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Deliverable 5.7 - Business case analysis for the modular installation of size > 50 kW per unit.

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Introduction

Goal, approach and assumptions

Introduction

Comsos project

The energy system in the EU is changing at a rapid pace. SOFC technology matches the demand of end-customers which have a need for flexible, distributed, efficient, reliable and clean energy.

Within the Comsos project three manufacturers aim to develop a new product and business proposition for the commercial sector. The commercial sector, with its relative high energy prices, continuous demand and significant volumes is assumed to be the right stepping stone towards achieving economies of scale.

All manufacturers will validate new product segments in collaboration with the respective customers and confirm product performance, the business case and size, and test in real life the distribution channel including maintenance and service. In function of the specific segments, the system will be suitable for volumes from few 10's to several 1,000 systems per year.

Goal

This document is an addition to the Comsos report *"SOFC in commercial sector - Business case analysis".* It will discuss the impact of installing multiple systems on the business cases for SOFC CHP in the commercial sector. What are the differences in the conditions that should be taken care of when installing

Scope:

- 3 types of SOFC systems from the following manufacturers:
  - Convion
  - Solidpower
  - Sunfire
- Timeframe 15 years
- Markets EU-27 & US

Commercial sectors:

- Hotel
- Supermarket
- Office Building
- Commercial site
- Sport centre
- Hospital
- Small commercial business
- Shopping centre
- Server room/ data centre

SOFC technology

manufacturers

Manufacturer:
Convion
Pnom: 60 kWe
Finland

Manufacturer:
Solidpower
Pnom: 12 kWe
Italy/Germany

Manufacturer:
Sunfire
Pnom: 25 kWe
Germany

Ne = >50%
Ntot = >90%
Product lifetime > 10 years
Availablity >90%

All key performance data are to be validated within the Comsos project

Approach

Although there are differences in the size of the systems within Comsos, it is assumed that the business cases not differ significantly. The customers that will be addressed are similar and the market conditions that need to be faced are comparable. In order to not compare the systems with each other but show the overall potential for commercial SOFC system, an analysis was made for a 30 kW system in D5.4, an imaginary average Comsos system.

In this deliverable the effect of modular installation of several units resulting in a >60 kW system is discussed. In order to do so we assume the installations of four of the average Comsos unit of 30 kW. This leads to a 120 kW modular system which will be the basis for the calculations.

The output will consist of insights into the impact of modular installation on:

1. Selling process
2. value drivers
3. type of market
4. business case

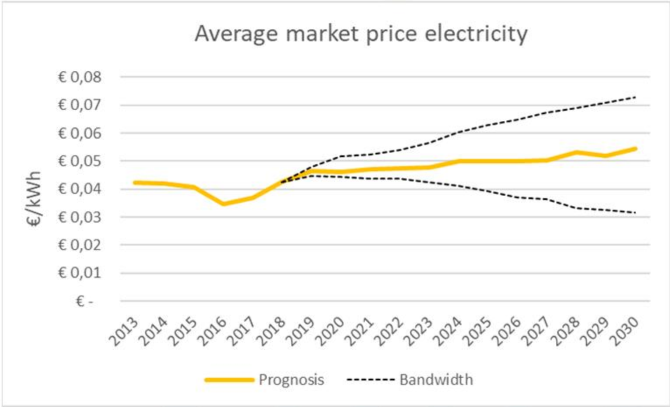
Assumptions

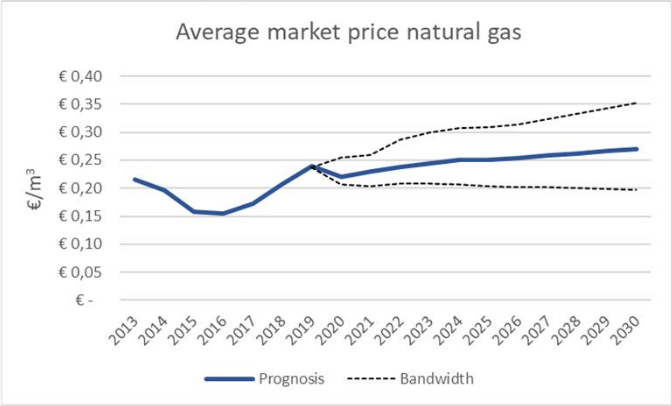
Energy prices

For the energy prices we have used public data from the Eurostat website and the website of the US Energy Information Administration (EIA). Especially due to taxation there are significant differences between countries.

The energy markets forecasts and developments have been highlighted within the INNOSOFC project and are continuously being monitored. For more information see [this report]

For this analysis we make use of the energy price development as depicted on the right. Both electricity and gas prices are assumed to increase gradually, despite the growing influx of renewable energy at near-zero marginal costs.





Selling process

Impact of capacity

Selling process

Different approach

The selling process of several units at one site can be very different from the process of one single unit since the total investment costs and involved energy amounts are consequently higher. A larger capacity of the total system often offers opportunities and benefits to the manufacturer. The following aspect will be discussed:

- Room for customer specific requirements
- Difference in business model
- Time investment customer

Selling process

Customer specific solutions

For smaller systems both the unit and the selling process needs to be rather standardized as the budget to take into account specific requirements is limited. Installing multiple units offers the room for customer specific solution since the total money flow is multiplied.

These customer specific requirements include adaptation to the product and the way the unit is integrated but also optimizing the specific terms so it suits the potential customers.

It improves the compatibility of the product to the end users situation which is an important requirement for the adoption of a new product. It offers a more interesting investment towards potential customers and it also opens up (niche)-markets of customers that face unique conditions.

Product requirements

Integration requirements

Terms and Conditions

Selling process

Time investment customer

The larger energy flow that is associated with installation of multiple systems allows also for the end consumer to invest more time into the way they arrange energy supply.

As the SOFC is not (yet) the standard solution, the end consumer needs time to get familiar with the characteristics of the system and its benefits. An increasement of the capacity of the system can lead to a decrease in the perception of complexity of the end consumer of the fuel cell which is positive for the adoption of the product.

Moreover, finding out the possibilities regarding specific subsidy schemes also might require a time investment as well as filling in the required paperwork.

- Product understanding
- Obtaining financial support

Selling process

Business model

Larger capacities allow for different business models than just the selling of the SOFC module. It allows for the exploration of alternative financing method.

An example of such a method is a power purchase agreement (PPA) in which energy can be sold (and possibly capacity and/or other services) instead of the product itself. Such a legal contract over a longer timespan (i.e., 10 to 20 years) could overcome the issue of high investment costs for a potential end consumer. It provides the end consumer with a reliable, constant, energy price over a longer period.

In general, PPAs typically are used only to implement larger projects (i.e. 100 kW or greater). This is due to several cost factors including transaction costs, financing costs and administration costs. For smaller systems the potential gains are not large enough to cover these additional costs.

Value drivers

Impact capacity on the value drivers

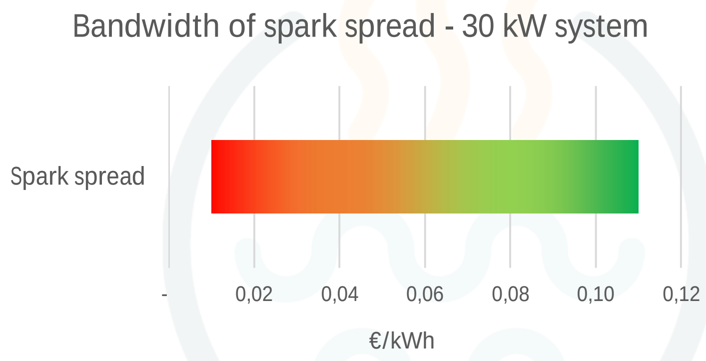
Value driver

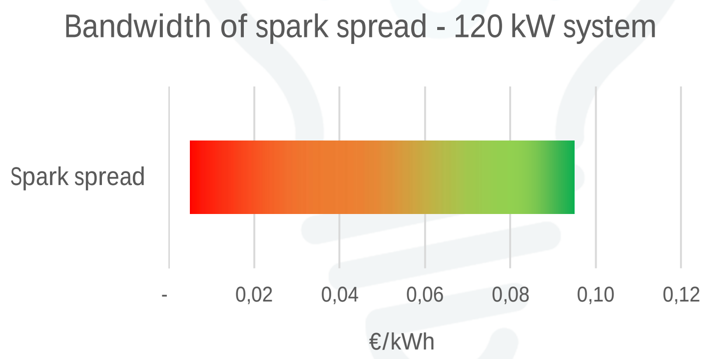
Impact on spark spread

The business case of a SOFC module is determined for a large extent by the value of the electricity that is produced by the SOFC compared to costs of the natural gas input. The margin that can be made is expressed via the spark spread:

$$Spark\ spread = pE - \frac{pG}{\eta E} + (pG \times \eta Th)$$

In the figures on the right it is shown that the spark spread tends to be negatively impacted by the volume. Due to the regressive character of the energy tax, the costs for the natural gas input for larger volumes is lower but the value of the produced electricity is therefore lower. The net effect is that the margin per kWh produced decreases slightly.





Value Drivers

Electricity

As for a single unit system, the value of electricity is also the main value driver for a multiple unit 120 kW SOFC system. Under the assumed price assumptions the total value per year can be up to €120.000. As mentioned before, due to the regressive character of the energy tax, the €/kW value of electricity is on average lower than in the case of a single unit (30 kW). The effect varies a lot per region and their energy taxation scheme. Taking into account our price assumptions, the relative value of the produced electricity in €/kW decreases with 5 to 25% at a capacity increase from 30 kW to 120 kW.

Share of electricity production in total value of SOFC

40% – 100%

*Value of electricity production per year**

€60.000 - €120.000

* Based on a 120 kW installation running baseload
** Taking into account the discussed price assumptions

Value Drivers

Heat

The value of the heat depends on the extent to which the heat can be used by the end user. If there is a baseload heat demand that can be fulfilled by the 120 kW SOFC system, the value of heat can be up to €24.000 a year. Again, the value of the heat per kW is likely to be lower in case of a larger system due to the lower gas price. Taking into account our price assumptions, the relative value of the produced electricity in €/kW decreases with 10 to 30% at a capacity increase from 30 kW to 120 kW.

Added value of heat in total value of SOFC

0% – 18%

*Value of heat fuel savings per year**

€0 - €24.000

* Based on a 120 kW installation

Value driver

Impact on-energetic benefits

Besides the direct value of the produced energy there are several non-energetic benefits that could be of value for the end users. In the main report "*"SOFC in commercial sector - Business case analysis"* all these value drivers are discussed in detail.

In this document the impact of the scale of the SOFC installation on the likelihood as well as the amount of value of these drivers. The scale of the plant can influence the likelihood as well as the impact of those certain value drivers.

The following value drivers will be discussed.

- Carbon reduction
- Value of Lost Load
- Back-up/prime power
- Nox and SOx emission limits
- Avoided grid costs
- High tier classification (data center)

Value drivers

Non-energetic driver

Carbon reduction

Larger end users are more likely to face a carbon reduction obligation and to be exposed to the public opinion. Therefore, carbon reduction could be a more relevant factor at larger scale. The value of carbon reduction could go up to 100 €/kW/year.

NOx and SOx emission limits

For larger systems the NOx en SOx emissions will be a more relevant factor since the reference technology has a higher risk of exceeding certain thresholds values. For the 100+ kW scale the low Nox and SOx emission is therefore an interesting value driver that can represent a worth up to 30 €/kW/year.

Higher reliability

For larger end-users the higher reliability is more likely to be a factor in their decision. However, the average value per kW might be a lower due to the larger volumes. This is especially a significant factor in the US for which the represented value can be as high as 150 €/kW/year but this depends strongly on the region and the application.

Back-up/prime power

This value driver is related to the higher reliability and only one of the two should be taken into account. The value for a 100 kW back-up system is around 200 €/kW/year.

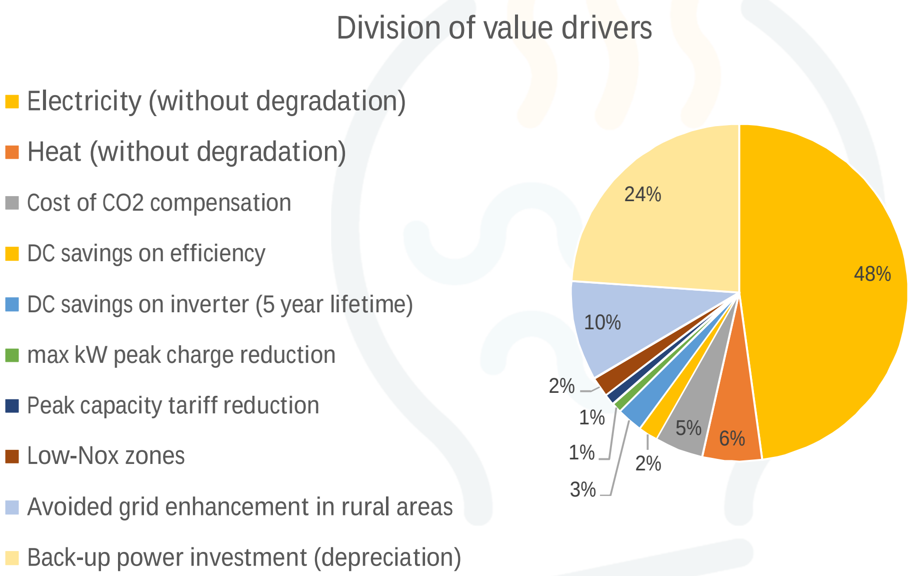
Avoided grid costs

The larger the capacity, the more likely some adaptation to the grid need to be made. However, this value is often not passed on to the end user so it can not always be monetarized into the business case.

Value drivers

Overview drivers

In an optimal case in which all non-energetic value drivers are relevant the division of value drivers for a modular 120 kW system at a commercial site would be as shown in the graph. Electricity makes up for a smaller part of the total value than in the case of a 30 kW system. The non-energetic value drivers play a more important role in the business case. Most non-energetic value drivers are more likely to be relevant at larger volumes and should therefore definitely taken into account in the business case.



Markets

Impact capacity on markets to target

Markets

Commercial sectors

For the purpose of Comsos we identified the following commercial sectors for which a mCHP unit might offer an interesting business case.

- Hotel
- Supermarket
- Office Building
- Commercial site
- Sport centre
- Hospital
- Small commercial business
- Shopping centre
- Server room/ data centre with heat del.
- Server room/ data centre

In this chapter the (electrical) capacity needs for the different sectors and their fit with the Comsos systems are discussed.

Target markets

Overview of characteristics and capacity fit

Target markets	variation in target group	Average base load use (kW)	Baseload coverage of total	Heat utilization	VoLL	Capacity fit with 30 kW	Capacity fit with multiple units
Hotel	Large	80	50%	High	Medium	Yes, for small scale. (+/- 2.000 m²)	Yes, only for very large scale limited
Supermarket	Medium	60	60%	Low	High	Yes, for small scale. (+/- 500 m²)	Yes, can cover total range.
Office Building	Large	10	25%	Medium	Low	Yes, medium sized office buildings (+100 people)	Limited, only large scale office buildings
Commercial site	Large	100	40%	Medium	Medium	Limited, only covering critical load might be option	Yes, but large variation in capacity needs
Sport centre	Medium	10	25%	Medium	Low	Limited, little base load capacity required	No, little capacity required
Hospital	Limited	200	75%	High	High	No, more capacity required.	Limited, only covering critical load might be option.
Small commercial business	Large	10	50%	High	High	Yes, but large variation in capacity needs	Yes, but large variation in capacity needs
Shopping centre	Medium	10	30%	Medium	Medium	Limited, little base load capacity required	No, little capacity required
NzeB appartment building	Large	10	40%	Medium	Low	Yes, larger buildings. (+ 60 homes)	Limited, too much capacity for most buildings
Data centre with heat delivery	Large	>200	90%	High	High	Limited, covering a single server room might be option	Yes, small scale datacenters
Data centre	Large	>200	90%	Low	High	Limited, covering a single server room might be option	Yes, small scale datacenter

Markets

Impact capacity

Most of the commercial sectors do not have a very standardized character and differ a lot depending on the size and the location. Their capacity need is therefore also varying.

In sectors such as supermarkets and hotels 10 to 60 kW units could be a solution for a large part of the sector, either with single units or multiple units installed.

For other sectors such as commercial sites or hospitals a single unit might in most cases only cover part of the base load. Multiple unit installation can be a solution in such cases .

On the other hand, for typical apartment buildings and office buildings the installation 10-60 kW will be sufficient to cover the base load and, if needed, the peak load.

However, the type of markets for 30 kW and 120 kW do not differ significantly. The different capacities allow more or less for the same target groups dealing with similar conditions.


Business cases
Impact capacity on business cases per region

Impact on Costs

Single versus multiple units installation

The costs of SOFC stacks scale up quite linearly with the size. However, all other elements become cheaper per €/kW when the capacity of the system increases. The costs of a 30 kW system will therefore be in general significantly higher than the cost 120 kW system. Previous studies mention a 20%-40% reduction in the costs in €/kW for a system increase of 4 times the capacity. It is assumed that a modular installation of multiple 30 kW units won't lead to lower system costs however installation costs and margins will be lower in this case.

For this analysis we take into account a 10% reduction in the retail price in €/kW for the multiple unit 120 kW* system compared to the single 30 kW unit. See attachment for the exact cost assumptions.

* Installing 4 units of the average Comsos system of 30 kW

Impact on cash flow

Single versus multiple units installation

The capacity has a large impact on the relative cash flow of a SOFC system. The cash flow per kW/year for a modular 120 kW systems is in general lower than the cash flow for a 30 kW based on the energetic financial value. Europe the average cash flow reduces with 70 €/kW/year which is in most cases approx. around 10-20% of the total cash flow. In the US the cash flow related to energetic financial value reduces on averages with 50 €/kW year.

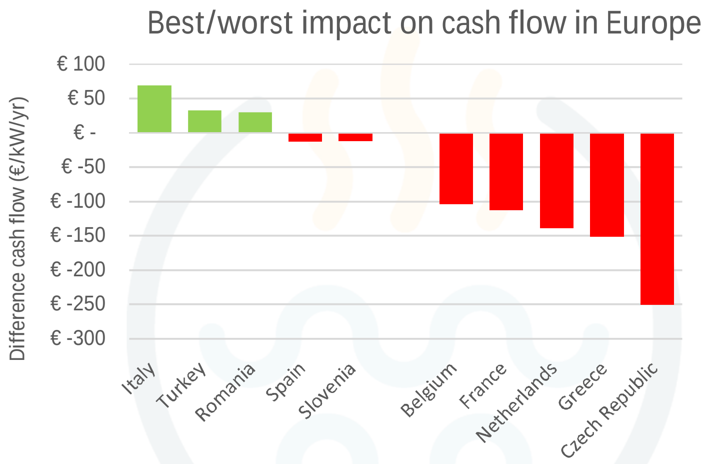
However, as mentioned, the non-energetic benefits may fully cover the loss in energetic value as well as a reduction of the maintenance costs. The total non-energetic benefits can potentially be as high as 500 €/kW. Integrating 10% more of that value into the business case already compensates the loss in the cash flow due to the decrease in energetic financial value.

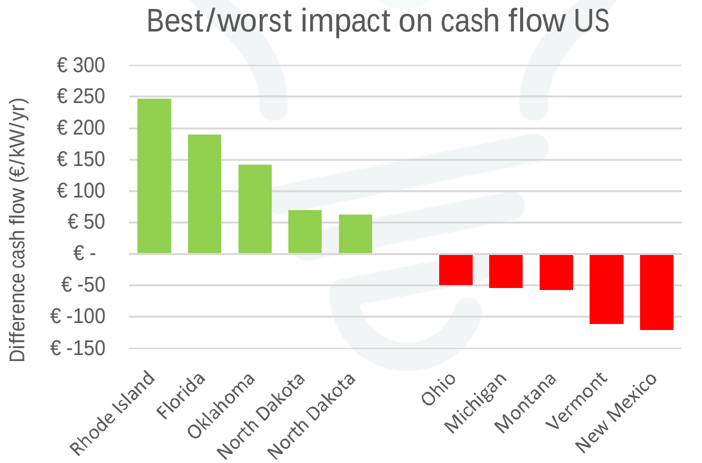
The average impact of increasing the capacity on the relative cash flow in €/kW is limited. However, due to the large variation in the energy prices and the non-energetic values the impact of the change from 30 kW to 120 kW differs. In some cases the relative cash flow of a 120 kW system can be approx. 20% (250€/kW/year) higher in case of a 120 kW system (see also next page).

Impact on cash flow

Difference per region

The figures on the right show the impact of the capacity change from a 30 kW installation to a 120 kW installation on the relative cash flow. To acknowledge the effect that larger end-consumers are more likely to value non-energetic benefits, the value of reduced outages (value of lost load, VoLL) is taken into account in the cash flow for the 120 kW system. In general it can be concluded that in the US the impact of installing multiple systems is in general better. This has to do with the less degressive character of the energy prices and a less reliable grid in the US. However, the impact differs significantly, which shows that it is crucial to pay attention to the energy pricing system at different volumes when targeting certain countries or states.





Business case

Europe case

The figure shows the acceptable retail price for a modular 120 kW system per European country. The general picture is similar as for the 30 kW system with UK and Germany among the most interesting SOFC markets. The case for the Italy is the best according to our calculations. Also, in Belgium, Spain and Portugal seem to be interesting markets for 120 kW systems.

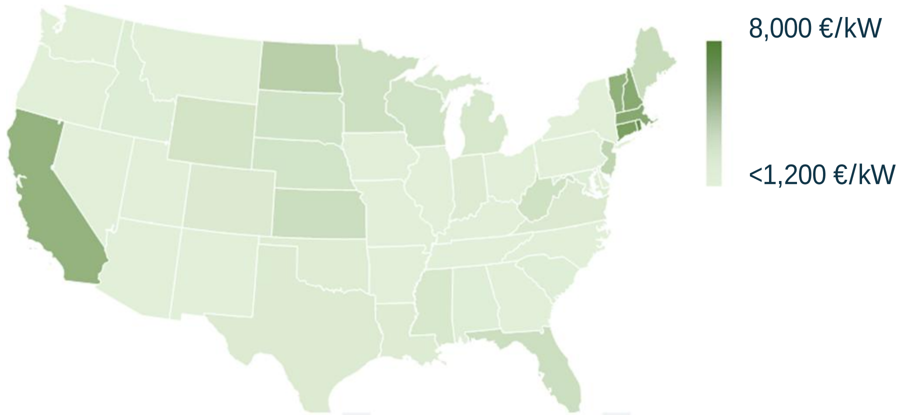
Acceptable retail price for a PBT of 10 years

Region comparison

US case

The figure shows the acceptable retail price for a 120 kW system per state in the US. The business case of some the West North Central states improves at higher capacity to an acceptable retail price of around 3.000 €/kW. However, the best regions are the New England states and California with an acceptable retail price between 4.500 and 6.000 €/kW.

Acceptable retail price for a PBT of 10 years



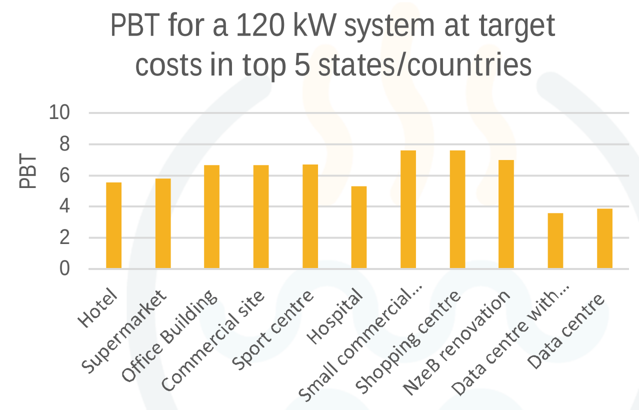
Sector comparison

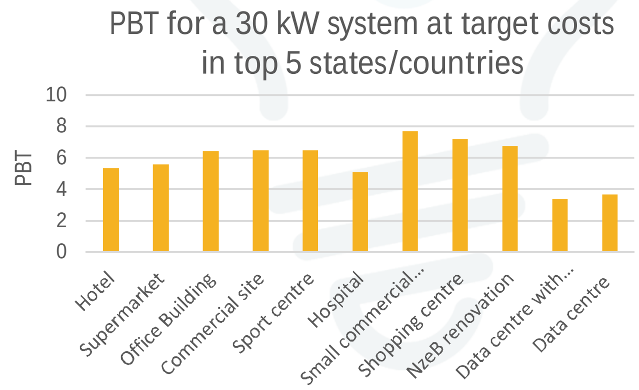
Impact of capacity

For all sectors the PBT for a multiple units 120 kW system is similar to that of a single unit system of 30 kW. The cash flow is in general slightly lower while the CAPEX in €/kW is also decreasing. The difference between the sectors is mainly based on the running hours that are assumed in the model.

In general it can be stated that the PBT depends on the possibility of making as much running hours as possible and on the possibility to integrate non-energetic benefits into the business case. A SOFC system running baseload at a commercial site with a back-up need is likely to have a very interesting business case.

A more in depth analysis on the different sectors and their energy needs you can find in the Comsos document “Market analysis of CHP solutions applied in commercial applications”






Conclusion
Key considerations
and recommendations

Conclusion

- As selling multiple units allows for a less standardized selling process it could help to reduce some barriers for the adoption of the system. Time investment in the costumer relation will reduce the perception of complexity that an end users might have regarding fuel cell technology. Moreover, the adaptability of the SOFC to the existing costumer specific situation can be increased by retrofitting the product to the costumer needs. Especially in the early stage of market development it could therefore be interesting to focus on selling multiple units.

- Selling a larger capacity allows for the exploration of alternative business models such as PPA or rental. This might remove barriers such as the high CAPEX for potential end consumers.

- At a larger capacity it is likely that the average value of the produced electricity is lower since in most countries the energy tariffs have degressive character. This is in most cases only partly compensated by the lower average gas price. The impact of the capacity on the energetic financial value differs significantly per region. The energy taxation scheme should therefore be taken into account by targeting specific markets

Conclusion

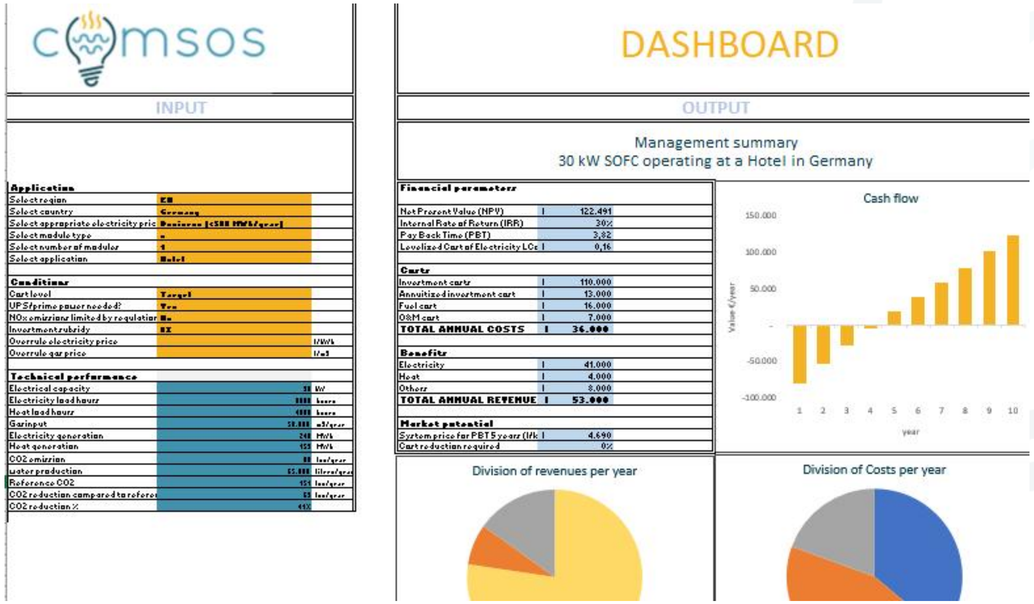
- The non-energetic value drivers are more important the business case for multiple units. Several non-energetic value drivers become more relevant or larger when the capacity of the system increases.

- The impact of the capacity on the cash flow in €/kW/year differs significantly between countries. Installing a multiple unit 120 kW system instead of a 30 kW system can lead to a 20% increase as well as a 20% decrease depending on the country. In general, the impact of the capacity on the US market is better than in Europe.

- The business case for a multiple unit 120 kW system can be as interesting or more interesting than the case for a single unit 30 kW system. The lower value of the electricity can be compensated by the non-energetic value drivers as well as by the lower investment costs.

Next step

A user friendly economic evaluation model, with an internet interface is currently under development and will be made available to inform intermediaries, installers and end-users about the economic possibilities of SOFC CHP and will be published on the COMSOS website.



Business case analysis for the modular installation of size > 50 kW per unit.

November 2019

Status: Final version

Authors: Arjen de Jong; Jeroen Buunk

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Attachment

Energy prices

In the Eurostat database the energy prices are provided for certain volumes for each country in Europe. In the analysis prices according to band IB and I2 (30 kW), and band IC and I3 (120 kW). The values chosen are including energy tax but excluding VAT and are from the 2nd part of 2018.

Band IA :		Consumption	<	20 MWh
Band IB : 20 MWh	<	Consumption	<	500 MWh
Band IC : 500 MWh	<	Consumption	<	2 000 MWh
Band I1 :		Consumption	<	30.000 m^3
Band I2 : 30.000 m^3	<	Consumption	<	300.000 m^3
Band I3 : 300.000 m^3	<	Consumption	<	3.000.000 m^3

The energy prices for the US are based on the data provided by the US Energy Information Administration. This data publicly available via:

https://www.eia.gov/naturalgas/
https://www.eia.gov/electricity/

For this analysis the price data of Q4 2018 for the commercial sector (30 kW) and the industrial sector (120 kW) has been used.

Approach

The business case analysis is based on:

1. Technological characteristics of each SOFC:
    1. Electrical and thermal efficiencies
    2. Degradation
    3. Stack life
2. An average 30 kW SOFC module (installation of 4 modules)
3. Real energy demand profiles per sector
4. Fuel and electricity price developments
5. National energy taxation schemes
6. Indicative capital and operational expenditure
7. Other relevant business vectors

The analysis makes a clear distinction of between the current development stage and the anticipated volume production stage.

The output will consist of insights into:

1. Value drivers
2. Relevant applications
3. Relevant markets

Assumptions per sector

Running Hours

	est. Running hours el.	est. Running hours heat
Hotel	8000	6000
Supermarket	8000	2000
Office Building	6000	4000
Commercial site	6000	4000
Sport centre	6000	5000
Hospital	8000	5000
Small commercial business	5000	3000
Shopping centre	6000	2000
NzeB renovation	4000	3000
Data centre with heat delivery	7000	4000
Data centre	7000	

In the standard calculations only the peak capacity and the value for lost load are included as non-energetic value drivers. For the data centres the added value of a higher Tier level is included.

Comsos targets

KPI	ComSos TARGET 2021
CAPEX	< 8000 at production volumes under 20 units/yr <6000 at production volumes of 20 - 100 units/yr <4000 at production volumes of several 100 units/yr
Durability	10 years (one stack exchange)
Availability	97
Electrical efficiency	> 50%
Thermal efficiency	30 – 40% Very high overall efficiencies of 90% are achievable. Even more is possible but these are application dependent.
LCOE	<1,5 * grid parity (grid parity possible, see example below)