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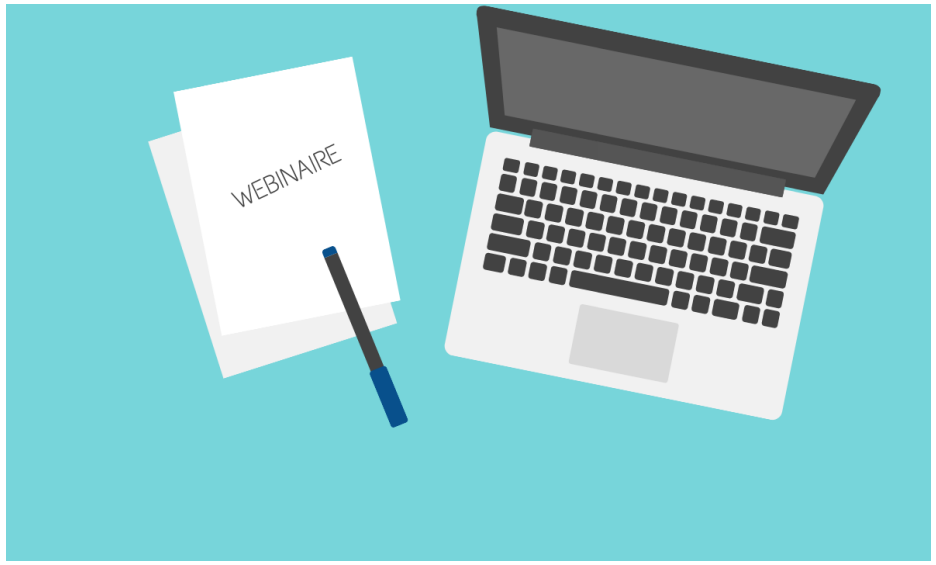
La cogénération, un outil performant du mix énergétique

02 février 2022



Avec le soutien et la participation de

Performances field-test de deux modèles de piles à combustible résidentielles commercialisées en Belgique (PEMFC et SOFC)

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Systems performance :

	Vitovalor PT-2 (PEMFC + gas boiler)	Bluegen (SOFC)
Heating output	0,9 - 30.8 kWth (boiler only) but 8 – 30.8 kWth (with FC + boiler)	/
Electrical output FC	750 W	0,5 – 1,5 kW (2 kW can be achieved)
Thermal output FC	Up to 1.1 kW	Up to 1 kW (@ 1,5 kWel & 20°C RT)
Yearly electrical production	Up to 6200 kWhel	13140 kWhel (@ 1,5 kWel)
FC LHV electrical efficiency	37%	60% (@ 1,5 kW)
Extra investments compared to (Viessman) boiler	±9 k€ TVAC	±20 k€ TVAC

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Field-test sites & Household profiles :

- Oostmalle :
  - active couple with 1 child
  - detached house
  - fully renovated (**floor heating** in main living rooms)
- Huy
  - active couple with 3 children
  - semi-attached house
  - partially renovated (only **high temperature terminal units**)
- Riemst
  - active couple with 1 child
  - recent detached house
  - **electric car** & pool (thermal recovery of the FC to the pool in summer)
- Duffel
  - active couple with 2 gwown-ups children (not often in the house)
  - attached house
  - partially renovated (**heat pumps**)
  - **electric car & solar panels** (3,5 MWc)

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Economic & ecological indicators assumptions :

- Cost assumptions TTC : June to December 2021
  - 0,333 €/kWh$_{el}$ & 0,093 €/kW$_{gaz}$ (BE) | 0,195 €/kWh$_{el}$ & 0,093 €/kW$_{gaz}$ (FR) www.CREG.be
  - Selling price = Purchasing price - Distributions and transports costs (of 0,15 €/kWh in BE - | 0,053 €/kWh in FR) www.CWAPE.be Ministère de la Transition Ecologique
- CO2 emissions assumptions :

Organization	Emission factor of natural gas combustion (LHV)	Emission factor for electricity production from natural gas power plant (LHV)	Emission factor for Belgian electricity consumption	Emission factor for Belgian electricity production
Internal Energy Agency (combustion only) [30] [31]	202 gCO$_2$/kWh (2013 but relevant) **B**	400 gCO$_2$/kWh (2013)	Not established	160 gCO$_2$/kWh (2020) **B**
IPCC 2014 (combustion only) [18]	202 gCO$_{2eq}$/kWh	370 gCO$_{2eq}$/kWh	Not established	Not established 50 gCO$_2$/kWh (FR)
European Commission CoM [29]	240 gCO$_{2eq}$/kWh (LCA) – (2008-2015) **C**	Not established	239 gCO$_{2eq}$/kWh (LCA) – (2013) **C**	Not established
Walloon regulator (CWaPe) – still used [17]	251 gCO$_{2eq}$/kWh (LCA)	456 gCO$_{2eq}$/kWh (LCA) **A**	Not established 93 gCO$_{2eq}$/kWh (FR)	Not established

- Method : comparison with reference machines (gas condensing boiler of 90 % LHV efficiency and, for assumptions A, combined cycle gas turbine of 55% LHV efficiency)

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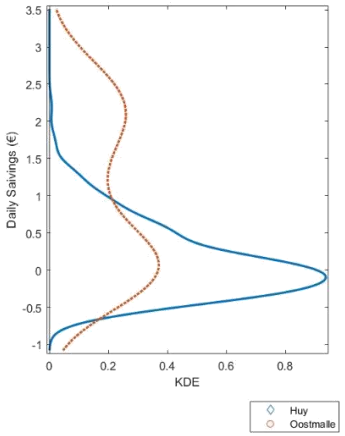
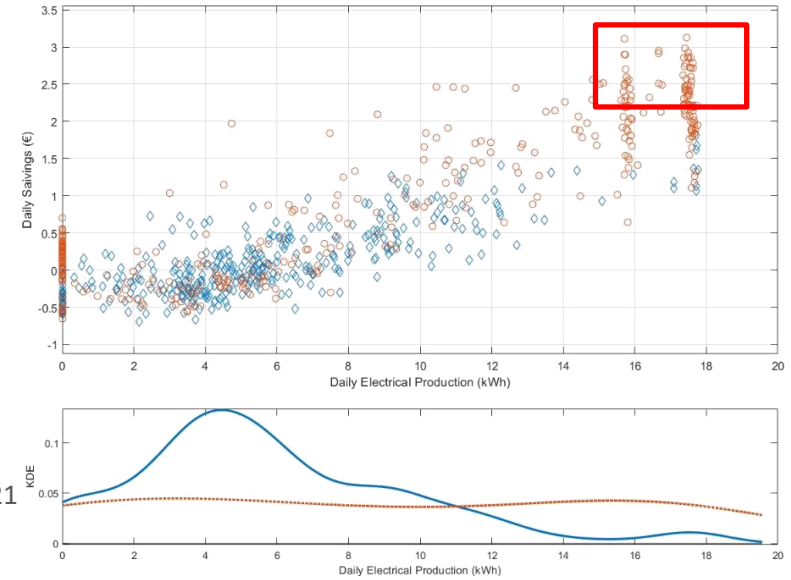
Field-test results:

	Huy		Oostmalle		Riemst	Duffel
	2020	2021	2020	2021	2021	2021
€ Savings	52 €	18 €	359 €	456 €	1435 €	1311 €
Total electricity produced	2175 kWh	2011 kWh	3213 kWh	3222 kWh	11843	12922
Total electricity consumed	270 kWh	298 kWh	254 kWh	258 kWh	11	2
Total DHW consumed	1599 kWh	1627 kWh	1998 kWh	2095 kWh		
Total SPH consumed	10779 kWh	10941 kWh	21481 kWh	27061 kWh	3569	2549
Total HHV gas consumed	19183 kWh	19403 kWh	32352 kWh	38181 kWh	24962	24239
LHV electrical efficiency	12,6%	11,5%	11,0%	9,4%	52,6%	59,1%
LHV thermal efficiency	71,5%	71,8%	80,4%	84,6%	15,8%	11,7%
LHV total efficiency	84,1%	83,3%	91,5%	94,0%	68,4%	70,8%
Demand Cover Factor	25,0%	25,0%	33,5%	34,5%	71,2%	82,9%
Supply Cover Factor	33,5%	37,6%	36,3%	34,1%	66,7%	58,6%

Duffel → 3,5 MWh of PV in 2021





- PEMFC yearly electrical production far from the 6,2 MhW → the FC shuts down if return temperature >50°C (more relevant in winter and with floor heating)
- ROI > 18 years for PEMFC's | ROI = ± 15 years for SOFC's (maintenance costs and public grants not considered)
  → strongly affected by supply cover factors and for PEMFC, the achievable daily electrical production → 1k€ yearly savings achievable → ROI = ± 9 years
- Tremendous electrical efficiency for SOFC's (Riemst a little lower partly due to partial load for vacation days)
- Min 2549 kWh of thermal production in Duffel → **should be enough for typical household yearly DHW alone**

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Field-test CO_2 balances :

	Huy		Oostmalle		Riemst	Duffel
	2020	2021	2020	2021	2021	2021
€ Savings	52 €	18 €	359 €	456 €	1435 €	1311 €
Total electricity produced	2175 kWh	2011 kWh	3213 kWh	3222 kWh	11843	12922
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Total SPH consumed	10779 kWh	10941 kWh	21481 kWh	27061 kWh	3569	2549
Total HHV gas consumed	19183 kWh	19403 kWh	32352 kWh	38181 kWh	24962	24239
CO_2 savings hyp A	-22 $kgCO_{2eq}$	-106 $kgCO_{2eq}$	574 $kgCO_{2eq}$	841 $kgCO_{2eq}$	739 $kgCO_{2eq}$	1115 $kgCO_{2eq}$
CO_2 savings hyp B	-413 $kgCO_2$	-440 $kgCO_2$	-152 $kgCO_2$	60 $kgCO_2$	-1854 $kgCO_2$	-1777 $kgCO_2$
CO_2 savings hyp C	-397 $kgCO_{2eq}$	-440 $kgCO_{2eq}$	-36 $kgCO_{2eq}$	217 $kgCO_{2eq}$	-1625 $kgCO_{2eq}$	-1480 $kgCO_{2eq}$
LHV electrical efficiency	12,6%	11,5%	11,0%	9,4%	52,6%	59,1%
LHV thermal efficiency	71,5%	71,8%	80,4%	84,6%	15,8%	11,7%
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CO_2 savings if indicator >0

- CO_2 balance – "Cogen friendly" assumptions A : PEMFC is positive only in Oostmalle – SOFC's show good performance
- CO_2 balance with real electricity mix assumptions : PMFC only slightly positive in Oostmalle and in 2021 – SOFC's show poor performance

→ Set of assumptions have tremendous impacts on CO_2 balances. As of today, gas is still a fossil fuel and cannot compete with low carboned energies.

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What happens to the indicators for France :

	Huy - BE		Oostmalle - BE		Riemst - BE	Duffel - BE
	2020	2021	2020	2021	2021	2021
€ Savings	52 €	18 €	359 €	456 €	1435 €	1311 €
CO_2 savings hyp A	-22 $kgCO_{2eq}$	-106 $kgCO_{2eq}$	574 $kgCO_{2eq}$	841 $kgCO_{2eq}$	739 $kgCO_{2eq}$	1115 $kgCO_{2eq}$
CO_2 savings hyp B	-413 $kgCO_2$	-440 $kgCO_2$	-152 $kgCO_2$	60 $kgCO_2$	-1854 $kgCO_2$	-1777 $kgCO_2$
CO_2 savings hyp C	-397 $kgCO_{2eq}$	-440 $kgCO_{2eq}$	-36 $kgCO_{2eq}$	217 $kgCO_{2eq}$	-1625 $kgCO_{2eq}$	-1480 $kgCO_{2eq}$
	FRANCE					
	Huy - FR		Oostmalle - FR		Riemst - FR	Duffel - FR
	2020	2021	2020	2021	2021	2021
€ Savings	-71 €	-97 €	149 €	254 €	185 €	194 €
CO_2 savings hyp A	-22 $kgCO_{2eq}$	-106 $kgCO_{2eq}$	574 $kgCO_{2eq}$	841 $kgCO_{2eq}$	739 $kgCO_{2eq}$	1115 $kgCO_{2eq}$
CO_2 savings hyp B	-622 $kgCO_2$	-629 $kgCO_2$	-478 $kgCO_2$	-266 $kgCO_2$	-3156 $kgCO_2$	-3199 $kgCO_2$
CO_2 savings hyp C	-675 $kgCO_{2eq}$	-690 $kgCO_{2eq}$	-468 $kgCO_{2eq}$	-216 $kgCO_{2eq}$	-3352 $kgCO_{2eq}$	-3367 $kgCO_{2eq}$

- Ratio electrical / gas price in France less favorable leads to poorer economic performance → not profitable without (public) grants
- CO_2 balances with electrical mix are even worsen “because” of France low carboned electrical mix
  - → gas shall be “defossilized” and/or
  - → the system shall provide flexibility services to the grid (by preventing gas turbines to be fired up) → **possible with the SOFC**

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Conclusions :

- *SOFC shows expected performance. PEMFC load factor is unfortunately about or below 50%.*
- *Biogas and/or flexibility services shall be implemented to inverse CO_2 balance → possible with SOFC*
- *Based on average energy bills and fixed contract, both systems are not economically profitable (especially in France) → dynamic day ahead 15-min contract achievable with smart meters (ex : Linky) can increase tremendously the earnings (especially with SOFC's as they are electrically driven)*

ULiege thermodynamics lab has also tested both systems in lab conditions and is studying field-test performance of other systems (heat pumps, hybridized heat pumps, gas condensing boilers, absorption heat pumps)