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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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Hydrogen Innovation & Research Centre, Herning

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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

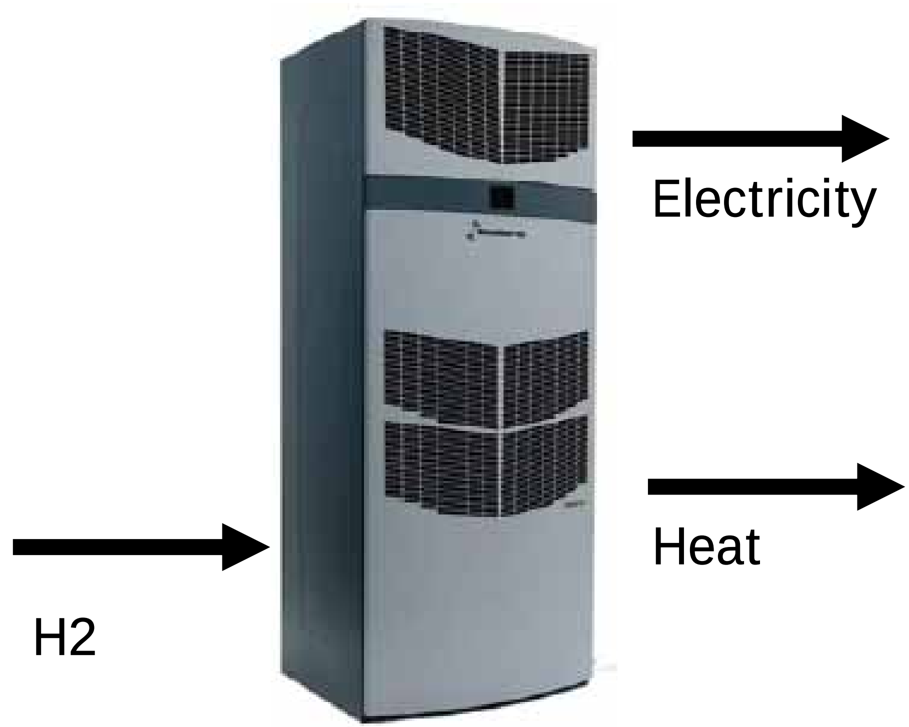
•Micro CHP's is currently too expensive and scale of production is necessary in order to get the prices down

The 3 Scenarios:

Wind ⟶ H2

Biogas ⟶ H2

Methanol ⟶ H2



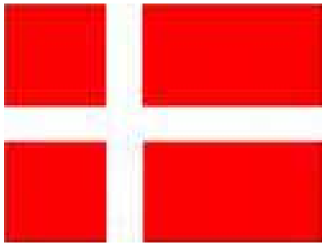
Case Biogas Germany

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 running or planned in



Case renewable methanol from flue gas in Island

CARBON RECYCLING INTERNATIONAL

Sources of CO_2:

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

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**

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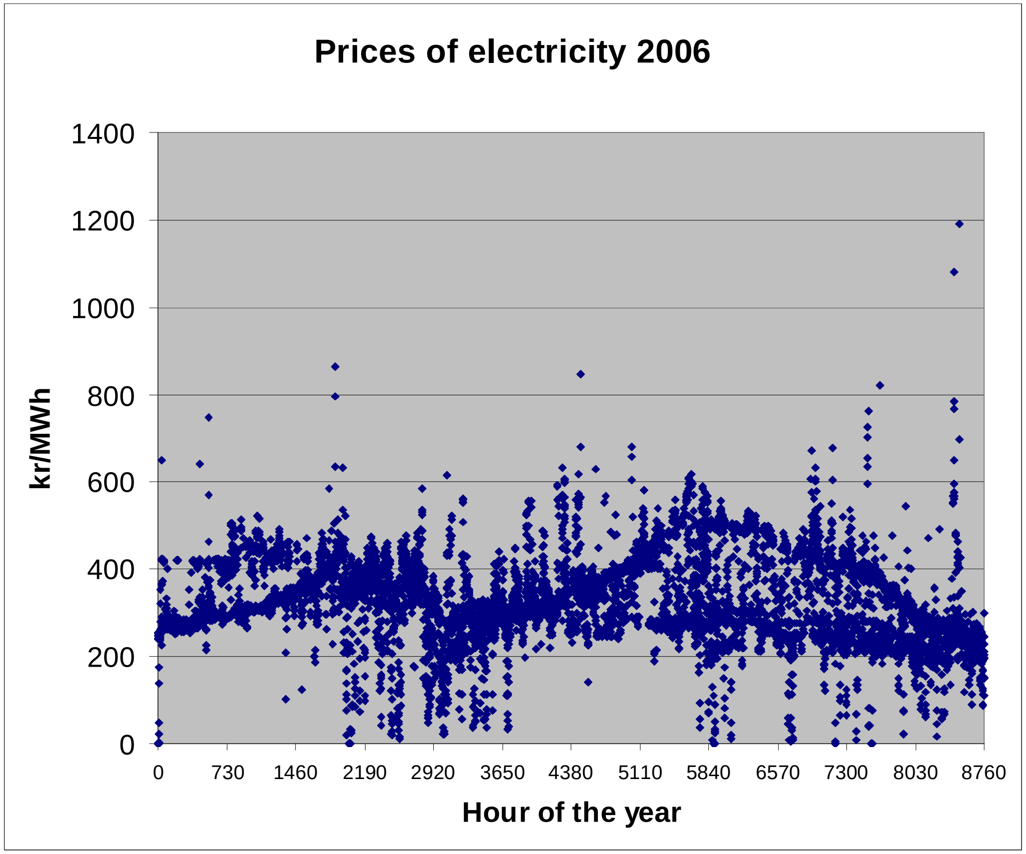
Wind/H2: Case Denmark



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)

ENERGINET.DK

Effektbalance 2006

Vest:

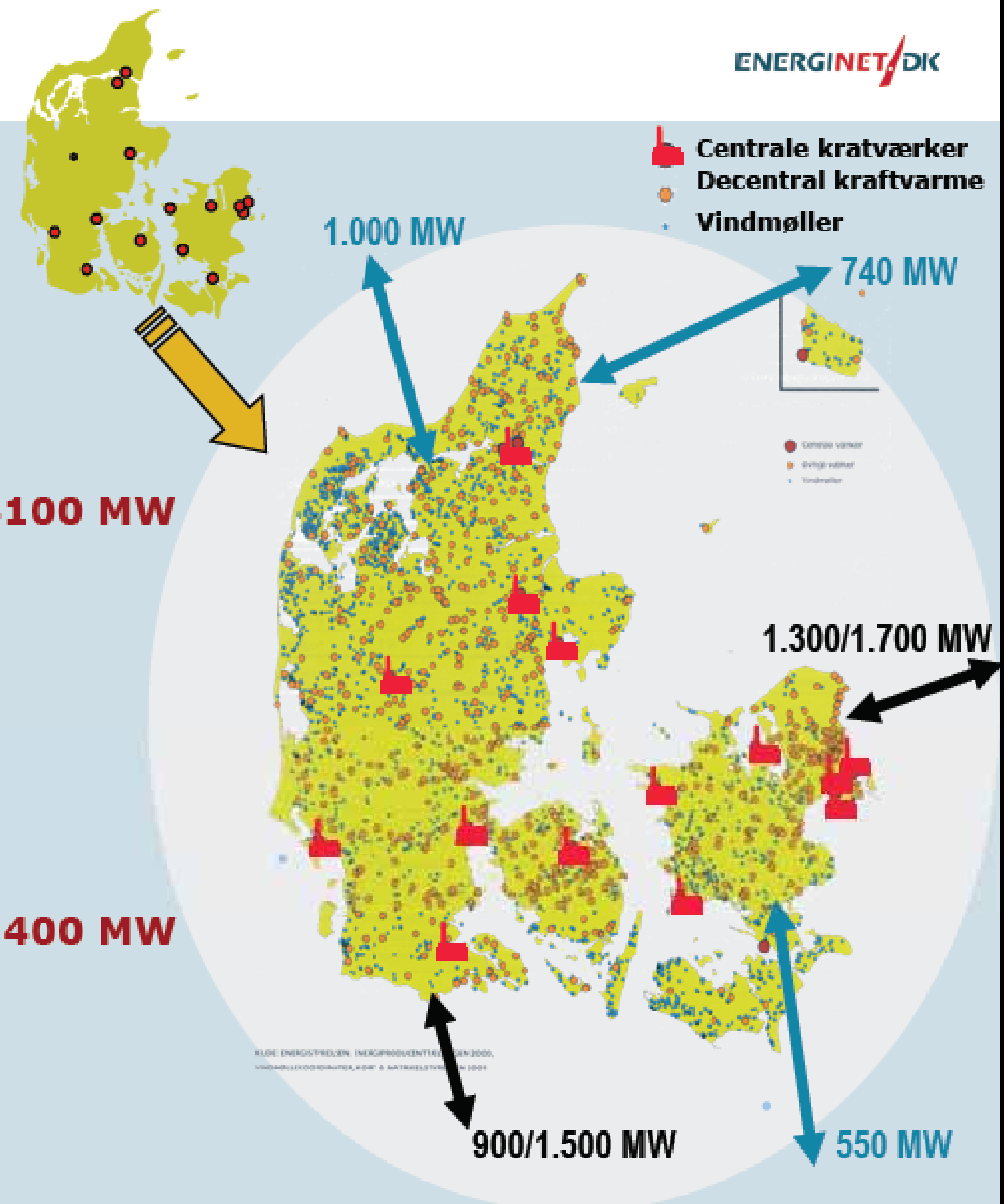
Forbrug	1.250 – 3.700 MW
Centrale kraftværker	3.400 MW
Decenbtral kraftvarme	1.700 MW
Vindkraft	2.400 MW
penetration vind:	**65 … 200 %**
CHP:	**46 … 136 %**

4100 MW

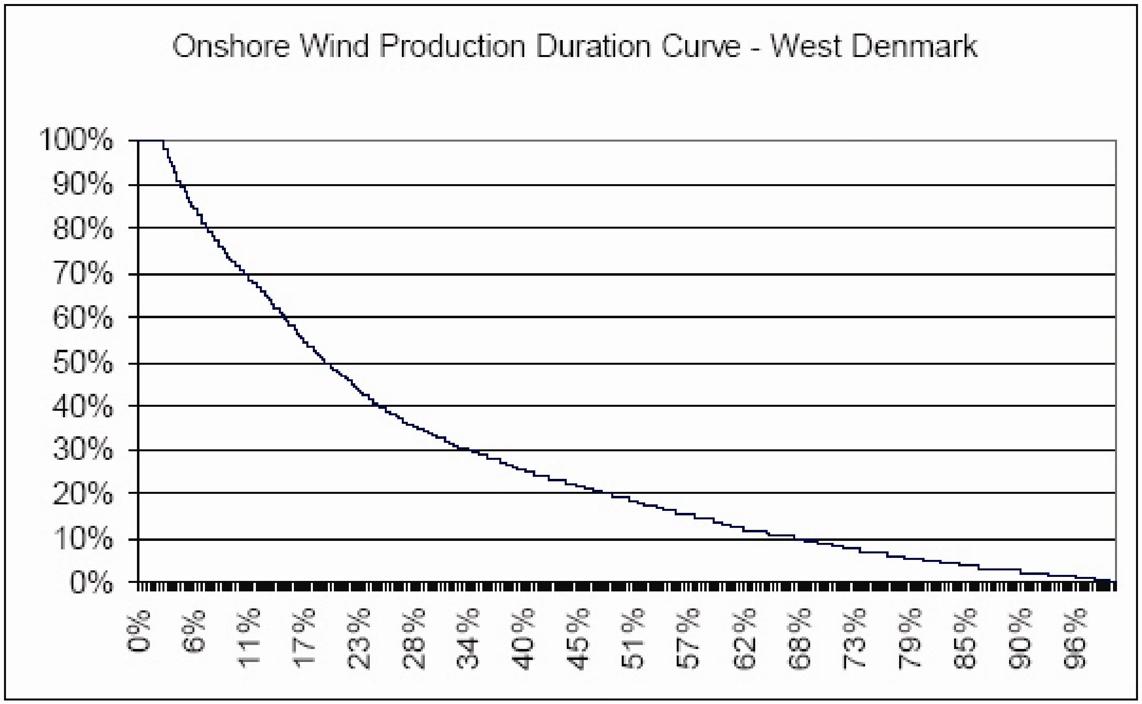
Øst:

Forbrug	880 – 2.600 MW
Centrale kraftværker	3.800 MW
Decentral kraftvarme	650 MW
Vindkraft	750 MW
penetration vind:	**30 … 85 %**
CHP:	**25 … 74 %**

1400 MW



Wind electricity - H2 – electricity why?



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Operation strategy: Grid connected wind/H2 FCHS

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

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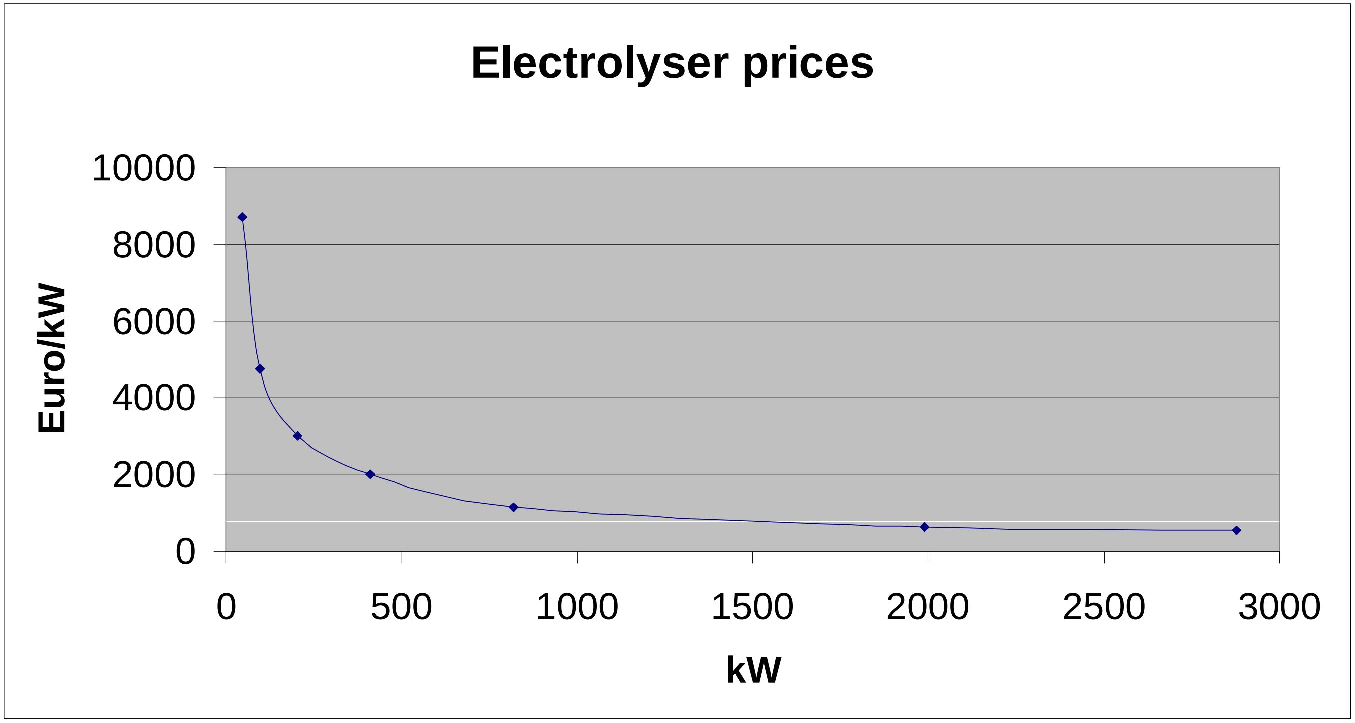
A quick look at electrolysers



H2 price H2College	16 houses 80 kW :	1,02 Euro/Nm3
H2 price H2PIA	200 houses 1 MW:	0,33 Euro/Nm3
	600 houses 3 MW:	0,21 Euro/Nm3

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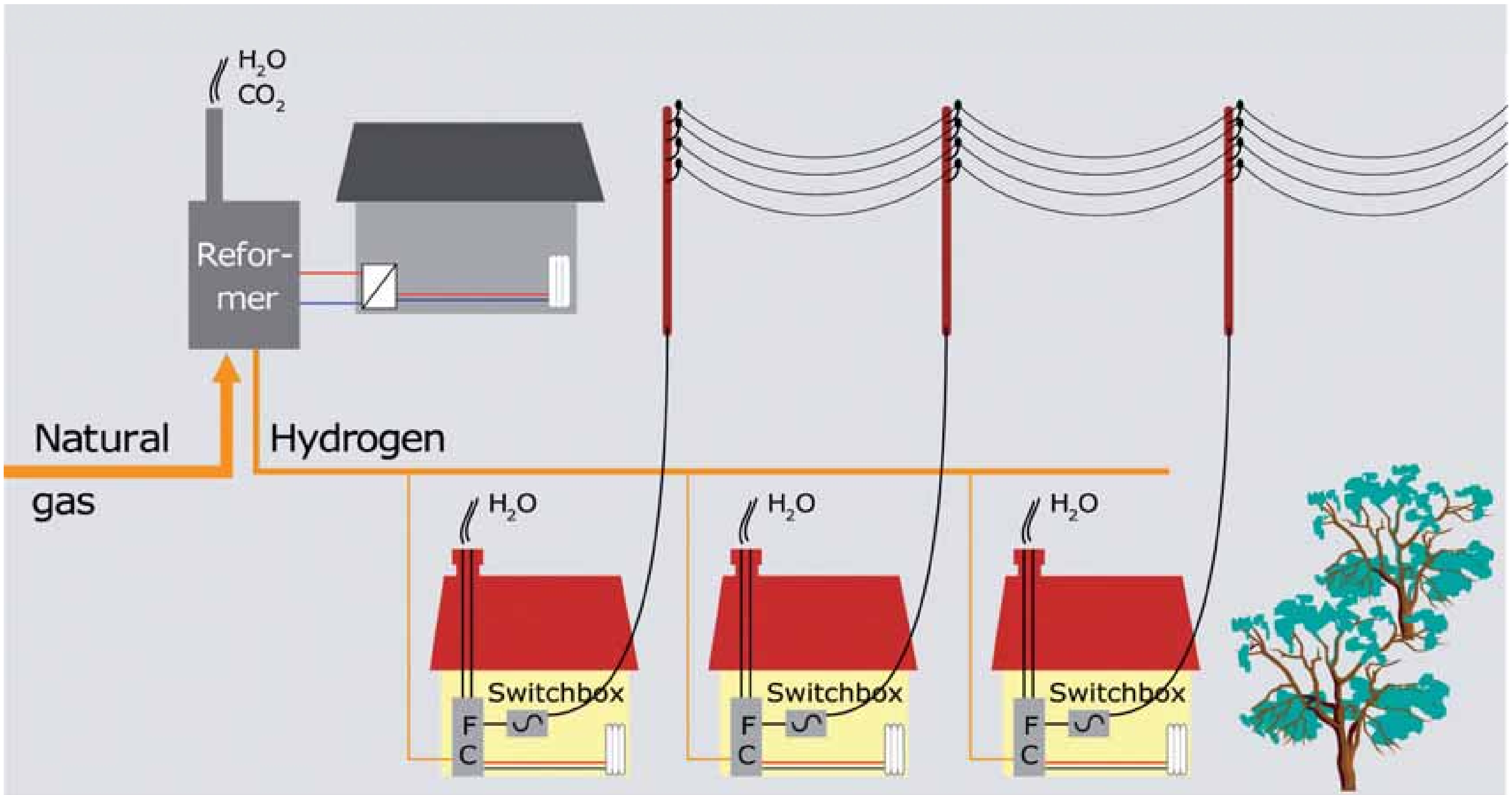
Optimizing energy efficiency and simplify the entire FCHS as much as possible.



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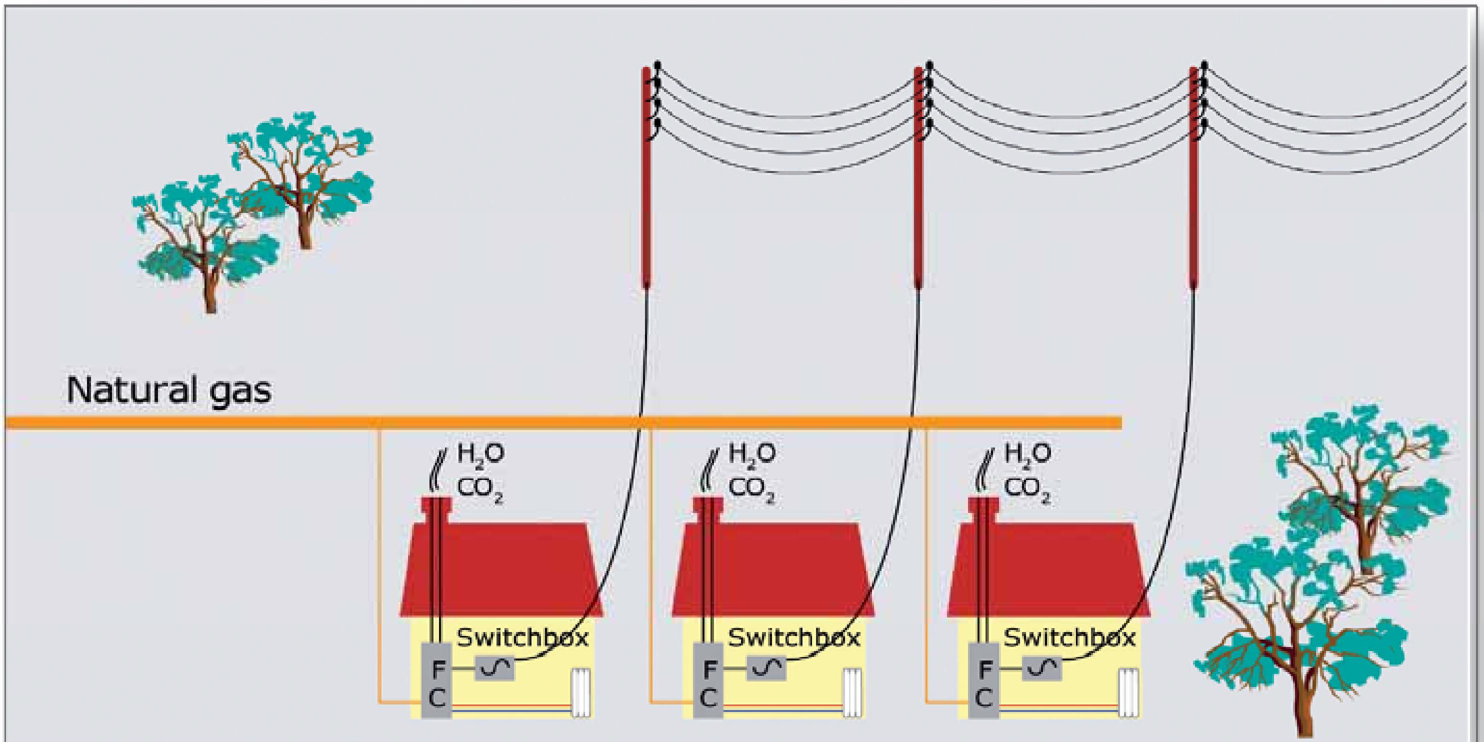

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Benefits/economic advantages arising from going decentral:

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

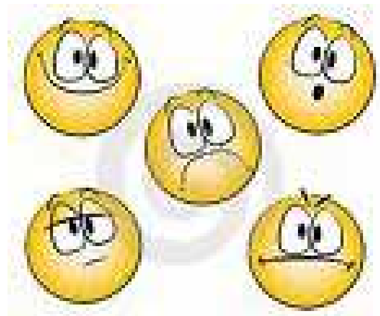
No loss of heat in a district heating system.

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



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Solution: We use HT PEM fuel cells instead!

Advantages:

•High tolerance to reformate 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.

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We now have <u>one</u> 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/H2 system for clusters of new houses in areas with a large proportion of fluctuating renewable energy sources in the electricity supply

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•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.

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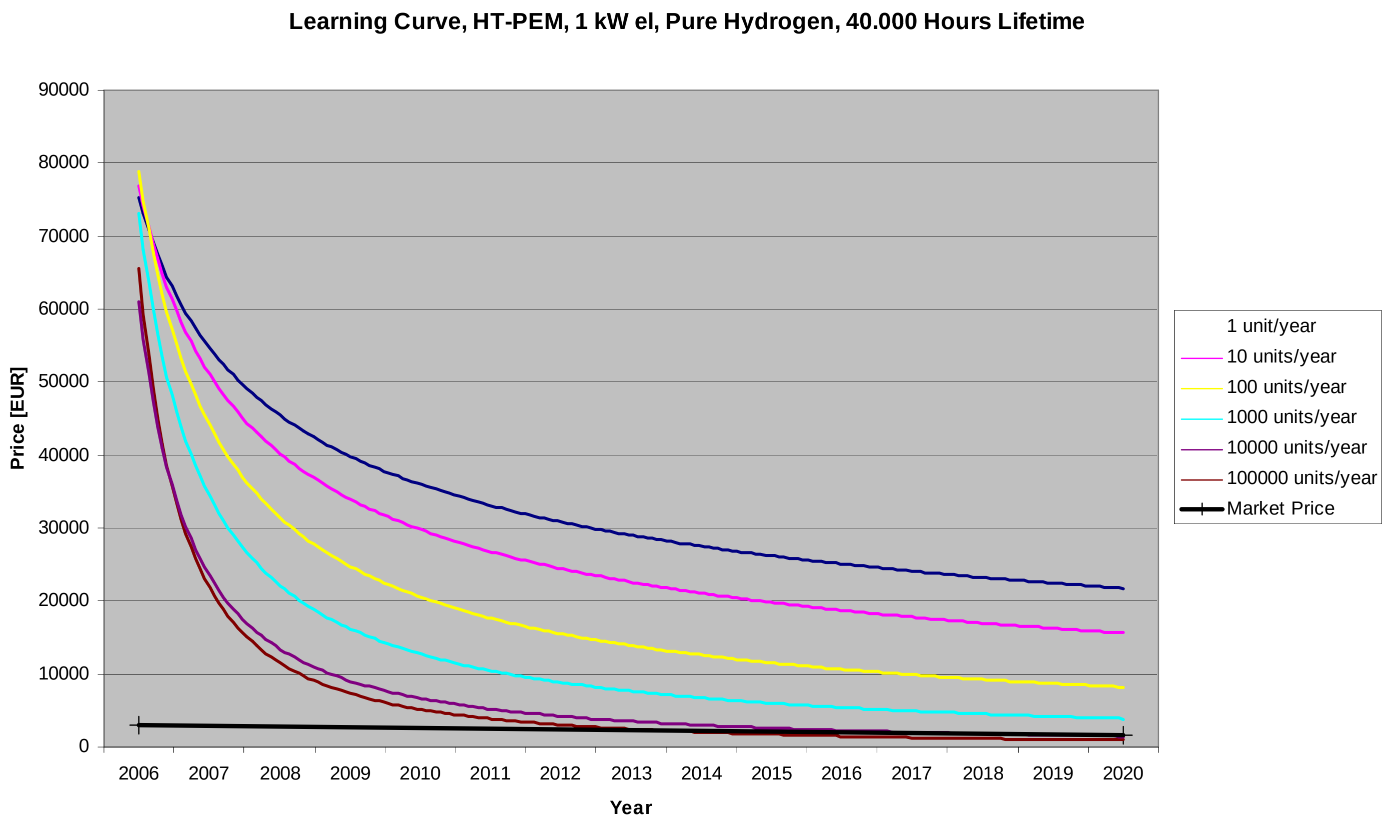
Cost reduction by learning and mass production:



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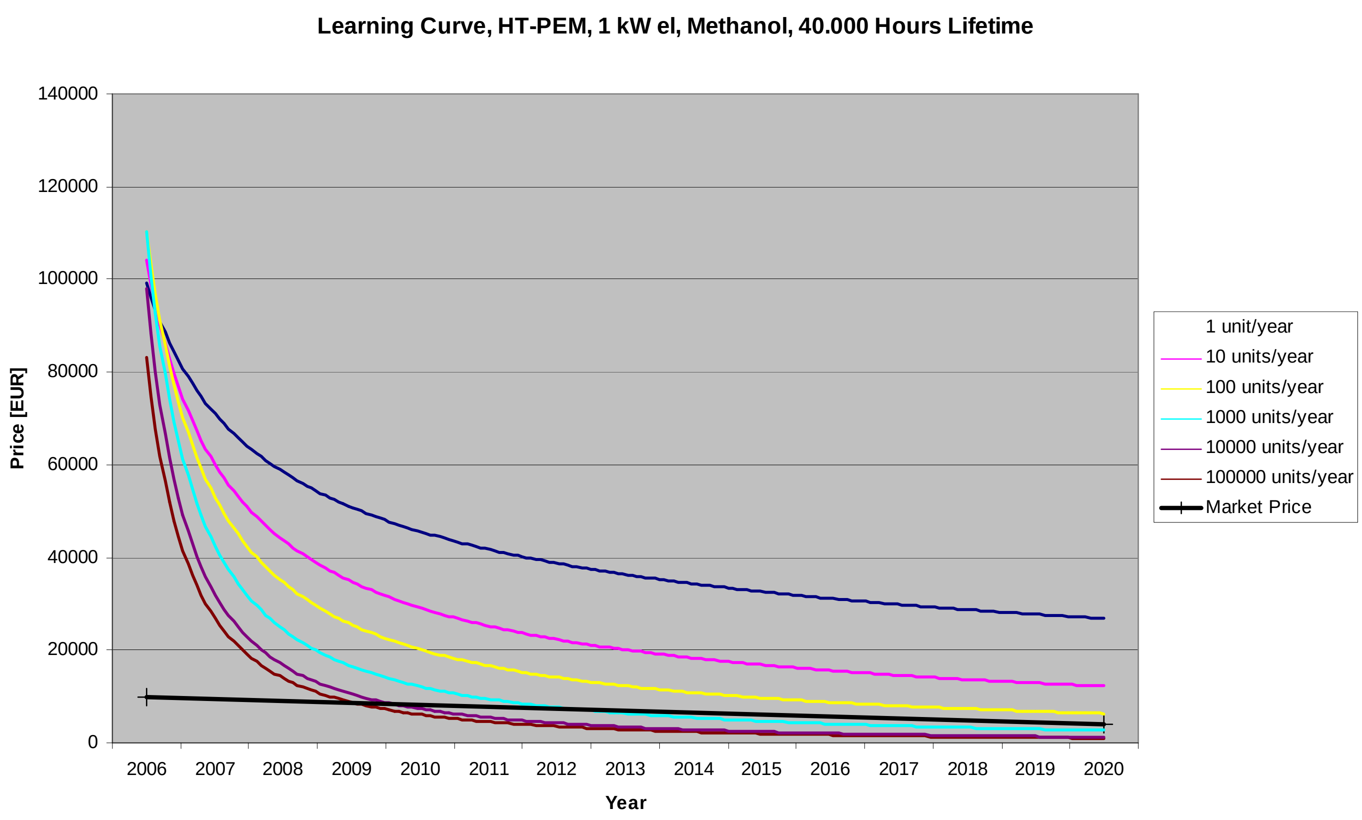

Intelligent Energy Europe

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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 electrolysers.

- Electrolysers are a well proven technology and it is reasonable to use a 20 year depreciation period.

Price of hydrogen via Electrolyses:	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	0,86	0,86	0,17	0,17	0,06	0,06
Maintenance costs		0,0060		0,0060		0,0060
Price of hydrogen		1,02		0,33		0,22

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Case Wind/H2 Denmark

		H2College	H2pia	H2PIA, 1500	H2PIA,10000, 2012
Net price of hydrogen used by CHP Euro/ Nm3		1,02	0,33	0,22	0,22
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
Electgricity tax per kWh		0	0		
Electricity tax per Nm3		0	0	0	0
Sum of tax ex. VAT		0	0	0	0
VAT %	25	0,26	0,08	0,06	0,06
Hydrogen price incl. tax per Nm3, Euro		1,28	0,41	0,28	0,28
Costs of hydrogen per house per year ex. depreciation Euro		3.181	1.029	686	686
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		8.461	4.549	3.236	1.366
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		-7.074	-3.162	-1.849	21

Total tariffs likely to be due 0,03 euro/kWh

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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