Superwind

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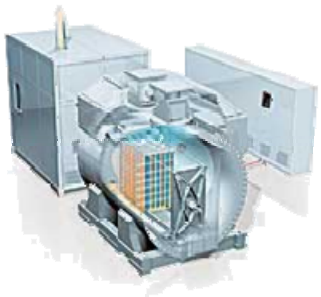
TU Delft
Technische Universiteit Delft

Where it all started !



FUEL CELL

Capable of internal reforming

- High temperature: 650 oC
- Runs on natural gas or biogas
- Internal heat to convert fuel into hydrogen
- High efficiency

Flow sheets calculations showed that:

- Hydrogen can be extracted
- Output of the fuel cell is flexible

What can be done with that flexibility?

Wind turbine + fuel cell = superwind

Large scale integration of wind energy

- may lead to grid congestion
- and increase the need for reserve and balancing capacity

Wind turbine owners have to pay for balancing costs

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Balancing costs

- Energy producers have to predict one day in advance how much they will deliver to the grid per hour.
- That information is given to the Transmission System Operator
- The day after operation, the actual amount delivered is measured.
- If the amount measured is different from the amount predicted, the producer has to pay for the balancing costs

Significantly decreases potential profit for wind turbine owners

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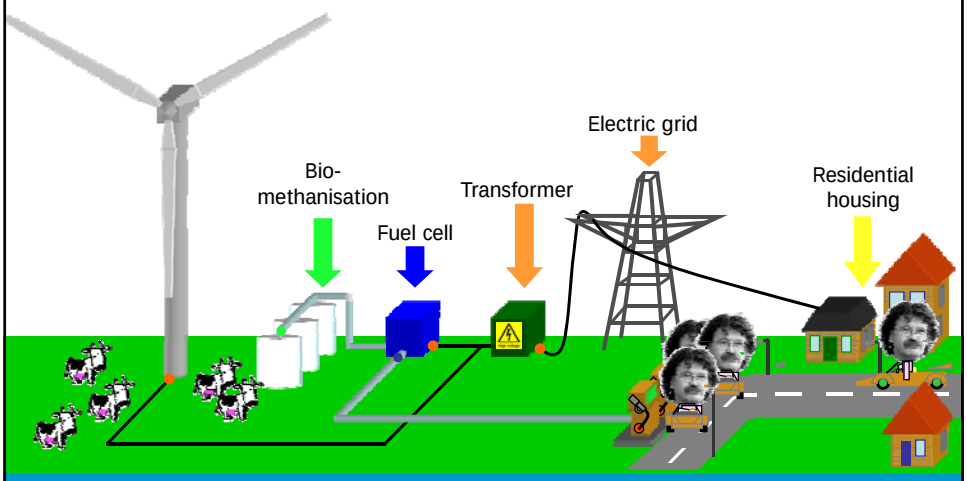
Superwind setup



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Feasibility:

Technically feasible?

- In theory YES!

Economically feasible? High degree of complexity

- **CAPEX** (Capital expenditure): currently 10,000 €/kW. SOFC target under SECA program 400 €/kW
- **OPEX:** Cost of fuel (natural or biogas) & O&M
  - Varies depending on which operation mode the fuel cell is used
- **Price and market for our products**:
  - Electricity:
  - Hydrogen: ~37 €/MWh
- **Accuracy of wind energy prediction**
- **Balancing costs**

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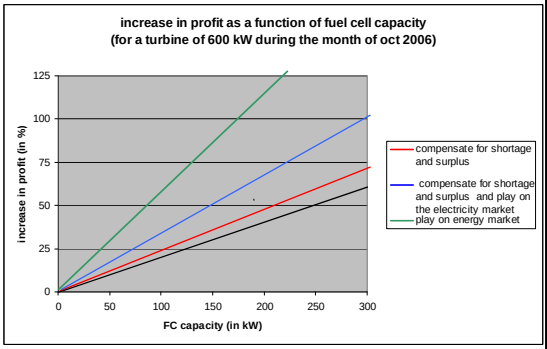
Feasibility:

Economically feasible?

- Energy market: APX
- Full flexibility of the system is not fully used if the fuel cell only compensates
- More interesting to also sell additional electricity on the market
- Selling electricity on the market is the most economically interesting



NG gas costs 25 €/MWh
H2 price: 37 €/MWh
CAPEX excluded
'profit' = MWhapx.APX(t) + MWh+.price+(t)-MWh-.price-(t)-MWhFC.COE +MWh.H2(t)

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What can we conclude?

A flexible energy system can generate additional profit

Superwind can help wind turbine owner to decrease their balancing costs

BUT this niche does not represent the most economically optimal way to use the flexibility of the system

Other possibilities?

• Imbalance market (short term trading of energy to maintain the system in balance)

• It can be used to adapt to a growing market for hydrogen and thus build an hydrogen infrastructure

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Questions?

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High degree of complexity

Economic feasibility depends on

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  - Electricity: APX market
  - Hydrogen: ~37 €/MWh
- Accuracy of wind energy prediction
- Balancing costs
- Fuel cell operation strategy

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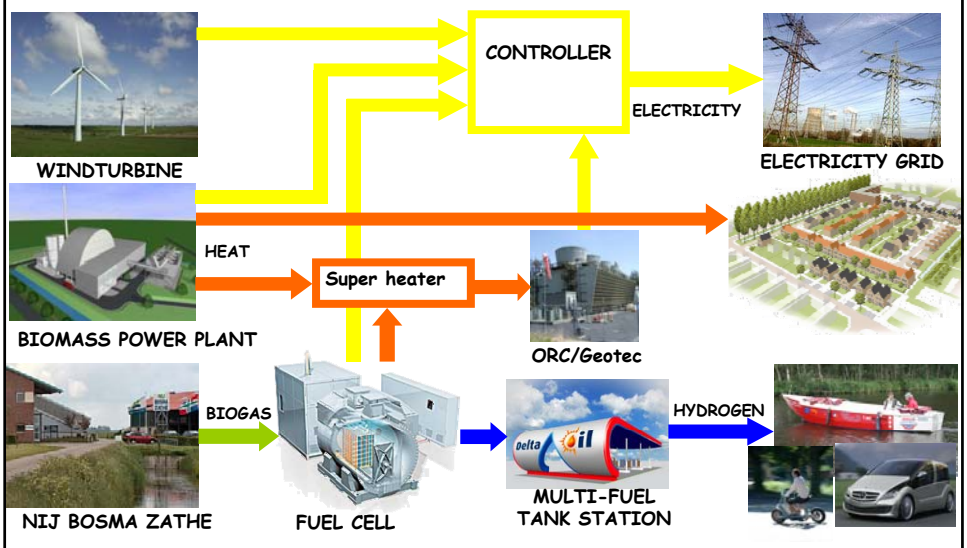

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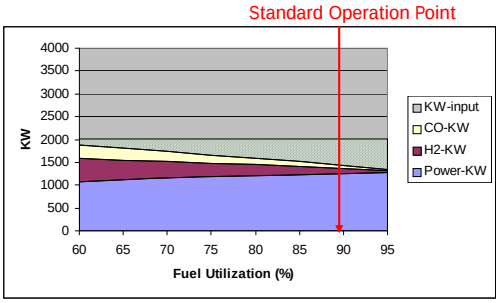
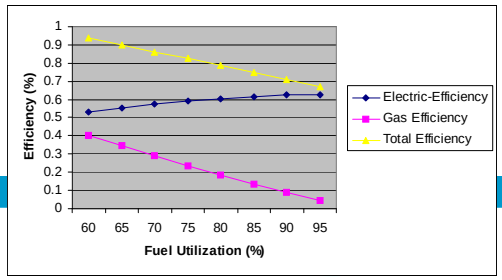
What is superwind?

Internal reforming fuel cell, an introduction

High efficiency mode

- Results based on flow sheets calculation for an IR-SOFC fed by natural gas
- Fuel utilization is decreased by decreasing the current density
- System can operate in a wide range of fuel utilization values from 95% i.e. 'normal' fuel cell operation mode up to 60% corresponding to hydrogen production mode.





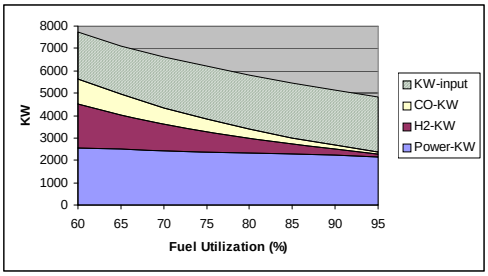
What is superwind?

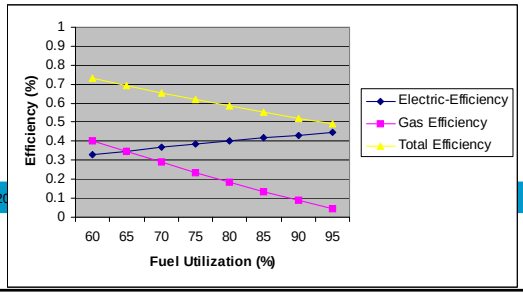
Internal reforming fuel cell, an introduction

High power mode

•Fuel cells can be operated at almost double power density.

• In addition also hydrogen is produced with equivalent 'double power'.





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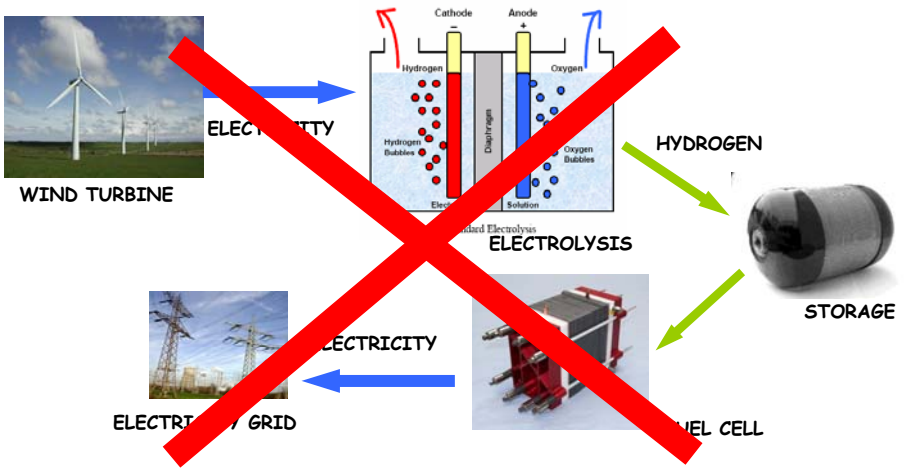
Wind turbine + fuel cell: usual approach



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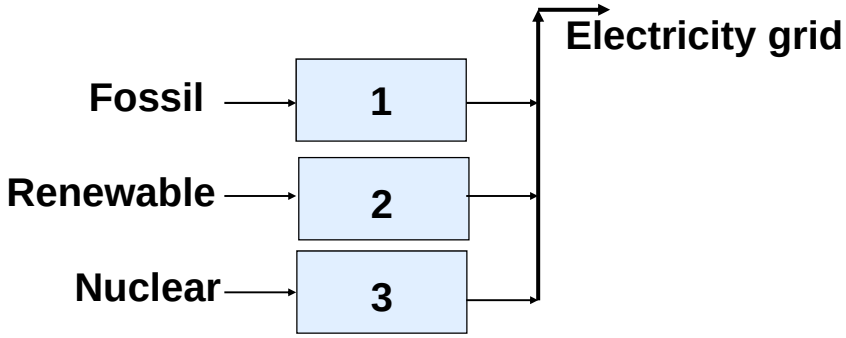
(un) sustainable hydrogen?!

Coupled linear electricity system



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Average balancing costs and APX price

Year	Shortage (in €/MWh)	Surplus (in €/MWh)	APX (in €/MWh)
2005	55 → -2	41 → -12	53
2006	59 → -1	52 → -6	58
Oct 2006	56 → -6	52 → +2	50
2007	41→ +1	38 → -4	42
2008 (until May 12th)	69 → -3	62 → -4	66

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Hydrogen

From wind energy: efficiency electrolysis: 80%

→1 MWh of wind energy generates 0.8 MWh of hydrogen

From fossil fuel: efficiency natural gas reformer: 80%

→1 MWh of fossil fuel generate 0.8 MWh of hydrogen

→ 1MWh of wind energy replaces 1 MWh of fossil fuel

Electricity

From fossil fuel: average efficiency 40%

To produce 1 MWh of electricity, 2.5 MWh of fossil fuel are needed

→ 1 MWh of wind energy replaces 2.5 MWh of fossil fuel

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A need for flexible energy production

- Increase in share of fluctuating renewable energy
- Power output of traditional power plants can't be easily changed
- Adapt to the market

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