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**Technology options to flexibly cope with
stochastic renewable resources including
the role of biofuels or synthetic fuels**

by

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and

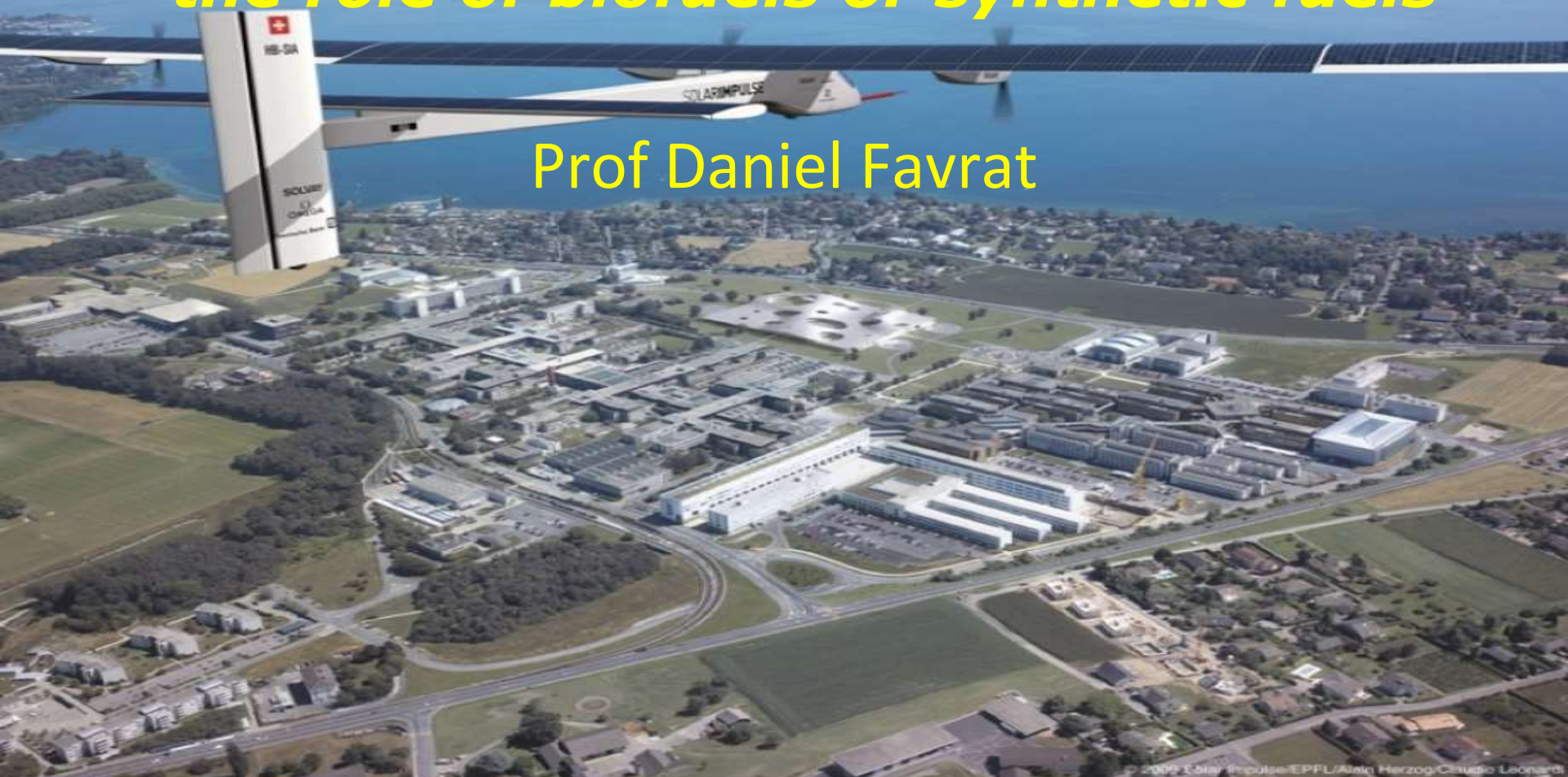
Member of WFEO Executive and Energy Committees

(World Federation of Engineering Organizations)

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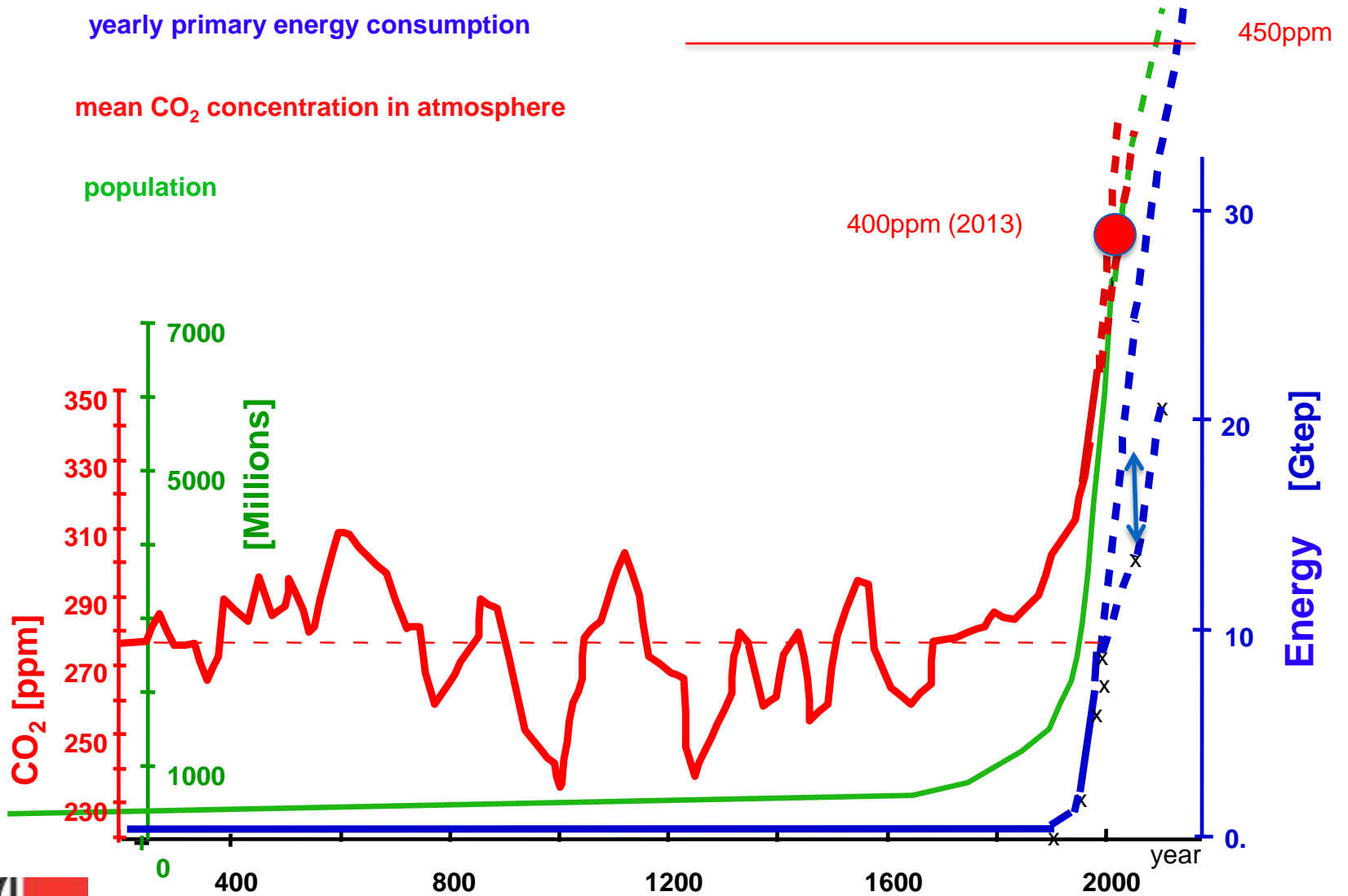
Technology options to flexibly cope with stochastic renewable resources including the role of biofuels or synthetic fuels

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Major trends Worldwide



Global environment is a major concern



We need innovation towards less degradation and lower emissions

- Physics: conservation of mass and energy
- The confusion about the term energy:
 - from the Greek word Σ Σ \odot Σ \langle , « containing work»
- But: driving forces result from unbalances (of exergy levels, of concentration in materials and fluids,....)
- Nature is a story of degradation: By degrading high “exergy” value from the Sun, Earth is able to generate vegetation and ultimately fuels and food for animals and humans
- Degradation is part of life..... But

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would be sustainable if the tremendous potential of the Sun-Earth-Space unbalance would be used properly to:

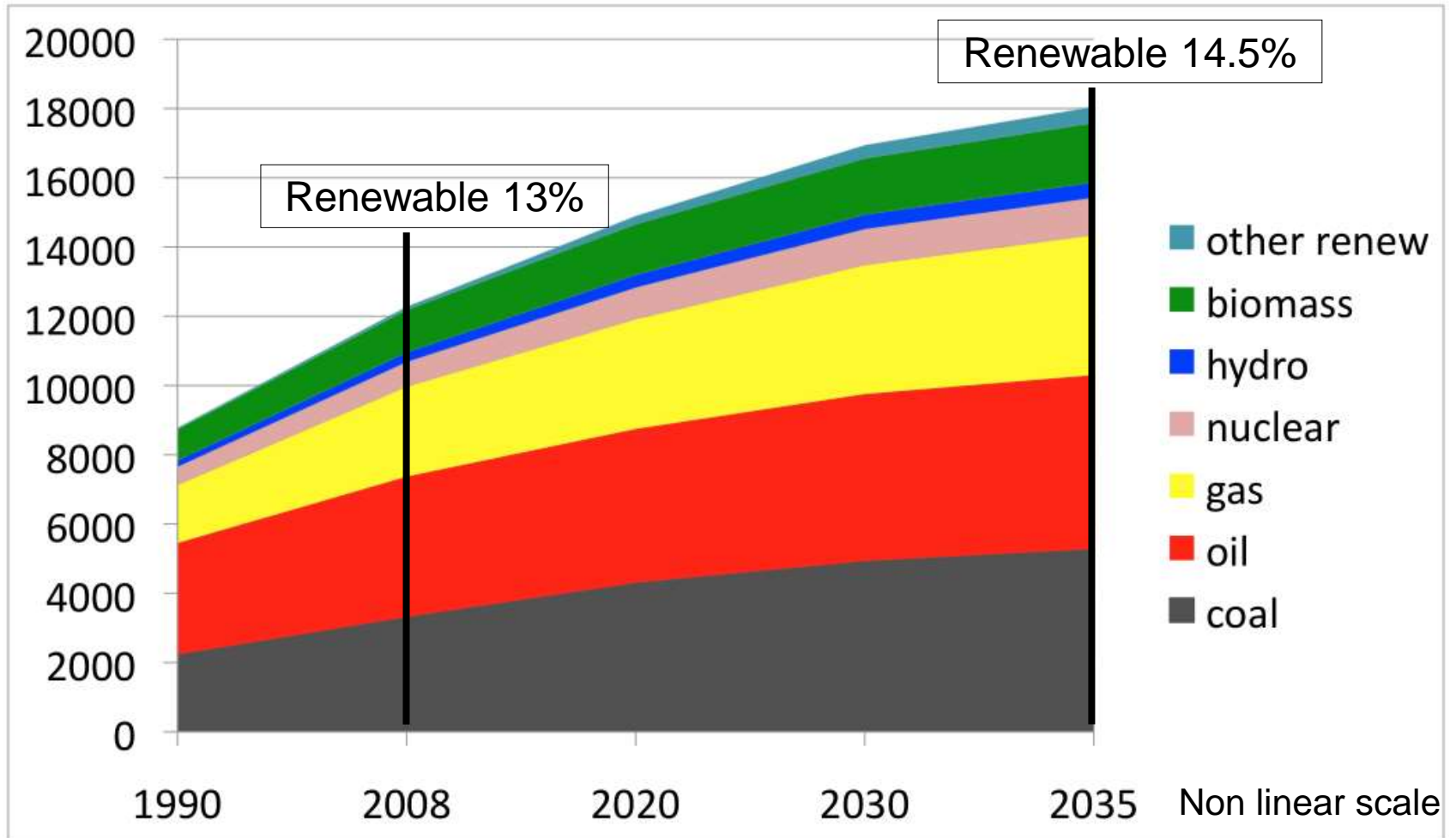
- satisfy energy services
- recycle materials and wastes
- clean or dessalinate water ,

Hence efficient use of commodities and renewable

The world energy demand until 2035

IEA current policies

World energy demand [Mtoe]

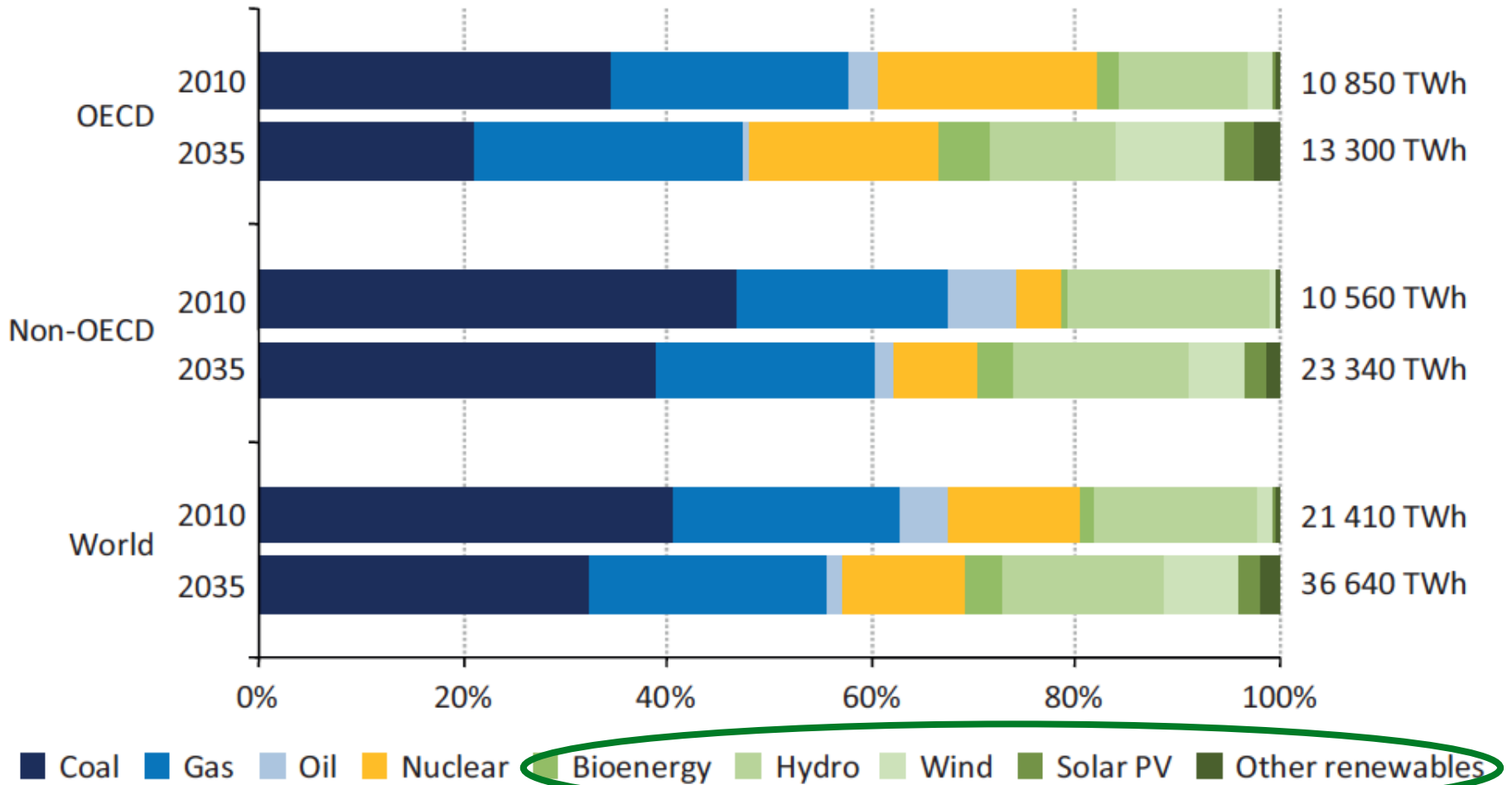


IEA Outlook 2010

A rather modest target !



Share of electricity generation by source (New Policy Scenario)



But significant growth of renewable electricity everywhere

Exploiting renewable: the daily and seasonal variations

- Solar: daily cycles + cloud/clear hours
- Wind: stochastic with dead periods (> a week)
- Hydro run of river: seasonal
- Geothermal: relatively constant
 - **Storage is the key**
- The most flexible:
 - hydro accumulation
 - fuel (wood, wastes, biofuels, H₂ or fossil)
conversion units

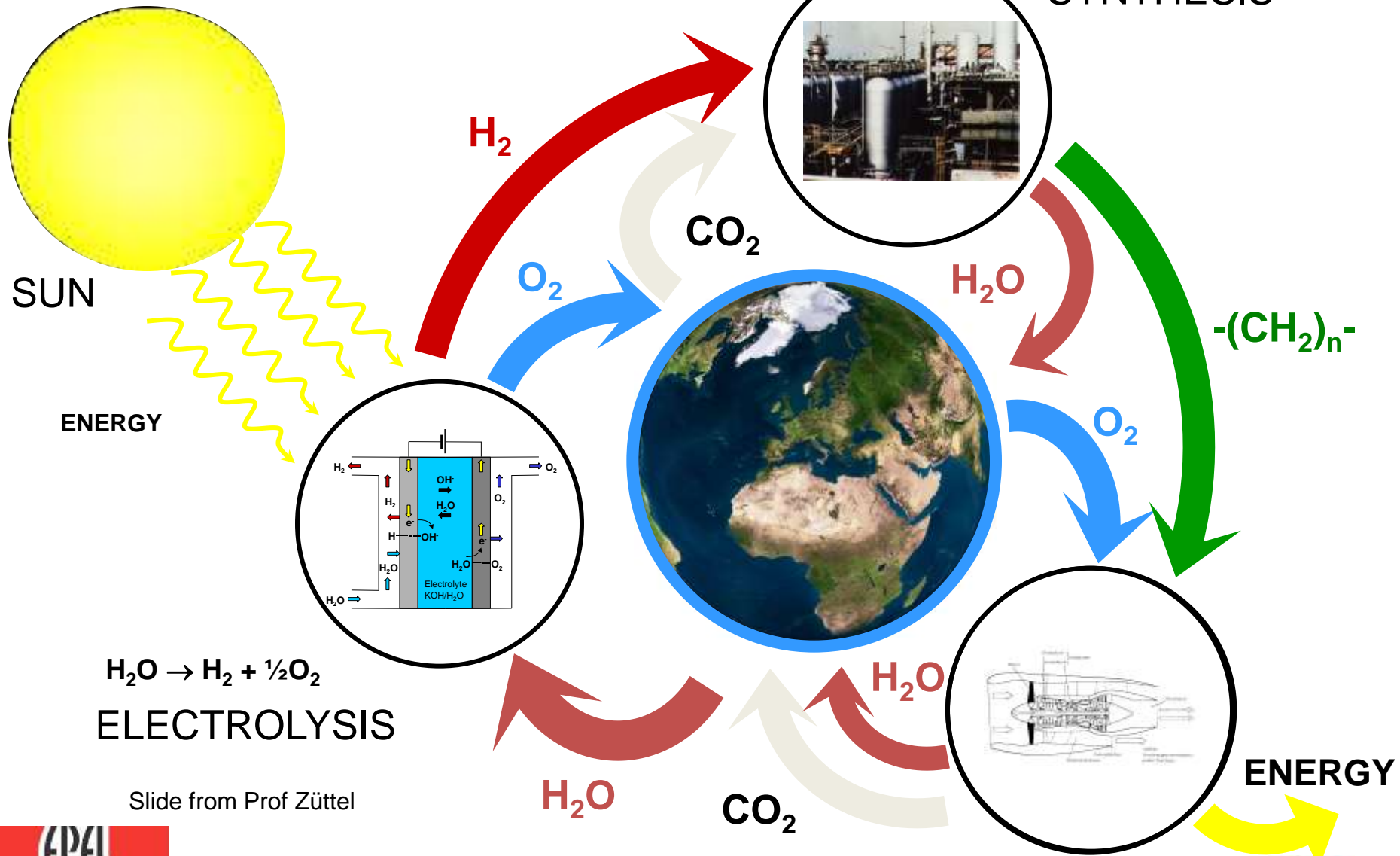
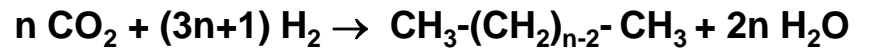
Storage scales and technologies

- **For hourly and daily fluctuations:**
 - Hydro pump storage whenever possible even envisaged at small scale (16 kV level)
 - Compressed air (including compressed compressed and hydro)
 - Batteries (ex: Li-Titanate with or without supercaps)
- **For seasonal variations:**
 - Hydro dams but often far from sufficient
 - Advanced conversion from fuels (either fossil, biofuels or synthetic fuels (power to gas or power to liquid fuels)
 - Engines with ORC waste heat conversion,
 - Fuel cells (SOFC) or hybrid SOFC-GT with CO₂ separation

Statement and medium term vision

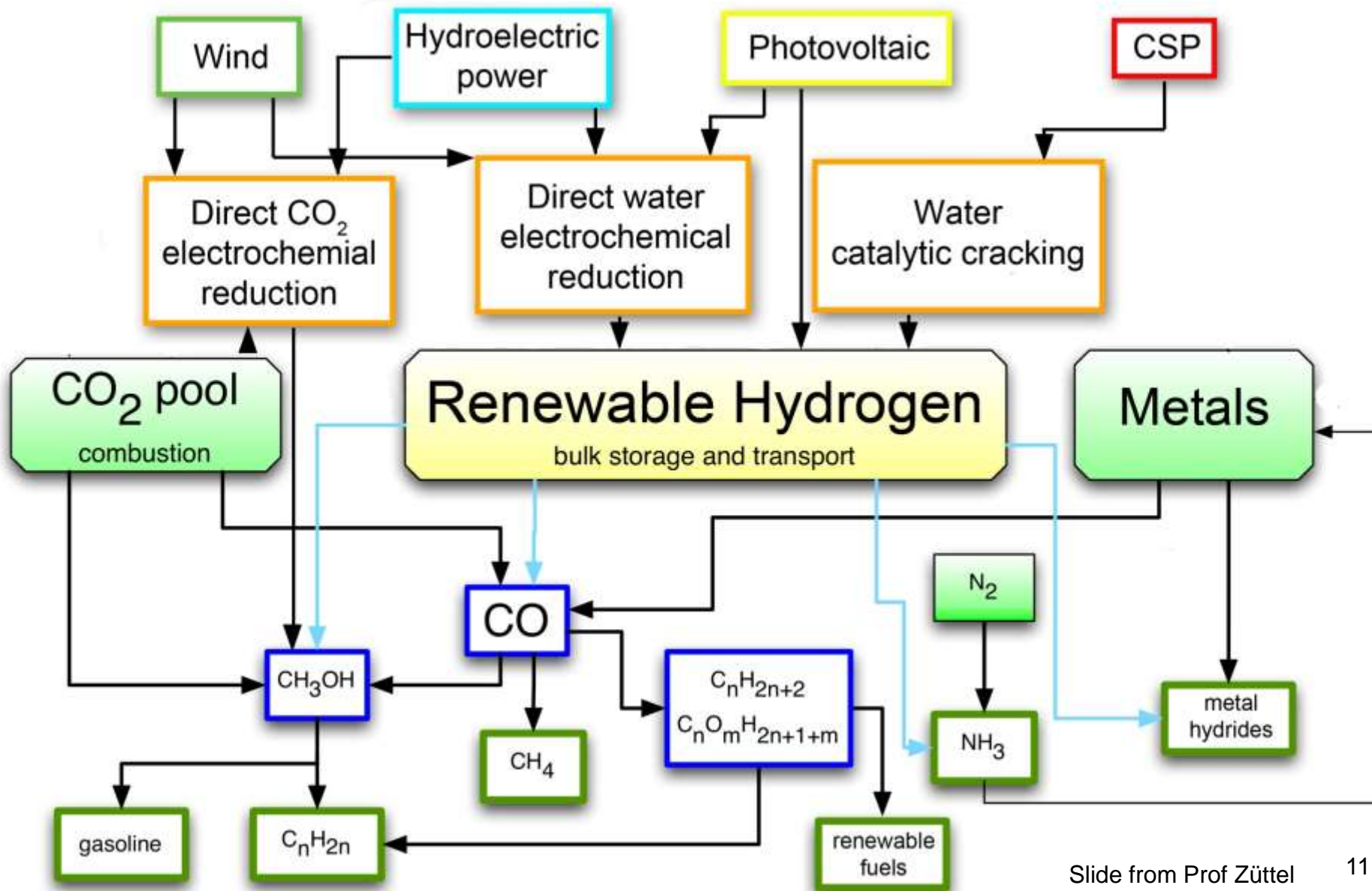
- Fossil fuels are still the cheapest and less cumbersome way to store energy
- Liquid and gaseous fossil fuels should be essentially used to backup renewable energies, in particular the stochastic ones (less and less used for base load production)
- In a longer term replaced by synthetic fuels

SYNTHETIC HYDROCARBONS

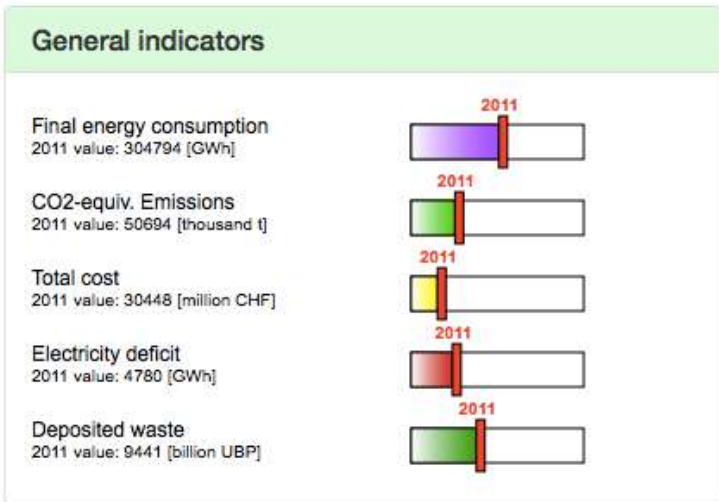


Slide from Prof Züttel

Renewable fuel refinery based on H₂



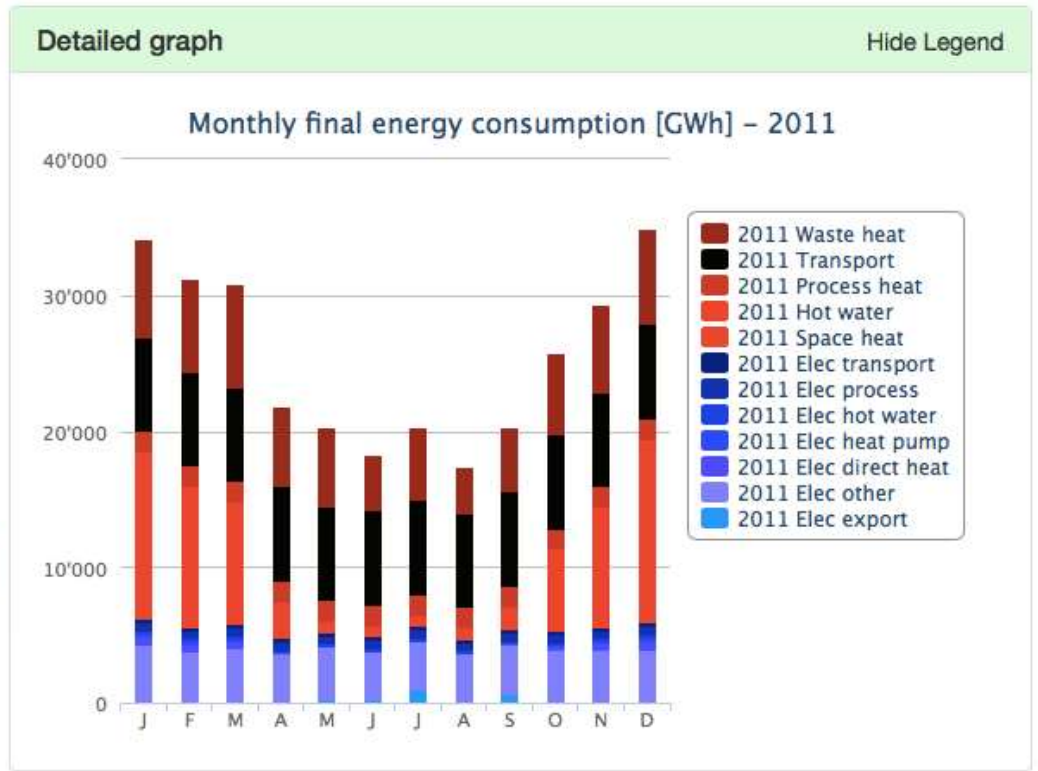
Swiss seasonal variations highlighted by Swiss energyscope.ch , a platform for energy scenarios



Target Year

Show today's situation

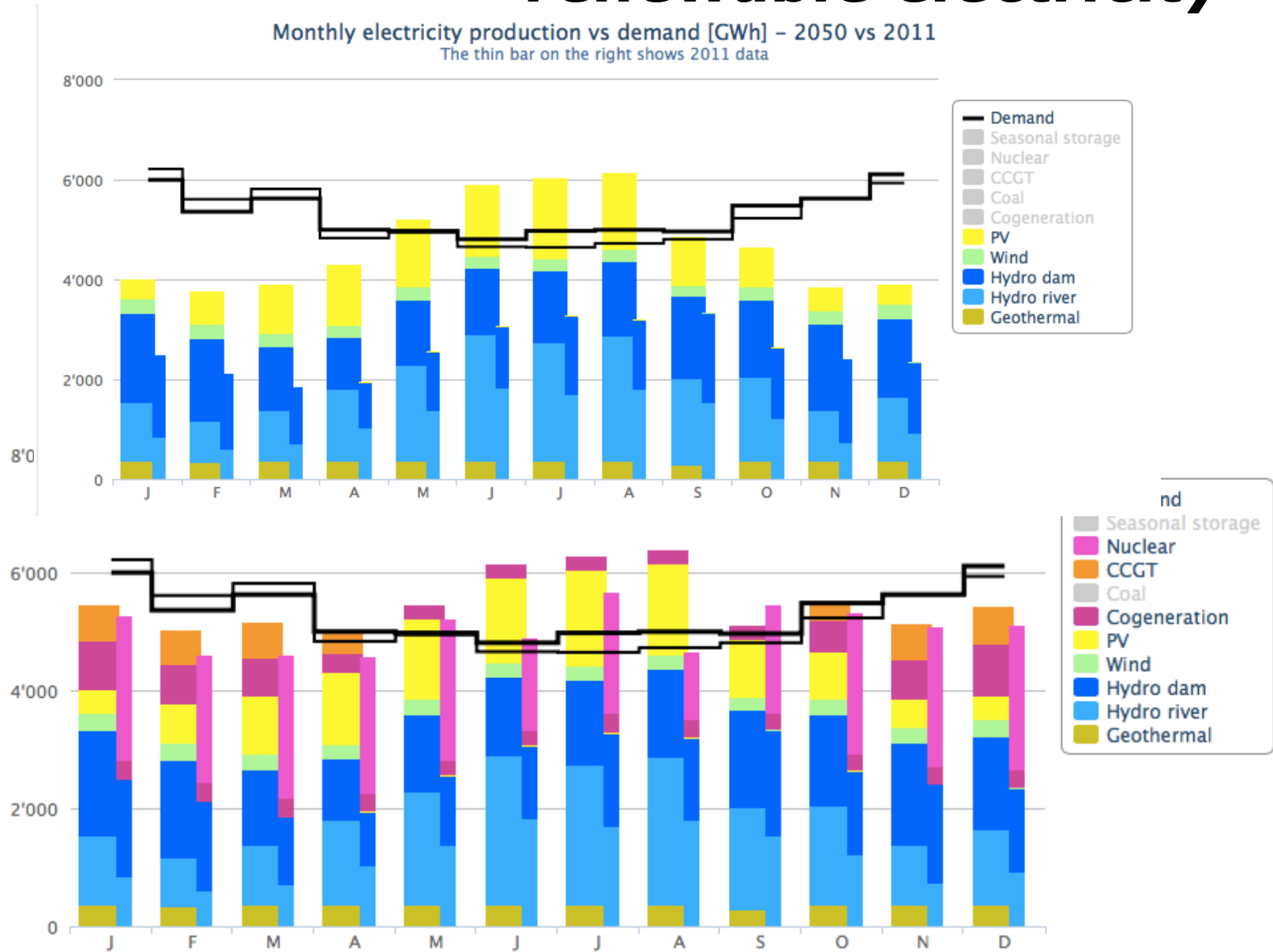
Please select the year you want to do computation for



- General
- Efficiency
- Transport
- Heating & Cogeneration
- Electricity



The example of Switzerland: Future renewable electricity



Renewable technologies have significant requirements for:

- materials***
- embedded energy***

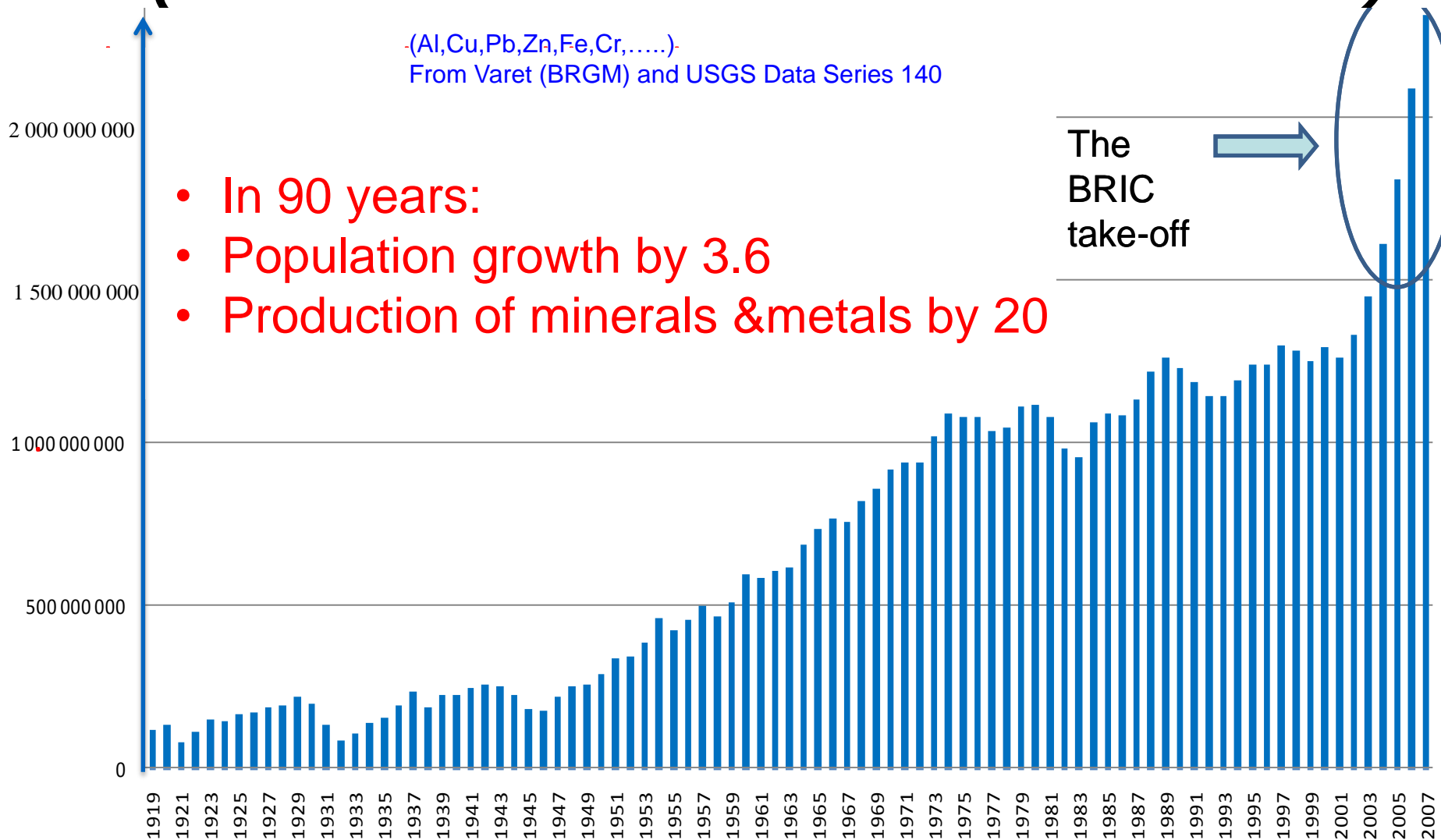
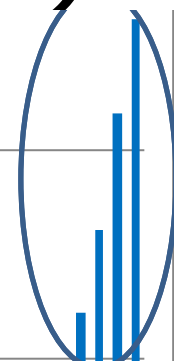
Trend of the World production (in metric tons of 14 minerals and metals)

(Al,Cu,Pb,Zn,Fe,Cr,.....)

From Varet (BRGM) and USGS Data Series 140

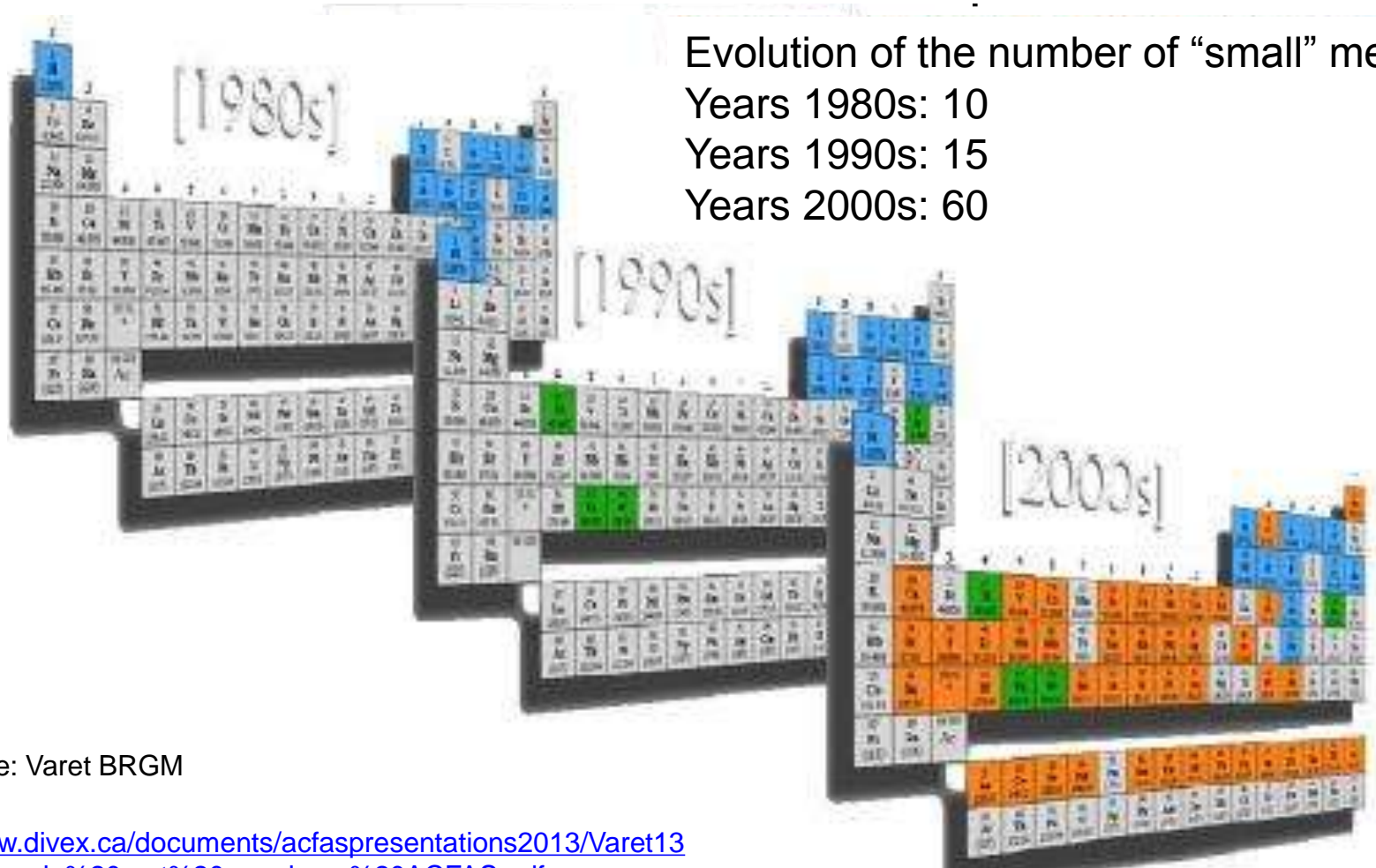
- In 90 years:
- Population growth by 3.6
- Production of minerals & metals by 20

The BRIC take-off



<http://www.divex.ca/documents/acfaspresentations2013/Varet13%20economie%20mat%20premieres%20ACFAS.pdf>

Diversification of the economy towards other ("small") metals



Source: Varet BRGM

<http://www.divex.ca/documents/acfaspresentations2013/Varet13%20economie%20mat%20premieres%20ACFAS.pdf>

Innovation towards sustainability

From a non sustainable abundance to:

- An energy and materials moderated approach (eco efficient energy and materials use, increased use of renewable, proper waste management including for CO2 and nuclear wastes)



Need for innovation

- with novel indicators (both technical and economical)
- Novel design and planning methods (holistic, LCA, etc.)
- Integrated systems with advanced technologies

Let us manage efficiently our commodities



**Thank you for your
attention !**