Deliverable 6.12

Initial report on market potential and business analysis

Author: VTT Technical Research Centre of Finland

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1. Introduction

Summary of project scope

The objective of the project is to develop and demonstrate a compact and highly efficient micro combined heat and power (CHP) system based on high-temperature proton exchange membrane fuel cell (HT-PEMFC) technology and a novel two-stage methanol reformer consisting of a aqueous phase reformer and a steam reformer. The developed micro-CHP system is intended as a back-up solution for sequential or simultaneous cogeneration of electricity and thermal energy in rural areas with unstable or zero grid availability. A core focus on thermal integration and waste-heat recovery enable high fuel utilization, high electrical- and CHP efficiency, and dynamic load response and fast start-up for flexible integration with intermittent renewable energy sources. The main project goals and expected impacts are summarized in Table 1 below.

Table 1: Expected project impact and KPIs.

Expected impact	KPI
Decrease system cost for small-scale CHP	CAPEX < 3000 €/kW
Decrease system size	System volume power density 30 W/L
Increase system lifetime	Degradation < 0.4 % / 1000h
Increased system efficiency	System electric efficiency > 50%
Fuel processor efficiency at BoL	> 85% fuel processor efficiency at BoL
Proved scalability of system and components	Design study of 50 – 100kW system
Flexible operation and RES support	Start-up time < 10 minutes

Purpose of the document

The EMPOWER project will deliver a complete business analysis of the introduction of methanol fuelled high temperature PEMFC units in CHP sector to understand the business case possibilities. Of particular interest are market analysis, concept analysis, and definition of potential applications as well as identification of early adapters, that is, the first customer segments and their needs. This present document is the first initial part of the business analysis and concentrates on current micro-CHP market size, comparison of commercial products, and the EMPOWER concept. In the second part of the business analysis (Deliverable 6.13 - Final report on market potential and business analysis) the scope is extended to CHP sizes of tens of kW and beyond. As one of the project outcomes is the design study for a 50-100 kW CHP system (Deliverable 5.4 - Study of scaling the methanol fuelled CHP system to 50-100 kW) it is of interest to link the market potential and business analysis with the design study.

2. Market analysis

Current market size and prospects

The global market for commercial combined heat and power (CHP) systems should reach $26.1 billion by 2022 from $20.2 billion in 2017 at a compound annual growth rate (CAGR) of 5.2%, from 2017 to 2022. The industrial sector of the global CHP systems market is expected to grow from $16.3 billion in 2017 to $20.7 billion in 2022 at a CAGR of 4.9% for the period 2017-2022. The commercial sector of the global CHP systems market is expected to grow from $2.6 billion in 2017 to $3.6 billion in 2022 at a CAGR of 6.6% for the period 2017-2022 (BBC Research, 2017).

The global combined heat and power (CHP) market is expected to register a moderate compound annual growth rate (CAGR) of 4.8% between 2020 and 2030. Annual capacities are anticipated to reach 19.55 GW from the 12.37 GW capacity estimate of 2020. Among the application segments, industrial and utility will continue to hold an average majority share of 85.5% throughout the forecast period. On the prime mover technologies front, gas-based engine and turbine will hold an average majority share of 81.9% during the same period (Frost & Sullivan, 2021).

Micro-CHP market size exceeded USD 1 billion in 2019 and is estimated to register over 11% through 2026. Reducing dependency on conventional fuels in line with ongoing investments toward renewable generation sources across developed & developing nations will boost the overall business scenario. Favourable government norms toward adoption of low GHG emission technologies including hydrogen fuelled CHP systems will complement the micro-CHP industry outlook (Global Market Insights, 2020).

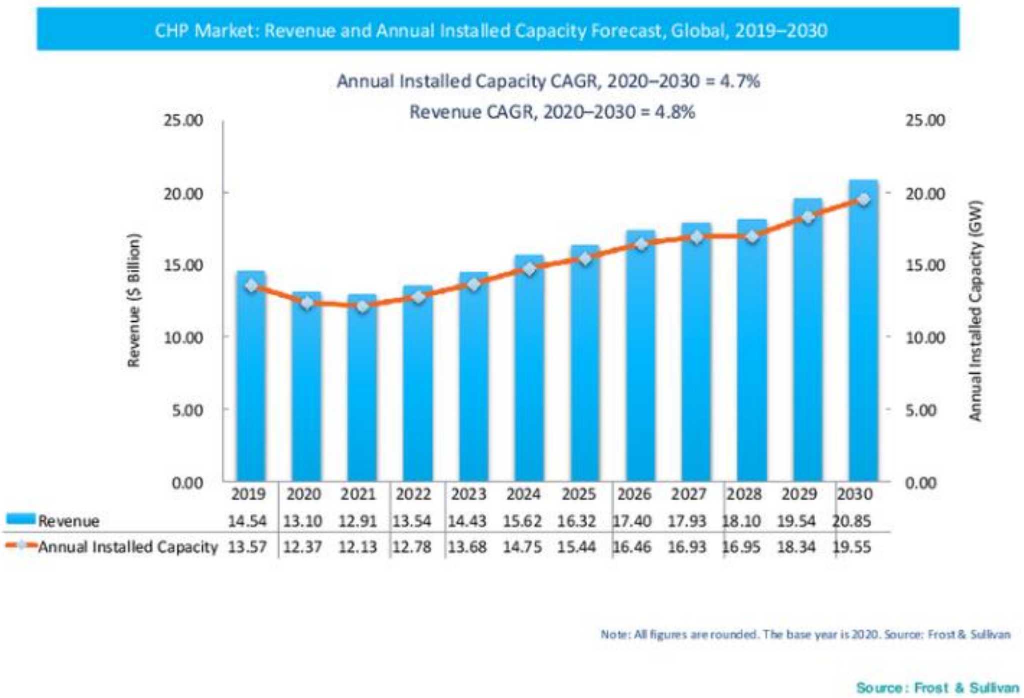

Figure 1. Revenue and Annual Installed Capacity Forecast, CHP Market (Source: Frost & Sullivan, 2021)

Current micro-CHP technologies

A micro combined heat and power (micro-CHP) is a technology that generates electricity and heat simultaneously from a single source of energy. CHP technology uses several types of fuels including natural gas, LPG, oil, renewable resources, and hydrogen. Micro-CHP technology can be used in multiple applications across commercial and residential establishments. Below are presented some examples of the current CHP technologies (BCC Research, 2017).

Internal combustion engine CHP

Internal combustion engine is essentially a diesel engine modified to run on natural gas or heating oil, connected directly to an electrical generator. Hence, it is very proven technology. Waste heat is taken from the engine's cooling water and exhaust manifold and used for heating needs. The engines can have a higher electrical efficiency than a Stirling engine, but are larger and mainly installed in commercial-scale applications.

Stirling engine

A Stirling engine CHP system is essentially a boiler with a Stirling engine built in. It is an external combustion engine that heats up when the boiler is being used. When this happens, gas stored in the Stirling engine expands due to the heat, and a piston connected to a generator produces electricity. While they are much quieter than internal combustion engines, they can only generate electricity when the central heating is being used, so are less efficient.

Fuel cell CHP technology

Fuel cell CHP technology generates electricity by directly converting the chemical energy from fuels to electricity rather than burning the fuel. It typically needs a reformer to convert carboneous fuel into carbon dioxide and hydrogen. The hydrogen then reacts with oxygen in the fuel cell to produce electricity. Waste heat is produced in this process, which is used within a hot water heating system.

Current micro-CHP manufacturers and products

In order to understand the status of micro-CHP markets, current manufacturers and their products were searched on internet. Tables 2-4 present current products and their key technical specifications as provided by the manufacturers through their websites. As it can be seen, most of the CHP systems use natural gas as fuel. In the fuel cell CHP systems, there are mainly low temperature PEM fuel cells and SOFC technologies, only one high temperature PEM fuel cell product on the market.

Table 2. Gas engine micro-CHPs on the market.

Manufacturer	Country	Model	Fuel	Power Electricity/Heat	Efficiency	Size Volume/weight
Yanmar	Japan	CP5WG1	Natural gas / LPG	5 kW_e / 10 kW_{th}	29% (el.) / 57% (th.)	0.8 m^3 / N/A
Yanmar/RMB Energie	Japan	neoTower 4.0	Natural gas	4 kW_e / 9 kW_{th}	Efficiency ratios 32 % (el.) 70 % (th.)	0.7 m^3 / 410 kg

Manufac-turer	Country	Model	Fuel	Power Electric-ity/Heat	Efficiency	Size Volume/ weight
Helec	UK	ENER-GIMIXER	Natural gas / LPG	8 kW_e / 20 kW_{th}	25% (el.) 67% (th.)	0.6 m^3 / 380 kg
Marathon Engine Systems / Axiom Energy Group	USA	ecopower	Natural gas / propane	4 kW_e / 14 kW_{th}	N/A	N/A
M-Trigen	USA	PowerAire 65	Natural gas / liquid propane	5 kW_e / 5 tons	N/A	2.8 m^3 / 620 kg
Eco Concept / microgen	Estonia	BioGen (Stirling engine)	Pellet and wood chip	1 kW_e / 6 kW_{th}	N/A	N/A / 250 kg
BDR Thermea Group	Netherlands	N/A	N/A	N/A	N/A	N/A
Aisin Seiki	USA	COREMO	Natural gas	2 kW_e / 3 kW_{th}	N/A	N/A
SenerTec	Germany	Dachs GEN2	Natural gas /LPG	3 kW_e / 8 kW_{th}	N/A	1.0 m^3 / 580 kg

Table 3. Turbine micro-CHPs on the market.

Manufacturer	Country	Model	Fuel	Power Electric-ity/Heat	Effi-ciency	Size Volume/ weight
Ansaldo Energia	Italy	AE-T100E	Biomass	< 75 kW_e / N/A	N/A	7 m^3 / 2770 kg
Tomkinson Heating / Micro turbine technology bv	UK	EnerTwin	Natural gas	3 kW_e / 15 kW_{th}	N/A	N/A
Samad Power	UK	TwinGen Boiler / MGT2	Natural gas / hydrogen	2 kW_e / 30 kW_{th}	Overall 92%	0.2 m^3 / 75 kg

Table 4. Fuel cell micro-CHPs on the market.

Manufac-turer	Coun-try	Model	Tech-nology	Fuel	Power Elec-tric-ity/Heat	Effi-ciency	Size Volume/ weight
Viessmann	Ger-many	Vitolator PT2	LTPEM	Natural gas	1 kW_e / 1 kW_{th}	37 % (el.)	1.3 m^3 / 326 kg
HELBIO	Greece	H_2PS-5	LTPEM	Natural Gas, LPG/ Propane, Biogas	5 kW_e / 7 kW_{th}	>35% (el. LHV) >50% (th. LHV)	0.8 m^3 / 200 kg
Solidpower	Ger-many	BG-15	SOFC	Natural gas with up to 20 % hydro-gen	2 kW_e / 1 kW_{th}	Overall, up to 88 %	0.5 m^3 / 250 kg
Toshiba	Japan	H2Rex/H2One	LTPEM	Hydrogen	4 kW_e / N/A	50% (el.) 40% (th.)	N/A
Sunfire	Ger-many	Sunfire-remote 900	SOFC	Propane / natural gas	1 kW_e / 1 kW_{th}	N/A	0.5 m^3 / 185 kg
Kyocera	Japan	N/A	SOFC	N/A	1 kW_e / N/A	Total ef-ficiency 55% (LHV), gener-ating ef-ficiency 87% (LHV)	0.1 m^3 / 5 kg
Bosch	Ger-many	N/A	SOFC	Natural gas / hy-drogen	5 kW_e / N/A	N/A	N/A
Vaillant	Ger-many	Callux	N/A	Natural gas	1 kW_e / 2 kW_{th}	N/A	N/A
SenerTec	Ger-many	Dachs 0.8	N/A	N/A	1 kW_e / 1 kW_{th}	N/A	N/A

Manufacturer	Country	Model	Technology	Fuel	Power Electricity/Heat	Efficiency	Size Volume/ weight
HEXIS	Germany	Galileo 1000N	SOFC	Natural gas	1 kW_e / 2 (+20) kW_{th}	35% (el.) 95% (overall)	1.0 m^3 / 210 kg
Remeha	Germany	eLecta 300	N/A	Natural gas	1 kW_e / 1 kW_{th}	N/A	3.4 m^3 / 350 kg
Elcore	Germany	Elcore 2400	HTPEM	N/A	N/A	N/A	N/A

EMPOWER compared to commercial products

Technical specifications of commercial products were analysed and compared with EMPOWER KIPs. Figure 2 shows the volume vs. power of commercial micro-CHP products. The EMPOWER micro-CHP goal (30 W/l) is significantly smaller than current commercial products. In order to be commercially feasible product, EMPOWER CHP should stay on the lower side of the fitted line in Figure 2.

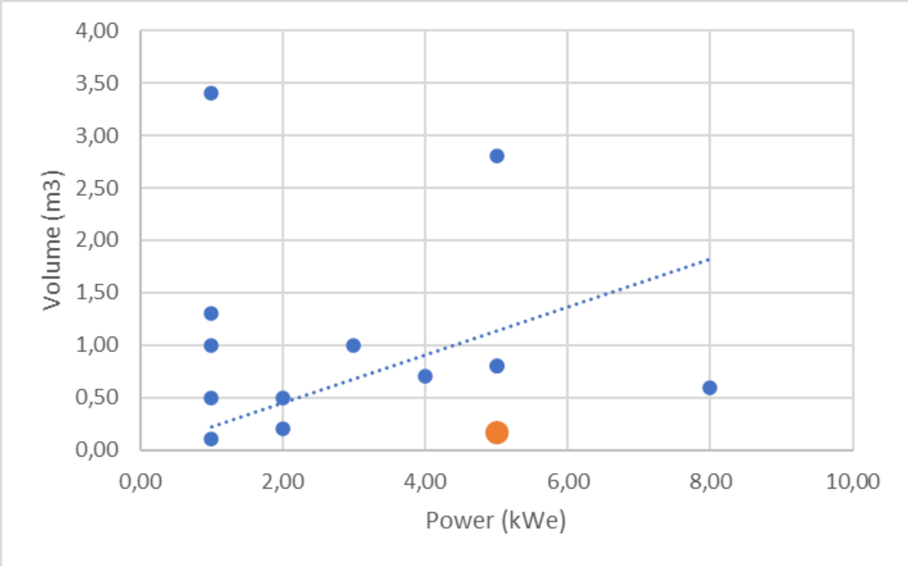

Figure 2. Power vs. volume of compared current micro-CHP systems. The EMPOWER CHP system is market as orange dot.

As the CHP produces both electricity and heat it is of interest to understand the power generation of commercial products and EMPOWER CHP. Figure 3 shows the thermal power vs. electrical power of commercial products and EMPOWER CHP. It can be seen that the trend is to produce more heat than electricity. However, EMPOWER CHP has almost 1:1 in terms of electrical and thermal energy. For this reason, EMPOWER CHP can be combined with large variety of applications. Hence, it is more flexible than other commercial products.

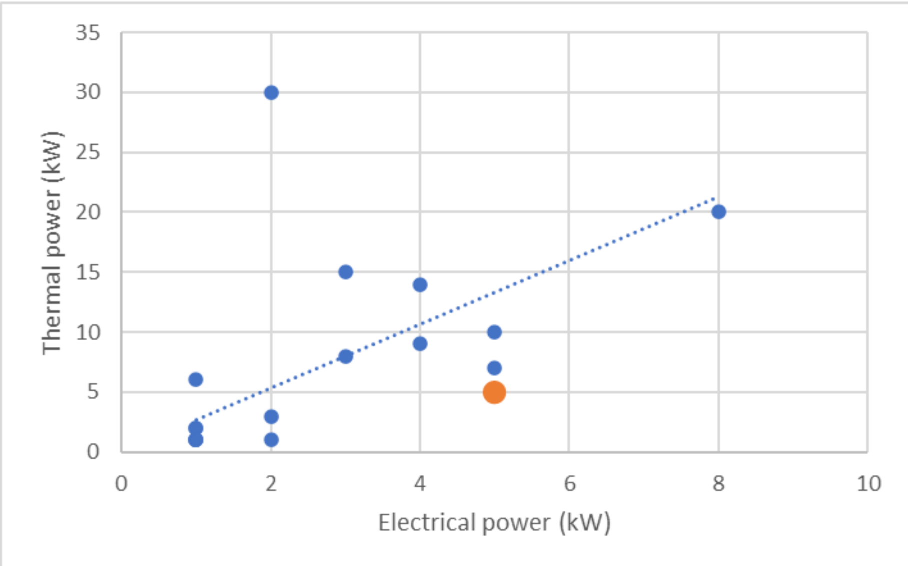

Figure 3. Electrical vs. thermal power of compare current micro-CHP systems. The EMPOWER CHP system is market as orange dot.

One of the most important technical specifications is the electrical efficiency (LHV) along with thermal efficiency of the whole CHP system. Figure 4 shows the electrical vs. thermal efficiency of commercial products and EMPOWER target. Most of the commercial products have electrical efficiency of 30-35% and only two products were found to show electrical efficiencies of 50%. As the EMPOWER target is to have system electrical efficiency of 50% it will be one of the most efficient products available.

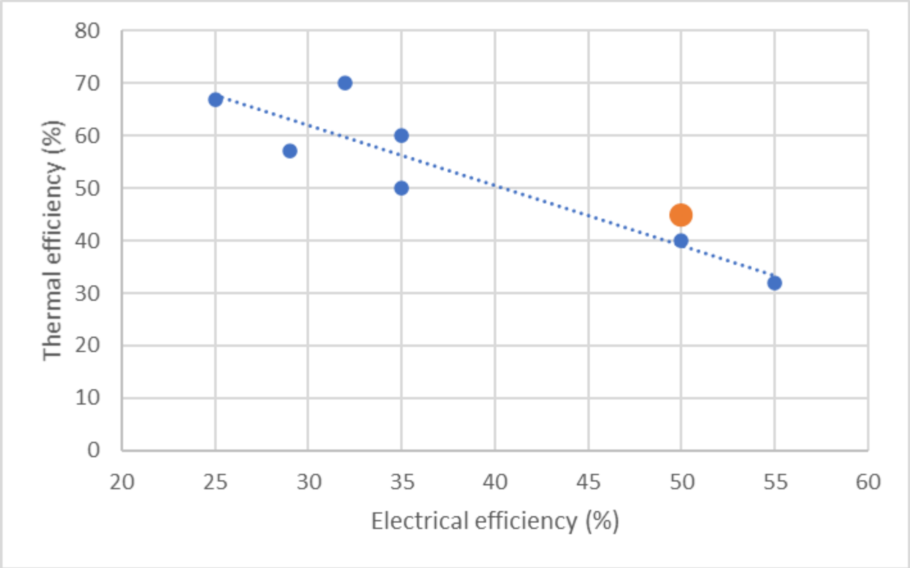

Figure 4. Electrical vs. thermal efficiency of compared current micro-CHP systems. The EMPOWER CHP system is market as orange dot.

3. Concept analysis

Methanol versus other fuels

Methanol is one of the world's most commonly shipped chemical commodity and more than 95 billion litres are manufactured every year. Industry has gathered around 100 years of experience in storing and transporting methanol. Since it remains liquid at ambient temperature and pressure, the infrastructure required to deploy it as a fuel is largely in place: combustion engines, fuel cells and power blocks could quite easily and affordably be adapted to methanol (Renewable Methanol Report, 2018).

Our market research did not find any other methanol-based CHP units on the market. For this reason, it is important to understand the benefits and possible challenges of methanol as fuel compared to other fuels, for examples LPG and compressed natural gas. Methanol is a clean liquid fuel that can be utilized, for example, as a hydrogen carrier for fuel cells. Methanol can be synthesized in a couple of ways. Traditionally, it has been made utilizing fossil fuels, with two-step process: first turning methane into syngas via steam methane reforming and then converting the syngas into methanol (Adnan and Kibria, 2020).

There is interest to produce the methanol so that the net carbon dioxide emissions are minimized throughout the process. When evaluating the total amount of carbon dioxide emissions in methanol synthetization process, the important factors in the process are 1) utilized feedstock and 2) utilized energy (Adnan and Kibria, 2020).

The emerging clean technologies have a common name "Power-to-Methanol". Important "Power-to-Methanol" routes include one-step CO_2-to-methanol electrolysis, two-step synthesis (with H_2O electrolysis) and three-step synthesis involving H_2O electrolysis and CO_2-to-CO electrolysis. It is estimated that power-to-methanol would be competitive given an electricity price below 0.03 €/kWh (Adnan and Kibria, 2020).

Table 5 presents the most common micro-CHP fuels and their prices in Europe. It should be noted that the prices of fuels differ significantly depending on the country. Table 5 also shows the lower heating value of the compressed natural gas, hydrogen, LPG and methanol. Methanol has a lower LHV than the gaseous and liquefied fuels in the comparison. However, methanol is liquid at room temperature and atmospheric pressure, which is beneficial in logistics. To compare liquid fuels, diesel has a LHV of approx. 11.8 kWh/kg, which is about twice as high. However, HTPEM fuel cells are twice or more efficient as gas or diesel generators, hence the amount of needed fuel is balanced.

Table 5. Comparison of typical micro-CHP fuels. Data taken from: Alternative Fuels Data Center, Eurostat, IHS Markit, Mikulski et al. (2018) and myLPG (website).

	Price in Europe [€/kWh]	Lower heating value [kWh/kg]
Compressed natural gas	0.04[1]	13.1
Hydrogen	0.07 – 0.16[2]	33.3
Methanol	0.1 – 0.11[3]	5.5
LPG	0.16[4]	12.6

1 non-household consumers, 2 green hydrogen, 3 green methanol, 4 in Sweden where LPG price is higher than in several other European countries

Table 6. Institutions involved in the production of Bio-methanol or Renewable Methanol (source: Renewable Methanol Report, 2018)

Methanol category	Commercial	Feasibility and R&D
Bio-methanol	BASF (GER) BioMCN (NL) Enerkem (CAN) New Fuel (DEN) Nordic Green (DEN)	Biogo (GER) Enerkem (NL) LowLands Methanol Heveskes Energy (NL) NREL (USA) Origin Materials (USA) Södra (SE)
Renewable methanol	CRI (IC) Innogy (GER)	Advanced Chemical Technologies (CAN) Asahi Kasei (JPN) Blue Fuel Energy (CAN) bse Engineering (GER) Catalytic Innovations (USA) CRI (CN/GER) Gensoric (GER) Infraserv (GER) Liquid Wind (SE) MefCO2 (GER) Neo-H2 (USA) Port of Antwerp (BE) Quantiam Technologies (CAN) STEAG (GER) Swiss Liquid Future (CH) thyssenkrupp (GER) USC (USA) ZASt (GER)
Low carbon methanol	GPIC (BAH) Methanex (CAN) QAFAC (QAT) SABIC (KSA)	Carbon2Chem (GER) FRESME (SE) GasTechno (USA) Haldor Topsoe (DEN) Maverick Synfuels (USA) NCF (CN) OPTIMeoH (GER)

Several companies and institutions across the world are producing renewable methanol or bio-methanol as a commercial activity. Many other actors are still in the research and development phase. An overview of these producers is seen in Table 6. A majority of these actors are based in Europe or Northern America. This indicates that the supply of methanol, and especially renewable methanol that is of large interest for the EMPOWER case, should increase during the near future. For the EMPOWER CHP system to be interesting for its potential customers it is also imperative that the fuel supply is easily available.

In future, it is estimated that the price of renewable methanol will decrease and close in to the price of current fossil methanol (Figure 5). However, according to the study, the cost of renewable methanol would still be approx. 50% higher.

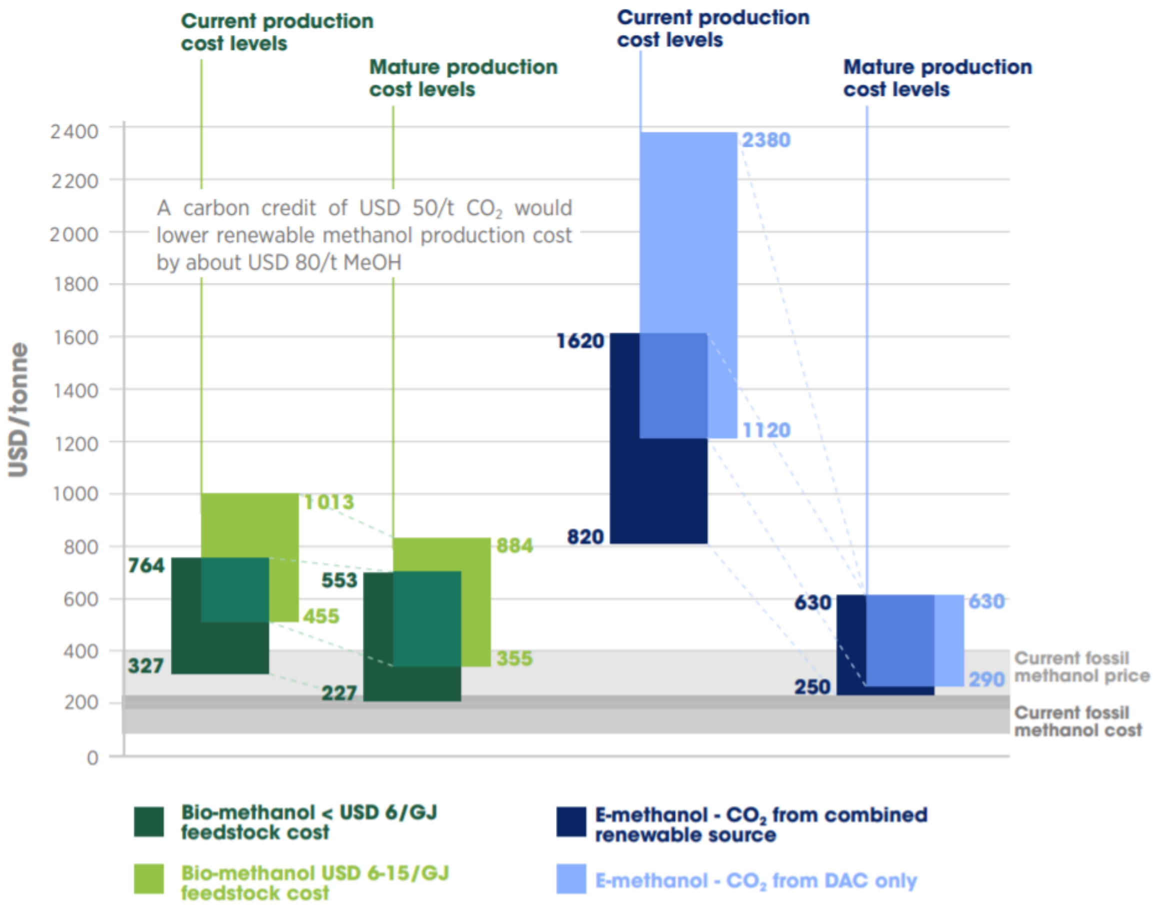

Figure 5. Current and future production costs of bio- and e-methanol (Source: IRENA AND METHANOL INSTITUTE, 2021).

Compared to fossil fuels, renewable methanol reduces carbon emissions by 65 to 95%, depending on the feedstock and conversion process. That is one of the highest potential reductions of any fuel currently being developed to displace gasoline, diesel, coal and methane. Additionally, the combustion of pure methanol produces no sulphur oxides (SOx), low nitrogen oxides (NOx), and no particulate matter emissions (Renewable Methanol Report, 2018).

Fuel cell powered CHP

Fuel cell technology is characterized by the clean, quiet and very efficient power generation systems. Fuel cells offer the excellent electrical efficiencies of 40% to 60% (LHV) and up to 85% efficiency in CHP systems. Price of fuel cell systems is still rather high for most industrial and commercial applications. These are the major features of these new emerging technologies that are driving the growth of the market (BCC Research, 2017).

In addition to the CHP characteristics described above, technological advancements in micro-CHP systems and fuel cell technology are driving the growth of the market. Micro-CHP systems are being developed to achieve better thermal efficiencies of up to 30% and reduce the emission of GHGs such as NOx by about 10 ppm. It is expected that performance and maintenance requirements will vary among the initial offerings. Longer-term goals are to achieve thermal efficiencies between 35% to 50% and NOx emissions between 2 ppm to 3 ppm using ceramic components, improved aerodynamic and recuperator designs and catalytic combustion. These are the major developments in the micro-CHP systems that are driving the growth of the market. Similarly, advancements in fuel cell technology such as reformer design, size reduction and improved manufacturing techniques are contributing significantly to the growth of the market (BCC Research, 2017).

Table 7. Performance Characteristics of Micro-CHP Systems and EMPOWER CHP concept (modified from BBC Research, 2017, U.S. Department of Energy and European Commissions Fuel Cell and Hydrogen Joint Undertaking, 2018).

Performance Characteristics	Micro-CHP	Fuel Cell
Efficiency	Most of the micro-CHP systems are incorporated with recuperator to provide high efficiency of up to 20% to 30% (LHV) range.	Fuel cell offers comparatively higher efficiency than combustion-based power plants. The efficiency of the EMPOWER HTPEM fuel cell is estimated to be approximately 50% to 60% (LHV).
Capital cost	The capital costs of the micro-CHP system are estimated to be approximately $500 per kW to $1,000 per kW for CHP applications.	The capital cost of the fuel cell CHP systems is on the higher side. The FCH JU target CAPEX for 2020 is 10000 €/kW for micro-CHP (0.3-5 kW) and 4500-7500 €/kW for mid-sized installations (5-400 kW). However, the price is estimated to decrease in the future due to advancements and increasing manufacturing volumes.
Availability	The availability of the micro-CHP system is estimated to be similar to other competing distributed resource technologies (i.e., in the 90% to 95% range).	Fuel cells are widely available and highly reliable systems. Planned maintenance breaks for the HTPEM fuel cell systems are with 2,500 hours intervals. Laboratory tests and demonstration have suggested the availability at 96% and 2,500 hours between forced outages.
Maintenance	Micro-CHP systems have substantially fewer moving parts than engines. The single shaft design with air bearings will not require lubricating oil or water, so maintenance costs should be below conventional gas turbines. Micro-CHP that use lubricating oil does not require frequent oil changes, since the oil is isolated from combustion products. Only an annual scheduled maintenance interval is planned for micro-CHP systems. Maintenance costs are being estimated at $0.006 per kW to $0.01 per kW.	The electrodes within a fuel cell, which comprise the stack, degrade over time reducing the efficiency of the unit. Fuel cell systems are designed such that the stack can be removed and replaced. It is estimated that stack replacement is required between four and six years when the fuel cell is operated under continuous conditions. The maintenance cost for HTPEM fuel cell systems is estimated to 0.04 €/kW, excluding reformer or stack replacements.
Applications	Micro-CHP systems are widely used for electricity generation application, peak shaving, and base loaded operation with and without heat recovery. They are also used to drive air compressors, refrigeration chillers and other prime movers.	Fuel cell system are widely used in low-pressure steam and hot water CHP applications due to their low temperature requirement for generating electricity and heat. Fuel cells are also widely used among the commercial and residential facilities as a peak shaving unit.

Benefits of EMPOWER micro-CHP

The EMPOWER micro-CHP system is designed to address multiple customer segments representing different needs for sequential and simultaneous cogeneration of heat and power. The intended use of the micro-CHP system is supplying heat and electricity in backup- and off-grid applications. In an off-grid installation or during grid outages, the micro-CHP system provides a highly efficient and dynamic power source, and the system is designed for integration and support of renewable energy sources such as wind and solar, etc. The intended applications for the system are in industrial or residential installations where the generated electricity is used for powering utilities and the waste-heat generated by the HT-PEMFC is used for space heating and preparation of domestic hot water for cooking, laundry, showering etc. Cogeneration promotes high system efficiency, but the system may operate in heat only- and power only mode when necessary.

The EMPOWER micro-CHP system is integrated into a trailer mounted container constituting a mobile workspace (see Figure 6). The container is easily loaded and unloaded from the trailer for quick deployment. The micro-CHP system provides heat for the mobile workspace and for external heat demands. During ongoing discussions with customers, the proposed design has been validated for complying with initial customer and use case requirements.

Figure 6. The EMPOWER micro-CHP will be installed into a mobile container (workspace).

4. Definition of potential applications

First customer segments and their needs

User 01 / Raw water test pumping.

Raw water test pumping cycles can be up to 1 month long and currently use diesel generators. The basic pump size is 5.5 kW, so the power supply should be 6 kW. Pump should have a frequency converter, which makes the starting current (of the pump) lower, and if necessary, the frequency converter can be used to adjust the water flow of the pump. The 5.5 kW pump operates at 400 V and takes about 11.2A of current when running at full capacity. Purity, “no fear of contamination”, and silent operation unlike diesel generators are some of the advantages of a methanol-powered micro-CHP.

User 02 / RES power (electricity and heat).

The goal is to generate backup power and heat source for 100-150 m^2 house. According to calculations, an older house needs 50 W/m^2 of heat. In newer houses, 40 W/m^2 is enough. In this scenario, the micro-CHP is connected to the circulating water system of the house and to the production of domestic hot water. The 5 kW system can maintain one property for several weeks. The same device generates electricity and house / water heating. Simple, quiet, and environmentally friendly.

This use case can have two different user situations. One is emergency power where electricity and heat are produced for at least 72 hours. The other operating situation is the connection of the fuel cell device to the water-air heat pump system. This gives the ability to generate electricity and heat in such (a day and year period) when they are particularly expensive. In Finland there is approx. 3 weeks in every winter when temperature drops under -20 °C. The required running time could be approx. 500 h.

User 03 / Mobile hospital heater and electricity device.

Using a fuel cell system as a mobile field hospital heater and power generation unit. This would mean that the electricity generated by the fuel cell would be diverted to three different uses: for heating, lighting, and electrification of various devices. Space heating would be produced by an air source heat pump and waste heat from the fuel cell system. The 5kW system can be split for example into 2 kW electricity to the lighting and electrification of various devices and 3 kW to the air heat pump. Such an air source heat pump can produce 10-12 kW heating power.

5. Summary and next steps

This report is the first out of two reports on market potential and business analysis for the developed fuel cell CHP system and the renewable methanol concept. The second report, Deliverable 6.13 - Final report on market potential and business analysis is finalized in the end of the project and extends the scope to CHP sizes for 50-100 kW.

The analysis showed that the global CHP market is expected to exceed $26 billion by 2022 and to grow with an annual growth rate of over 5%. The market for micro-CHP applications, which were of particular interest for this report, exceeded $1 billion in 2019 and is estimated to increase by 11% through 2026. Drivers for this development are the overall investments toward renewable generation sources to reduce the dependency of conventional fossil fuels. Further, legislation and government norms towards adoption for low GHG emission technologies increase the potential for fuel cell and hydrogen fueled CHP systems.

The current micro-CHP technologies can broadly be divided into gas engine, turbine, and fuel cell micro-CHP systems and most of the use natural gas as fuel. Of the fuel cell based CHPs, only one other HTPEM micro-CHP was found (Elcore, Germany). The others are based on LTPEM or SOFC technology. Compared to the existing micro-CHP products, the EMPOWER project targets are ambitious: both the power-to-volume ratio and electrical power to thermal power are larger than for the existing products. Further, the targeted electrical efficiency is higher than for the compared products. However, the CAPEX of fuel cell CHPs is considerably higher than for fossil fuel driven systems.

The analysis showed also that renewable methanol production is being studied by many companies and other actors. Studies by IRENA and the Methanol Institute have showed that with mature production methods, the cost of renewable methanol could be close to the current price of fossil methanol today, which would further benefit the concept of methanol fueled fuel cell CHP systems. Hence, this initial analysis showed that there exists a substantial market for both 5 kW and 50-100 kW CHP systems. Further, there are strong drivers today and in future to run these systems with renewable fuels, which is beneficial for the EMPOWER case as renewable methanol could be largely available in future and the KPIs of the planned product would can compete with the existing CHP products.

As next steps, the following report on market potential and business analysis will couple the market analysis with the design study of 50-100 kW systems. In addition, the analysis is extended to the MW-scale for the district heating and industrial CHP and maritime sector. Input to this analysis will already be gathered from webinars on on EMPOWER project arranged in cooperation with Uporto summer school on fuel cells in September 2021.

References

Alternative Fuels Data Center, U.S. Department of Energy
https://afdc.energy.gov/fuels/properties?fuels=CNG,LPG,HY,ME

BCC Research (2017) Commercial Combined Heat and Power (CHP): Global Markets to 2022

European Commission's Fuel Cell and Hydrogen Joint Undertaking (2018). Addendum to the Multi-Annual Work Plan 2014-2020.

Eurostat: Natural gas prices for non-household consumers
https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Natural_gas_prices_for_non-household_consumers,_second_half_2020_(EUR_per_kWh)_v1.png

Frost & Sullivan (2021) Flexible CHP Systems will Play a Significant Role in Grid Stabilization and Resilience

Global Market Insights (2020) Micro CHP Market Growth Report 2020-2026

IHS Markit: Europe emerges as leader in hydrogen economy
https://ihsmarkit.com/research-analysis/europe-emerges-as-leader-in-hydrogen-economy.html

IRENA AND METHANOL INSTITUTE (2021) Innovation Outlook : Renewable Methanol, International Renewable Energy Agency, Abu Dhabi.

Mikulski, Maciej (2018). Public final report: Methanol as an alternative fuel for vessels. 10.13140/RG.2.2.29463.11686.

Muflih A. Adnan, Md Golam Kibria (2020) Comparative techno-economic and life-cycle assessment of power-to-methanol synthesis pathways, Applied Energy, Volume 278, 115614, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2020.115614.

myLPG: Chart of fuel prices in Sweden
https://www.mylpg.eu/stations/sweden/prices/

Renewable Methanol Report (2018) by Charlie Hobson and Carlos Márquez (ed.), Methanol Institute 2018