Solar energy for the near future

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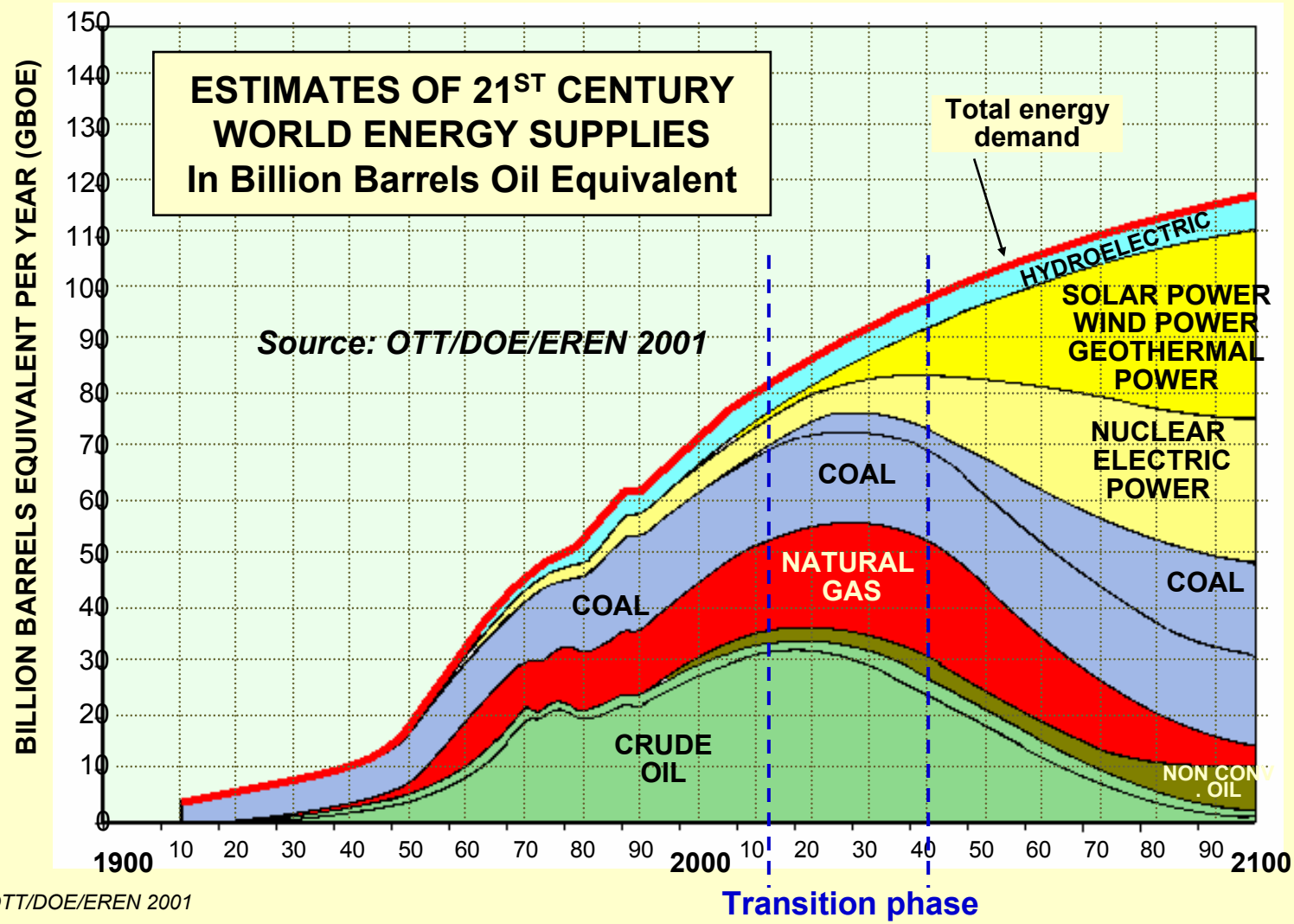
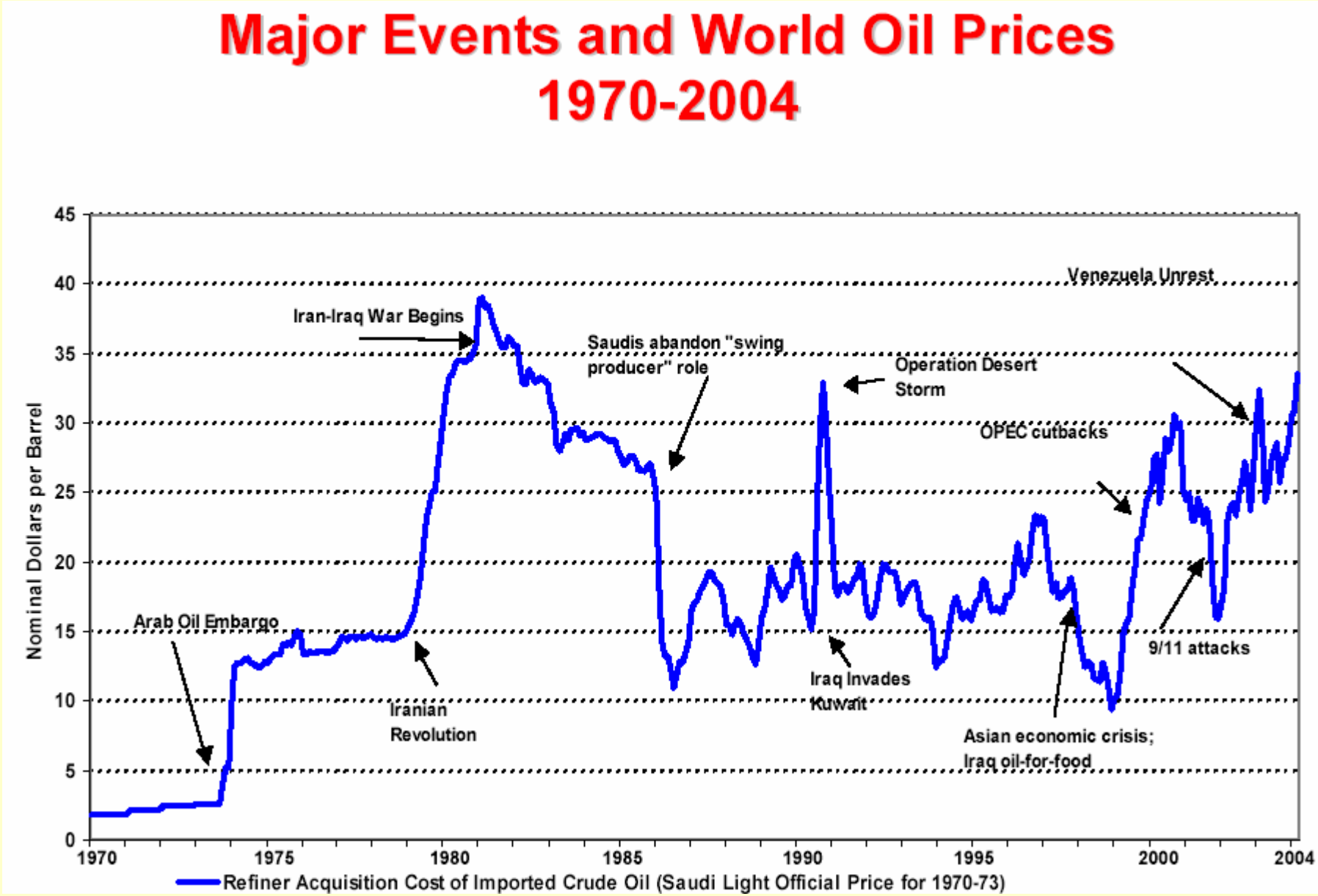
OIL: World Energy Supplies (Depart. of Energy USA)

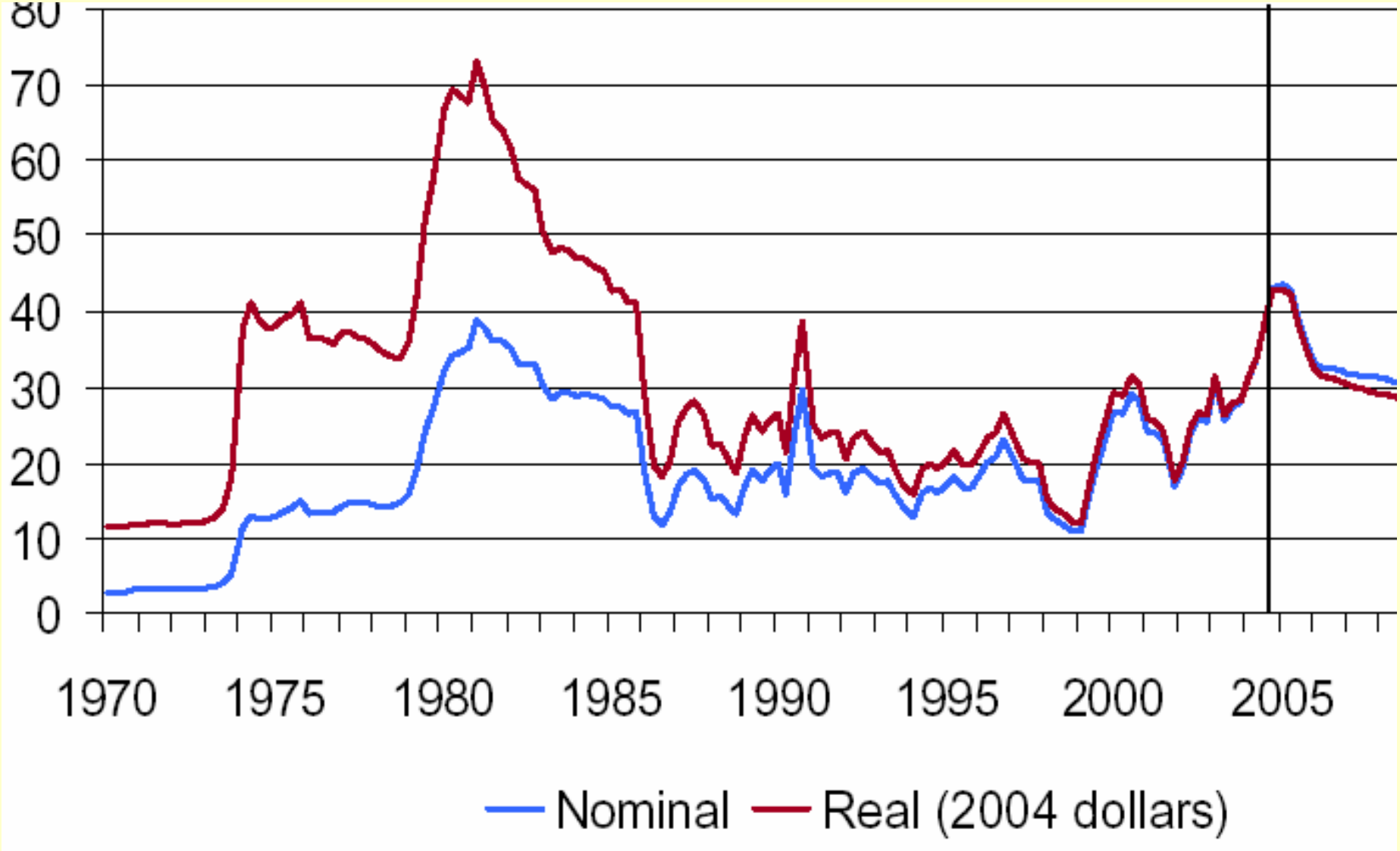


Source: OTT/DOE/EREN 2001

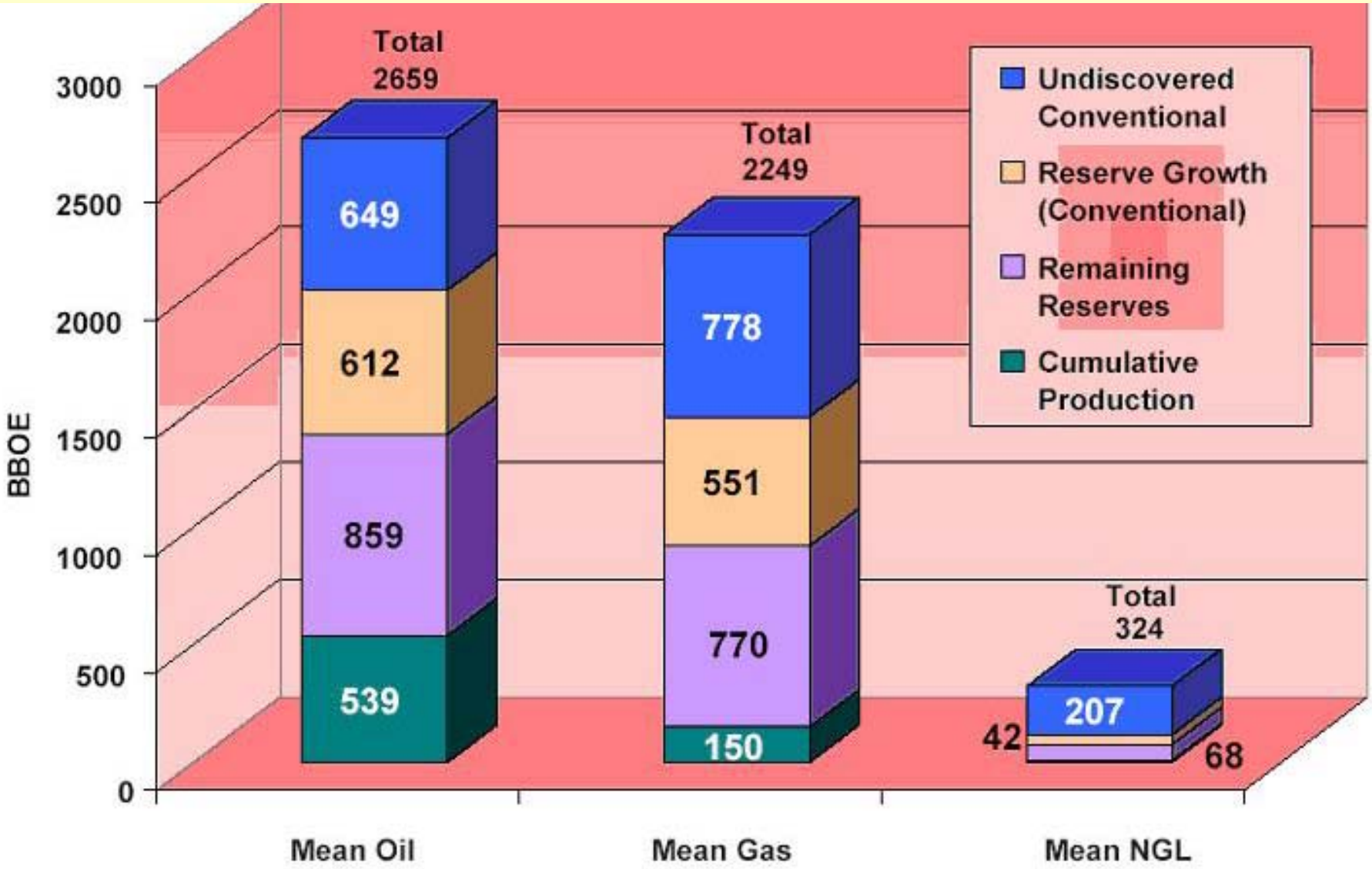
OIL : Oil prices



Oil price in $-2004



OIL: Oil And Gas Reserve



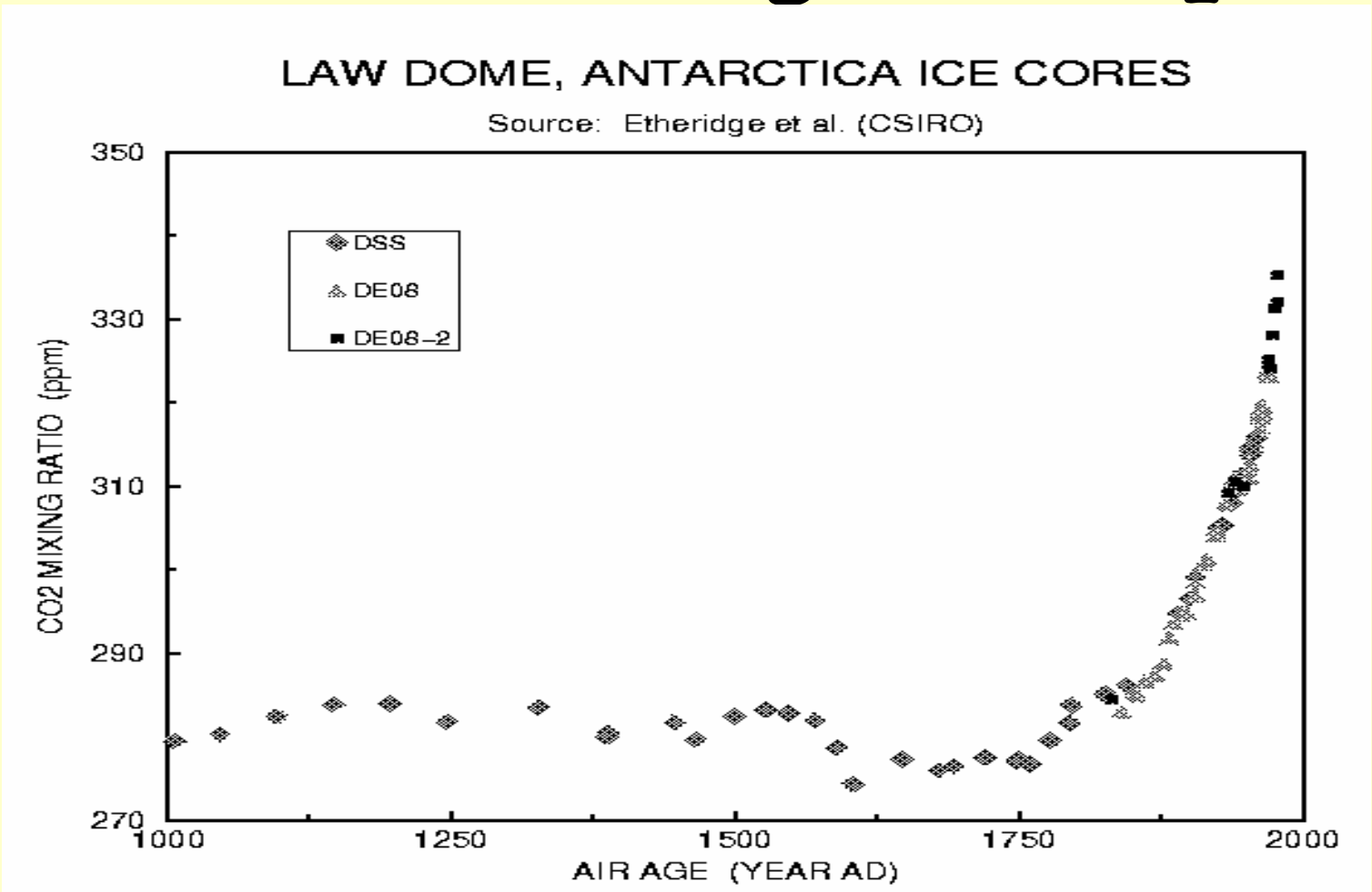
OIL: producers

Assessed OPEC Sustainable Capacity

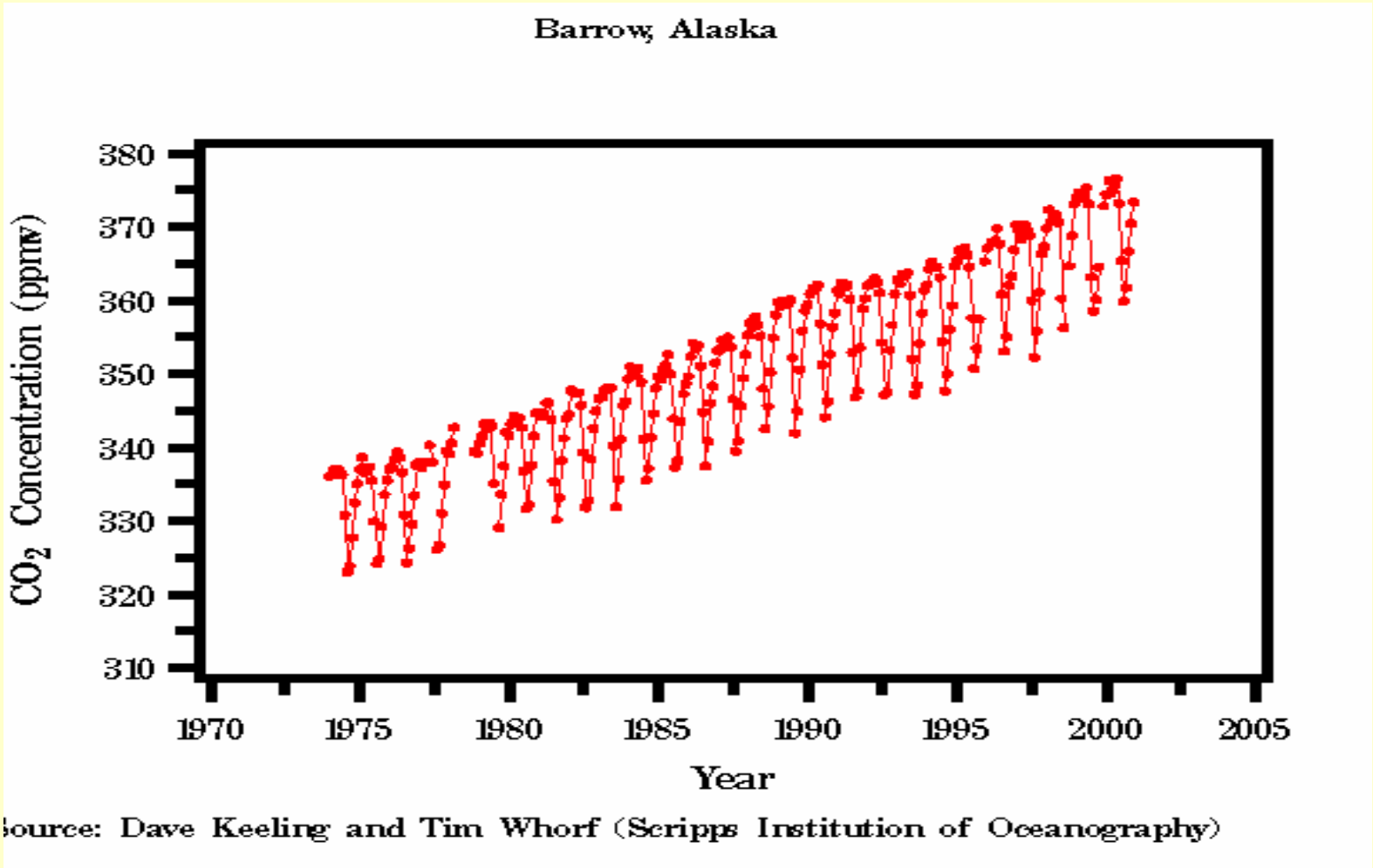
Million b/d

	2000	2001	2002	2003	2004	2005	2007	2010
Saudi Arabia	10.5	10.5	10.5	10.5	10.5	10.6	11.1	12.0
Iran	3.7	3.8	3.7	3.8	3.9	4.0	4.2	4.4
Iraq	2.7	2.7	2.7	2.5	3.2	3.7	5.0	6.0
Kuwait	2.4	2.3	2.3	2.4	2.4	2.4	2.5	2.6
UAE	2.5	2.5	2.5	2.5	2.5	2.6	2.7	2.8
Qatar	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0
Total Middle East	**22.5**	**22.5**	**22.5**	**22.5**	**23.4**	**24.2**	**26.5**	**28.8**
Algeria	0.9	0.9	1.0	1.1	1.2	1.3	1.5	1.6
Libya	1.5	1.5	1.5	1.5	1.5	1.6	1.6	1.8
Nigeria	2.2	2.1	2.2	2.2	2.3	2.4	2.5	2.7
Indonesia	1.3	1.2	1.1	1.1	1.1	1.1	1.1	1.0
Venezuela	2.9	3.0	2.9	2.9	3.0	3.1	3.4	3.7
Total OPEC	**31.3**	**31.2**	**31.2**	**31.3**	**32.5**	**33.7**	**36.6**	**39.6**

Global changes: CO_2



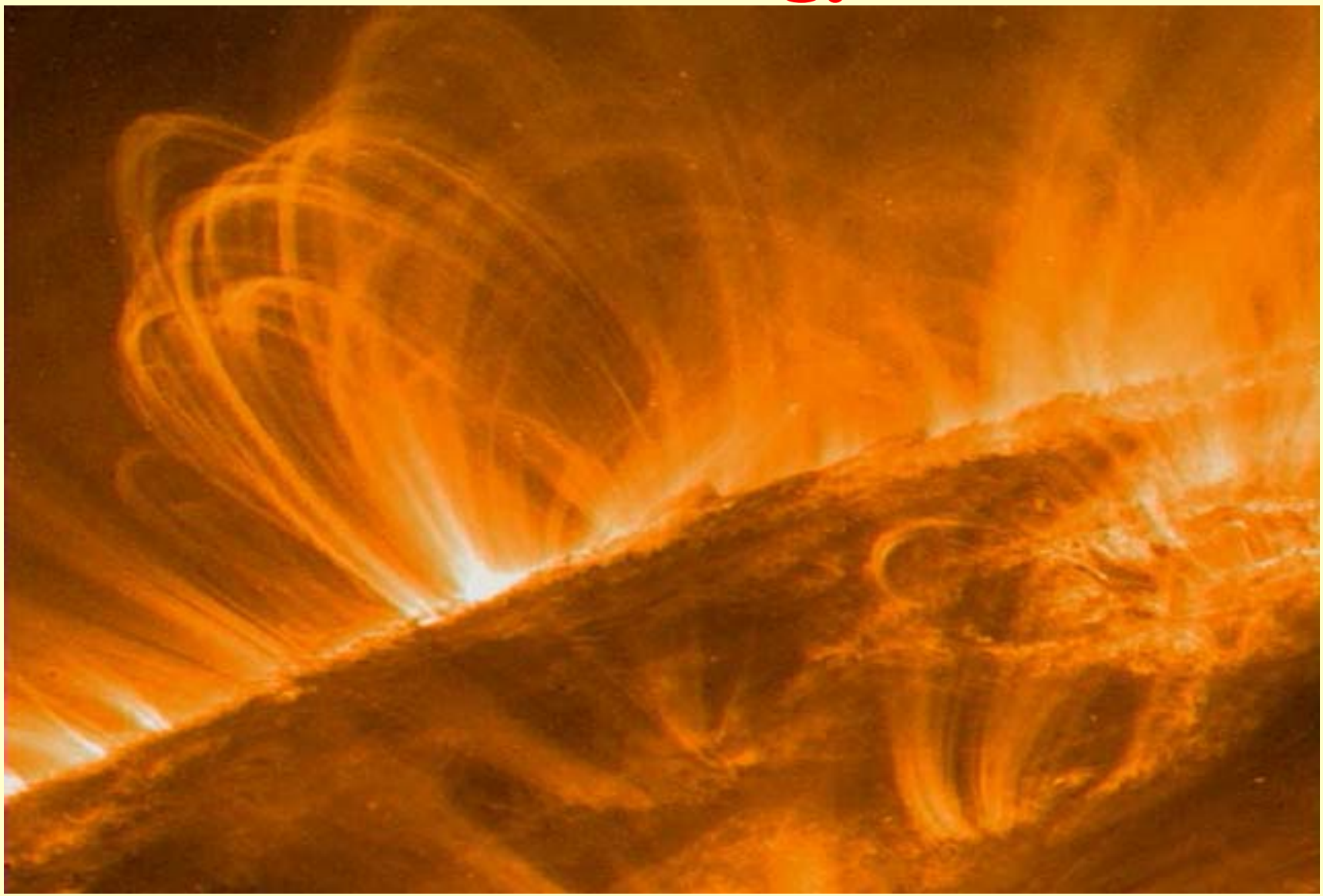
Global Changes: CO_2



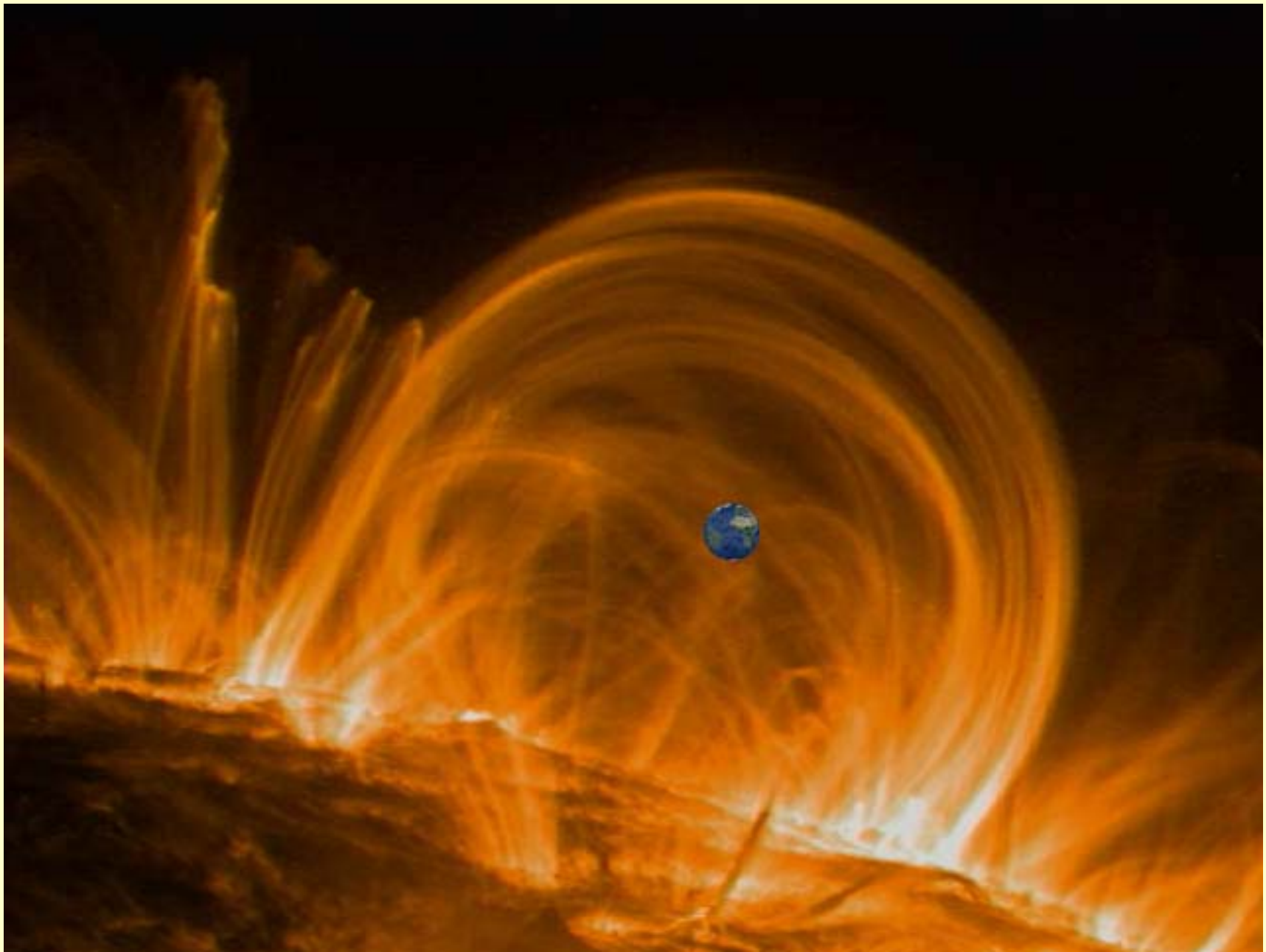
OIL- Fossil fuel: true and false

Oil today is very expensive	Oil today is very cheap
Cheap oil is for ever	Cheap oil will be available only for a few more years
Iraq is a major producer	Iraq supplies 4% of the world production
Greenhouse gas pollution can be limited	Greenhouse gas pollution increases exponentially

Where energy is?



Where energy is? (earth is in scale)



Solar energy availability

- **World consumption is 10^{-4} the solar energy supply**
- **Saudi Arabia (the world largest oil producer) receives from the sun 800 times its oil energy production.**
- **Indirect solar energy such as wind and photosinthesis products are more concentrated**

Where energy is?: Earth Income

SUN 300 TW: wind	120.000 TW =$1.2\ 10^{17}$ W 30 TW photosinthesis
Natural radioactivity	30 TW
Tidal energy	3 TW
Year World consumption	10 TW
So why worry?	

Because we want “concentrated” energy

What kind of energy?

1 Kg of gasoline	10.000 Cal = 4.2 10^7 Joule Price 1 €
Low volume 30-40% efficiency in	High temperature electric conversion
1 m^2 of solar radiation at south Italy latitude	250 W for 24 hours 2.2 10^7 Joule Price ?
Large surface	Low efficiency

What kind of energy?

1. A lot
2. Ready to use
3. Concetrated

- The best way to concentrate sun energy is photosinthesis.
- In the last century men are being burning 0.1-0.2 billion of years of photosinthetic processes

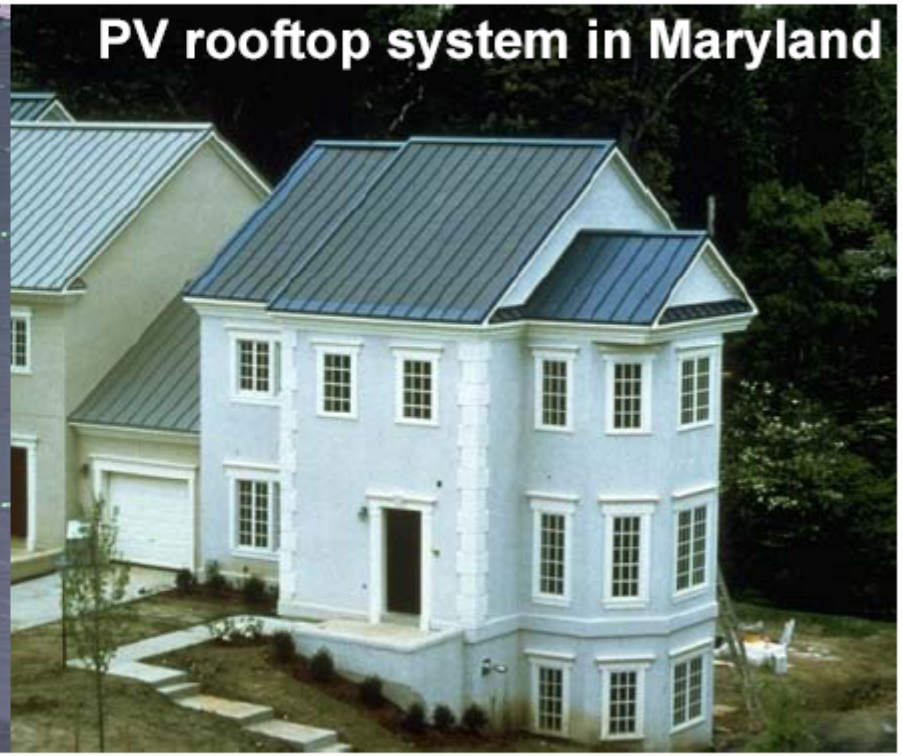
Solar exploitation systems

- **Photovoltaic Cells (PV) 500 Euro/m^2**
- **Mirror collectors 200 Euro/m^2**
- **Water collectors 80-100 Euro/m2**

Many other poor technolgies, for example:

- **Black sack with bottom insulation (efficiency 25-30%)**
- **Solar ponds (efficiency 20-25%)**

On-Grid Systems
Building integration of PV



- Integration of PV in architecture is a fast-growing market

The PV marketplace

Projected price reduction

(constant'97 dollars)*

Comparative cost 7 cent

	1997	*2010*	*2020*	*2030*
Cost of energy (US$/kilowatt-hour)	0.30	0.14	0.08	0.047
Turn-key system price (US$/watt)	6.46	2.98	1.75	1.03

(* Adapted from EPRI RE characterization report)

- Costs reductions of 5% / yr.
- Will be competitive with conventional sources around 2010 (California), for Canada 2020.

Photovoltaic: advantages and drawback

1. Expensive
2. Low efficiency
3. Non trivial managing
4. Ratio steel/kw >> than for a nuclear reactor (what about nuclear energy?)
5. Not negligible environment impact
6. Electric output

Characteristic of mirrors plants

	Solar One	*CESA-1*	*Themis*	*Commercial*	
Country	**US**	**Spain**	**France**	?	
Collector area	71084	11880	10740	1'800'000	m2
Tower Height	55	60	100	239	m
Peak power	35.5	5.9	5.4	900	MWatt
Ave power	10.1	1.7	1.5	255	MWatt
Land Area				10	km2

Mirrors: advantages and drawback

1. Expensive
2. Non trivial managing
3. Ratio steel/kw >> than for a nuclear reactor
4. Not negligible environment impact
5. Good efficiency
6. Electric output

New trend in solar energy research

1. **Cheap systems**
2. **Low investement**
3. **Robustness**
4. **Simple managing**
5. **Ad hoc final uses**

Several efforts are in progress:

- **Biomass and anaerobic digestion,**
- **thermophyl bacteria: methane and hydrogen production**
- **Solar collector with poor materials**
- **Solar ponds**
- **……**

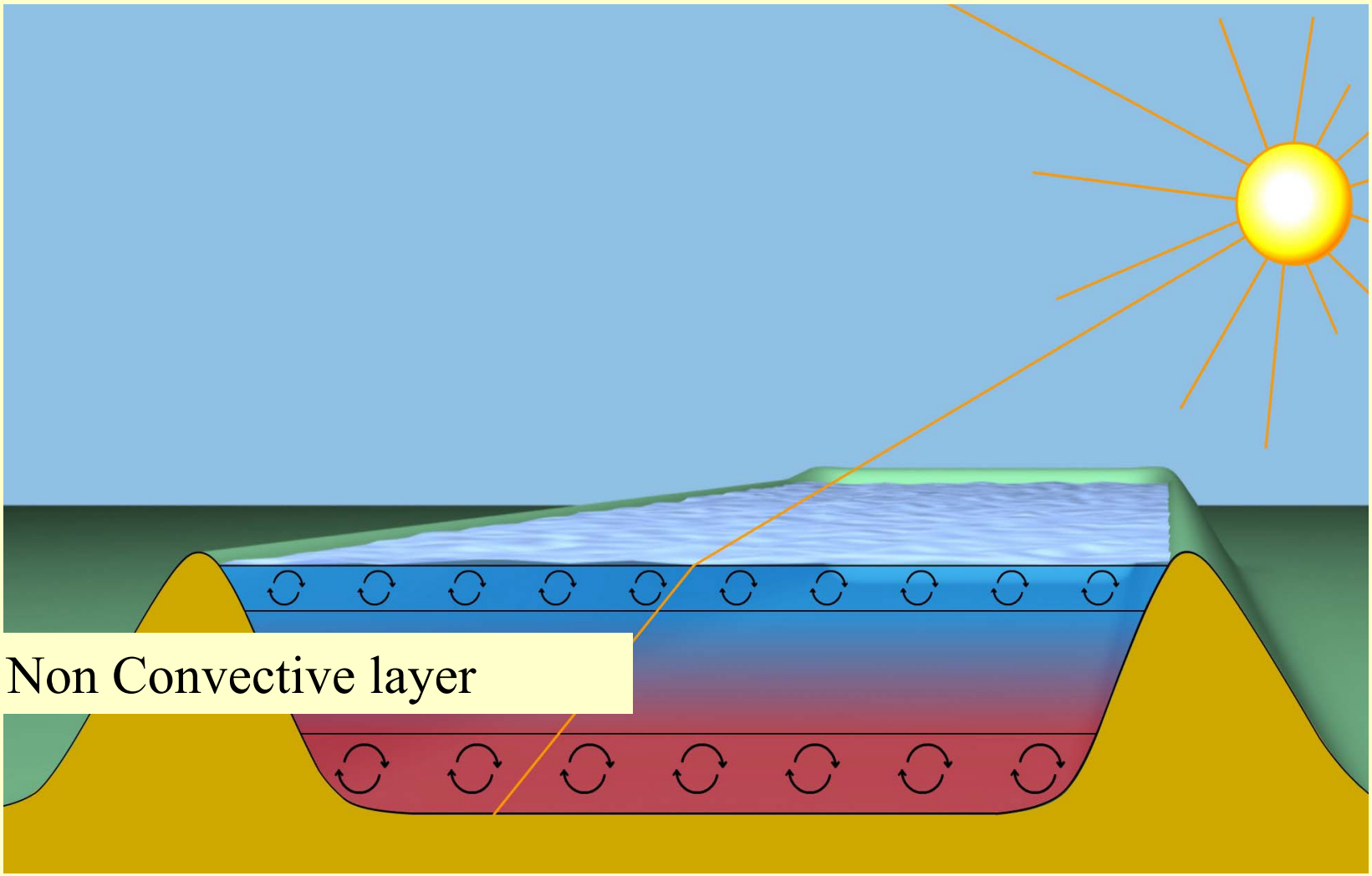
Solar pond: The system

- **The salt-pan is the system's starting point: brine is used as a heat reservoir at a temperature of 90-95 C°**

- **Hot brine releases thermal energy into sea water (35 grams of salt per litre) which in a Multi-Effect Distillator (MED) produces drinking water, leaving a water residue with a higher salt concentration (45-50 grams per litre).**

An Italy salt-pan (more than 200 km^2 of unused salt pan)

Solar pond: the concept



An operating solar pond: Pyramid Hill (Australia)

A natural solar pond: Medeveto (Carpaze)

First measures: Annals der physics1899

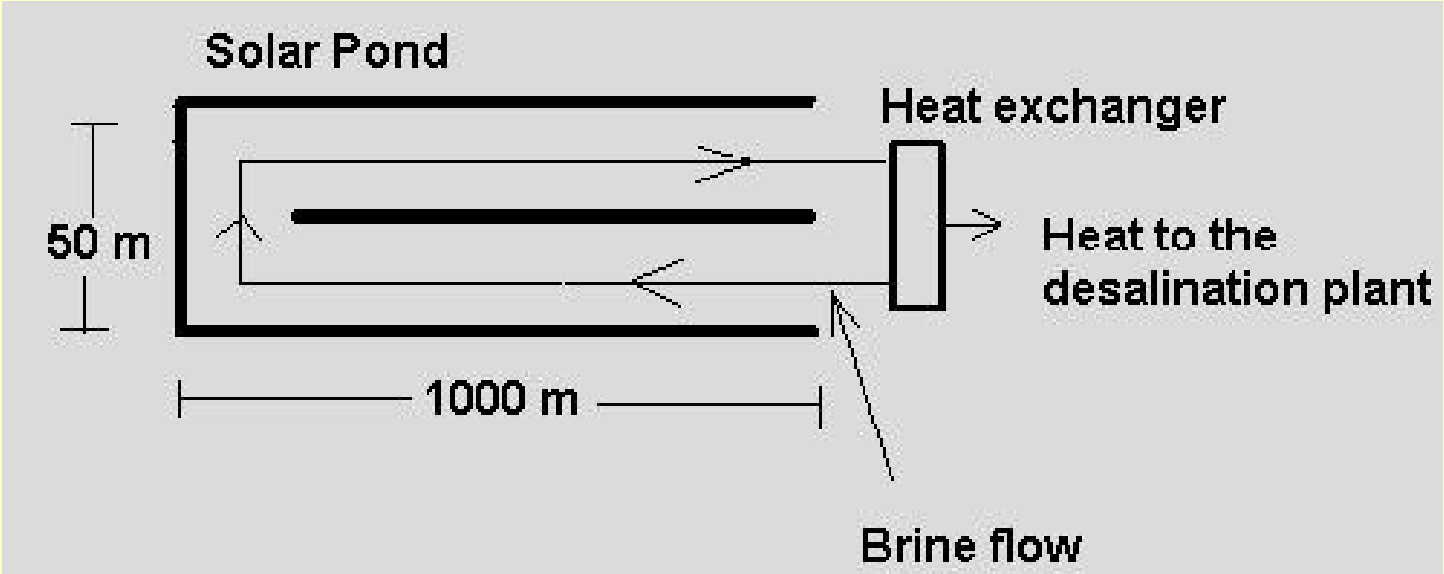
Solar Pond: the problem of heat extraction

Brine is a very corrosive fluid and up to now heat extraction was done with a very expensive titanium heat exchanger.

An idea developed in collaboration with Cabibbo is to extract heat by means of a very slow water flow.

The challenge is to do this without breaking the non convective gradient layer

Heat extraction: core concept



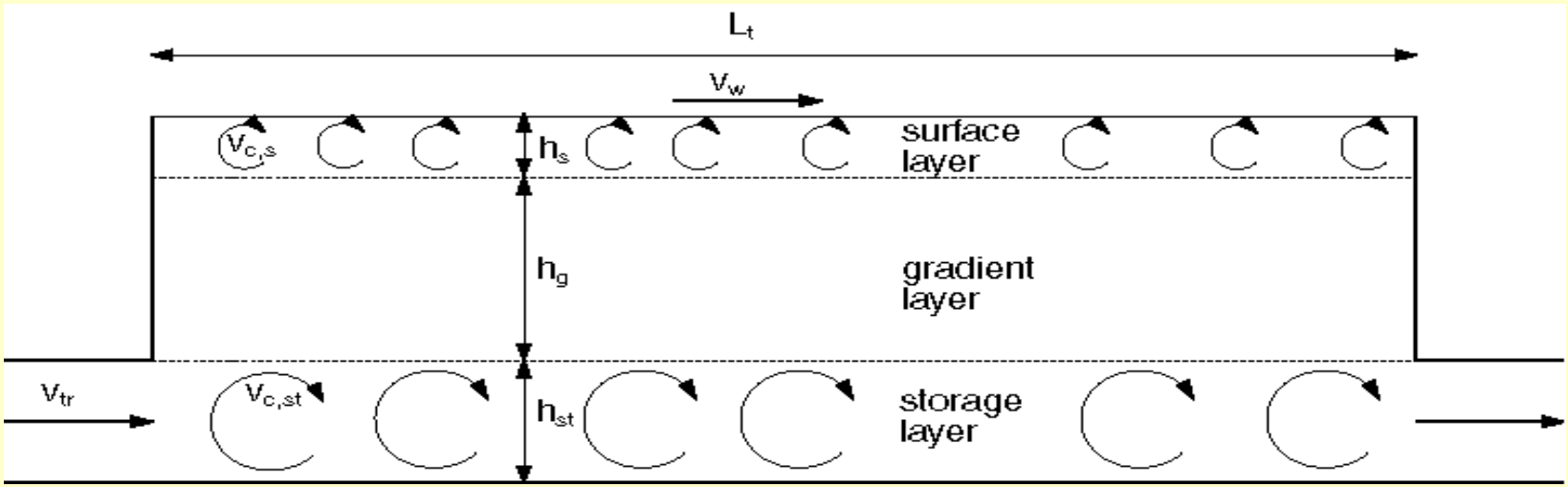
- inlet-outlet $\Delta T = 20^{o}C$;
- Brine flux is of $5x10^{-2}$ m^3/s;

Brine velocity $V_{tr} = 2x10^{-3}$ m/s.

Convective motion = 10-30 10^{-3} m/s

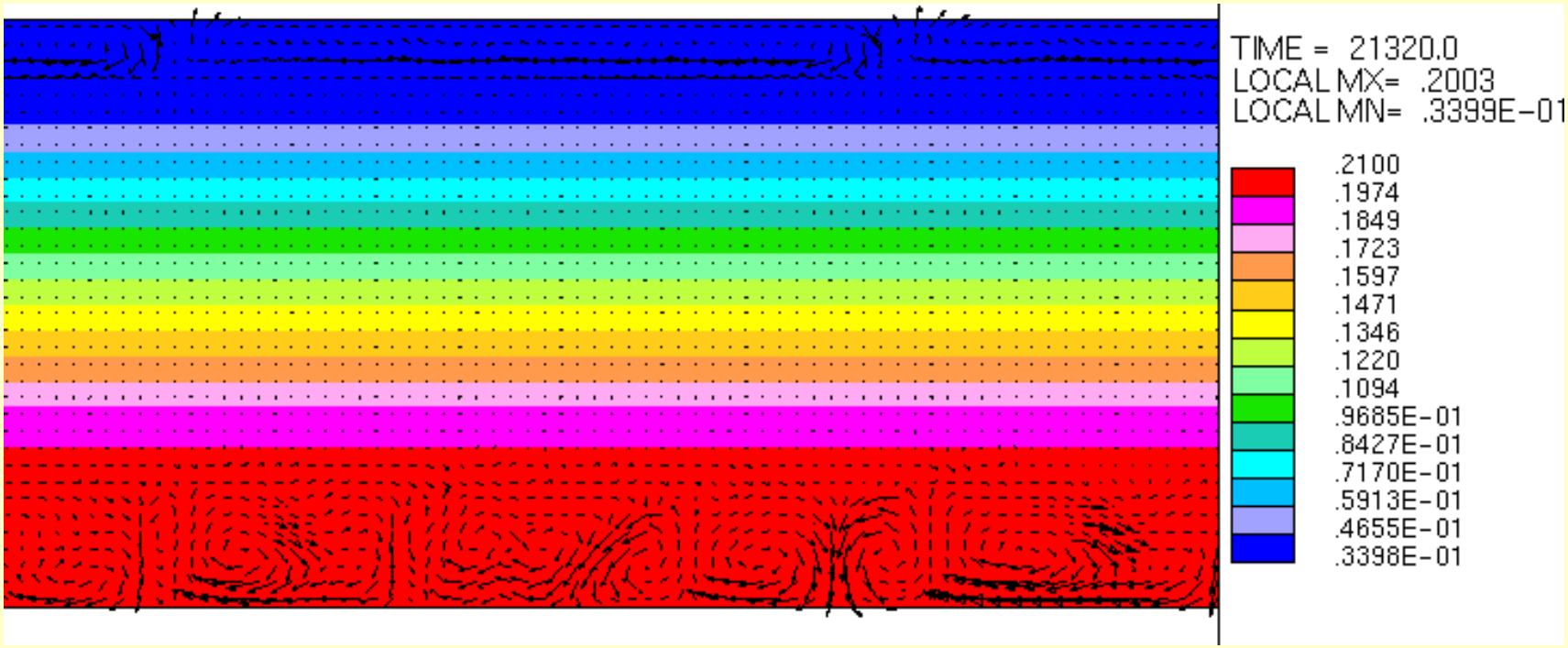
Heat extraction

Heat is extracted using pumps which induce a very slow flow in the deep layer of the pond (typical velocity of 3 m/hour)



Salt concentration and velocity field

Convective velocity is <v>=0.8 cm/s
Whereas the speed of the flow is of 1 mm/sec



A standard low temperature desalination plant

Solar pond: advantages and drawback

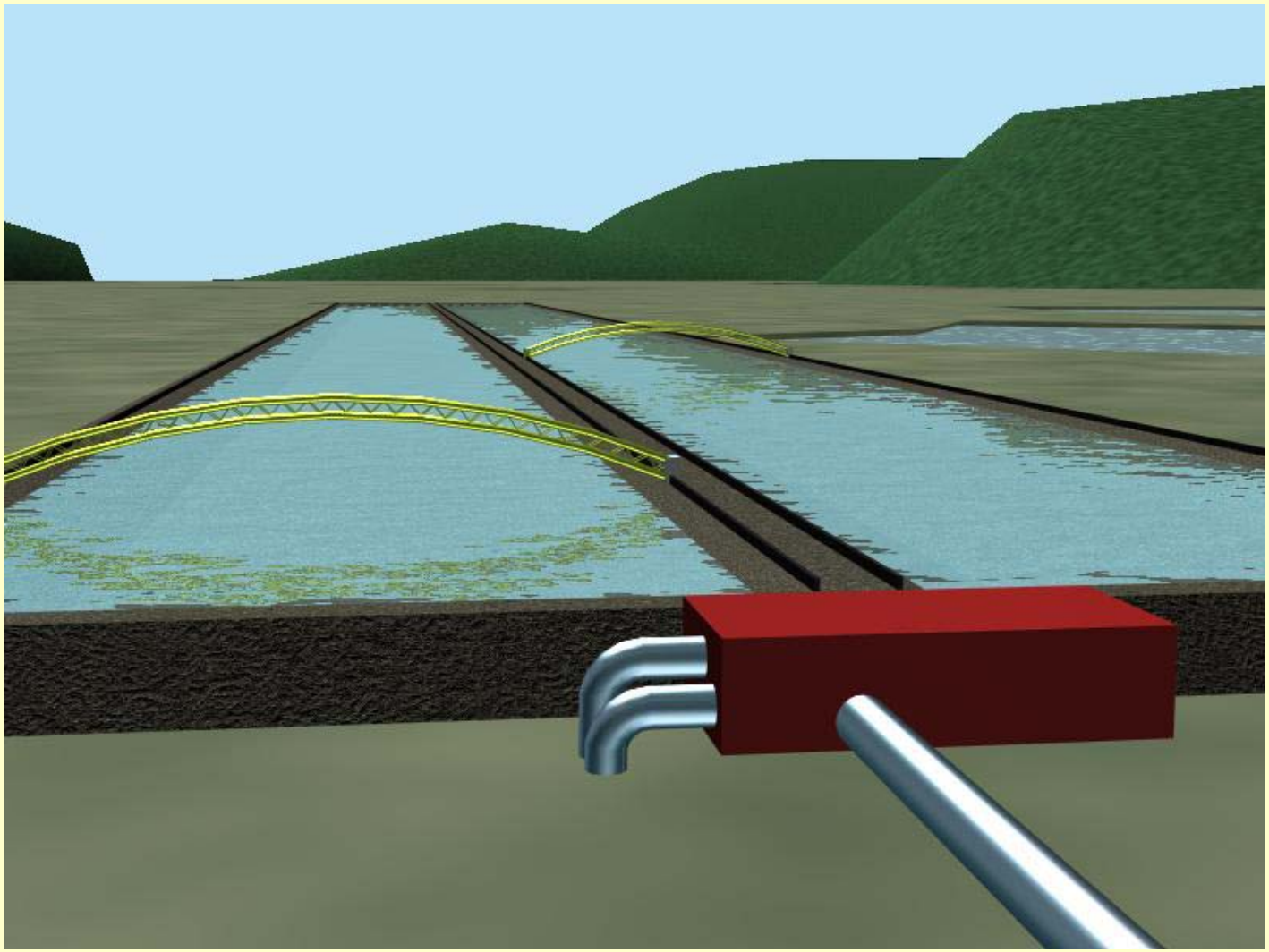
1. Low effciency and low enthalpy
2. Not suitable for electric production
3. Cheap and robust
4. Negligible environmental impact
5. Easily coupled to desalination plants
6. Suitable for large (100 MW) plants

The cost of a large desalination plant

1. A system, capable of producing 50.000 m^3 a day, requires a solar pond of 2 Km^2
2. The full cost of a solar pond is about 30 MEuro
3. The desalination plant cost is 36 MEuros
4. Costs for a m^3 of drinking water produced:
   - 0.15 MED exercise
   - 0.5 Solar pond exercise
   - 0.05 potabilisation
   - 0.45 mortage of the plants (15 years)
   - ***TOTAL = 0.70 Euro /m^3***

In a standar plant the cost is 0.5 Euro + 6 oil liters

SP: the pilot plant (UE project)



Solar energy: true and false

Solar energy is cheap	Solar energy is very expensive
Solar energy is clean	Solar energy is polluting
Oil companies are oppsed to alternative energies	Everybody wants to use fossil fuels and electricity
Technique is a minor problem in solar energy exploitation	Research is needed to develop solar energy systems

Conclusions

Reasearch and technology are absolutely necessary