



Regional markets of RES-fuel cell systems for households

Cost reductions of FCHS due to the development of an aggregated market.

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## RES-FC MARKET

### Objective of WP4

Cost reductions of FCHS due to the development of an aggregated market.

### Primary Challenges

- How can we obtain the renewable hydrogen carrier at the lowest possible price?
- Optimizing energy efficiency and simplify the FCHS's as much as possible
- Lifetime versus price.
- Micro CHP's is currently too expensive and scale of production is necessary in order to get the prices down

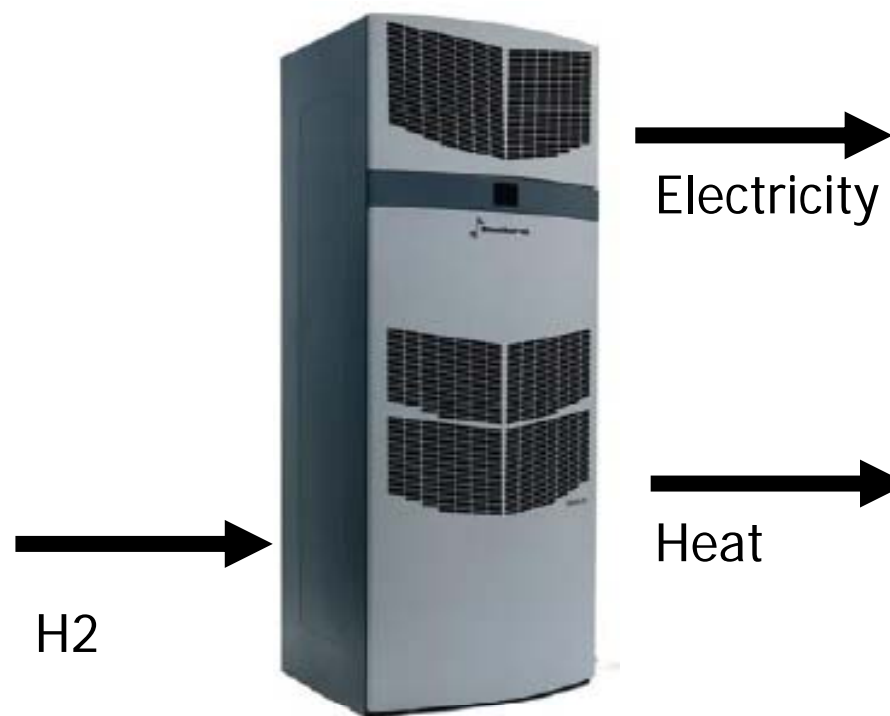


## The 3 Scenarios:

Wind → H<sub>2</sub>

Biogas → H<sub>2</sub>

Methanol → H<sub>2</sub>

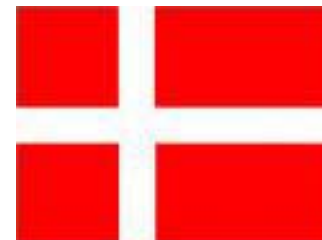


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### Case Biogas Germany

Total production costs for 1 kWh Bio methane 9-11 Euro cent  
Including grid-injection and transmission costs (large plants)  
Price NG from most utilities: 6-7 Euro cent.

Non the less are several projects with biogas upgrading  
and NG grid injection is running or planned in



## **Case renewable methanol from flue gas in Island**

### **Sources of CO<sub>2</sub>:**

Geothermal gas and emissions from aluminum smelters

### **Sources of hydrogen:**

Hydrogen produced from electrolysis.

### **Production from 2009-10**

Capacity 25 metric ton/day and 1000 after smelter opening

Price target medium term 150 usd/metric ton.

### **Comparison:**

Current methanol price Europe: 466 usd/metric ton.

Medium term price estimate: 145 usd/metric ton



**CARBON RECYCLING  
INTERNATIONAL**

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### Availability of renewable methanol and biogas?

The price FCHS operators has to pay for the fuel will be the domestic market price:

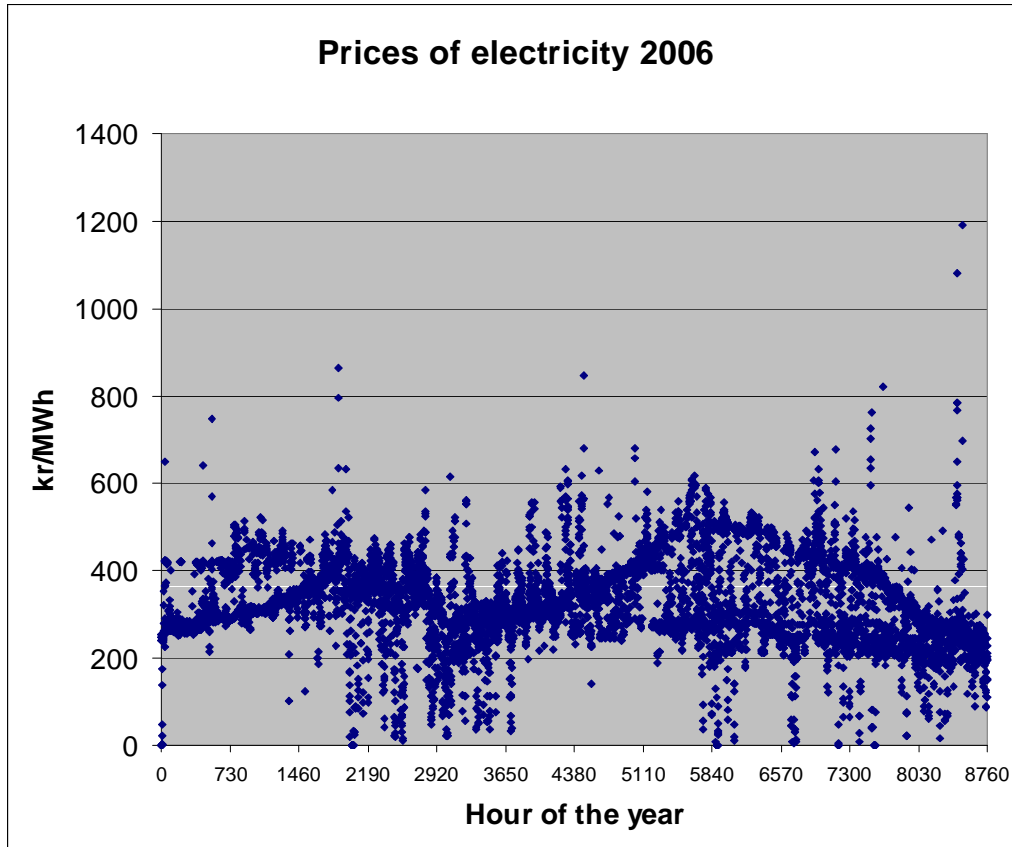
whether or not the production of the fuel is subsidized due to its renewable origin.

Large scale availability of these 2 renewable hydrogen carriers will thus depend upon

- **Government subsidy programmes**
- **Market prices**



## Wind/H2: Case Denmark



## RES-FC MARKET



The price setting in the electricity market is influenced by:

**Supply side:** The relative large proportion of wind power in the energy system.

**Demand side:** Variations in consumption (day night, weekend)

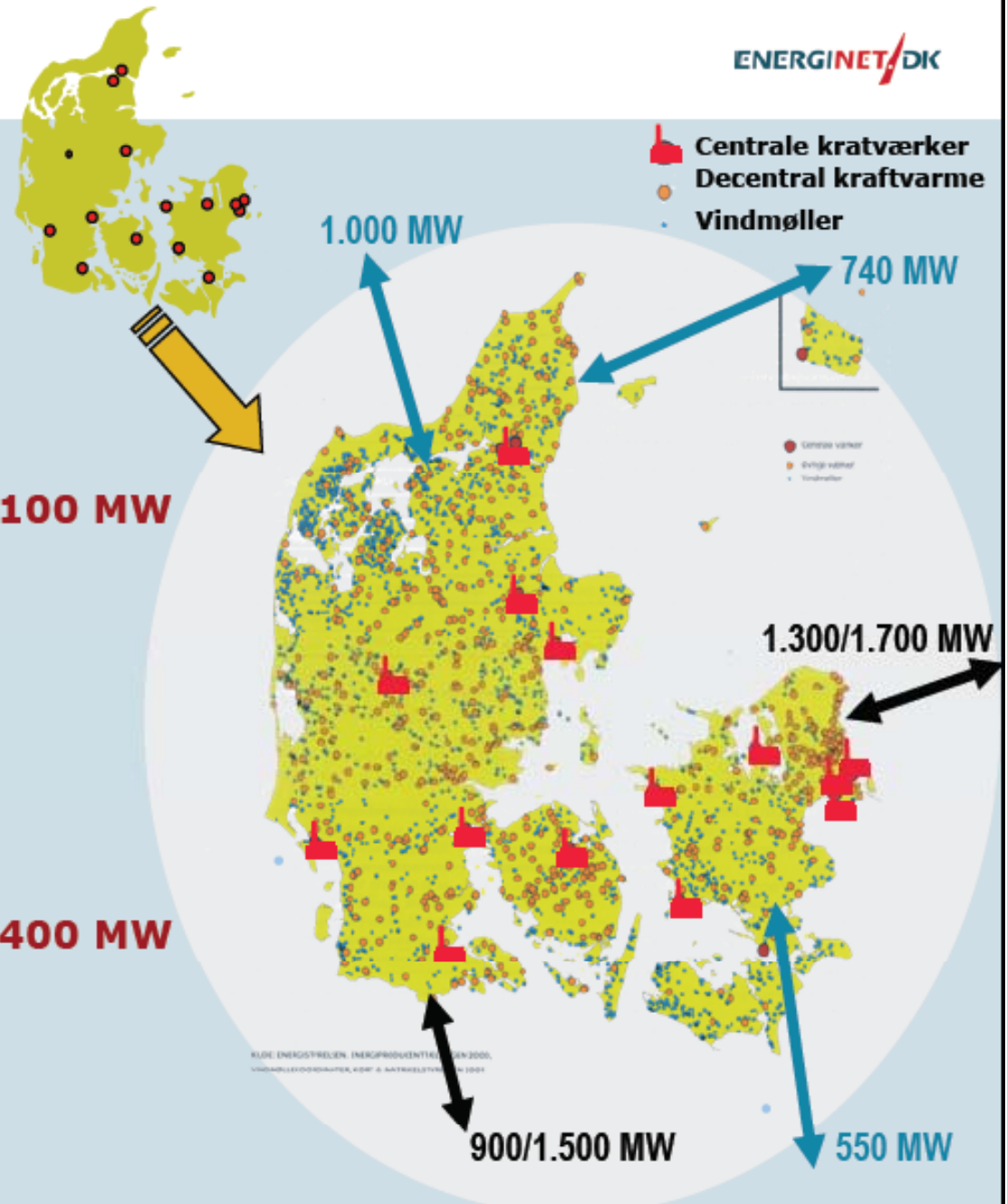
# Effektbalance 2006

## Vest:

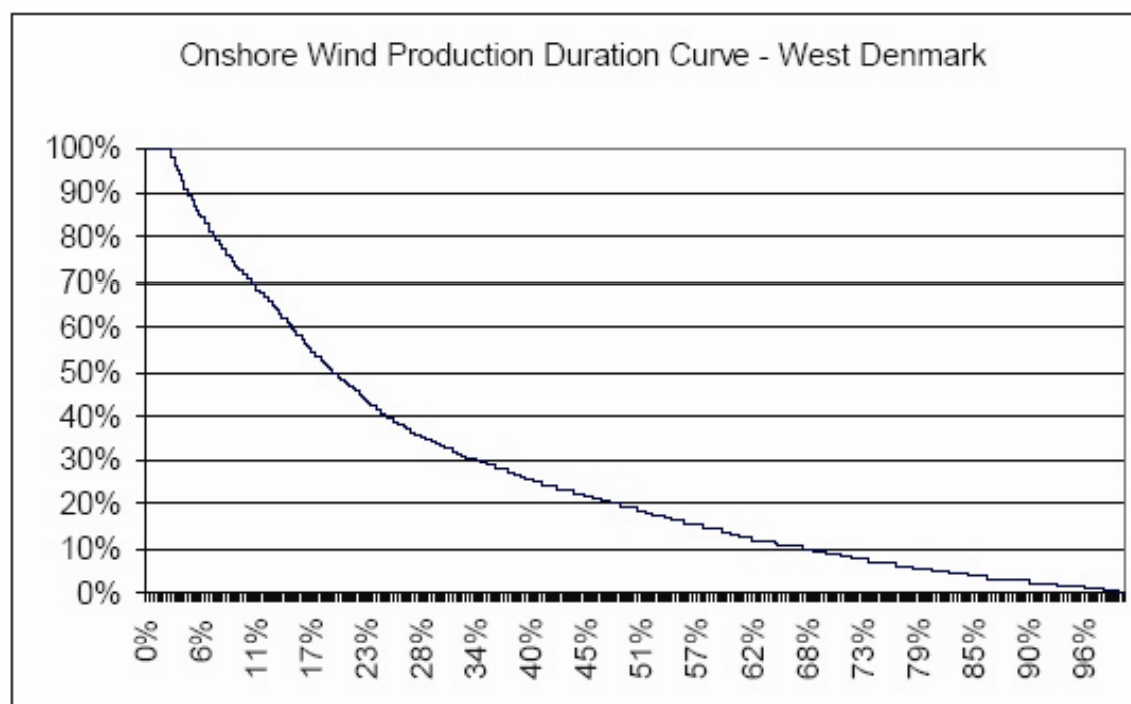
Forbrug	1.250 – 3.700 MW
Centrale kraftværker	3.400 MW
Decentral kraftvarme	1.700 MW
Vindkraft	2.400 MW
<b>penetration vind: 65 ... 200 %</b>	
<b>CHP: 46 ... 136 %</b>	

## Øst:

Forbrug	880 – 2.600 MW
Centrale kraftværker	3.800 MW
Decentral kraftvarme	650 MW
Vindkraft	750 MW
<b>penetration vind: 30 ... 85 %</b>	
<b>CHP: 25 ... 74 %</b>	



## Wind electricity - H2 – electricity why?



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### Operation strategy: Grid connected wind/H2 FCMS

**We purchase electricity and run the electrolyser when electricity is cheap:**

- Night time and when it is very windy

**When the price of electricity is high we:**

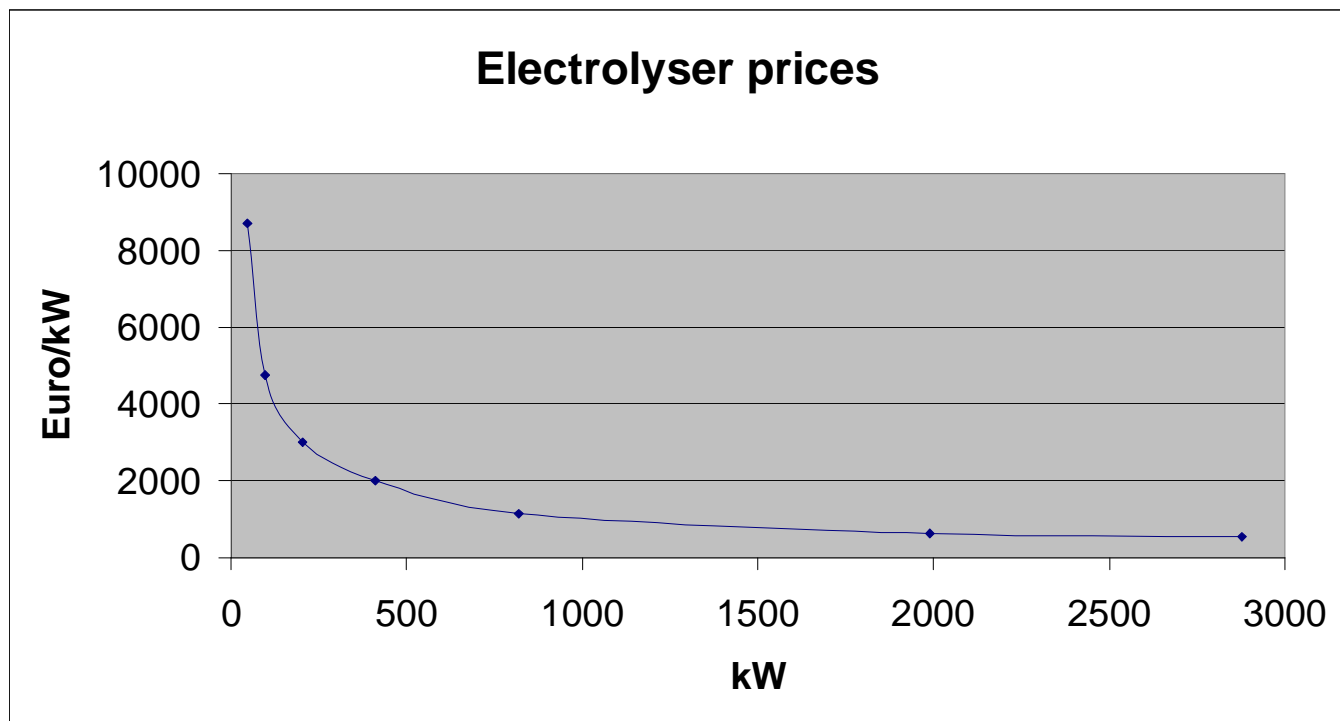
- Run the fuel cells according to heat demand
- Excess electricity will be sold to the grid

**Operation in the first demonstration projects**

- Demand variations
- Solar cell arrangement



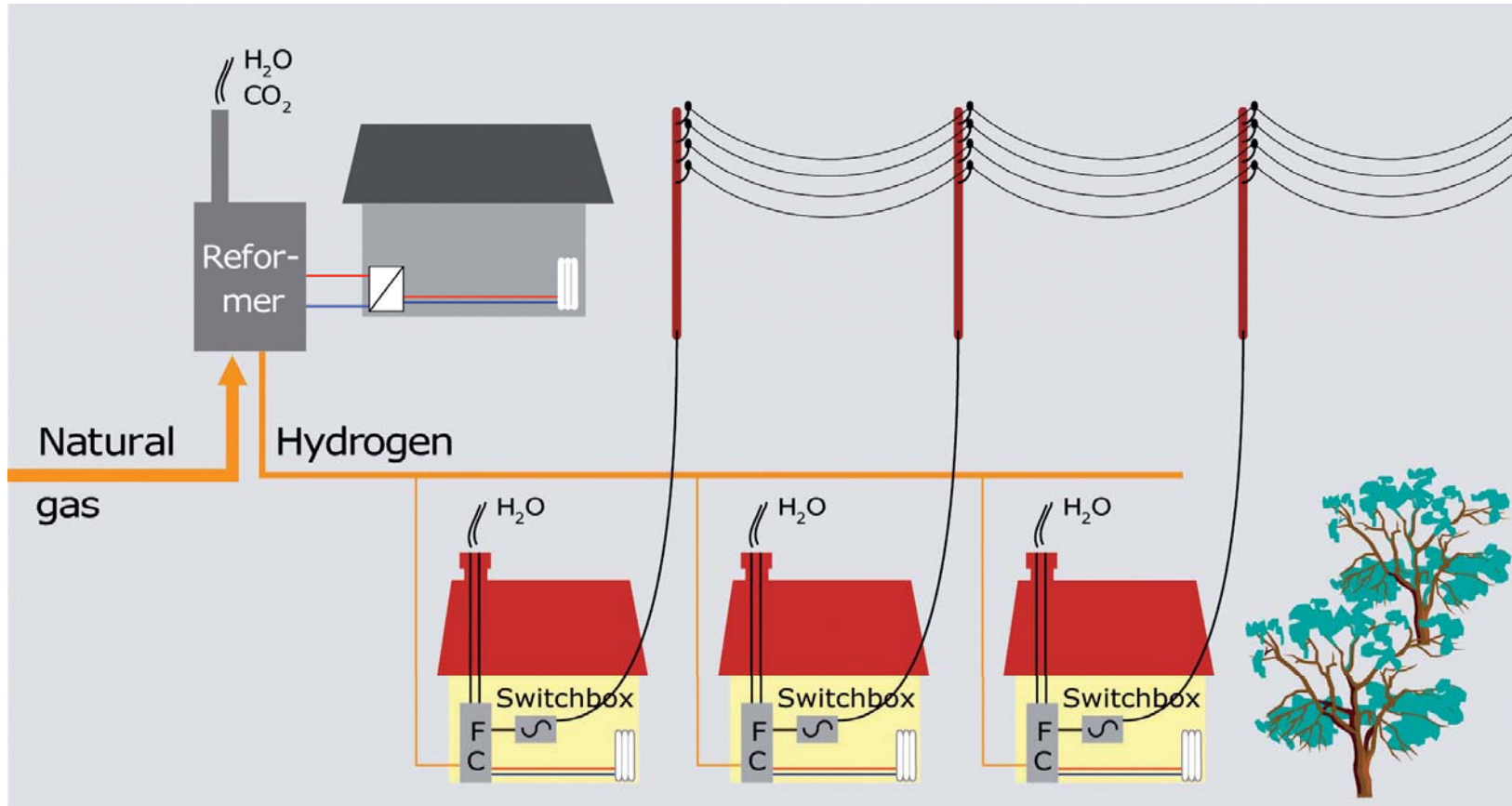
### A quick look at electrolyzers



H2 price H2College	16 houses 80 kW :	0,76 Euro/Nm3
H2 price H2PIA	200 houses 1 MW:	0,28 Euro/Nm3
	600 houses 3 MW:	0,22 Euro/Nm3

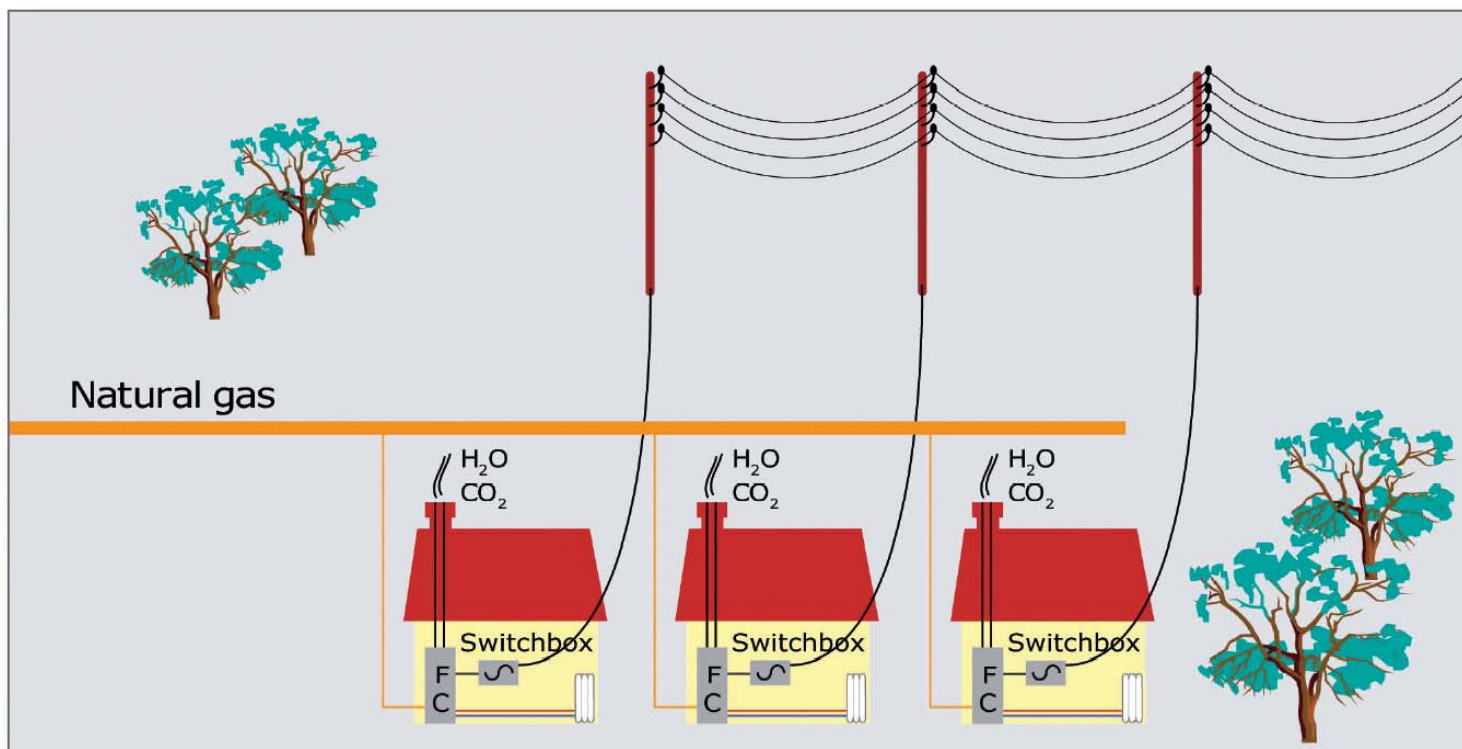
## RES-FC MARKET

Optimizing energy efficiency and simplify the entire FCHE as much as possible.



## RES-FC MARKET

Optimizing energy efficiency and simplify the entire FCHS as much as possible.



## RES-FC MARKET

### Benefits/economic advantages arising from going decentral:

**Not necessary to build a hydrogen distribution system**

**Not necessary to link it to clusters of houses (non disruptive).**

**Not necessary to build a district heating system**

**No loss of heat in a district heating system.**

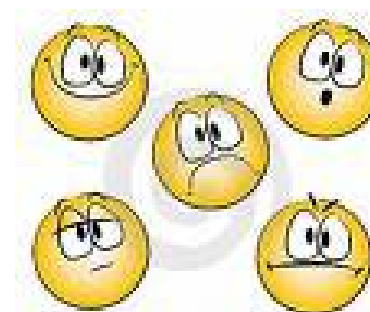


### But new challenges

**Small decentralized reformers is not a mature technology!**

**LT PEM fuel cells are very sensitive to impurities.**

**Making small reformers supplying pure hydrogen is very costly**



## RES-FC MARKET

**Solution: We use HT PEM fuel cells instead!**

### Advantages:

- High tolerance to reformat impurities such as carbon monoxide and sulphur.
- The technology is suitable for a modular systems design.

### Which mean that:

- We can use simpler and cheaper reformers which can be designed as plug on units.
- We can use the same basic system for regions with different heat and electricity requirements.



## RES-FC MARKET

We now have one basic fuel cell system that has the potential to capture market shares across hydrogen carriers and climate zones.

**Bio methane/ NG system for areas with NG grid**

**Methanol system for areas without district heating and NG grid**

**The electrolyser/H<sub>2</sub> system for clusters of new houses in areas with a large proportion of fluctuating renewable energy sources in the electricity supply**



## RES-FC MARKET

### •Lifetime versus price – what do we go for?

#### Target of the WP in the beginning of this project:

Improvement of economic performance of RES-FCHS by 40-50% - reducing costs for RES-FCHS to a level < 5,000 EUR/kWe.

#### Not a relevant objective after all!

Short lifetime system with 5000 hours lifetime.  
(1 year of operation).

Long lifetime system is more expensive but...

Significantly cheaper per kW output for the end-user (longer depreciation period)

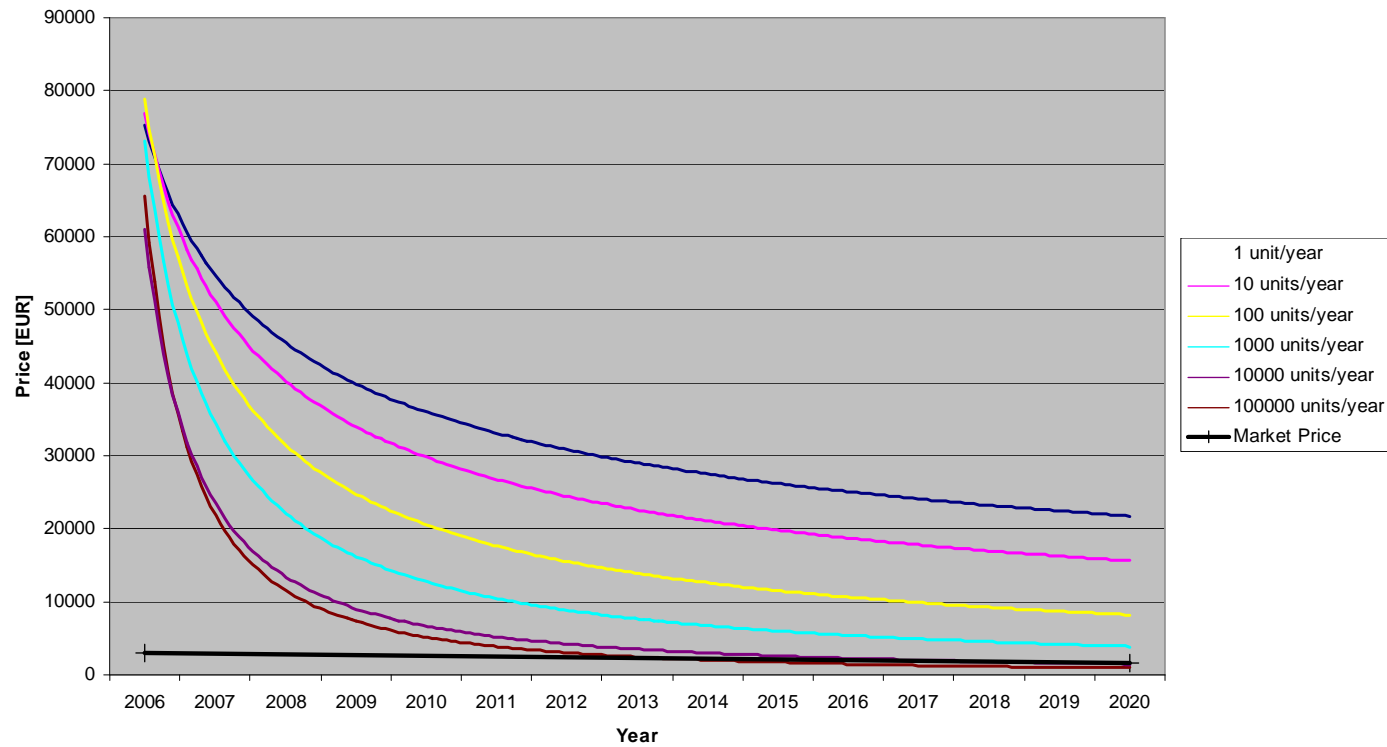


#### We achieve the long lifetime by:

- Adding more stacks
- Running the system at a low load.

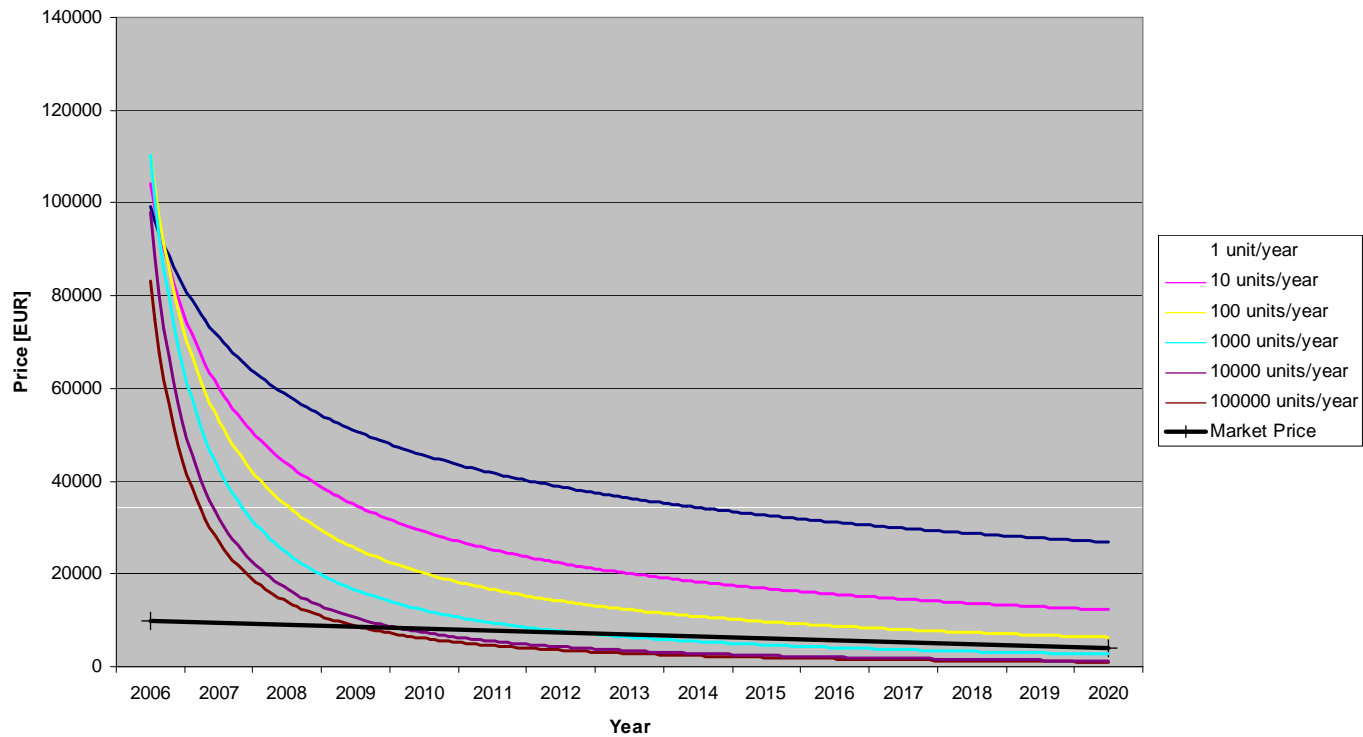
## Cost reduction by learning and mass production:

Learning Curve, HT-PEM, 1 kW el, Pure Hydrogen, 40.000 Hours Lifetime



# RES-FC MARKET

Learning Curve, HT-PEM, 1 kW el, Methanol, 40.000 Hours Lifetime



## RES-FC MARKET

Cost calculations on isolated regional projects versus a collaborative approach:

### Wind/H2: Case Denmark

- It is likely that we can obtain a 25% cost reduction on electrolyzers.
- Electrolyzers are a well proven technology and it is reasonable to use a 20 year depreciation period.



<b>Price of hydrogen via Electrolyses:</b>	H2College	H2PIA	Euro/Nm3	H2PIA	Euro/Nm3
Price of electricity at average off peak time Euro/kWh	0,0307		0,0307		0,0307
Efficiency kwh/Nm3 hydrogen produced	5		5		5
Price of electricity at off peak time Euro/Nm3 hydrogen produced		0,15		0,15	0,15
Size of electrolyser kW (from calculation)	83		1042		1042
Price of electrolyser per kW, Euro/kWh (from curve)	5000		1000		750
Price of electrolyser, Euro	415.000		1.042.000		781.500
Number of operation hours per day	8		8		8
Life time of electrolyser in years	10		10		20
Depreciation per kWh consumed by the electrolyser, Euro	0,171		0,034		0,013
Depreciation per Nm3 produced by the electrolyser, Euro	0,60	0,60	0,12	0,12	0,04
Maintenance costs		0,0060		0,0060	0,0060
Price of hydrogen		0,76		0,28	0,20

Case Wind/H2 Denmark

	H2College	H2pia	H2PIA, 1500	H2PIA,10000, 2012
Net price of hydrogen used by CHP Euro/ Nm3	0,76	0,28	0,20	0,20
Grid payment per kWh	0	0		
Grid payment per Nm3	0	0	0	0
PSO per kWh	0	0		
PSO per Nm3	0	0	0	0
CO2 per Kwh heavy process	0	0		
CO2 per Nm3	0	0	0	0
Electricity tax per kWh	0	0		
Electricity tax per Nm3	0	0	0	0
Sum of tax ex. VAT	0	0	0	0
VAT % 25	0,19	0,07	0,05	0,05
Hydrogen price incl. tax per Nm3, Euro	0,95	0,35	0,25	0,25
Costs of hydrogen per house per year ex. depreciation Euro	2.370	873	624	624
Price of CHP Euro	26.400	17.600	12.750	3.400
Lifetime of CHP year	5	5	5	5
Depreciation of CHP Euro/Nm3 hydrogen	2,12	1,41	1,02	0,27
Depreciation of CHP Euro/kWh hydrogen	0,60	0,40	0,29	0,08
Depreciation of CHP per year	5.280	3.520	2.550	680
Costs of hydrogen per house per year incl. depreciation Euro	7.650	4.393	3.174	1.304
Consumer price of electricity incl. tax, Euro/kWh	0,27	0,27	0,27	0,27
Consumer price of heat incl. tax, Euro/kWh	0,13	0,13	0,13	0,13
Value of electricity production from CHP Euro	970	970	970	970
Value of heat production from CHP Euro	417	417	417	417
Value of CHP production per year	1.387	1.387	1.387	1.387
Value of CHP production minus cost of hydrogen	-6.263	-3.006	-1.787	83

**Conclusion:**

**How do we make this technology commercial?**

**Short term:**

Initiate more publicly co funded demonstration projects.

**Medium term/market introduction:**

Establish feed in tariffs/subsidies and tax exemptions

Establish clear and transparent legislation