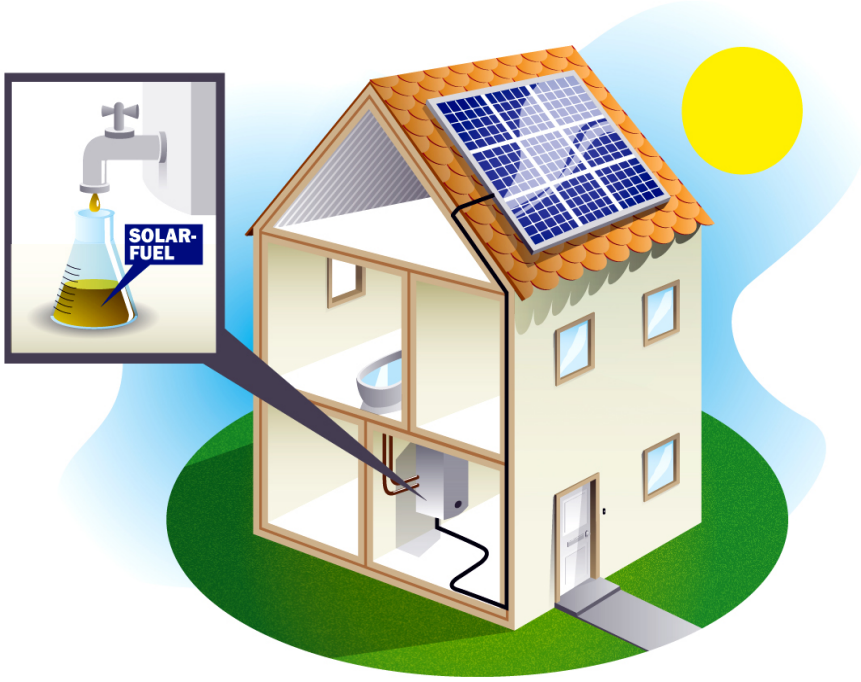
Solar fuels:
technology & economics conclusions

17 march
- Solar Fuels - EJ Sol
- Solar PV - W Sinke
- CO2 neutral fuels - R vd Sanden

24 april
- 100% sust. elec 2050 - K Blok
- H2 storage J de Joode
- Solar Fuels - conclusions EJ Sol



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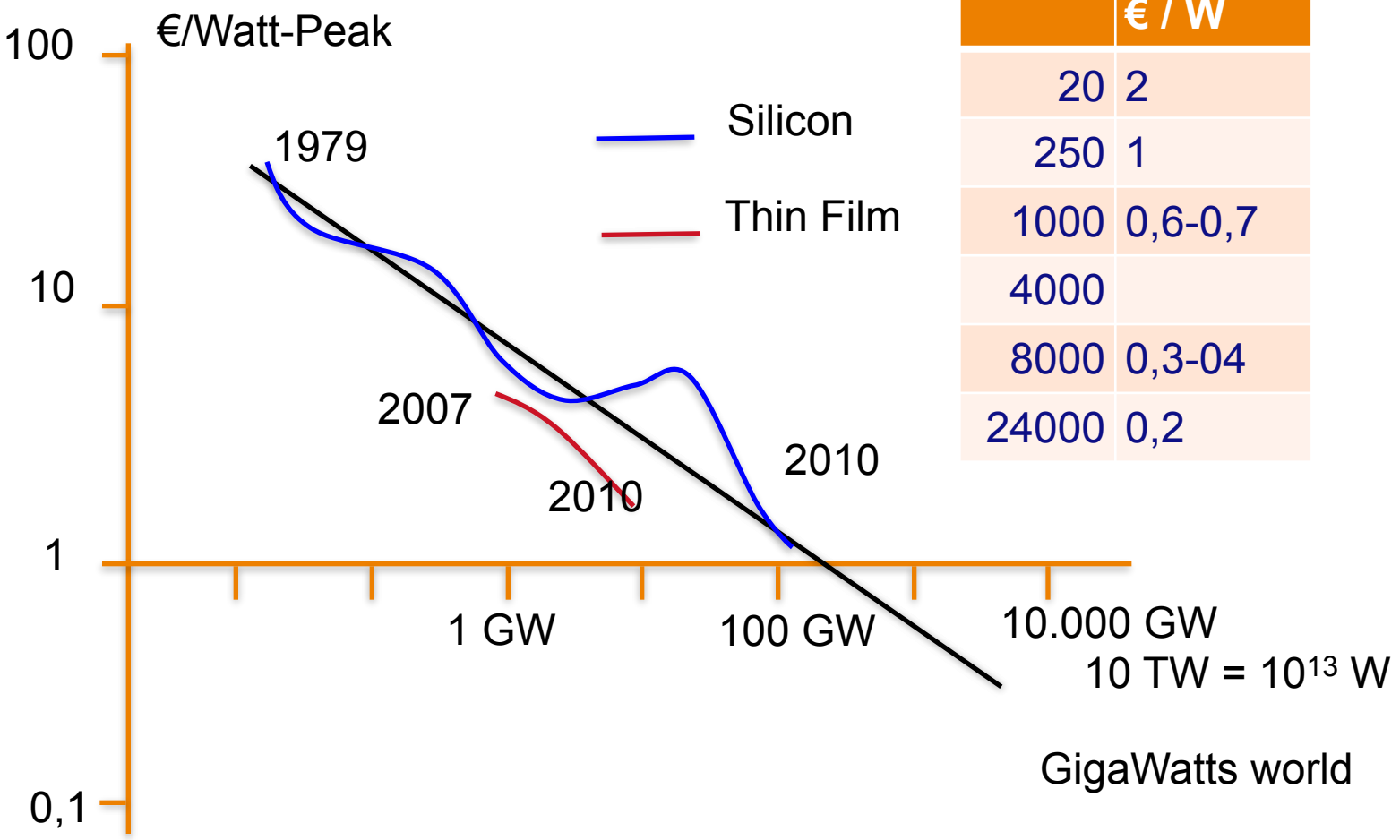
Learning curve for Solar Modules



GW	Module € / W
20	2
250	1
1000	0,6-0,7
4000	
8000	0,3-04
24000	0,2

2040: 20 m2 at 40% efficiency and 0,2 €/W_p costs 1600 € and gives you 8000 kWh/y

The most optimistic view: solar storage solved

Chemergy (solar storage) scenario:
if every one does a little, we achieve a little, so we need
for 4B people 80.000 GW_p not a 3000 in 2050 (800 in 2030)

year	GW Cum. Installed panels	Learning Curve € / W	1 GW fabs	New fabs added that year	Sales output all fabs
2010	35	2	13	7	40B
2015	285	1	88	15	50B
2020	1210	0,60	263	47	140B
2025	3320	0,40	544	71	300B
2030	7205	0,28	949	96	280B
2040	22800	0,20	2134	146	400B
(2050)	80000				

Electrical energy sustainable by 2050

Electricity today at home (2p) requires 3650 kWh/y or 10 kWh/d, by 2050 electricity (elec car, heatpump) requires 50 kWh/d/p x 16 M p in NL = 800 GWh per day or 200 GW_p during 4 h sun

Solar	%	NL	Germany	EU/Europe	World
People &space	m	16M and 41.k km	80M and 350k km	≈400M/750 4M/10M km	≈8B & 150M km
2010			14 GW		40 GW
2020	avr		52 GW	200 GW	
2020	10	20 GW	70 GW	400 GW	1.000 GW
2030					
2040	100			8000 GW	24.000 GW
(2050)	100	(**=2,5% NL**			(80.000 GW =0,25 % opp.

Other 17 march presentations

Wim Sinke:

Solar PV van niche naar impact

Dit is nog maar het begin:
naar super hoog rendement, en naar super lage kosten
- maar ook de waarschuwing dat opslag een uitdaging wordt

Richard van de Sanden

Energy storage in CO2 neutral fuels

CO2 neutral energy infrastructure (with gas buffer)
CO2 or H20 —- CO and H2 —- Gas-to-Liquids
direct (7%) or indirect (20%) CO2/H2O to CO/H2 conversion

Content

- Introduction
  - Summary previous presentation
- Let’s translate our sustainable energy challenge to your home
- Conclusions

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Your home solar PV (PhotoVoltaic) panels

Energy = Joule = Watt x sec or kWh (compare it with distance (km))

Power = Watt, in solar W_p (Watt-peak) (similar to speed = m/s or km/h)

Solar radiation in NL is 1000 W_{peak}/m^2 , then PV at 20% efficiency gives 200 W_p/m^2

Price for a solar panel is today 1-2 €/W_p and cost 200 - 400 €/m^2

Your roof 20 m^2, then you get 4000 kWh/y solar PV for 4000-8000 € + installation

but solar PV is peaky (**6h/d peak** at 20 m^2 at 200 W/m^2 = **24kWh/d**)

and your average use per household is 3600 kWh/y, or 10 kWh/d,

so you need buffering for the night and over multiple days

Storage is needed, use old e-car batteries (at 80%)

20 m2 at 200 W = 4kW during 6 hour implies 24kWh/d on sunny day

For 20 h (24 – 6 h sun) you need 18/24 of 10 kWh ≈ 7,5 kWh storage needed

Lead battery (car) 35 Wh per kg ≈ 7,5 kWh/35 Wh/kg ≈ 200 kg

Note: the other 14 kWh/d of the 24 kWh/d you upload that day to the net or:

Electrical car: 14 kWh gives you 50-100 km

So on a very sunny day (6 hour peak) 24 kWh/d you get from your 20 m^2
your daily 10 kWh/d electra with the aid of an old e-car battery
and with the rest (14 kWhd) you charge your e-car(s) or you upload it

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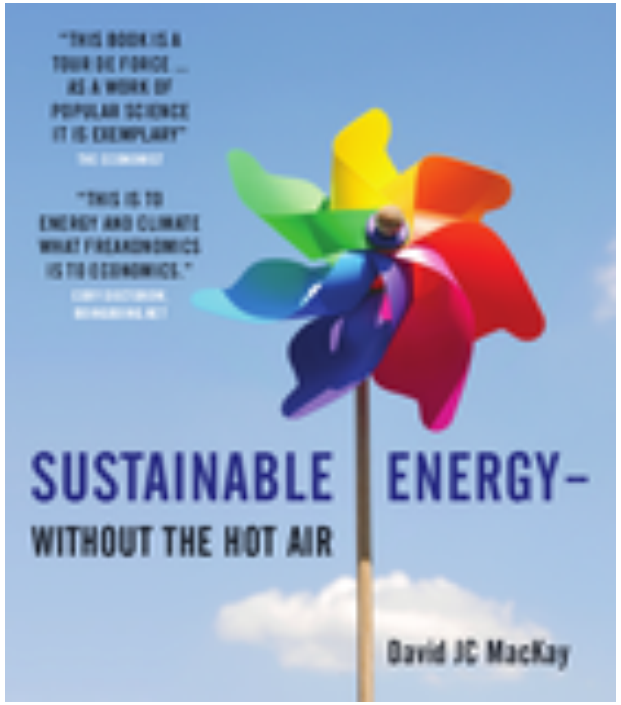
Fine, but ….

1 - cars tend to be cordless if you want to use them
and they happen to be **not** at home during day time



2 - by 2050: 10 kWh/d per household might not be reasonable,
100 kWh/d electricity per household (2 person) is more likely, why

Sustainable Energy- without hot air

free PDF version of book of Peter MacKay:

www.withouthotair.com

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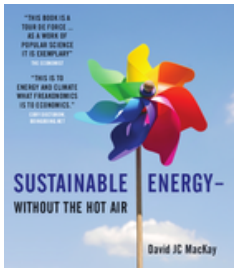
Sustainable Energy without hot air

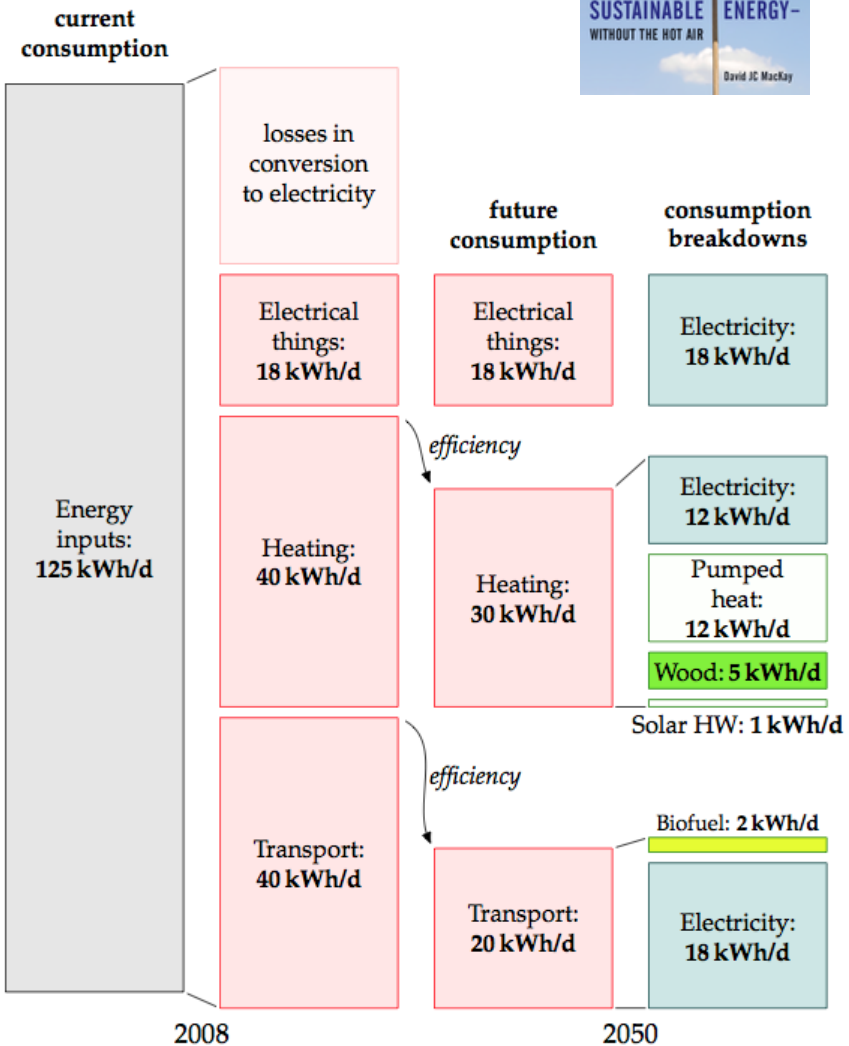


Ambition full sustainable in 2050:

Electrical energy use per person
≈ 50 kWh/d/p, or 100 kWh/d/house

100 kWh/d/p in 2050, then you
need 200 m² PV / house at 20%
or say 100 m² PV / house at 40%

If storage at 10 kWh/d/home took already 200 kg lead batteries, 100 kWh/d is not realistic with 2000 kg to be replaced ever year



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You don't have 100 or 200 m² on your roof, only 20 m² shadow free max

8 Million household that require 80-180 m² (100 or 200 -20 m² on own roof)

8 M x 80-180 m² = 640-1440 km² 40-20% efficiency panels in NL

NL is 40.000 km² large, so 1000 km² 2,5% of landscape

(note: today NL has 150 km² horticulture under glass)

let's say if each farm with 50 hectare and would install 2 hectare country side PV fields (4% of their landspace)

that would be possible,

and only if during peak hours we storage the surplus

of 1000 km² x 200 W/m² = 200 GW_p

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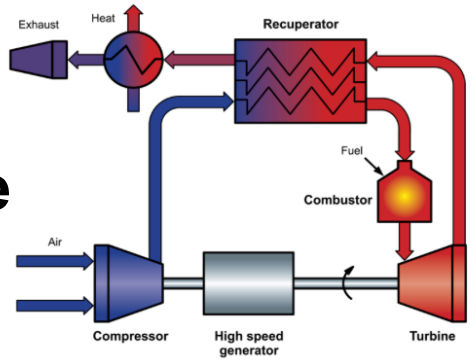

Intermezzo 2015-2025: load your car at night at home

micro CHP (Combined Heat & Power) (e.g. MTT-eu.com)

Heat your home during evening and night with a CHP solution

during 8 hours generate 20 kW thermic and 3 kW elec.

8 h x 3 kW = 24 kWh to load the car battery for 100km

8 h x 20 kW = 160 kWh to be spread over night & day

then you need a (heat storage) boiler of say 1000 lt.


But what if you replace your gas by heat-pump

3600 kWh/y electra (10 kWh/d) and 2000 m^3/y gas

2000 m^3 on 100 days implies an equivalent of 48 kWh/day heat
… with a heat pump with a COP of 4 you need 12 kWh/d electricity

Assume 20 m^2 PV at 200W= 4kW during 6 hours = 24 kWh/d
of which 10 kWh/d for electricity and 12 kWh/d for heat-pump

But you need to store the generated heat for the other 18 hours

at 12 kWh/d elec=48 kWh/d heat = 48 x 3600 kWs = 180 MJ/d
then you need a boiler with 1000 litre water with a delta T of 50^0 C


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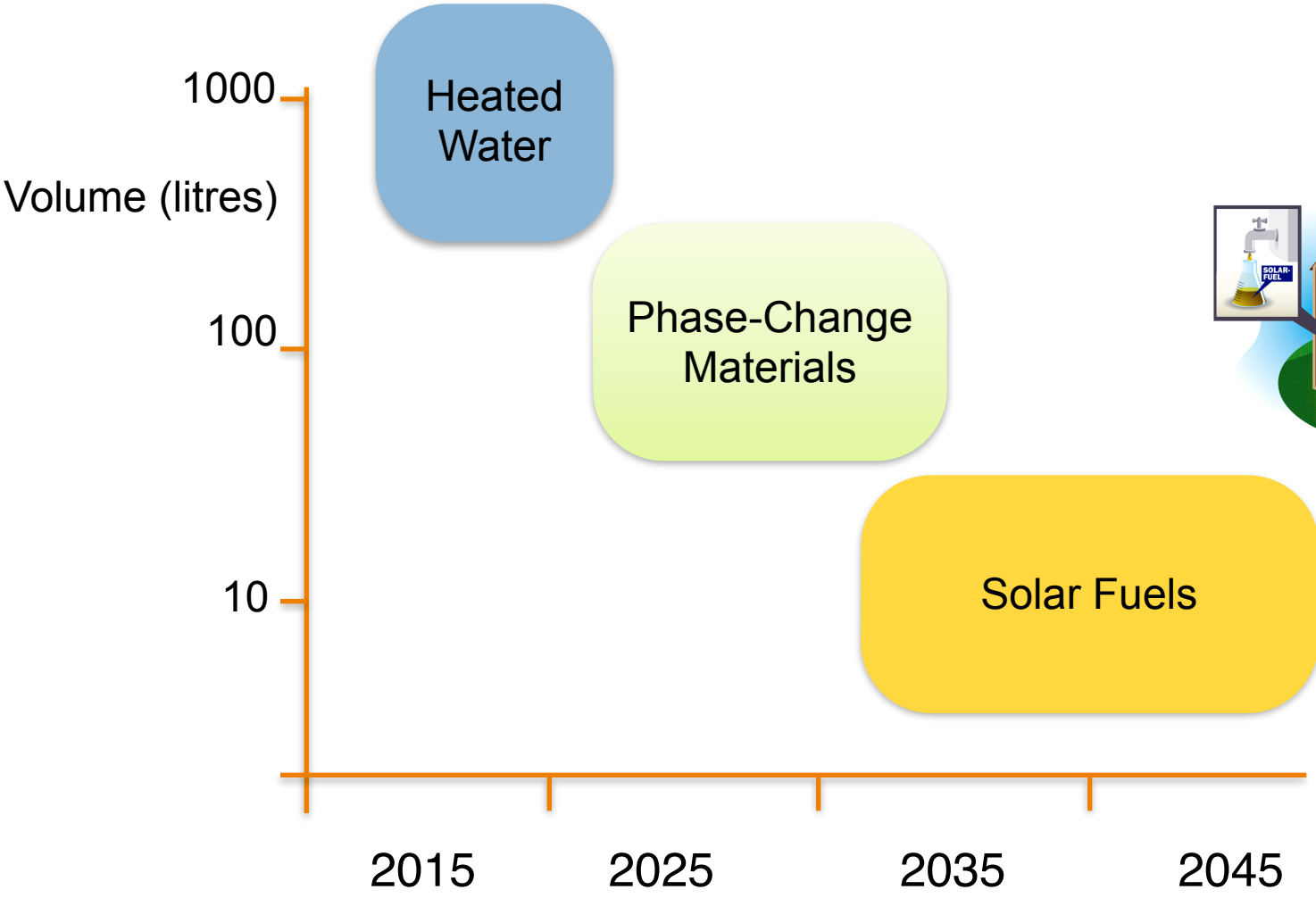
A roadmap ambition for energy storage at home



Chemergy – just like photosynthesis as in nature
Moore's law: from mainframe to tablet in 40 years
Solar learning curve: from power plant to home box

Surplus Electricity

↓

Electrolyze water:

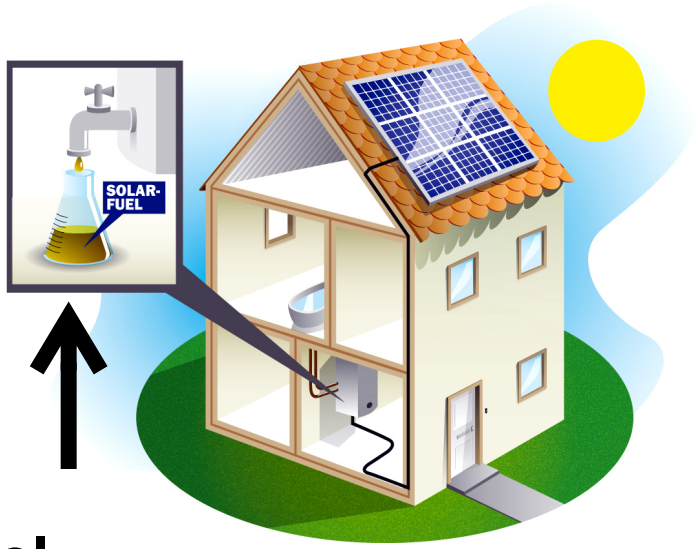
$2H_2O \rightarrow 2H_2 + O_2$

↓

$CO_2 + 3H_2 \rightarrow H_2O + CH_3OH$

↑

Surplus CO_2



Methanol

800 GWh stored into 133 M kg = 170 M lt methanol
Or at home 100 kWh/day into 16 kg = 20 lt methanol


Conclusion

- **Introduction**
  - Summary previous presentation

- **Let's translate it to your home**
  - It will not be a simple clearly to predict path toward 2050
    - but shift towards more electricity and less fossil fuel for heating
    - and significant increase of use of electricity (car and heat)
    - and need for more local storage
      - start at home with heat (not transportable) and local CHP
      - future solutions with solar fuels initially at industrial sites
      - as with CO/H2 (RvdSande) and H2 (today)
      - further isolate houses (20 m2 panels) and shift to generating PV electra and fuels for transport outside city for industrial use

- Discussion