Deliverable 5.4 Business case analysis for the 10-50 kW range per unit

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Lead contractor	Energy Matters

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Dissemination level		
PU	Public	X
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Introduction

Goal, approach and assumptions

Introduction

The energy system in the EU is changing at a rapid pace. SOFC technology matches the demand of end-customers around the EU where there is 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.

This report investigates the business cases for the commercial sector.

Goal

Determine the business cases for SOFC CHP in the commercial sector

Scope:

- 3 manufacturers: Convion, Solidpower and 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

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
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 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

Technology

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

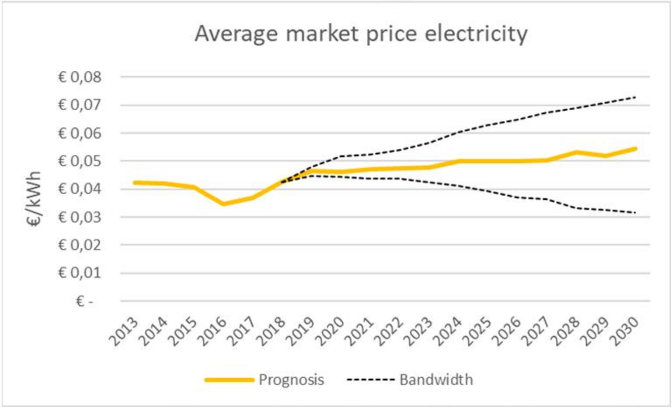
Assumptions

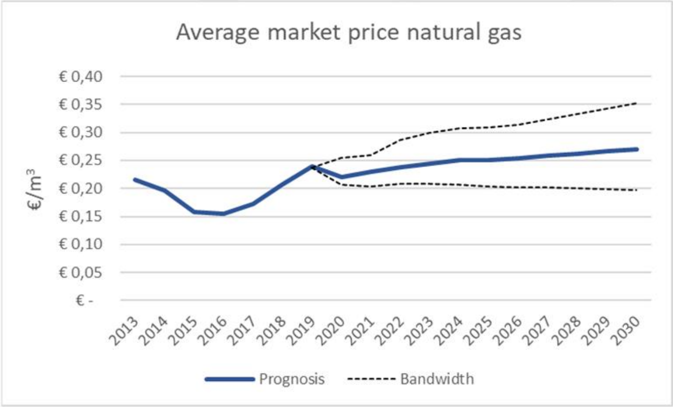
Energy prices

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.





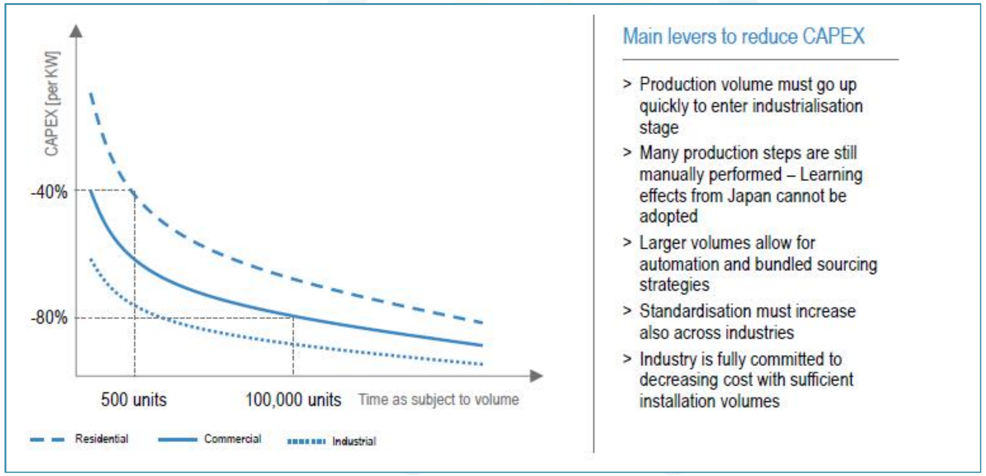
Assumptions

Cost data

Basis for the costs are indications provided by the manufacturers, which have already performed their own cost-down analysis. The extensive work done by Roland Berger and DOE on this matter is taken into account here as well. The cost data for the volume production stage are given for a magnitude of 10+ MW/year.

A full in-depth cost-comparison in the Comsos project is scheduled to be completed in Q3 of 2019 which will give insights into the achievability of the costs and pathways to enhance cost reductions.

This report will be updated accordingly should significant differences arise from this analysis.



Large cost down potential (Roland Berger study)

Value drivers

Overview of main value drivers and their dynamics

Value Drivers

Electricity

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. The share of the electricity production in the total value depends on the number other relevant value drivers for an end user as well as the price the end-user would pay for electricity in the grid. The electricity price varies between countries in Europe and between states in the US. The average electricity in Europe is higher than in the US. However, in the US several states, especially in the North-East, have a high electricity price.

Share of electricity production in total value of SOFC

50% – 100%

*Value of electricity production per year**

€20.000 - €40.000

* For a 30 kW system; base load production

JT4 add: price
Jan-Willem Tolkamp; 21.6.2019

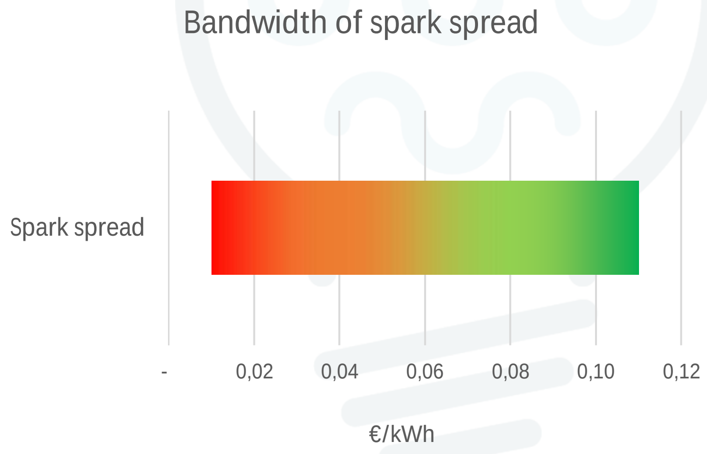
Value Drivers

Electricity – spark spread

Important aspect to increase value

- Important for a successful business case is that SOFC should deliver base load electricity production to optimize value creation.
- Due to the regressive character of the energy taxes, the value of avoided electricity purchase is higher if the remaining electricity demand is minimized.
- On the other hand, due to the regressive character of the energy taxes, the costs of the additional gas purchase is lower if there is already a large gas demand on location
- Rule of thumb: to have an interesting business case at volume production stage in the commercial sector the value of the electricity produced should be at least above 0,12 €/kWh.

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



Value Drivers

Heat

The value of heat produced depends of course on the alternative source of heat that is avoided. Because the SOFC will require a gas connection, it is assumed that a condensing gas boiler is used next to the SOFC. The value of the heat produced is therefore coupled to the gas price divided by the energetic efficiency of the boiler.

The amount of heat delivered is strongly dependant on the return temperature of the heating system. This is assumed to be 50 °C but be lower if low-temperature heat distribution is used. A lower temperature means the SOFC can deliver more energy from the same exhaust heat energy.

Added value of heat in total value of SOFC

0% – 10%

*Value of heat fuel savings per year**

€0 - €6.000

* For a 30 kW system

JT5 add: can

Jan-Willem Tolkamp; 21.6.2019

Value Drivers

DC Savings efficiency and inverter

An SOFC produces direct current which has to be transformed into AC to be put on the internal/external grid.

In some cases, such as power electronics, lighting or electrolysers the DC power can be used directly and saves on the conversion losses.

Possible the need for the inverter is eliminated completely but that is not taken into account here.

Added value of DC savings in total value of SOFC

2% – 4%

Value of DC savings per year

€800 - €1.400

Value driver

Non-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. The following aspects are taken into account:

- 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

Carbon reduction

The upcoming years carbon reduction is going to play a larger factor in the choice regarding energy supply. What the exact value is of carbon reduction will depend on the region, policy conditions and the options for reduction. The value of the carbon reduction is in our analysis defined by the costs of reaching the same reduction with PV. The value used in the analysis is €25/ton. A 30 kW baseload operating SOFC would save over 60 ton of CO_2 per year. In specific conditions (strong desire to reduction; little opportunities) reaching carbon reduction could be worth up to €50/ton. This value is shown as the maximum value of the bandwidth.

Added value of carbon reduction in total value of SOFC

↑ 3% – 7%

Value of Carbon reduction per year

↑ €1.600 - €3.200

Value Drivers

Higher reliability (Value of Lost Load)

How much a higher reliability and protection against power outages is worth to end-users has been tried to capture by the concept of value of lost load (VoLL) expressed in (€/kWh). The VoLL differs per region and per market. The actual benefits per year depend on the expected duration of outages. The average outage time in the US is way higher than in most parts of Europe. The impact of this value driver is in general way higher in the US. In sectors (e.g. hospitals; financial sector)with a high VoLL the value per year can be as high as €3.600. While in, for example, Germany the value of a higher reliability in a sport centre has a negligible value.

Added value of a higher reliability in total value of SOFC

0% – 8%

*Value of a higher reliability per year***

€100 - €3.600

Value Drivers

Back-up/Prime power

SOFC systems can be used directly for energy islanding, as is demonstrated by Convion or can be used indirectly with adaptive controls and a small electrical storage.

The function of back-up power / prime power is very valuable as the alternatives to provide a second source is costly in most cases. The reference is a diesel generator with UPS function.

Good examples can be found in large data centres where extensive risk assessments lead to a very reliable but also expensive system operation.

Added value of avoided need back-up power in total value of SOFC

↑ 12% – 20%

*Value of avoided need back-up power per year***

↑ €6.000 - €9.000

Value driver

Avoided grid costs

The SOFC can provide additional electrical capacity to the grid, reducing the need for local grid enhancement or larger power transformers, providing savings for the Distribution System Operator (DSO) or for end-users that need to invest a larger electrical connection. This value is not commonly recognized by DSO’s and therefore sometimes difficult to monetize into the business case.

Share of avoiding grid cost in total value of SOFC

2% – 9%

Value of avoiding grid costs per year

€ 800 - €4.000

Value driver

NOx and SOx emission limits

In some cities and regions there are stringent Nox limits where new production is not allowed (anymore).

This could present an business opportunity for SOFC technology as regular gas engines and turbines will require expensive gas cleaning systems or may not be allowed at all if they are not able to meet near-zero standards.

Share of avoiding NOx emissions in total value of SOFC

0% – 2%

Value of avoiding NOx emissions per year

€ 0 - €1.000

Value driver

High tier (data center)

The tier level of a data center refers to the level of redundancy. A higher level of redundancy means a higher availability. The value of a higher tier can be significant. For this analysis we have assumed an increase in tier level from 2 to the highest level of 4. The value of such an increase is assumed to be €780/kW*. For the analysis 50% till 75% of this value is taken up by adaptations and additional cooling. This leads to a large impact on the business case. However, the uncertainty of this added value is large and implementation

Share of higher tier total value of SOFC

↑ 12% – 25%

Value of higher tier per year

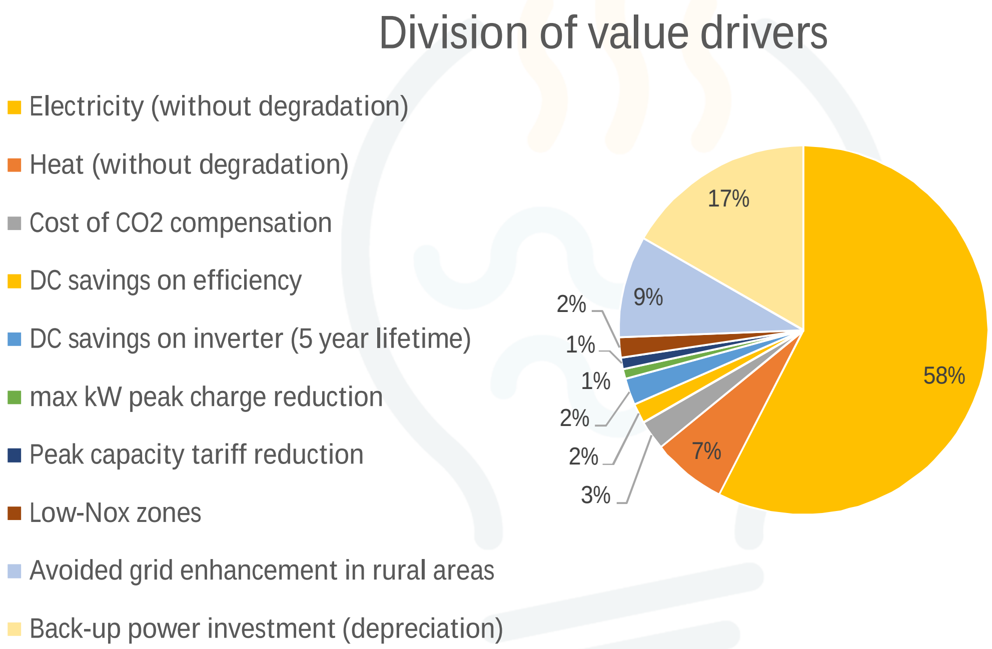
↑ € 6.000 - €12.000

* Data Centre Investment: An investment model & associated risk-return profile; Real estate & Housing (2014)
Towards sustainable data centres, van den Berg et al, 2018

Value drivers

Overview drivers

In an optimal case in which all non-energetic value drivers are relevant the division would be as shown in the graph. Heat and electricity make up for 2/3 of the created value while also the avoided grid enhancement and the avoided back-up power investment have a significant impact.



Value drivers

Overview

The great variety of value drivers can make it hard to find the best applications for this technology. However, the best market potential can be established in sectors in which:

Customers have a

- Baseload profile of electricity
- High additional fuel demand (means lower fuel prices)
- Need for back-up power / high value of lost load

In countries/regions with a

- Good spark spread (high electricity price vs low fuel price)
- Weak electricity system (production and distribution)
- High carbon, Nox or SOx reduction target

Market and regions

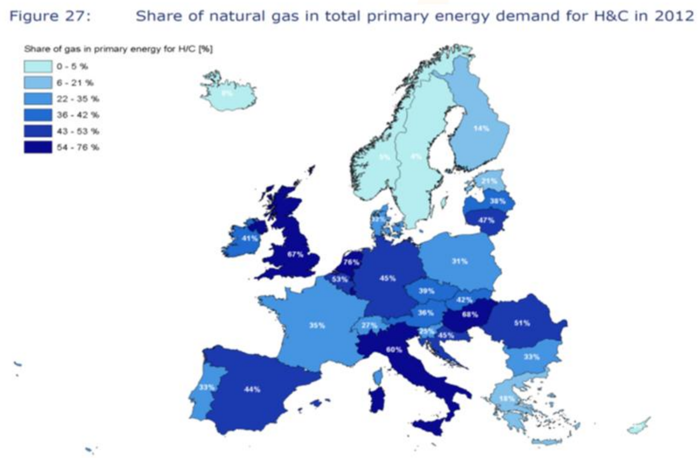
Opportunities of SOFC in different markets and regions

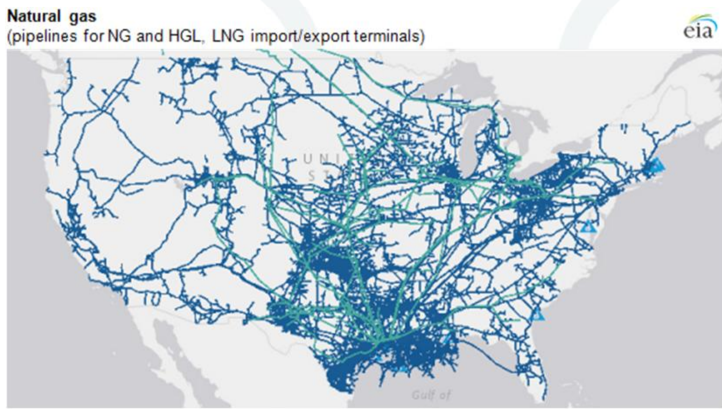
Introduction

The business case analysis for COMSOS focusses on:

- Well-developed energy markets with a strong gas and electricity infrastructure
- High energy prices due to environmental taxation
- Existing supply chains for CHP
- The focus is therefore on EU and U.S. In a later stage the opportunities in Asia will be explored as well

- The analysis is performed with a 30 kWe SOFC with an average performance of the three manufacturers.



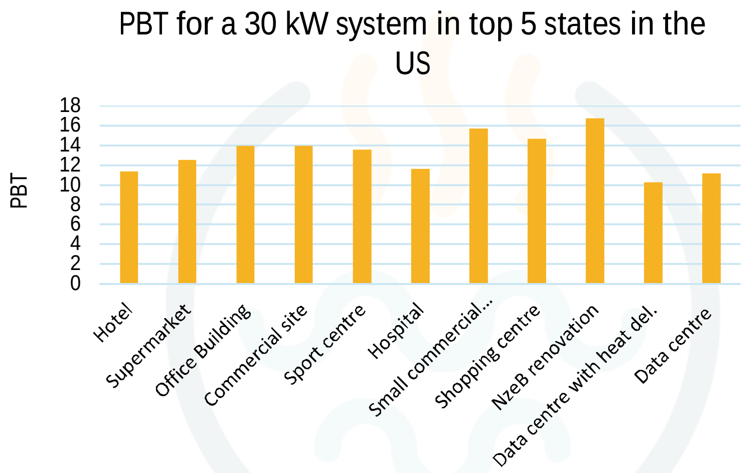


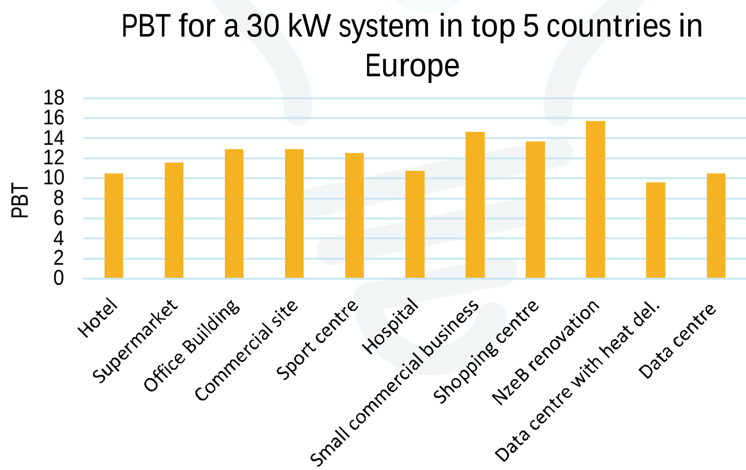
Sector comparison

At current costs

The business cases analysis of commercial SOFC CHP, without taking into account specific incentive schemes, shows that pay-back times are often above ten-years which is a critical time-period. This outcome is logical given the current production levels.

In several EU countries and U.S. states however there are beneficial incentive schemes, tax exemptions and white certificates. This is also elaborated in the INNOSOFC report. For more information see [this report].

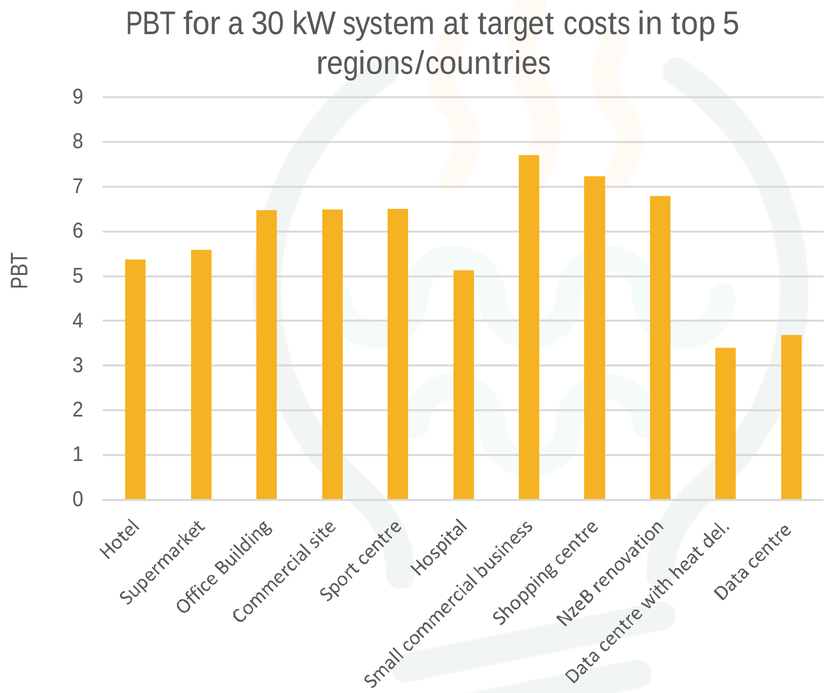




Sector comparison

At target cost

At higher production volumes the cost per unit drop drastically as will be discussed in the [cost target section](). This in turn leads to a drastic drop in pay-back time. For most sectors the payback time will be around 5 years and the IRR is above 10%.

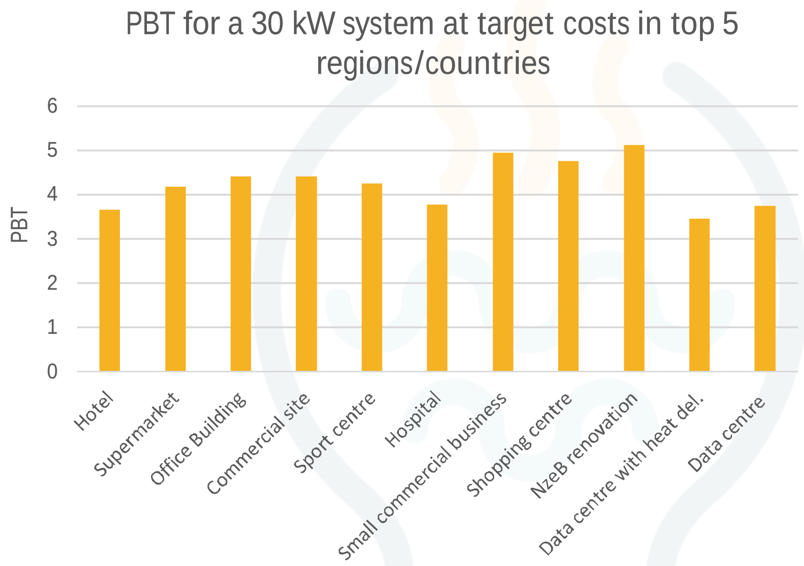


Sector comparison

At target cost back-up power

If the value driver of back-up power is taken into account the average pay-back time drops with approximately 2 years. This value is not included in the data center business case as the higher reliability is already included in the business case.

The avoided cost of back-up power is not applicable in every specific situation. Taking into account back-up power should be seen as an interesting niche application.



Sector comparison

Most valuable markets

Standard application

Based on these analysis there is a business case for SOFC within several markets. However, small commercial businesses, shopping centres and NzeB renovation are less interesting due to the more varying electricity demand. The exact business case per application will depend on the specific conditions. The three main criteria as mentioned in the value drivers section should be taken into account. For the analysis per region and the cost target analysis the application in a hotel is taken into account.

Data center application

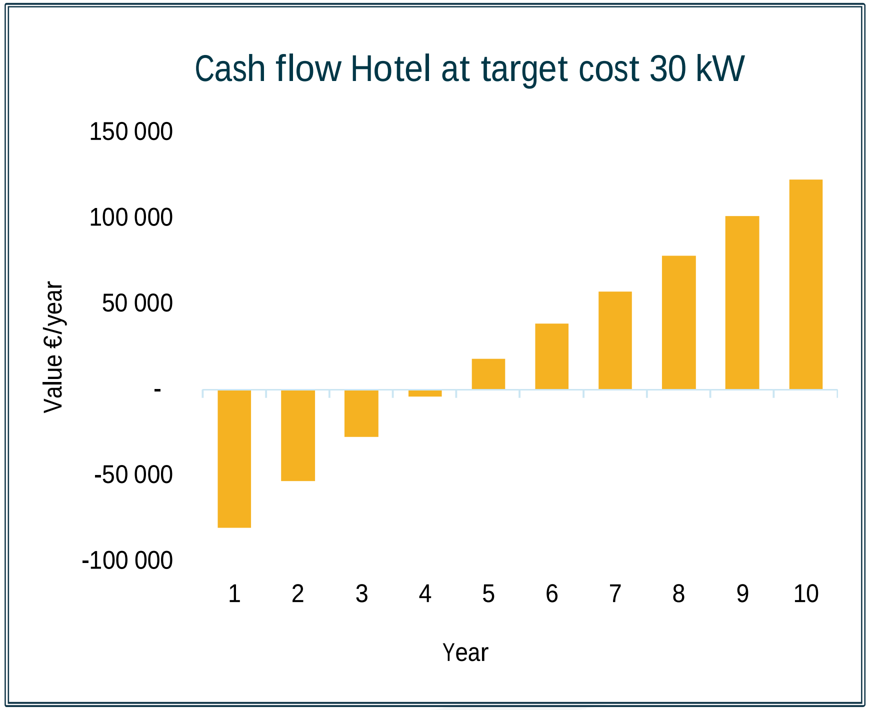
The best business case based on our analysis is the application in a data center. This is due to the high added value of a tier increase that is assumed. As is mentioned, the uncertainty of this application is high and implementation asks for very specific adaptations. More in-depth research is needed to validate the value that SOFC will have at data centers.

Hotel

Cash flow

A hotel is considered as the most relevant sector currently due to:

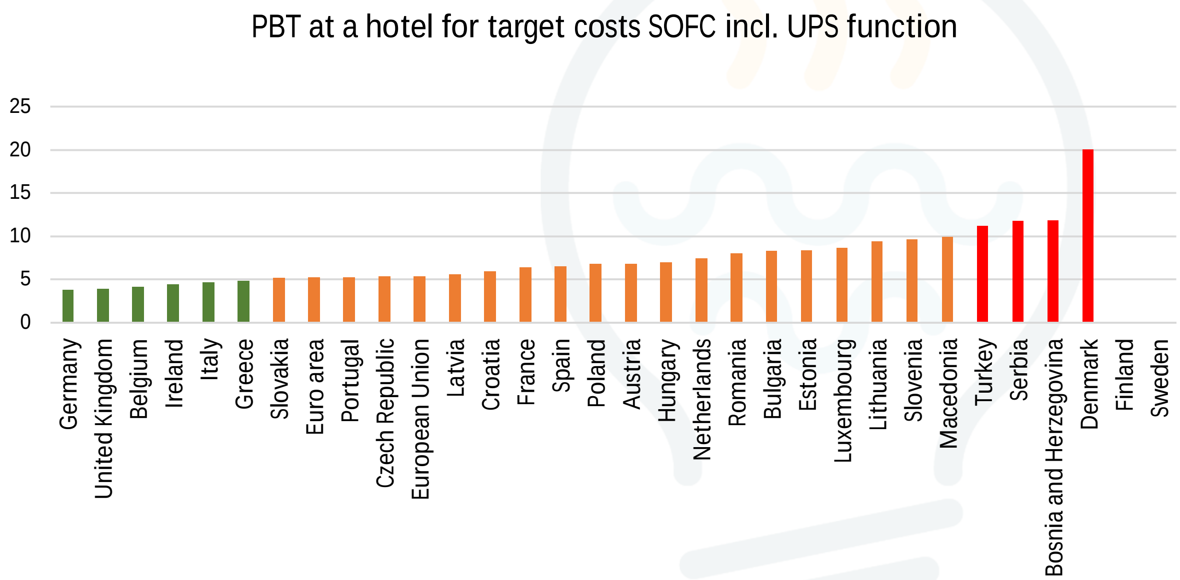
- Mostly internationally driven companies with green profile or seeking for full compliancy with energy regulation
- Scale of the SOFC is sufficient
- Baseload use of electricity
- High heat demand (resulting in high fuel demand and therefore low prices)
- Use for back-up power
- Many existing engine-based CHP



Region comparison

Europe

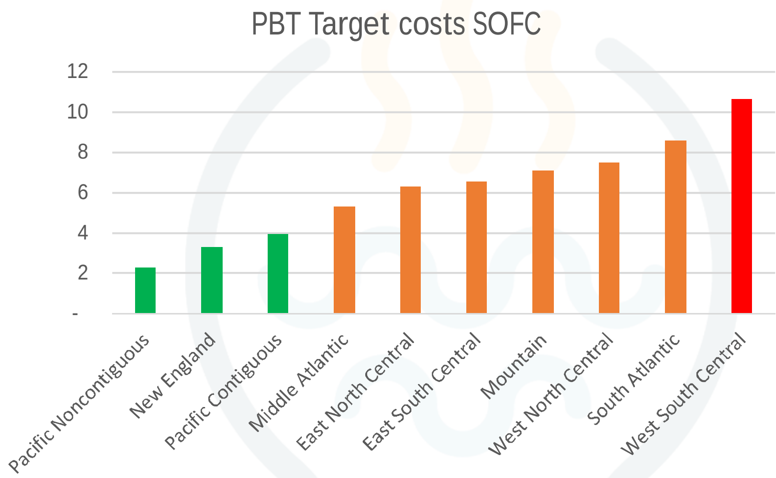
The top countries for SOFC CHP application are the ones that offer the best revenues on reducing electricity costs for end-customers. In the graph on the right all EU-27 countries are shown for the same application, a hotel at target costs. Around 10 countries a pay-back time of 5 years is reached, which is acceptable for a large part of the prospective customers.



Region comparison

United States

The business case for SOFC differs per state in the US. The graph shows the PBT per region in the US. The pacific non-contiguous states Hawaii and Alaska have potentially the best conditions for SOFC. However, the limited gas infrastructure and market reduces the chances for SOFC. New England offers also a interesting potential for SOFC, with best conditions in Vermont and Connecticut. From the pacific states it is mainly California that offers an interesting business case. In other regions most states have a PBT above 5 years, mainly due to low electricity prices.



Cost targets

Required cost levels to reach interesting business cases

Cost price targets

Cost down potential

To come to mass application the system costs of SOFC technology need to come down as mentioned in the assumptions. Several studies* have shown the large potential in cost reduction that can be expected. This is due to:

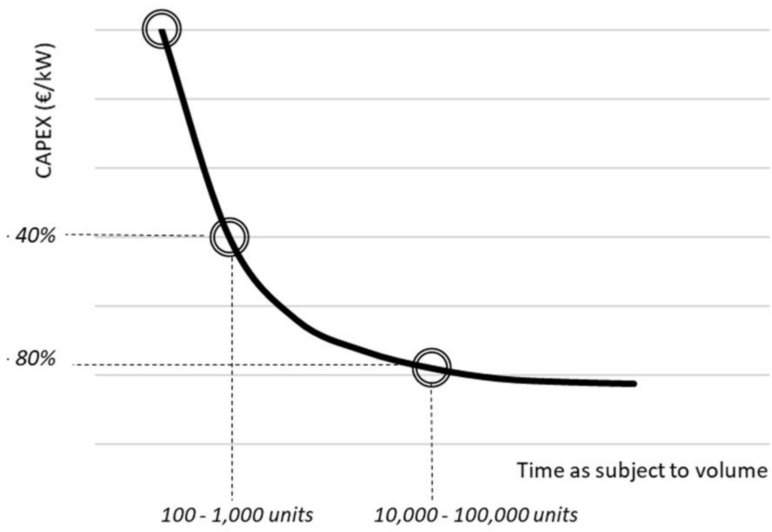
-Standardisation

-Automation

-Bundled sourcing strategy

Cost down depends on production volume. Production volume needs to go up to reach mass market. From previous research* it can be concluded that cost reduction of 40% by production of 100-1000 units and a cost reduction of 80% at a production volume of 10.000 to 100.000 units.

Cost down potential SOFC technology



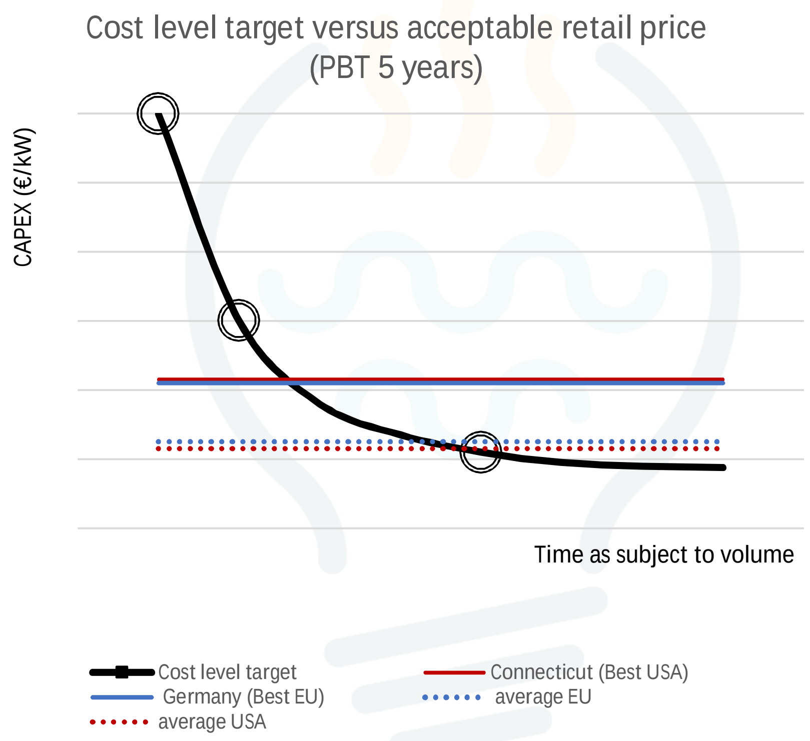
* Manufacturing cost analysis fuel cell systems; Battelle Memorial Institute
Advancing Europe's energy systems, stationary fuel cells in distributed generation; Roland Berger

Acceptable retail price

Current and target cost

Market chances of SOFC depend on the relation between the system costs and the acceptable retail price for the end users. In the graph it is shown that the acceptable retail price are within reach at volume production stage.

The acceptable retail price for a baseload operating system in Germany or Connecticut is around €4.000/kW. On average the acceptable retail price in the US and Europe is around €2.000/kW. This is in reach for mass produced SOFC systems.



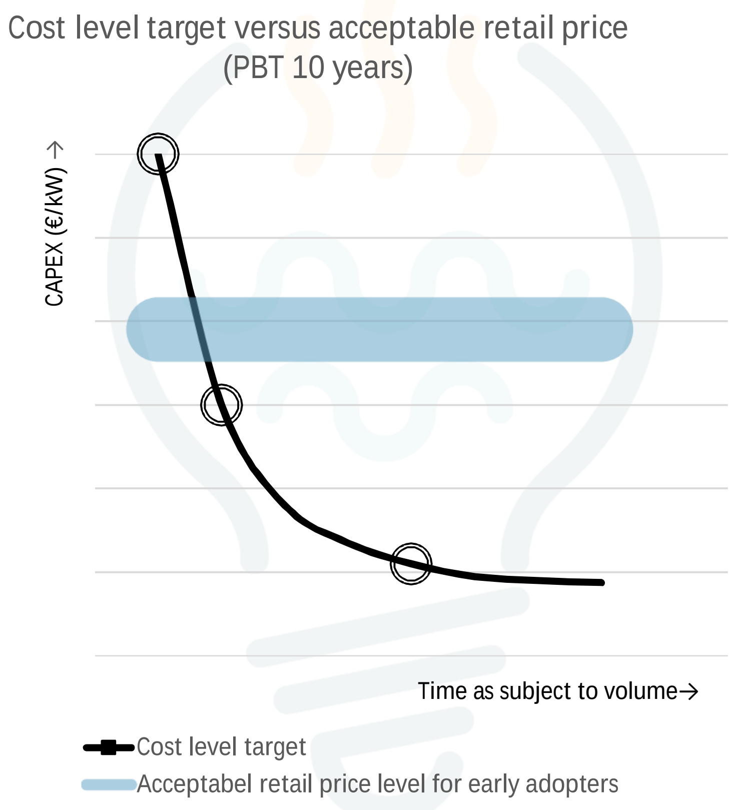
JT15 within

Jan-Willem Tolkamp; 21.6.2019

Acceptable retail price

Early adopters

The early adopters of SOFC technology might accept a longer PBT for their investment. Moreover, besides the spark spread other non-energetic benefits such as carbon reduction might be relevant for this type of end-user. The acceptable retail price for early adopters is around 6.000 – 8.000 €/kW. This price level can be in reach depending on the subsidy scheme that might be in place.



Acceptable retail price level

PPA

The graph shows the acceptable cost price when end users are offered a PPA for 15 years with a 10% reduction compared to the expected market price for 15 years. In this case, the acceptable cost price becomes close to the current system costs. The security and predictability of the price level of their energy can be a compelling reason to choose for SOFC technology.

Conclusion

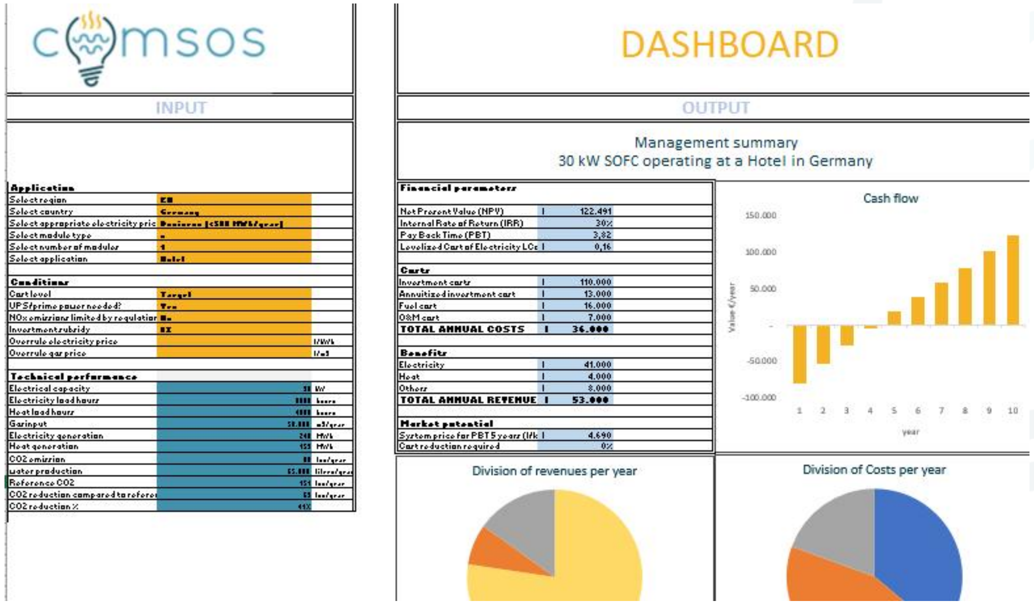
Key considerations
and recommendations

Conclusion

- The products developed under the COMSOS project have outstanding technological performance and present end-customers a radical new proposition. Business case analysis at target costs show a wide applicability through different sectors and countries
- Commercial SOFC CHP applications offer a good business case in 9 out 11 applications at target cost levels. The profitability depends mostly on local markets and regulation. Many countries and states in the EU and the U.S. fulfill the economic criteria for application at target costs.
- The products need to transform from single units to (semi-)mass produced units to achieve economies of scale and reach target costs. This will require a local, national or European incentive scheme to compensate for the investment risk of these companies.

Conclusions

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.



Recommendations

The follow up of this business case analysis is work to be carried out within the COMSOS project:

- Performing cost analysis to secure the findings of this report
- Gathering operational data to perform financial risk assessment and further assess the bankability of SOFC CHP technology for the commercial sector
- Addition of countries in which manufacturers are active to the model

SOFC in commercial sector

Business case analysis

June 2019

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This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 779541.
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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. 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 has been used.

Attachment

Value of Lost Load

The value of lost load is calculated based on the following formula:

$$Benefit\left[\frac{€}{year}\right] = VOLL\left[\frac{€}{kWh}\right] x\ Yearly\ energy\ lost\left[\frac{kWh}{year}\right]$$

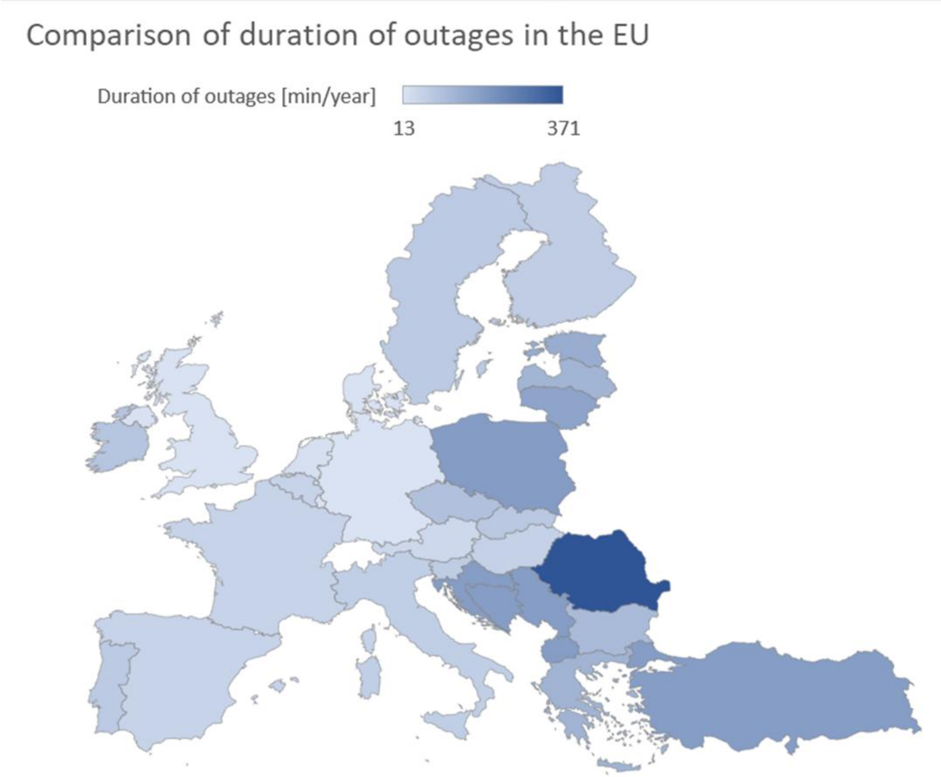
Where:

$$Yearly\ energy\ lost\left[\frac{kWh}{year}\right] = Avg.hours\ of\ outage\left[\frac{h}{year}\right] x\ Annual\ consump.of\ the\ firm\ [\frac{kWh}{8760h}]$$

Appendix

Duration of outages

Average duration of outages including major events for consumers in Europe is 105 minutes.* This is mainly caused by a few outliers like Romania. Western European countries have in general a duration of outages that is way below an hour/year. The reliability of the grid is the highest in Germany, Denmark and the Netherlands with only approx. of 15 minutes of downtime per consumer.

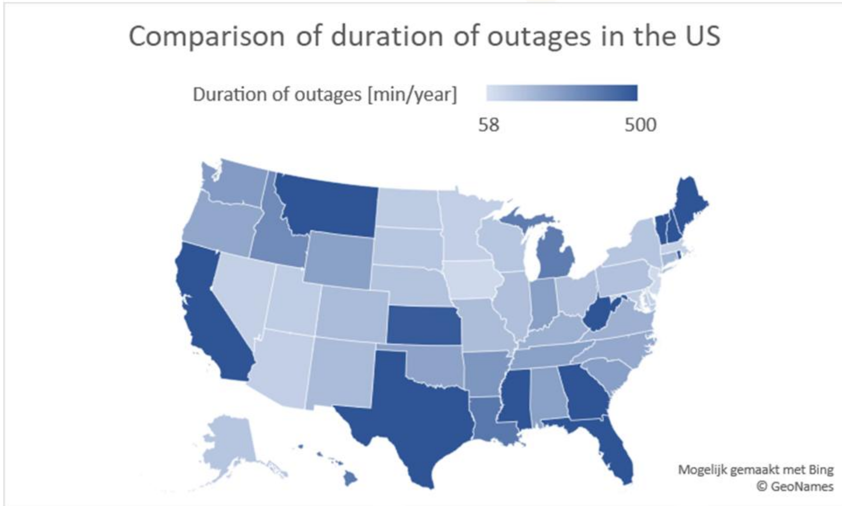


* CEER Benchmarking Report 6.1 on the Continuity of Electricity and Gas Supply

Appendix

Duration of outages

Average duration of outages including major events for consumers in the US is 269 minutes.* This is significantly higher than the average in Europe. Especially in the South of the US the duration of outages can be long mainly due to natural disasters.



* U.S. Energy Information Administration, Annual Electric Power Industry Report (EIA-861 data file)