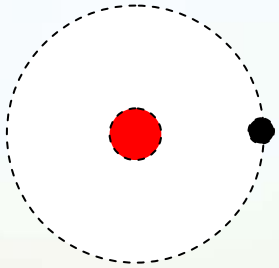
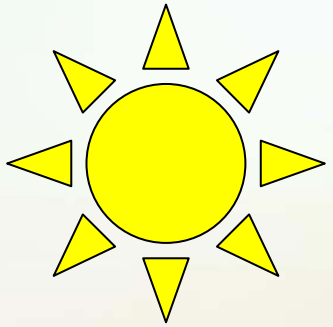
QUO VADIS,

NUCLEAR OR SOLAR?

ENERGY POLICY OPTIONS FOR THE ARAB WORLD





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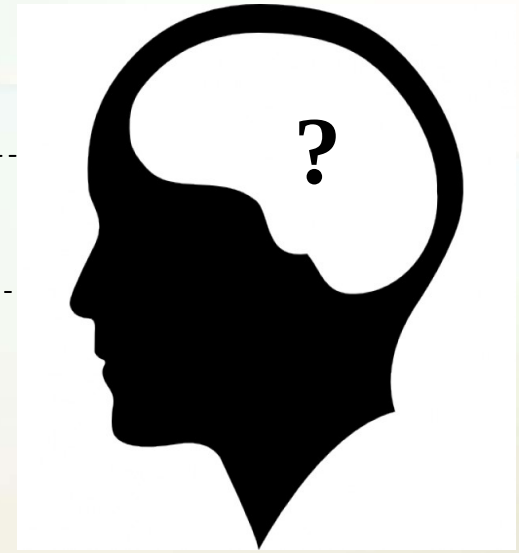
SOLAR



NUCLEAR

Organization

1. Introduction
2. What is Sustainable Development?
3. Energy for Sustainable Development
4. Solar Energy Resources versus Fossil Fuel Reserves
5. Solar Energy Potential in the Arab World
6. Sun is the Source of Renewable Energy and the Oceans are a Major Alternative Source of Water
7. Solar Energy for Desalination in the Arab World
8. Advantages of Solar Energy
9. Solar Collector Systems
10. The Nuclear Option for Energy and Water
11. Nuclear Research in the Arab Region
12. Nuclear Power- What is now known from Decades of Experience
13. Conclusion

Energy is the single most important challenge facing humanity today

- Nobel Laureate Richard Smalley, April 2004, Testimony to US Senate

Direct sunlight is potentially the most powerful renewable energy source. In less than an hour, the Earth receives the same amount of energy from the sun as is used globally by man during a year. In contrast to most other energy technologies, solar energy is only limited by cost of conversion and intermittency in time. Direct use of sunlight yields up to 100 times more electricity per land area than biomass grown for use in power plants. Solar energy at present only amounts to a small fraction of the World's primary energy supply but solar technology markets are developing and growing fast.

- Energy Committee at the Royal Swedish Academy of Sciences,10 November 2008

If I were you, I would stop trying to make Saudi Arabia the oil capital of the world and make Saudi Arabia the energy capital of the world. You should take your cash right now and go out and buy half the solar capacity in the whole world and you should start at the equator. All the way around the equator and go north and south until you put solar power everywhere the weather will tolerate it. You will save the planet, and get richer.

- Bill Clinton, speech in Saudi Arabia in January 2006

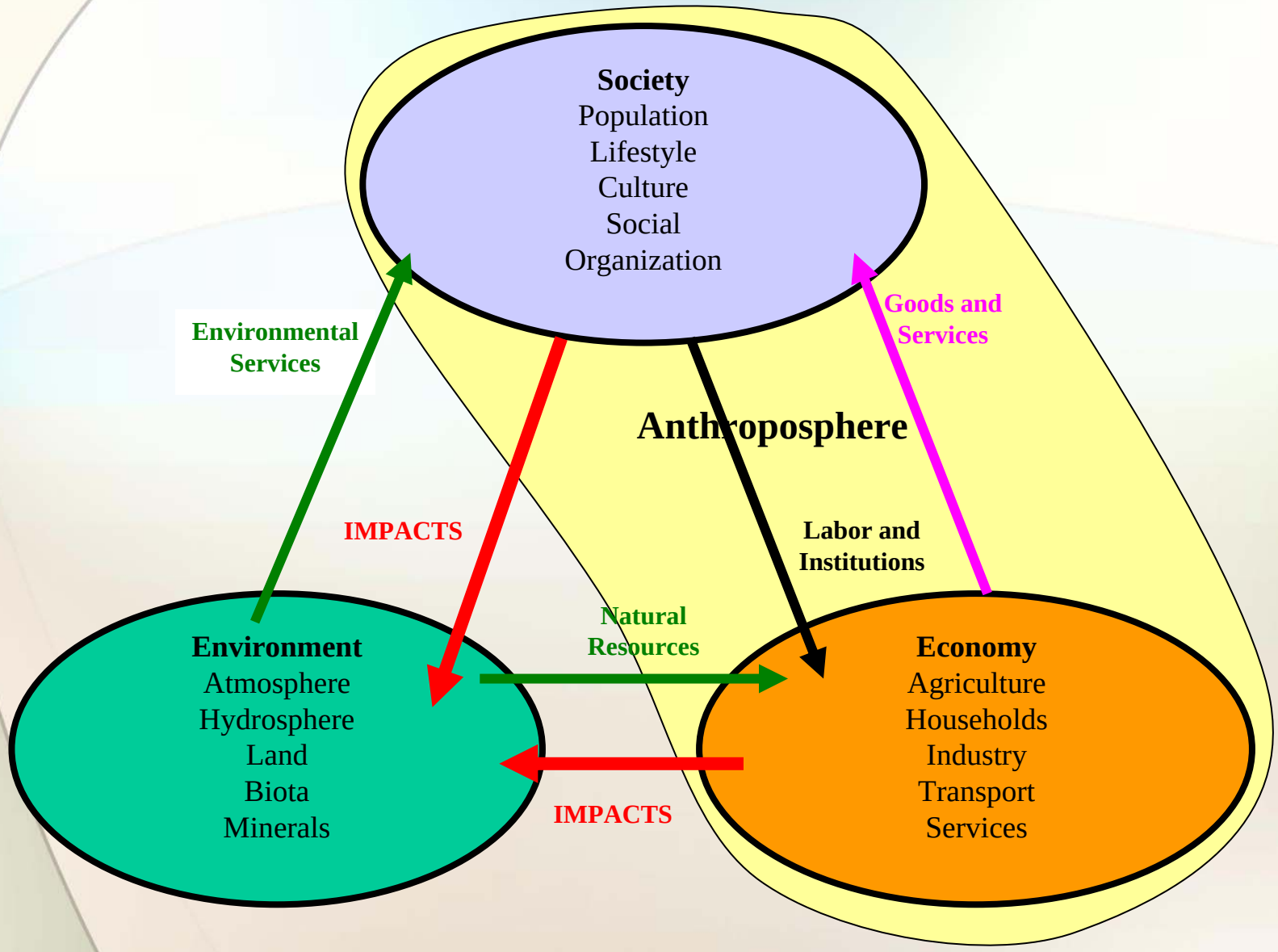
SUSTAINABLE DEVELOPMENT

Development that meets the present needs and goals of the population without compromising the ability of future generations to meet theirs. **(WCED 1987)**

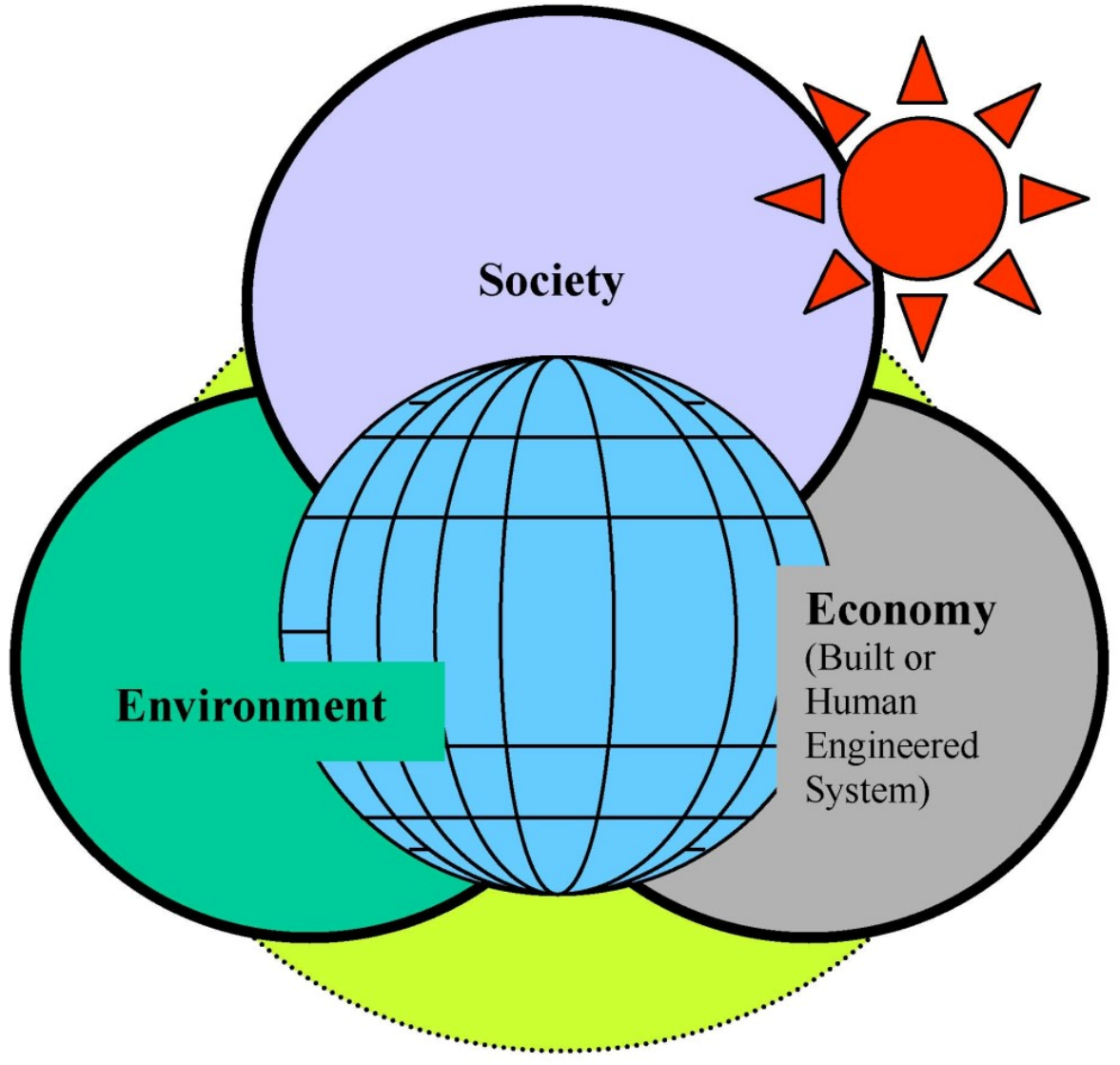
involves

Social and Economic Development, Environmental Conservation.

Complex interactions among the various subsystems of The Earth System



Major components of The Earth System



Sustainability Limits (Herman Daly)

- **The rates of use of renewable resources should not exceed their rates of regeneration.**
- **The rates of use of non-regenerable resources should not exceed the rates at which renewable substitutes are developed.**
- **The rates of pollution emissions should not exceed the assimilated capacity of the environment. Furthermore it should not encroach into and damage the environments for future generations by long life contaminants such as radioactive nuclear waste.**
- **Using natural resources no faster than they can regenerate themselves and releasing pollutants to no greater extent than natural resources can assimilate them (Angela Merkel).**

Human Capital

- **We need to develop qualified and committed professionals who will play a leading role in the sustainable development of the region and its integration into the global economy. We need to share experiences related to the implementation of education for sustainable development at Universities in the Arab Region.**

Sustainable Energy

- energy systems, technologies, and resources that are not only capable of supporting long-term economic and social development needs, but that do so in a manner compatible with
- (1) preserving the underlying integrity of essential natural systems, including averting catastrophic climate change;
- (2) extending basic energy services to the more than 2 billion people worldwide who currently lack access to modern forms of energy and energy products such as desalinated water; and
- (3) reducing the security risks and potential for geopolitical conflict that could otherwise arise from an escalating competition for unevenly distributed fossil fuel resources. In other words, the term ‘sustainable’ in this context encompasses a host of policy objectives beyond mere supply adequacy (Lighting the way: Toward a sustainable energy future, 2007).

SOLAR ENERGY RESOURCES VERSUS FOSSIL FUEL RESERVES

Annual solar energy potential of the world deserts
=33Mkm² **(according to UNEP =** 36 Mkm²)

Annually received energy in deserts world wide

= 80 Million TWh

= 10,000 Billion ("Giga") tons of coal

=50,000 Billion BOE

=300,000 Exa **(10^{18})** Joules

(BGR 2005**)**

Based on an average insolation of 2.22TWh/km²

SOLAR ENERGY POTENTIAL IN THE ARAB WORLD

- According to OAPEC 2015 the oil reserves in Arab countries: 712.2 billion.
- Solar average irradiance can be considered varying between 2.35 to 2.4 TWh/km^2
- Considering 1 barrel of oil is equal 1600 kWh, 2.35 TWh is equivalent to 1.468750 million barrels of oil and 2.4 TWH / km^2 is also equivalent to 1.5 million barrels of oil. However in some North African Arab countries the solar average irradiance can reach to about 2.8 TWh/km^2/a.
- Total Solar Thermal Energy on Arab deserts = 14 x 106 x 0.87x 2.35 TWh/km^2/a= 28.623 million TWh/a or 17889 billion barrels of oil equivalent (BOE) annually.

SOLAR ENERGY POTENTIAL IN THE ARAB WORLD

- Average solar radiation potential for the desert surfaces in the Arab Region (*Equivalent Electric Energy*) =2.35 x 0.25 = 0.5875 TWh/km^2/a (0.25 for combined cycle which is Solar-Electric Aperture Related Efficiency.)
- Considering that the average irradiance to be 2.35 TWh /km^2 and the thermal energy over the Arab land is 14 million x 2.35 = 32.9 million TWh, =20 562.5 billion BOE.
- This ANNUAL Renewable is about 28 times the TOTAL EXISTING ARAB OIL RESERVES which are Nonrenewable.
- So, the solar energy resource in the Arab region can supply not only the energy needs of the Arab people but also meet global energy needs.
- In other words: Any conceivable global demand for energy, today or in future, could be met from solar energy in deserts.

CO_2 emissions/ MWh_e in tons

- **1. Solar Thermal Power Plants:** 0.01–0.015
- **2. Gas Fired Combined Cycle Power Plants:** 0.5
- **3. Steam /Coal Fired Power Plants:** 0.9

Example: A 50MW **solar thermal plant (with 1km^2 collector) at** 80% **of average capacity over one year of operation will cause only about** 3500-5250 tons of CO_2 emissions **while, a typical** gas fired combined cycle plant **will cause** 175000 tons of CO_2 emissions**.** Coal fired power plant **will cause** 315369 tons **of** CO_2 **emissions. Solar alternative implies a huge reduction of greenhouse gas emissions.**

Pan Arab Grid

- Arab Countries **have initiated several bilateral and sub-regional efforts to connect the Pan-Arab electrical networks together into one grid –** forming the integrated Arab Electrical System**.**

The Pan-Arab Grid has been divided into four possible groups:

- Maghreb Region **(Morocco, Algeria, Tunisia and Libya)**
- EJLIS **(Egypt, Jordan, Lebanon, Iraq and Syria)**
- GCC **Countries and the Yemen**
- Other **(Sudan, Djibouti, Mauritania the Comoros Islands)**

SUN IS THE SOURCE OF RENEWABLE ENERGY AND THE OCEANS

- **Just as the** sun is an alternative source of energy **to meet future demands,** the oceans **are an alternative water resource.**
- **However, extraction of** fresh water **from the oceans requires significant development of desalination infrastructure.**
- Desalination **is very energy-intensive, and** sustainable energy systems **urgently need to be developed.** The most arid lands are also those blessed with abundant solar energy **and this needs to be exploited for large-scale production of** freshwater from the oceans.

SOLAR ENERGY FOR DESALINATION IN THE ARAB WORLD

- **Desalination has already made a major contribution to quality of life in the most arid regions of the world, particularly the Arab region.**
- **Without desalination, many of these regions would have remained uninhabited.**
- **With rising global demand, uneven distribution of freshwater and increasing population.**

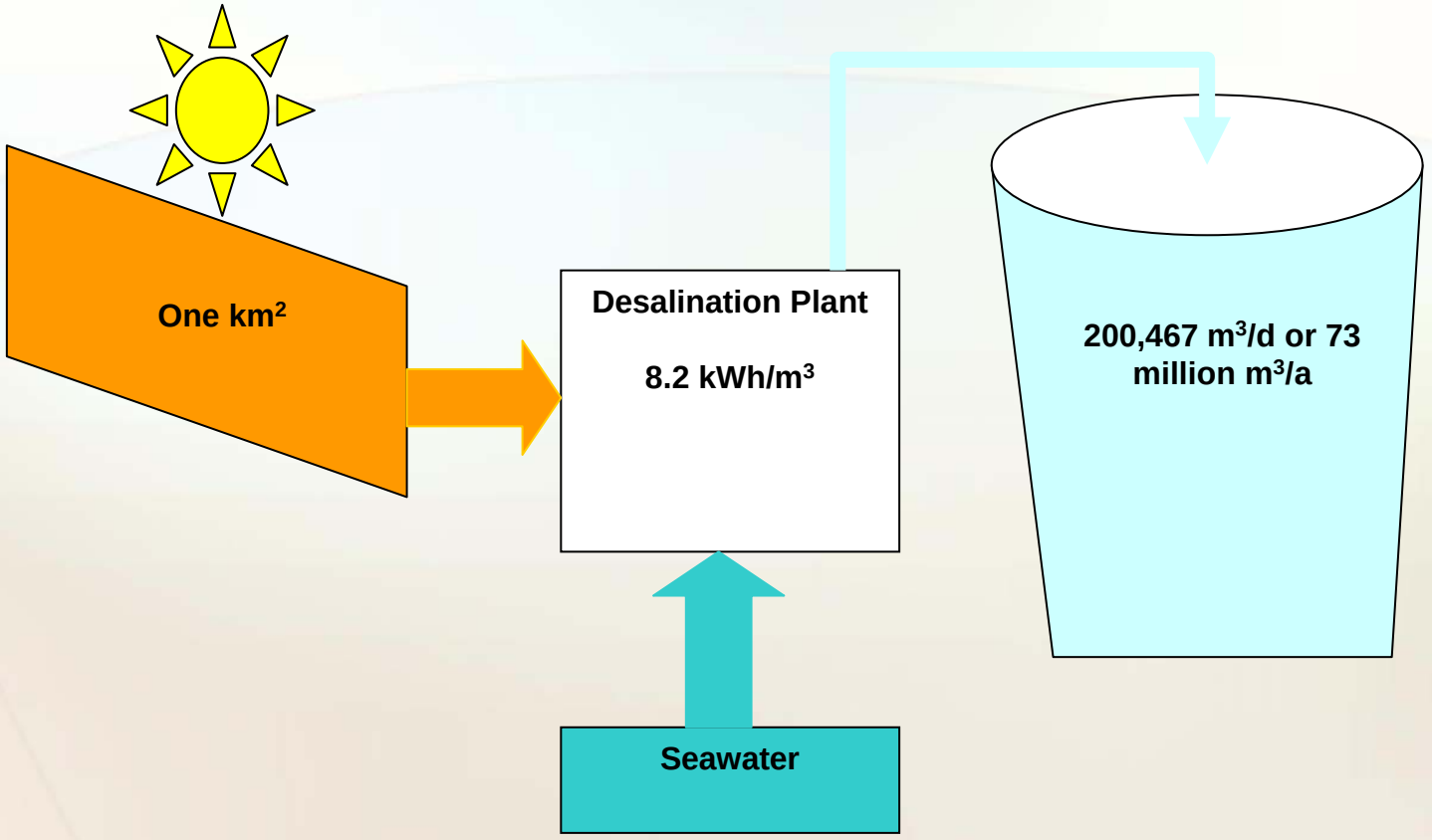
SOLAR ENERGY FOR DESALINATION IN THE ARAB WORLD (*continued*)

- **The total installed capacity of desalinated water systems in the world in 2006 was about** 37 million m^3/d or 8140 Mgd **which is expected to increase drastically in the next decades.**
- **The dramatic increase in desalinated water supply will create several problems, the most significant of which are those related to energy consumption.**
- **It has been estimated that production of** 25 million m^3/d requires about 285 million barrels of oil per year

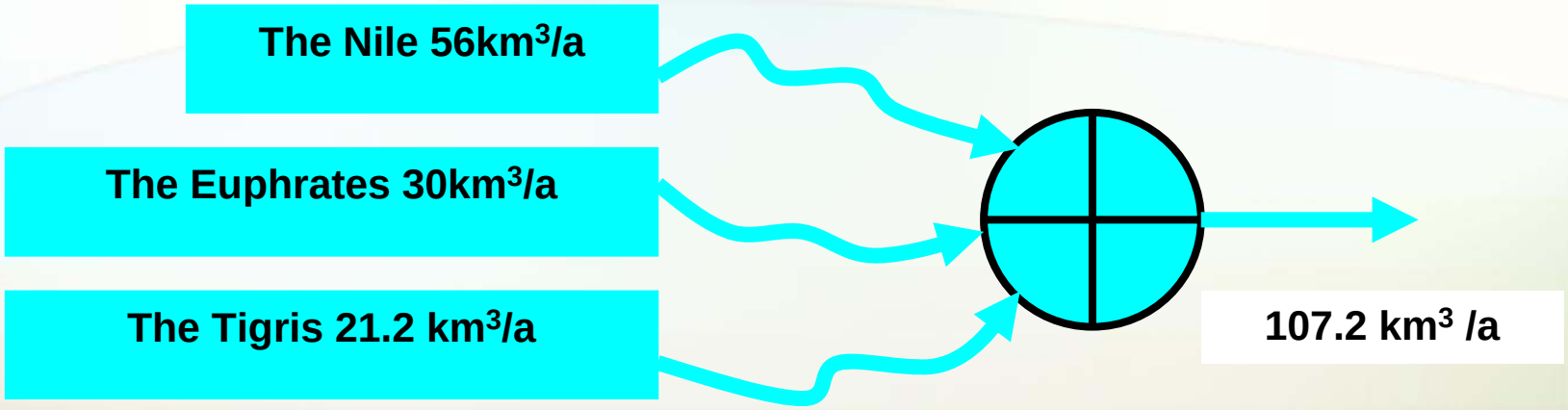
SOLAR ENERGY FOR DESALINATION IN THE ARAB WORLD (*continued*)

- **Can we afford to burn oil on the scale needed to provide everyone with fresh water?**
- **The Arab World and many other arid regions of the world, are blessed with non-polluting renewable resources of energy - Solar Energy and other resources.**

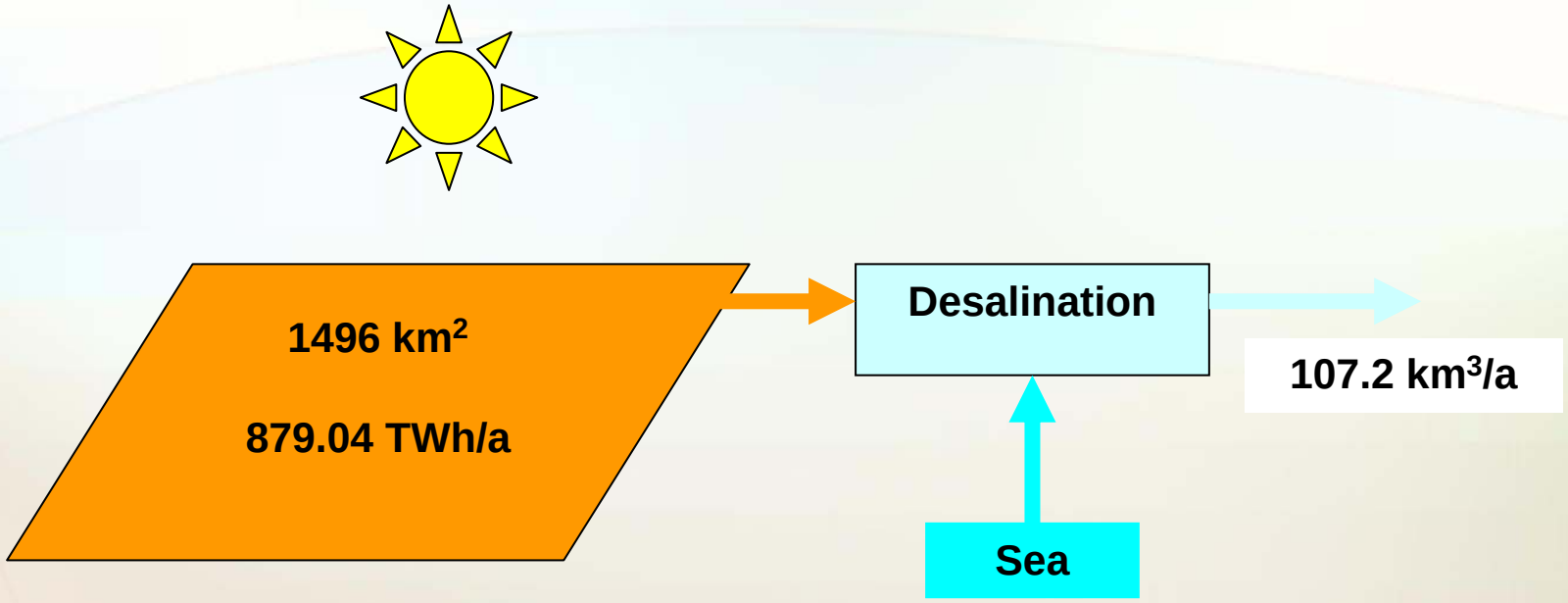
SOLAR ENERGY FOR DESALINATION IN THE ARAB WORLD (*continued*)



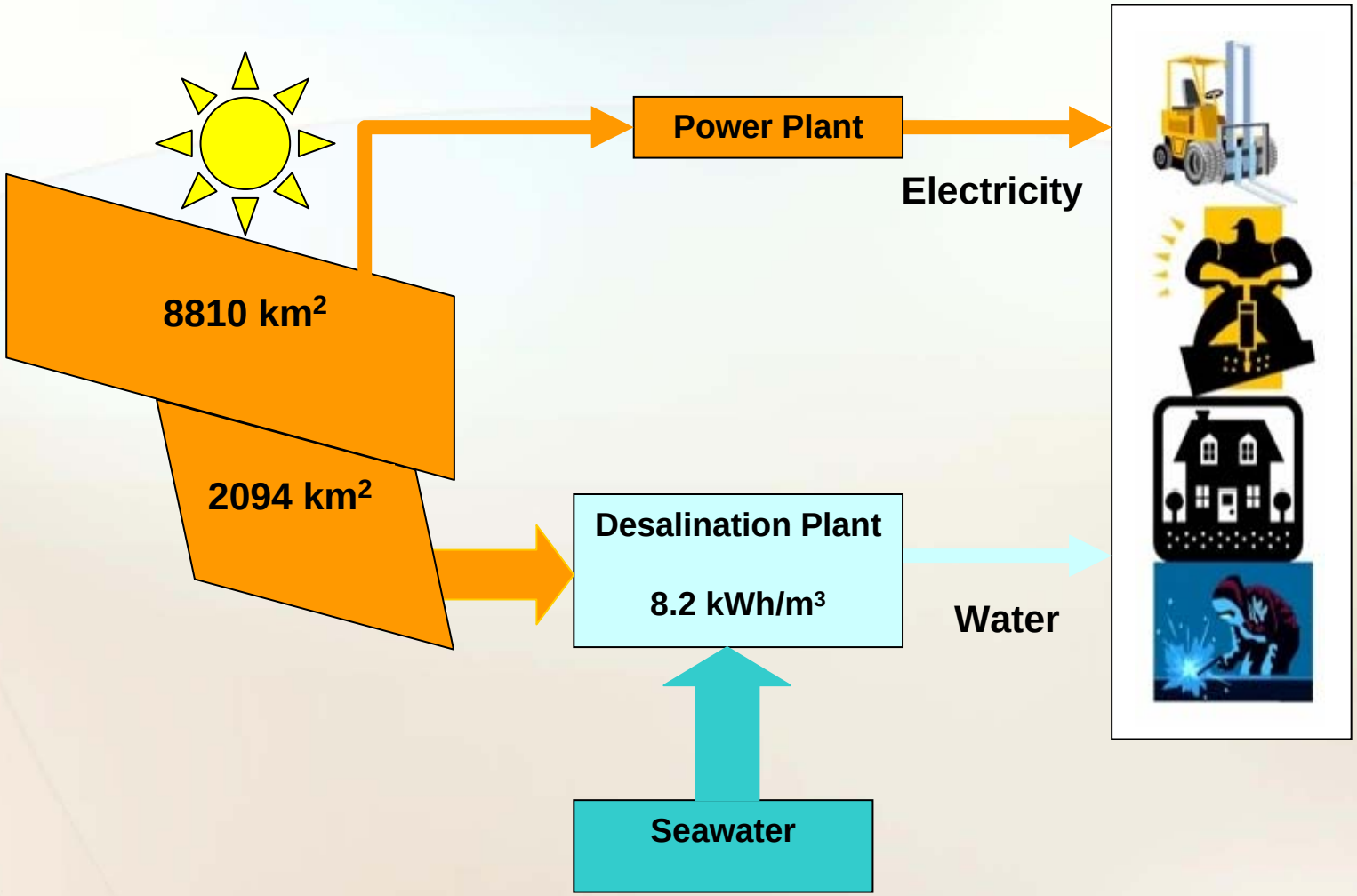
Total annual water flow in the three major rivers of The Arab world



Solar collector of 1496 km^2 can produce three more Rivers



SOLAR ENERGY FOR DESALINATION IN THE ARAB WORLD (*continued*)



BENEFITS OF SOLAR ENERGY

- Reliable and clean source of primary energy supply, abundantly available, offers future energy security
- Effectively replaces fossil fuels
- Generates no green house gas emissions or pollution of any other kind; hence, no global warming, no climate change
- Helps meeting Kyoto Protocol Guidelines
- Poses no radiation risks
- Protects against fuel price volatility
- Solar power plants can be built in deserts which may have few other uses
- Lead time for building solar power plants is short
- Can deliver power on demand through its features of allowing operation flexibility with other fuels and thermal storage capability
- CSP power plants can be coupled with desalination plants
- Offers flexibility in building generation capacities (several kW to several 100 MW)
- Some of the solar power plant technologies require far less amount of utility water than conventional power plants

SOLAR COLLECTOR SYSTEMS

These systems can be classified as follows:

- 1. Concentrating

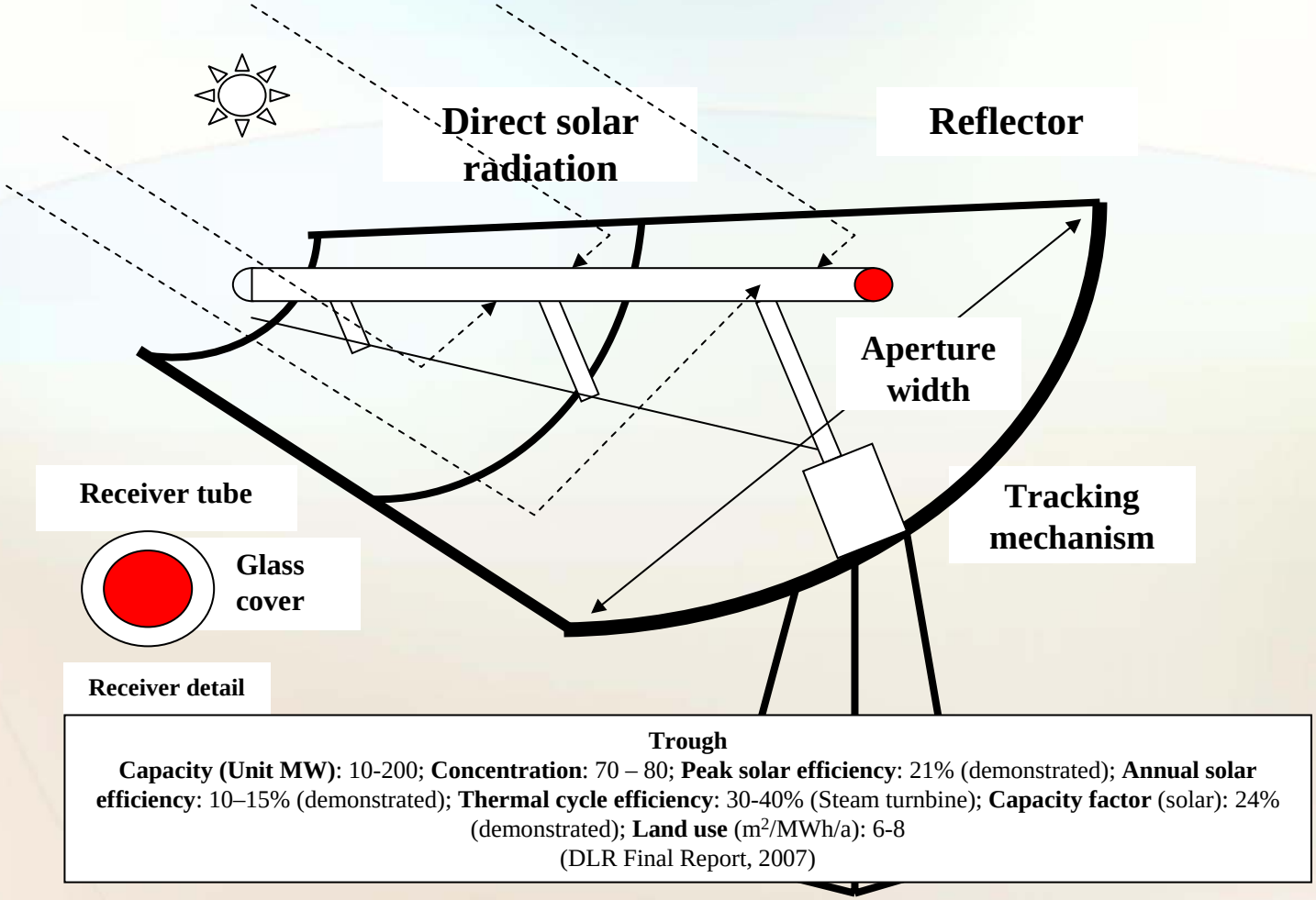
  a) Thermal

- **Parabolic Trough**
- **Fresnel reflector**
- **Dish-Stirling type CSP collector**
- **Power Tower**
- **b) Photovoltaic (CPV) Systems**
- 2. Non-Concentrating

  Flat Plate Collectors

  Photovoltaic (PV) Panels

Trough type CSP collector

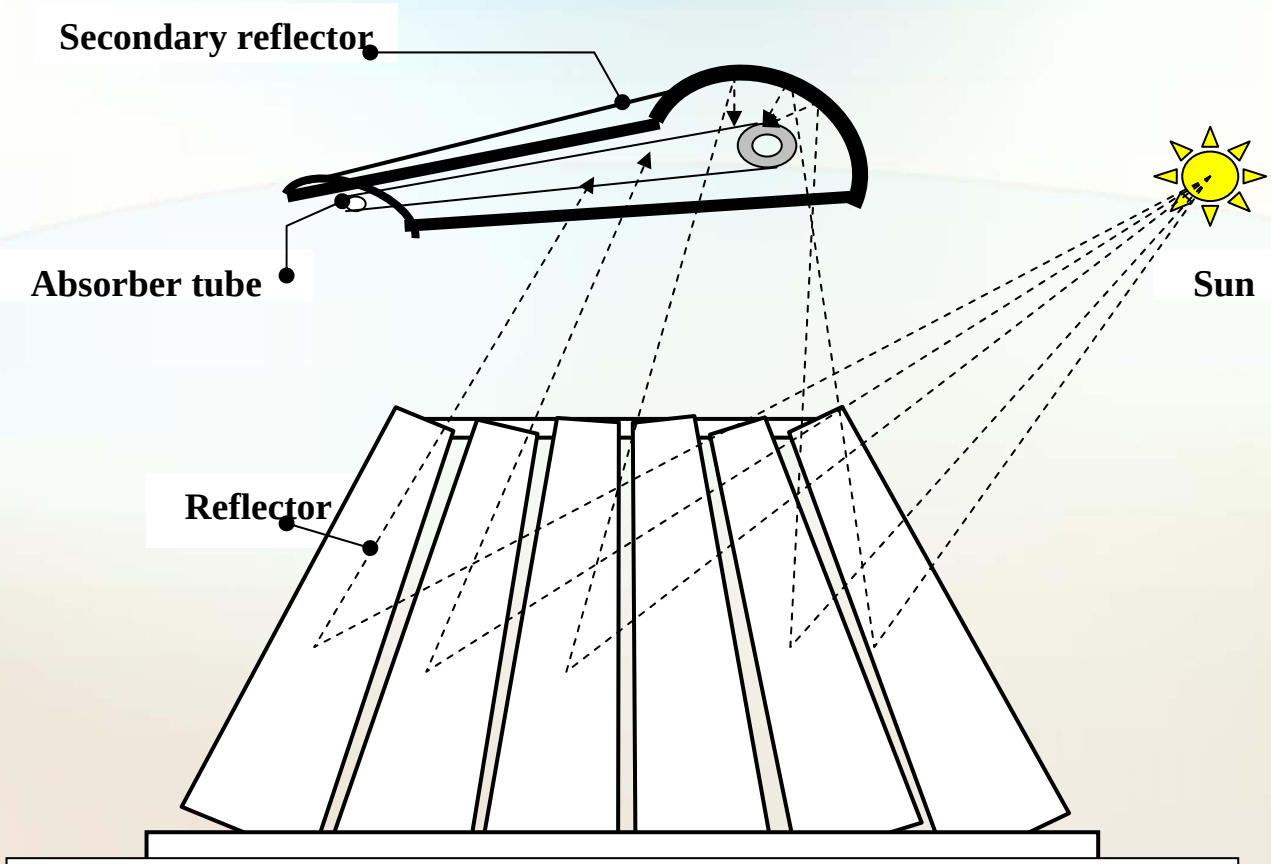


Trough

Capacity (Unit MW): 10-200; **Concentration**: 70 – 80; **Peak solar efficiency**: 21% (demonstrated); **Annual solar efficiency**: 10–15% (demonstrated); **Thermal cycle efficiency**: 30-40% (Steam turnbine); **Capacity factor** (solar): 24% (demonstrated); **Land use** (m^2/MWh/a): 6-8

(DLR Final Report, 2007)

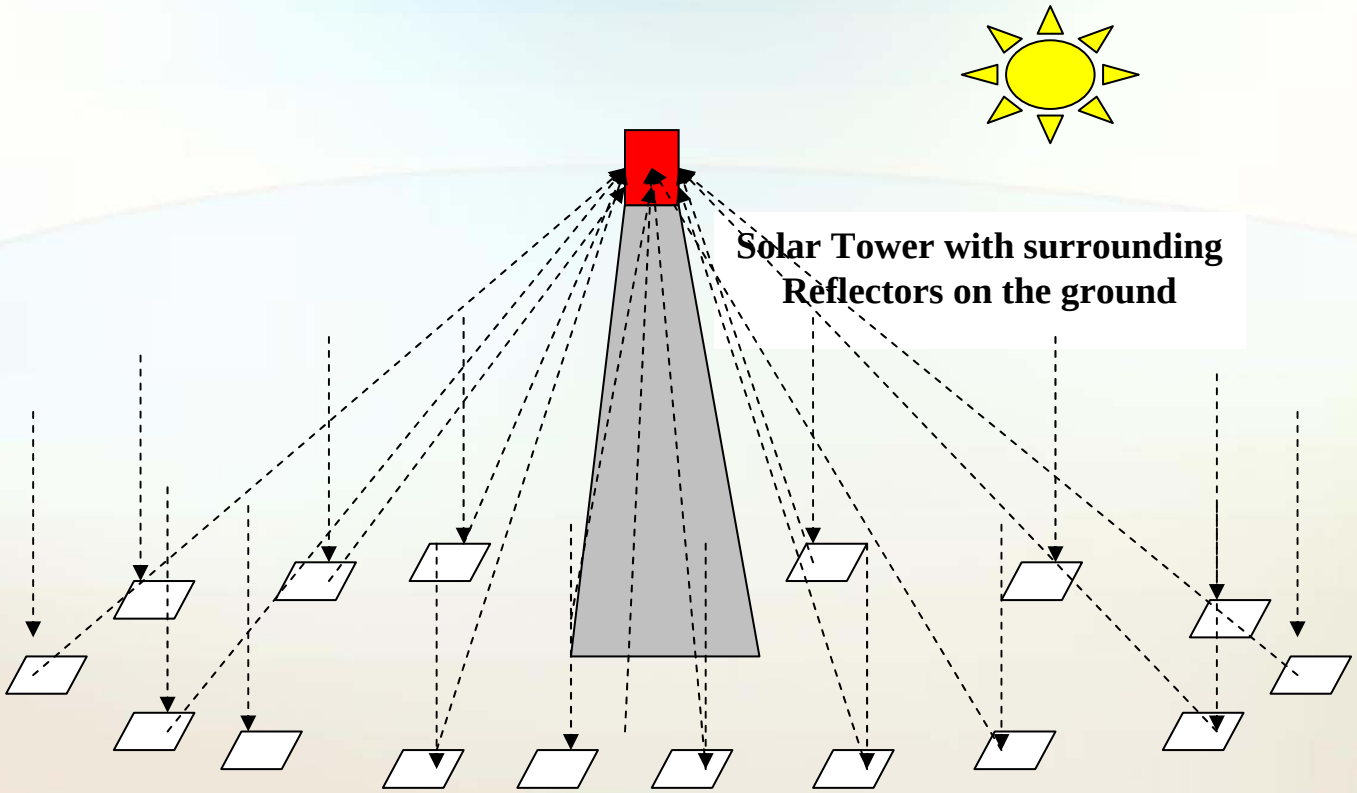
Fresnel type CSP collector



Fresnel

Capacity (Unit MW): 10-200; **Concentration**: 25 – 100; **Peak solar efficiency**: 20% (projected); **Annual solar efficiency**: 9–11% (projected); **Thermal cycle efficiency**: 30-40% (Steam turnbine); **Capacity factor** (solar): 25-90% (projected); **Land use** (m^2/MWh/a): 4-6 (DLR Final Report, 2007)

Power Tower type CSP collector

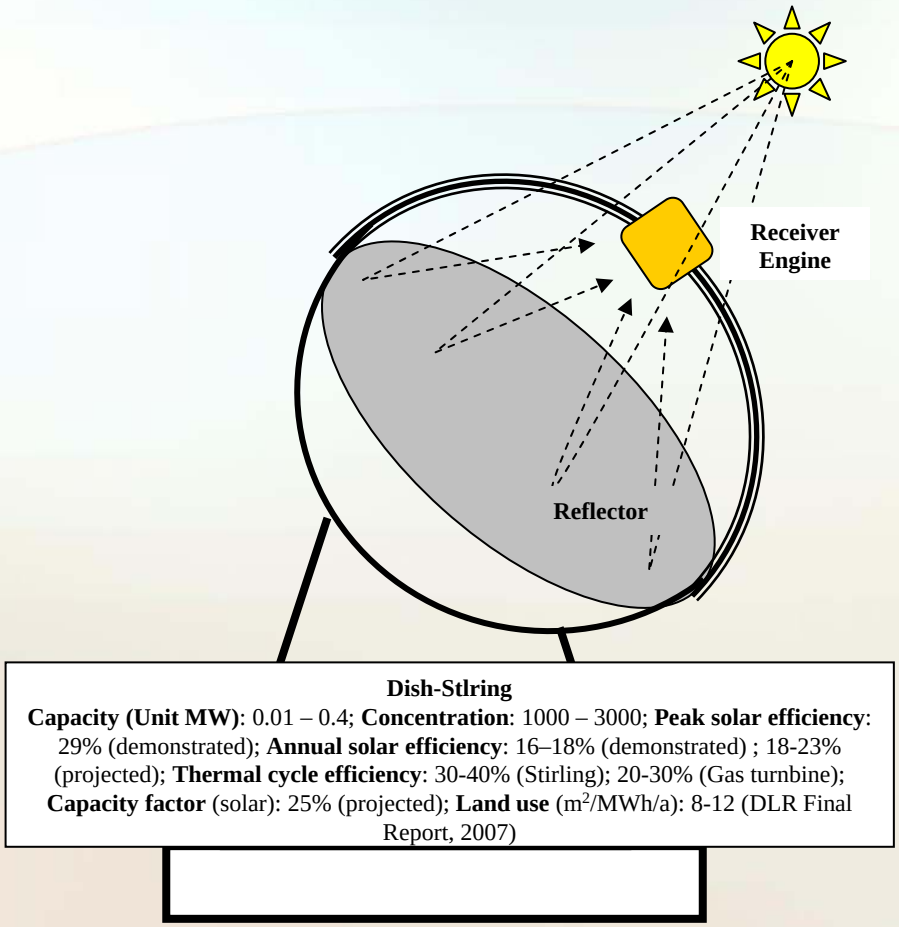


Power Tower

Capacity (Unit MW): 10-150; **Concentration**: 30 – 1000; **Peak solar efficiency**: 20% (demonstrated); **Annual solar efficiency**: 8-10% (demonstrated); **Thermal cycle efficiency**: 30-40% (Steam turnbine); **Capacity factor** (solar): 25-90% (projected); **Land use** (m^2/MWh/a): 8-12

(DLR Final Report, 2007)

Dish-Stirling type CSP collector



Dish-Stlring
Capacity (Unit MW): 0.01 – 0.4; **Concentration**: 1000 – 3000; **Peak solar efficiency**: 29% (demonstrated); **Annual solar efficiency**: 16–18% (demonstrated) ; 18-23% (projected); **Thermal cycle efficiency**: 30-40% (Stirling); 20-30% (Gas turnbine); **Capacity factor** (solar): 25% (projected); **Land use** (m^2/MWh/a): 8-12 (DLR Final Report, 2007)

Performance of the four CSP systems

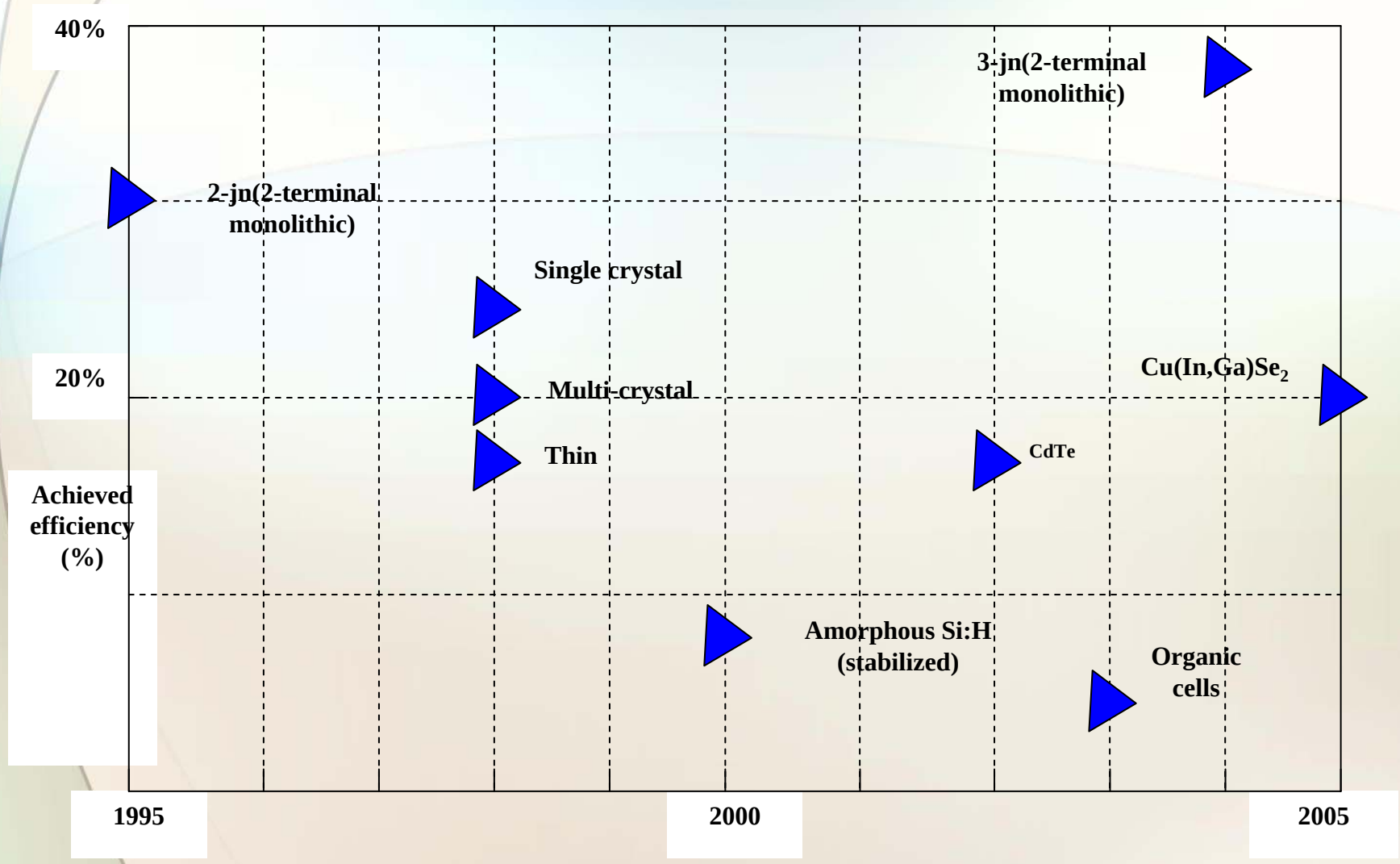
(Source: AQUA-CSP, “Concentrating solar power for seawater desalination”, DLR Final Report, 2007**)**

	Capacity Unit MW	Concentration	Peak Solar Efficiency	Annual Solar Efficiency	Thermal Cycle Efficiency	Capacity Factor (Solar)	Land Use m^2 /MWh/y
Trough	10-200	70 - 80	21% (d)	10–15% (d)	30-40% ST	24% (d)	6-8
				17-18% (p)		25-90% (p)	
Fresnel	10-200	25 -100	20% (p)	9-11% (p)	30-40% ST	25-90% (p)	4-6
Power Tower	10-150	300 - 1000	20% (d)	8-10% (d)	30-40% ST	25-90% (p)	8-12
			35% (p)	15-25% (p)	45-55% CC		
Dish-Stlring	0.01 – 0.4	1000 - 3000	29% (d)	16-18% (d)	30-40% Stirl	25% (p)	8-12
				18-23% (p)	20-30% GT		

(d) = demonstrated, (p) = projected, ST=steam turbine, GT =gas turbine, CC=combined cycle, Solar efficiency = net power generation/incident beam radiation; Capacity factor = solar operating hour per year/ 8760 hours per year.

Progress of research and achieved efficiency values of various types of solar cells

(Source: NREL)



SOLAR COLLECTOR SYSTEMS *(continued)*

- **Sun is the source of nearly all our energy. New technologies allow us to harness solar energy with improved efficiency.**
- **Thermal and photovoltaic solar panels have become a symbol of renewable energy and a greener future**
- **Their growth is tremendous.**
- **Falling prices have been one reason for this explosive growth.**
- **Chinese companies have entered the solar panel market and gained a market share of more than 50 percent.**

SOLAR COLLECTOR SYSTEMS *(continued)*

- **PV pioneers are not just competing with each other, but also with concentrated solar power (CSP), also called solar thermal power, which reflects sunlight to heat liquids in tubes or atop towers to create steam.**
- **CSP boasts economies of scale. The largest solar power plants in the world, and the largest ones planned, are CSP plants. And the more mirrors reflect sunlight, the more steam is available for the turbines.**
- **On the other hand, PV can more easily integrated into existing grids and needs little planning time, even in urban centers.**

The Nuclear Option for Energy and Water

Nuclear Fuel Resources

(*NEA & IAEA, 2006*). (*World Nuclear Association)*

- **Earth's crust has two main ores for Uranium**
- **High-grade ore (2% U, 20000ppm) and Low-grade ore (0.1% U, 1000ppm)**
- **The average concentration in the continental crust is less than 3ppm.**
- **The total stock of reasonably assured and inferred resources of the world is 4,742,853 tU**
- **Available only in certain parts of the world.**
- **Until 1990 the global Uranium production was more than the required amount but thereafter it fell short by about 30000 tU In the Arab world only Jordan has 78,975 tU- less than 2% of the world' average.**
- **Nuclear fuel resources are nonrenewable**

Nuclear Power Plants - Past and Present

- In 2007, world's total nuclear stations was 439
- 117 reactors were already shut down.
- The operating units were 23 years of age on average–a year older than those that were shut down.
- 8 new units in 2004, all except 5 in Asia/Eastern Europe-conspicuously, the Asian Development Bank has financed none,
- The operating plants were hit economically.
- Private investors are scared and distanced themselves from the nuclear business.
- Many companies went bankrupt in the US; orders after 1973 were not completed and most orders placed after 1978 were cancelled and no new orders have been placed.
- Nuclear exit programs became the trend now.
- Public opinion mounted against the nuclear units

The Discouraging Economics of Nuclear Energy

- **Costs of construction, waste management and decommissioning proved to be overwhelming**
- **Non-fuel operations and (O&M) costs are seldom prominent in studies of economics of nuclear energy**
- **The assumption of low running costs was proved wrong**

Environmental Impacts of Nuclear Energy

- Dangerous radioactive pollution of the environment at all stages – ore processing, transport, etc.
- Challenges in waste management
- The disposal extends to wide areas. Some can never be completely cleaned up and several sites have to be closed. The disposal is a major pressing problem at present at the time of site selection for nuclear plants.
- A matter of great public concern
- The economics of Nuclear Programs without consideration of these costs is flawed.

Nuclear Disasters

- Three-mile Island
- Chernobyl
- Fukushima
- These are enough to caution us

NUCLEAR RESEARCH IN THE ARAB REGION

- **Lack of native human resources with expertise and skills to design, construct and operate nuclear plants is the biggest drawback.**
- **Education and research programs exist only in small scale in some Arab countries**
- **These are not at all adequate develop in the native population expertise and skills required to assume responsibilities in nuclear projects.**

NUCLEAR PROGRAMS IN THE ARAB REGION

- Only based on cooperation with other countries.
- Algeria with the USA, China and France, Egypt with Russia, Morocco with Russia and China, Tunisia with France.
- Jordan was considering purchase of Candu heavy water reactors.
- Libya’s moves to build a plant with Areva reactor were opposed by Germany.
- Egypt's nuclear plans were frozen and Syria abandoned plans for a VVER-440 reactor after the Chernobyl accident.
- GCC countries -Kuwait, Saudi Arabia, Bahrain, the United Arab Emirates, Qatar and Oman- with agreed with IAEA in 2007 to cooperate for a feasibility study for regional power and desalination program.
- In 2009 Korea has won the bid for four power plants in the UAE.
- Strong concerns have been voiced by many citizens in the UAE and neighboring countries.

Nuclear Power- Lessons from Decades of Experience

- **Dangers abound and safety is difficult to ensure.**
- **Nuclear wastes would be a deadly legacy for our children.**
- **The economics of nuclear power is found to be full of risk.**
- **Nuclear option is not a solution to the Global Warming problem.**
- **Nuclear power capability can breed illegal nuclear weapons and can also to proliferation of nuclear weapons.**
- **Nuclear option is not part of the Clean Development Mechanism (CDM)**
- **Nuclear energy resources are not renewable.**
- **Nuclear power cannot provide a lasting solution for our energy problem.**

Then Quo Vadis, Nuclear or Solar?

- **The answer is indisputably SOLAR.**
- **Solar radiation- clean, unlimited, and very economic source of energy.**
- **It is abundant- especially over the Arab Land.**
- **It comes free of charge from its skies.**
- **This is the only sustainable source of energy in the true sense of the word.**
- **It gives rise to other renewable forms of energy.**

Solar Energy

- **Only renewable sources of energy are the means to attain sustainable development.**
- **Solar energy- the mother of other renewable sources- is the primary driver for most physical and all biological processes on our planet.**
- **It would be the best choice for sustainability of our modern civilization.**

The Arab countries must avoid the dark and hazardous path of Nuclear option

They should fully move towards Sustainability under the bright Sun above their heads.

THANK YOU