Clean Sustainable Energy Sources, Carriers and Storage

Gustav R. Grob, Fellow of the Energy Institute F.EI
Executive Secretary, International Sustainable Energy Organization ISEO
Chairman of ISO/TC203/WG3 Technical Energy Systems Analyses
President of the International Clean Energy Consortium ICEC

Energy Situation

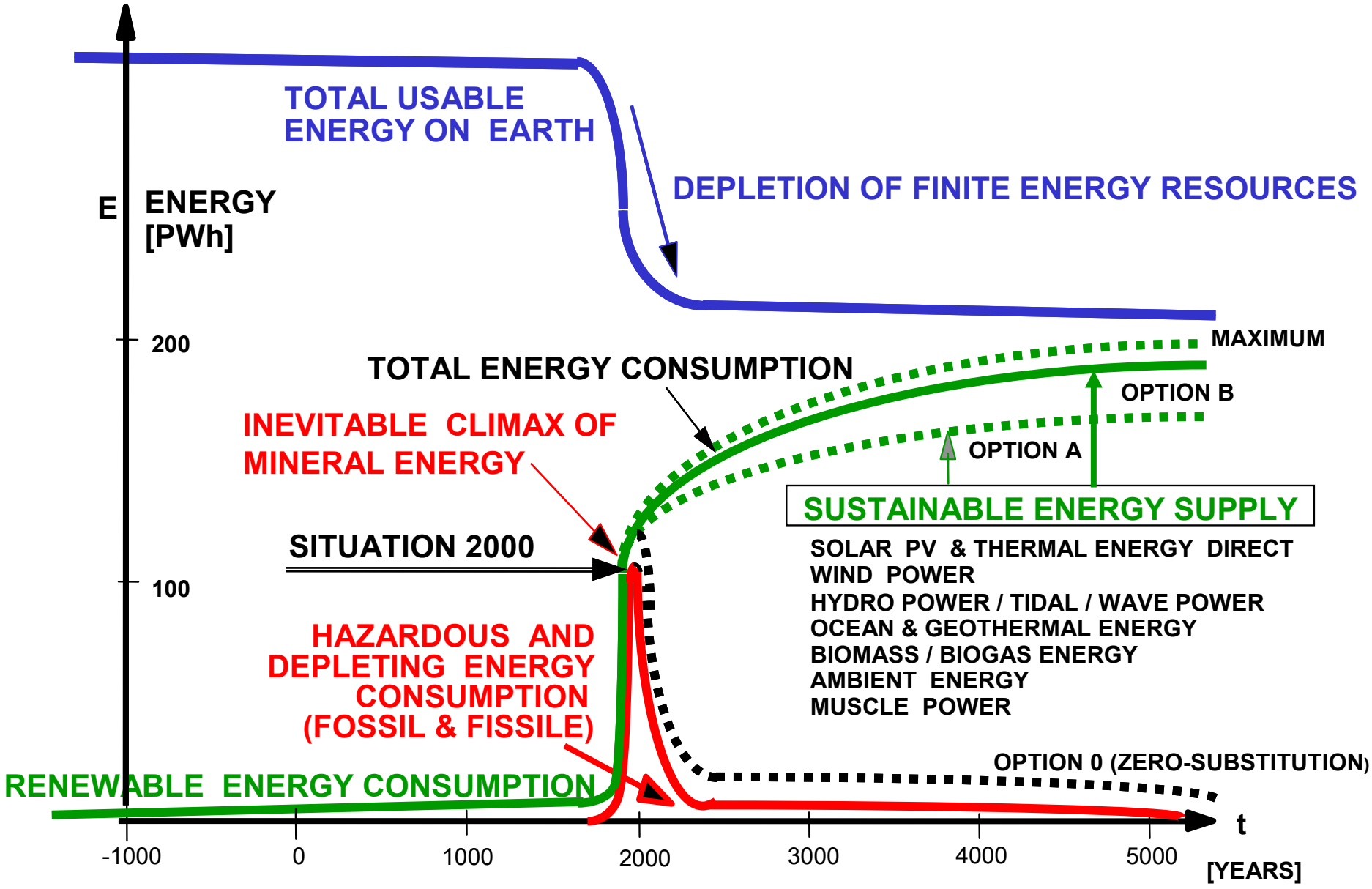
- Total world energy use ~140 PWh p.a. → 16'000 GW at 8600 h
  > 80 % from finite, unsustainable mineral energy resources
- 4'000 GW installed electric base load and fluctuating power capacity world-wide (ground solar and wind power production is fluctuating)

  $\sum$ Energy : $\sum$ Electricity = 4 : 1 to 5 : 1 ratio

- 994 GW USA → 3,30 kW per capita (2010)
- 860 GW China → 0,66 kW per capita (2010) = <u>world average</u>
- 160 GW India → 0,16 kW per capita (2010)
- China plans additional 80 GW power capacity annually
- World needs minimum 400 GW p.a. more for economic growth, better life styles, electric mobility and replacements of obsolete, unsustainable thermal coal, gas, oil and nuclear power plants

➢ All mineral fuels coal, petroleum, gas and Uranium

must be replaced by clean energy in this century !



ENERGY HISTORY & FORECAST

SOURCE : ISEO

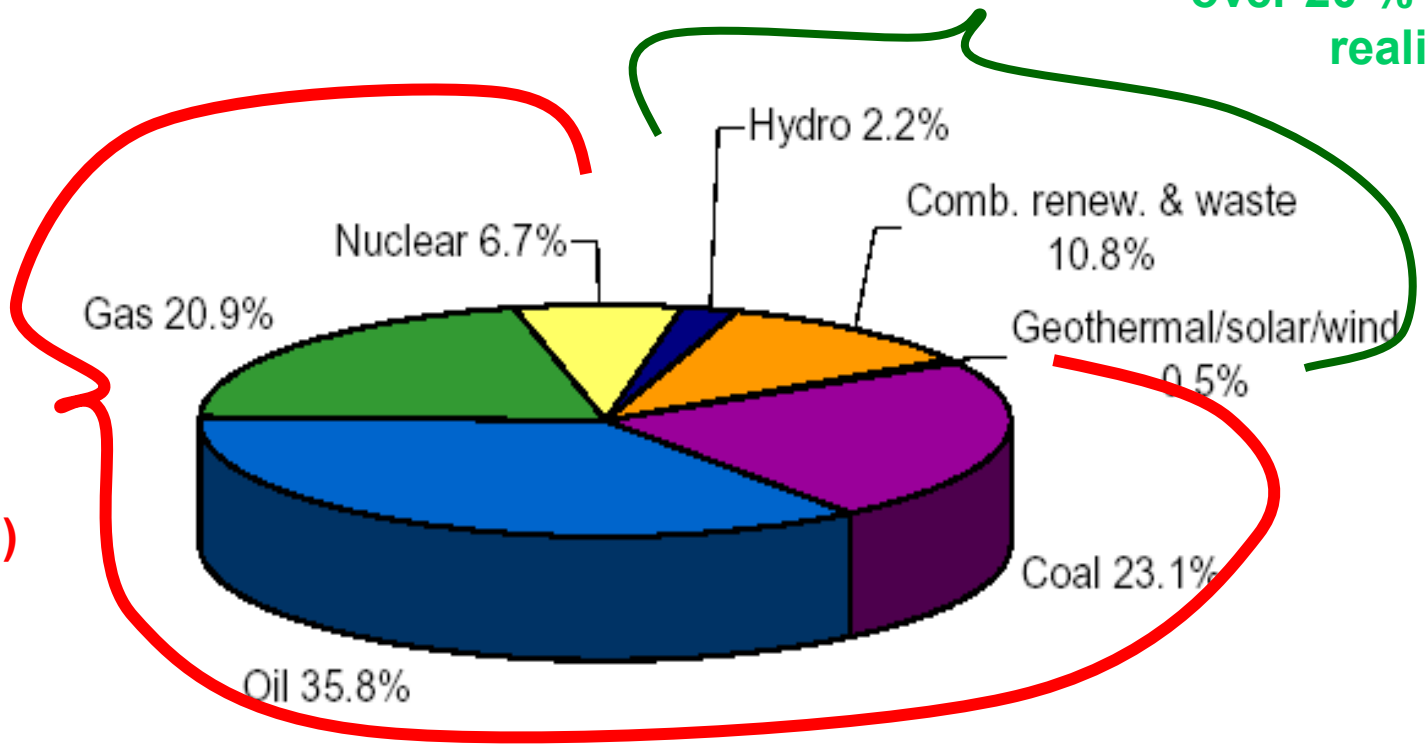
Share of Total Primary Energy Supply* in 2002

Renewable Energies only 13,5 %

according to IEA-OECD

- over 20 % in reality

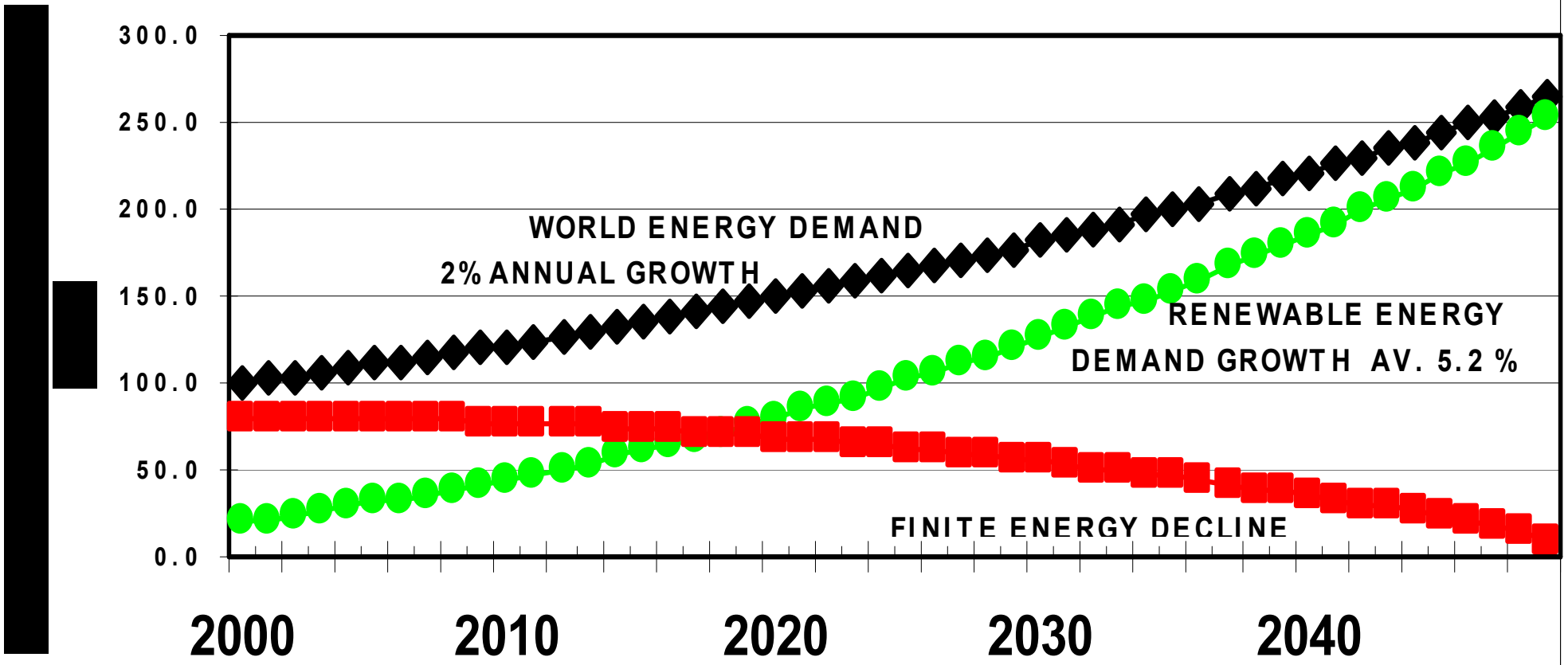
World



Mineral Energies 86.5 % (Combustion Pollution, Depletion !)

124 PWh

WORLD ENERGY SCENARIO 2000 - 2050



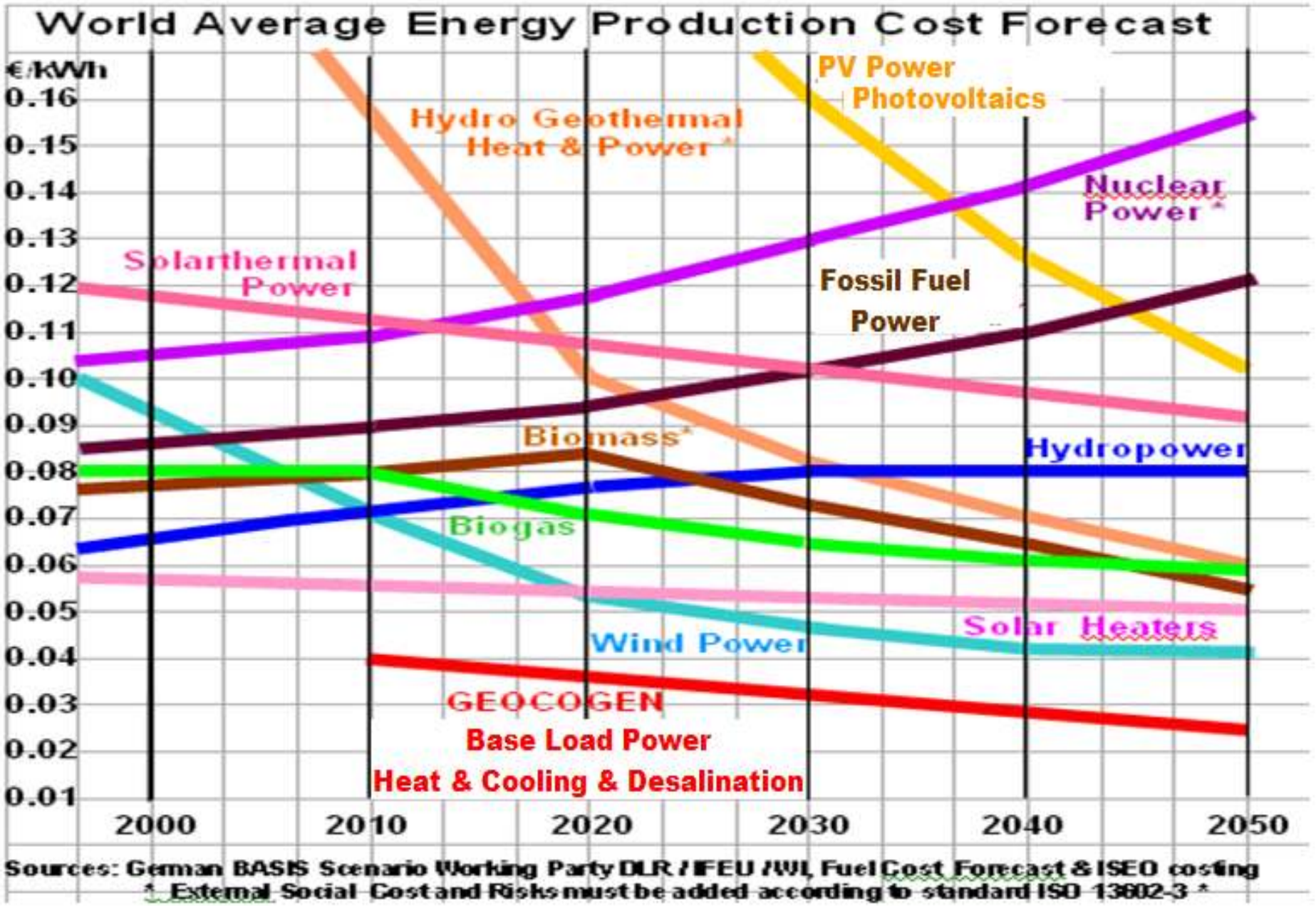
Source for Finite Energy Data: ASPO at www.peakoil.net & Kyoto Protocol

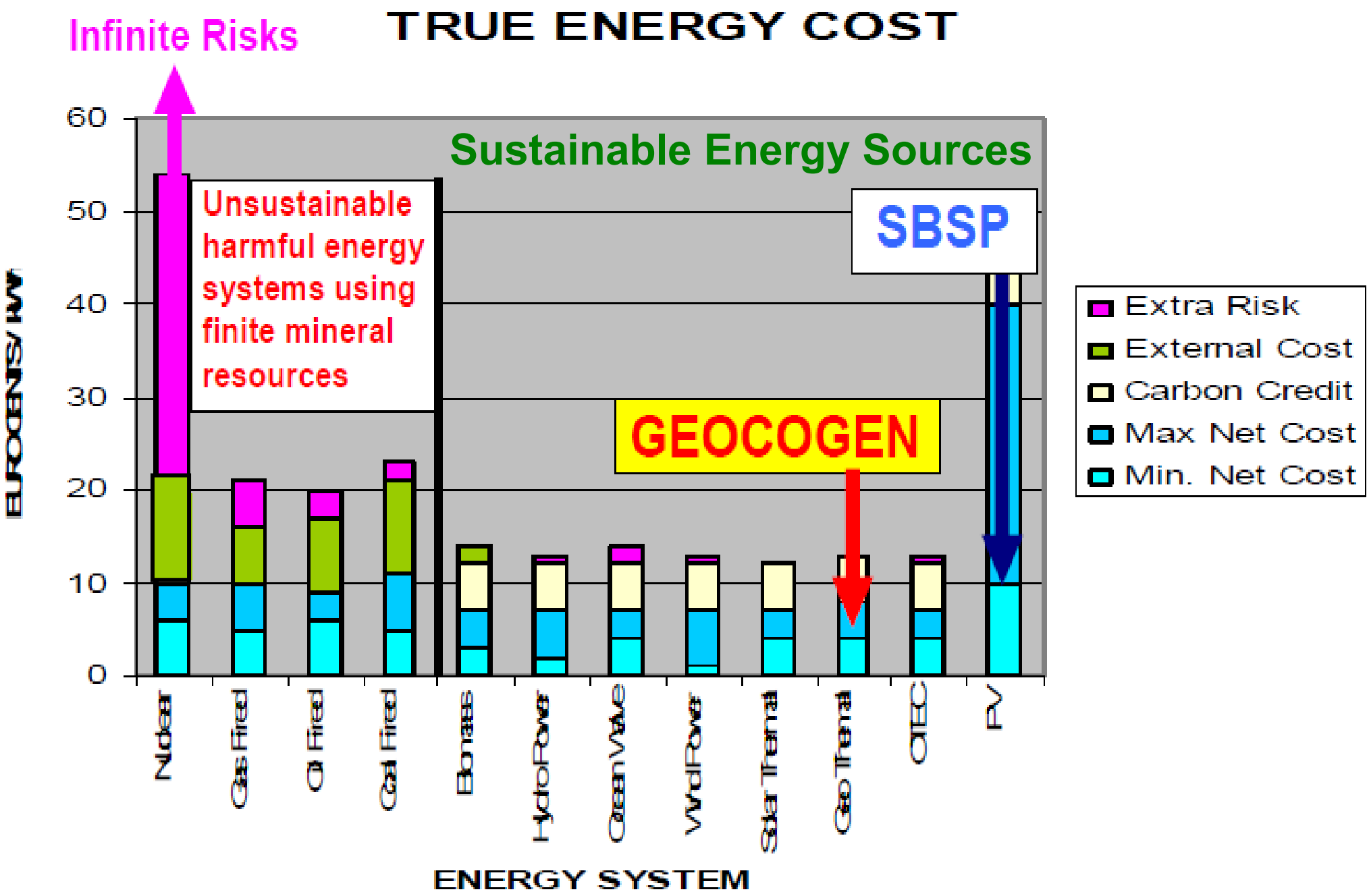
Energy Option	Immediately Feasible		Theoretical Potential
- Bio energy (competing with food !)	(50)	PWh/year	(80)
- Hydropower	8		15
- Geothermal Electricity Conventional	2		
- Geothermal Energy Hot Dry Rock	80		400
- Geothermal Heat from aquifers	4		
- Wind Power	53		160
- Solar Power PV incl. SBSP	60		
- Solar Thermal Power	40		435
- Solar Direct Active Heat	20		
- Solar Passive Heat	10		
- Ocean Energy	15		200
- Heat Pumps	10		50
- Muscle Energy	1		10
- Novel Energy Technologies (R&D)	50		200
Total Renewable Energy Potential	350 PWh/year		max. 1550 PWh/year

more than twice the present world energy consumption

Factors affecting electricity generation cost

- **Optimal system** type, size, location, taxes
- **Fuel prices** escalation, emission levies, taxes
- **Carbon Credits** € / $ per saved Ton of CO_2
- **External Cost** environment, climate and health
- **Risks** of disasters, wars, terror, contamination:
  exposure of power plants to sabotage, tornados, earth quakes or meteorites causing radioactive catastrophes, epidemia, explosions, leaks, spills


World Average Energy Production Cost Forecast
€/kWh
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
2000
2010
2020
2030
2040
2050
PV Power
Photovoltaics
Hydro Geothermal
Heat & Power *
Nuclear
Power *
Solarthermal
Power
Fossil Fuel
Power
Biomass*
Hydropower
Biogas
Solar Heaters
Wind Power
GEOCOGEN
Base Load Power
Heat & Cooling & Desalination
Sources: German BASIS Scenario Working Party DLR / IFEU /WI, Fuel Cost Forecast & ISEO costing
* External Social Cost and Risks must be added according to standard ISO 13602-3 *


TRUE ENERGY COST
Infinite Risks
Sustainable Energy Sources
Unsustainable harmful energy systems using finite mineral resources
SBSP
GEOCOGEN
60
50
40
30
20
10
0
Extra Risk
External Cost
Carbon Credit
Max Net Cost
Min. Net Cost
Nuclear
Gas Fired
Oil Fired
Coal Fired
Biomass
HydroPower
OceanWave
WindPower
Solar Thermal
Geo Thermal
OTEC
PV
ENERGY SYSTEM

Deep Hot Rock Geothermal Energy

Borehole systems

a) Hydraulic fracturing by high pressure with relatively small energy yields

or

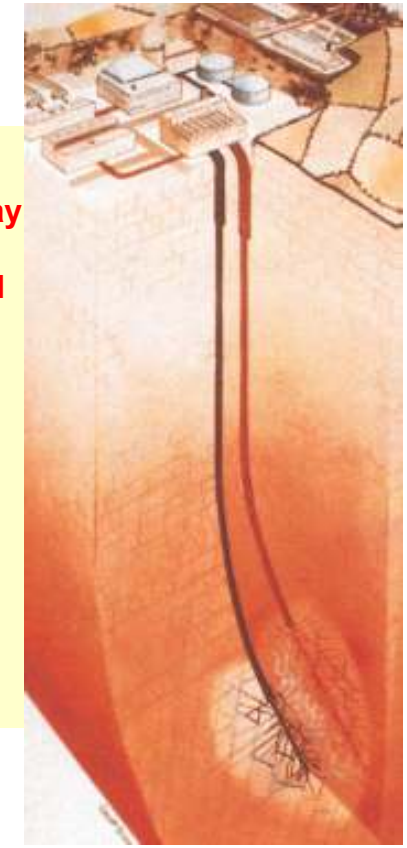
b) Boreholes to geothermal aquifers in open systems with limited energy

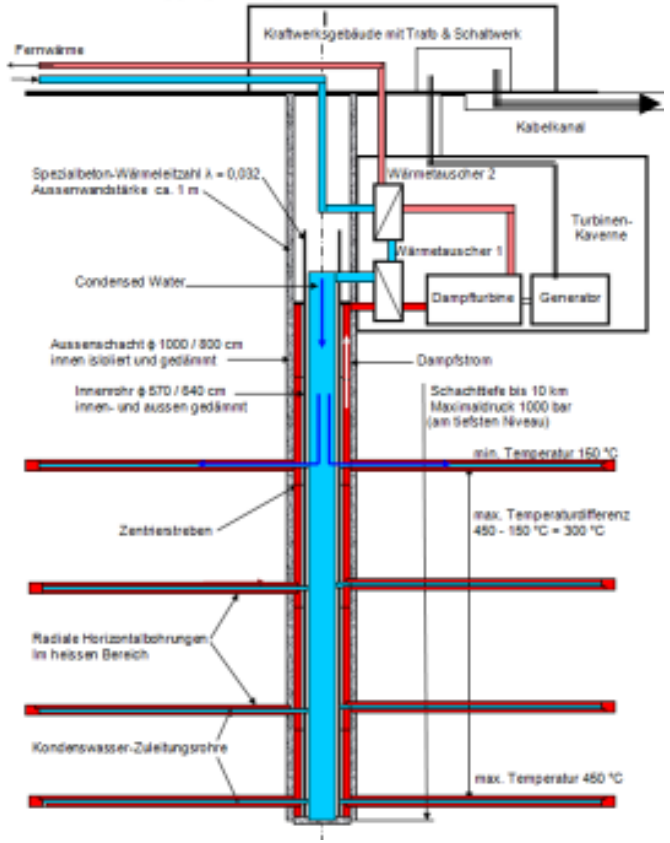
GEOCOGEN®
high-power geothermal energy

Hot-dry Rock system with safely controlled closed primary water cycle in insulated well

and

secondary steam turbine cycle with co-generation for district heating, AC, greenhouses, industry





Disadvantages:

a) Water is finding way of lowest resistance = limited Energy yield

b) Only in hydro geologic strata often far from consumers. Often high energy transport cost. Often limited to heat production only.

Energy cost:
5-10 €¢ /kWh

Advantages:
No yields by hazard !
Super performance (GW).
No fuels or waste problems.
Excavated materials re-used.
Base load power plus heat

Energy cost: 2–4 €¢/kWh

Advantages of geothermal deep well energy co-generation GEOCOGEN®

- Produces electricity and heat (suitable also for AirCon)
- Much lower net cost than any other energy source
- Can be built near agglomerations and substations
- Less energy transmission line cost – hence also less transmission losses than other power plants
- Invisible, no air or water pollution and no noise
- Ideal power source for clean electric vehicles
- No radiation risks or other health hazards
- Creates new clean sustainable jobs
- No waste disposal problems !
- Long life !

No problem !

Applications

GEOCOGEN®

Electricity

Heat

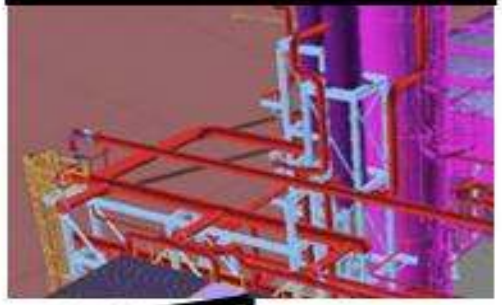
By-Products

District Cooling
District Heating

Spas

Agriculture

Desalination
Process Heat



Sea Water
Byproducts

Salt

Potable Water

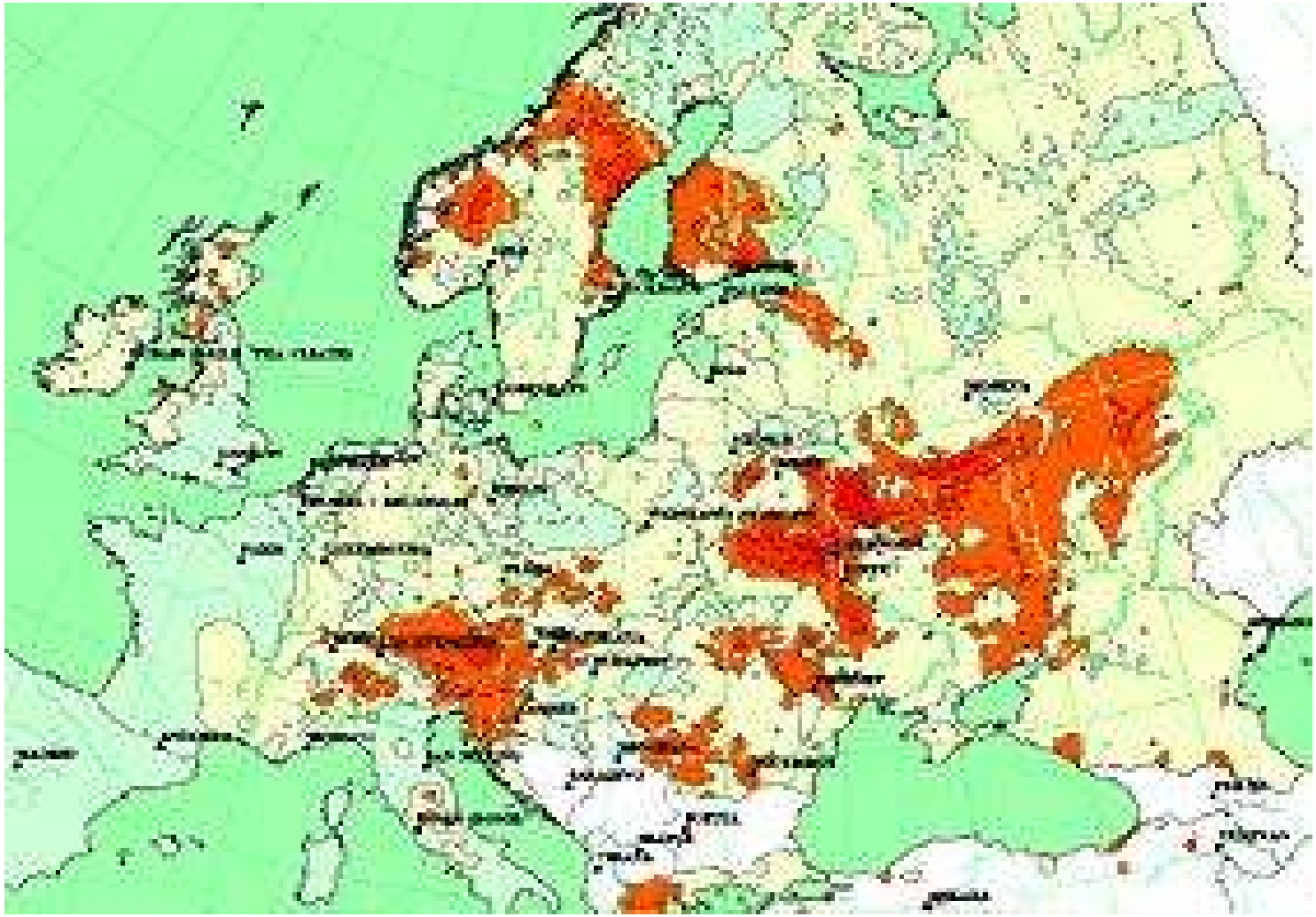
GEOCOGEN® **Co-generation plants**

supply clean, sustainable electricity and heat for desalination and by-products
<u>at the lowest cost</u>

Typical GEOCOGEN® or SBSP locations in Europe

Finite Nuclear Power (to be replaced)

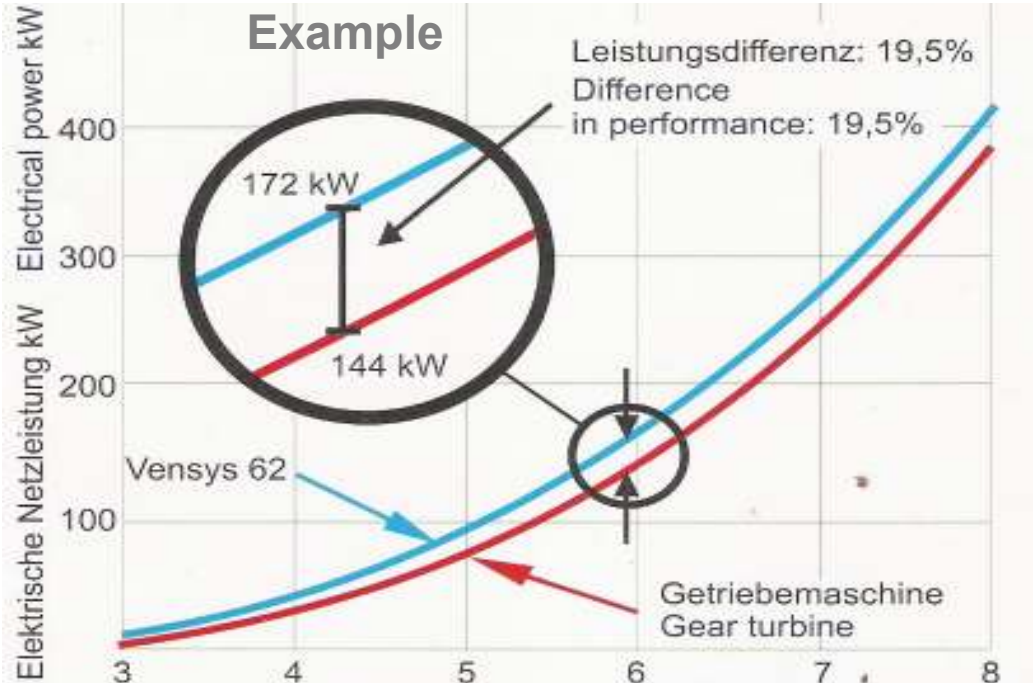
Radioactive contamination of Europe including Chernobyl fallout



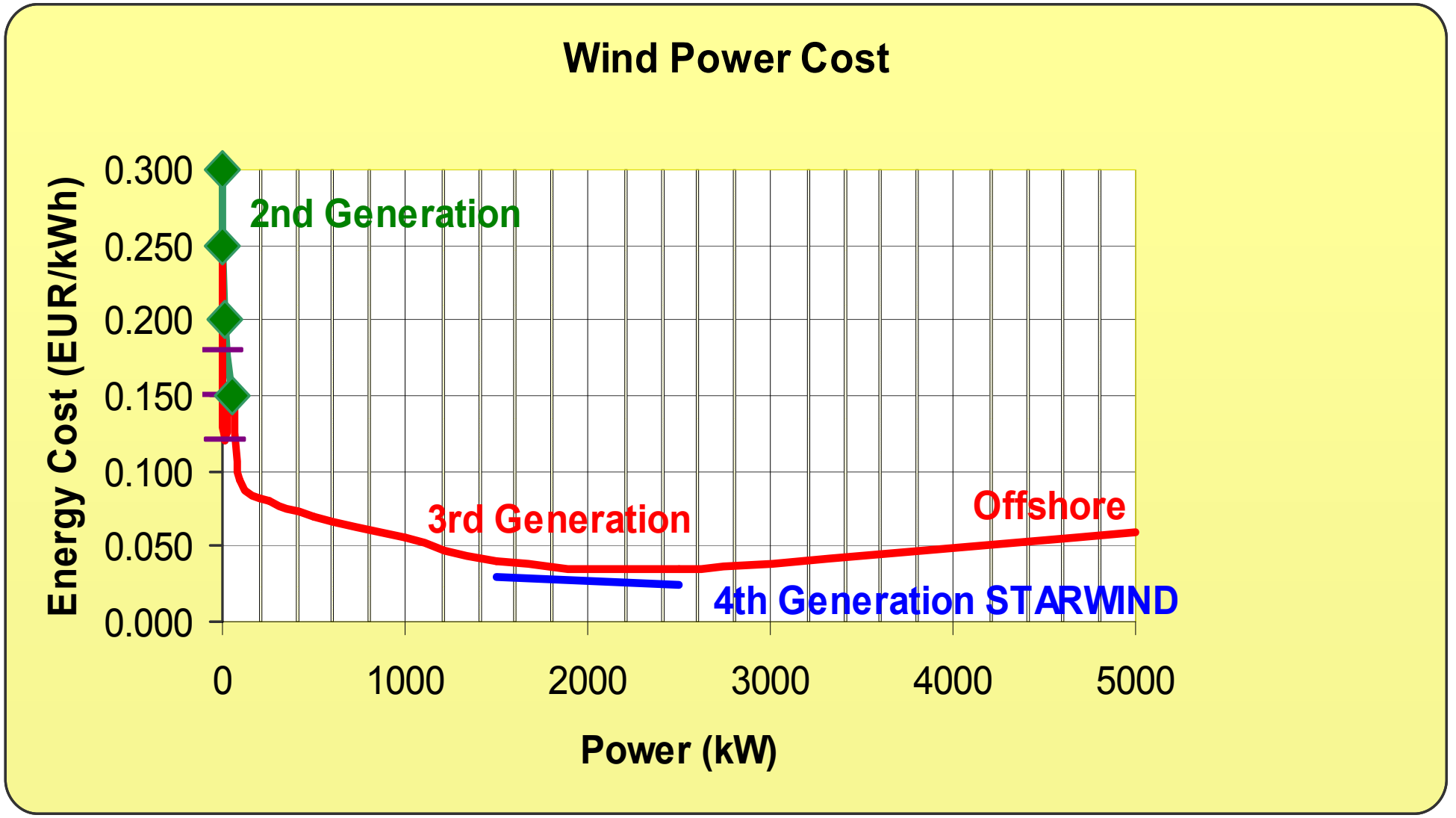
Grande Dixence in the Alps of Switzerland
the world‘s highest power dam (2 TWh/a)
one of the 500 Swiss hydropower plants

4th Generation STARWIND

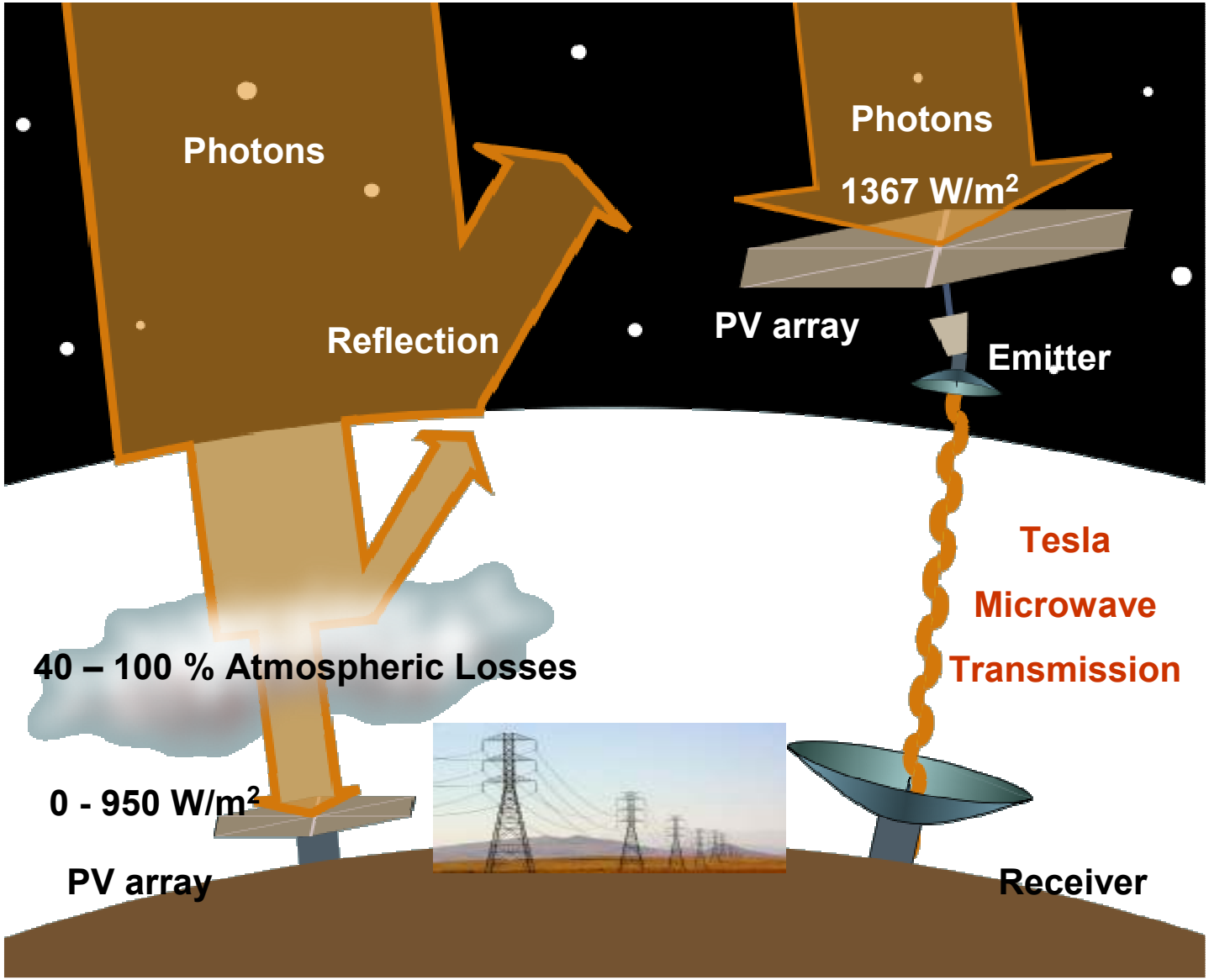
- Gearless, permanent magnets, pitch controlled
- Advanced concrete tower at much lower cost
- Lower maintenance cost and very long life
- Highest efficiency / less copper and steel



4th Generation Wind Power



Ground PV vs Base-Load Space PV Power



Advantages of Space-based Solar Power

- Generates base load electricity
- Higher yield than terrestrial PV systems
- Can be stationed anywhere above consumption
- Less energy transmission line cost – hence also less transmission losses than other power plants
- Invisible, no air or water pollution and no noise
- Ideal power source for clean electric vehicles
- No radiation risks or other health hazards
- Creates lots of new clean sustainable jobs
- No waste disposal problems !
- Long life

Tools for Clean, Sustainable Energy Implementation

- **ISO 13602-1 Energy Systems Analyses Standard**
- **Joint ISO-IEC Standardization Committee JTC2**
- **Global Energy Charter for Sustainable Development**
- **International Carbon Credit Mechanisms (CDM, JI)**
- **Polluters pay accounting principle (world-wide)**
- **International Tax Reforms:**
  more Taxes on Pollution – less on Productive Income

SUSTAINABLE ENERGY STORAGE OPTIONS

to match clean energy supply and demand – UPS, hourly, daily, weekly, seasonally

ENERGY STORAGE MEANS	ELECTR. STORAGE		HEAT/COLD STORAGE	CHEMICAL (FUELS)	MECHANICAL STORAGE	ORGANIC STORAGE
SYSTEMS	base load	peak power				
Electrochemical batteries	X	(X)				
Physical batteries	X	X				
Super capacitors	X	X				
Superconductors	X	X				
Heat or cold storage tanks			X			
Building mass			X			
Water (boilers, ice storage)			X			
Hydrogen, liquefied, compressed, met.hydr				X		
Hydrogen peroxide				X		
Methanol (synthetic)				X		
Potential energy					X	
Kinetic energy					X	
Hydraulic storage*					X	
Mechanical springs					X	
Air, steam, gas compressed					X	
Food for & in bodies						X
Biomass ((solid, liquid, gas)*				X		X
Metals (aluminium, zinc, magnesium etc.)				X		
Molten Salt			X			

* Hydropower is a prime energy source but when pumped up also an energy storage system

** Biomass and food are often considered as prime energy sources but are stored solar energy

Energy Carriers

- Electricity > omnipresent & unlimited applications
- Microwaves > for energy transmission in space
- Water & Steam > for limited pipe distances
- Hydrogen > in pipelines & mobile storage devices
- Other Gases > in pipelines & underground conducts
- Methanol > universal synthetic liquid fuel
- Peroxide > in special tanks and pipes
- Living Beings > the oldest bio energy carriers (food)

Specific International Standards on Energy, Environment and Quality

- ISO International System of Units (SI System)
- ISO 9000 series for Quality Management
- ISO 14000 series for Environmental Management
- ISO 13600 series for Technical Energy Systems (TC203)
- ISO Standards for Solar Thermal Energy
- ISO Standards for Hydrogen Technologies (TC197)
- ISO Standards for Internal Combustion Engines
- ISO Standards for Thermal Insulation
- ISO Standards for Air and Water Quality
- ISO Standards for Soil Quality
- ISO Standards for Ship Safety
- ISO Standards for Gas Cylinders
- ISO Standards for Cryogenic Vessels
- ISO Standards for Architecture

- IEC Standards for Photovoltaics (PV Systems)
- IEC Standards for Fuel Cells
- IEC Standards for Hydropower
- IEC Standards for Wind Power Generators
- IEC Standards for Electric Vehicles and Batteries
- IEC Electric Safety & Environment Protection
- IEC Electric Installations in Buildings

Tasks of new joint ISO-IEC committee JTC2

Energy is the largest economic sector, one of the key activities of ISO and the main reason for IEC.

Sustainable energy became the generic term for the entire scope from renewable energies, clean energy carriers, energy storage, energy efficiency and clean mobility supported by

- **The United Nations Commission for Sustainable Development CSD and the UN-ECE commission for Sustainable Energy**
- **The UN Environmental Program UNEP with the World Meteorological Organization WMO and their joint IPCC for the framework convention on climate change UNFCCC and the World Health Organization WHO**
- **The World Conservation Union IUCN, the International Sustainable Energy Organization ISEO**
- **The specialized NGOs on energy efficiency, renewable energy and energy carriers**

Due to the global importance of energy and the key role it is playing in both IEC and ISO a joint ISO/IEC effort is needed to resolve interdisciplinary problems in international standardization, which are becoming more and more important also for the UN organizations WTO, UNDP, UNIDO, UNCTAD, UNITAR and the World Bank Group.

Important subjects in both standardization domains are the clean energy carriers like **Hydrogen** which is split into ISO/TC197 & IEC/TC105, **Metrology** based on the SI system of ISO/TC12 & IEC/TC25, **Solar energy** also in the case of hybrid collectors and **Space PV**, **Geothermal cogeneration** with its steam turbines and generators, **Bio energy** also producing electricity, **Wind turbines** by IEC containing gears of ISO, electromechanical **Ocean energy** and the **electric vehicles** handled by ISO/TC22 & IEC/TC69. Some of these emerging technologies do not yet have ISO or IEC standards because of their interdisciplinary complexity with their mechanical, civil engineering, chemical process and electrical subsystems. They all need urgently a joint interdisciplinary standardization effort to enable the industry to produce such systems due to the rapid depletion of finite mineral energy resources with rising ecological and climatic concerns about global warming.

Hence a fully fledged **JTC 2** on energy is needed under the title **Sustainable energy technologies** with

SC1 Terminology (replacing the JPC committee on energy efficiency and renewable energy)
SC2 Technical energy systems (ISO/TC203 to be harmonized with other TCs and SC1)
SC3 Energy statistics (ISO/DIS 13602-3 to be harmonized with SC1, UN, EU and IEA statistics)
SC4 Energy carriers other than electricity (hydrogen at ISO/TC197, peroxide, methanol etc.)
SC5 Geothermal energy (not yet existing in ISO or IEC - cooperation with CEN needed)
SC6 Bioenergy (not yet existing in ISO or IEC - only in CEN for some solid biomass)
SC7 Space energy (Space vehicles ISO/TC 20 & Photovoltaics IEC/TC 82)
SC8 Marine energy with its mechanical and electric subsystems in cooperation with CEN
SC9 Electric road vehicles and tractors (ISO/TC22, ISO/TC23, IEC/TC21, IEC/TC69, IEC/TC105)

Electric Mobility and Smart Grids

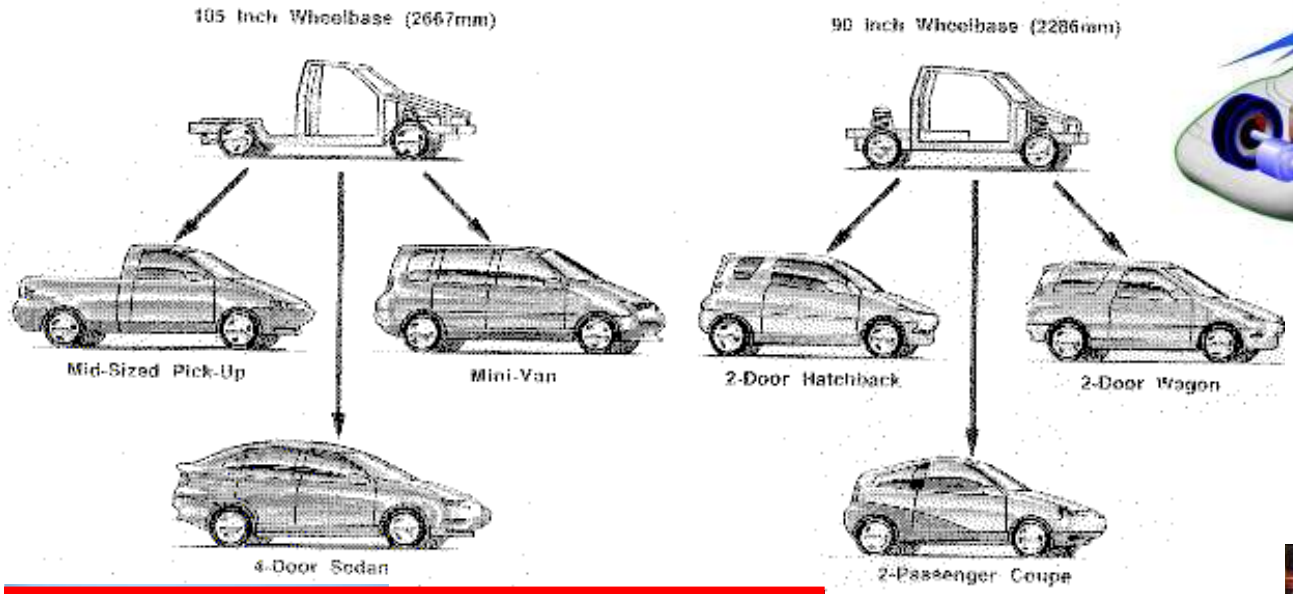
- > 90 % instead of < 20 % Energy Efficiency

  ⬇ ⬇

  Electric Drives vs Combustion Engines

- Zero Pollution and Less Noise
- Cheaper Energy Logistics by the Grid
- Collective Peak Energy Storage Capability
- Perfect Energy Management
- Less Maintenance Cost
- Much Longer Life

Proposed Electric Vehicle Platforms



EV Concept

Solar Car

The Toyota electric Rav e4

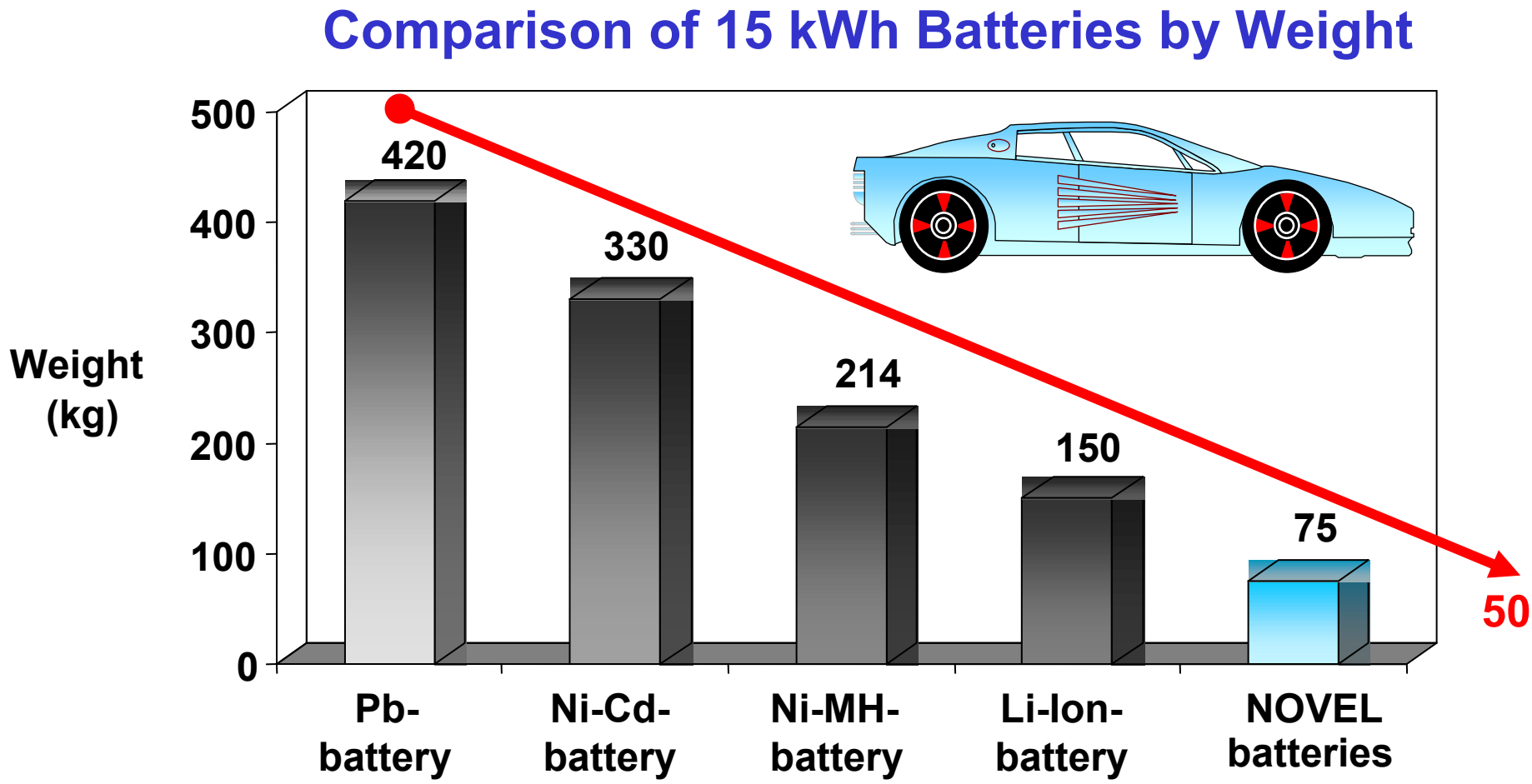
AC Propulsion's TZero

Battery Charging

The electric GWiz

The Citroen electric Berlingo Van

Future Electric Cars - Long Range & Long Life



COMPARISON OF VEHICLE DRIVE TRAIN COST (40 kW; 240'000 km over 6 years)

Drive Options / Criteria	Battery NOVEL	Hydrogen Fuel Cell	Hydrogen * Combustion	Gasoline Combust.
	Li-ion or ZEBRA	Amb. Temp. Storage	Cryogenic Storage **	Gasoline Tank
Relative Drive Investment $/W	0,75	2,35	1,35	< 0.20
Energy Cost $/km	0,03	0,07	0,16	0,15
Relative Weight kg	350	250	250	200
Average Range km	300	400	200	400
Energy Efficiency %	0,75	0,32	0,13	0,13
E + Cap. Cost $/km (Total Vehicle Cost)	< 0,20	0,56	0,46	0,28

Remarks

* a standard 4-cylinder combustion engine is used

** gasoline version: 1$/Liter, 10 Liters per 100 km

*** AC/DC charger on board the electric car for easier battery charging

**** cryogenic H_2 storage boil off loss depending on parking duration

the same gear box assumed for all options

including energy management, storage and power train

> energy supply at 0,1 $/kWh or H_2 at 1 $ per Litre gasoline equivalent

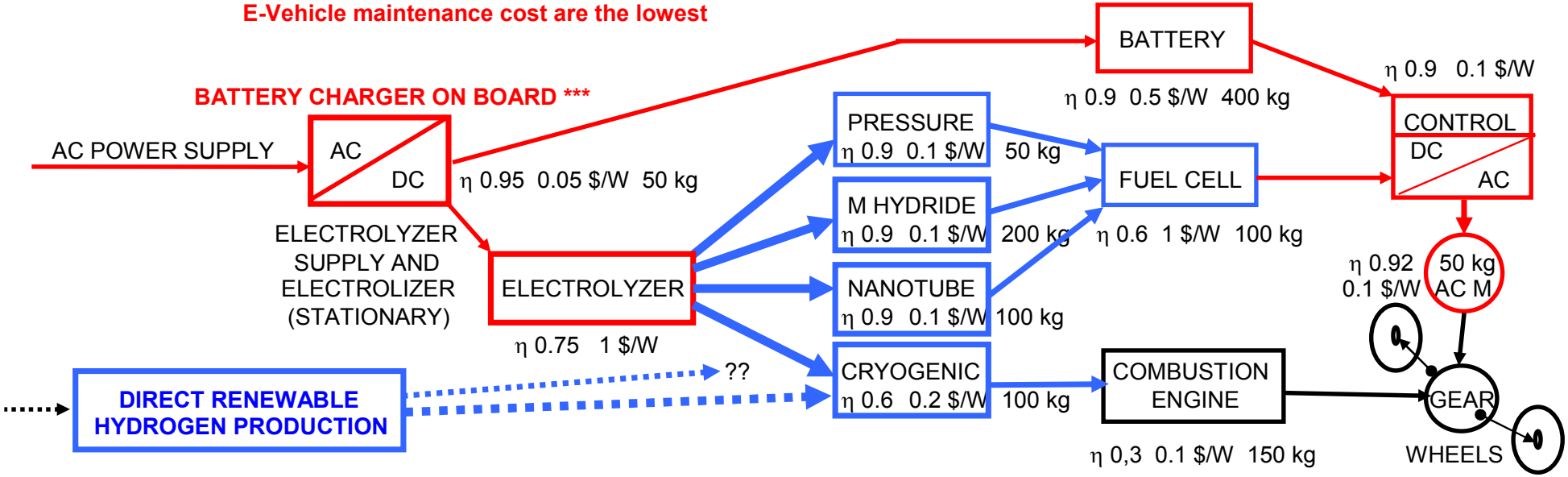
> average weight of energy management, storage and power train

> with one tank filling or one full charge (plus extra charges at stops)

> total efficiency over whole energy chain to gear box

> at 6 % interest over 3 years and 240'000 km usage incl. service & spares

E-Vehicle maintenance cost are the lowest

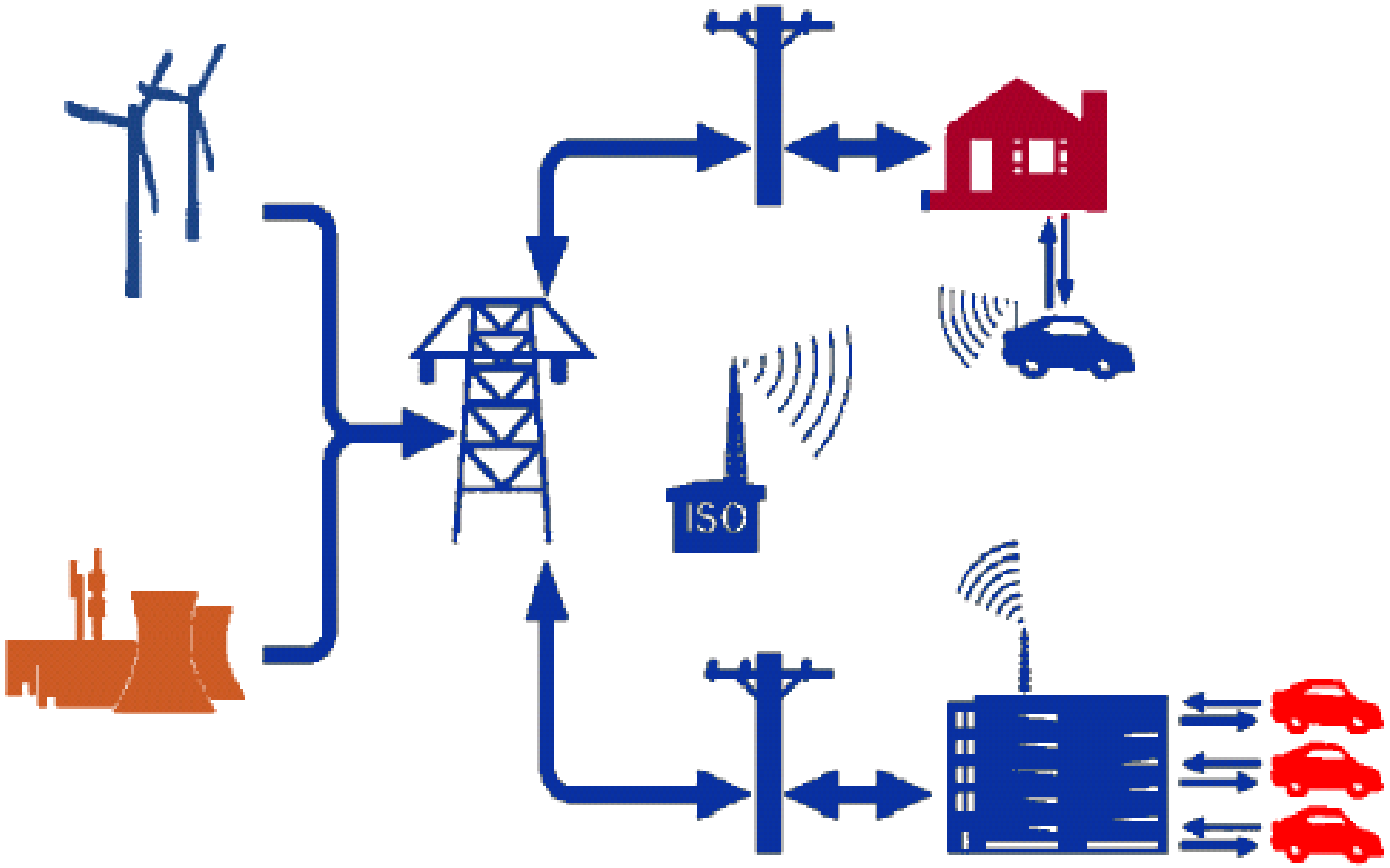


The Merits of Bicycles & Electric 2 & 3 Wheelers for Good Health and Congested Areas

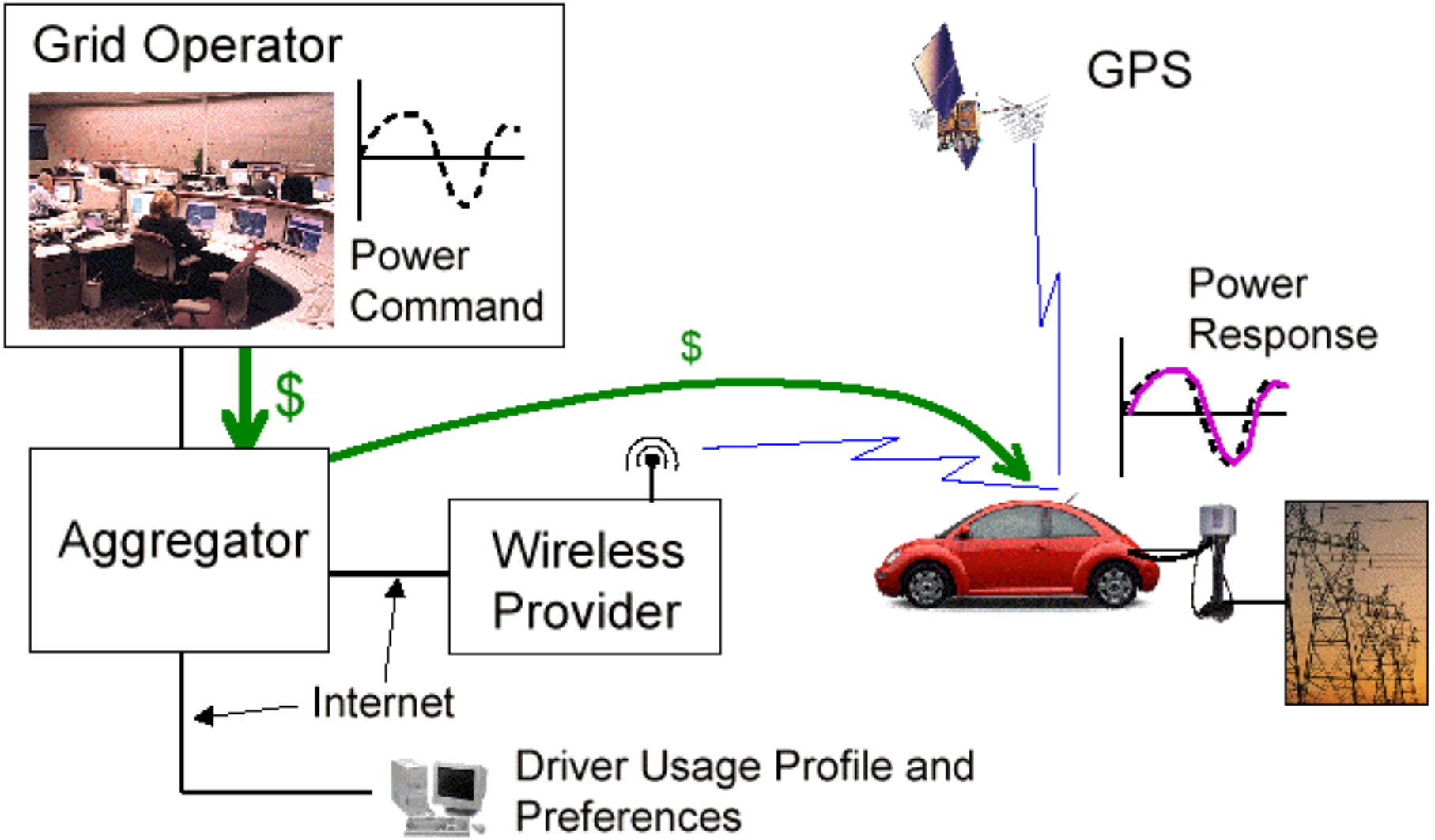
Taiwan Mail Service

The link between electric vehicles and power

The Smart Grid



Smart Power Grid Practicalities



International Sustainable Energy Organisation for Renewable Energy and Energy Efficiency

ISEO, POB 200, CH-1211 Geneva 20 - Tel: +41-22-910-3006 - Fax: +41-22-910-3014
Preparatory Commission e-mail:info@uniseo.org - http://www.uniseo.org

www.uniseo.org

- Background & Reasons for ISEO
- Appeal to all Nations
- About the ISEO Mandate
- Principles of ISEO Operation
- ISEO Organization Chart
- ISEO Network & Web-Links
- Statute of ISEO
- Global Energy Charter
- Blueprint for Clean Energy
- Implementation Tools-ISO/IEC
- ISEO News and Events
- Contact ISEO Secretariat
- Application to ISEO

Hydropower	Wind Power	Biomass	Geothermal
Solar Energy	Ocean Power	Heat Pumps	Muscle Energy
Clean Transport	Statistics	Efficiency	Education
Architecture	Policy	Legal	Financing