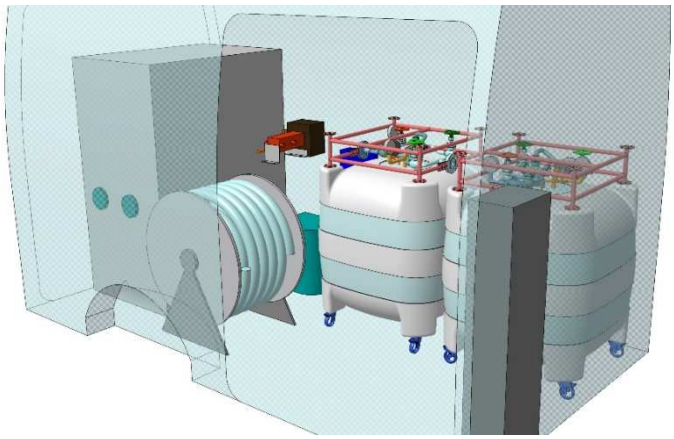
# Design concept of a vehicle with a permissible total weight of 3.5 tons used as a mobile refuelling station for LNG fuel



Project Team:

Dr.-Ing. D. Andrich

Dipl.-Ing. S. Andrich

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# Content

# 1 Introduction

Through the Paris Agreement targets have been agreed globally to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future. European Commission in its EU strategy to reduce methane emissions defines challenges but also opportunities for European Union related to the methane as a source for pollution but also for energy production. This strategy sets out measures to cut methane emissions in Europe and internationally. It presents legislative and non-legislative actions in the energy, agriculture, and waste sectors, which account for around 95% of methane emissions associated with human activity worldwide. The Commission will work with the EU's international partners and with industry to achieve emission reductions along the supply chain. As announced in the EU strategy for energy-system integration, the Commission will re-examine the gas market regulatory framework to facilitate the uptake of renewable gases, including by considering issues such as the connection to infrastructure and the market access for distributed and locally connected production of renewable gases. In addition, opportunities for further targeted support to accelerate the development of the market for biogas will play a significant role in the achieving the strategic goals.

Nevertheless, even methane from the natural gas is still a better alternative for other fossil fuels and contributes to the creating a neutral economy defined in the European Green Deal. Important is however a strengthening holistic approach to create synergy between different sectors and application of new technological solutions contributing to more efficient and environmentally friendly use of this energy source. Liquifying is a one of possible steps that can help to reduce methane emissions and at the same time creates several options for economical benefits.

The transport sector , for example, amounts to almost one quarter of greenhouse gas emissions (GHG) in the European Union (EU). Natural gas has a 15[2]-25[3]% GHG emissions-reduction potential for heavy-duty vehicles and shipping. The technology of gas engines is mature and supported by major industry players like Wartsila, Iveco and Volvo. Feedstock for LNG is traditionally natural gas. However, renewable power and biogas produced out of waste can be used as feedstock and are key to producing renewable bioLNG. Additionally, bioLNG offers a compatible mix with, or in some cases a replacement to, LNG and may exhibit in excellent environmental credentials. Biomethane and bioLNG offer almost 100% GHG emissions reduction. These are therefore important components in achieving the emission targets in the EU to meet the Paris Agreement.

*LNG (liquefied natural gas) is natural gas converted to liquid by cooling it to -163 degrees Celsius. It is stored in insulated containers that keep the gas liquid. LNG achieves a higher reduction in volume than with CNG, meaning that a larger amount can be transported over a longer distance. LNG use in vehicles also offers the possibility to cover longer distances, making it an ideal fuel for trucks and buses. Compared to CNG the energy content of the unit of volume is three time higher: 1 litre Diesel fuel corresponds to 4,7 litre CNG at 200 bar and to 1,6 litre LNG. Due to its low sulphur emissions LNG is becoming the fuel of choice also for the shipping industry. LNG can also be produced from renewable sources, blended with natural gas and used as bio-LNG.*

**Small-Scale (bio)-LNG**

Nowadays the main activities of the LNG business focus on mega projects and big-scale LNG market and the comparatively diminutive market of small-scale LNG (ssLNG) doesn't get much attention.
Small-scale liquefied natural gas (ssLNG), a niche but nascent industry that is already profitable and scalable, boasts significant potential. It is well placed to meet the growing demand from the shipping and trucking industries for fuels that are more environmentally friendly than oil and diesel. ssLNG also enjoys advantages in addressing off-grid power generation for industrial and residential needs in remote locations. Even if there are many market players, this segment is generally not yet on the radar of the industry participants but taking into consideration market development it should be.
As companies approach the ssLNG market, they should be prepared to act quickly. In selected applications, such as marine and off-grid power generation, it will be vital for participants to establish first-mover advantage. But they will also need to have the right strategy in place, underpinned by the appropriate capabilities, which include the ability to build partnerships across the LNG chain.

Small-scale LNG (ssLNG) refers to the end-use of natural gas in its liquid form, as opposed to gaseous gas (distributed via pipelines). It covers the value chain from the exit of the large-scale / bulk terminal to the final consumption of LNG.

**Liquid Energy Project and its contribution to the unlocking of the micro-scale market**

The Liquid Energy project addresses still untapped potential of using (bio-)LNG as an alternative energy source. The project's focus on micro/nano-scale technological solutions requires cooperation on the cross-border level to bridge players on the market being in the initial development phase.

The Liquid Energy project addresses still untapped potential of using (bio-)LNG as an alternative energy source. The project's focus on micro/nano-scale technological solutions requires cooperation on the cross-border level to bridge players on the market being in the initial development phase. As every new market, the one, addressed by the project is characterised by low level of knowledge about relevant actors, products and services and a lack of market critical mass of stakeholders on the national / regional level.

As a consequence, joining existing resources, knowledge and relevant actors on cross-border level (as a common and more coherent region than whole EU) can significantly contribute to the creation of critical mass and unlocking (especially) business cooperation in this technological area. Additionally, low number of organisations dealing with (bio-)LNG technological solutions calls for joining resources within the South Baltic partnerships to speed-up necessary development processes, especially cooperation between business and science to compete on the global level on the new market, addressed by the project.

# 2 Goals and purpose

Decentralised solutions for end-users are a foreseen complementary possibility as a contribution to the energy transformation. They can contribute to the wider application of the methane and thus in the end, hydrogen technologies for the energy supply for the small-scale users: business (production), transport and logistics, private users. With the micro-scale mobile refuelling (bio-) LNG station, the aim is to replace stationary LNG refuelling infrastructure (ergo costs reduction) by a mobile solution tailored to the market demand. This is also important in a discussion on the application of bio-LNG, keeping in mind the scale of the delivered fuel – from biogas plant with liquefaction technology to the end-user.

Another aspect that seems to play a significant role for success of the micro-scale mobile (bio-)LNG refuelling station is its potential role for the future market addressed by the Liquid Energy project in a context of necessary flexibility of the logistics of the (bio-)LNG as the future energy source. Also, rural areas where new energy-supply models become more and more important (as defined in the “EU strategy to reduce methane emissions”), smart solutions addressing a micro-scale market require new technical solutions for supply of the end-users from either LNG logistics centre (e.g. terminal, stationary station) or biogas plant with liquefying module (last 100 km). In the rural areas self-supply, or supply of the agriculture machines seem to be an alternative for the local or regional economy / business.

In the growing LNG market, it is important to consider other applications besides fuel use. For example, the low-cost conversion of LNG into hydrogen, which is then used in a wide variety of ways, is a potential market size that needs to be considered. Within this market, small customers in particular come under pressure because they are not always accessible by tanker trucks. Especially in urban areas or densely built-up industrial areas, a product close to the end user such as the mobile LNG tank station can help out. Here, not only the dimensions of the vehicle, but also the associated accessibility is a great advantage. A smaller filling quantity also ensures faster operational readiness, as the tank of the mobile filling station requires less filling time. Especially with the aim of representing an alternative to stationary filling stations and thus being available quasi "on demand". The customer is relieved of the logistical problems of a stationary filling station.
The latter is also a clear advantage against the background of a direct supply chain between large plants or bio-gas plants that produce LNG / BIO-LNG and the rural or smaller customers. The mobile filling station thus forms a missing link, especially for small and micro consumers.

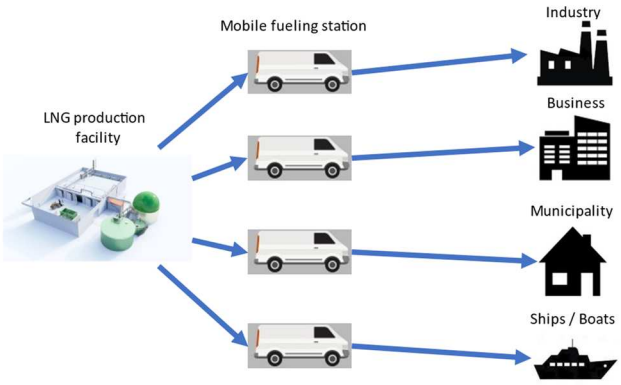


**Figure 1:** A system of new market addressed by the mobile refueling station

# 3 Application areas

There are three major end uses for ssLNG: marine fuel (bunkering), fuel for heavy road transport, and power generation in off-grid locations. The market is relatively immature. However, several major energy companies are already involved in ssLNG, including Shell, Engie, ENI, Gasum, and Gazprom. The size of the market is expected to grow to approximately 100 million tons per year by 2030.

Liquefied natural gas is mobile: Since it has only about six hundredth the volume of gaseous natural gas, it can be loaded into large tankers and transported over long distances by ship or truck. Thus, LNG can supply regions with natural gas that do not have a continuous pipeline system that could supply them with natural gas. Economies can purchase LNG via so-called LNG import terminals and regasify it locally in order to feed it into the local natural gas network for the heating market or other uses.

LNG is also used as an alternative, more environmentally friendly fuel in shipping and heavy haulage. Regasification and feeding into the natural gas network are not necessary for this. Instead, LNG is landed via so-called “small-scale terminals” and used directly to refuel ships or transported to LNG filling stations for heavy goods vehicle traffic. Compared to diesel engines in particular, modern LNG-powered engines emit less CO2, around 20% less in ships and heavy goods vehicles. In addition, any proportion of bio-LNG produced from bio-gas and, in the future, synthetic LNG, which is produced with the help of renewable electricity, can be added to LNG engines.

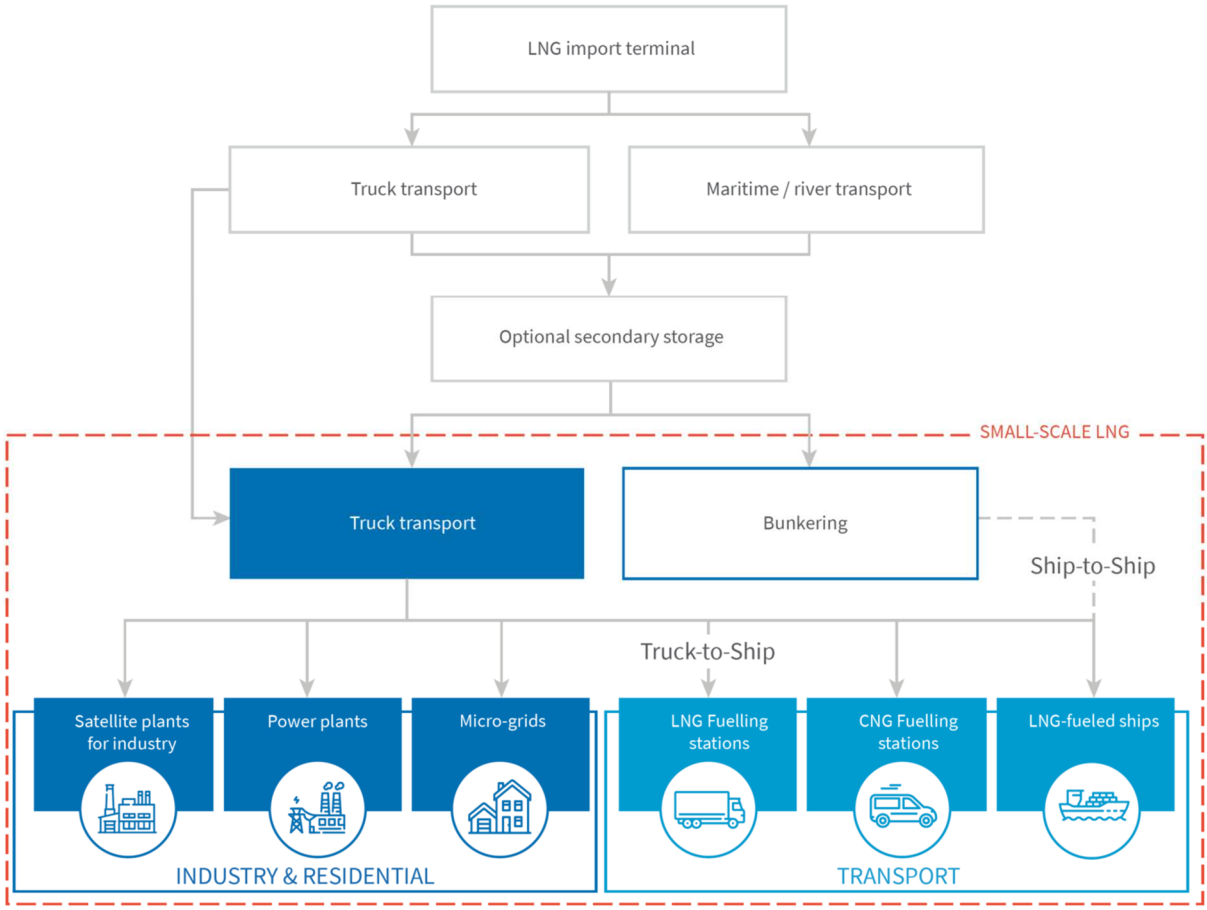


**Figure 2:** LNG Logistics Chain and small-scale LNG uses (scope of the study), (FTI, 2020)

FTI Consulting, Inc. has identified **six main segments** of small-scale LNG in Europe, which can be regrouped into two macro-segments:

1. Stationary or Mobile consumption.

1.1 **LNG for industrial consumers not connected to the natural gas network**. Usually, LNG is used as a substitute to oil products (gasoil, liquified petroleum gas, heavy fuel oil) in industrial processes. It is supplied directly by trucks from LNG terminals equipped with truck loading bays, and then stored and re-gasified on consumer's site by a satellite LNG plant.

1.2 **LNG for power generation in isolated areas** (notably islands). LNG is supplied from the exit of the bulk terminal to the power plant through a "virtual pipeline" of trucks and ISO containers.

1.3 **LNG as a supply source for isolated natural gas networks** (micro-grids). In this case, LNG is transported by trucks or ISO containers directly to a satellite plant that re-gasifies and injects natural gas into the local network.

2. Mobile consumption: Transport

2.1 Liquified natural gas (LNG) for heavy-duty trucks, mainly road tractors > 40 T, distributed at LNG fuelling stations.

2.2 Compressed Natural Gas from LNG (L-CNG) for light-**duty vehicles, vans, buses and trucks**, distributed in Compressed Natural Gas fuelling stations supplied by LNG trucks.

2.3 LNG as a marine fuel – or bunkering, as a substitute to oil marine fuels, distributed either as truck-to-barge-to-ship (for large vessels) or truck-to-ship (for smaller vessels).

The mobile tanker is suitable for use in all LNG applications for transportation, storage as well as distribution of LNG as primary energy supply. LNG is used as a heating gas in residential, public and commercial buildings in conjunction with condensing technology as well as liquid heat transfer media (water, thermal oils) as well as for radiant heat heating systems (floor, wall heating).

Natural gas is also used in water heating for a wide variety of sanitary application scenarios. As a rule, these applications are combined with condensing boilers and buffer storage systems for effective heat energy utilization. This case for example, affects up to 60% of single-family homes in Germany.

The use of LNG in the application for energy conversion into electrical energy as well as heat energy is favoured with the most modern technologies such as fuel cell technology in connection with low CO2 emissions. Available cycle technologies for the recycling of the accruing CO2 via the hydrolysis of hydrogen lead to so-called synthetic or turquoise methane. In order to avoid the so-called methane slip (methane release during the individual process stages of generation, transport and distribution as well as utilization), technologies for gas recirculation (direct consumption, re-cooling, discharge into collecting tanks) are installed in the mobile tanker.

Another field of application of the mobile filling station is the supply of natural gas to natural gas-fired combined heat and power plants. As a result of combined heat and power generation and thus possible efficiencies of 60% and more, this technology is better than the pure combustion of natural gas in condensing boilers. In condensing boilers, part of the exhaust gas heat can usually be additionally utilized by means of a crossflow heat exchanger.

The development of LNG-fuelled fuel cells with the decoupling of the electrical and thermal energy has become a leading technology for the use of methane-containing gases. Here, the possibility of using LNG via distribution by means of a mobile refuelling station is energetically and economically effective. A sustainable and environmentally sound infrastructure can thus be established.

The increasing use of LNG in truck transportation requires the provision of technical solutions for unloading LNG-fuelled vehicles in preparation for maintenance and repairs.

Unloading of LNG-fuelled vehicles in case of emergency or accidents is possible by means of the mobile refuelling station. Currently, in such situations, the LNG / natural gas is discharged into the environment. So far, there are no reliable technical solutions for such applications.

Methane containing gases like LNG (liquid natural gas) or bio-LNG (liquid biogas) as primary energy carriers are a future potential of energy supply due to their high energy density, their possibility of environmentally friendly generation and the ever decreasing loss rates into the free atmosphere. With the development of the concept of a mobile LNG / BIO-LNG filling station, an important future market-oriented infrastructure is being advanced.

# 4 Functional parameters of the application.

The vehicle meets the most diverse functional requirements for comprehensive use as a means of transport, distribution unit, safety system for special applications, part-time storage, transfer, as well as for minimizing boil-off gas in the various handling processes.

## 4.1 Concept of the final output

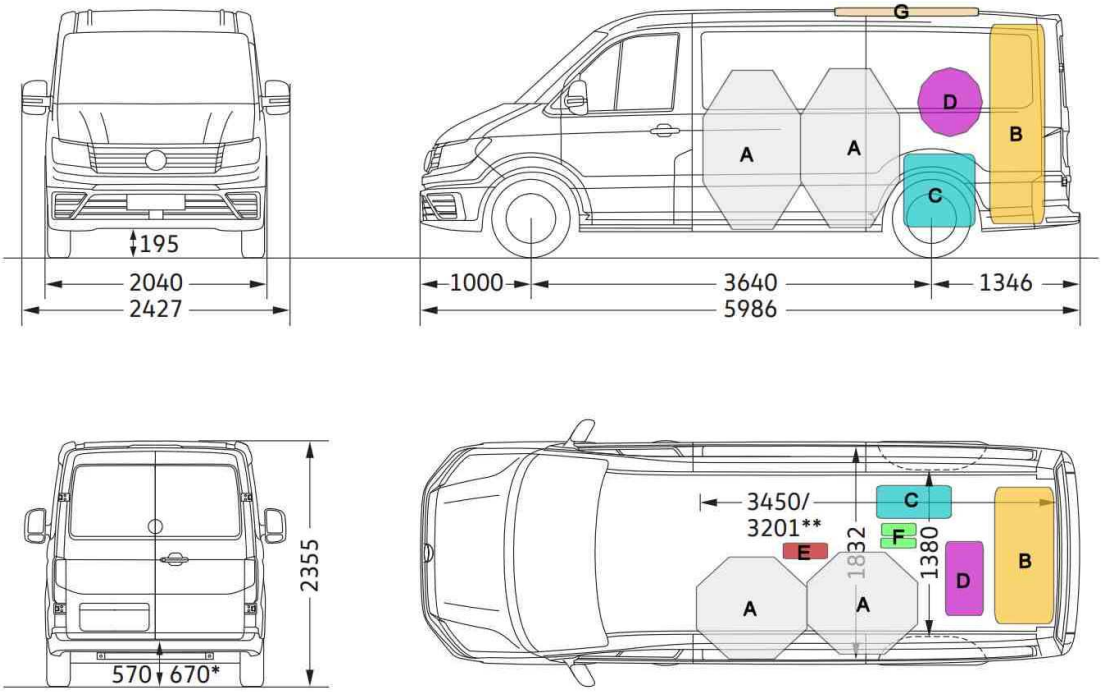


**Figure 3:** Concept of the final output Source BEF GmbH

Legend:

A – Cryogenic tank: 920 mm X 920 mm X 1200 mm (WxLxH) Approx. weight: 300kg x2

B – LNG Dispenser module: approx. (WxLxH): 1300 mm X 730 mm X 1680 mm Approx. weight: 300kg

C – Air compressor: approx. (WxLxH): 320mm X 390mm X 460mm, weight: 12kg

D – Hose drum for the approx. 10m fuel hose: Diameter of 500mm, width: 700mm, weight: 120kg

E – Air Driven liquid pump: 446 mm X 238 mm X 241 mm (WxLxH), weight: 12kg

F – Additional Lithium battery: 100Ah LIONTRON LX Smart 25,6V LiFePO4, weight 26kg

(G – Solar panel: 1012 mm X 689 mm X 10 mm)

These main parts are fitted into the VW Crafter 35 and connected to the floor or a support.

To move the BEER-kryo-Vessels in and out of the VW Crafter 35, a support ramp system from aluminium will be used.

The BEER-kryo-Vessels will be connected by flexible fluid pipes and stainless-steel pipes DN25.

The electrical power supply for the equipment is implemented completely separately from the vehicle's on-board power supply system. For this purpose, an independent energy system is installed. This system consists of a solar panel system on the roof of the vehicle, a charging system for lithium accumulators, a 100Ah lithium accumulator LiFePO4 and a 1.8 kW inverter.

The LNG dispenser module is installed at the rear of the vehicle. The connections to the BEER cryogenic vessels will be flexible.

For the boil-off gases and the gas phase produced during the refuelling process, a manifold for gas recirculation and a cargo hold venting system will be installed.

3D-Schematic of the loading volume of the vehicle which will be used, without the piping:

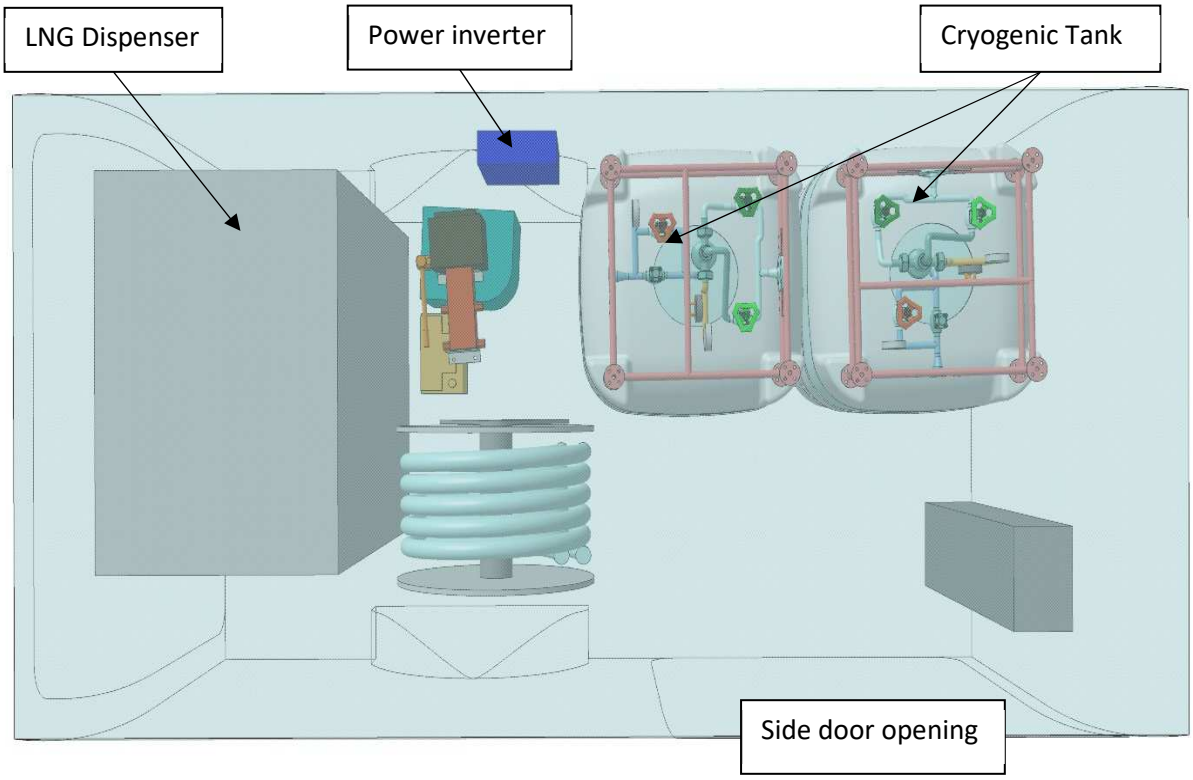


**Figure 4:** Top View 3D-Schematic of the loading volume of the vehicle Source BEF GmbH

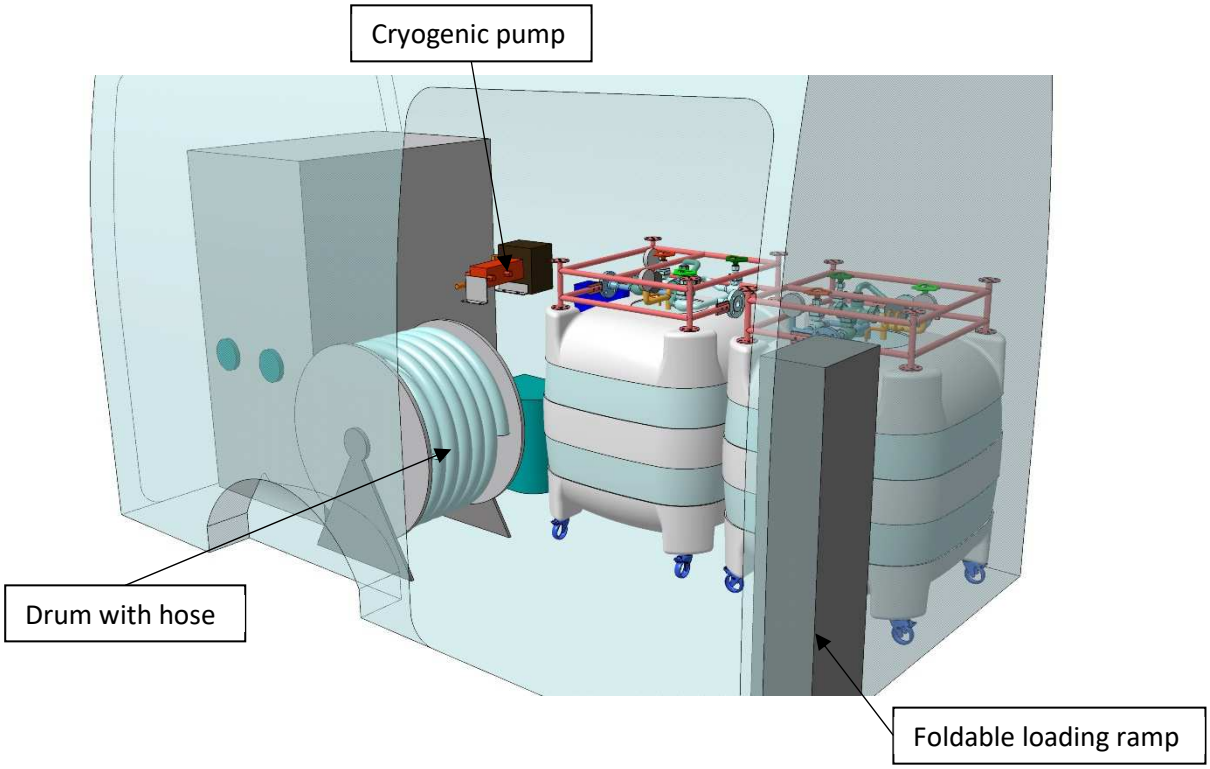


**Figure 5:** Side View 3D-Schematic of the loading volume of the vehicle Source BEF GmbH

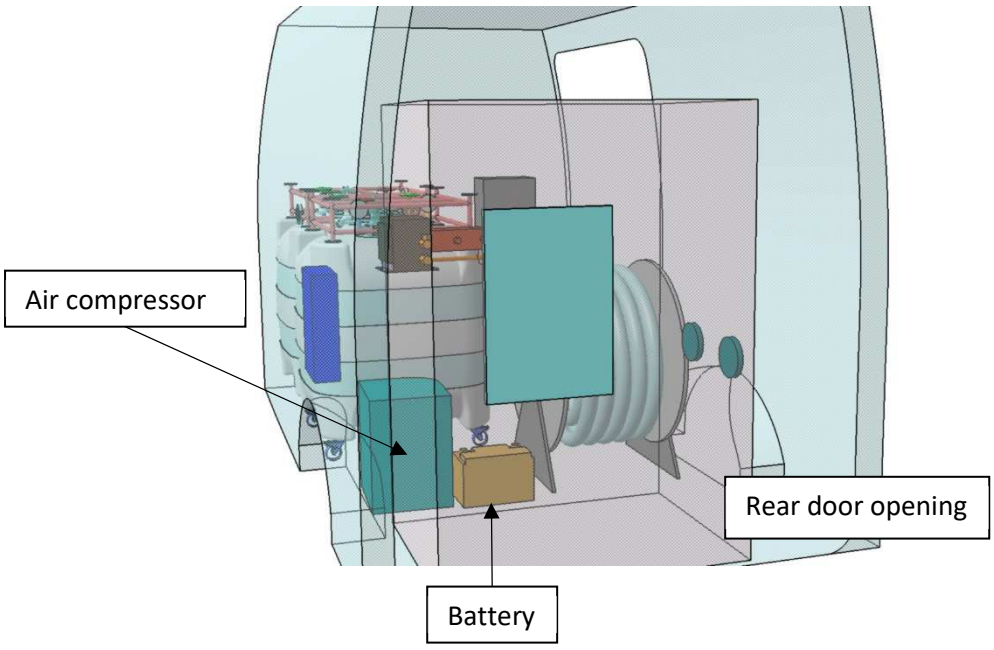


**Figure 6:** Rear View *3D-Schematic of the loading volume of the vehicle* Source BEF GmbH

## 4.2 Foreseen parameters

In order to develop the mobile filling station for LNG fuel, it was important to considered which parameters are important and necessary for each part of the station. Then, based on these parameters, the first selection of parts was made.

### 4.2.1 Vehicle:

- vehicle mass total 3,5 t
- loading space 3450 x 1832 mm
- motorization min. 120 kW
- load compartment openings side sliding door, rear doors
- additional option. Electric / hydraulic lifting platform

### 4.2.2 Tank volume:

- storage tank - pay load 65-80 kg LNG
- decanting tank - up to 10 bar pressure compensation for 100 litre gas phases

### 4.2.3 Cryogenic Pump:

- pump for LNG in liquid state at -162°C
- fluid phase - flow rate max. 20 lpm. (DN 20 pipe), delivery height 5 m, about 1 kW output with 24-48 V on-board voltage
- gas phase - flow rate max. 30 lpm. (DN 20 pipe), delivery height 5 m, about 0.8 kW output with 24-48 V on-board voltage
- suction pressure: 1-6 bar
- working pressure: 6-16 bar
- flange connection EN-ISO, DIN
- dry running condition
- available space max. 900 x 1000 x 1000; max. weight 100 kg

### 4.2.4 Hose:

- DN 20 corrugated hose with thermal insulation, rotary coupling 1"(IMO), effective length approx. 15 m
- Adapter for lever and rotating coupling 1" loose and fixed block

### 4.2.5 Power supply:

- battery-supported, 100Ah, 1,8 kW inverter

#### 4.2.6 Compressed air:

- Compressor 10 bar, 15 litre air chamber, AC 230V / 50Hz or DC 24 / 48 V, 1.1 kW, 150 l / min compressed air
- Compressed air hose 10 m with compressed air gun

#### 4.2.7 Gas recirculation:

- Gas recirculation / boil-off in a second container up to 10 bar and 100 litre gas phases

#### 4.2.8 Control system

- sensors flow rate, temperature, pressure, filling volume / filling quantity Solution
- Display of monitoring equipment for pumps, security systems, leaks, pressure, and temperature
- Display documentation and operation

#### 4.2.9 Loading system for exchange of the tank:

- ramp system from aluminium with min. 300 kg load capacity

#### 4.2.10 Protective staff equipment:

- jacket, pants, shoes, gloves, face protection

#### 4.2.11 Dispenser module

- all the necessary certificates
- a display, which can even be used to integrate a payment system
- overflow protection
- emergency stop button
- mass flow meters
- filling guns, and air return guns

## 4.3 Selected components

Based on the parameters set in the previous chapter, an initial selection of parts to be used was made.

### 4.3.1 Vehicle

Since FSN-Ferdinand Schultz Nachfolger is a specialist in special vehicle construction with a focus on VW vehicles, a car from the range of VW was selected for carrying out of the pilot investment.

VW Crafter 35 Medium-length wheelbase with high roof 2,0-I-TDI BMT FWD Euro 6d

- Dimensions: 5986 x 2427 x 2590 mm
- Cargo space: 11,3 m³
- Max payload: 766-1428 kg


**Figure 7:** VW Crafter 35 Medium-length wheelbase with high roof 2,0-I-TDI BMT FWD Euro 6d https://commons.wikimedia.org/wiki/Category:Volkswagen_Crafter?uselang=de


**Figure 8:** VW Crafter 35 Medium-length wheelbase with high roof 2,0-I-TDI BMT FWD Euro 6d https://commons.wikimedia.org/wiki/Category:Volkswagen_Crafter?uselang=de


**Figure 9:** VW Crafter 35 Medium-length wheelbase with high roof 2,0-l-TDI BMT FWD Euro 6d https://upload.wikimedia.org/wikipedia/commons/3/33/Volkswagen_Crafter_-_przestrze%C5%84_%C5%82adunkowa_%28MSP17%29.jpg

**Figure 10:** *VW Crafter 35 Medium-length wheelbase with high roof 2,0-l-TDI BMT FWD Euro 6d* https://upload.wikimedia.org/wikipedia/commons/4/41/Volkswagen_Crafter_%283%29_TT_Berlin_2017.JPG

### 4.3.2 Tank / Cryogenic vessel

BEER-kryo® mobile storage container for cryogenic fluids of the 2nd generation (cryo vessel 2.0)

**Figure 11:** BEER-kryo® mobile storage container for cryogenic fluids Source BEF GmbH

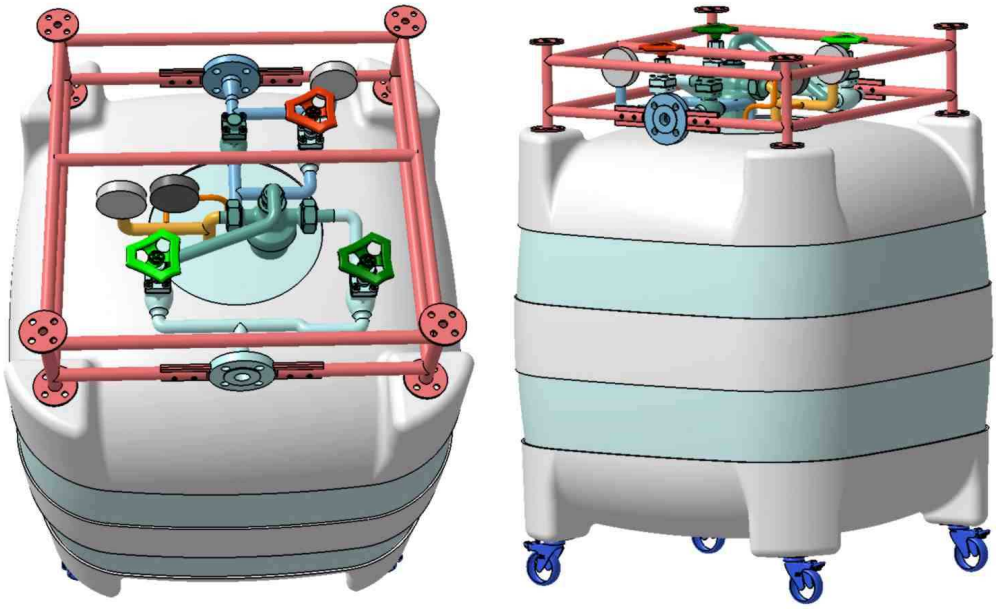

**Figure 12:** BEER-kryo® mobile storage container for cryogenic fluids Source BEF GmbH

**Parameters of the vessel**

The BEER-kryo® family of containers is a stackable container system for storing and transporting cryogenic fluids, especially LNG and bio-LNG. The product development status achieved enables the transport of liquid nitrogen (-196 °C) at an internal pressure of 3 bar.

The system is characterized by passive thermal insulation (no vacuum) based on the use of nanostructured materials and a proportion of fibre composites of more than 85%. The containers are designed to be stackable so that several individual storage units can be integrated into a standard container. Optional, depending on the regional requirements, the tank can be built without an inner steel body.

**Specifications for use as an LNG tank:**

- Cryogenic medium: LNG (~ 98% concentration of methane content), density: 450 kg / m³
- Medium temperature: -162 ° C
- Tank operating pressure range: 0-4 bar
- Ambient temperature: -50 to +80 ° C
- No explosion protection necessary
- Stainless steel 1.4307 is used for all steel part
- optional: temperature, flow measurement, evaluation electronics (CAN open bus), software for evaluation electronics (display, data logger, ...)

The technical certification for mobile road use (DEKRA) as well as use on small boats and yachts up to 25 m LOA (DNV formerly DNV-GL) will take place in Q4 2021 - Q2 2022.

**Fitting System:**

- Flange 1 “IMO system for loading and unloading the liquid phase
- Flange 1 “IMO system for discharging the gas phase
- 3 x manual valves to control the respective media flow
- 1 x check valve in the pipe system for loading the liquid phase
- 1 x pressure measurement for loading the liquid phase of adaptation to the charging station
- 1 x pressure measurement for the internal pressure of the container
- 1 x differential pressure measurement for the level indicator

**Technical data tank with steel inner body:**

- Capacity: 150 l => 65 kg LNG
- External dimensions: L: 836 mm W: 836 mm H: 1126 mm, height without castors: 1028 mm
- Empty weight **215 kg**
- Operating pressure: 4 bar, maximum charge pressure 6 bar
- Boil-off rate without internal recooling: approx. 0.29% per day

**Technical data tank with FRP system structure:**

- Filling quantity: 200 l => 90 kg LNG
- External dimensions: L: 836 mm W: 836 mm H: 1126 mm, height without castors: 1028 mm
- Empty weight **110 kg**
- Operating pressure: 3 bar, max. Charge pressure 5 bar (current state of development)
- Boil-off rate without internal re-cooling: approx. 0.29% per day

**Technical Drawing**

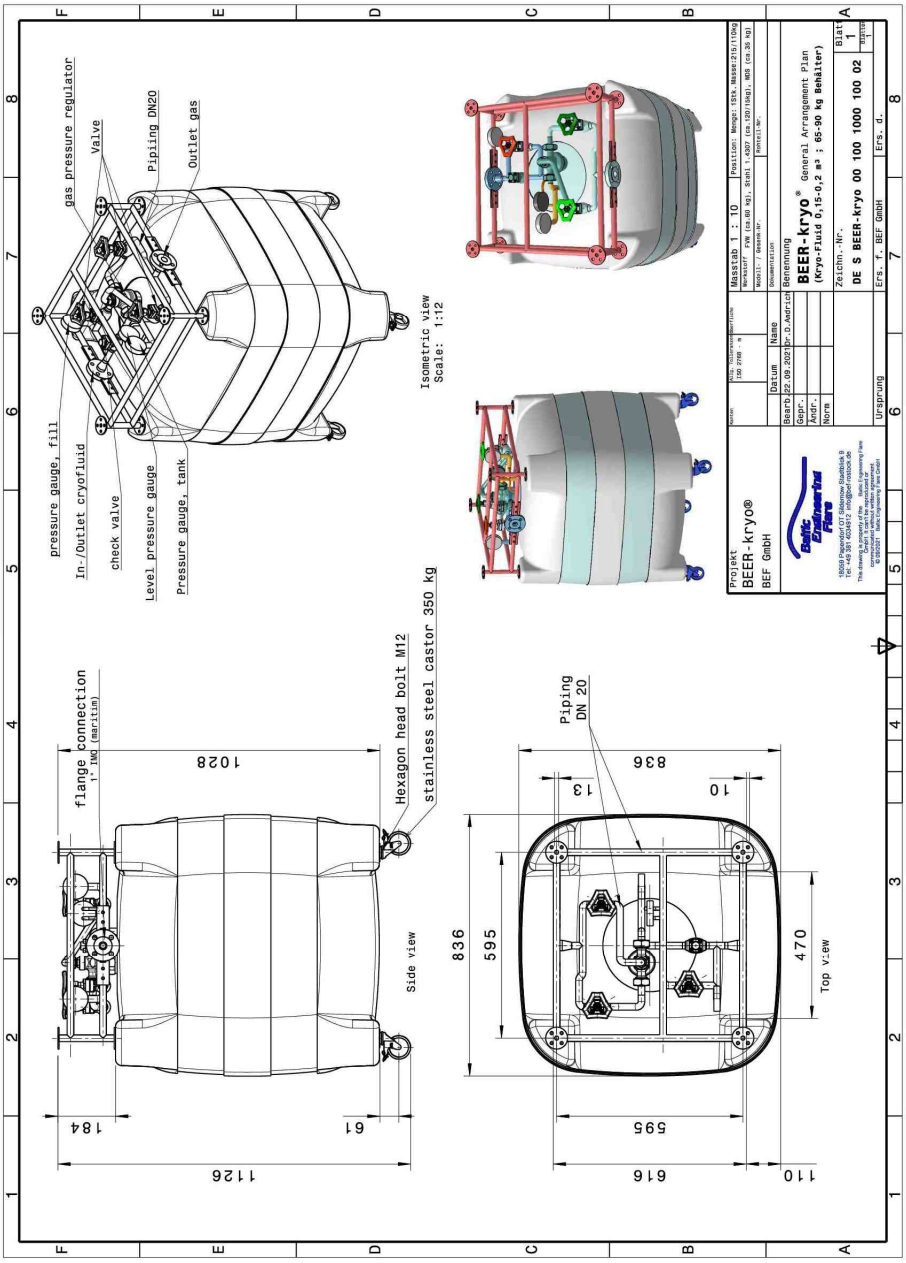


**Figure 13:** Technical Drawing BEER-kryo® Source BEF GmbH

### 4.3.3 Cryogenic Pump:

Initially, it was planned to use a pneumatic or electric pump. However, after research and through inquiries with manufacturers, it was learned that these are not suitable for this application. This is because most pumps are not designed for our transport volume and are therefore significantly larger and therefore heavier than necessary. In addition, the pneumatically operated pump would require an additional pneumatic system that would weigh about the same as the pump itself. Therefore, it was decided to use an air driven pump, because it is not only smaller and lighter, but can also be driven by an air compressor. This is also used for cleaning the receptacles after filling.


**Figure 14:** Cryogenic Pump HD-tech GmbH & Co. KG (https://www.h-d-tech.de/product-details/58896/)

**Technical data**

- max.operating pressure 86 bar
- Delivery pressure (bar): 4 x Pa + Ps
- Stroke volume 320 $cm^3$
- double acting, 1 air drive
- Modification: spacer,
- End cap rotated 180 °
- Sealing material: neoprene
- Medium: LNG
- Temp.: -160 ° C
- Drive pressure: 4 bar
- Compressed air consumption: 0.5 $Nm^3$ / min
- Suction pressure: 3 bar
- Operating pressure: 11 bar
- Delivery rate: 10 l / min

### 4.3.4 Hose:

Due to the option to remove the tanks from the vehicle, it is easier to use flexible hoses to connect the different parts. During research it was found that composite hoses fulfil the same parameters as normal steel hoses but are significantly lighter in weight.

**Figure 15:** Hose GUTTELING BV (https://www.gutteling.com/products/multi-lng-white-hoses)

**Certification**

Multi-LNG White hoses are produced and tested according to international standards like EN 13766, IMO IGC and EN 12434.

**Construction**

- Inner wire: Stainless steel 316
- Lining: Polyester fabrics and flms
- Outer cover: Polyamide
- Outer wire: Stainless steel 316

**Physical properties**

- Maximum elongation: 10% on proof pressure
- Electrical resistance: 2,5 Ohm p/mtr < 2”
- 1,0 Ohm p/mtr >/= 2”
- Maximum twist: 10° p/m
- Min. burst pressure: 5x working pressure (safety fact 5:1)
- Max. flowrate: on request
- Max. tensile strength: on request
- Pressure losses: on request
- Temperature range: -196°C upto +50°C

### 4.3.5 Power supply:

To meet the requirements for the supply of electricity, a system with solar panels on the roof of the vehicle will be used. This system will use solar modules known from the field of shipbuilding, which are flexible and resilient. Since the air compressor and the LNG dispenser need a different voltage than the solar panels supply, an additional inverter is needed. Finally, the generated electricity is stored in an additional battery. Thus, a use even without sunshine is guaranteed.

#### *4.3.5.1 Solar module*

**Figure 16:** solar module SW 20185 SunWare GmbH & Co KG (https://de.sunware.solar/produkte/solarmodul/58)

The solar module SW 20185 is designed for larger solar systems. The powerful 100Wp module is designed for 12V systems, but can be used in serial connection at 24V systems. Depending on the irradiation, the module supplies a charging current of up to 5,75A.

**Technical Data:**

- Pmax 110.0 Wp
- Imax 5.87 A
- Umax 18.74 V
- Uoc 22.2 V
- Isc 6.34 A
- no of cells 35 Stck.
- cell sizes 104.0 x 156.0 mm
- laminate ETFE/EVA/ETFE
- Lenght 1012.0 mm
- width 689.0 mm
- Product weight 4.7 kg
- Cell Characteristic
- Multicystalline Solar Cell
- Current Temp. Coeff. (Isc): 0.06%/K
- Voltage Temp. Coeff. (Uoc): -0.34%/K
- Power Temp. Coeff. (Pmax): -0.42%/K
- Standard test conditions: AM 1.5, 1000W/m², 25°C

*4.3.5.2 Power inverter for pure sine wave*


**Figure 17:** Power inverter FraRon electronic GmbH (https://www.fraron.de/wechselrichter/reiner-sinus/24v-auf-230v/swi1200w24v-reiner-sinus-24v-dc-230v-ac-1000-2000w/a-1760268/)

**Technical Data:**

- 1800 watts for max. 15 minutes
- 1500 watts continuous power
- 3000 watts short time peak (25ms)
- 20 to 33V DC input voltage range
- crystal precise 230V AC, 50 Hz output voltage
- FI residual current circuit breaker integrated in AC output
- pure sine wave, distortion factor max. 3%, efficiency max. 90%
- standby consumption 0,6A
- alarm signal at 21V battery voltage
- deep discharge protection, disconnection of the consumer at 20.0V battery voltage
- overvoltage protection, disconnection at more than 33V DC at the input
- the 230V AC output is short circuit proof
- the 24V DC input is protected against polarity reversal by fuses
- automatic shutdown of the voltage transformer in case of overload
- temperature protection, protective shutdown at more than 60°C in the housing
- microcontroller controlled
- temperature and load controlled fan, the fan runs only when needed
- Power switch on the device (on - off switch)
- Dimensions H=100mm, W=283mm, L=415mm
- 6,7kg weight including connection cable (without packaging)
- E-mark (e-mark) (This mark states that the device may be operated on land and water in vehicles)

#### *4.3.5.3 Storage battery*


**Figure 18:** Storage battery Liontron GmbH & Co. KG (https://liontron.com/wp-content/uploads/2020/10/lifepo4-24100-1.jpg)

**Technical Data:**

- Model LISMART24100LX EAN / GTIN 4260586370294
- Rated capacity 100Ah / 2560Wh
- Voltage range 22.0 .. 28.8V
- Rated voltage 25.6V
- Cycle life ≥3000 @90% DoD
- Charge characteristic CCCV / IU
- Bulk voltage 28.4 – 29.2V
- Float voltage 27.0 – 27.6V
- Recommended max. charge current 50A
- Max. charge current 100A
- Max. discharge current 150A
- Pulse discharge current (≤20Sek.) 200A
- Battery Management System integrated
- Monitoring Bluetooth 4.0 with Smartphone App
- Application 24V installation, parallel connection only
- Protection class IP65
- Temperature (discharge) -20°C .. +60°C
- Temperature (charge) 0°C .. +45°C
- Temperature (storage) -40°C .. +60°C
- Arctic Upgrade optional, for usage up to -30°C
- Terminal M8
- Terminal arrangement Positive terminal left
- Warranty 5 years manufacturer warranty
- Weight 27.5 kg
- Dimensions (L x W x H) in mm 390 x 233 x 255

### 4.3.6 Compressed air:

Matching the foreseen parameters, an air compressor was chosen. Although it has a lower vessel capacity but based on the delivery rate data it is sufficient.


**Figure 19:** air-compressor Güde GmbH-&-Co.-KG (https://www.guede.com/cgi-bin/twinklecom.cgi?contentidx=0&param=SHOP&parameter=PAGE&command=3&artref=50083)

**Technical Data:**

- Rated voltage: 230 V
- Frequency: 50 Hz
- Engine power (P1): 1,1 kW
- Operating mode: S3 / 25 %
- Engine speed: 3400 1/min
- Buction: 200 l/min
- eff. devlivery rate at 0 bar: 148 l/min
- eff. devlivery rate at 4 bar: 80 l/min
- eff. devlivery rate at 7 bar: 60 l/min
- Max. pressure: 10 bar
- Vessel capacity: 5 l
- Number of cylinders: 1
- Number of compressed air couplings: 1
- Manometer: 1
- Cable length: 170 cm
- Noise declared value: 97 dB

### 4.3.7 Gas recirculation:

The Gas recirculation and collecting the boil-off gas be realised by adding the second BEER-kryo-Vessel, with up to 4 bar and 100 litre gas volume.

### 4.3.8 Control system:

The control system required for the respective refuelling process is installed in the LNG dispenser. It is supplemented by additional measurement and control technology appropriate to the respective application scenario.

- sensors flow rate, temperature, pressure, filling volume / filling quantity Solution
- Display of monitoring equipment for pumps, security systems, leaks, pressure, and temperature
- Display documentation and operation

### 4.3.9 Loading system for exchange of the tank:

For the loading system, the choice was between a wider single ramp or two narrower ramps, as well as the choice between fixed and mobile. To save weight and space, the mobile and foldable version was chosen. The next decision was to use two narrower ramps, which have the option of an additional stand to increase the possible load. Furthermore, they can adapt to different unloading systems, which have different widths.

**Figure 20:** Loading system GeoTech (https://www.geotech-pro.com/de/prodotti-geotech/klappbare-laderampe-226-cm-aus-aluminium-fuer-rasentraktoren-atv-usw/)

**Technical Data:**

- Product features
- Model: ATV-001 - cm 226
- Body material: aluminum
- Type: curved
- Total load as a pair on 2 points (for each ramp): 340 kg
- Length per unit: 226 cm
- Width per unit: 29.5 cm
- Bevel: yes
- Rubberized support surface: yes

### 4.3.10 Protective staff equipment:

The personal cryo protective equipment as occupational safety for handling LNG for industrial use contains:

**Figure 21:** personal cryo protective equipment CryoShop (https://www.cryoshop.de/CRYO-INDUSTRIAL-Set-unterarmlang::299.html)

#### *4.3.10.1 Full face protection*

Protection against splashes of cryogenic liquefied gases such as liquid nitrogen. Extra-large visor to protect neck and face.

#### *4.3.10.2 Cryo hand and arm protection (medium)*

Protective gloves CRYO-INDUSTRIAL® GLOVES. Specially designed for industrial use requiring a high level of abrasion resistance.

#### *4.3.10.3 Cryo-body protection*

Protective apron CRYO-INDUSTRIAL® APRON CIA 42 width 610mm x length 1070mm

### 4.3.11 Dispenser module

The dispenser is one of the most important parts within the mobile gas station. Although it is possible to design one, it was decided to buy an existing dispenser. It is tested for safety and has all the necessary certificates. Furthermore, it has built-in comfort functions such as a display, which can even be used to integrate a payment system. There are also options such as integrated overflow protection and an emergency stop button. The current choice is the RT-LNG112 LNG Dispenser.

LNG dispenser adopts a gantry structure, and the columns, panels, and front doors are made of stainless-steel plates. The main components are mass flow meters, pressure sensors, IC card electronic control systems, small ticket printers, explosion-proof control power supplies, LNG computer controllers, pneumatic valves, ball valves, stop valves, safety valves, metal hoses, filling guns, and air return guns, Process piping and casing, etc.


**Figure 22:** Dispenser module Source: BlueSky Energy Technology (https://blueskynewenergy.com/wp-content/uploads/2021/08/2-1-LNG-dispenser-2.png)

**Technical data:**
Ambient Temperature: -40℃~+55℃
The pipeline temperature: (-196°C~+55)°C
Ambient humidity： 30%〜90%
Power: AC220V or DC24V -- Rating power: <100W
Flow rate: (1~80) kg/min
Measurement precision: ±1.0%
Rated working pressure: 1.6MPa
Gas-filling preset range: 1~9900 kg
Capable of saving the data when out of power, extending the display time, and repeating display.
Equipped with IC card reader.
Leaves the communication ports, so it can communicate with the filling station management system.

# 5 Target groups

The target groups for the use of a mobile storage, transport and tank system for small-scale technical LNG application scenarios are diverse. The classification can be made into stationary site-based applications and mobile land-, rail-, road-, water- and sea-based application scenarios for the use of liquefied methane containing (LNG, BIO-LNG, synthetic liquid methane).

Mobile land-, rail-, road-, water- and sea-based deployment scenarios

- Realization of various modes for storage, transport as well as distribution
- ferries, fishing boats, yachts, pleasure boats
- Agricultural machines of any kind especially usable for the use of BIO-LNG
- Trucks in emergencies for loading and unloading of LNG tanks
- buses for passenger transport in local public transportation
- future rail vehicles with LNG propulsion units

Stationary applications

- private LNG use in heating and hot water systems of single and multi-family homes
- office buildings, public institutions, authorities and sovereign buildings with corresponding
- production facilities of small medium-sized enterprises with a daily energy consumption of up to 500 kWh
- agricultural enterprises with a machine park where LNG / BIO-LNG can be used (Claas, John Deere); developments of corresponding gas engines starting in 2020
- self-sufficient refuelling and final refuelling of agricultural machinery in the open field (vehicle with four-wheel drive and wide tires)
- small regional food producers for heating, thermal and electrical energy consumption
- small, medium, and large plants for biogas generation in rural areas
- small on-site production units for hydrolysis of hydrogen and CO2 to synthetic methane
- small liquefaction plants for biogas in rural areas

Technical solutions, handling processes for the use of LNG BIO-LNG in small utilization units:

- Container exchange as tank vessels for direct consumption in stationary and mobile units
- Storage tanks up to 500 l or mass equivalent of 250 kg in stationary and quasi-mobile units
- Refuelling from a cryogenic container into a stationary or mobile container or tank
- Storage tank in stationary and mobile units with use of the LNG / BIO-LNG, methane from the tank

# 6 Possible transport quantities

The transport capacity of the mobile filling station vehicle is variable and can be adapted to the respective application scenario.

The basic requirement is the maximum total weight of the vehicle of 3.5 t. This total weight may be exceeded because of the requirements for driving the vehicle with a standard EU driving license class B must not be exceeded. The arrangement of a third container of type 2 FVW with a total weight including LNG filling of 200 kg is possible under conditions of mechanical load securing.

This results in the following capacity data in accordance with the already specified application scenarios for with the maximum permitted filling volume of the individual containers:

Option 1 : maximum loading with 3 vessels 200 l for container exchange refuelling / unloading pressure max. 3 bar.

Option 2 : loading with 3 vessels; 200 l for vessels exchange; 200 l refuelling with vessels refuelling pressure max. 3 bar, 200 l for gas intake during refuelling pressure max. 3 bar

Option 3 : loading with 1 vessels 150 l for refuelling pressure max. 5 bar, 1 vessels 200 l for gas absorption during refuelling pressure max. 3 bar

Option 4 : loading with 1 vessels 150 l refuelling pressure max. 5 bar as well as 2 vessels 200 l refuelling pressure max. 3 bar for vessels exchange

Option 5 : loading with 1 vessels 200 l for refuelling pressure max. 3 bar, 1 vessels 200 l for gas absorption during refuelling pressure max. 3 bar

Option 6 : loading with 1 vessels 150 l for unloading pressure max. 5 bar, 1 vessels 200 l for gas absorption during unloading of stationary and mobile (boats, vehicles, ...) vessels at unloading pressure max. 5 bar

With a variation of the filling volumes of the individual containers depending on the requirements of the end user, further most different loading combinations are possible.

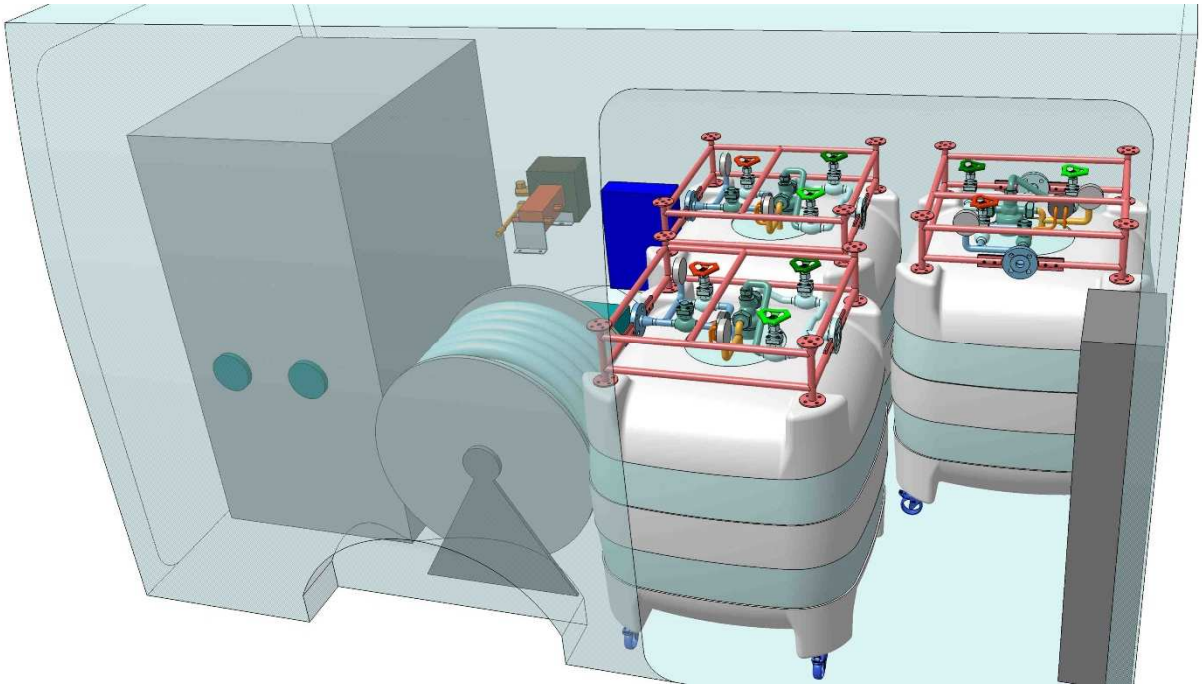

**Figure 23:** Side View with possible 3 200l FRP BEER-kryo Vessels BEF GmbH

# 7 Images and source list