Master class days on energy and climate

Geert Verbong

Day 3 Solar cells
Introduction

Why these lectures?
• At KNAW (Royal Netherland Academia of Arts and Sciences) several discussions devoted to Climate and various Energy Options
• Realization that it is not easy to get quality information
• New series primarily for PhD and MSc students
• Aimed at getting information in detail

Organization:
• Daan Schram, Initiator, professor emeritus physics TU/e
• Geert Verbong, Technology & Sustainability studies
• Mieke Rossou-Rompen, Secretary
• Terje Hansen, group PMP Physics department
• Dennis de Clerck, communication
Program

First year: 2008-2009
- Climate
- Biofuels
- Solar cells (today)
- Nuclear Fusion & Thermal Solar (April 7)
- Energy Availability and Energy Use (May 26)

Second year 2009-2010
- Hydrogen/Fuel Cells, Wind and Water Energy
- Geothermal Energy/Energy Storage, Agriculture
- Electricity: Networks and Storage
- Nuclear Energy & CCS
The problem

World energy consumption in TW (BP statistical review 2006)
The problem

2004 Worldwide Energy Sources in TW (Wikipedia)
Renewable Energy, end of 2006 (GW)

## Renewable Energy Resources

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Current use (2001)*</th>
<th>Technical potential*</th>
<th>Theoretical potential*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydropower</td>
<td>9</td>
<td>50</td>
<td>147</td>
</tr>
<tr>
<td>Biomass energy</td>
<td>50</td>
<td>&gt;276</td>
<td>2,900</td>
</tr>
<tr>
<td>Wind energy</td>
<td>0.12</td>
<td>640</td>
<td>6,000</td>
</tr>
<tr>
<td>Solar energy</td>
<td>0.1</td>
<td>&gt;1,575</td>
<td>3,900,000</td>
</tr>
<tr>
<td>Geothermal energy</td>
<td>0.6</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Ocean energy</td>
<td>not estimated</td>
<td>not estimated</td>
<td>7,400</td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
<td>&gt;1,800</td>
<td>&gt;4,000,000</td>
</tr>
</tbody>
</table>

Current use is in primary energy equivalent.
For comparison, the global primary energy use was **402** EJ per year in 2001.


**Exajoules per year:** \(10^{18} \text{ J/yr}\)
The Challenge

PV
• Very large potential
• Very small contribution (2009)

Development of PV (*Perlin, From space to Earth*)
• Started in space
• Successive niches
• Next step: grid connected applications
• Not (yet) competitive
The Challenge 2

Two guiding principles
- Increasing efficiencies solar cells
- Reducing (production) costs

Search for new concepts and production technologies

Questions
- Cristalline silicon dominant (94%), potential for improvement of Si?
- Breakthroughs needed, possible?
- Potential of 2\textsuperscript{nd}, 3\textsuperscript{rd} generation solar cells?
Morning Program

09:15 – 09:30  Introduction dr. G. Verbong, TU/e
09:30 – 10:30  The solar (r)evolution
               Prof. dr. W.C Sinke, ECN, UU, EU PV Tech. Platf.
10:30 – 11:30  New developments in thin, high efficiency,
               crystalline silicon solar cells,
               Dr. J. Rentsch, Fraunhofer Institute SES, Freiburg
11:30 – 11:45  Break
11:45 – 12:50  Advanced thin-film silicon solar cells
               Dr. M. Zeman, TU Delft
12:50 – 13:45  Lunch
Afternoon Program

13:45 – 14:45  Solar cells based on polymers
               Prof. dr. ir. R. A. J. Janssen, TU/e

14:45 – 15:45  Thin-Film Solar Cells based on Nano-Structures
               Prof. dr. J. Schoonman, TU Delft of

15:45 – 16:00  Break

16:00 – 17:00  The Terawatt challenge: High throughput processing and scale vs. solar cell efficiency
               Prof. dr. ir. M.C.M. van de Sanden, TU/e

17:00 – 17:15  Short summary of the chairman

17:15          Drinks and dinner (with registration)