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NUKLEARNA ENERGETIKA POSLIJE FUKUŠIME: RENESANSA ILI SAHRANA?

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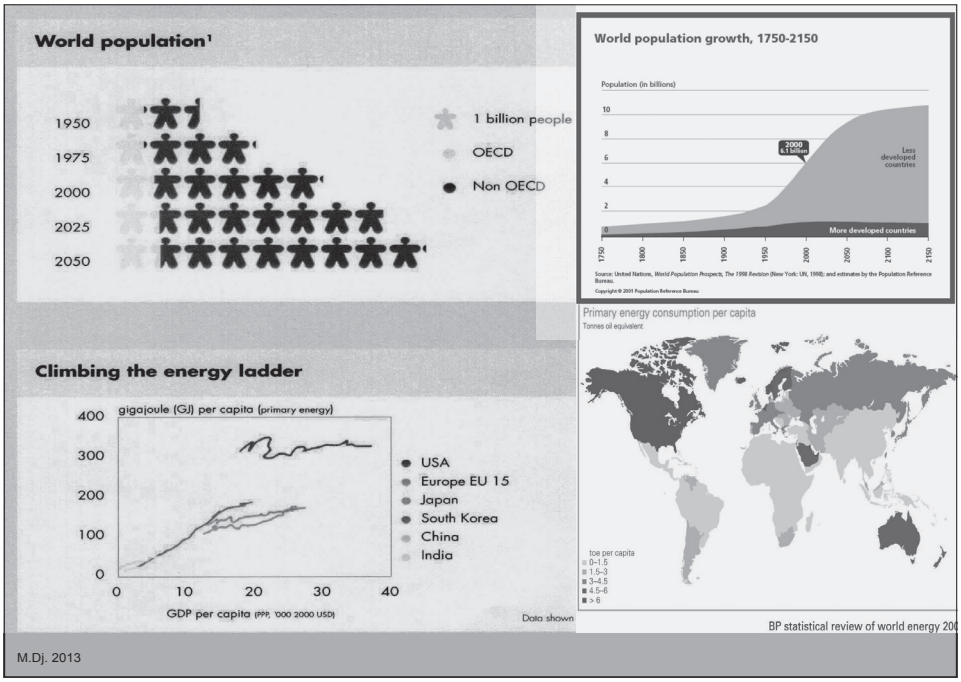
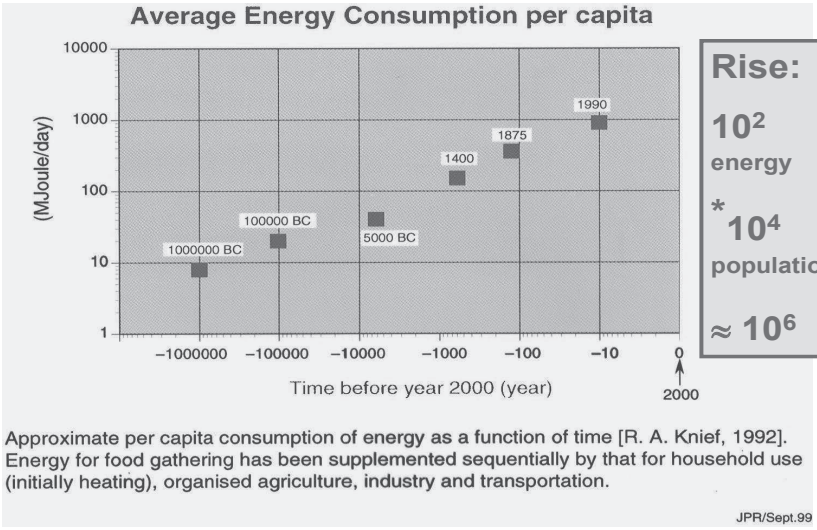
Humanity's Top Ten Problems
for next 50 years
1. ENERGY
2. WATER
3. FOOD
4. ENVIRONMENT
5. POVERTY
6. TERRORISM & WAR
7. DISEASE
8. EDUCATION
9. DEMOCRACY
10. POPULATION
2004 6.5 Billion People
2050 ~ 10 Billion People
IZAZOVI BUDUĆNOSTI
I ENERGIJA
M.Djurovic, 2013.


World population¹
1950
1975
2000
2025
2050
1 billion people
OECD
Non OECD
World population growth, 1750-2150
Population (in billions)
2000
6.1 billion
Less developed countries
More developed countries
Climbing the energy ladder
gigajoule (GJ) per capita (primary energy)
USA
Europe EU 15
Japan
South Korea
China
India
GDP per capita (PPP, '000 2000 USD)
Primary energy consumption per capita
Tonnes oil equivalent
toe per capita
BP statistical review of world energy 200
M.Dj. 2013



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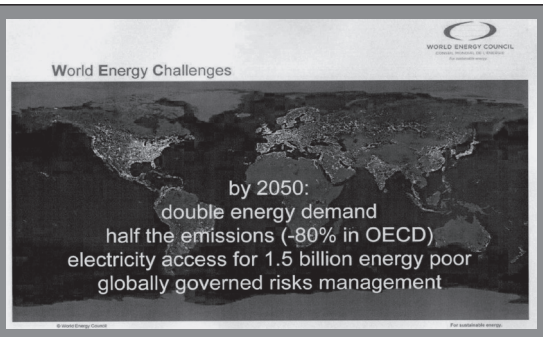
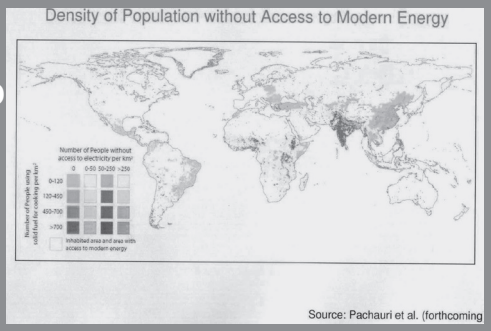
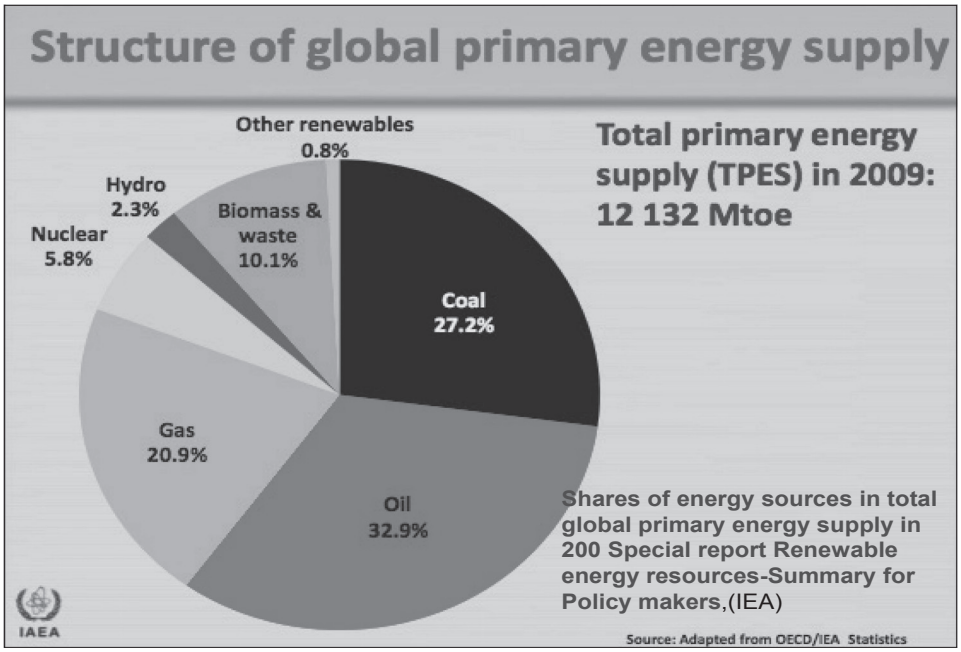
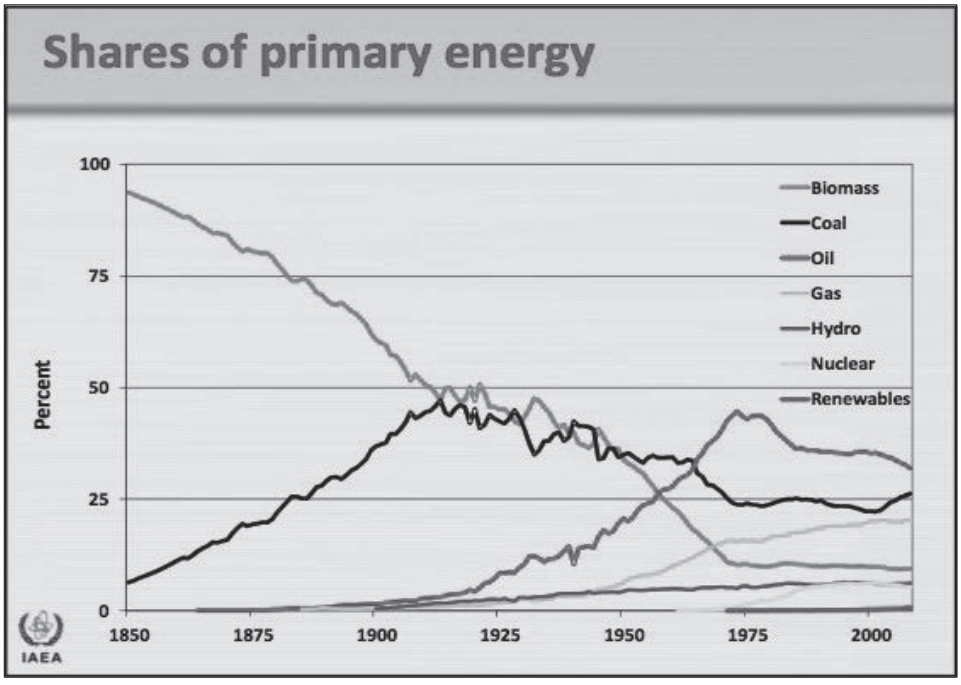


THE WORLD WILL NEED BETWEEN 40% AND 50% MORE WATER, ENERGY AND FOOD BY 2030 YEAR




Structure of global primary energy supply
Other renewables 0.8%
Hydro 2.3%
Biomass & waste 10.1%
Nuclear 5.8%
Coal 27.2%
Gas 20.9%
Oil 32.9%
Total primary energy supply (TPES) in 2009: 12 132 Mtoe
Shares of energy sources in total global primary energy supply in 200 Special report Renewable energy resources-Summary for Policy makers,(IEA)
Source: Adapted from OECD/IEA Statistics
IAEA


Shares of primary energy
Percent
100
75
50
25
0
1850
1875
1900
1925
1950
1975
2000
Biomass
Coal
Oil
Gas
Hydro
Nuclear
Renewables
IAEA

COST:

To install one kilowatt of new capacity ranges from:

*** US$500 to US$1500 for natural gas,**

*** US$1900-5800 for coal, US$4500-7500 for nuclear,**

to the renewable energies with

*** US$1300-2500 for wind, US$2600-3500 for geothermal,**

*** US$3000-5000 for solar thermal, and**

*** US$3900-9000 for solar photovoltaic (PV).**

To generate (current) existing power (/kWh) is:

*** US$0.01 for hydropower, US$0.02-0.04 for coal,**

*** US$0.029 for nuclear, US$0.04-0.07 for natural gas.**

*** For renewable energies, it is US$0.04-0.09 for biomass power,**

*** US$0.045-0.10 for wind,**

*** US$0.06-0.15 for solar thermal, US$0.10 for geothermal,**

*** US$0.10 for tidal, US$0.12 for wave, and**

*** US$0.21 to US$.83 for solar PV.**

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DRIVING FORCES OF WORLD ENERGY SUPPLY AND DEMAND*

1. **Economic Growth Rate.** **Global GDP multiplied by 4**
2. **Energy Consumption Growth Rate.** **Assuming the developing countries only reach the European level (45% of the USA) by the year 2100, then the energy consumption would have to increase by a factor 6(!) from the present 13 TWatt-year.**
3. **Investment Requirements.** $38 trillion needs to be invested in energy until 2035. This will require an average annual spend of $1-1.2 trillion of which 40-50% will be in oil and gas projects. - 66n-OECD countries $17trillion required in electricity generation and transmission
4. **Demographic Changes** **.Energy consumption per capita grows with economic development. Inevitable closing of the gap in per capita consumption between developed and developing countries****
5. **Climate change/weather change=CO_2 Emission.** **Reaching 380ppm for the first time**
6. **Technology development & Innovations**
7. **Global Energy Intensity.** **Energy efficiency of global economy worsened for 2nd straight year**
8. **Oil Prices.** **Spending on oil imports is near record highs. Geopolitical tensions have a direct impact on oil and gas price**
9. **Development of Alternative Energy Sources**
10. **Geopolitical tensions have a direct impact on oil and gas price**

* Some of these factors are more predictable than others.

** **The Chinese government estimates that China electricity production needs to be increased by a factor of 6 to 7 in the next 30 years. The problem is somewhat worse in India.**

Energy scenarios

WEC: A, B, C (SRES)
IEA, Wuppertal
Club of Rome (10- total destruction),
IIASA, EREC
BP
EC
Shell, New Lens Shell
Many others

- ***The cost of electricity is quite the same in all the scenarios (except the very high renewables one)***

- **All scenarios account for significant share of renewable**

- help scientists and policy analysts to identify the main dimensions and drivers that shape those future worlds;
- help them to explore and understand the dynamic links among the main drivers and to assess their relative importance (in terms of potential impacts) as sources of uncertainty;
- allow a more systematic and full appreciation of the uncertainties that lie ahead in the energy and environment domain.

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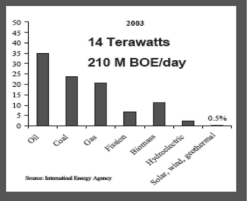
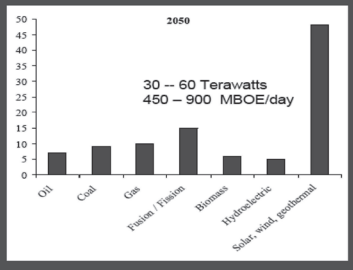
The ENERGY REVOLUTION (The Terawatt Challenge)





The Basis of Prosperity
20st Century = OIL
21st Century = ??

WORLD ENERGY COUNCIL
CONSEIL MONDIAL DE L'ÉNERGIE
For sustainable energy.

Every week 1000MW nuclear PS to reach 15 TW in 15 years

The biggest single challenge for the next few decades:

ENERGY
for 10^{10} people

At MINIMUM we need 10 Terawatts (150 M BOE/day) from some new clean energy source by 2050

For worldwide peace and prosperity we need it to be cheap.

We simply can not do this with current technology.

TRANSITION FROM 2003 TO 2050

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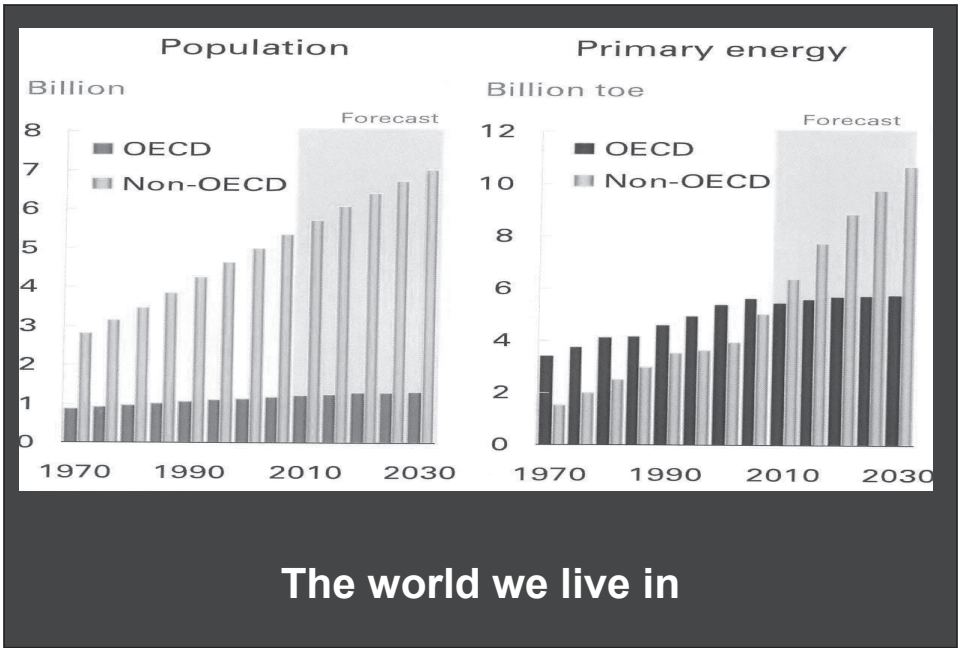
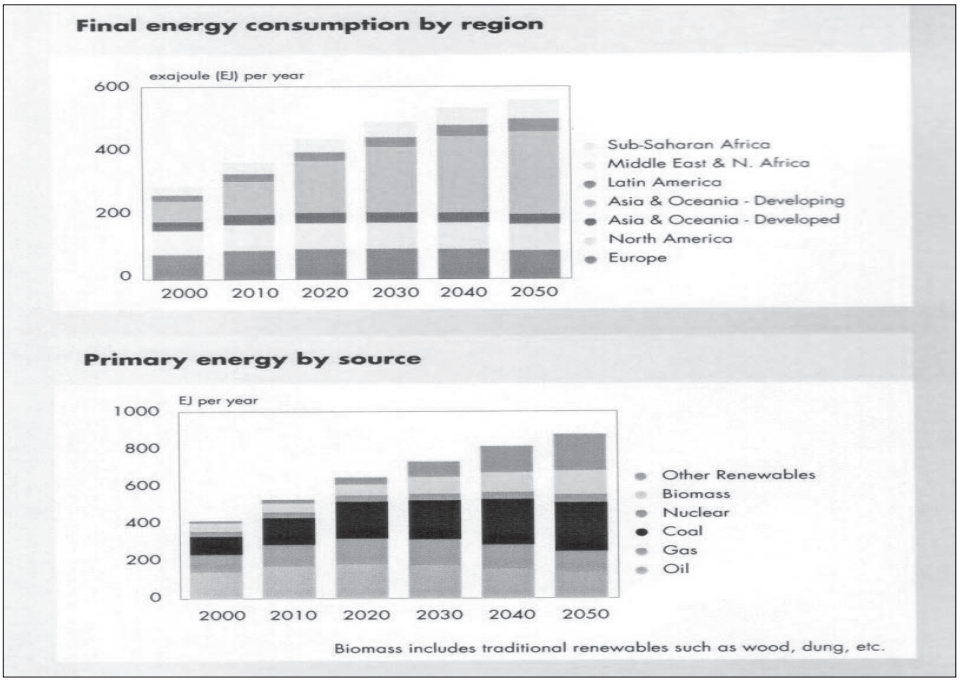
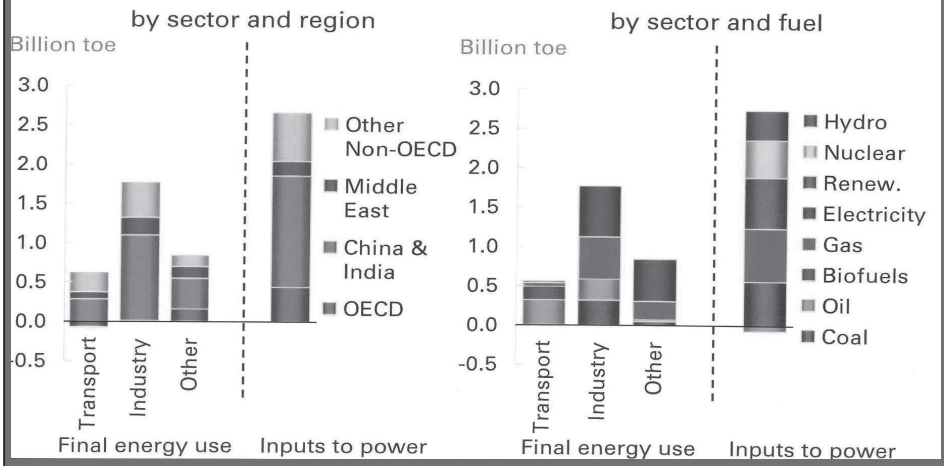
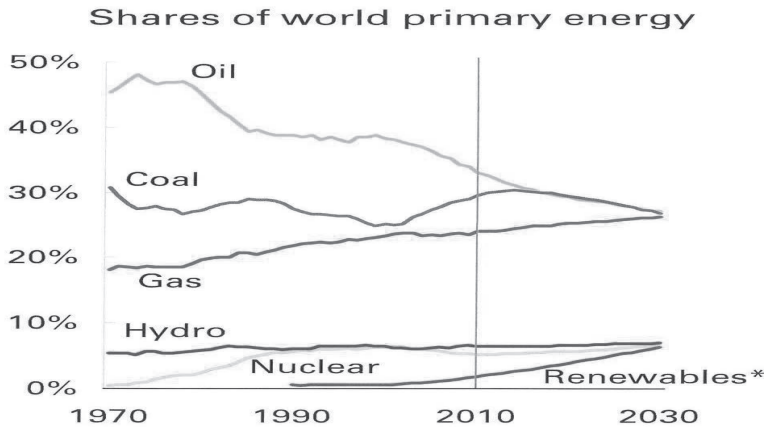

Population
Billion
Forecast
OECD
Non-OECD
8
7
6
5
4
3
2
1
0
1970
1990
2010
2030
Primary energy
Billion toe
Forecast
OECD
Non-OECD
12
10
8
6
4
2
0
1970
1990
2010
2030
The world we live in

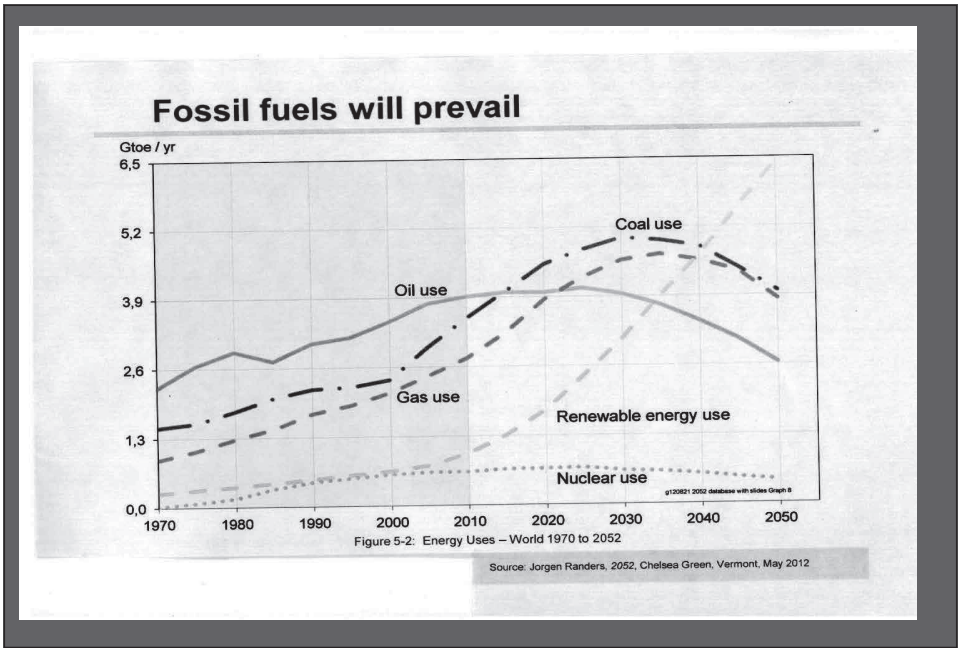

Final energy consumption by region
exajoule (EJ) per year
600
400
200
0
2000
2010
2020
2030
2040
2050
Sub-Saharan Africa
Middle East & N. Africa
Latin America
Asia & Oceania - Developing
Asia & Oceania - Developed
North America
Europe
Primary energy by source
EJ per year
1000
800
600
400
200
0
2000
2010
2020
2030
2040
2050
Other Renewables
Biomass
Nuclear
Coal
Gas
Oil
Biomass includes traditional renewables such as wood, dung, etc.



World energy consumption 2010-2030 by sector and region (BP)



World energy potential and share



TO UNDERSTEND THE ISSUE:

1 Gwatt of electric power requires:
3 million tons of coal per year
20 km² of solar cells
200 km² of windmills
2000 km² of fast growing trees
700 kg of thorium per year in the Energy Amplifier

25 Tons per year of Helium 3 to supply USA

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Recent years and months have seen increasing attention being paid to the issue of energy security. There are a number of concerns and fears such as :

► **Oil and other fossil fuel depletion (peak oil, etc)**
► **Reliance on foreign sources of energy**
► **Geopolitics (such as supporting dictatorships, rising terrorism, "stability" of nations that supply energy)**
► **Energy needs of poorer countries, and demands from advancing developing countries such as China and India**
► **Economic efficiency versus population growth debate**
► **Environmental issues, in particular climate change**
► **Renewables and other alternative energy sources**
► **Energy insecurity combined with other global issues risks fueling conflict, repeating past mistakes in history**

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If we don't change direction soon, we'll end up where we're heading (IEA – WEO 2011)

►**One thing is sure: rising incomes & population will push energy needs higher.**
o By 2030/2035 35-50% greater than present
o **2030 the ratio for global demand will be 60/40 in favour of the non-OECD.**

► **Oil supply diversity is diminishing, while new options are opening up for natural gas.**
o The 'easy oil' has either gone or is declining rapidly
o Crude oil remains as leading primary energy resource until at least 2030
o OPEC increases its global supply share from the current 33% to 46%
o Non-OECD crude oil demand overtakes OECD demand in this decade.

► **Less nuclear would lead to higher CO_2 emissions, increased energy prices and growing energy import bills** o **We are emitting about twice the amount of CO_2 that the atmosphere can integrate.** Environment impact: If present practices continue, the pollution of the Earth will be dramatic, with very unpleasant consequences:2, CH4, etc. ~ global warming ~ rise in sea level, climate instability (greater energy stored in the Earth's atmosphere), outburst of epidemic illnesses, etc.

► **Power sector investment will become increasingly capital intensive with the rising share of Renewables**
o **By 2030 the ratio for global demand will be 60/40 in favour of the non-OECD**

► **Despite steps in the right direction, the door to 2°C is closing**

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Mapping a Better Energy Future

The Energy Future *Absent New Policies*

- **Security of oil supply is threatened**
- **Gas security is also a growing concern**
- **Investments over the next decade will lock in technologies that will remain in use for up to 60 years CO_2 emissions by 2050 will be almost 2.5 times the current level!**

On current trends, we are on course for an "unstable, dirty & expensive energy future" carbon intensity of the world economy will increase

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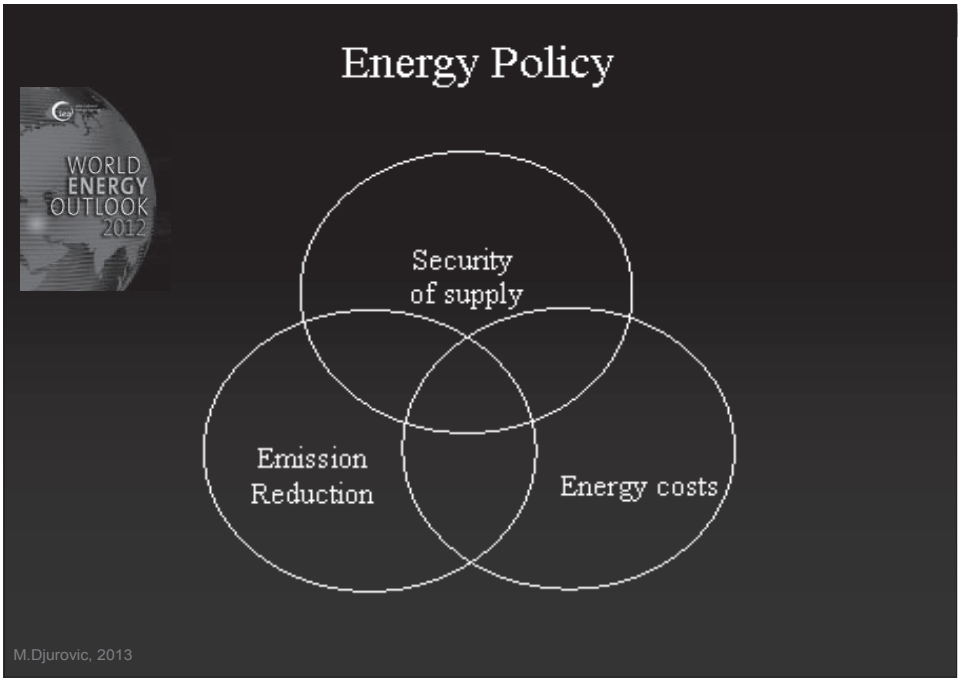

A dual strategy is needed to solve the energy problems:

1. *Conservation: maximize energy efficiency and minimize energy use, while insuring economic prosperity*
2. Develop new sources of clean energy

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Policy Trends

- **Many more countries putting policies in place, particularly outside OECD than in 2005.**
- **45 of the 56 focus countries now have RE Electricity targets, including 20 non-OECD members.**
- **53 of the 56 focus countries have electricity support policies in place, compared to 35 in 2005.**

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Questions

1. How much energy will the world need in the coming century?
2. What does this projected energy consumption imply for CO_2 emissions?
3. What do these CO_2 emissions imply for the atmospheric CO_2 concentration?
4. How much future energy will need to be "C-neutral," if the atmospheric CO_2 concentration is to be stabilized?
5. What are the consequences of delaying development of C-neutral power?
6. Could 15 TW of C-neutral power be derived from fossil fuels?
7. Could 15 TW of C-neutral power be derived from sources that produce electricity?
8. What are some of the challenges associated with supplying 15 TW of C-neutral nuclear power?
9. What are the theoretical, extractable and technical potentials of the various renewable energy resources and what is the potential for further development of solar electricity?
10. Which renewable energy resources have the greatest potential for supplying 15 TW of C-neutral power?

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What we shall be seeing ?:

- ☐ **Fundamental re-engineering of the world's energy industry around low carbon solutions and architecture that will:**
- ☐ **Cost trillions and take decades**
- ☐ **Be heavily policy-driven (incentives and disincentives)**
- ☐ **Inevitable, given economics**
- ☐ **Be funded by capital markets**
- ☐ **Be risky to bet against**

(source IEA)

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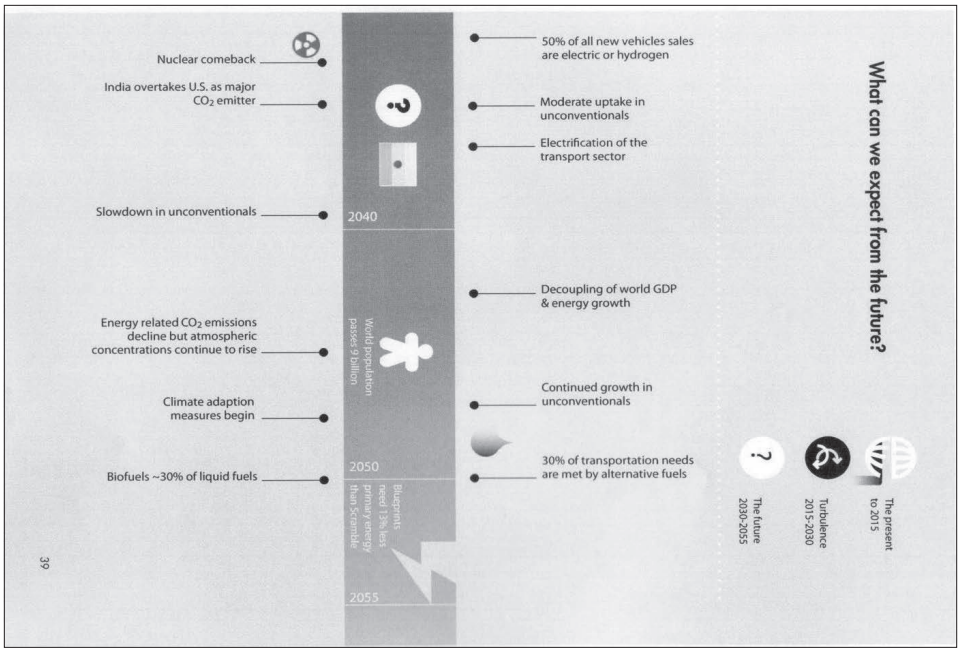


WEC solution

Keep all energy options open No technology should be idolized or demonized and energy efficiency must be increased.

Ensure the necessary investment in energy infrastructure For this, cost-reflective energy prices are essential - systems which do not pay for themselves are ultimately unsustainable.

Adopt a pragmatic approach to market reform This would accommodate specific policy measures to achieve certain objectives, while allowing for the operation of the market to the maximum possible extent.

Place priority on the measures needed to ensure reliability of supply Above all this depends on energy diversity, supported by sound market design and improved generating plant performance.

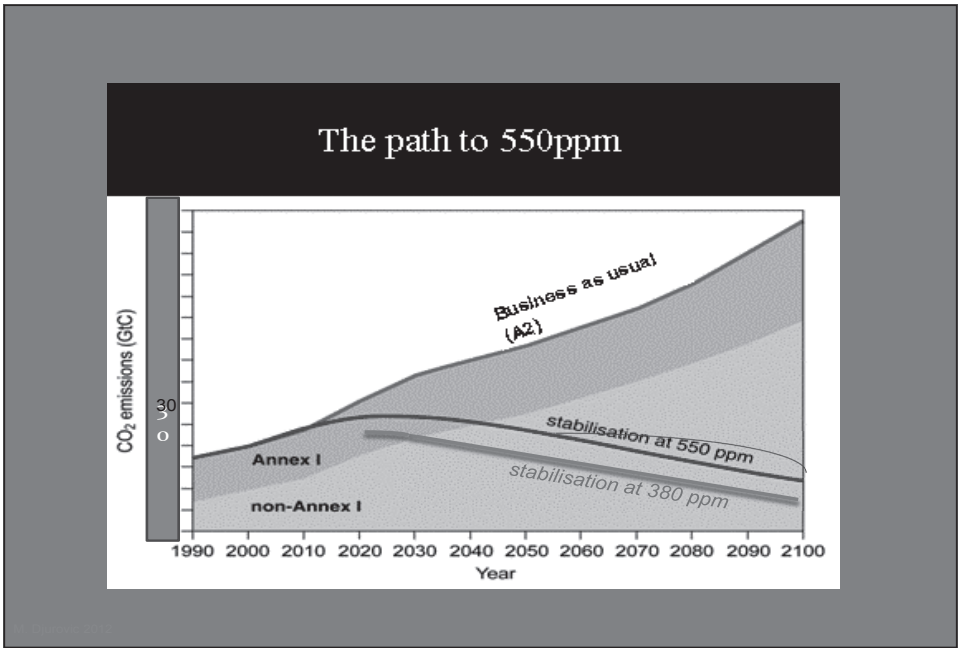
Promote regional integration of energy supply systems This further supports reliability and calls for stronger regional collaboration.

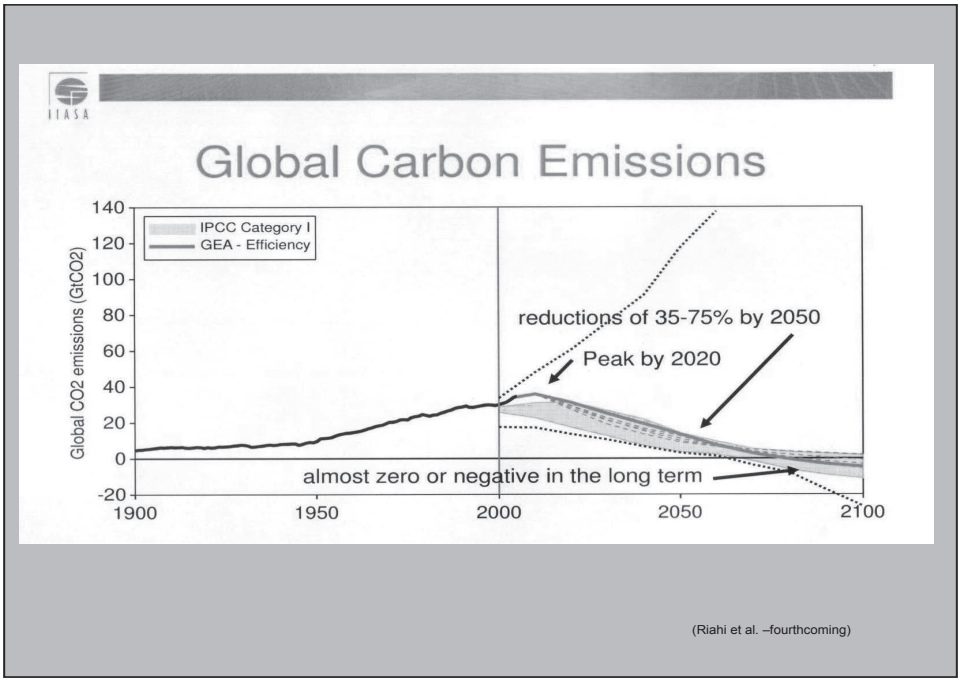
Exploit the "win-win" opportunities of emerging climate change responses The mechanisms, whether voluntary or regulated, should embrace least cost emissions reduction, encouraging transfer of clean technology from industrialized to developing countries.

Ensure technical innovation It is vital to reconciling development with environmental protection and calls for strong, sustained support for R&D

Foster and sustain public understanding and trust This in turn depends on energy sector transparency and better public information, starting in particular with young people.

(source: WEC statement 2005, Sidney)





(Riahi et al. –fourthcoming)

Three options exist to respond to the CO_2 challenge

- Reduce carbon intensity of energy
- Reduce energy intensity of wealth
- Reduce wealth

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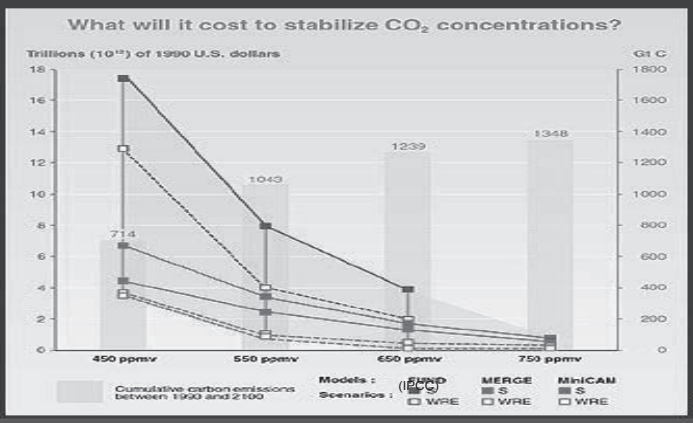
$$$ AGAIN !



34 GT/2011 year

SYR - FIGURE 7-3

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ENERGY GOALS

- Universal Access to Modern Energy
- Double Energy Efficiency Improvement
- Double Renewable Share in Final Energy

Aspirational & Ambitious but Achievable

Toward a more Sustainable Future

- Providing (almost) universal access to affordable clean cooking and electricity for the poor
- Improving energy security throughout the World
- Limiting air pollution and health damages from energy use
- Limiting climate change

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Where will be renewable?

- ☐ **Renewables have come of age and will have a key role in a secure and sustainable energy mix**
- ☐ **Despite challenges, RE deployment will accelerate in the medium term**
- ☐ **Renewables will become more competitive and enter new geographic markets, especially in non-OECD**
- ☐ **Transition will not come alone by itself. It will require:**
  - **-A predictable and cost-effective policy environment**
  - **-Smart, flexible energy systems and adjusted market frameworks capable to integrate large shares of renewables (variable and non-variable)**
  - **-Sustained RD&D investment**

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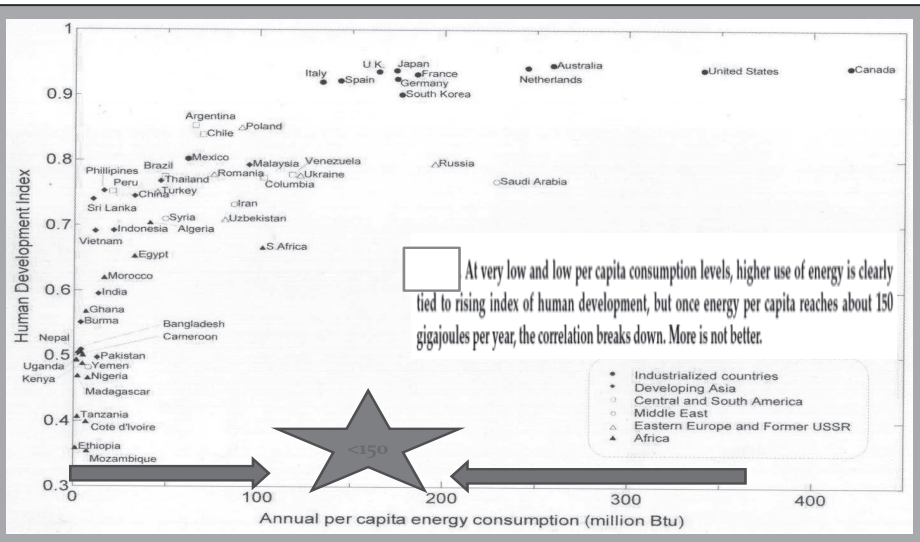

The UN HDI and annual per capita energy consumption for 60 most populous countries 2005

(Human Development Report, UNDP, Energy information Administration)

August 2012:

Citi Bank proudly shows how North America is becoming the new ‚Middle East'.

Figure 3. Abundant shale plays, accessed by hydraulic fracturing and horizontal drilling technology, are a key driver behind North America becoming the globe's "energy island" by 2020; EIA map of North American shale plays

Source: EIA

From: Energy 2020: North America – The New Middle East?
Edward Morse et. al. Citi, NY, 2012

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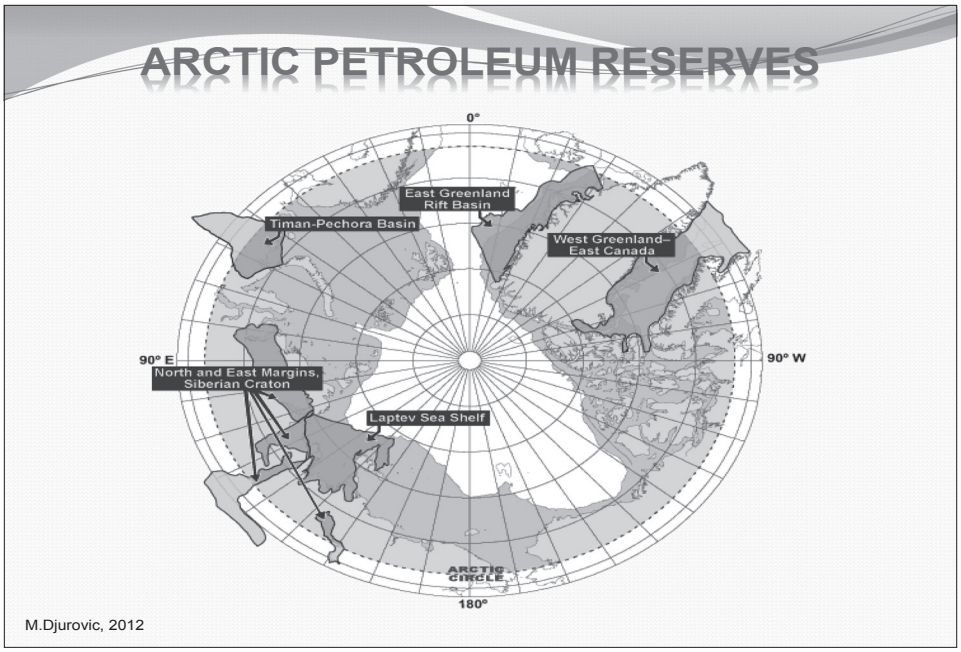
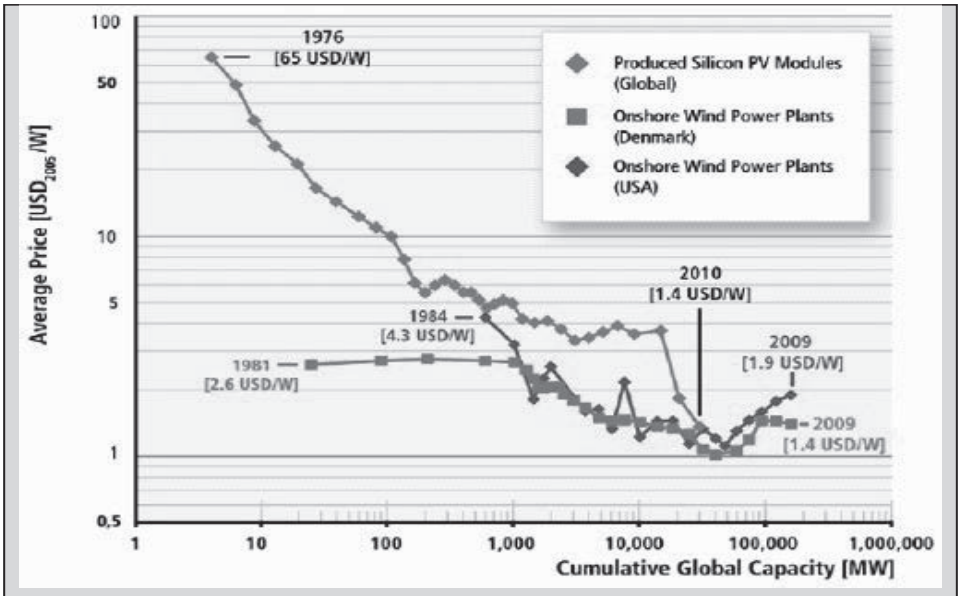
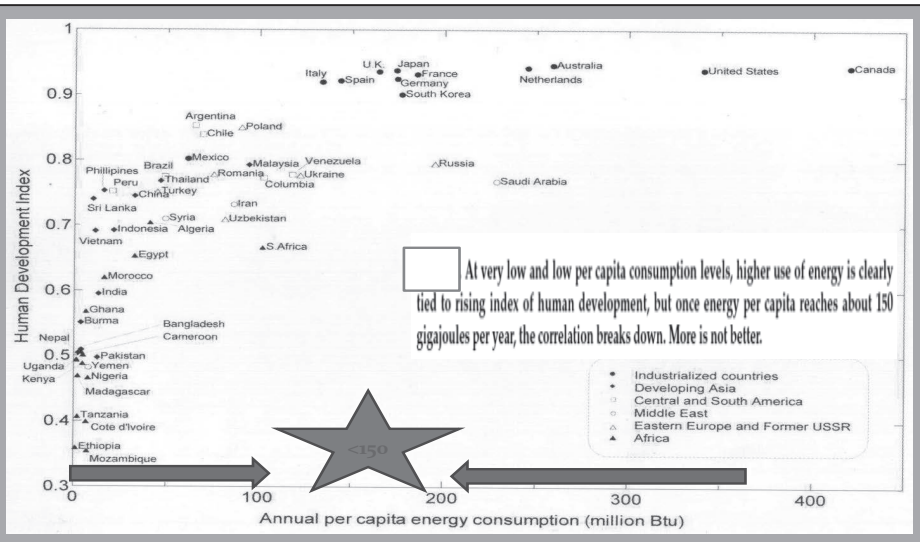




Solar and Wind Cost Curves



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