Energy in a growing world

Can there be sufficient energy for a developing world?

Daan Schram
Emeritus Eindhoven university of Technology
FOM Institute of Plasma Physics
Background: Solar cell materials/ nuclear fusion

Energydays: www.tue.nl/energydays
Geert Verbong Terje Hansen
Floran Peeters Dennis de Clerck
Mieke Rossou-Rompen Rian Campen

Support: College van Bestuur TU/e, Faculties TN/ IE&IS
Many colleagues here and elsewhere, KNAW ----
Energydays:

Information in detail

David J.C. Mac Kae, Sustainable Energy – Without the hot Air, UIT Cambridge UK 2009
Also available on www.withouthotair.com.
T. Behringer, Kulturgeschichte des Klimas, Beck
F. Pearce, When the rivers run dry, Beacon, Boston
J. Hermans, Energie survival gids, Beta text, Bergen
Energy in a growing world, a retrospective

Contributions of many colleagues

10 Energydays academic years 2008/09 & 2009/10

<table>
<thead>
<tr>
<th>Day 1 Climate</th>
<th>Day 2 Biofuels</th>
<th>Day 3 Solar cells</th>
<th>Day 4 CSP &amp; Nuclear Fusion</th>
<th>Day 5 energy use &amp; availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Wahner</td>
<td>A. Domburg</td>
<td>W. C. Sinke</td>
<td>N. J. Lopes Cardozo</td>
<td>W. J. van der Zande</td>
</tr>
<tr>
<td>A. Kattenberg</td>
<td>R.A. van Santen</td>
<td>J. Rentsch</td>
<td>J. Rapp</td>
<td>G.J. Kramer</td>
</tr>
<tr>
<td>R.S.W. van de Wal</td>
<td>Wim van Swaaij</td>
<td>M. Zeman</td>
<td>Ch. Linsmeier</td>
<td>J. H. Blom</td>
</tr>
<tr>
<td>P. Levelt</td>
<td>Bram van der Drift</td>
<td>R. J. A. Janssen</td>
<td>H. Müller-Steinhagen</td>
<td>R. Segers</td>
</tr>
<tr>
<td>J. Lelieveldb</td>
<td>Udo de Haes</td>
<td>M. van de Sanden</td>
<td></td>
<td>N. D. van Egmond</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Day 6 Fuel cells , H₂ Storage transport</th>
<th>Day 7 Nuclear energy &amp; wind and water</th>
<th>Day 8 geothermal &amp; built environment</th>
<th>Day 9 CCS &amp; energy &amp; ghg in agriculture</th>
<th>Day 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>L. J. F. Hermans</td>
<td>T. van der Hagen</td>
<td>M.M. van Aarssen</td>
<td>D. Jansen</td>
<td>A. M. Diedereren</td>
</tr>
<tr>
<td>J. J. C. Geerlings</td>
<td>H.J. Allelein</td>
<td>J. Lichtenberg</td>
<td>E. Wesker</td>
<td>J. J. C. Bruggink</td>
</tr>
<tr>
<td>W. G. Haije</td>
<td>B. van der Zwaan</td>
<td>H. A. Zondag</td>
<td>R. Arts</td>
<td>C. J. H. Midden</td>
</tr>
<tr>
<td>D. Stolten</td>
<td>J. de Rouck</td>
<td>J. Kristinsson</td>
<td>P.S. Bindraban</td>
<td>D. C. Schram</td>
</tr>
<tr>
<td>N. D. van Egmond</td>
<td>P. Gerbens-Leenes</td>
<td>H. Frey</td>
<td>J. Bouma</td>
<td>A. Heertje</td>
</tr>
</tbody>
</table>

This talk: a retrospective, my impression
Is it a beta problem?

*Bee flying: energy spent in flight < energy collected in honey from flower*


*Energy shortage or: too much use of energy? Infinite energy supply? Is that possible? Desirable?*
Growing world: consequence of: cheap/abundant energy?

- fossil fuels → CO₂
- water/
- Use bio/forests
- food

New energy carriers
Balance use, availability

Availability/ rise/ rise demand
Climate consequences
Energy scenarios: expectations & reality
Need new renewable energy
Analysis: UK: possible but demanding!
World perspective: Mega cities south: Huge agenda
Role university: develop new energy sources
Critical analysis, Change needed: priorities: alpha
1. Climate?

CO₂ very risky experiment: outcome uncertain, but certainly worrisome

Enough plans/ goals: very long transition/ promises:  
But: in 2050 still fossil dominated?

CO₂ will continue to rise? no ways to stop?

True renewables: Solar/wind --- too expensive: or: gas/ oil/ coal too cheap?
Climate, other changes?

Are CO$_2$ and temperature rise only threats?  
Groundwater levels, water stress, carbon content in upper layer soil?  
Deforestation, urbanization, change surface albedo?  
Acidification oceans  
More causes?

What about other greenhouse gases? NO$_2$, CH$_4$, CO, O$_3$ ----  
→ agenda technical science:  
visualization green house gases! Satellite

Other green house gases: if stopped: lasts only months – years  
Only CO$_2$ remains
Climate: T rises ---

**Note:** look at: land average/ northern hemisphere
(world average with sea: more difficult to see changes)

---

**CO₂ expected to keep rising?**

**Global energy power demand:**

2008: 6.5 Billion people: 12 TW
2050: 8-10 billion people: 20TW

---

Rene Janssen: day3

---

**Experiment to be continued?**
**Climate and (un)certainties:**

- Man made influence on the sun is estimated to be 0.2 °K.

- Risky: Likely to increase further, present view (Nature 09): absolute quantity CO₂ limited of which about ½ is already emitted.

---

**Graph:**

- Per brandstoftype
- ExaJoule/ jaar
- 10^{18} J/yr
- Gas
- Oil
- Coal

---

**From:** Lessen uit mondiaal verkennen
**Milieu en Natuur Planbureau**

**As usual:**

- CO₂ ppm
- NO₂ ppb
- CH₄ ppb
- δO¹⁸ %

**Thousands yrs**
Climate monitoring

Very important contribution: essential for critical position university:

*Can we “see” the influences and change climate?*

Maybe we should stay away somewhat from only technological fix?
Climate: monitoring: Carbon tracker

Winter: net carbon production

Summer: net carbon consumption

Note: forests are more effective in moderate regions: deforestation there is greater loss. If more dry: then less carbon fixed

CarbonTracker Europe : Wageningen University contribution to the Integrated Carbon Observing System (ICOS) ; http://www.icos-infrastructre.eu
Climate monitoring

But: integrated over year: net sources CO₂ CH₄

→ We do it ourselves (CO₂ & CH₄)

Climate and monitoring: satellite: Sciamachi/ Envisat

Note: look at: land average/ northern hemisphere
(world average with sea: more difficult to see changes)

http://www.esa.int/esaCP/SEM1DUQ08ZE_index_0.html
Climate and uncertainties: some notions: observations

New: several observables can be observed on internet: (TW!)
Ice extend/ sea heights etc
IR detection of molecules: \( \rightarrow \) column density \((1/m^2)\) \(\text{CO, CO}_2, \text{CH}_4, \text{NO}_2\)
Satellites: OMI, Sciamachi, --- (Lefelt day2)

Example \(\text{NO}_2\):
correlation with transport?
Other changes:
Water precipitation changes:

Dryer in south
Wetter in north
Arctic ice extend

2009

2010

Median 1979-2000

Arctic ice: decreases dramatically

2007: smallest, but 2010: both passages ice free

See also Van der Wal Day1

Oceans:

*sea-surface temperatures: increases in the North Atlantic and European marginal seas.*

Temperature changes of the yearly average between 1978 and 2002

Source: PIK, based on Hadley Centre, 2003

Ocean currents remain unaffected?

*Dijkstra Day1*

Dust/ aerosols temper T rise?

*Lelieveld Day1*

Acidification oceans
Something needs to be done:

Transition

Revolution to renewable energy sources

Same society with much less energy? 1/3? 1/5?

For Europe not much time:
New energy, still << fossil fuels?

- Solar cells/ local/ desert/ very large source/ requires new concepts
- Solar thermal (CSP): available, in desert: Surface area requested < biofuels
- Biomass: dispute: (competition food, large area deforestation, carbon water)
- Wind/ water waves/ tide/ geothermal: available
- Hydropower
- Nuclear requires new generation?
- Nuclear fusion?

But: will they ever be?

Oil gas so easy, so cheap
Sun: potential & demand (in light)

Enough (sun) potential: *but elsewhere*
New energy: the sun: CSP

-Solar cells
- Concentrated solar power (CSP) Spain/ Sahara, viable option?

Kramers Junction
California US
345 MW ^

Projected cost electricity

plan Germany:
Desertec in North Africa
Mueller Steinhagen, Day 4
New energy: Solar cells

Possible: expensive? Cost ~ large car?!
New architecture
Solar cells: needed

Possible!? Requires $4 \times 10^5$ km$^2$ for world energy by 2050

Materials: Silicon ---
Efficiencies $> 15 – 20\%$

Fabrication technologies
Fast thin layer growth
Structured, nano?

Needed: $> 20$ km$^2$/dag
→ roll on roll off processing

Sinke, Janssen, vd Sanden Day3

If car $\sim 100$ m$^2$, then this is equivalent to $> 10$ million cars/year
New energy Solar cells: costs

Most pressing issues for large scale:
new thin layer solar cell types
high efficiency
of abundant materials
fast production
Biofuels

Global Energy Demand: ~420 EJ
~ 45 EJ by biomass?

Traditional biomass: ~29 EJ
Commercial: 16 ± 6 EJ

Liquid Biofuels ~0.5 EJ

Potential for 2nd generation: but:
Contribution limited

Competition with food, Bindraban, Day2

Carbon content in soil: Bouma day 9
Conflict Water
## Other options:

<table>
<thead>
<tr>
<th>Wind</th>
<th>Water: waves/ tidal</th>
<th>Geothermal</th>
</tr>
</thead>
</table>

*Most: electricity:
see later! makes sense: better efficiency
Limited storage needed*

<table>
<thead>
<tr>
<th>Storage</th>
<th>Batteries</th>
<th>Hydropower</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DC High Voltage</td>
<td>Smart grids</td>
</tr>
</tbody>
</table>
Longer term

Nuclear: newer generations: more efficient use/ shorter radiation times

Nuclear Fusion:

ITER
Demo
Reactor

End of this century?
Concluding: New energy options:

To be honest: not simple:

Or large volumes/surfaces partly new materials, fast production

Thus challenge: perfect agenda for university

But: no easy fix!
Energy use and options MacKay

An analysis in numbers: kWh/day/person

David J.C. Mac Kae, Sustainable Energy – Without the hot Air, UIT Cambridge UK 2009
Also available on www.withouthotair.com.
See also film on this site
Energy use and renewable energy options MacKay

Mac Kay: analysis for UK: all in one unit: kWh/day

Analysis use in kWh/day/person
- Stuff
- Food
- Housing
- Transport

Analysis energy options in kWh/day/person
- Wind/ Sea waves tidal
- Nuclear
- Biomass
- Sun
  (& sun elsewhere)

Possible: First: no limitations, no nimbys

Needed: expand this analysis: also for Netherlands/ Europe: not world!!
Analysis MacKay: UK use per person kWh/day

Thus: first order:

Transport (oil mainly)
Heating houses (mainly gas)
Electricity (coal & gas)

Differences partly due to: embedded energy in products
A plan: MacKay: analysis per person

Traditional use pattern & maximized renewables

But realistically: UK realistic renewables

Add nuclear
Add energy elsewhere
A plan: MacKay including map UK

125 kWh/d

- Electrical things: 18 kWh/d
- Heating: 40 kWh/d
- Transport: 40 kWh/d

45 kWh/d

- Electrical things: 18 kWh/d
- Heating: 30 kWh/d
- Transport: 20 kWh/d

Plan M

Future consumption

- Solar in deserts: 16 kWh/d
- Nuclear: 16 kWh/d
- Tide: 3.7
- Wave: 0.3
- Hydro: 0.2
- Waste: 1.1
- Pumped heat: 12 kWh/d
- Wood: 5 kWh/d
- Solar HW: 1
- Biofuels: 2
- PV: 2
- Wind: 8

Dpt Trade &
Associated costs

Some of associated costs:

<table>
<thead>
<tr>
<th>Description</th>
<th>Capacity</th>
<th>Cost 1</th>
<th>Cost 2</th>
<th>Cost 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear power: 40 stations</td>
<td>45 GW</td>
<td>£60bn</td>
<td>£1000</td>
<td>£1600</td>
</tr>
<tr>
<td>Clean coal</td>
<td>8 GW</td>
<td>£16bn</td>
<td>£270</td>
<td>£5700</td>
</tr>
<tr>
<td>Concentrating solar power in deserts: 2700 km²</td>
<td>40 GW average</td>
<td>£340bn</td>
<td>£5700</td>
<td>£1000</td>
</tr>
<tr>
<td>Land in Europe for 1600 km of HVDC power lines: 1200 km²</td>
<td>50 GW</td>
<td>£1bn</td>
<td>£15</td>
<td>£15</td>
</tr>
<tr>
<td>2000 km of HVDC power lines</td>
<td>50 GW</td>
<td>£1bn</td>
<td>£15</td>
<td>£15</td>
</tr>
<tr>
<td>Biofuels: 30 000 km²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood/Miscanthus: 31 000 km²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Very demanding! But cheaper than Iraq war?
It can be done, but:

Requires reduction of energy use
Nuclear and/or solar in desert

Energy flows (im-)possibilities
Large part: oil → transport; gas → heating; coal → electricity
Not easy to control! And significant loss (electr, transport)
Renewables: primarily electricity

Savings/reduction: gas:
-Domestic/housing: isolation, sun, co-generation etc
- Electricity: sun/wind, co-generation

Transport in present form: difficult to change: Less?
Electric cars with renewable energy?

- Nothing beats the comfort of fossil fuel
- When driving, nothing beats a tank full of gasoline,
  
  Jo Hermans Day5
One measure: Low energy housing:

Seasonal thermal heat storage, hot water supply, solar cells, isolation

House can become energy neutral or even generating

Enormous challenge: must happen with existing houses

New materials/methodologies
New architecture

New urban design: Frey: Vauban: Day 8

+ Electric storage
Electric car
Less
Possible measures

**Housing**: a large portion is avoidable: clear agenda
Note: emphasis on existing housing (besides regulation for new)
Interesting for Technical University!!

**Food**: Meat! Is in modern life small energy part

**Transport**: largest in modern society: less transport!
Most difficult: emotionally: life style change!
and: gas/ oil best energy carrier and cheap

Development cars: electric?
Change concept of individual transport??

*How much transport can the climate stand?*
World >> than UK, Europe, US

New world = The South
There are serious problems

Expectations (TVO): in 2030:
> 30% of world population in slums in large cities
  - Insufficient water/ energy/ sanitation
  - 50% young people
Energy use and prosperity

Energy use will increase

Mac Kay
## The larger world

<table>
<thead>
<tr>
<th>Food versus Biofuels, deforestation, sea, threats water shortages/floods</th>
</tr>
</thead>
</table>

General observation: feeding the world is possible  
Energy wise: limited portion  
But: water stress, too low groundwater levels: serious threats  
Competition biofuels

Note: depends on developing climate, water levels ---  
this year: problems: *Threats hunger* *(Bloomberg)*
The larger world: Baud day TVO

In 2030: >80% in the developing south: in megacities!
Partly in slums (the younger part)

Serious agenda!!
Water, sanitation/electricity

32% of world in slums
43% of urban population in developing regions
78% of urban population in least developed countries lives in slums
Number of slum dwellers growing to 2 billion
Energy availability world

Soon: serious tensions: political/ economical
   We need to be prepared, start now!

World larger problems:
   poverty, hunger, diseases, shortages
   The real challenge

Infinite energy?: is that possible/ desirable?
   There is no easy technological fix!?
Energy in world perspective

For $\beta$- technical science: clear agenda: new energy/ less use

For $\alpha/\gamma$: philosophy/ priorities : what is important

*How to make common agenda?*

What is economy?
Conclusions

Climate: serious threat! Make it visible with maps ---

More threats than CO₂

New energy sources needed: even if more expensive?

Possible but demanding

World moves south: many large problems, megacities with slums

Will be serious competition on food, water energy

We need an aggressive agenda
Energy in world perspective

For $\beta$-technical science: clear agenda: new energy/less use
But is it a $\beta$ problem? Is it our problem?

For $\alpha/\gamma$: philosophy/priorities: what is important
How to make common agenda?
What is economy?

Is it an $\alpha$ problem?