scenario analysis, with results posted to operational and corporate dashboards.

Digitalisation provides significant opportunities for creating more efficient operations, better directing budget spend and effective allocation of resources, which should directly impact customer satisfaction, network safety and regulatory performance.

6. ACKNOWLEDGEMENTS

7. REFERENCES

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