ISEO

World Renewable Energy Survey

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Executive Summary

ISEO conducted a world survey about the potential of renewable energy, in cooperation with $NGOs, Academia and statistics for the cross-correlation of data from participating countries, which ranged from European Nations to Asia, Africa, the Americas to various Island States.

The objective of the survey was to determine whether and how the depleting mineral energy resources with their detrimental side effects can be substituted, what investment will be needed and how established infrastructures would be affected. One significant observation was that many government respondents did not know some options in the questionnaire matrix. The survey revealed also that all existing energy statistics ignore some renewable energy options.

Conclusions

1. **There is more affordable renewable energy available on Earth than humankind ever needs at the foreseeable population growth rate.**

2. **Most renewable energy systems are competitive with the depleting non-renewable sources - even more so if the full costing "polluters-pay" principle is applied.**

3. **All nations are able to become energy self-sufficient with renewables and thus can drastically reduce pollution by cleaner, more efficient power plants and transport modes.**

4. **The remaining mineral energy resources can and shall be conserved for higher added value purposes in the chemical and metallurgical industries.**

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1 - Introduction

ISEO was asked to conduct an independent world survey to find out the truth about the total potential of the renewable energy mix, in cooperation with relevant NGOs, Academia and statistical sources for the cross-correlation of data from participating countries, which ranged from a diversity of the European Nations to Asia, Africa, the Americas to various Island States.

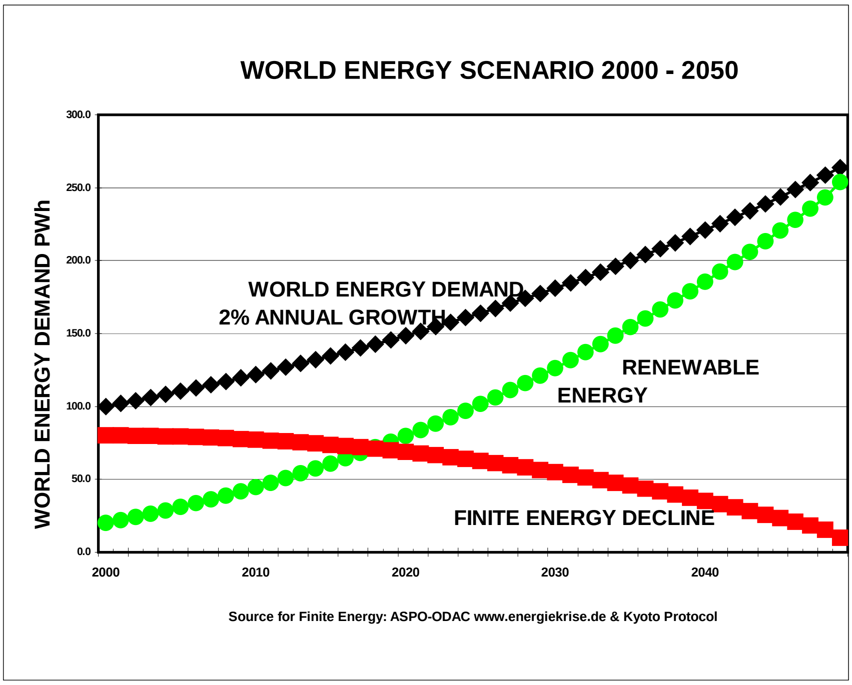
The objective of the survey was to find answers to the urgent questions whether and how the depleting mineral energy resources with their detrimental side effects can be substituted, what investment will be needed and how established energy infrastructures would be affected. One significant observation was that too many government respondents did not know the total potential, because of a lack of information and sustainable energy policy and therefore ignored some options in the questionnaire matrix. The survey revealed also that all energy statistics are lacking some renewable energy options.

The general conclusion is that more renewable energies are available than humankind ever will need at the anticipated population growth and that these energy systems are competitive with non-renewable sources with their fluctuating prices and supply uncertainties - even more so when the full costing principle is applied.

Depending on the demographic, geographic and climatic situation of the individual country, self-sufficiency with clean, renewable energy is mostly possible with an appropriate energy mix supplementing each other – which can be called the “Renewable Energy Symphony” – such as wind plus hydropower or wind plus ocean power, always complemented by solar energy, bio energy including muscle energy and geothermal energy in their different forms, which are economically viable on the average.

Hence, the future energy scenario shown in the graphs below is feasible, thus allowing humanity to prosper without the combustion of precious mineral resources, which then can be conserved for better uses by future generations.

The question of funding such a restructuring process of the energy sector can also be answered affirmatively, since renewable energy systems are on the average less costly than mineral-based energy systems. Renewable energy systems have a longer technical life, do not depend on excessive price fluctuations, do not damage the environment and are – as an additional benefit – more labour-intensive than the conventional resource-intensive energy concepts with their health penalties, thus adding social benefits.



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2. The Renewable Energy Matrix – Basis for a new ISO standard

The fatal fallacy of past energy statistics was that they were altogether incomplete and biased towards conventional, tradable energy only, often falsifying the picture by confusing prime energy with useful end energy, as specified by the ISO standards series 13602 and mixing sometimes coal with biomass under "solid fuels". Another confusion appears frequently with hydropower, which is sometimes classified as "renewable", especially for small turbines and sometimes as "non-renewable" or "unecological" for "large" hydropower, while both are renewable by the ISO definition and very large hydropower can be very ecological too in arid mountain areas.

A renewable resource is clearly defined in ISO 13602-1 as follows: "Natural resource for which the ratio of the creation of the natural resource to the output of that resource from nature to the technosphere is equal to or greater than one".

The new energy matrix, which shall become an ISO standard for statistics and forecasting, in order to facilitate the international comparability of energy systems shows all energy sources - commercial and-non commercial - giving a complete picture, including the emerging ocean power, ambient temperature harvested by heat pumps, as well as the significant share of muscle energy – human and animal - which must also be taken into account, since muscle powered mobility and work might be substituted by fuelled engines and vice versa, while only the latter appeared in official statistics.

Subject		Total Primary Energy Use (TJ)				Total Number of Units [1]				Total Generation Capacity in GW [2]				Total Final Energy Use (TJ) [3]			
Energy Categories	Notes	**1997**	**2000**	**2010**	**max. (4)**	**1997**	**2000**	**2010**	**max. (4)**	**1997**	**2000**	**2010**	**max. (4)**	**1997**	**2000**	**2010**	**max. (4)**
Solid Fuels (finite)	3.01																
Crude Oil / Petroleum Products	3.02																
Natural Gas	3.03	see total final energy use															
Nuclear Power	3.04																
Cogeneration Heat (from CHP)	3.05	this is secondary energy															
Subtotal Finite Energy																	
Biomass (total)	3.06																
Biogas (part of Biomass)	3.07																
Biofuels (liquid Biomass)	3.08																
Bio-energy cogeneration	3.09																
Hydrogen	3.10	from other prime energy sources															
Hydro Power	3.11																
Hydro Pumping	3.12	for energy storage															
Wave Power	3.11																
Tidal Power	3.11	**Note:**															
Wind Power	3.13	Prime Energy from Bio and															
Geotermal Power	3.14	other natural sources like															
Geothermal Heat	3.15	Solar Radiation, Water &															
Solar Power	3.16	Wind Flows, Muscle Power															
Solar Heat	3.17	are difficult to measure															
Ocean Power	3.18	and are threfore not															
Ocean Heat	3.19	to be indicated															
Heat by Heat Pumps	3.20																
Subtotal Renewable Energy																	
GRAND TOTAL ENERGY																	
Energy Uses for Traffic																	
Fossil fuel land vehicles (indiv.)	3.21																
Electric land vehicles (individual)	3.22																
Renewable fuel land vehicles (i.)	3.23																
Bicycles & Tricycles	3.24																
Total individual land vehicles																	
Work Animals	3.25																
Fossil fuel buses																	
Electric buses																	
Renewable fuel buses																	
Fossil fuel trucks & lorries											**Note:**						
Electric truck & lorries											Other Demand Side						
Renewable fuel truck & lorries											Data can be found						
Fossil fuel ships											in the IEA statistics.						
Electric (solar) ships											for various categories						
Renewable fuel ships																	
Fossil fuel rail transport																	
Electric rail transport																	
Renewable fuel rail transport																	
Fossil fuel aeroplanes																	
Renewable fuel aeroplanes																	
Renewable fuel rockets																	
Total Transport Energy																	
TOTAL POPULATION												**TOTAL GNP**					

Explanations see below Please return to: **WSEC Chairman, POB 63, CH-6315 Morgarten / Zug Fax +41-41-750-9020, e-mail info(** E = estimated

Explanatory Notes: **To avoid duplication of efforts use as far as possible the figures you may already have prepared for IEA statistics**

An overview of presently known energy types and their international standards committees are shown in the following energy family tree with their past world shares in the total mix, which are changing rapidly in the next decades, followed by the ISO definition of energy services expected from these energy sources.

THE ENERGY FAMILY TREE AND INTERNATIONAL STANDARDIZATION

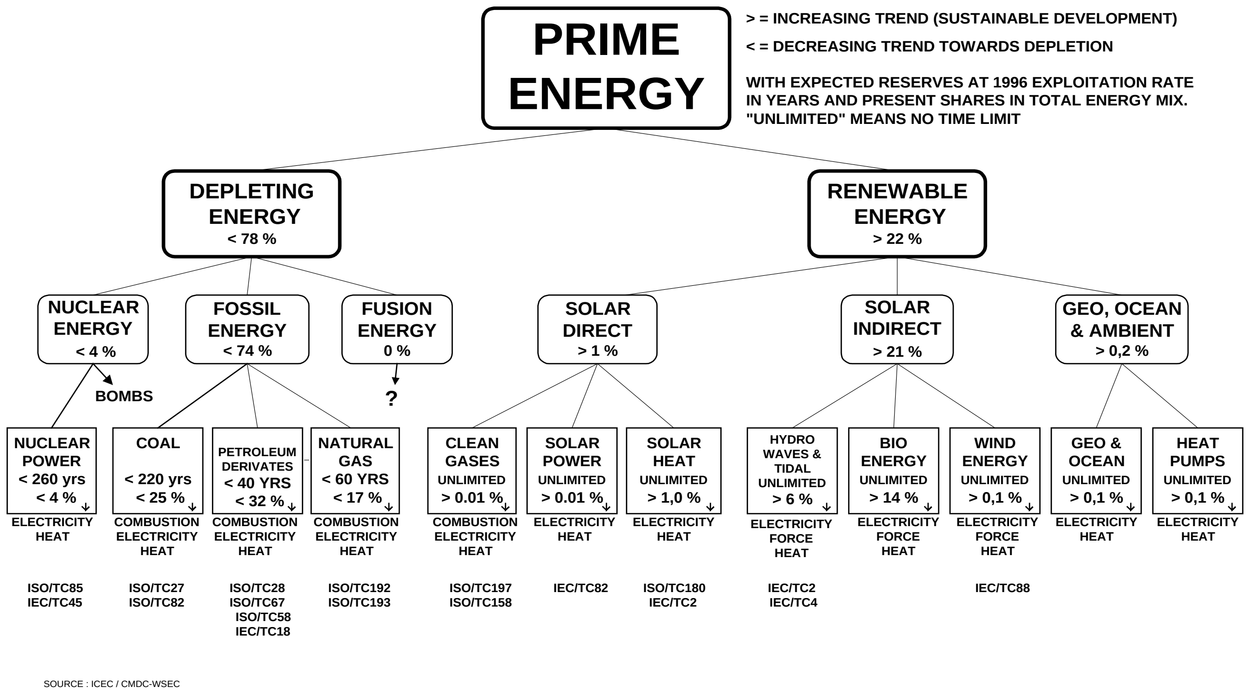


Fig. 2 ISO and IEC in the energy family tree

Energy services
Useful energy output of any final technical energy consumption system.

Examples of energy services:

- mechanical work, transportation, force
- pumping, venting and vacuum applications
- thermal uses (specific heating and cooling)
- audio and ultrasound applications
- vibrations for useful purposes
- lighting / illumination / magnification
- magnetic applications
- data processing, information
- telecommunication, television, visual displays
- physical therapy and diagnostics
- measurement and control
- electrochemical and physical processing

Source: ISO 13602-1

2.1 Definition of Energy

In the international ISO systems of units energy is defined as follows:

Quantity	Symbol	Definition	Name of unit	Symbol for unit	Conversion Factors and remarks
energy	**E**	**All kinds of energy**	**Joule**	**J**	**1 J = 1 Nm**

the energy unit derived from the unit W times h = Wh or multiples of it is also legally permitted, instead of Joule

energy is the work done when the point of application of a force F of 1 N is displaced through a distance of 1 m in the direction of the force

work	**W, (A)**	$W = \int F \, d\mathbf{r}$			
potential energy	E_p, **V, Φ**	$E_p = \int F \, d\mathbf{r}$			
kinetic energy	E_k, **T**	$E_k = \frac{1}{2} mv^2$			
power	**P**	**rate of energy transfer**	**Watt**	**W**	**1 W = 1 J/s**
efficiency	**η**	**ratio of an output power to an input power**	**one**	**1**	

Source: Standards Handbook / ISO 31-3 (1992)

No other energy units are permitted by law in most nations.

In practical life there is electrical, thermal and mechanical energy needed in energy end-use systems, rendering energy services, according to the definitions in international standard ISO 13602-1.

Electricity as the universal energy carrier for every purpose has to be available on demand, i.e. there is base energy and peak energy needed from the power supply viewpoint.

Energy storage is desirable where the supply-on-demand might be interrupted or intermittent and it is necessary where the safety might be in peril.

Mineral energy resources in the form or fossil hydrocarbons are finite and have to be substituted for reasons of depletion and due to harms to the environment and health.

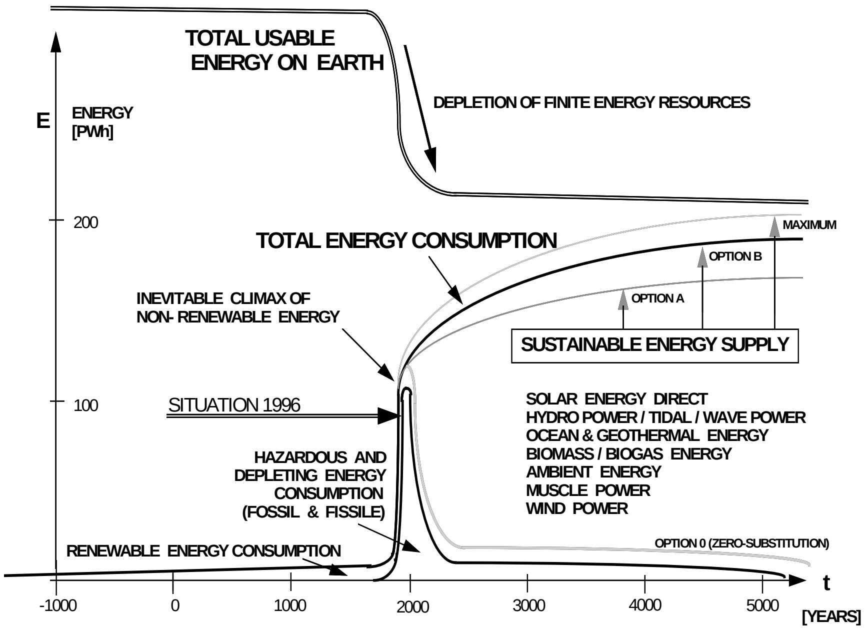
Synthetic fuels, such as hydrogen and bio-diesel have to be produced from renewable energy sources. However, direct electricity use –for mobility by improved storage devices - might replace most combustion engines and turbines with their low efficiencies, pollution and noise.

Bio fuels are directly combusted or refined from energy crops or biomass waste.

2.2 Biomass, ranking No. 4 - the oldest Source in the total energy mix

Bio energy, with about 14 % share of the total, is the oldest and largest renewable energy sector, but is often missing in the statistics and plans because of the non-commercial character in many cases. Theoretically biomass could provide all necessary energy if more intensely grown, which might not in the best interest of humankind, who does not like monocultures in some scenic areas.

The diagram below shows that bio energy had a 100 % share in pre-industrial and pre-historic times during thousands of years.



SOURCE : ICEC / CMDC-WSEC

Fig. 1 ENERGY HISTORY & FORECAST

With full utilization of agricultural and domestic waste biomass, a considerable amount of heat and electricity can be produced in every country, providing good base band electricity supply and plenty of heat on demand.

The complete biomass definitions as suggested for the new ISO standards are as follows:

Biomass is a complex matter. Partly it is commercially traded, but partly it is internally used on farms, in sugar mills, saw mills, private homes etc., which must be estimated for this forecast.

Biomass includes wood fuels, agricultural energy crops & residues, municipal waste, black liquor, commercial & non-commercial, liquid & gaseous bio fuels.

Woodfuels include fuelwood, forestry and mill residues, energy plantations like willow, poplar, eucalyptus etc. and charcoal & pellets made from such wood fuels.

Agricultural energy crops & residues include herbaceous & perennial plants like miscantus, reed grass, rapseed, bagasse, straw, stalks, husks and dung and pellets made thereof.

Biogas comprises an estimate of all commercial and non-commercial sources directly used or supplied to pipelines, fuel cells stations etc. Its calorific value is part of total biomass (3.06). Biogas includes landfill & sludge gas, digester gas, gasified biomass etc. as sub-products of total biomass (to be included in total biomass energy content of 3.06).

Biofuels (liquid) comprise all options such as ethanol from sugar cane, biodiesel from rapseed, methanol from any biomass etc. Their calorific value is part of total biomass under 3.06 i.e. the liquid biofuels ethanol, methanol, biodiesel, alcohols etc. are sub-products of total biomass (to be included in total biomass of 3.06).

Co-generation from any biomass energy systems.

2.3 Hydropower ranking No. 5 in the total energy mix and still expandable

Depending on the topography and hydrology of the country there are from nil in flat areas still up to hundreds of GW hydropower potential like China, which could be exploited, with the handicap in some regions of long transport distances to the agglomerations and difficult access to the cascades and reservoirs in some cases, which on the other hand often help the habitat and development of tourism.

The following forecast by the International Hydropower Association IHA agrees with the sum of most national questionnaire replies:

Today, hydropower provides 20% (2600 TWh/year) of electricity in the world (12900 TWh/year). Of 175 countries, which have available data, more than 150 have hydropower resources. For 65 of them, hydro produces more than 50% of electricity; for 24, more than 90% and for 10, practically the total.

According to the Hydropower & Dams Atlas (H & D, 1999), world hydro potential is as follow:

- Gross hydro potential: 40,500 TWh/year
- Technically feasible: 14,300 TWh/year
- Economically feasible: 8,100 TWh/year

The installed capacity is about 700 GW (corresponding to the 2600 TWh/year). The remaining exploitable capacity represents 1500 GW (producing 5500 TWh/year). It is estimated that by the middle of this century, the consumption of electricity in the world will be multiplied by a factor of 2.5 to 3.0. Hydropower will contribute largely to this development.

2.4 Geothermal Energy - No. 6 in the total energy mix with huge unearthed potential

There are records of geothermal utilization in more than 50 countries. Geothermal energy is used both directly as heat and for the generation of electricity. The present utilization of presently known technologies geothermal energy in the world is the following:

	Installed capacity MW	Energy produced TWh/a
Direct use for heating	15’000	35
Generation of electricity	8,020	49

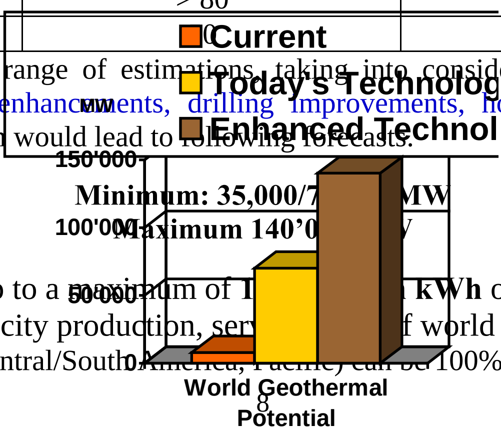
The use of geothermal energy has increased rapidly during the last three decades. In this period the growth rate for electricity generation has been 9% per annum and about 6% per annum for direct use. Geothermal energy is highly competitive to other energy sources in most countries with cost range of:

	Investment $/kW	Energy cost $/kWh
Direct use	200 – 2,000	0.005 – 0.05
Electricity	800 – 3,000	0.02 – 0.10

The variation in cost is more depending on infrastructure conditions than on resource conditions.
The world potential of geothermal energy is large:

	World potential	
	GW	TWh/a
Direct use	> 80	> 400
Electricity	[illegible]	220

It is possible to identify a range of estimations, taking into consideration the possibility of new technologies (permeability enhancements, drilling improvements, hot dry rock, low temperature electricity production), which would lead to following forecasts:

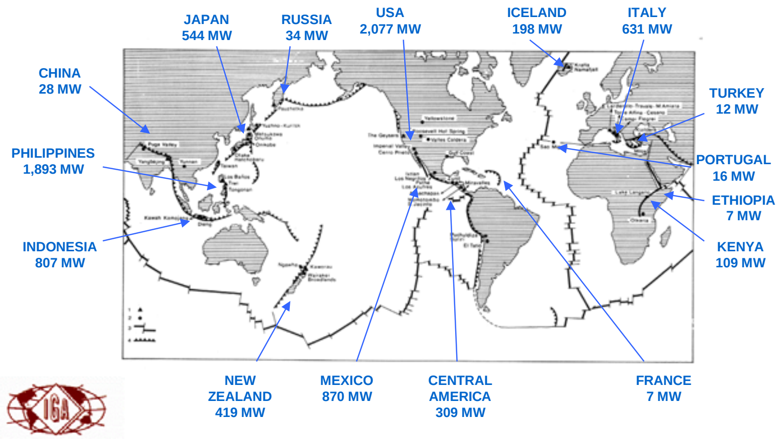


Minimum: 35,000/7[illegible] MW

Maximum 140'0[illegible]W

It is possible to produce up to a maximum of **1[illegible] kWh** of electricity annually, i.e. **8.3%** of total world electricity production, ser[illegible]f world population. **39** countries (located mostly in Africa, Central/South America, Pacific) can be 100% powered. Such new technology will allow to complement any other renewable energy option and makes it possible to substitute coal and other fossil fuels economically and ecologically in every single country, thus relieving the endangered climate, the environment and the hazardous miners jobs of an otherwise hopeless situation.

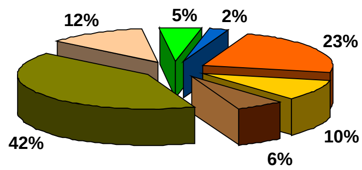
World Geothermoelectric Production 2002



World Direct Uses of Geothermal Heat in 2000

- **Thermal installed capacity:** **15,145 MW_t**
- **Thermal energy utilization:** **190,699 TJ/yr = 52,630 GWh**

Categories:	[TJ] *
Space heating	42,926
Greenhouses	18,902
Fish-farming	11,733
Spas	79,546
Heat pumps	23,275
Heat process	10,220
Others	4,097
TOTAL	**190,699**



(*) Data based on 58 countries

2.5 Wind Energy – No. 7 in the total energy mix with record growth

Wind power is the success story of the nineties with an unparalleled growth rate at more and more competitive cost at favourable wind situations with regular average wind speeds in excess of 6 m/s. Modern wind generators are in the WM class up to 5 MW.

The world wind energy estimates are as follows:

The total installed capacity in Europe is expected to reach 220 000 MW by 2020. Other prominent countries include the USA, India and China. The United States has now a total installed capacity of some 3 GW, which is expected to rise to 250 GW by 2020 and beyond in 2050.

China's wind potential alone is about 250 GW onshore and about 750 GW offshore, thus beating all other renewable energy estimates and giving hope that coal fired power plants, which perform only a small fraction of the wind potential, might soon become superfluous.

Due to the large available global resources (estimated at 53 PWh), a further growth in wind power can be expected, which will increasingly move to off-shore sites.

2.6 Solar Energy – active and passive - the nearly unlimited driving force for life

The total solar irradiation on Earth is a multiple of any future energy demand, but its harvesting requires a lot of space and high investments, which limits its sensible application to roofs and to landscapes of no other uses such as deserts areas.

For photovoltaic power generation there is still a cost constraint, i.e. it makes solar power only viable in remote locations without grid access or as an ecological "additive" to the general power mix consisting of much cheaper options.

Solar thermal power plants of different types can reach competitive cost, if they are gigantic and not too distant from the electricity users, or in case of hydrogen production transportable in pipelines not exceeding 1000 km.

Solar collectors used as water heaters or pre-heaters are much more economical than PV panels, so that it would seem logic to produce hybrid solar panels with a combined production of electricity and hot water.

A forgotten solar energy source in statistics is the passive solar architecture in countries where heating is required. The yield might be estimated at some 10 billion kW (10 GW) or 10 TWh, if it is assumed that about half of the world population needs seasonal heating during half of the year in their dwellings, if they are built accordingly in line with PLEA and ISEO principles.

A global estimate of the practical solar potential could assume that every citizens on Earth could have at least 2 m^2 solar surface on the average, either for electric or thermal use.

At an assumed world population of 10 billion in 2050 this would result in 20 billion m^2 usable roof space, which would yield for

PV	3 TW installed capacity
or for thermal collectors	10 TW installed capacity
or for PV	some 6 PWh electricity
and for heat	some 20 PWh heat production

plus a large amount of solar power from deserts in excess of any energy need of humankind, given the feasibility of long distance transport form the deserts to inhabited areas.

2.7 Ocean Energy

There are four ways to harness ocean energy:

1 - Tidal energy
results from the gravitational fields of the moon and the sun. Four trial installations exist of total of 260 MW. There is now a mature technology, but still quite high cost with little cost reduction potential. There is a high impact on the shore environment.

2 - Marine currents
are caused by thermal and salinity differences in addition to tidal effects. Demonstration stage only. The potential is still difficult to estimate

3 - Ocean waves
are generated by the action of the winds blowing over the ocean surface. Very large potential. Experimental, integrity and visual acceptance problematic

4 - Thermal energy (Ocean Thermal Energy Conversion or OTEC)
resulting directly from solar radiations. Small scale demonstration in 80's and 90's. Huge capital costs, R&D spending was halted but the potential is still there in equatorial regions and particularly viable if combined with Greenhouse cooling, fish farming and natural air conditioning as demonstrated on the Big Island of Hawaii.

The ocean energy potential is enormous but still untapped and limited to coastal areas.

The total contribution of ocean energy along coasts could easily exceed the potential of hydropower, if industrially developed on a large scale.

2.7 Ambient energy harvested by Heat Pumps – underestimated old energy source

The use of heat pumps in colder climes became very popular in some European countries, but is not yet globally recognized. The thermal yield is typically about four times the consumed electricity.

If all half of the world population needs seasonal heating in 2050 the produced energy by heat pumps could reach some 10 TWh

2.8 Muscle Energy – the animal and human energy contribution

The oldest energy systems are the human and animal muscles, which still perform all over the world a lot of mechanical energy, but were not mentioned in any energy statistics. Count the millions of work animals, horses, elephants, buffalos, camels or sledge dogs, which are not in energy statistics, in spite of their excellence in sustainability, but motor vehicles and tractors with their polluting fuels are in the statistics, giving an incomplete, biased picture of unsustainable versus sustainable forms energy !

Assuming that the world population is performing only some 100 W for their mobility during two hours per day, this represents 600 GW power now and 1 TW in 2050, or annually around 400 TWh now or 670 TWh in 2050 in mechanical energy, covering about 0,4 % of the world's total energy needs – clean, sustainable and eternally available without energy cost, if the already existing food chain is not counted, and keeping people much fitter, slimmer and healthier compared with noisy, polluting rides in cars or on motor bikes.

Animal power must be added to this human energy supply, thus replacing polluting tractors, which might then bring the estimate for 2050 to about 1 PWh p.a. Statistics and forecasts for all these sustainable forms of energy versus their fuel consuming, polluting competitors are overdue and will show that at least 1 % of total energy needs can be covered by the combination of human and animal muscle energy

3. Cost and Investments

The investment for renewable energy is on the average in the same order like mineral-based energy systems. The cost per Joule or kWh is lower if the total costing principle according to ISO 13602-1 is applied.

3.3 How much

In an ongoing ISEO study the cost of all renewable energy options are further evaluated to give the energy planners better guidance. The total annual investment derived from the ISEO scenario at about 1000 USD/kW average investment which amounts to an annual world-wide supply side investment volume of about 1 trillon USD.

3.4 From where

There is enough capital in the world economic system, but it is still mostly spent on the wrong unsustainable systems and on military, each to the extent of about 1 trillion USD. It is overdue that investors and governments are revising their investment plans towards sustainable ends only if humankind wants to survive on Earth.

4. Impacts on Infrastructures and Labour

Sustainable energy has a very favourable impact on the labour situation by creating many local jobs to build renewable energy systems. The infrastructures are also positively influenced by sustainable energy systems, because of the better efficiency and decentralized energy production, thus relieving the power grid, improving supply security with less blackout risks and reducing transport cost of fuels.

5. Environmental and Social Benefits – a Question of Survival

It is no question any more with the rising public awareness that more efficient, renewable energy systems reduce the burden on nature and health care.

6. General Conclusions

From the compiled data it can be assumed with confidence that following economically exploitable renewable energy potential exists, which is competitive with mineral resource based energy systems

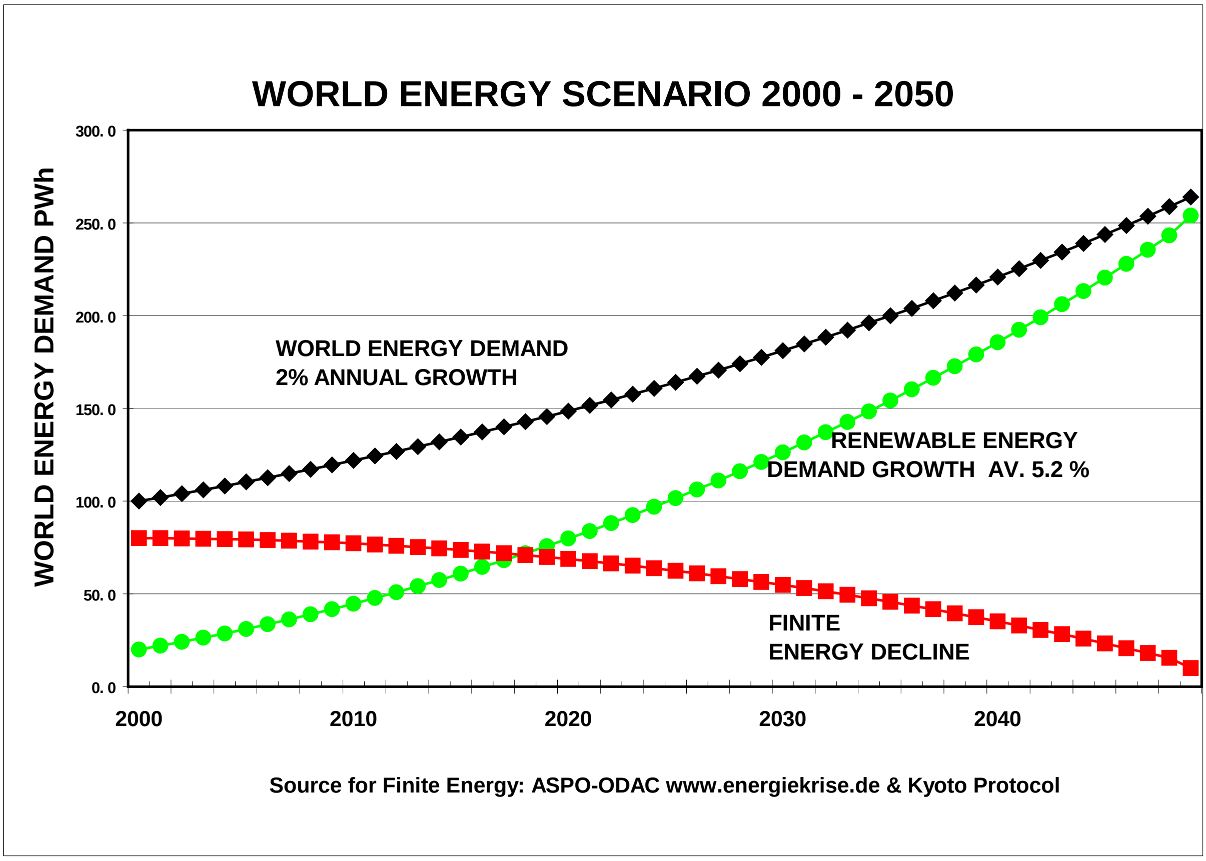
Energy Option	Immediately Feasible	Theoretical Potential	PWh/year
- Bio energy	50	78	
- Hydropower	8	14	
- Geothermal Electricity Conventional	2		
- Geothermal Electricity Hot Dry Rock	20	388	
- Geothermal Heat	4		
- Wind Power	53	160	
- Solar Power PV	6		
- Solar Thermal Power	40	435	
- Solar Active Heat	20		
- Solar Passive Heat	10		
- Ocean Energy	15	202	
- Heat Pumps	..10	50	
- Muscle Energy	1	10	
- Novel Energy Technologies (R&D)	100	200	
Total RE potential	339 PWh/year	1537 PWh/year	

Hence, the ISEO scenario can be fully accomplished !

The sum of all immediately feasible renewable energy is 339 PWh or 45 % more than projected consumption in the ISEO scenario with a theoretical potential reserve of nearly five times more which allows a time horizon of over one millennium. Hence there is no lack of renewable energy and the dwindling mineral resources can be conserved for much better purposes than just combusting them with lots of hazards to produce energy services at mostly very meagre efficiency.

However, what was not mentioned yet in this study yet, are the new renewable energy systems under development, which might provide a multiple of all known energy sources on Earth at lower cost and with less cumbersome harvesting problems – the ultimate, decentralized energy solution.

Former Saudi Petroleum Minister Sheikh Zaki Yamani remarked some years ago, “the petroleum age will not come to an end because of a lack of reserves, but rather because of revolutionary new technology”. This might come true sooner than one may dream of.



More on website www.uniseo.org

7. Outlook and Recommendations

The world is facing the historic challenge to restructure the entire energy sector according to the ISEO scenario, not only because of the dwindling mineral resources and energy security, but more urgently for environmental and health reasons.

Governments and private sector energy planners have to adapt their priorities and decisions to these facts and must consider all renewable energy options, which are viable in their geographic areas.

Financial institutions have to redirect their funds into sustainable systems only and must abstain from prolonging harmful systems or replacing old systems with harmful ones again.

Legislators have to become more active in this field and oblige the government executives to adapt to the new sustainable energy policy instead of cementing obsolete energy concepts under the political pressure of reactionary “business-as-usual” special interests.

The term “Total Prime Energy Supply” (TPES) must be replaced in all statistics by the term “Useful End Energy”, which is much more meaningful for the supply side planning of energy systems in the post fossil fuel age.