



Pathway to a Competitive European
Fuel Cell micro-CHP Market

Deliverable 1.9 – Report 1 on Training and Certification

Element Energy – March 2020



PACE project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 700339.

This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme and Hydrogen Europe and Hydrogen Research.

Deliverable 1.9 - Outline

Report 1 on Training and Certification

- The first PACE report on training and certification has been prepared by Element Energy as a set of training materials which provide an introduction to fuel cell mCHP as a technology, focused particularly at installers.
- These materials have been created using training modules from the Callux project as base material. The training modules were first translated into English and then updated to reflect the current knowledge of the PACE OEMs.
- The training material is split into 3 core modules:
 1. FC mCHP Basics
 2. Planning, Dimensioning and Formal Requirements
 3. Electrical and Heating Installation
- In the next phase of T1.4 (Working group on training and certification), these training materials will be disseminated to key training and certification stakeholders in the FC mCHP industry.



Pathway to a Competitive European
Fuel Cell micro-CHP Market

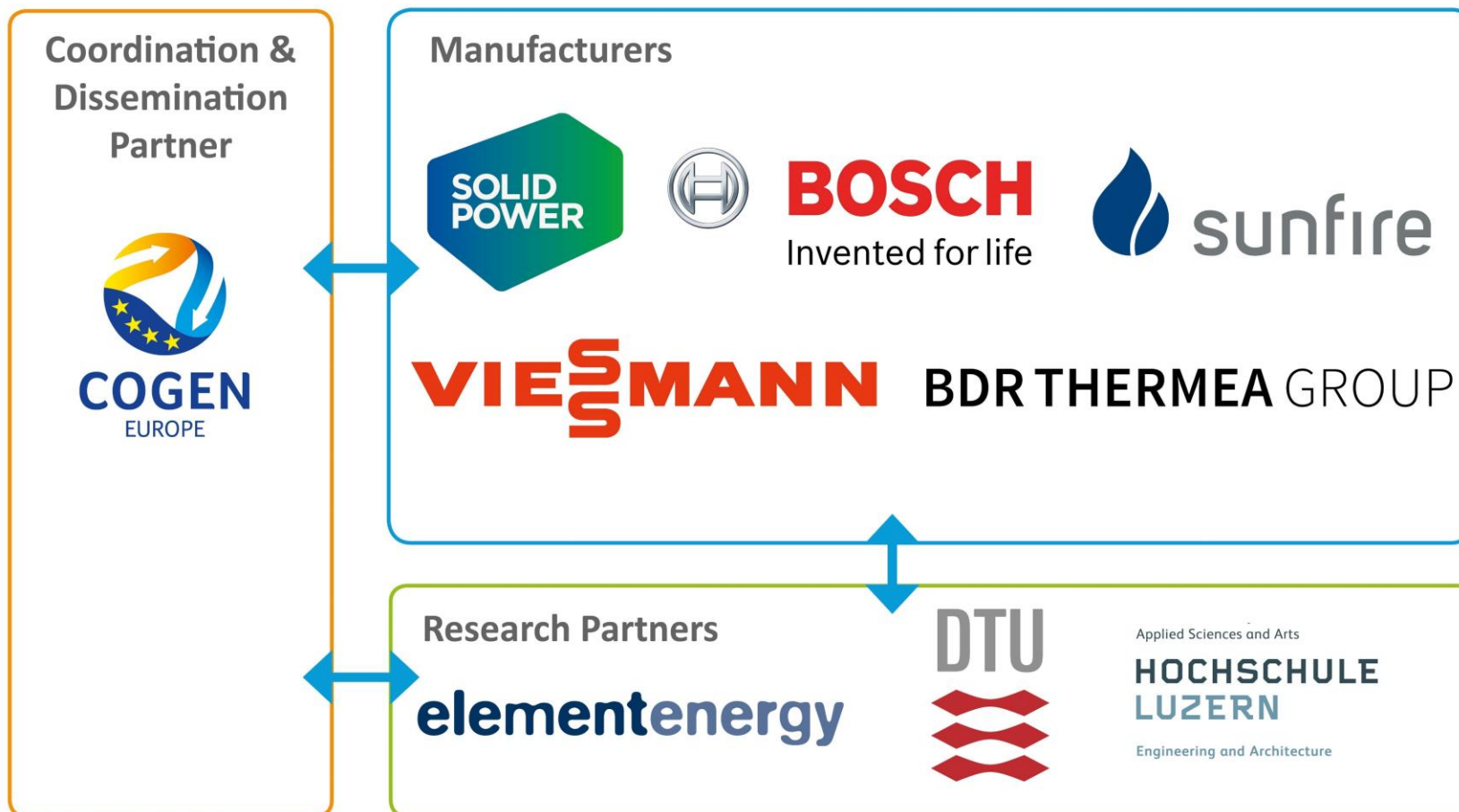
Fuel Cell Combined Heat and Power for Specialised Trade – Training Documents

Module 1: Basics



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- The purpose of these training modules is to provide a general overview of the potential of Fuel Cell micro-Combined Heat and Power (FC mCHP) units as part of the future of European domestic energy.
- Each module in turn will focus upon a different aspect of FC mCHP units, with the aim to provide a working knowledge of the considerations installers working with this technology will need to make.
- Specific material for each FC mCHP product can be obtained from each unit manufacturer, who also offer specific training on their units.
- These materials have been based upon material developed during the Callux project (2008-2016). Consequently, thanks go to NOW GmbH for permitting the use of this material:

List of Abbreviations

Module 1: Basics

- CHP – Combined Heat and Power (also known as Cogeneration)
- mCHP – Micro Combined Heat and Power Unit
- FC – Fuel cell
- FCH JU – Fuel Cells and Hydrogen Joint Undertaking
- GDL – Gas Diffusion Layers

- kW – Kilowatt
- kWh – Kilowatt Hour
- MW – Megawatt
- PEMFC – Proton-Exchange Membrane Fuel Cell
- SOFC – Solid Oxide Fuel Cell
- VPP – Virtual Power Plant

I. Basics

1. Cogeneration (CHP)
2. Fuel Cell (FC)
3. Primary Energy Comparison

II. The Fuel Cell CHP (FC CHP)

1. General (Promising features, how it works etc)
2. Market and Environment

III. Fuel Cell CHP Consultancy

1. Goals, methods, process (advice for selling the right unit to the right customer)

IV. Further Topics

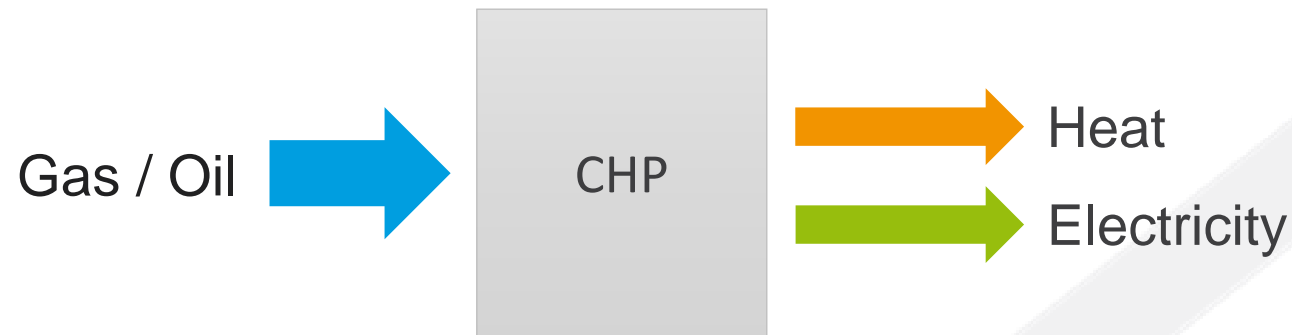
1. CO₂ and pollutant emissions
2. FC CHP in the energy system of tomorrow
3. Operation and safety



I. Basics

I 1. Cogeneration (CHP)

Definition



Source: WBZU, ZSW, Callux / ModernLearning GmbH

Definitions of terms:

“Combined heat and power generation is the simultaneous conversion of fuel into electrical energy and useful heat in a stationary technical plant”

(Germany’s Combined Heat and Power Act, 2016)

I. Basics

I 1. Cogeneration (CHP)

The energetic advantage of combined heat and power generation:

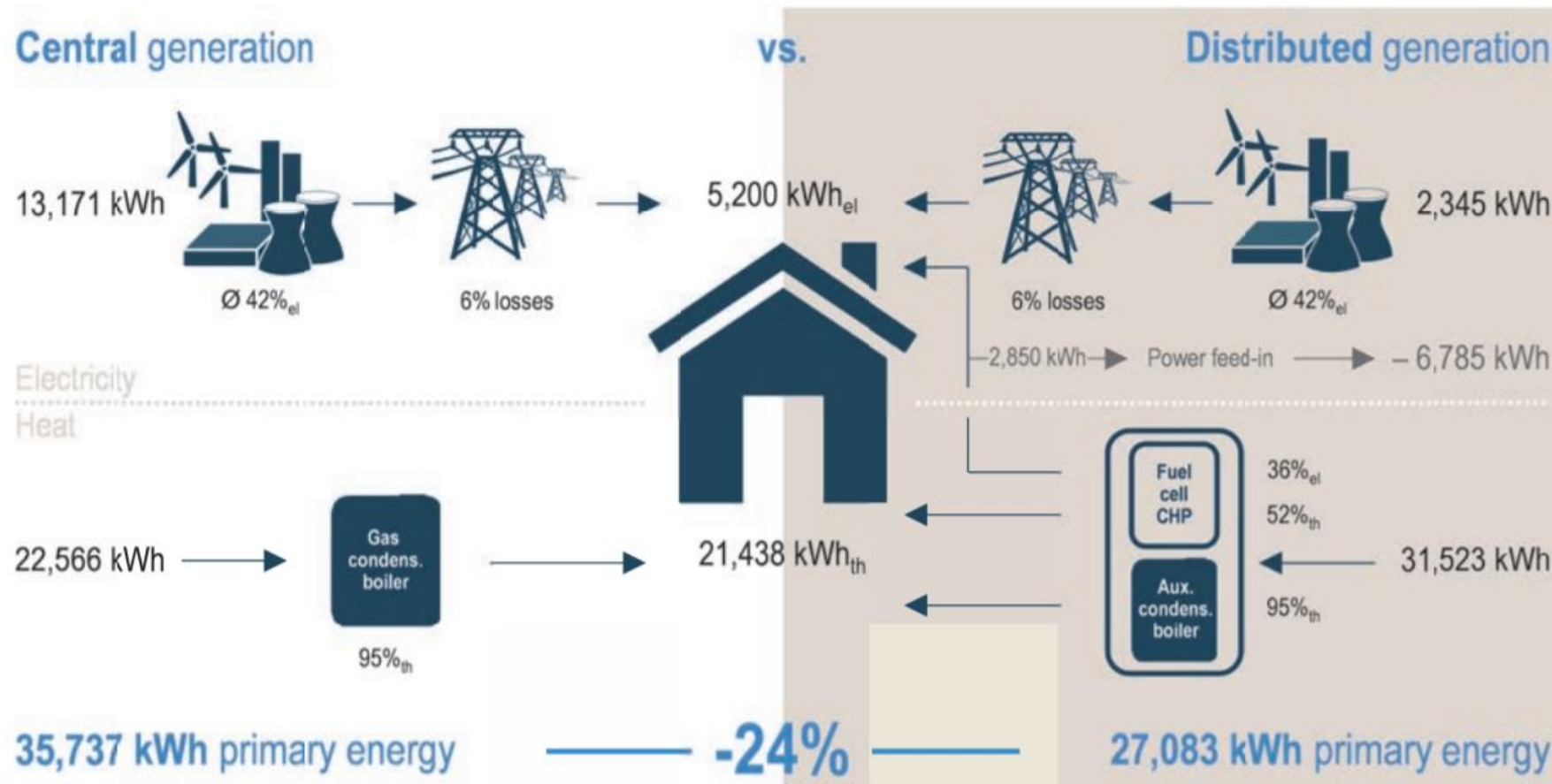


Figure Source:
"Advancing Europe's
Energy Systems:
stationary fuel cells in
distributed generation"
(FCH JU, 2015)

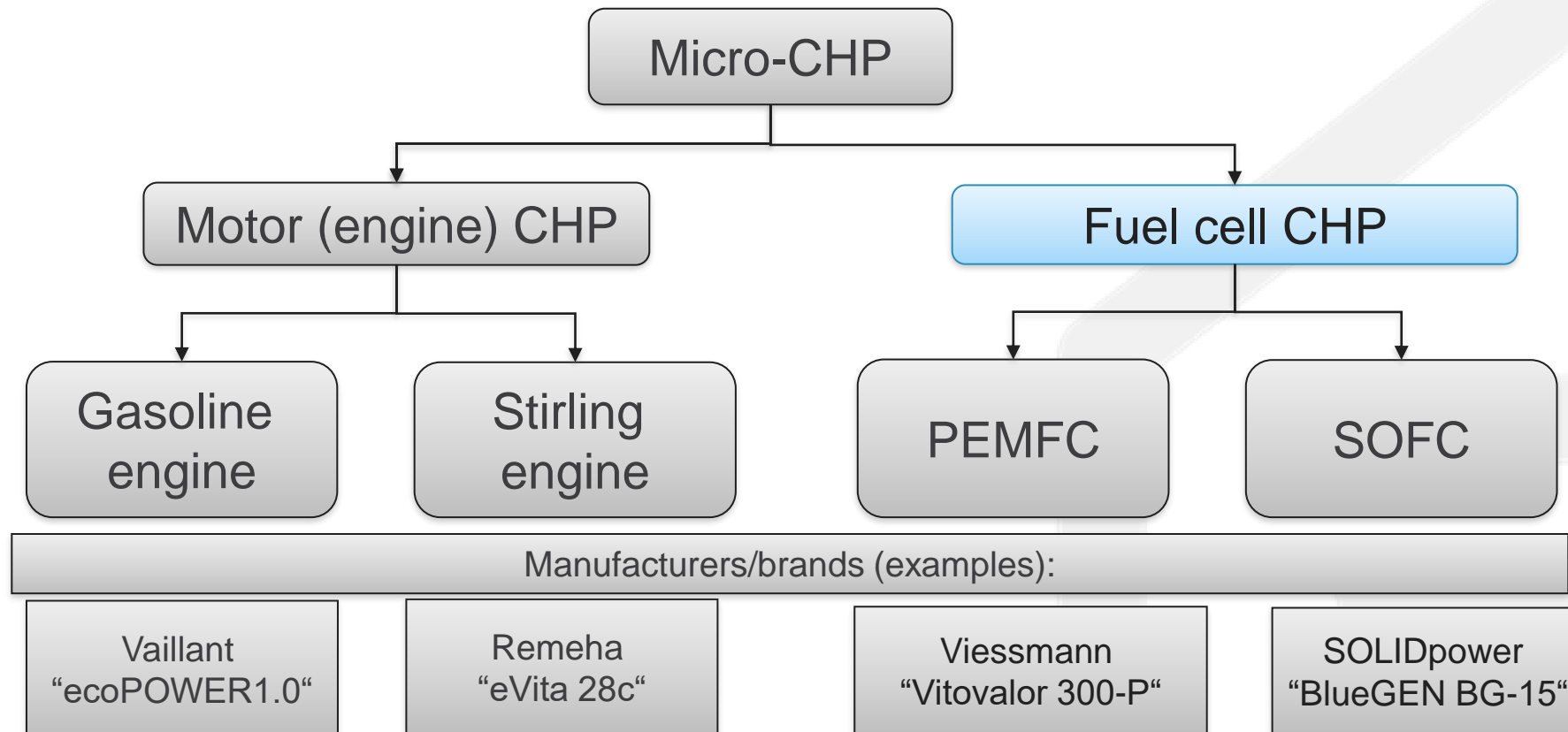
I. Basics

I 1. Cogeneration (CHP)

Classification

Designation	Range of application	Technology used	Electric power	Possible fuels*
Large CHP plants / combined heat and power plants	Decentralised in large residential complexes, hospitals, industry and commerce	Internal combustion engine, gas turbine	up to several MW	natural gas, heating oil EL, coal, landfill, sewage, biogas
small-scale cogeneration	Decentralised in apartment buildings, housing estates, industry and commerce	Combustion engine, gas turbine, fuel cell (up to 1 MW)	up to 2.000 kW	Natural gas, EL heating oil, landfill, sewage, biogas, hydrogen
Mid-scale CHP	decentralised in apartment buildings, industry and commerce	Combustion engine, Stirling engine, fuel cell	Up to 50 kW	natural gas, EL heating oil, biogas, hydrogen
Mini-CHP	decentralised in apartment buildings, industry and commerce	Internal combustion engine, Stirling engine, steam expansion engine, fuel cell	Up to 15 kW	natural gas, liquid gas, EL heating oil, biogas, hydrogen
Micro-CHP	decentralised in detached and semi-detached houses	Internal combustion engine, Stirling engine, steam expansion engine, fuel cell	Up to 5 kW	natural gas, liquid gas, EL heating oil, biogas, wood pellets, hydrogen

Product types Micro-CHP (output < 2 kWel):



I. Basics

I 1. Cogeneration (CHP)

Properties Micro-CHP (power < 5 kW_{el}):

	Engine (combustion)	Stirling (engine)	PEMFC*	SOFC**
Electrical Output	from 1 kW	from 1 kW	from 0.3 kW	from 0.7 kW
Thermal Output	from 2.5 kW	from 3 kW	from 0.7 kW	from 0.6 kW
Sensitivity to maintenance	many moving parts	fewer moving parts, external combustion	only fans, pumps contain moving parts	only fans, pumps contain moving parts
Electrical Efficiency	ca. 20 - 30 %	ca. 10 - 15%	37 %	33 – 63 %
Modulation Capability	good	good, but slower	good	design dependent

History:

Birth of the fuel cell

- 1839: Discovery of the FC by Sir W. Grove



Source: engl. Wikipedia

Renaissance of the FC - Space Travel

- 60s: Development and deployment of the Apollo program
- 80s : Development and deployment for space shuttle program



Source: NASA, public

Early markets

- ca. 1990: rediscovery of the FC
- Approx. 2000: Prototypes and pre-series production
- Currently: commercially available products
- Advances in (subsidised) market uptake particularly in Japan (ca. 400,000 units installed) and in Germany and Belgium

I. Basics

I 2. Fuel Cell (FC)

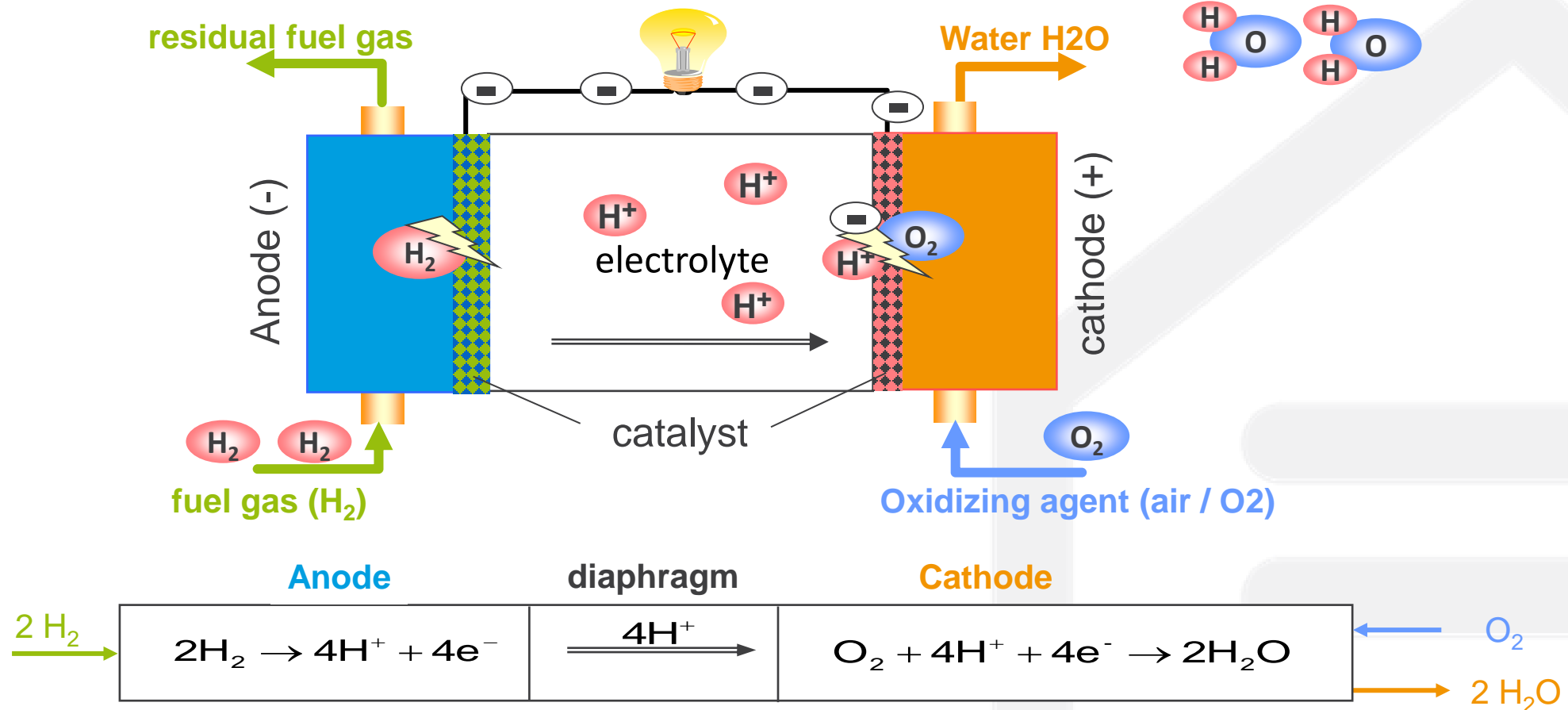


Examples of model mCHP units
Source: PACE

I. Basics

I 2. Fuel Cell (FC)

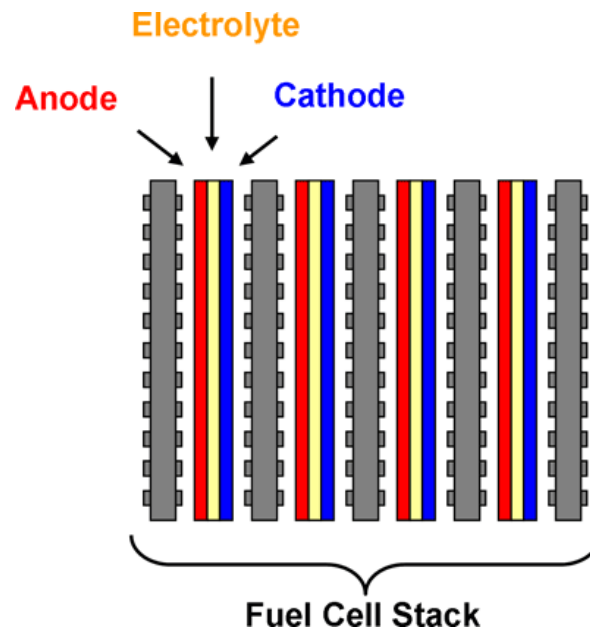
Functional principle of a FC using the example of a PEMFC:



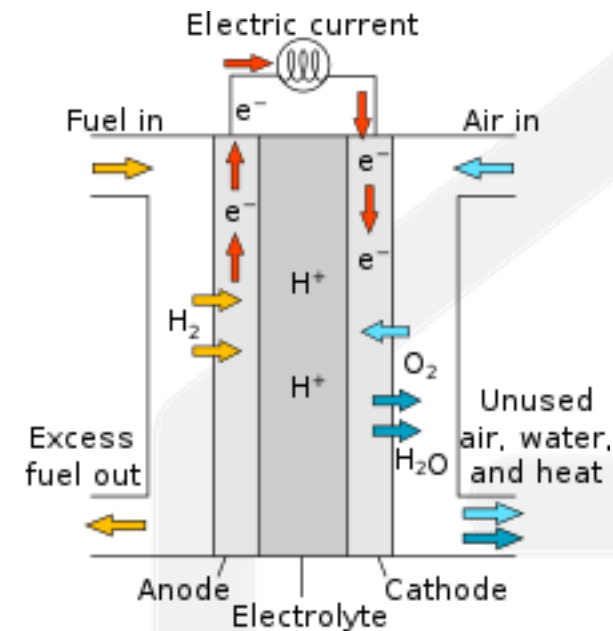
I. Basics

I 2. Fuel Cell (FC)

Construction of a stack of several fuel cells:



Source: Sigma Aldrich



Source: Wikipedia

If several individual cells are connected in series, this is referred to as a fuel cell stack. The voltages of the individual cells add up to the total voltage.

I. Basics

I 2. Fuel Cell (FC)

Stack Build-Up

1. Electrolyte (membrane)

Provides ion transport and separates anode and cathode.

2. Electrodes

This is where the electrochemical reactions take place.

3. Exchange membrane

Electrode membrane: "heart" of the fuel cell.

4. Gas diffusion layers (GDL)

Are necessary for the supply and distribution of the reaction gases.

5. Bipolar plates

Fine channels in the plates ensure the supply and distribution of hydrogen and oxygen.
They also serve as "electron collectors".

I. Basics

I 2. Fuel Cell (FC)

What does a stack need?

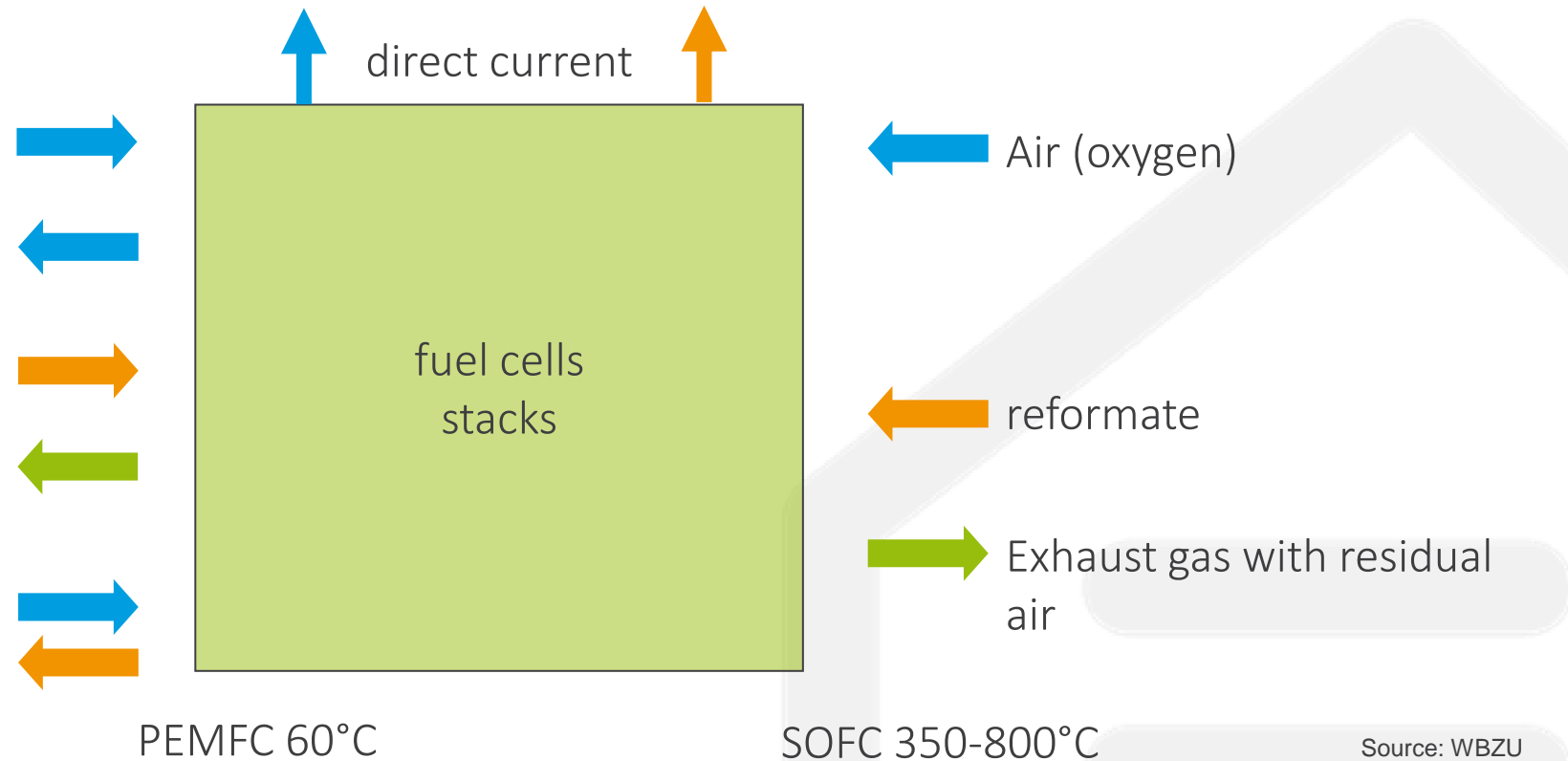
Air (oxygen)

residual air

Hydrogen (reformate)

residual hydrogen

Cooling water: return /
flow



Source: WBZU

SOFCs cannot be cooled with water. Instead, the heat is discharged through exhaust gas with residual air. This discharge is mostly used to heat the incoming air and gas, and to feed the gas-reforming process to create H_2 and CH_4 .

I. Basics

I 2. Fuel Cell (FC)

Fuel cell types

Source: WBZU, ZSW, Callux

	AFC	PEFC/PEM* DMFC	PAFC	MCFC	SOFC*
Designation	Alkaline FC	Polymer electrolyte / direct methanol FC	Phosphoric acid FC	molten carbonate FC	Solid oxide FC
Temperature	low	<100°C		up to 800°C	high
Catalyst Material	noble	Platinum		Metals	less noble
Gas Requirement	ultrapure	4-5.0 H ₂		C _n H _m	less pure
Cell Efficiency	low	40-50%		50-60%	high
System Complexity	high	Reformer		Internal Reformer	low
Start-Up-Time	low	Seconds		Hours	high
Dynamism	high				low

I. Basics

I 2. Fuel Cell (FC)

Examples of fuel cell types in domestic energy supply

PEMFC

Proton Exchange Membrane Fuel Cell

- Low temperature FC
- Natural gas operation with external gas treatment
 - Catalyst material: Platinum
 - Lower cell efficiency
- Quick start up time (0.5-1hr)

SOFC

Solid Oxide Fuel Cell

- High temperature FC
- Natural gas operation with internal gas treatment
 - Catalyst material: Nickel
 - Higher cell efficiency
 - Longer start up time

I. Basics

I 3. Primary Energy Comparison

Case study of a German house

- Detached house, inhabited by 4 persons
- Year of construction 1953, 2010 modernized
- Heated surface: 101 m²
- Heat requirement: 18,000 kWh_{th}:
 - 15,600 kWh heating,
 - 2,400 kWh hot water
- Power requirement: 3,500 kWh_{el}
- Fuel cell heater (FC CHP)
 - Electrical power: 1,0 kW_{el},
 - Thermal capacity: 1,8 kW_{th}
- Auxiliary heater
 - Thermal power max. 20 kW_{th}

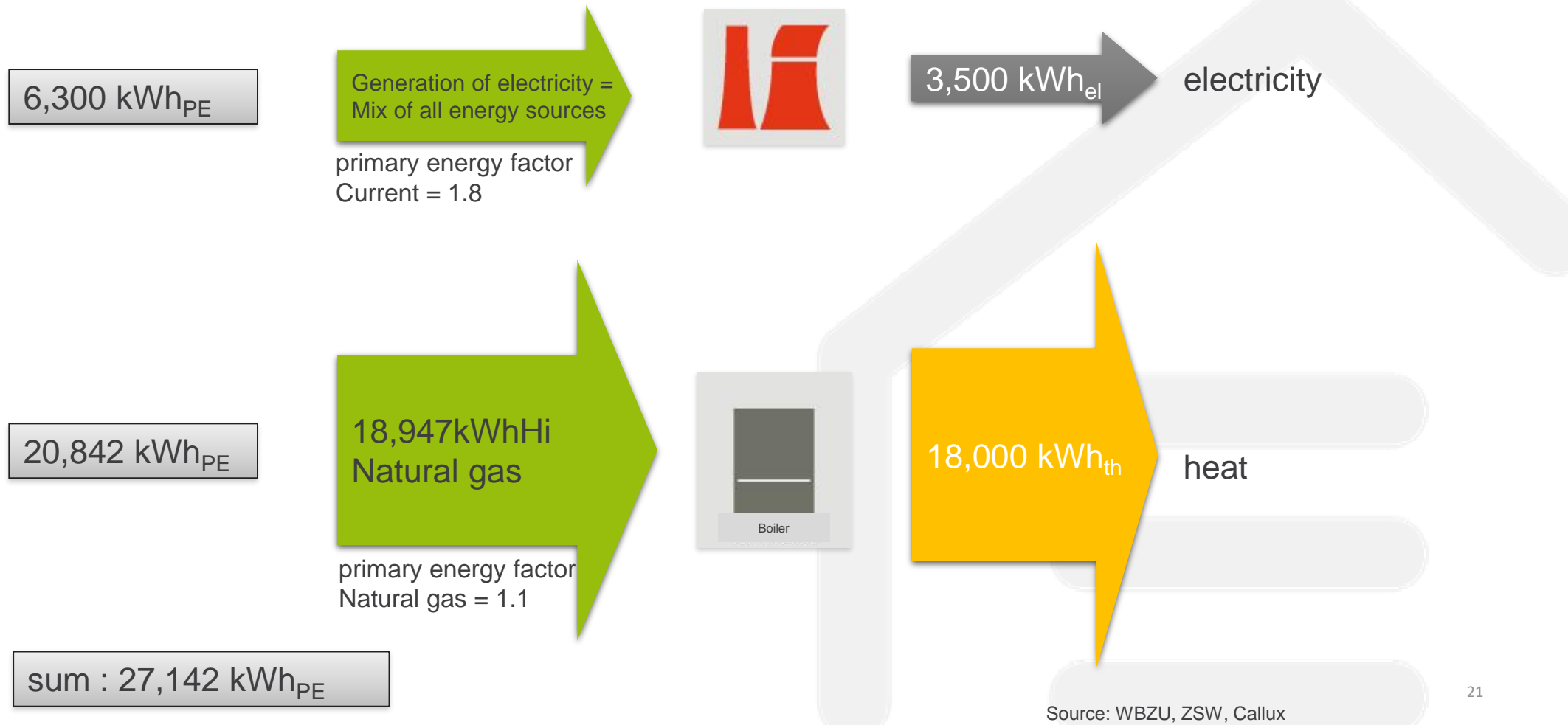


Source: Callux



Whilst this example shows a typical example in which PEM fuel cells are suitable, another typical scenario which exists is a new build (highly insulated) house with a heat pump that is fed by an electricity-led (SOFC) FC mCHP. This mix of technology provides very large primary energy savings.

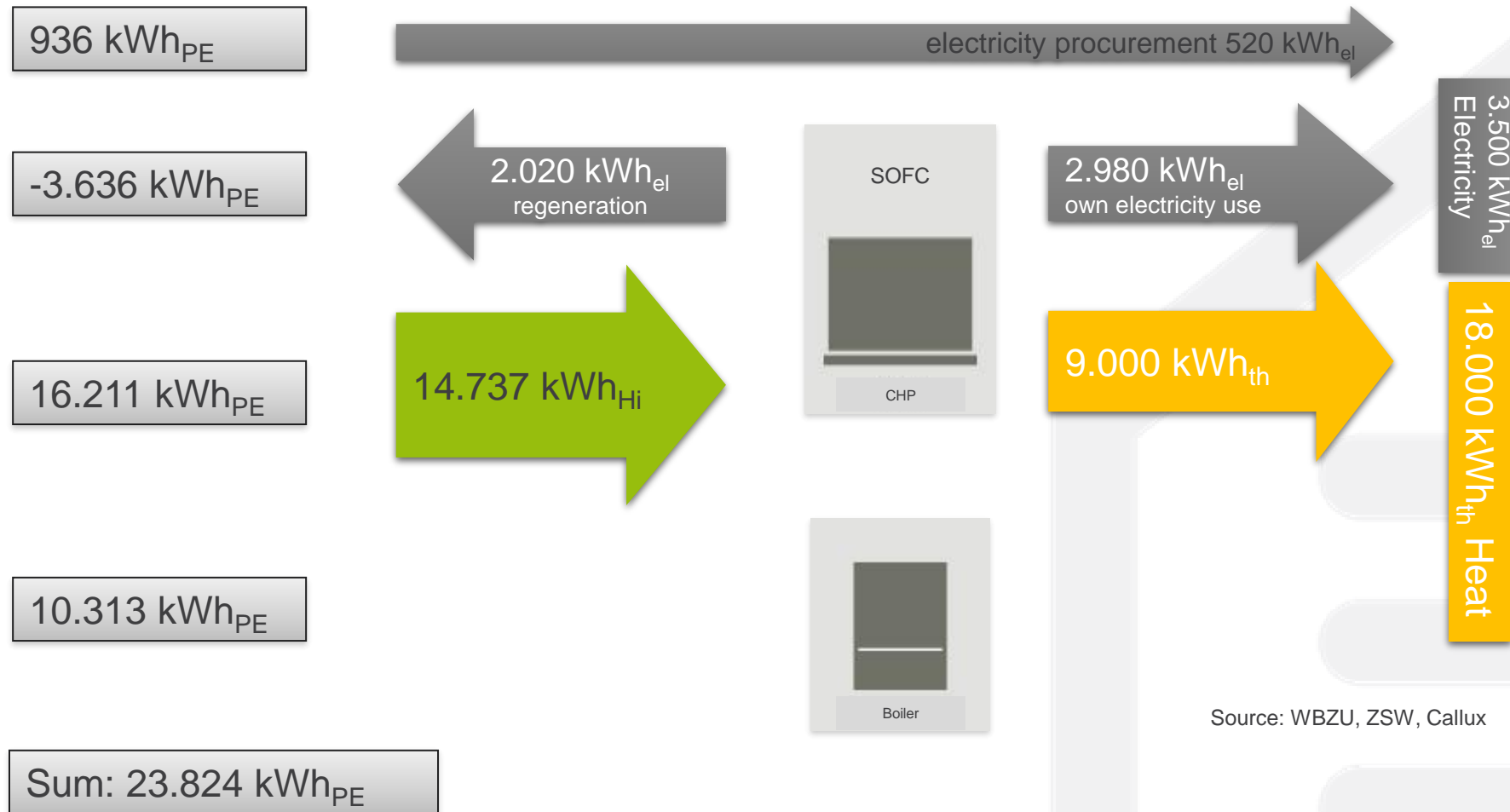
Primary energy use (typical German house) – separate generation



I. Basics

I 3. Primary Energy Comparison

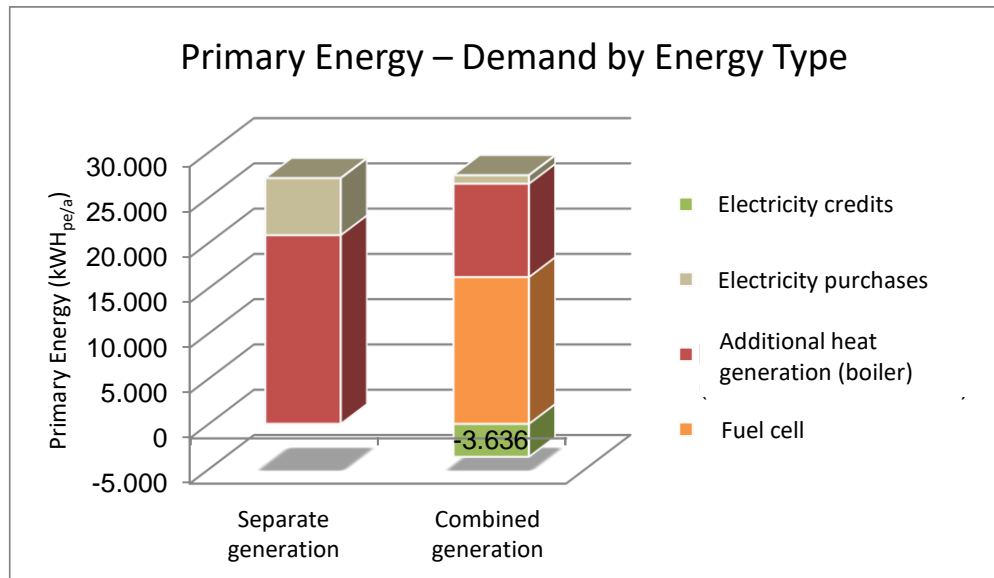
Primary energy use – coupled generation



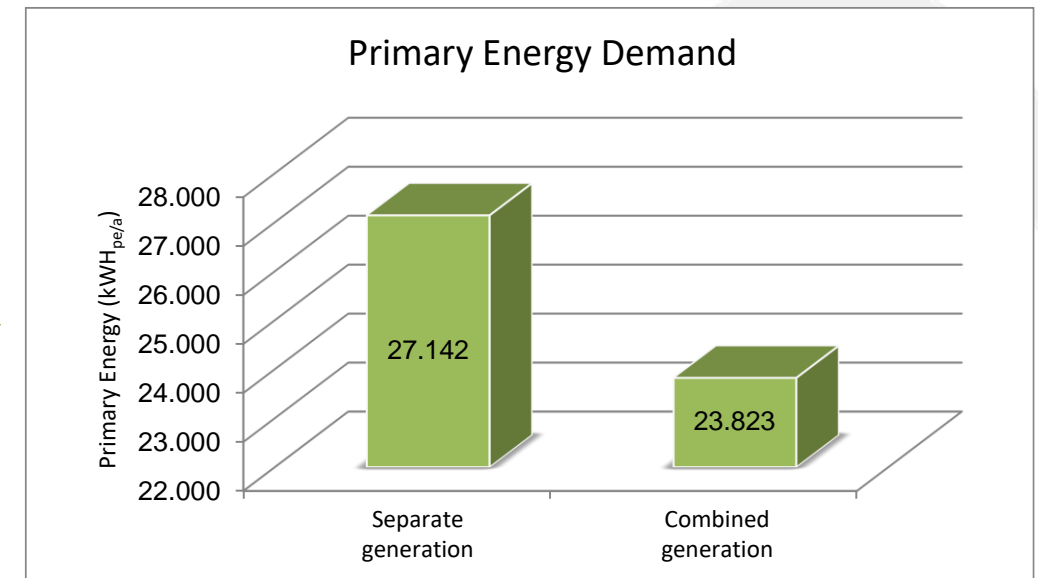
Overall primary energy use is reduced thanks to a reduction in the required natural gas and because electricity is being fed into the grid

Source: WBZU, ZSW, Callux

Comparison of Separate and Combined Generation



Source: Gertec GmbH



Source: Gertec GmbH

The energetic advantage is approx. 12 % (with a running time of 5,000 full usage hours per year).

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1. General (Promising features, how it works etc)
2. Market and Environment

III. Fuel Cell CHP Consultancy

1. Goals, methods, process (advice for selling the right unit to the right customer)

IV. Further Topics

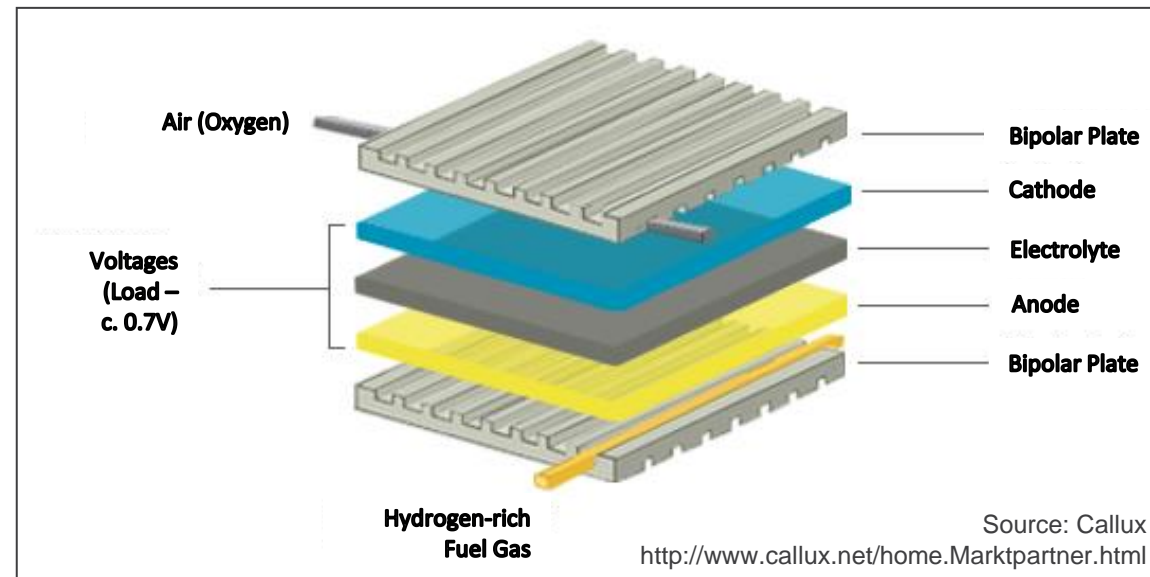
1. CO₂ and pollutant emissions
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3. Operation and safety



Fuel Cell CHP

II. The Fuel Cell CHP

II 1. General



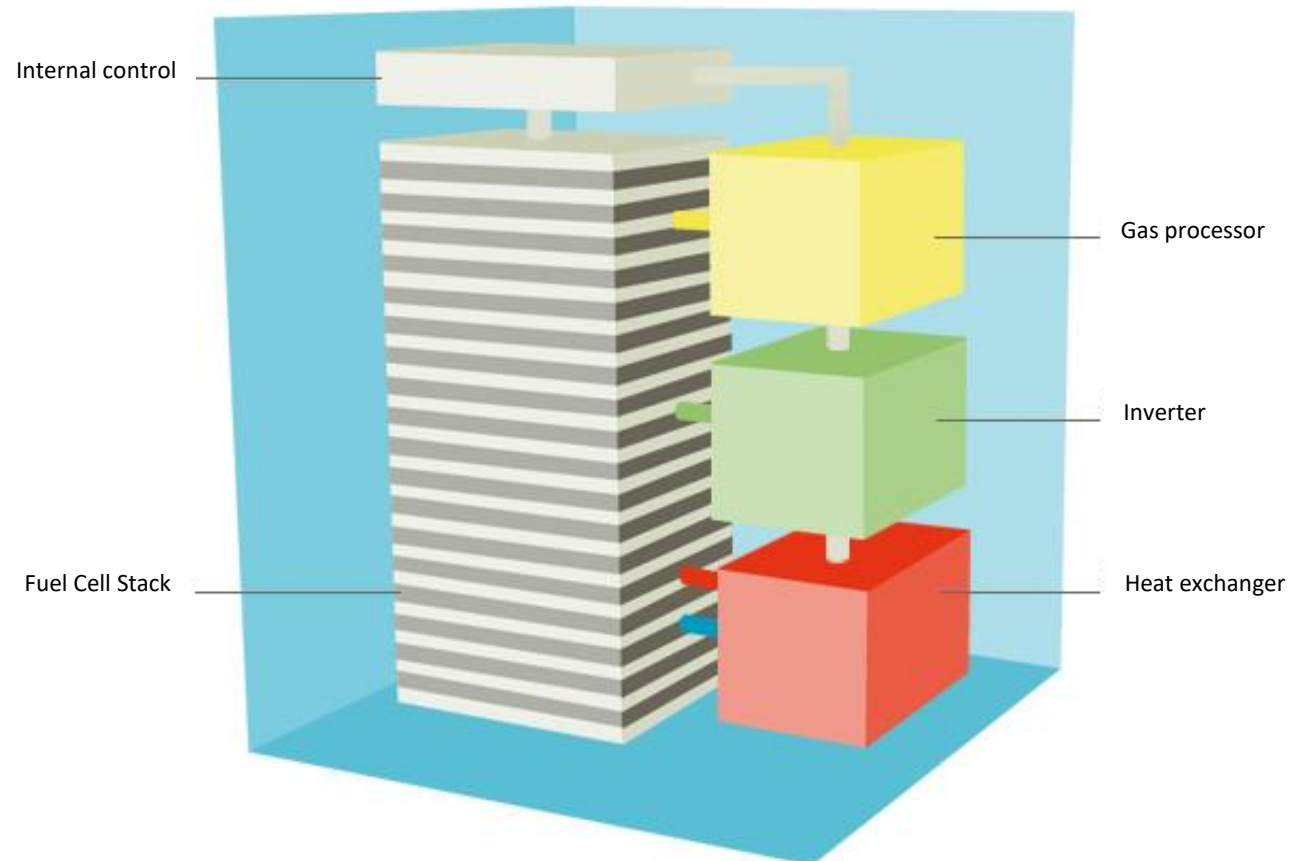
FC with bipolar plate
(eg. PEMFC)

Stationary fuel cell are micro-cogeneration systems. They run on hydrogen, which can be produced from natural gas or biogas, and convert the energy used directly into electricity and heat by electrochemical means.

II. The Fuel Cell CHP

II 1. General

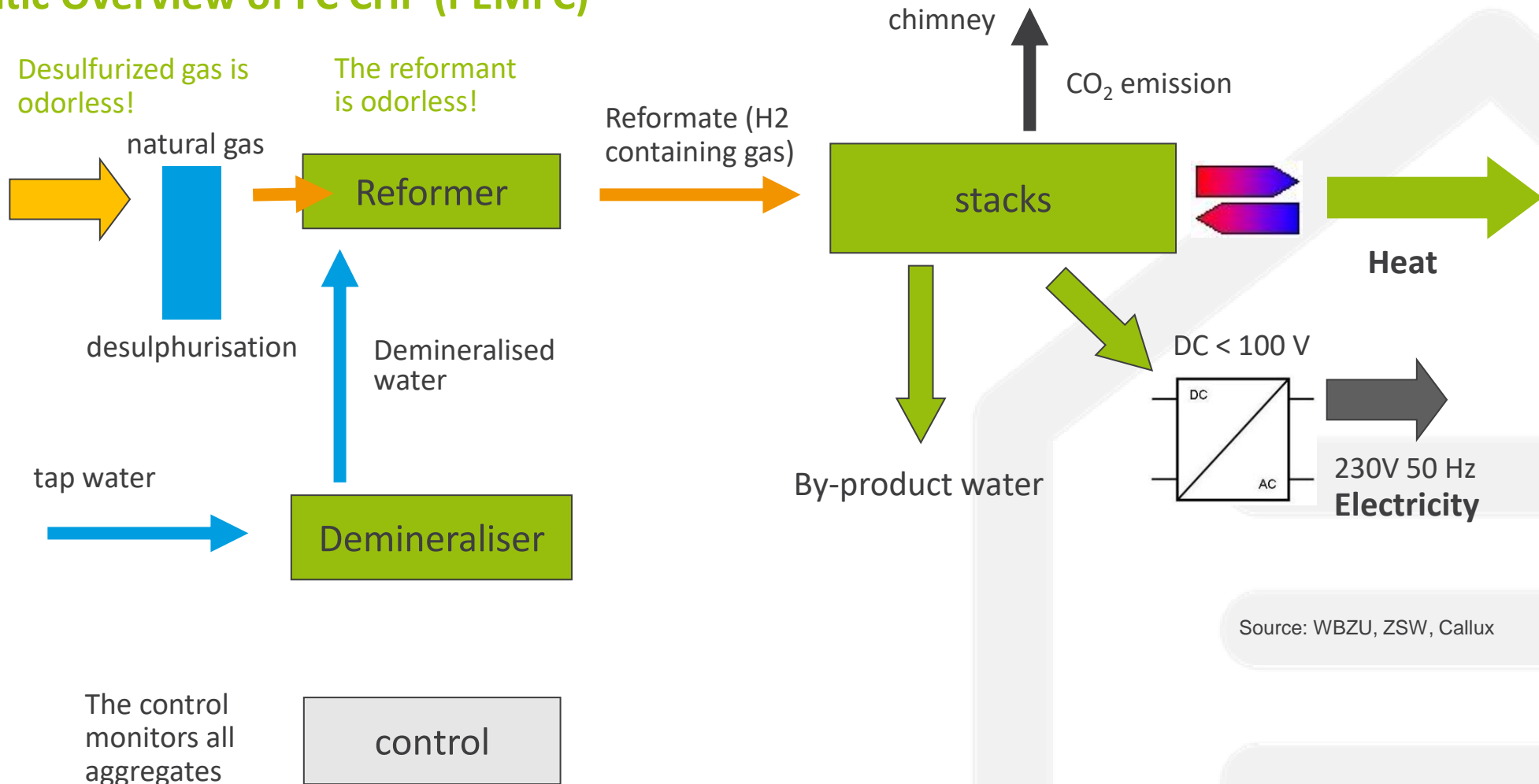
Schematic Representation of a FC CHP



II. The Fuel Cell CHP

II 1. General

Schematic Overview of FC CHP (PEMFC)

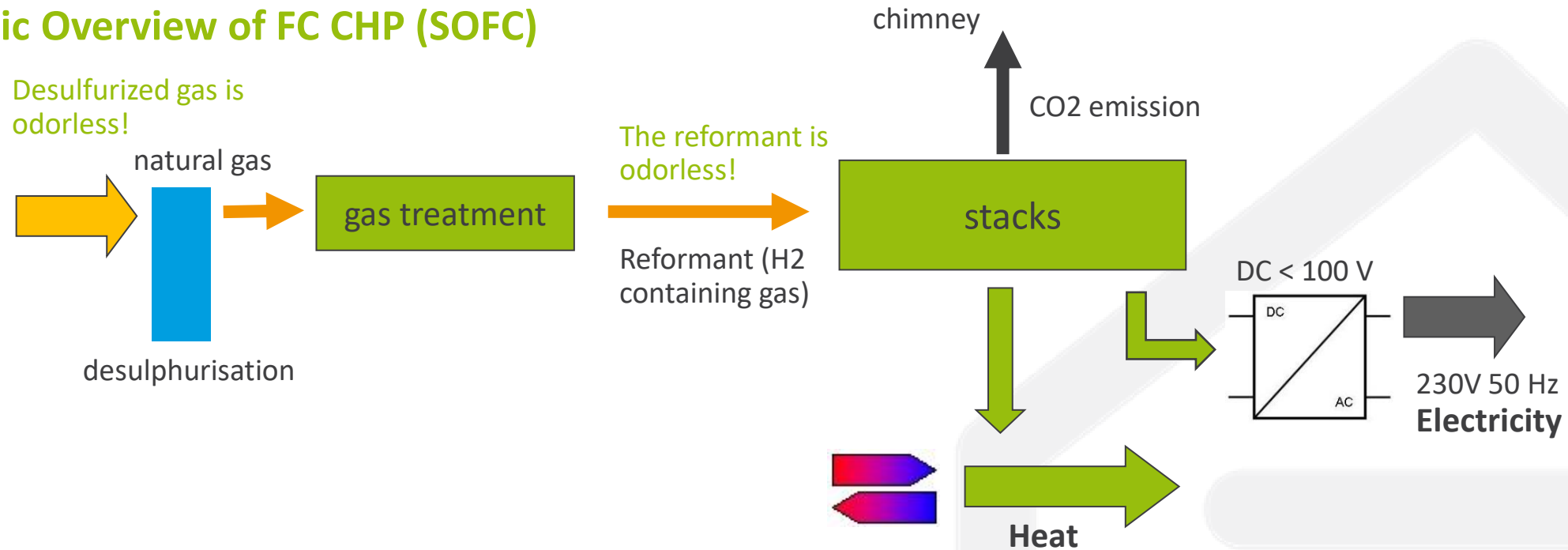


Source: WBZU, ZSW, Callux

II. The Fuel Cell CHP

II 1. General

Schematic Overview of FC CHP (SOFC)



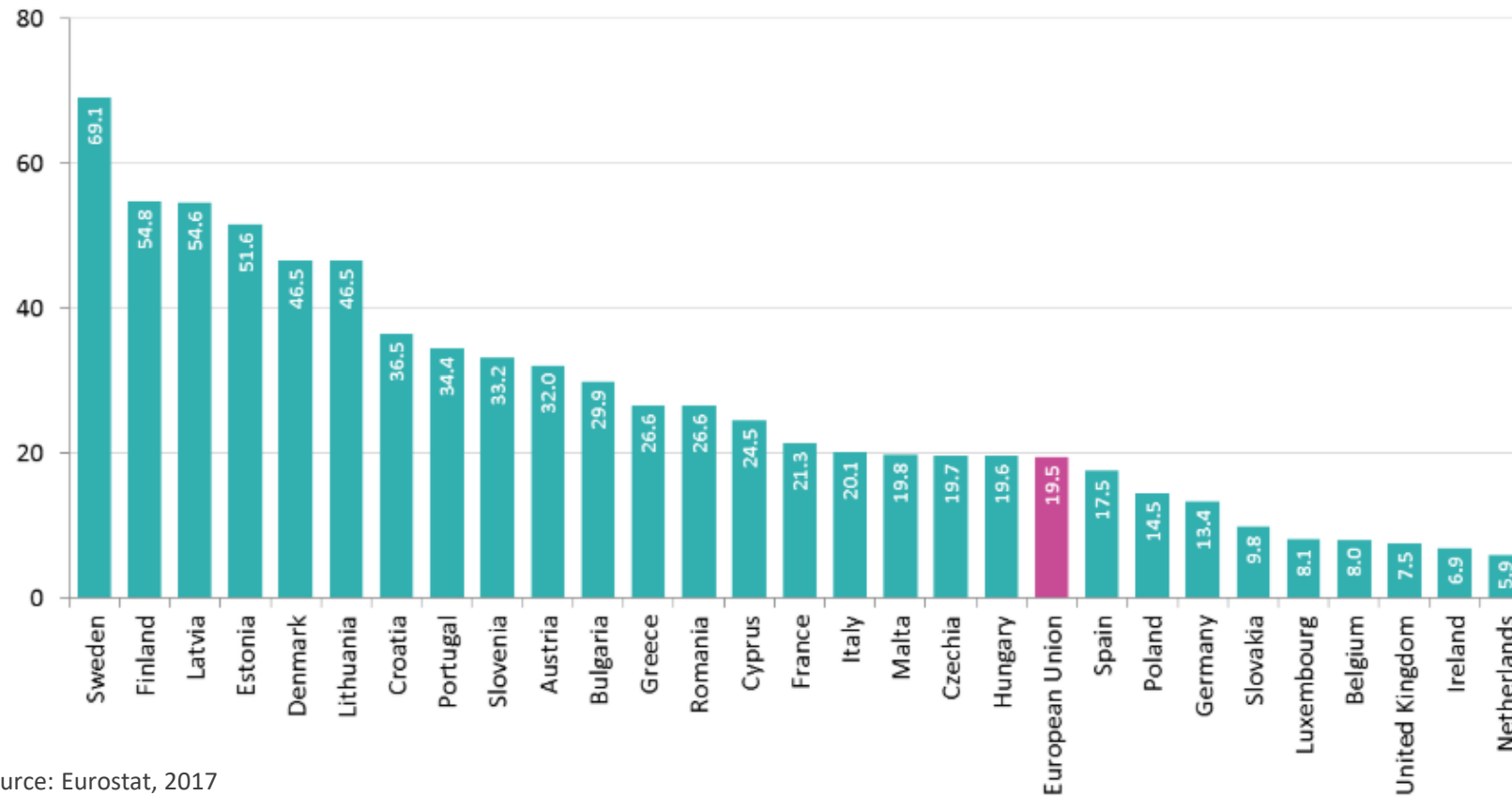
Source: WBZU, ZSW, Callux

II. The Fuel Cell CHP

II 2. Market and Environment

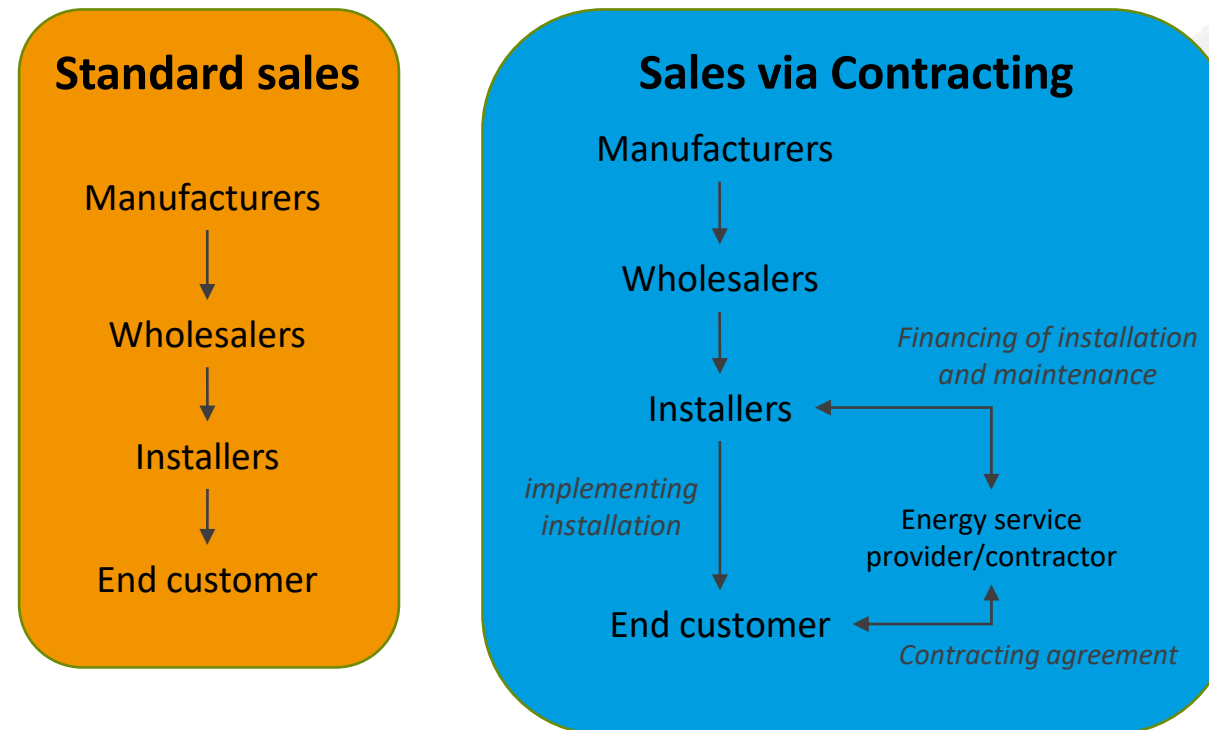
The need to modernise outdated heating technology across EU

Share of total energy used for heating and cooling coming from renewable sources, 2017
(%)



New Technology, New Distribution Models

Depending on the manufacturer or sales partner, different sales models are conceivable.



II. The Fuel Cell CHP

II 2. Market and Environment

General Market Overview (1)

				
Manufacturer	Bosch	SOLIDpower - BlueGEN	SOLIDpower – BlueGEN BG-15	Sunfire
Type	SOFC	HT SOFC	SOFC	SOFC
Electrical Output	0.7 kW	1.5 kW	1.5 kW	0.75 kW
Thermal Output	0.7 kW	0.6 kW	1.0 kW	1.25 kW
Electrical/Thermal Efficiency	45% (2016)	60%/25%	53-57%/40%	38%/50%
Overall efficiency	85%	85%	88-93%	88%
Fuel flexibility	H-gas, L-gas, Green-Gas (methane)	H-gas, L-gas, Green-Gas (methane)	I2H, I2E	LPG, Natural gas
Stack Lifetime	90,000 hours (2016)	60,000 hours	40,000 hours	-
System Life	10 years	15 years	Min 10 years	Min 10 years

General Market Overview (2)

II. The Fuel Cell CHP

II 2. Market and Environment



Manufacturer	BDR Thermea	Viesmann – Vitovalor 300-P	Viessmann SOFC (Galileo successor)
Type	PEMFC	PEMFC	SOFC
Electrical Output	0.75 kW	0.75 kW	1.0 kW
Thermal Output	1.1 kW	1.0 kW	1.25 kW
Electrical/Thermal Efficiency	37%/55%	35-40%/53%	40%/50%
Overall efficiency	92%	90%	90%
Fuel flexibility	Natural gas (E/LL)	Natural gas (E/LL)	Natural gas (E/LL)
Stack Lifetime	80,000 hours	80,000 hours	Over 35,000 hours
System Life	Up to 20 years	More than 10 years	More than 10 years

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IV. Further Topics

1. CO₂ and pollutant emissions
2. FC CHP in the energy system of tomorrow
3. Operation and safety



III. Fuel Cell CHP Consultancy

III 1. Goals, methods and processes

The Right Technology for the Right Customer

FC CHPs are still expensive and require appropriate consultation with the customer - pay attention to the customer's reaction (e.g. their external impression).

Do not be a salesman, but a consultant – an understanding the customer and their needs (e.g. energy demand, economical use) is the most important factor. The goal is to find the best solution.

The starting point is the technical feasibility and wishes/perceptions of the customer. The basis for this is competence and trust.

By asking the right questions (instead of explanations), consultants can optimally adjust to the customer. The advantages of this technique are:

- The customer's wishes and ideas become clear
- Customers feel they are taken seriously and in are good hands - creates trust
- With casual questions, important keywords can be brought into play

III. Fuel Cell CHP Consultancy

III 1. Goals, methods and processes

Listening and (re)acting competently

Consultations are dialogues! Interested parties want to exchange ideas.

Interested customers are usually already well informed before a consultation. Nevertheless they often have incorrect assumptions. These are to be corrected based on the context and using best judgement.

The art of the consultation consists of:

- responding flexibly to ideas and using emotions positively,
- correcting any false assumptions convincingly (not offensively),
- making complex facts easy to understand.

III. Fuel Cell CHP Consultancy

III 1. Goals, methods and processes

Multi-stage consulting processes are crucial

1. Clarification of key points

- Technical and structural framework conditions
- Customer's ideas
- Financability / estimation of investment costs / sales models

2. Planning

- Develop concrete plans
- Create a quote
- Create profitability calculations

3. Order placement

III. Fuel Cell CHP Consultancy

III 1. Goals, methods and processes

The (formal) counselling interview

The (formal) consultation takes place at the customer's request and should be well prepared.

Part of the preparation:

- Make an appointment (allow enough time (1.5 - 2 h)),
- Ask customers to have electricity and gas bills for the last 2-3 years ready at hand,
- Review existing customer data, if applicable, and
- Make notes for preliminary talks.

Checklist:

- business card, camera, notepad, pencil
- Checklist for on-site inspection
- FC CHP documents, product brochures
- Notebook with animations/calculation program if necessary
- Meter or hand laser length measuring device.

III. Fuel Cell CHP Consultancy

III 1. Goals, methods and processes

The (informal) consultation – using customer contact proactively

- Informal consultations are discussions on specialist topics that can take place anytime and anywhere - are potential "door openers"
- Actively use this non-binding discussion to give food for thought or tips "in confidence" (e.g. for service activities)
- For this, every employee of your company should:
 - Know the most important arguments, performance data and general conditions required for FC CHP
 - Be able to respond competently to requests (and do so)
 - Point out FC CHPs to customers as an option
- Use easily understandable terms, e.g. electricity-generating heating, micro or mini power station

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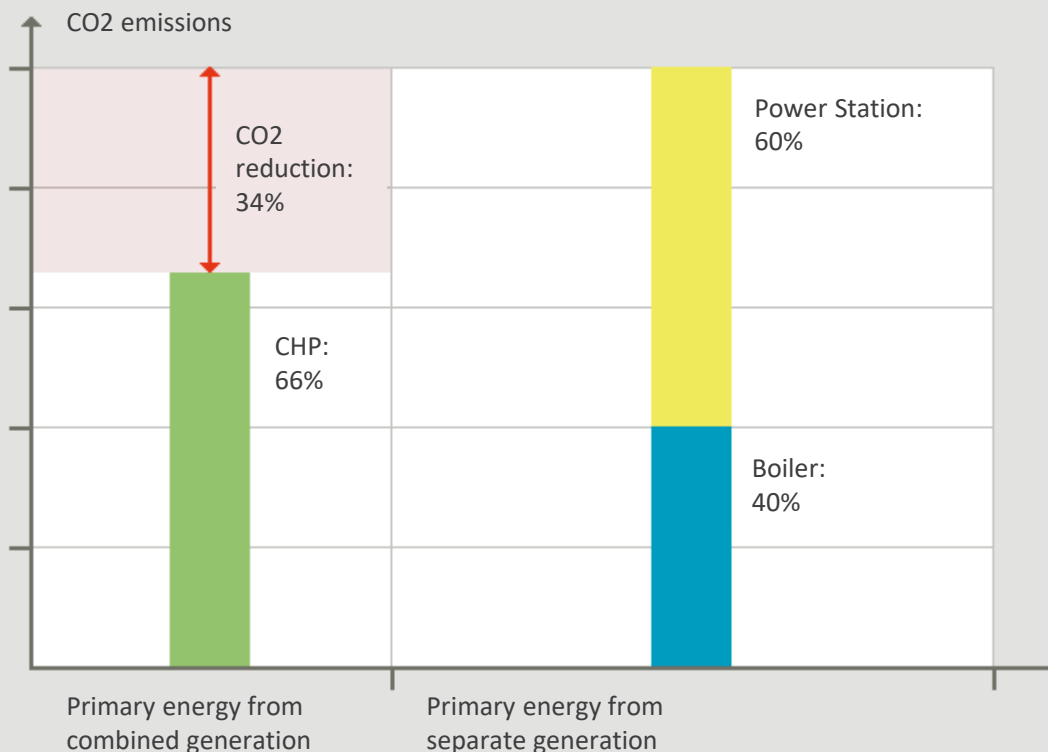
IV. Further Topics

1. CO₂ and pollutant emissions
2. FC CHP in the energy system of tomorrow
3. Operation and safety



Primary energy demand and CO₂ emissions

CO₂ emissions for the useful energy of 34 units of electricity and 56 units of heat



IV. Further Topics

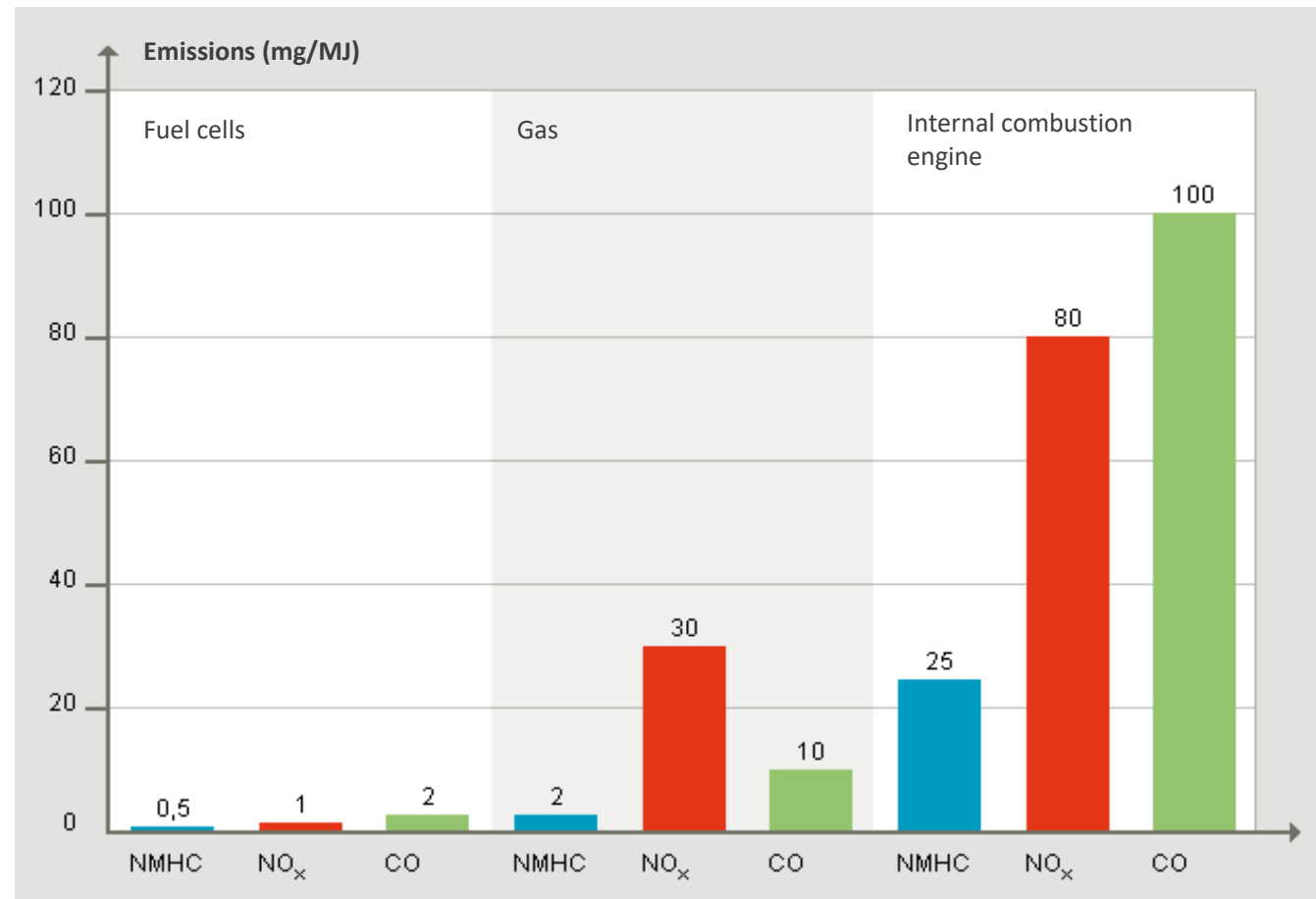
IV 1. CO₂ and Pollutant Emissions

- Whilst this graph shows a typical example, actual CO₂ savings can be larger depending upon the electricity mix in a specific country (e.g. countries with a larger proportion of coal on the electricity grid) and whether the gas feed is fully natural gas or biogas (more biogas = larger CO₂ saving).
- In addition, almost all fuel cell mCHPs are compatible with hydrogen following small adjustments to the units. They are thus potentially carbon neutral.
- The key message: FC mCHPs offer a CO₂ reduction now and a carbon-free future.

Pollutant emissions

IV. Further Topics

IV 1. CO₂ and Pollutant Emissions

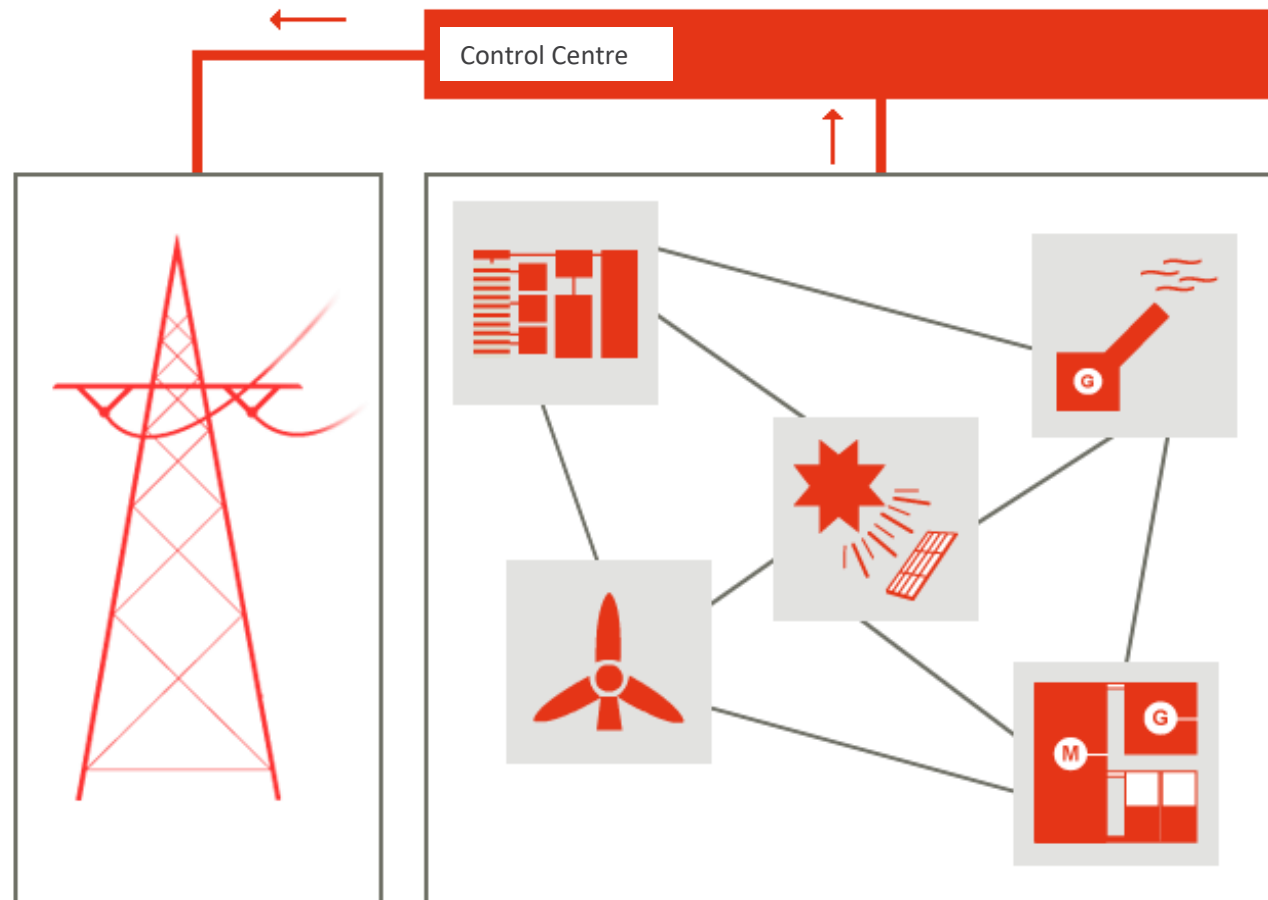


Source: Callux, <http://www.callux.net/files/basismodul/start.html>

IV. Further Topics

IV 2. FC CHP in the energy system of tomorrow

FC CHP in tomorrow's energy system – virtual power plants (VPPs)



Source: Callux, <http://www.callux.net/files/basismodul/start.html>

IV. Further Topics

IV 3. Operation and Safety

Operation

FC CHP are not designed for operation in isolation:

- Current-controlled operation with (subsidised) CHP only permissible if the heat can always also be used.
- Power cannot be regulated to the second.
- Electricity (from the mains) is required to start the FC CHP.
- FC CHP are therefore generally operated in parallel to the mains (although can run “Off grid” on a battery).
- In the event of a mains failure, isolated operation is conceivable for the device alone - for safety reasons, however, a mains disconnection occurs immediately.
- The device itself, however, continues to be supplied with electricity and continues to generate heat, which can also be used.

IV. Further Topics

IV 3. Operation and Safety

Safety when using hydrogen

- FC CHP are gas appliances running on gas from the grid (natural gas, liquid gas, biogas, hydrogen gas blends).
- Large quantities of hydrogen are also bound in natural/bio gas: Natural gas group H, for example, consists of 89% methane (CH₄).
- In FC CHP only very small amounts of H₂ are present (less than 1 litre between reformer and stack)
- The technical processing of H₂ has been standard in the industry for many decades.
- H₂ is non-toxic and does not harm the environment
- FC CHP naturally meet all safety requirements - just like any other tested gas appliance.



Pathway to a Competitive European
Fuel Cell micro-CHP Market

All material in this training pack is
credited to material developed during
the Callux Project.

Thanks are offered to NOW for
permitting use of this material:



Contact:

PACE | c/o COGEN Europe
Avenue des Arts 3-4-5
1210 Brussels
Belgium

Phone: +32 - 2 772 82 90

Email: info@pace-energy.eu

Web: www.pace-energy.eu





Pathway to a Competitive European
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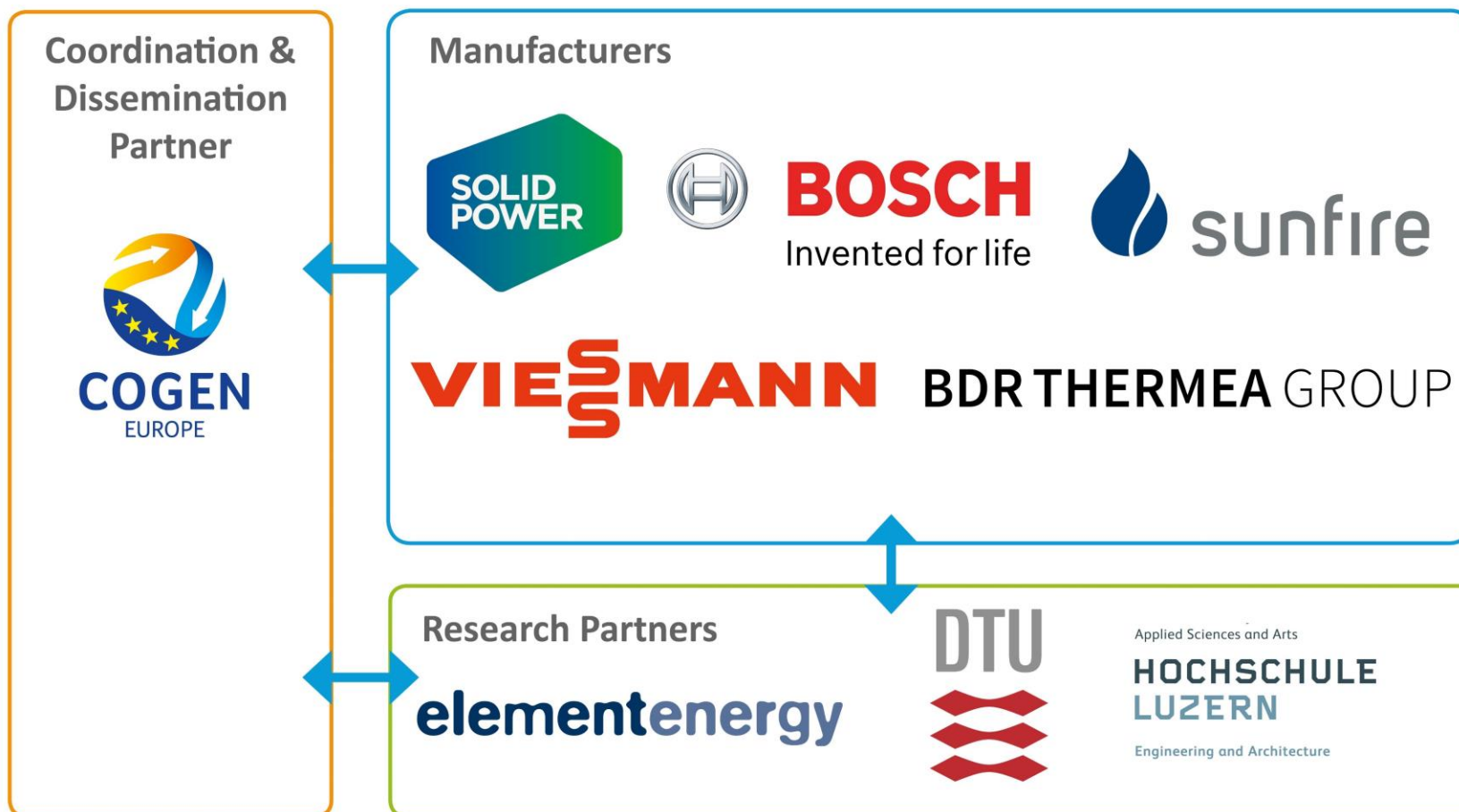
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Module 2: Planning, Dimensioning and Formal Requirements



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- mCHP – Micro Combined Heat and Power Unit
- FC – Fuel cell
- FCH JU – Fuel Cells and Hydrogen Joint Undertaking
- GDL – Gas Diffusion Layers
- kW – Kilowatt

List of Abbreviations

Module 2: Planning, Dimensioning and Formal Requirements

- kWh – Kilowatt Hour
- MSD – Mains Monitoring Units with Allocated All-pole Switching Devices (MSD)
- MW – Megawatt
- PEMFC – Proton-Exchange Membrane Fuel Cell
- SOFC – Solid Oxide Fuel Cell
- VPP – Virtual Power Plant

I. Requirements for the Use of a FC CHP

1. Heat and Electricity Demand
2. User Behaviour
3. Preconditions for Installation
4. Installation of the FC CHP

II. General Planning Requirements

1. Checklist
2. Hydraulics
3. Storage
4. Supply and Exhaust System
5. Electric installation
6. Data Transfer

III. Formal Requirements

1. During the Planning
2. Before Operation
3. After Installation/Commissioning
4. Paperwork/Explanations
5. Subsidy Funding



Heat-lead appliances

- Similar or higher electrical vs thermal output (e.g. 0.7kW each for Bosch SOFC; 0.8kW electrical vs 1.5kW thermal output for Sunfire SOFC)
- Similar or higher thermal efficiency vs electrical efficiency
- Suit households with high heat demand but lower electrical demand (e.g. older buildings in cold climates without electrified heating appliances)
- Note that an additional peak load boiler is often required regardless

I. Requirements for use of a FC CHP

I 1. Heat and Electricity Demand

Electricity-lead appliances

- Higher electrical vs. thermal output (typically ~1.5kW electrical output and 0.6kW thermal output)
- Higher electrical efficiency than thermal efficiency
- Suit households with electrified heating appliances or notably large electricity consumption (e.g. regular electric vehicle charging)

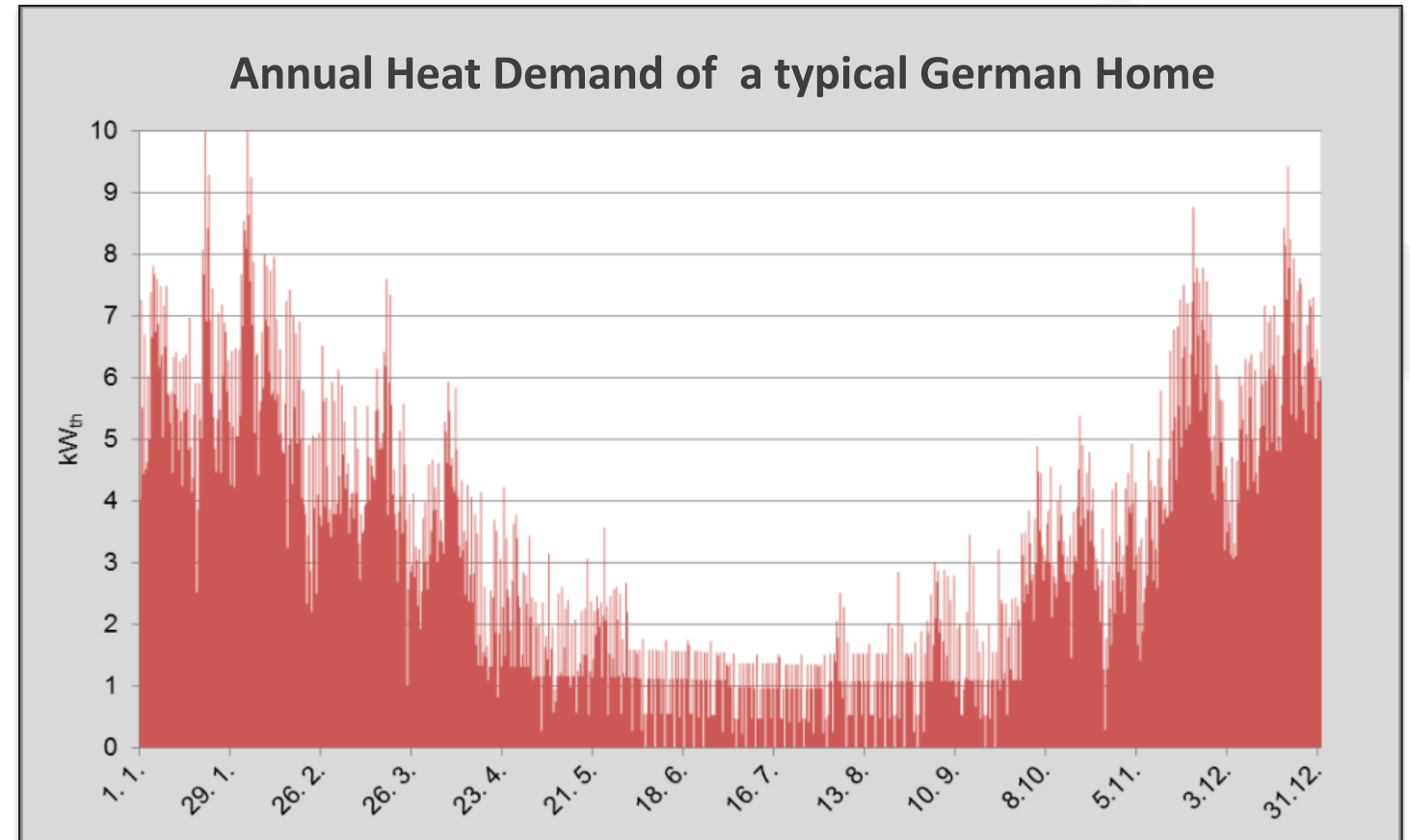
Heat Demand

Given that the heat requirements of a building are seasonally-determined (see graph) and FC mCHP units ideally run constantly, it is recommended to have a separate hot water storage paired with a FC mCHP that is capable of modulating its thermal output to match the peak load boiler.

The thermal output of the FC CHP should cover a maximum of about 20% of the peak load. It is therefore important to determine what the peak load of the building might be.

I. Requirements for use of a FC CHP

I 1. Heat and Electricity Demand



Source: Callux; Gertec GmbH

Electricity Demand

At 8,760 operating hours per year (constant operation), a FC CHP with 1 kW_{el} output at full load would produce 8,760 kWh of electricity per year.

The FC mCHP covers the base load. Higher requirements are drawn from the grid and excess electricity is fed into the grid.

I. Requirements for use of a FC CHP

I 1. Heat and Electricity Demand

Country	Annual Electricity Demand for 4-person Family (kWh)	Source
Germany	3,500	Callux
UK	3,700	Enerdata
Italy	2,500	Selectra
Netherlands	3,605	City Centre Estates



Source: Hager.de

I. Requirements for use of a FC CHP

I 2. User Behaviour

User Behaviour

Like all modern systems, FC CHP work automatically and with high efficiency.

Nevertheless, users can influence the function, economy, and efficiency of a system through their behaviour.

They should therefore be familiar with the system characteristics/control system and energy-relevant processes in the building.

Also, in order to avoid possible user errors leading to a loss of comfort, a detailed introduction to the system upon installation is important.

I. Requirements for use of a FC CHP

I 3. Preconditions for Installation

Installation Considerations

- Natural gas connection (including additional requirements such as condensing boiler)
- Available power supply (requirements: 230 Volt/50 Hz)
- Exhaust gas discharge: what is the required minimum length of the flue line? Is an open or direct flue possible? Is fresh air intake possible?
- Condensation removal (taking into account its calorific value)
- Are FC CHPs authorised and legal?
- Is a data (internet) connection possible?
- Space requirement: what is the minimum height, width and depth of the installation room?
- Is it possible to provide decalcified water?

I. Requirements for use of a FC CHP

I 4. Installation of the FC CHP

Requirements arise from

- Building regulations and fire protection laws
- Heating regulations
- Technical rules for gas installation
- Sound insulation
- Room size: Installation area, room height, work area for maintenance, connection options for water and gas, supply and return air, waste water
- Options for multiple use
- Access points

I. Requirements for use of a FC CHP

I 4. Installation of the FC CHP

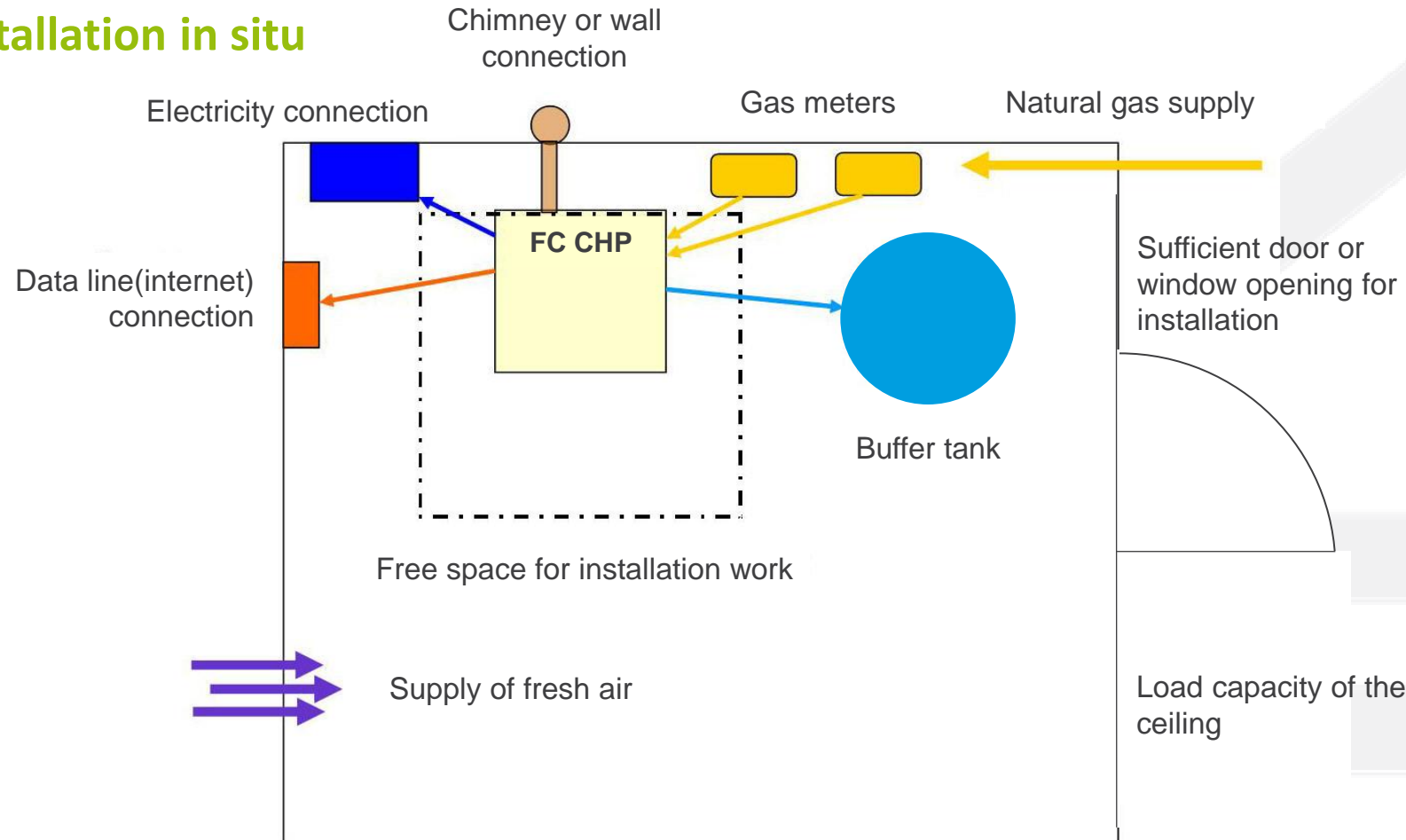
Installation of the FC CHP

- For delivery and installation, the following must be considered:
 - Size of door openings or stairs
 - Possibly necessary construction measures (e.g. breakthrough)
 - Angle of inclination when transporting the FC CHP
 - Suitable transport equipment (the largest individual component is usually the buffer storage tank)
- The installation room requires the following:
 - Sufficient space for the FC CHP and connection to the heating system (see manufacturer's documentation)
 - Accessibility for maintenance and repair work (approx. 0.5 - 1.0 m in front of and next to FC CHP)
 - To be able to withstand static load
 - To be dry, frost-free and ventilated

I. Requirements for use of a FC CHP

I 4. Installation of the FC CHP

An example of installation in situ



I. Requirements for the Use of a FC CHP

1. Heat and Electricity Demand
2. User Behaviour
3. Preconditions for Installation
4. Installation of the FC CHP

II. General Planning Requirements

1. Checklist
2. Hydraulics
3. Storage
4. Supply and Exhaust System
5. Electrical installation
6. Data Transmission

III. Formal Requirements

1. During the Planning
2. Before Operation
3. After Installation/Commissioning
4. Paperwork/Explanations
5. Subsidy Funding



Working with Checklists

Ensure the correct technical checklist for the unit being installed is obtained before installation begins

Source: Bosch

Location:
Name:

Province:

Postcode: City:

Street:

Telephone:

User data:
Inhabitants: adults: children:

Employed: school:

Building:
☐ Single family house ☐ stand-alone ☐ mid-terrace house
☐ End-terrace house

With basement ☐ yes ☐ No

Floors:

Living space, heated [m²]:

Year of construction:

Reconstruction measures:
When have the measures been realized?

Which measures have been realized?

Is a gas connection installed already?
☐ Yes ☐ No ☐ planned
Distance of gas connection to µCHP-System [mtr]:

When is it planned to install the gas connection?
 Jan

II. General Planning Requirements

II 1. Checklist

Which gas quality is provided by your utility company?

☐ H-gas ☐ L-gas ☐ different

Description of delivered gas, upper heating value [kWh/m³]:

If possible, please enclose your latest gas accounting!

The µCHP-system shall be installed at which location in the building?

☐ Roof ☐ Cellar ☐ residential area ☐ garage
☐ Different place

Description of installation space (width x height x depth), please enclose picture or drawing.

Passing of exhaust-gas line

☐ Vertical ☐ horizontal

Vertical length [mtr]:

Horizontal length [mtr]:

Please enclose picture or drawing with chimney position.

Current heat generator

☐ Gas ☐ oil ☐ solid ☐ heating rod ☐ heat pump
☐ Different

Description of heat generator when „different“ is chosen:

Performance [kW]: age [years]:

How was the energy consumption during the last 3 years [kWh/a]?

2009

2010

2011

Please enclose a picture of the current installation.

How often is domestic water tapped in your household (shower, bathing number/week)

☐ 1-5 ☐ 5-10 ☐ 10-15 ☐ 15-20

Is a circulation line installed?

☐ Yes ☐ No

Are renewable energies used?

☐ Yes ☐ no

Which renewable energies?

Please answer only, if photovoltaic is installed.

☐ 100% feed-in of produced electricity to the grid
☐ Feed-in and own consumption

Electricity consumption:

How was the electricity consumption during the last 3 years [kWh/a]?

2009

2010

2011

Electronic installation

Is it possible to install additional meters in the electric meter cabinet?

☐ Yes ☐ No

Are heat generator and electric meter cabinet installed at the same floor?

☐ Yes ☐ No

If no: How many floors are in between?

Are heat generator and electric meter cabinet installed in the same room?

☐ Yes ☐ No

If no: How many walls are in between?

How far is the distance between electric meter cabinet and µCHP-location [mtr]?

Please enclose picture or drawing for each.

Network operator and utility company

Who is your current utility company?

Who is your network operator?

II. General Planning Requirements

II 2. Hydraulics

Requirements for Hydraulic Integration

1. Heat from the FC CHP must be dissipated reliably
2. Ability to meet heat demand
3. Ability to realise long running times for the FC CHP
4. Efficient use of fuel used

The hydraulic integration

- is based on the manufacturer's specifications,
- is comparable with other efficient technologies such as heat pumps, solar heating backup, etc.

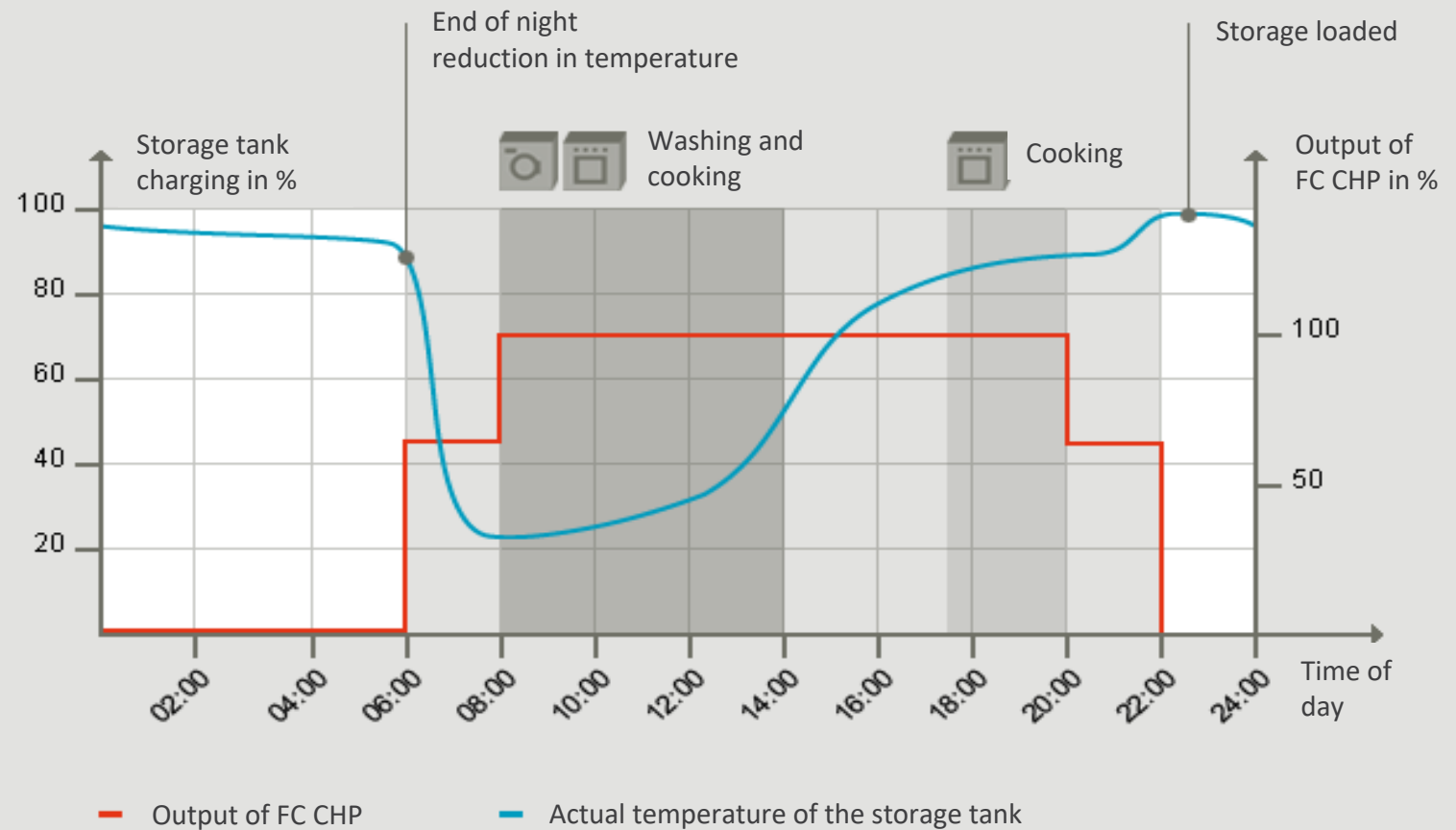
It is important to coordinate integration with the unit manufacturer's suggestions/requirements.

Storage and the FC CHP

II. General Planning Requirements

II 3. Storage

Demand adjustment through storage management



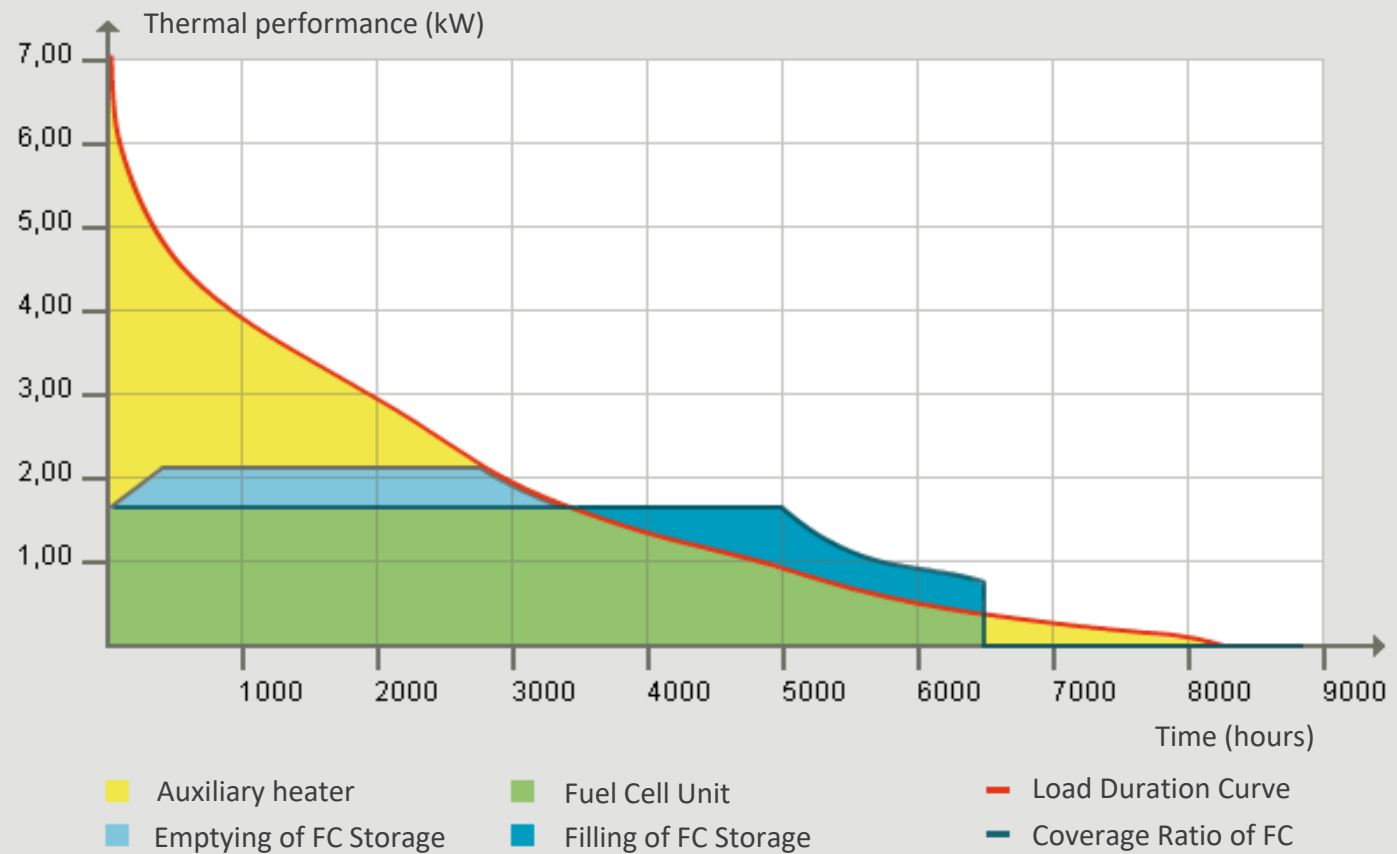
Storage and the FC CHP (2)

NB. This curve is based upon a
FC mCHP with a heat output of
1.5kW. The shape of the curve
depends upon the size of the FC
mCHP heat output

II. General Planning Requirements

II 3. Storage

Load duration curve of warming demand and coverage by FC CHP (example)



II. General Planning Requirements

II 4. Supply and Exhaust System

Framework conditions for the supply and exhaust air system:

- Classification of FC CHP according to equipment class is crucial
- Similar requirements often apply to FC mCHPs as for gas condensing boilers
- Important to use moisture-resistant exhaust pipes due to low exhaust gas temperatures
- Ensure that condensation is extracted (see manufacturer's instructions)
- Length of exhaust system and number of deflections according to manufacturer's specifications
- Early consultation with chimney cleaning providers is useful – they need to agree with the installation

II. General Planning Requirements

II 4. Supply and Exhaust System

Regulations by country

Country	Regulation Name	Description	To-do for Installer
Denmark	Gasreglementet	Same requirements as a conventional boiler	Must be a certified plumber.
France	Arête du 2 aout 1977; Arrêté du 30 novembre 2005	Same requirements as a conventional boiler	Must be a certified plumber
Germany	DVGW G2000 (2011)	Same requirements as a conventional boiler	Unit requires registration with gas grid operator by both the qualified installer and the user. Fees vary as there are 730 different operators.
Italy	UNI 7129 (2008) / UNI 7140 (2013)	Same requirements as a conventional boiler	Must be a qualified installer compliant with CEI and UNI regulations.
UK	Gas Safety Regulations (1998)	Same requirements as a conventional boiler	Installer must have undertaken CCN1 Gas Safety Assessment and hence be on the Gas Safe Register.

II. General Planning Requirements

II 5. Electrical Installation

Electrical Installation

There is no common EU framework on the requirements for electrical installation.

Energy Efficiency Directive (2012/27) requires member states to adopt simplified grid connection ‘install and inform’ procedures. In theory means grid operators provide priority or guaranteed access to grid for highly energy efficient tech. This is rarely truly the case in reality.

The most important questions to answer in advance of installation are:

- Is it a new or old building?
- Is the meter cabinet large enough to accommodate a feed-in meter?
- Does the energy supplier allow the connection of electricity generating systems to the grid?
- Do electricians need special training/certifications to be able to carry out FC mCHP installations in your country?

Connection of a FC CHP:

- What are the electricity meter requirements in your country?
- What are the electrical safety requirements in your country (e.g. for a circuit breaker/mains power protector in case of surges?). This may vary depending on if unit-owner plans on only self-consuming electricity vs selling surplus to the grid.

Regulations by country

II. General Planning Requirements

II 5. Electrical Installation

Country	Regulation Name	Description	To-do for Installer
Denmark	<ul style="list-style-type: none"> Teknisk Forskrift 3.2.1 	<ul style="list-style-type: none"> For power producing plants with current below 11A /11kW. Based on EU nor, EN 50438. DSO responsible for registering of metering data and reporting of plant data to TSO. 	<ul style="list-style-type: none"> Use a bidirectional meter. Facilitate the signing of agreements between the producer (FC mCHP owner) and the DSO and TSO (this paperwork takes 1-2 weeks to clear). No special qualifications required for electrician.
France	<ul style="list-style-type: none"> Decree No. 2008-386 	<ul style="list-style-type: none"> Sets a clear list of requirements -> 	<ul style="list-style-type: none"> Requirement for a circuit breaker with public access (NF C 14-100); electronic meters; and an agreement between the DSO and the producer (usually takes 1 month to clear – requires signatures). Two meters required if selling surplus electricity. Qualified electricians required for commissioning.
Germany	<ul style="list-style-type: none"> KWK-G, Kraft-Wärme-Kopplungsgesetz VDE-AR-N 4105:2011-08 	<ul style="list-style-type: none"> Enshrines right for all CHP units to be connected to electricity grid. Outlines a number of forms that need to be filled in before commissioning and after commissioning. 	<ul style="list-style-type: none"> Fill in forms G1, G2, G3, F2 and a Scheme Plan before installation. Fill in form F1 after commissioning. Installers require special training on CHP units and grid connection.
Italy	<ul style="list-style-type: none"> CEI 0-21 CEI 64-8 	<ul style="list-style-type: none"> Specific requirements concerning protection devices and metering. DSO personnel required to complete metering. Defines design and installation criteria and how to complete compliance certificate for electrical installation. 	<ul style="list-style-type: none"> A security circuit breaker is required, along with a bidirectional smart meter. Facilitate agreement between DSO and producer (average 20 days for completion). Must be a qualified electrician to complete grid connection.
UK	<ul style="list-style-type: none"> EREC G83/2 	<ul style="list-style-type: none"> Operates on a ‘fit and inform’ basis in which mCHP unit is connected to the grid and then DSO is informed (G83 notification). Products must be certified under Microgeneration Certification Scheme (MCS). 	<ul style="list-style-type: none"> Only a generation meter is required, not an export meter. Installer must be certified under Microgeneration Certification Scheme (MCS).

II. General Planning Requirements

II 6. Data Transmission

Data (internet) Connection

FC CHPs are currently designed with remote monitoring. Data communication is often a necessary condition for receiving funding under EU-funded projects (such as PACE). The units can also run without data connection.

Before selecting the data (internet) connection, it is necessary to check which communication options are available at the installation site and what costs they cause.

Some units require an ethernet connection, and some can use WiFi/GSM.

In order to protect the connection against unauthorized access, encryption technology is required for data transmission.

I. Requirements for the Use of a FC CHP

1. Heat and Electricity Demand
2. User Behaviour
3. Preconditions for Installation
4. Installation of the FC CHP

II. General Planning Requirements

1. Checklist
2. Hydraulics
3. Storage
4. Supply and Exhaust System
5. Electric installation
6. Data Transfer

III. Formal Requirements

1. During the Planning
2. Before Operation
3. After Installation/Commissioning
4. Paperwork/Explanations
5. Subsidy Funding



III. Formal Requirements

III 1. During the Planning

Gas network operator and natural gas supplier

Gas network operator:

- FC CHPs register as conventional gas appliance (by locally approved gas installation company)
- Manufacturer's documents must be enclosed (CE declaration of conformity, approval certificate for exhaust system)
- Specify the connected load
- Installation of a separate calibrated meter
- If there is no gas connection, agree on a natural gas network connection contract with gas meter and, if necessary, pipe connection

Natural gas supplier:

- Contact recommended

III. Formal Requirements

III 1. During the Planning

Chimney sweeps and building authorities

It is important(/mandatory in some countries) to contact (district) chimney sweeps prior to installation:

- A necessary process for gas supply by gas network operators.
- Include this in planning at an early stage
- Certifies the suitability and safe usability of the exhaust system
- If necessary, coordinate new exhaust system with the chimney sweep and submit technical documentation from the FC CHP manufacturer.
- Fireplace acceptance takes place after commissioning.
- Note approval requirements vary

III. Formal Requirements

III 2. In Operation

Electricity grid operator

As detailed before, sometimes DSOs and TSOs must approve use of a FC mCHP plant and the right to feed CHP electricity into the distribution grid. The process requires:

- Requesting application for grid connection and for operation of a generation plant (by approved electrical installation company),
- Submission of manufacturer's documents (declaration of conformity and safety certificate) and documentation on the installation site (site plan and system diagram).

A separate electricity meter is often required in this case – a generation meter with bidirectional measurement. This will need to be commissioned.

From a legal point of view, the FC CHP operator must conform to grid use rules. Details will have to be provided to the grid operator to organise remuneration.

There are associated small business regulations that may be relevant to the FC CHP operator (especially for VAT purposes).

III. Formal Requirements

III 3. After installation/commissioning

After installation considerations

There are specific requirements in each national jurisdiction for the specific requirement relating to how the unit must be verified to allow the start of grid-connected generation (relating to grid balancing etc).

The unit exhaust pipe system, data (internet) connection, auxiliary boiler function and overall unit function will also need to be verified during the commissioning process.

Re-inspection interval differs by country, but is usually every 2 years (and is generally dependent upon the service contract).

III. Formal Requirements

III 4. Paperwork/Explanations

Paperwork for tax office and electricity network operator

Specific paperwork submission requirements also apply to different national contexts.

Such paperwork that might be required include formal taxation certificates relating to the contribution of electricity to the grid/tax breaks for low-carbon technology.

Moreover, the electricity network operator will have requirements for the paperwork that must be submitted before grid connection can be initialised.

III. Formal Requirements

III 5. Subsidy Funding

General Funding Advice

Before placing the order to purchase or install the FC CHP, clarify the requirements for investment support and, if necessary, submit an application.

It is important, too, to examine whether multiple funding schemes are eligible together - some funding programmes are not jointly approved with other funding schemes.

Possible funding sources are included on the next slide.

As of Nov. 2019 (source: PACE, Challoch Energy)	Feed-in-tariff	Feed-in- premium	Quota obligation and certification scheme	CAPEX support	Tax incentives	Self-production incentives	Others
Poland	Yes	No	No	No	No	No	No
Italy	No	No	White certificates	No	Very general, rarely apply to cogeneration	Tax exemption on the gas used	No
The UK	Yes, starting 1st January 2020	No	No	No	No	No	No
France	No	No	No	No	No	No	No
Austria	No	No	No	Yes, if electrical output >100kW and supplies the public heating district	No	No	No
Belgium (Flanders region)	Yes, not specific to µCHP. Green electricity certificates are issued for systems >10kW if biogas is used.	No	No	No	No	No	Up to 30% of costs if installation <10kW, Jan 2018
The Netherlands	No	n/a	n/a	n/a	n/a	n/a	n/a
Germany	Yes	No	No	Yes, investment incentive program for mini-CHP from the Federal Environment Ministry	Yes, tax relief based on the Energy Tax Act	Yes	No
Switzerland	No	No	No	n/a	n/a	n/a	n/a
Luxembourg	Yes	No	n/a	n/a	Yes, mCHP plants between 1 and 6kW subsidised by the state	n/a	n/a

Additional Materials

Specific material on the FC mCHP is available in German on the Buderus webpage:

<https://www.buderus.de/de/technische-dokumentation?query=FC10&searchType=query>

Material on the specification of each PACE manufacturer's units will be found in PACE D1.7 'Summary report on specifications for 'Gen Y' systems for use in communication'. This has yet to be published, but once it has a link will be added to this slide.

In addition, each FC mCHP manufacturer has specific training materials for their unit, which is generally only issued during training events.



Pathway to a Competitive European
Fuel Cell micro-CHP Market

All material in this training pack is
credited to material developed during
the Callux Project.

Thanks are offered to NOW for
permitting use of this material:



Contact:

PACE | c/o COGEN Europe
Avenue des Arts 3-4-5
1210 Brussels
Belgium

Phone: +32 - 2 772 82 90

Email: info@pace-energy.eu

Web: www.pace-energy.eu





Pathway to a Competitive European
Fuel Cell micro-CHP Market

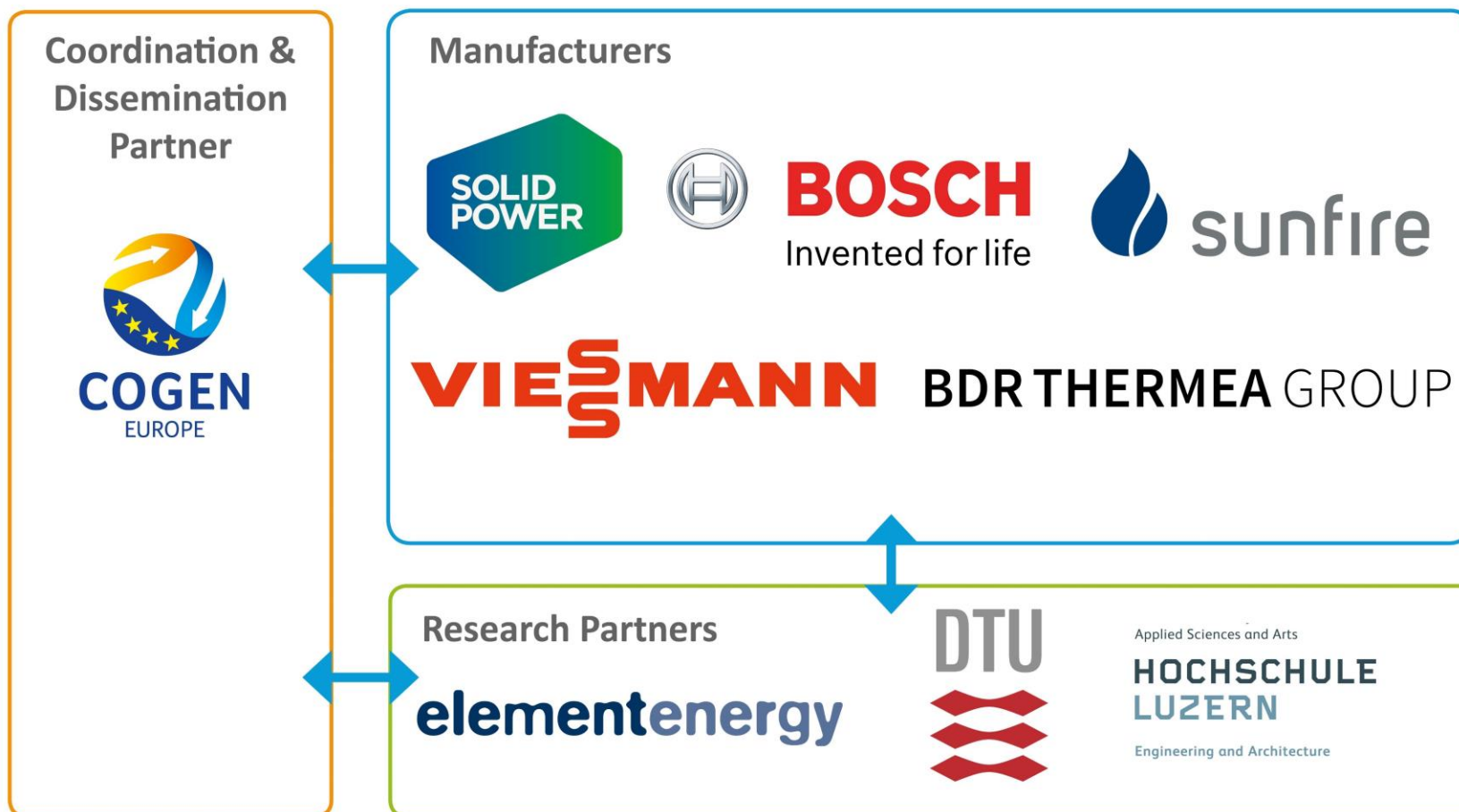
Fuel Cell Combined Heat and Power for Specialised Trade – Training Documents

Module 3: Electrical and Heating Installation



PACE project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 700339.

This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme and Hydrogen Europe and Hydrogen Research.



- The purpose of these training modules is to provide a general overview of the potential of Fuel Cell micro-Combined Heat and Power (FC mCHP) units as part of the future of European domestic energy.
- Each module in turn will focus upon a different aspect of FC mCHP units, with the aim to provide a working knowledge of the considerations that installers working with this technology will need to make.
- Specific material for each FC mCHP product can be obtained from each unit manufacturer, who also offer specific training on their units.
- These materials have been based upon material developed during the Callux project (2008-2016). Consequently, thanks go to NOW GmbH for permitting the use of this material:

- CHP – Combined Heat and Power (also known as Cogeneration)
- mCHP – Micro Combined Heat and Power Unit
- DSL – Digital Supply Line
- FC – Fuel cell
- FCH JU – Fuel Cells and Hydrogen Joint Undertaking
- GDL – Gas Diffusion Layers
- ISDN Integrated Services Digital Network
- kW – Kilowatt

List of Abbreviations

Module 3: Electrical and Heating Installation

- kWh – Kilowatt Hour
- MW – Megawatt
- N&S – Network and System
- PEMFC – Proton-Exchange Membrane Fuel Cell
- SOFC – Solid Oxide Fuel Cell
- VPP – Virtual Power Plant

I. Overall Process of Installation

II. Electrical Installation

1. Requirements for the Power Supply
2. Connection Options
3. Automatic Electricity Network Disconnection
4. Remote Monitoring/Data Communication

III. Heating Installation

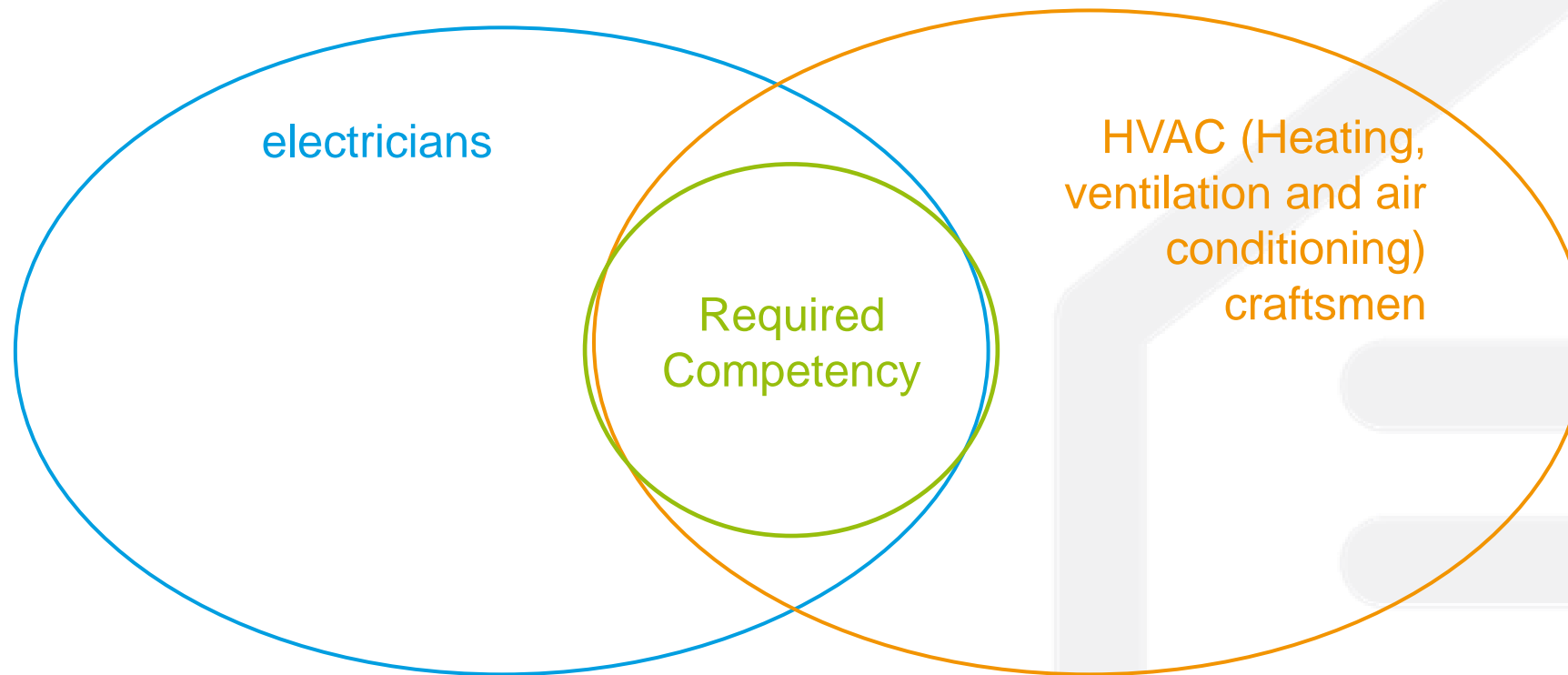
1. Requirements for the Installation Site
2. Hydraulic Integration
3. Supply and Exhaust System



I. Overall Process of Installation

The installation process and the participants

Allocation of work between the trades – requires knowledge of both the structure and connection of a FC CHP



I. Overall Process of Installation

Example of a workflow

- Preparatory work
- On site if necessary: bricklaying work, making breakthroughs, if necessary plastering and painting work etc.
- Delivery of the system to the customer
- Preparation of gas/water/heating connections
- Preparation of supply and return air connections
- Preparation of electrical connections
- Decommissioning of the existing heater
- If necessary, create a temporary solution for heating and/or hot water preparation.
- Dismantling of existing boiler components
- Device installation (FC CHP & storage)
- Structure and connection of buffer storage tank
- Structure and connection of auxiliary heater
- Preparation of internet connection
- Commissioning peak load boiler, heating operation is resumed
- Structure and connection FC CHP
- Commissioning by the factory customer service department

I. Overall Process of Installation

II. Electrical Installation

1. Requirements for the Power Supply
2. Connection Options
3. Automatic Electricity Network Disconnection
4. Remote Monitoring/Data Communication

III. Heating Installation

1. Requirements for the Installation Site
2. Hydraulic Integration
3. Supply and Exhaust System



II. Electrical Installation

II 1. Requirements for the Power Supply

Planning of electrical integration

- Meter cabinet: this is the main cost of electrical installation, along with the wiring to the FC CHP
- Suitable measuring equipment ("electricity meters") approved by utilities must be used
- The meters must be balancing or summing (i.e. all 3 phases must be balanced)
- Approved meters can be e.g. following models:



active supply meter



subscription
counter



bidirectional counter

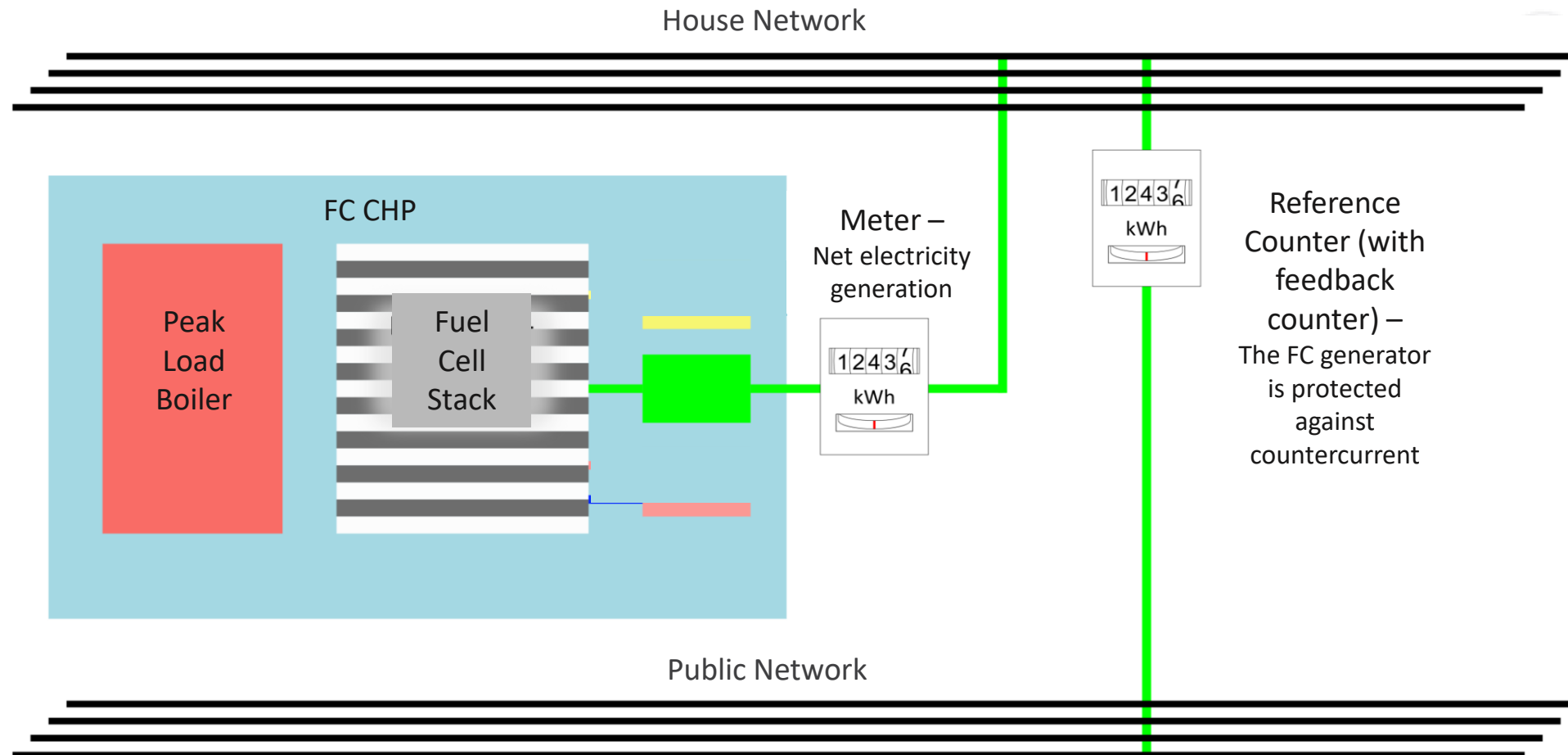


Meter cabinet

II. Electrical Installation

II 2. Connection Options

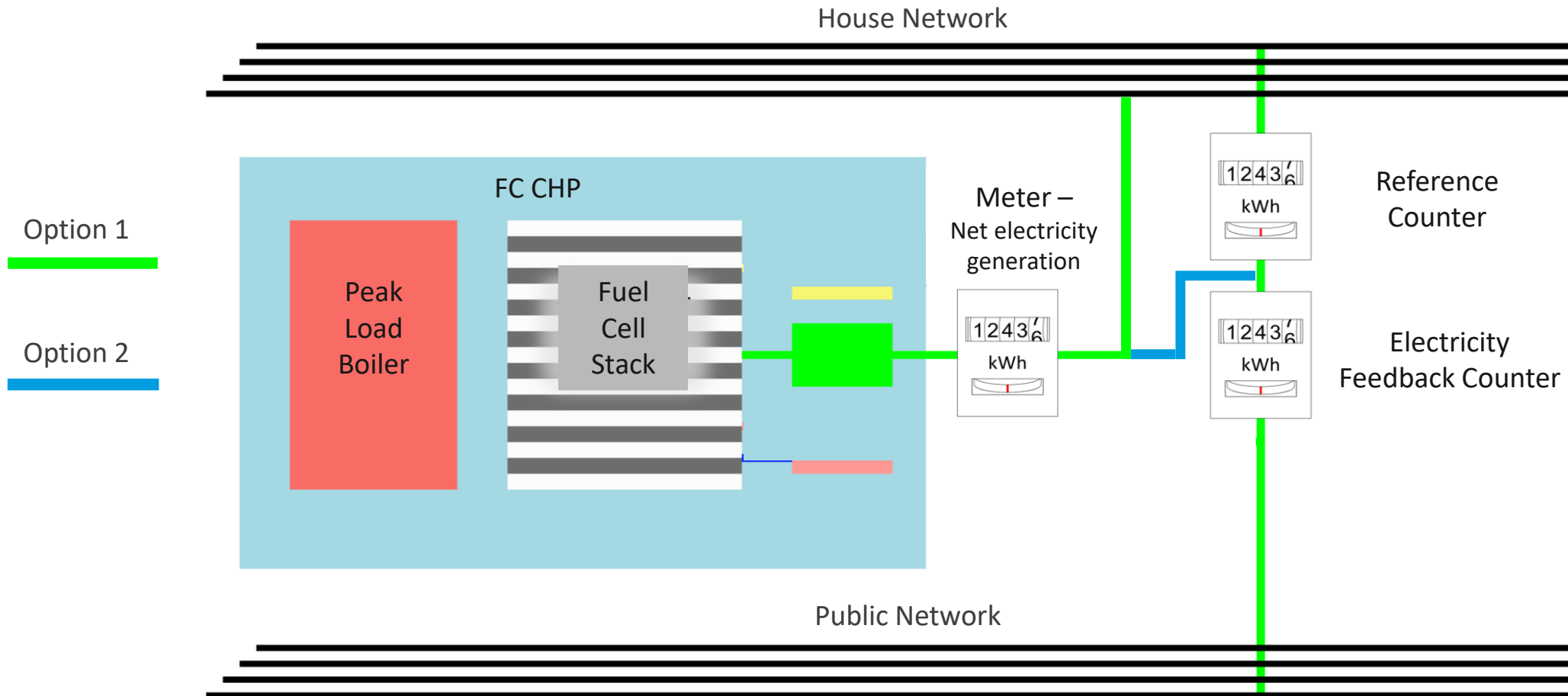
Example of a direct connection feed



II. Electrical Installation

II 2. Connection Options

Example of a connection variant accommodating excess supply

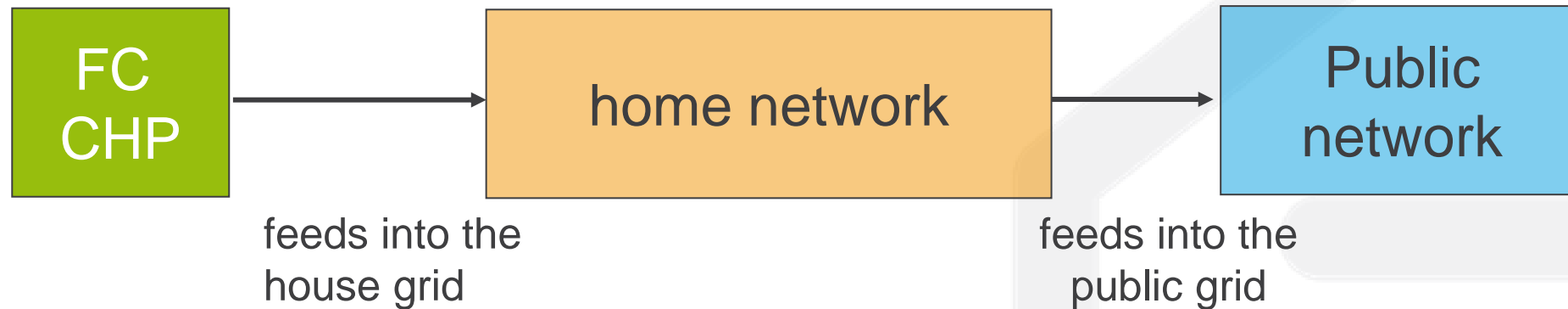


II. Electrical Installation

II 3. Automatic Electricity Network Disconnection

Safety Devices

- Mains and system protection fulfils an important safety-relevant task, allowing adherence to safety laws

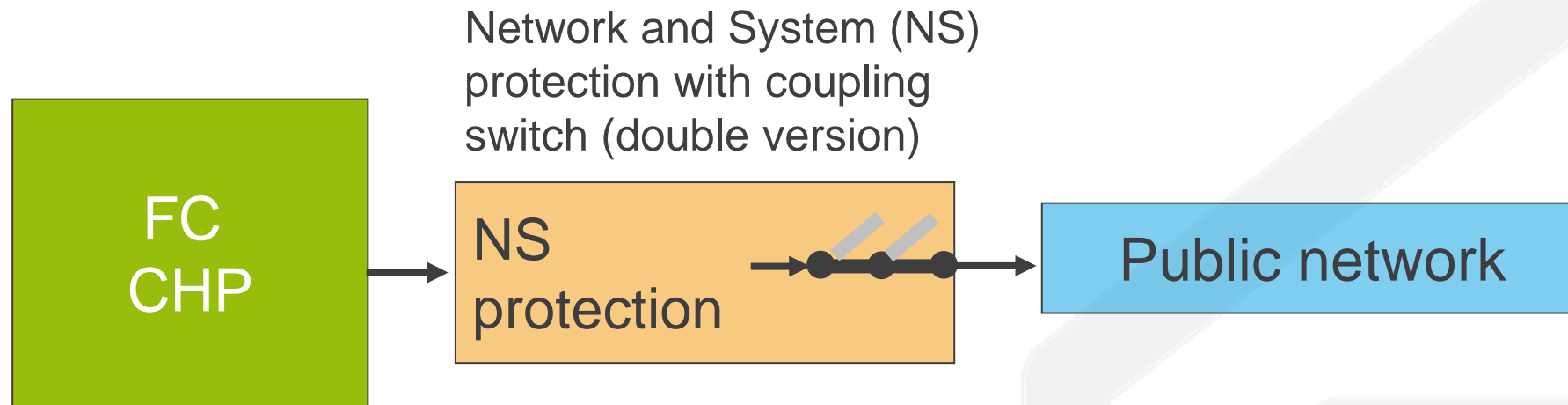


- If the public network is switched off for repair work, the line would be live due to regenerative power supply: Danger!

II. Electrical Installation

II 3. Automatic Electricity Network Disconnection

Safety Devices – automatic network disconnection



The NS protection checks for:

- Voltage drop or increase
- Frequency fall or increase
- Island network detection

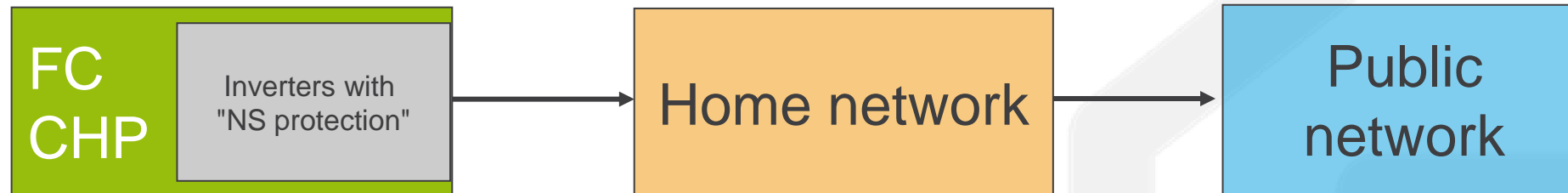
II. Electrical Installation

II 3. Automatic Electricity Network Disconnection

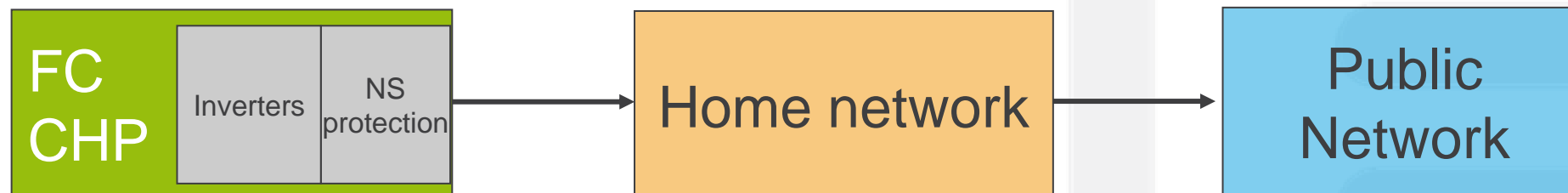
Safety Devices - Variations

In principle, three variants are conceivable for the connection of the specified mains and system protection:

1. Inverter with "NS protection" in the FC CHP



2. Inverter and extra "NS protection" in the FC CHP

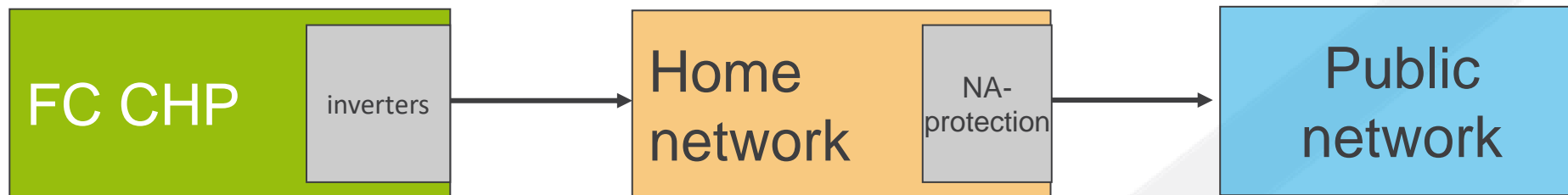


II. Electrical Installation

II 3. Automatic Electricity Network Disconnection

Safety Devices - Variations

3. Inverter in FC CHP and "NS protection" in the home network



- Off grid operation possible (with island operation capable inverter)
- House network possibly live even when public network is switched off

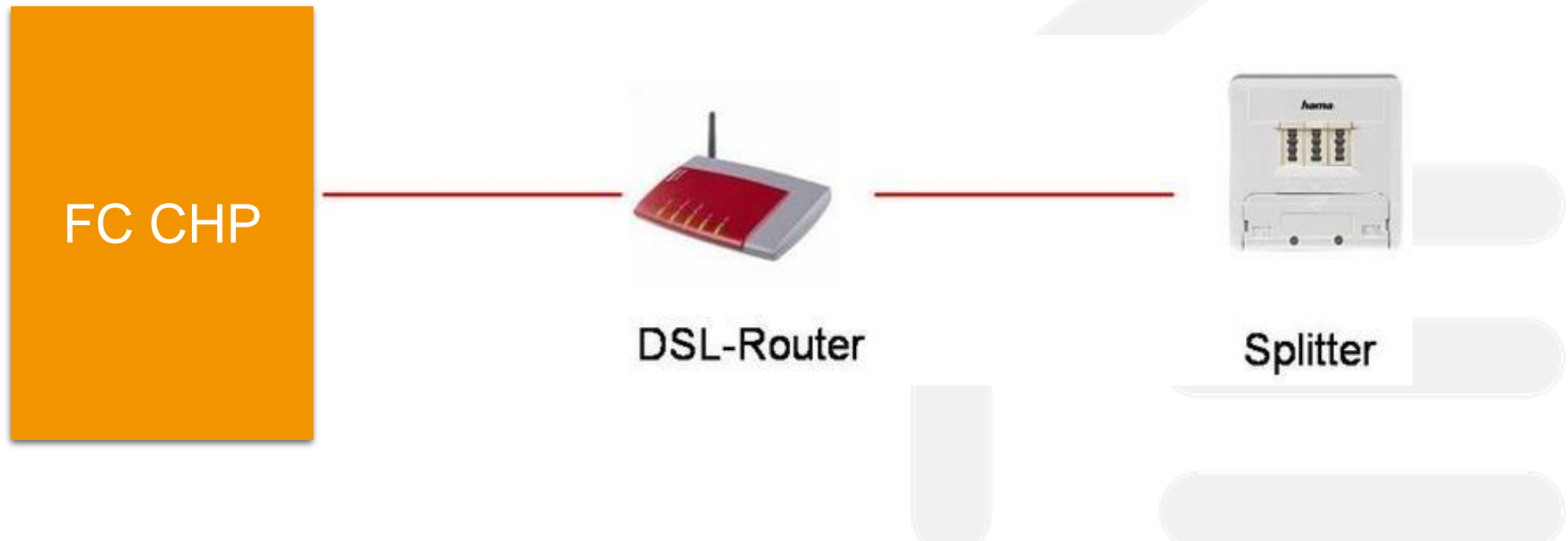
For all three circuit variants, the electrician must ensure compliance with the safety regulations and accident prevention regulations!

II. Electrical Installation

II 4. Remote Monitoring/Data Communication

Connection of Data Communication

Having covered the theory in Module 2, the practical installation and commissioning of the data communication is presented here.

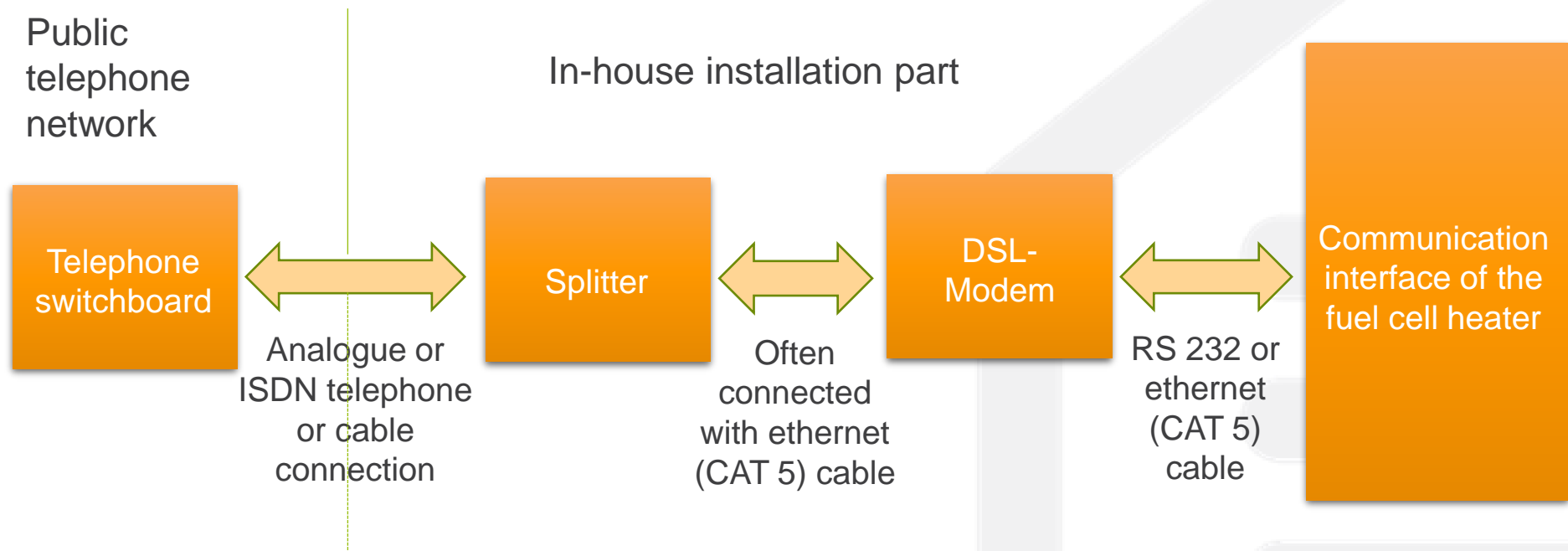


II. Electrical Installation

II 4. Remote Monitoring/Data Communication

Connection of Data Communication – a possible variant

The components must be connected according to the manufacturer's instructions. (Unless the heater manufacturer has supplied ready-made communication modules).



I. Overall Process of Installation

II. Electrical Installation

1. Requirements for the Power Supply
2. Connection Options
3. Automatic Electricity Network Disconnection
4. Remote Monitoring/Data Communication

III. Heating Installation

1. Requirements for the Installation Site
2. Hydraulic Integration
3. Supply and Exhaust System



III. Heating Installation

III 1. Requirements for the Installation Site

Building Regulations, Fire Regulations and Sound Insulation – General Considerations

As noted in the previous training module (Module 2), there are specific requirements pertaining to the installation of FC mCHP units which need to be taken into consideration in different countries.

In general, these cover the following:

- Minimum dimensions of the installation room;
- Access points to room and FC mCHP unit (for maintenance);
- Flue options for exhaust gases;
- Sound insulation options in installation room;
- Gas installation technical rules.

III. Heating Installation

III 2. Hydraulic Integration

Hydraulic Integration

In order to ensure safe heat dissipation and as many operating hours as possible for the FC CHP, a heating water buffer or combination storage tank should generally be available. As a rule, a drinking water storage tank alone is not sufficient.

In the case of underfloor heating or large heating requirements, a buffer storage tank may not be required. Then it must be ensured that forced circulation is possible (at least one radiator or one heating surface without shut-off valve).

Check whether the heat can also be dissipated in the event of a power failure (in which case systems will automatically turn off):

- When installing valves with electric actuator: normally open
- Pump operation via FC CHP
- When using a hydraulic separator, a pump would also have to be operated via the FC CHP on the secondary side

III. Heating Installation

III 2. Hydraulic Integration

Hydraulic Integration (2)

In order to be able to make the heat available according to demand, there are two solutions:

- an efficient peak boiler (auxiliary heater)
- a buffer for the heat. This can look different depending on the application:
 - A drinking water storage tank can be used for domestic hot water preparation.
 - Individual heating systems and buildings are able to store heat and can absorb peak loads.
 - A heating water buffer tank can store heat centrally and be flexibly available.
 - A combination cylinder can store domestic hot water and heating water.

A combination of all solutions makes economic sense! This is commonly provided with all FC mCHP systems as a result.

III. Heating Installation

III 2. Hydraulic Integration

Hydraulic Integration (3)

In order to make possible a long running time of the FC CHP :

- it should be possible to store the heat produced;
- it should be possible to cover demand peaks from a buffer tank;
- It should be ensured that the auxiliary heater is not required too frequently.

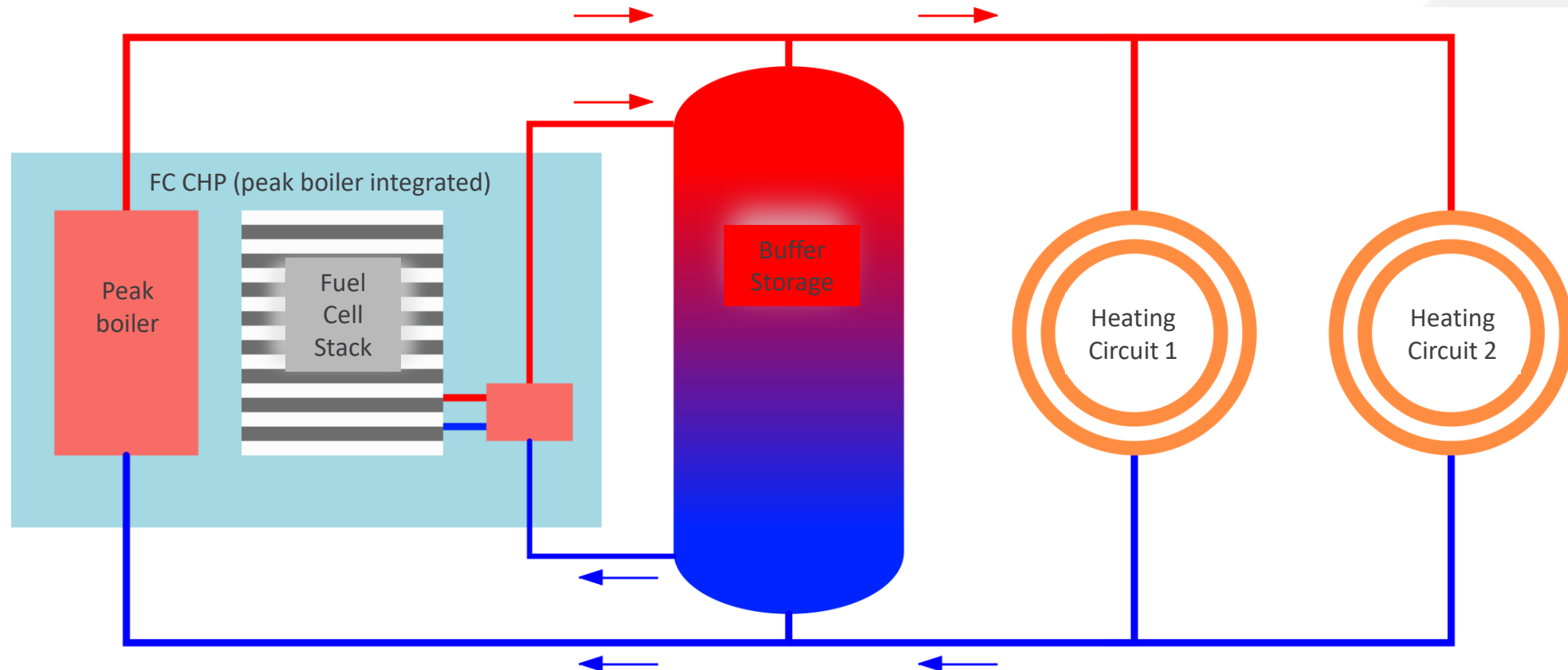
If the auxiliary heater is installed as an independent device, it must be ensured that it:

- can be operated parallel to the FC CHP;
- is not constantly flowed through (kept warm).

III. Heating Installation

III 2. Hydraulic Integration

Simplified Hydraulic Diagram



NB. Note that the peak boiler can also be separate

Source: Callux; Handwerkskammer Osnabrück-Emsland, www.hwk-os-el.de

Design of Supply and Exhaust Air Systems

Gas appliances of the type C (sealed room):

- Combustion air is extracted from the open air (via a closed system).
- Room air independent

The "combustion chamber" is tightly sealed off from the installation room.

Gas appliances of type B (open flue):

- Combustion air is extracted from the room
- Room air-dependent
 - The "combustion chamber" is open to the installation room.

III. Heating Installation

III 3. Supply and Exhaust System



Supply and Exhaust Duct Gas Appliance
Part C

Source: Callux; Handwerkskammer Osnabrück-
Emsland, www.hwk-os-el.de

III. Heating Installation

III 3. Supply and Exhaust System

The Device Types can be Grouped Together – Type C (Sealed Room)

Exhaust system certified with the gas appliance:

- C1: Horizontal through outer wall or roof
- C3: Vertically above the roof
- C5: Separate, in different pressure ranges

Connection to a chimney provided by the customer or to an air/flue gas system provided by the customer:

- C4: Via an air/exhaust system for multiple occupancy
- C8: Separate, exhaust gas via exhaust system for multiple occupancy, supply air directly from outside

Connection to a separately approved pipe system:

- C6: Via a system not tested with the gas appliance

Other

Type plate:

The nameplate indicates the possible device types here: C13x, C33x, C43x, C53x as well as B23 and B33

Moisture / condensate:

Due to the low exhaust temperatures it is necessary that all exhaust pipes used are moisture resistant.

The condensation must be removed (see manufacturer's instructions).

III. Heating Installation

III 3. Supply and Exhaust System

VKK 226			
Brennwertkessel			
DE, cat. II <small>2N3P</small>			
Typ C13x, C33x, C43x, C53x, B23, B33			
Erdgas G20/G25 - 20 mbar			
	Erdgas		Flüssiggas
P(40/30°C) =	5,1 - 22,5 kW	6,4 - 22,5 kW	
P(50/30°C) =	4,9 - 21,5 kW	6,3 - 22,1 kW	
P(80/60°C) =	4,8 - 21,0 kW	6,0 - 21,0 kW	
Q =	4,8 - 22,0 kW (Hi)	6,0 - 22,0 kW (Hi)	
Tmax =	85°C		
PMS =	3bar		
Wasserinhalt	100 l		
Speicherladung = 24,0 l; Q=24,0 kW (Hi)			
230 V~ 50 Hz 45 W IP 20			
Vor der Installation die Installationsanleitung lesen! Gerät nur in einem Raum installieren, der die maßgeblichen Belüftungsanforderungen erfüllt! Vor Inbetriebnahme die Bedienungsanleitung lesen! Wartungshinweise entsprechend Bedienungsanleitung beachten !			
CE 0085		EAN-CODE	

Source: Callux; Vaillant Deutschland GmbH & Co KG,
Bedienungsanleitung ecovit, www.vaillant.de



Pathway to a Competitive European
Fuel Cell micro-CHP Market

All material in this training pack is
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permitting use of this material:



Contact:

PACE | c/o COGEN Europe
Avenue des Arts 3-4-5
1210 Brussels
Belgium

Phone: +32 - 2 772 82 90

Email: info@pace-energy.eu

Web: www.pace-energy.eu

