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# District station
***Design of a 'future proof' district station***

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The Netherlands

## ABSTRACT

*Objective*
The objective of this research is to design an intelligent district station for regional gas distribution networks. This district station will be designed in order to adapt to future developments. It will support recent developments such as the injection of “new” gases, variable gas flows and smart grids.

*Novelty and main contribution*
Current district stations in the gas infrastructure are operating independently. They have fixed limiting values which are used to transfer and deliver gas from a higher pressure level towards a predefined lower pressure level. Each station operates stand-alone. A safety valve will close and shut down the district station when pressure levels are exceeded. In an area with multiple district stations the other stations need to provide an extra gas flow to maintain the defined pressure, when one station fails.

This study defines and describes a district station which cooperates with the other stations in the same part of the gas distribution network. The intelligence that enables district stations to cooperate will determine autonomously (without human interference) what kind of action is needed when unusual changes in gas flow or pressure are detected at one of the district stations. To measure, react and control pressure and flow it uses an assembly instruments and smart communication solutions.

*Brief method description*
Firstly, a list of future developments is composed. General future developments for gas networks are determined by means of literature study and rated on their probability and impact.
Secondly these critical future developments are used to adopt functional demands.
Finally the design for hardware, software and the integration is given. Combining the different components leads to the schematic design.

*Results*
The innovation in the gas station of the future is the software. By using smart net management solutions the gas station is able to perform its duties partly stand alone, regionally or company wide. In the gas station processes are measured and monitored and when needed the pressure and/or capacity is regulated. When off boundary measurements can’t be solved locally the gas station starts to communicate with other gas stations in the same network. Then pressure and/or capacity is regulated regionally.
Company wide the net management software regulates the gas networks by using different kind of forecasting models (i.e. demand-response, weather and price models)

## CONTENTS

# 1. INTRODUCTION

The objective of this research is to design an intelligent district station for regional gas distribution networks in the Netherlands. This district station will be designed in order to adapt to future developments. It will support social developments such as the injection of “new” gases, variable gas flows and smart grids.

Current district stations in the gas infrastructure are operating “stand alone”. They have fixed set points which are used to transfer and deliver gas from a higher pressure level towards a predefined lower pressure level. Each station performs its duties as if it is a stand-alone application. A safety valve will close and shut down the district station when pressure levels are exceeded. In an area with multiple district stations the other stations need to provide an extra gas flow to maintain the defined pressure, when one station fails.

Firstly, a list of future developments is composed. General future developments for gas networks are determined by means of literature study and rated on their probability and impact.
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Finally the design for hardware, software and the integration is given. Combining the different components leads to the schematic design.

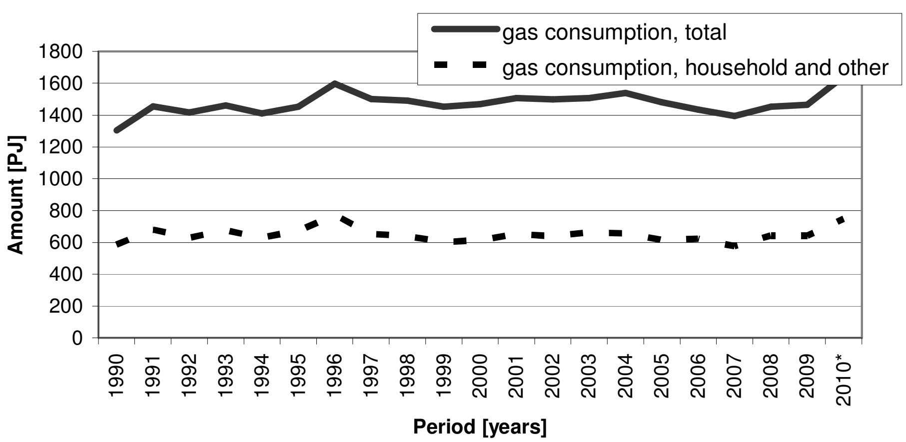
# 2. FUTURE DEVELOPMENTS

In order to indentify “future” functional demands for a gas station an exploration of developments is performed. For the Netherland six developments[1] are described including the current gas consumption as a reference.

1. Influence of ‘new’ gases;
2. Behaviour of different kinds of customers groups;
3. Ability to support smart grid applications throughout the entire network;
4. Regulator position;
5. Physical aging of the network (including components);
6. Loss of (technical) know-how.

## 2.1. REFERENCE

In the Netherlands a steady overall consumption of gas is approximately 1500 [PJ] per year over the pas 20 years. The 1500 [PJ] per year represents the total gas consumption. When specified to households and other small consumers the gas consumption is 650 [PJ] per year (graph 1).




*Graph 1 Historic consumption level natural gas in the Netherlands*[2]

## 2.2. INFLUENCE OF NEW GASES

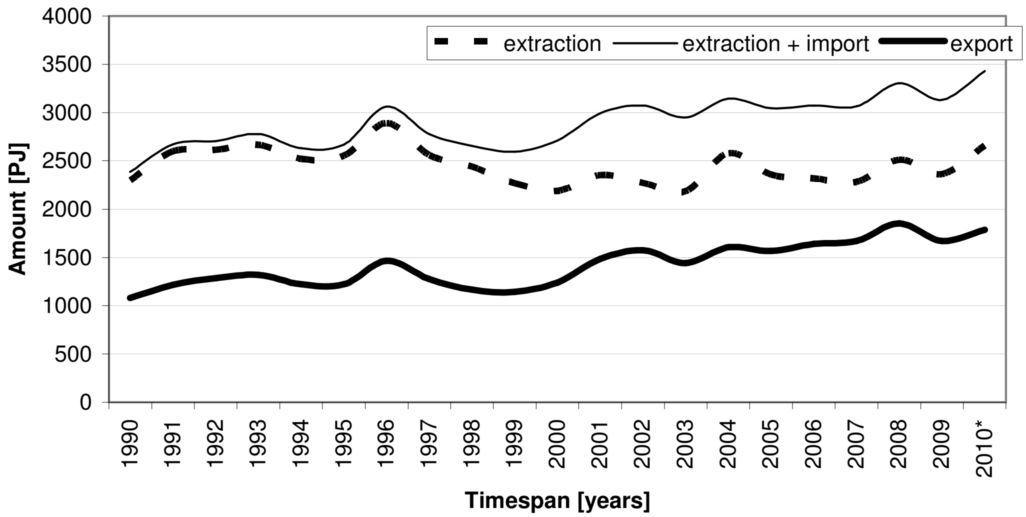
To determine the influence of new gases on a gas station three developments are described. First the influence of other gases on the current gas standard (Groningen gas) is described. Followed by the development of biomethane and biogas. Last hydrogen is described as development.

*Other gases*

The Groningen gas field was discovered by the NAM (Dutch Oil Company) in 1959. Since then the gas sector in the Netherlands uses this field as standard for gas distributed in regional networks. Nowadays any other gas in the Netherlands is altered towards the Groningen gas standard. Apart from to the Groningen gas two other standards are defined in the Netherlands[3]:

- Gas with a high caloric value (H-gas): 48 - 56 MJ/$m^3$;
- Groningen gas (G-gas): 43.5 - 44,4 MJ/$m^3$;
- Gas with a low caloric value (L-gas): 42.5 - 47 MJ/$m^3$.

During the last 15 years the rate of extraction is slowly decreasing and import slowly increasing



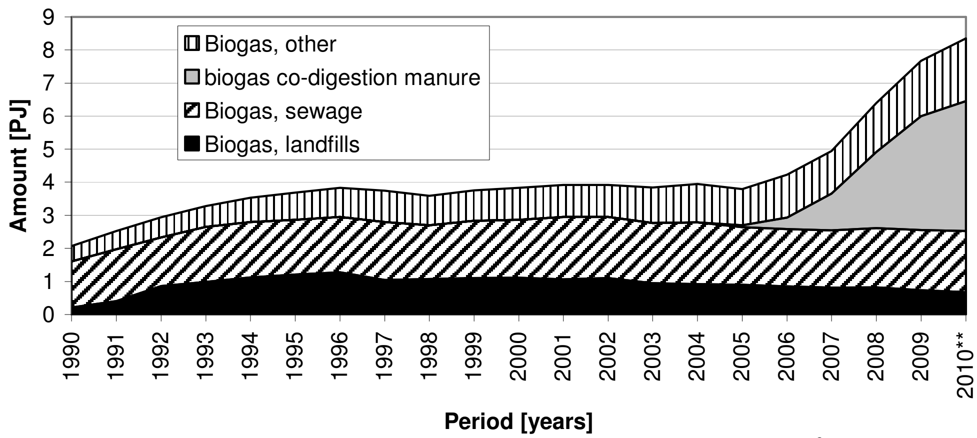

*Graph 2 Share of Groningen gas extraction to yearly gas consumption in the Netherlands[2]*

From graph 2 it is evident that in the (near) future the percentage of Groningen gas (extraction) will decline further resulting in a larger share of other gases. The current share of import is 23% percent of total gas consumption before export. The imported gases originate mainly in Great Britain, Russia and Norway[4]. The different values of methane in these gases vary from 91 to 70. This relative large difference has great influence in the performance of gas appliances. This change in composition means there is a need to measure the amount of energy transported in stead of the quantity of gas transported.

*Biogases*

The share of biogas/biomethane producers is increasing in the Netherlands. The increase of production over a period of 20 years is shown in graph 3.

The amount of produced Biogas is increasing. This increase is explained by the increase of biogas produced by means of co-digestion as shown in graph 3. Current development rate over time will reach a maximum of 15% biomethane/ biogas production. The ambition of the Dutch workforce "New Gas" is to achieve a 50% biomethane/biogas production with respect to the overall gas demand of approximately 1500 [PJ] (graph 1)[5].




*Graph 3 Amount of biogas production in the Netherlands*[6]

The introduction of large shares of biogas/biomethane results in the need of injection of biomethane and possibly the injection of biogas. Injection of biomethane and possibly biogas need to be combined with the development of smart grid. When injecting biomethane or biogas into the grid it is important to measure and monitor the gas quality. It can even be necessary to regulate the gas injection.

The change in composition of the gas by other gases means there is a need to measure the amount of energy transported in stead of the quantity of gas transported.
Resulting in multiple functions:

- Measurement of
  - Quality
  - Energy
  - Capacity/flow
  - Pressure
  - Temperature
- Monitor of
  - Quality
  - Capacity/flow
  - Pressure
- Regulate
  - Capacity/flow
  - Pressure

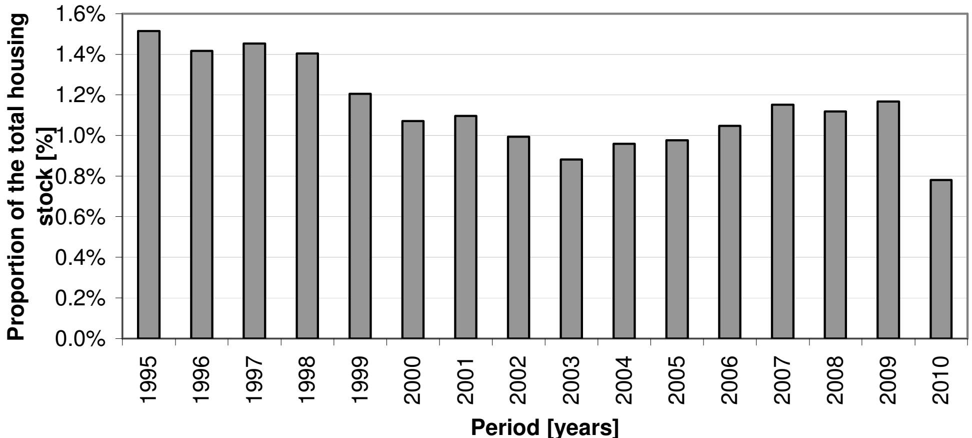
*Hydrogen*[7]
With a declining share of fossil fuels in energy supply, the reliance on alternative sources will increase. The preference will mainly be on renewables. In the case of large-scale production of wind and solar power storing of energy is required. Hydrogen is expected to play an important role in this storage issue.
But hydrogen storage is still problematic and the chain efficiency for hydrogen wind, solar is still too low. Moreover, the costs of hydrogen from solar and wind is still very high and pure hydrogen from biomass requires a lot of extra cleaning steps. Together these methods are currently rather expensive and complex, but do have a great potential for the long term.
For the coming years the probability of hydrogen as new gas in the distribution networks is low. The impact would be high, but the time span until impact is minimum 50 years.

## 2.3. FUTURE CUSTOMERS

Current customers have shown steady gas consumption over the past 20 years (see graph 1). How these customers will evolve over time is analysed by dividing the future customers into the groups: new domestic buildings, existing domestic buildings and utility/industry.

*New buildings*
New and more energy efficient buildings are completed during the coming years. For these new buildings relative small gas consumptions are expected.

Study shows a relative low share of new buildings (growth) compared to the total housing stock (approximately one percent) as shown in graph 4.



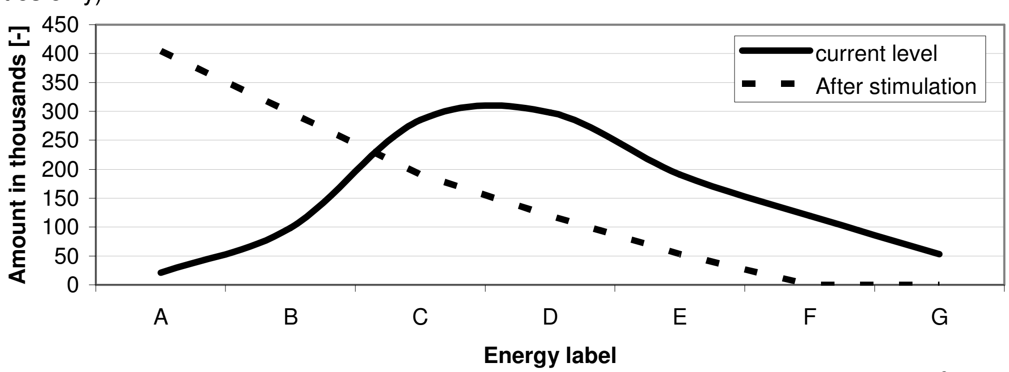

*Graph 4 Share of new buildings on total in the Netherlands*[8]

This growth results in approximately 8 million buildings in 2050 (7 million buildings in 2011). New buildings are therefore expected to represent 12.5 percent of the total housing stock.

From 2020 the regulator demands these buildings to be energy neutral, meaning yearly heat demand will decrease to nearly zero.
The (peak) gas demand for this kind of costumers depends on the technique which is used to prepare hot water. If conventional methods are used to prepare hot water the capacity of gas required is relative high in comparison to the overall gas demand. If new methods are used the peak gas demand can decrease or even increase over time.

This unpredictable change in capacity results in the need to measure, monitor and regulate the capacity/flow and pressure of gas networks.

*Existing buildings*
The current amount of existing buildings is approximately seven million in the Netherlands. Approximately 35% is owned by building associations (level 2001)[8].These building associations are stimulated to improve their building performance and reduce their energy needs. This is achieved by the use of energy labels, representing the amount of energy which is needed per household during one year. The current level of energy use and after stimulations is shown in graph 5 (for rental properties only).

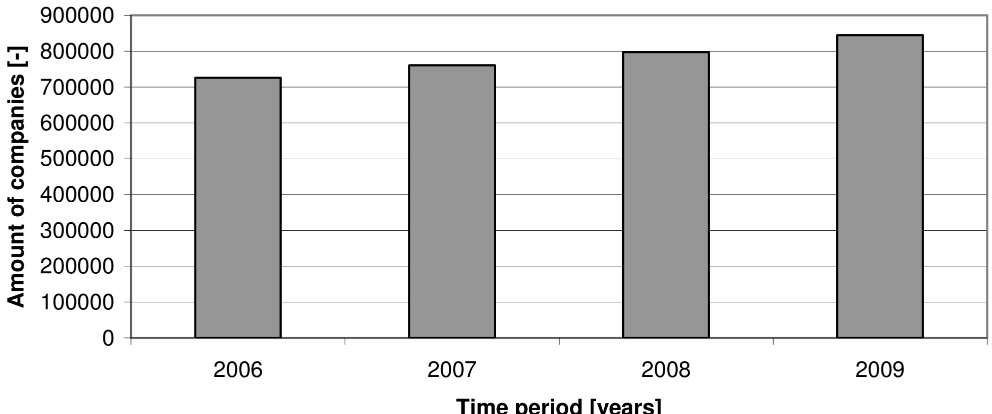



*Graph 5 Current level energy labels and after stimulation (only rental properties)*[9]

The reduction in energy need from C/D to A/B leads to an energy reduction of approximately 25-30 percent in heat demand. This results in an overall energy reduction of approximately 10 percent (25-30 percent reduction at 35 percent share of buildings).

The overall gas demand for heating of existing buildings will therefore decrease during a time span of 10 years.
Like with the ne buildings (peak) gas demand for this kind of costumers depends on the technique which is used to prepare hot water. If conventional methods are used to prepare hot water the capacity of gas required is relative high in comparison to the overall gas demand. If new methods are used the peak gas demand can decrease or even increase over time.
In this case there is also the need to measure, monitor and regulate the capacity/flow and pressure.

*Utility/Industry*
Study on possible energy savings in the industrial sector show a possibility of energy savings. This is mainly achieved by using the 3R principle of reduce, reuse and recycle. Furthermore there is a clear shift in using climate neutrally produced electricity at the cost of oil, gas and coal[10]. Comparing the steady growth of companies (graph 6) with these structural energy savings no great changes in gas demand are expected in the sectors utility and industry.




*Graph 6 Amount of companies in the Netherlands*[11]

## 2.4. SMART GRID

In the United States, the Smart Grid concept is defined as the modernization of the nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve each of the following, which together characterize a Smart Grid. Translation the smart grid functionality towards gas networks results in[12]:

1. Increased use of digital information and regulates technology to improve reliability, security, and efficiency of the gas grid.
2. Dynamic optimization of grid operations and resources, with full cyber-security.
3. Deployment and integration of distributed resources and generation, including renewable resources.
4. Development and incorporation of demand response, demand-side resources, and energy-efficiency resources.
5. Deployment of `smart' technologies (real-time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices) for metering, communications concerning grid operations and status, and distribution automation.
6. Provision to consumers of timely information and regulate options.
7. Development of standards for communication and interoperability of appliances and equipment connected to the gas grid, including the infrastructure serving the grid.
8. Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services.

The main characteristics result in three main functions for smart grid in gas networks:

- Measure, time to implement 5 to 10 years from now;
- Monitor, is already applied on a major share of gas stations;
- Regulate, time to implement 10 years form now.

## 2.5. REGULATION

The Dutch regulator issued an energy report in which the regulation horizon is described for the coming four years[13]. The core of the Dutch policy is: Enable the transition to a cleaner energy supply; keep a economic perspective and ensure a reliable energy supply. The regulator has chosen a policy with five priorities. The influence of these five priorities on the gas grid is described below:

*1. A modern policy on industry*
In which the regulator states to utilize the special position of the Netherlands as gas land. The government foresees a great role of gas as relative clean en in stock energy source for future energy supply.

*2. Expanding the share of renewable energy*
Promote innovation to enable renewable energy competitive with fossil energy in the long term. And achieve a share of 14% renewable energy in 2020 (4% share in 2010) in the short term.

*3. Accommodate all energy options on the way to 2050*
The Dutch government strives for a balanced mix of gray and green energy in an integrated energy market. In which the European trading system for emissions (ETS) is the most important instrument to reduce the emission of $CO_2$.
Reduction of $CO_2$ emission will be achieved by an increasing share of renewable energy in combination with energy savings, nuclear energy, $CO_2$ capture and co storage.

*4. Green Deal*
Concrete actions are funded by a combination of government and society.

*5. Investing in a well-functioning European energy market with an adequate infrastructure. Cross border integration of national network operators is made possible.*
An adequate infrastructure is needed for a clean, secure and affordable energy supply. Three relevant developments are a larger share of renewable energy, more cross-border transport and the increase in share of decentralised energy production (the networks have to be adapted to 2way traffic).

The regulator summarizes these five priorities results in:

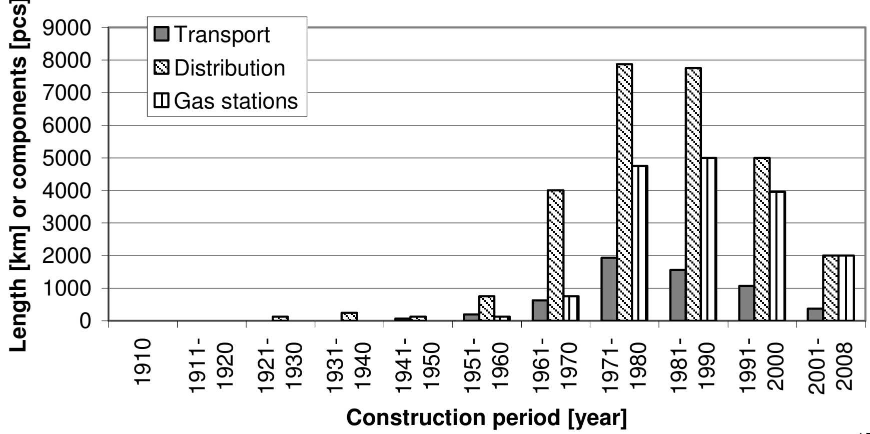
- Enabling a share of 14% renewable energy by 2020;
- Accommodate all energy options;
- Increase the share of decentralised energy production by adapting the network to two-way traffic of energy.

A large share of the 14% renewable energy can be achieved using biomethane/biogas as instead of natural gas. In 2030 to 2050 it is possible to reach a 20 to 50 percent share of biomethane in the national gas grid[14].

To accommodate all energy options (natural) gas can be used flexibly to support the increase of weather dependant decentralised sustainable energy. To ensure this flexibility a (natural) gas grid is required which can locally deliver the right amount of gas at a the right time depending on overall conditions like weather, electricity pricing, etc. This is achieved by a system, which is locally regulated and has a forecasting ability.

## 2.6. AGING

Pipes and components in the gas network are liable to aging. For the different parts of the network of the amount of kilometres or components per time period is inventoried (see graph 7).




*Graph 7 Age distribution gas network ( typical distribution system operator )*[15]

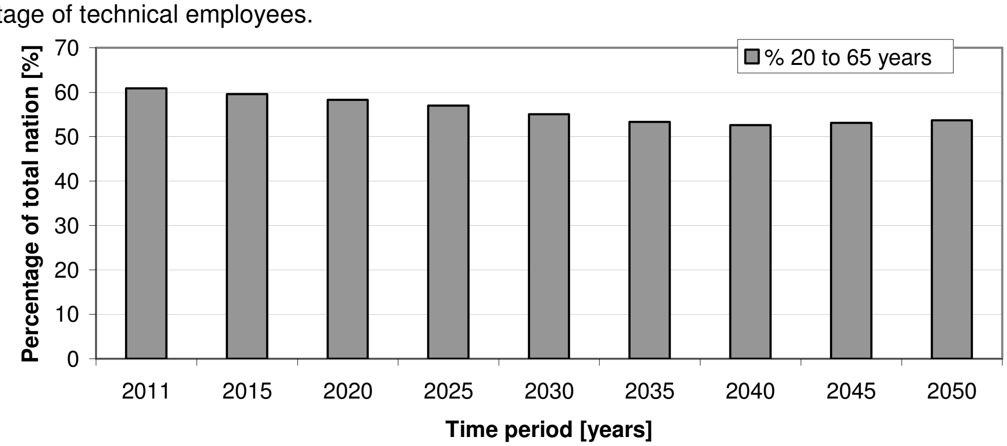
Most pipes and gas stations are constructed from 1970-2000. Meaning most network materials are 10 to 40 years old. There are different life time expectations for the different kind of materials used. Some materials can be replaced later then others based on risks, leakage, etc.

The Dutch safety board has shown an urge in replacement of certain older materials, especially cast iron. Insight in where to replace first and how to regulate the other parts of the network is indispensable.

The future gas grid has the ability to check the status it is operating in and whether components are working within the right bandwidth. In the future this ability can be extended to a self healing network/gas stations. This requires the gas station to have an indication of its status and accuracy.

## 2.7. KNOW-HOW

Due to demographic developments in the Netherlands there is a change in age distribution. This results in a lower share of workers (age of 20 to 65 year old, see graph 8). Combined with a lower interest in technical professions the expectation is that in a time span of 10 to 15 years there is a shortage of technical employees.




*Graph 8 Age distribution in the Netherlands for the coming 50 years*[16]

The shortage of technical employees with the knowledge of gas infrastructure and gas stations urges other ways to maintain a reliable, secure and affordable energy infrastructure. Future gas stations will need to perform tasks that are nowadays performed by mechanics.
Needed functions of the gas station are the ability to: perform system diagnostics, locally regulate gas network and have net management capabilities.

# 3. COMPONENT SELECTION

This chapter describes the component selection based on the future developments and their functional demands.

## 3.1. BIOMETHANE / BIOGAS INJECTION

To inject biomethane / biogas a gas station needs to use hardware to combine natural gas and biomethane/biogas as supply for a network. This can be achieved by a simple 3 way valve. Hardware needed for measurement, monitoring and regulating of biomethane or biogas are described in the following paragraphs.

## 3.2. MEASUREMENT

Quality measurement of gas is needed to determine the composition of the gas. When the composition of the gas is known the energy value can easily be calculated. So quality and energy measurement are combined in one hardware demand.
In this case the gas composition is measured using an innovative infrared principle and additional analytical software is used to convert the gas composition into amount of energy measured. For the measurement instruments of quality/energy, capacity/flow, pressure and temperature market available instruments are used.

## 3.3. MONITOR & REGULATE

Flow, pressure and quality are measured and monitored by use of software. If boundaries of flow and pressure are crossed the system interferes and alters the process parameters in order to achieve normal conditions again. To achieve this, a flow regulator is used.
Gas quality of biomethane / biogas is also measured, but can not be altered. Therefore it should be possible to interrupt the injection of biomethane or biogas. This is easily achieved by a standard shutdown valve.

## 3.4. INDICATION

The gas station needs the ability to determine their status and whether it is functioning within the right accuracy. Therefore all mentioned instruments should be able to conduct a self check and determine what their status and accuracy is.

## 3.5. SYSTEM/NETWORK

The ability of different stations to regulate processes in a network by using net management capabilities in combination with diagnostics are all software demands. This net management software needs to be implemented on gas station level and at a companywide level.

To monitor and regulate quality, capacity/flow and pressure one must use so called feed forward software. This feed forward software allows the gas station to predict changes and react even before critical physical changes have passed.

## 4. SCHEMATIC DESIGN

Future developments for the gas networks are and result in a set of components. These components are combined in a schematic design of the future proof gas station (see figure 1).

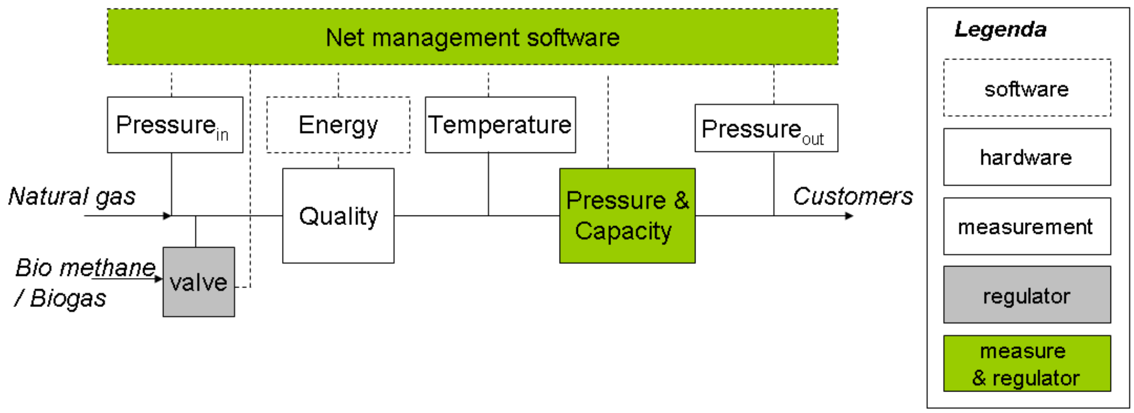



*Figure 1 Schematic design of the future proof gas station*

This gas station has the ability to inject biomethane or biogas into the natural gas network. It locally measures and monitors pressure, quality/energy and capacity. When needed it regulates pressure and capacity. In case of quality/energy measurement and monitoring, the gas station is able to interrupt the injection of biomethane/biogas.

Figure 1 shows that most components are sole measurement instruments and available in the market. There are just two more complex components: One to interrupt the gas injection and one able to regulate capacity and flow.

The innovation in the gas station of the future is the software. By using smart net management solutions the gas station is able to perform its duties partly stand alone, regionally or company wide. In the gas station processes are measured and monitored and when needed the pressure and/or capacity is regulated. When off boundary measurements can't be solved locally the gas station starts to communicate with other gas stations in the same network. Then pressure and/or capacity is regulated regionally.
Company wide the net management software regulates the gas networks by using different kind of forecasting models (i.e. demand-response, weather and price models)

*For example:* The temperature of a region somewhere in the Netherlands is rising relatively fast. This means that the demand of gas will decrease due to lower heating demand. At the same time a biogas producer is producing a large amount of biogas which is fed into the network of the region. The monitoring and regulating system will start to turn down the delivery of natural gas in the gas stations in this gas network to allow maximal input of biogas at all times. If necessary the software will even send a pre warning signal to the biogas producer to enable the producer to slowly turn down its production process.

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## 6. LIST OF FIGURES