SPS – European Perspectives

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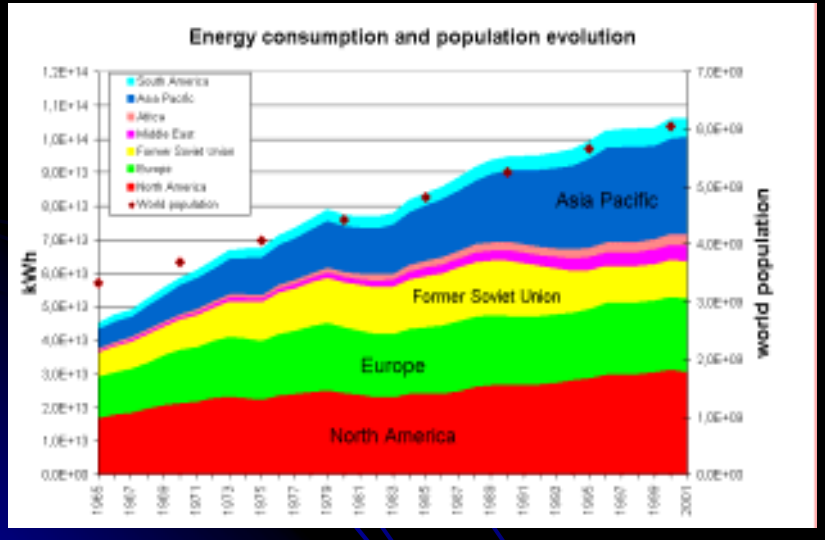
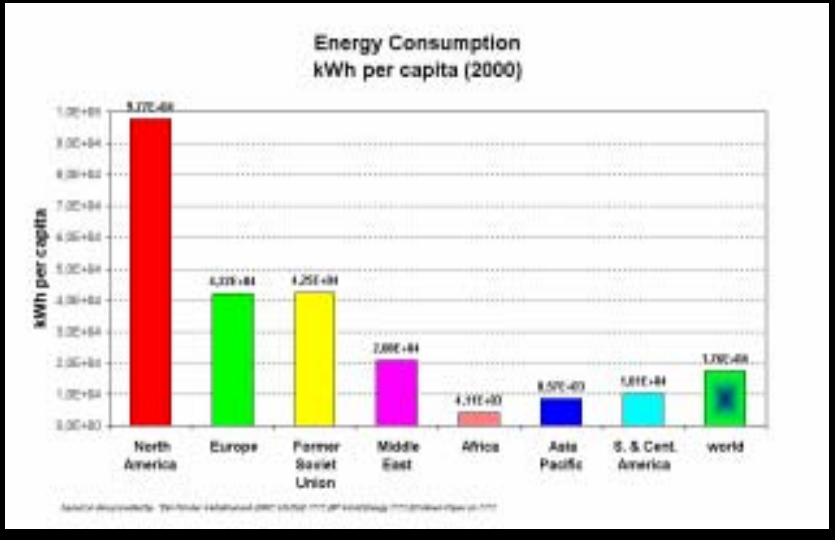
"The only thing about the future that you could not predict was the history you did not know."

H. Truman

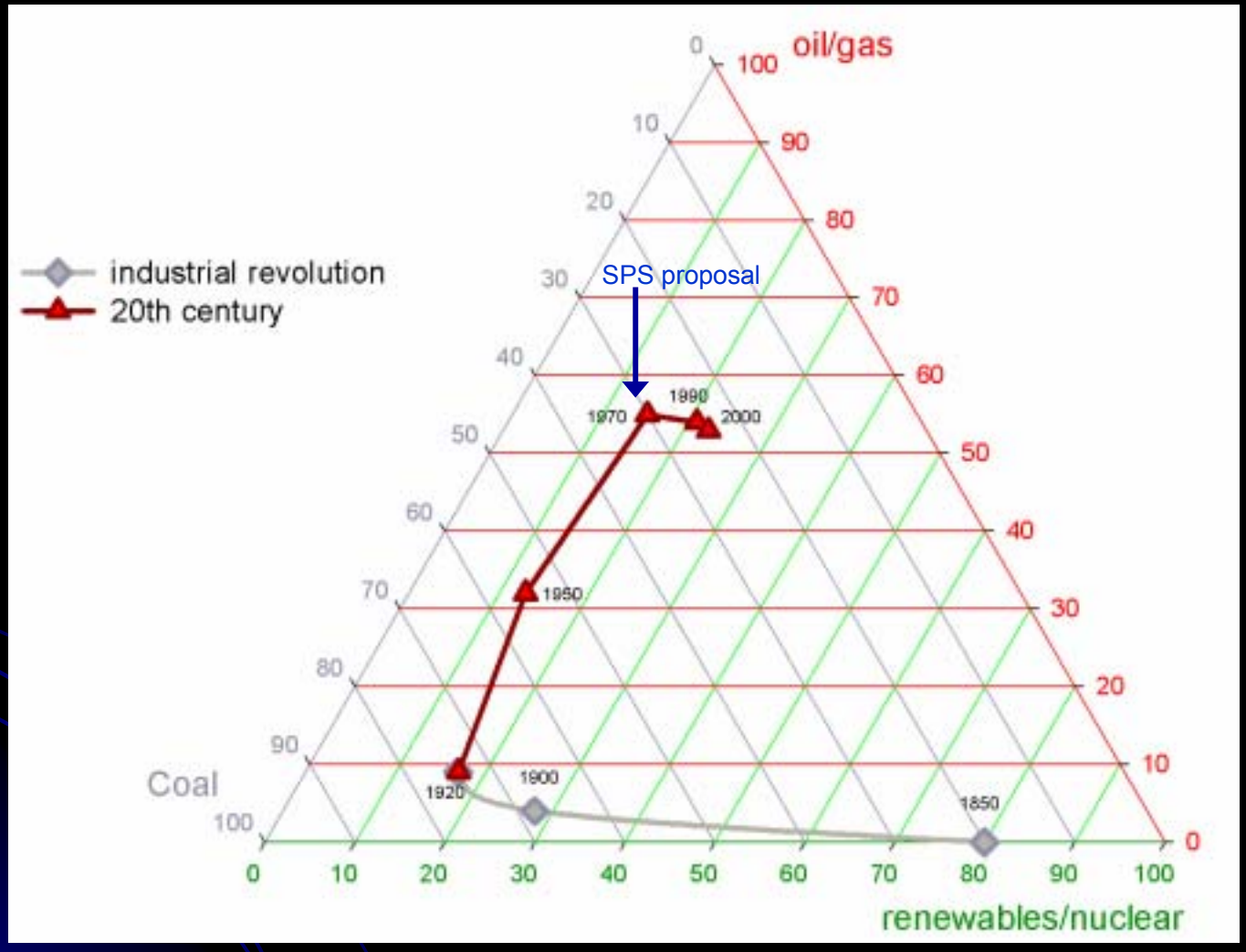
background

- energy availability and societal wealth closely related
  - Additional climatic, geographic and societal influences
- 1965 -> 2000: ~2.5 increase
- Most of the increase due to developing countries, but
- 14% of world population (North America & Europe) use 50% of total energy
- Per capita Europe uses 2.5 times the World average (North America: 5.5 times)





All data and graphs in this presentation are based on data provided by: European Commission, *Green Paper-Towards a European Strategy for the Security of Energy Supply, 2002;* 2. US DoE, *Annual Energy Review 2000;* 3. *BP statistical review of world energy, June 2001;* 4. International Institute for Applied System Analysis & World Energy Council, *World Energy Perspectives 1998, 5. UN statistics on world population*


oil/gas
Coal
renewables/nuclear
industrial revolution
20th century
SPS proposal
1850
1900
1920
1950
1970
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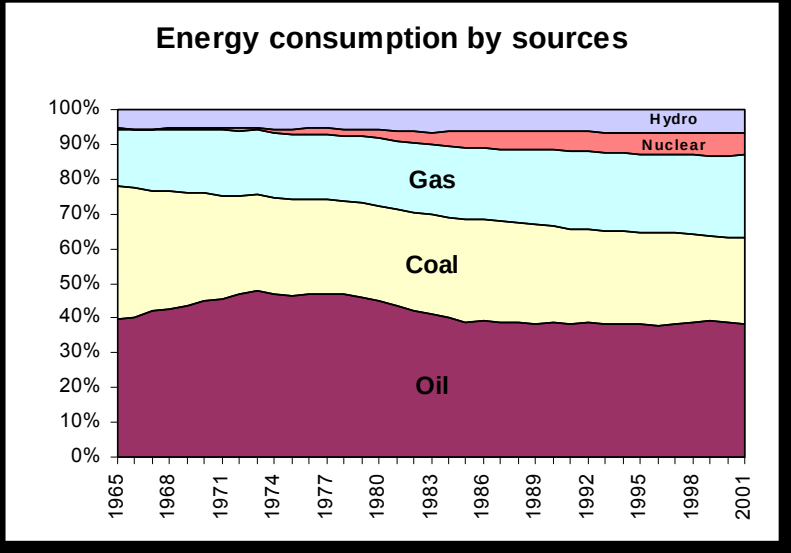
100

background

- 78% of our consumed energy from non-renewable sources
- World transport depend almost exclusively on oil

- Oil, coal and gas reserves sufficient probably until ~2100
- Nuclear fission fuel (breeder cycle) reserves sufficient until ~2150
- Energy market highly conservative and reluctant to change (e.g. prediction for solar and nuclear energy)



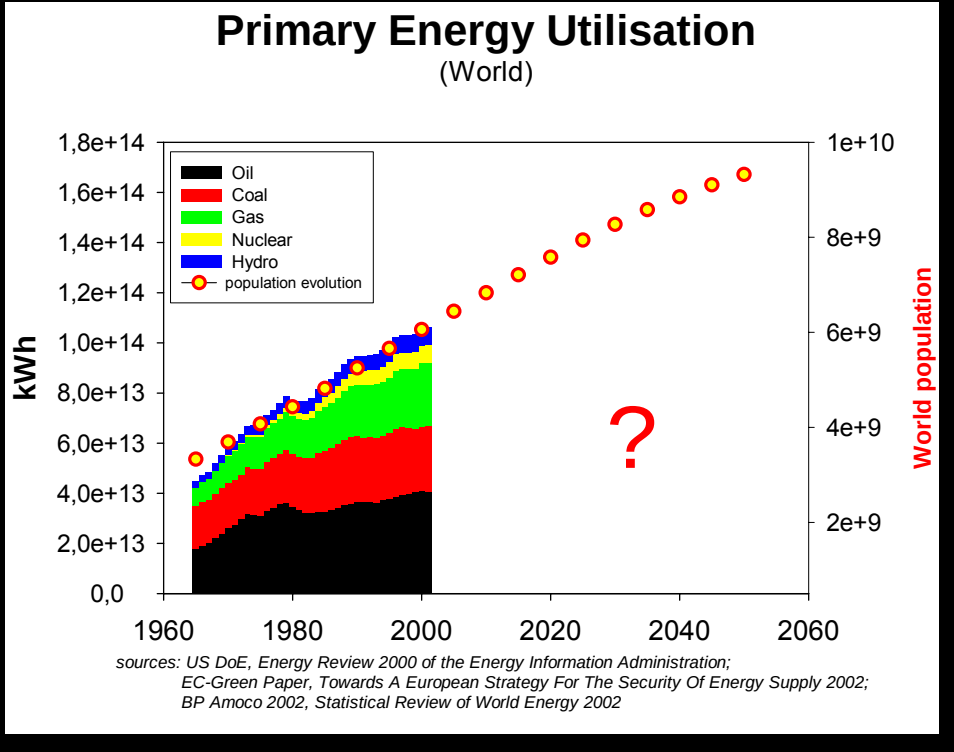
⇨ Probably enough non-renewable energy for this century, but …

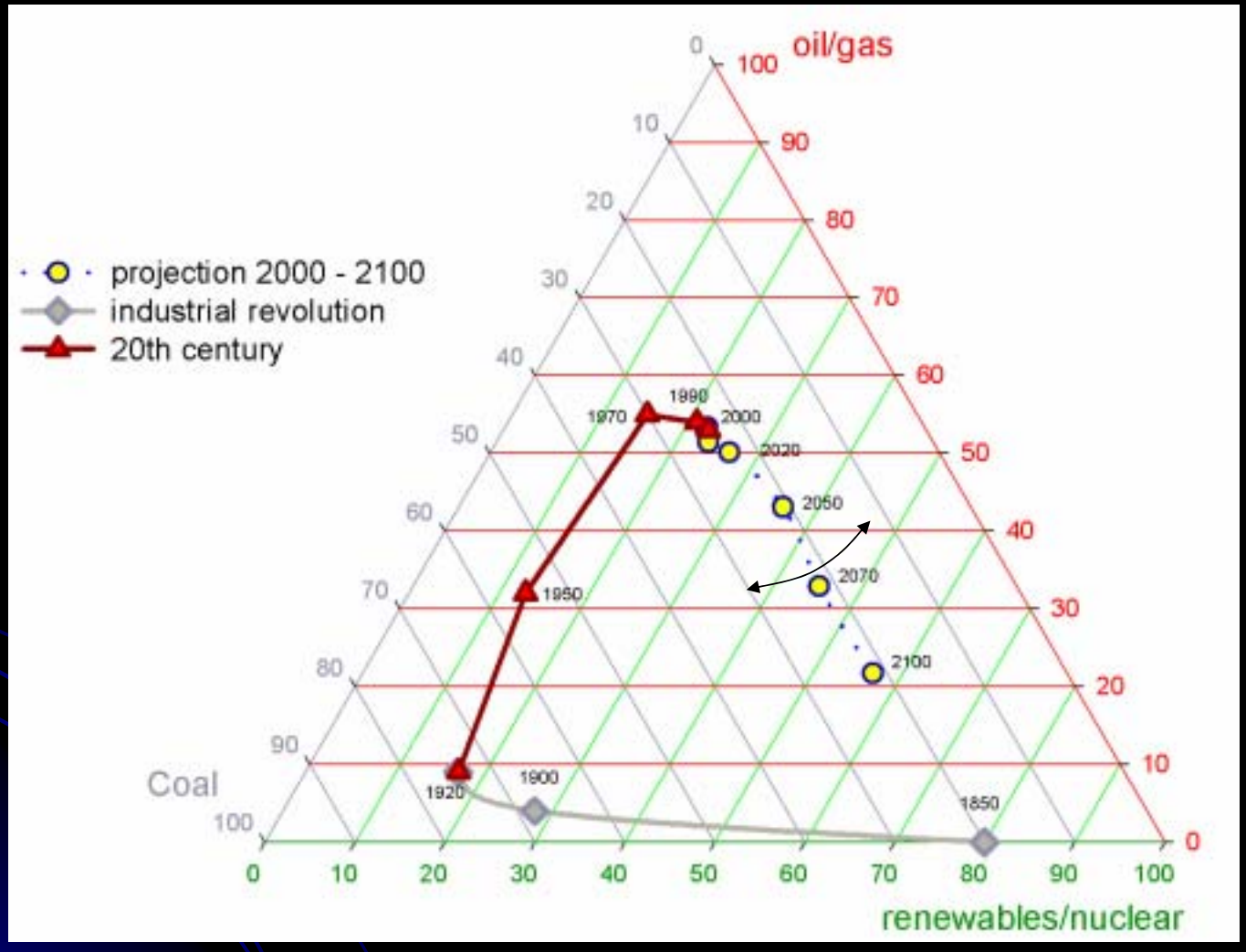
background

- Strong strategic energy-import dependence
  - Europe: rise from 50% (now) to 60-70% in 2020
  - ⇨ Incentives for combined electricity/hydrogen cycles
- Environmental burden
  - energy production responsible for almost 100% of CO_2 emissions
  - Possible/probable dramatic effect on climate
  - Increased economic pressure due to environmental changes

⇨ Gradual shift to renewable and clean energy needed

⇨ Shifting speed determined by ecological necessities




projection 2000 - 2100
industrial revolution
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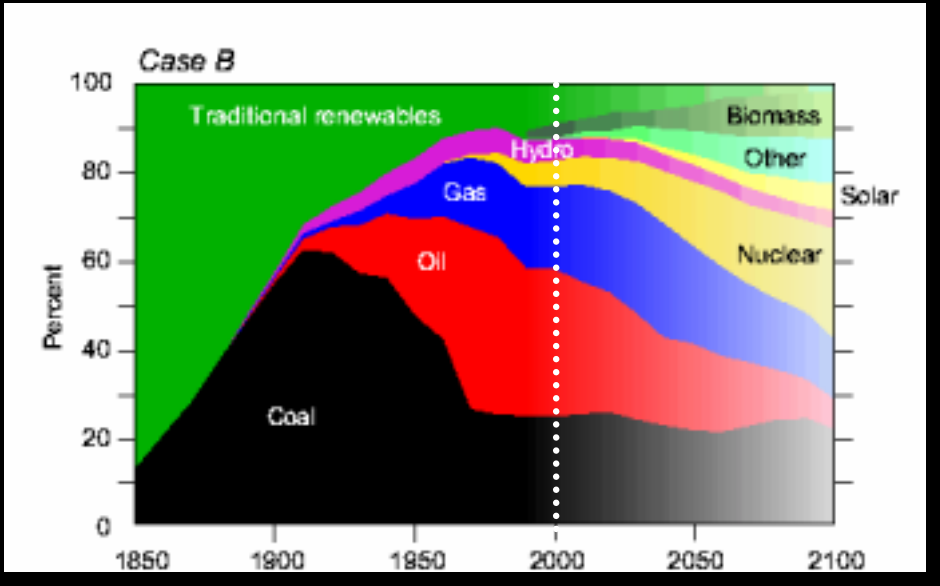
2050
2070
2100

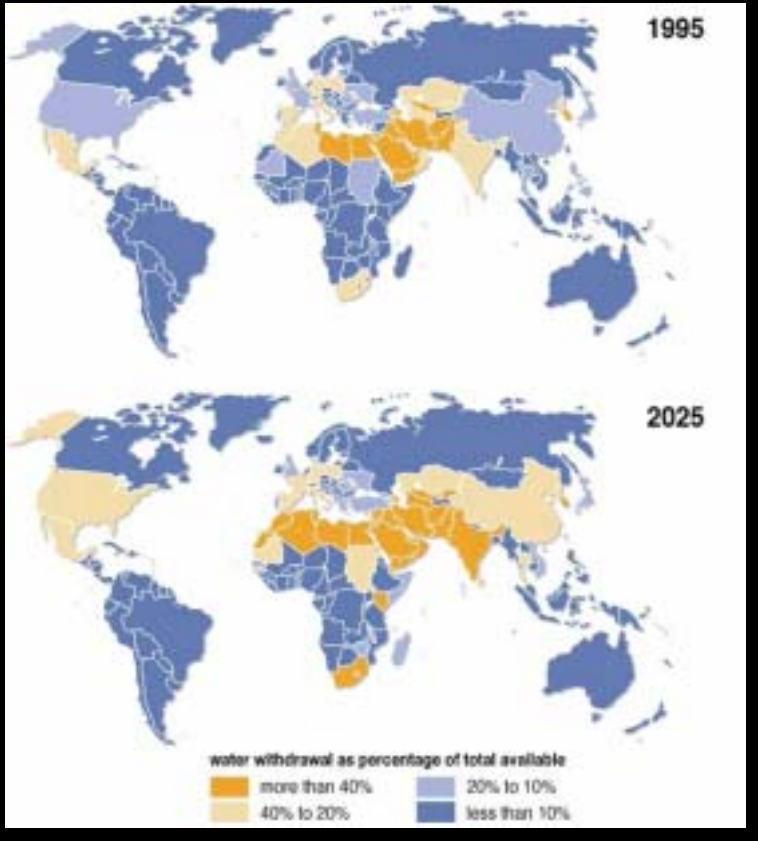
background

- Additional factors:
  - Highest growth in energy demand in developing countries – cheap energy required for development
  - Willingness to pay for “clean” energy limited in developing countries (tends to rise with income)



possible (realistic) scenarios

- Common aspects/trends:
  - Shift from direct use of oil/gas towards electricity
    - New transport energy: electricity/hydrogen (fuel cells)
- Additional aspects:
  - Drinkable water resource limitations
    - Natural groundwater reserves depletion
    - Significant additional energy needed for water processing
- ⇨ Need for
  clean,
  permanent,
  high density,
  high levels of
  … electrical energy



possible (realistic) scenarios

Primary energy sources

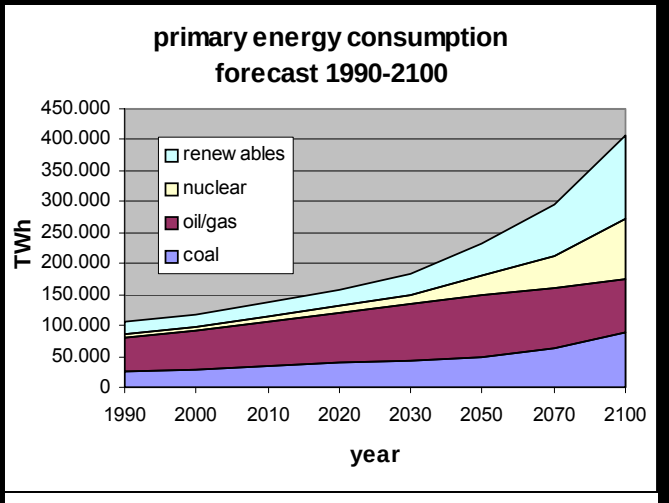
- Nuclear fission and fusion
  - nuclear breeder plants and final storage locations
- Terrestrial biomass, solar and wind energies
  - Realistic achievable levels: ~10-15%, optimistic levels: ~20-30%

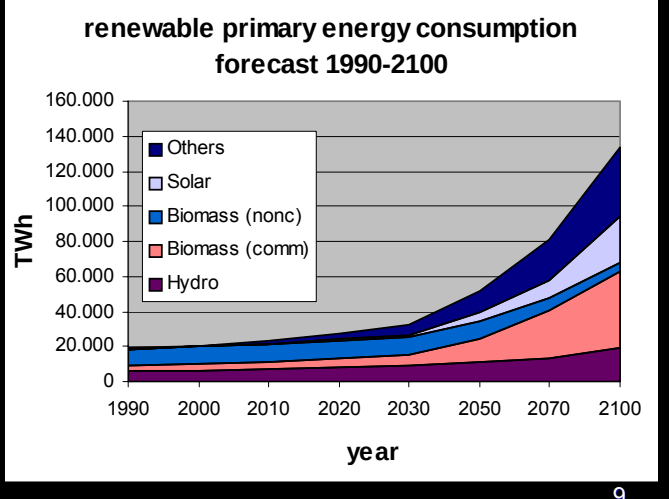
Energy use

- Hydrogen technology and fuel cells
  - Transport: reduction of oil and gas
  - ⇨ Increased electricity needs
- Massive improvements in energy efficiency
  - Potential of 1.9×10^{12} kWh only in EU (10% of total consumption)
- Extraction and large scale (below surface) storage of CO_2
  - Unknown environmental effects and high costs
  - No radical changes in energy consumption

New primary energy source from space

- Solar Power Satellites





SPS - past research efforts

- 1925: idea by Tsiolkovski
- 1968: proposal by Peter Glaser
- 1975: NASA programme:
  - WPT by μ-wave
- 1977: DoE/NASA
  - Concept Development and Evaluation Programme (total ~40M$$_{('95)}$$)
- 1981: US NAS
  - Electric Power from Orbit – A Critique of a SPS System
- 1983: Japan:
  - MINIX (830W WPT - plasma exp.)
- 198?: USSR/Russia/Ukraine
  - Orbiting mirrors/lenses
  - LEO flywheel energy accumulator
  - Experiments on MIR
- 1990: ISAS
  - "SPS 2000" (10 MW LEO)
  - 1993: ISY-METS (WPT rocket exp.)
- 1990-93: Mitsubishi RI
  - Japan SPS reference system
  - '92,'94,'95: WPT experiments (Kobe)
- 1995: NASDA/MRI study
  - GEO laser SPS system
- 1995-96: NASA
  - Fresh Look Study
- 1998: NASA
  - SSP Concept Def. Study
- 1999: ESA/DLR
  - SE&U Study
- 1999/2000: NASA
  - SSP Exploratory Res.&Techn. programme (SERT) (~15M$)

SPS-current research efforts

- US:
  - NASA: J. Mankins, follow up of “SERT”
  - budget: ? M€
  - Current reference: Sun-Tower, 8-15 B€ cost-to-first-power
    μ-wafe WPT (5.8GHz), 200m FET phased array antenna
    SSO-LEO –> MEO –> GEO,
    70m circular concentrators (1 MW_e), ≤15km long, modular
    4km diam. ground site
- Japan:
  - coordinated long term investments
  - NASDA-ISAS (merging), METI, IHI, Kyoto Univ., Kobe Univ.
    - timetable: 2008: 50 kW LEO demonstrator
      200x: 250 MW LEO demonstrator
      2020: 1 GW GEO system
  - Budget (2002): ~ 0.8 M€ (METI: 420k€, MEXT: <400k€)
- Russia/Ukraine:
  - Continuous research, limited funding
- Europe:
  - no coordinated effort, but …

Image © Sunsat

current research efforts

- Europe
  - WPT experiments/studies in France (La Réunion)
  - punctual system studies in Germany, France and Italy
  - isolated research efforts in critical, SPS-related technologies (e.g.):
    - light weight structures
    - advanced PV cells
    - advanced energy conversion systems
    - Light weight μ-wave components
  - Research efforts neither motivated nor aimed nor applied for SPS –> part of our goal

Proposed Mission Statement

The SPS network should …

- Assess innovative system concepts for space solar power systems,
  - within a timeframe of 20 to 50 years,
  - taking into consideration the current legal framework,
  - with a special emphasis on the study of advances in enabling key technologies.
- Rely where appropriate on existing economic analysis and forecasts
- Include the assessment of SPS for in-space use
- not duplicate the “Fresh Look Study”
- Last for initially 1.5 to 2 years
- Identify (small) demonstrator experiments for key technologies

Programme

09:30 – 09:50	Introduction and Overview	(F. Ongaro, L. Summerer, ESA)
09:50 – 10:10	Recent/planned SPS activities in France (+WPT in La Reunion)	(Guy Pignolet, CNES)
10:10 – 10:30	Recent/planned SPS activities in Germany (+Astrium)	(Wolfgang Seboldt, DLR)
10:30 – 10:50	Recent/planned SPS activities in Italy	(GianClaudio Cassisa, Alenia)
--- coffee break ---		
11:00 – 11:20	SPS activities at the LCSR/EPEE CNRS	(Iskender Gökalp, CNRS)
11:20 – 11:40	SPS from a launching industry perspective	(Max Calabro, EADS LV)
11:40 – 12:00	The role of power from space with the global economy	(Marco Bernasconi, Andromeda)
12:00 – 12:30	Open discussion	

focus on:
- Recommended research topics
- Preliminary goals and work plan
- Other European research on SPS (not (re)presented)
- International cooperation
- small demonstrator mission proposals

Purpose of this meeting

… to bring together European research groups involved in SPS to

- Assess the current activities on SPS
- Establish an open (first mainly European) network
- Stimulate cooperation and coordination between the participants
- Identify European strengths and key technology areas for further studies
- Identify possible international cooperation
- Propose and recommend research axes
- Identify and propose demonstrator experiments
- Consider the possibility of proposing a Network of Excellence on SPS in the frame of the 6th FP of the EU
- Assess the possibilities to position this work in the light of the UNISPACE III recommendations (participate in WG of S&T subcommittee?)

Key concept components (technical)

- Energy generation
  - Advanced PV cells (mass, efficiency, lifetime)
  - Sunlight pumped laser generation (mass, efficiency)
  - Advanced: PV cell generation of lunar soil
- Wireless Power Transmission
  - μ-wave transmission
    - low mass generators, efficiency (Solid state vs electron tubes)
    - Temperature issues
    - Wave tubes (mass)
  - Laser transmission
    - source and frequency
    - Beam steering and beam safety
    - Terrestrial energy conversion system (PV, thermoelectr. generators)
    - Beam density and transition losses
  - Atmospheric transition
    - losses and environmental effects
  - Legal constraints (current)
    - power density, safety and security issues

Key concept components (technical)

- Automation and robotics
  - Reliable, autonomous in space assembling
  - Robotic in space servicing
- Material sciences
  - Large light weight structures
- Space transportation
  - In space transportation systems
  - Influence of e.g. space elevator

How to proceed

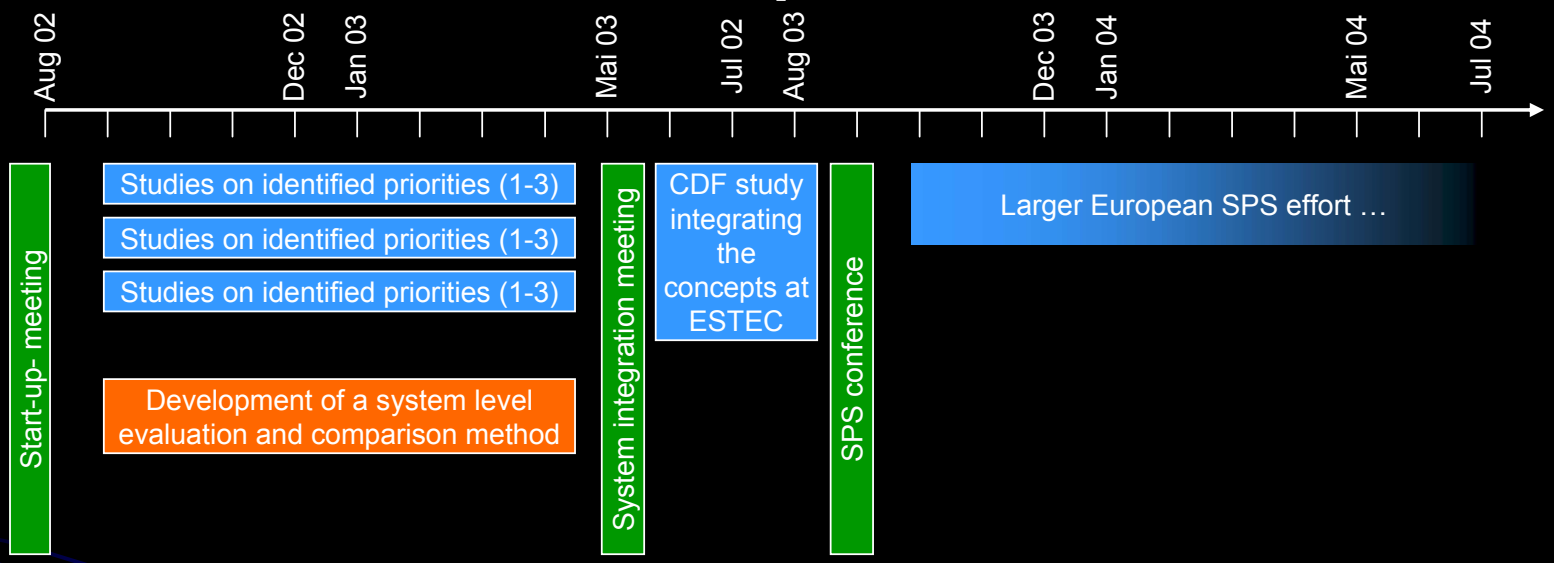
- Proposed Procedure
  - Phase I:

Framework, scope and decision structure of the study	ESA
Identification of European expertise	all
Identification of primary research areas	all
(short) review of past results	ESA
Identification of different funding sources (e.g. EU)	all

  - Phase II:

Studies on key technologies	
Iterative development of a European Standard Model	all
Preparation of SPS Workshop 2003	ESA
… t.b.d.	

How to proceed



- Identification of Priorities
- Repartition of tasks