DESERTEC FOUNDATION

How can 10 billion people live sustainably on Earth ?

DESERTEC

a solution model for a

Sustainable World with 10 billion People

thru Clean Power from Deserts

Dr. Gerhard Knies
DESERTEC Foundation, Supervisory Board,
Chair of Board of Trustees
Co-ordinator of TREC
gerhard.knies@DESERTEC.org

Brief calendar of DESERTEC mile stones

- 26.04.1986 Tschernobyl Accident
- 21.09.2003: Founding of the Trans-meditarranean Renewable Energy Co-operation TREC in Hamburg, and begining of DLR CSP studies
- 1.04.2006 creation of the brand name DESERTEC for the TREC plan to put DESERts and TEChnology into service for global energy and climate security. .
- 3.12.2007 presentation of the DESERTEC White Paper „Clean Power from Deserts for a world with 10 billion people“ to European Parliament in Brussels.
- 15.01.2008 consultation with French President‘s office for Union of the Mediterranean UfM and Mediterranean Solar Plan MSP
- 13.07.2008 Union for the Mediterranean and the MSP announced
- 1.10.2008 Proposal for DESERTEC Industrial Initiative to MunichRe
- 23.01.2009 Founding of DESERTEC Foundation DF
- 13.07.2009 Announcement of DESERTEC Industrial Initiative Dii
- 30.10.2010 Founding of DESERTEC University Network DUN

DESERTEC – *a solution model* for a Sustainable World with 10 billion People thru Clean Power from Deserts

1. Humankind on the way to 10 billion people,
2. earth's carrying capacity is declining from 5 to 3 billion.

I will describe how by DESERTEC

sufficient clean power from deserts can be provided:

what are the required volumes for 10 billion people,

the required pace for the 2° limit,

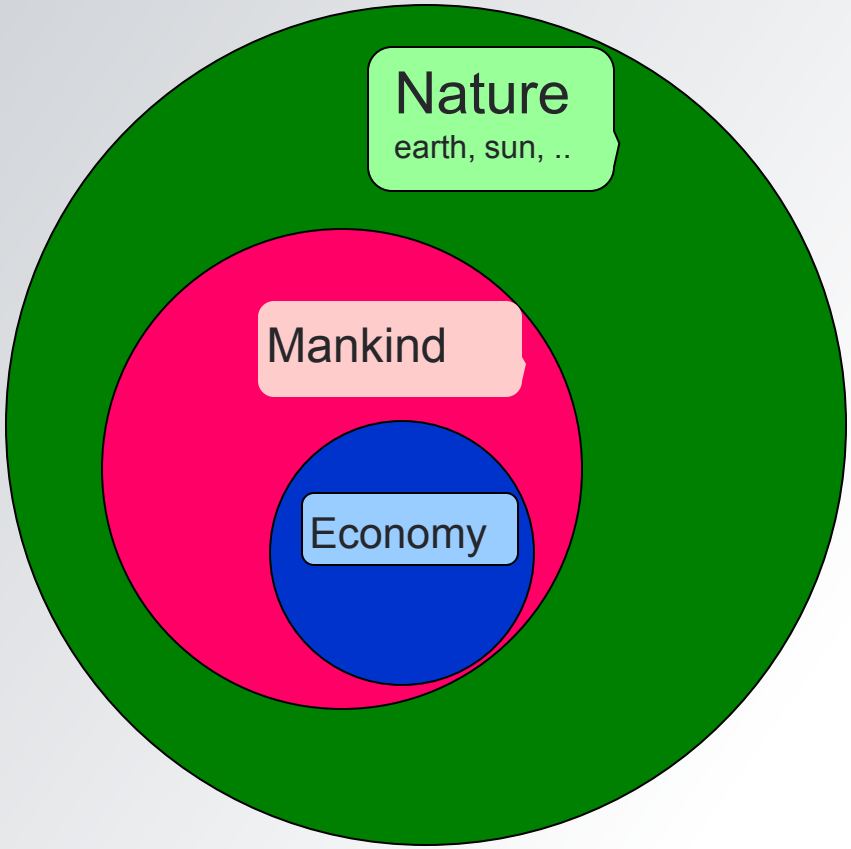
the needed technologies and financial incentives,

and the needed political approaches to put the DESERTEC Concept in place at a global scale.

Sustainability = strategy of survival for a growing mankind on a finite planet

Structural diagrams for 2 different views of sustainability,

scientists view E < M < N



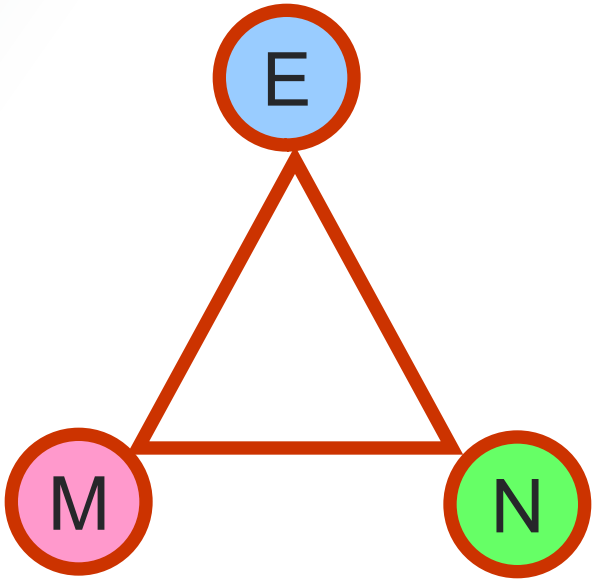
economists view:

M and N=external resources for E

Claim: Maximal market economy

➔ optimal sustainability

(„invisible hand“ effect)

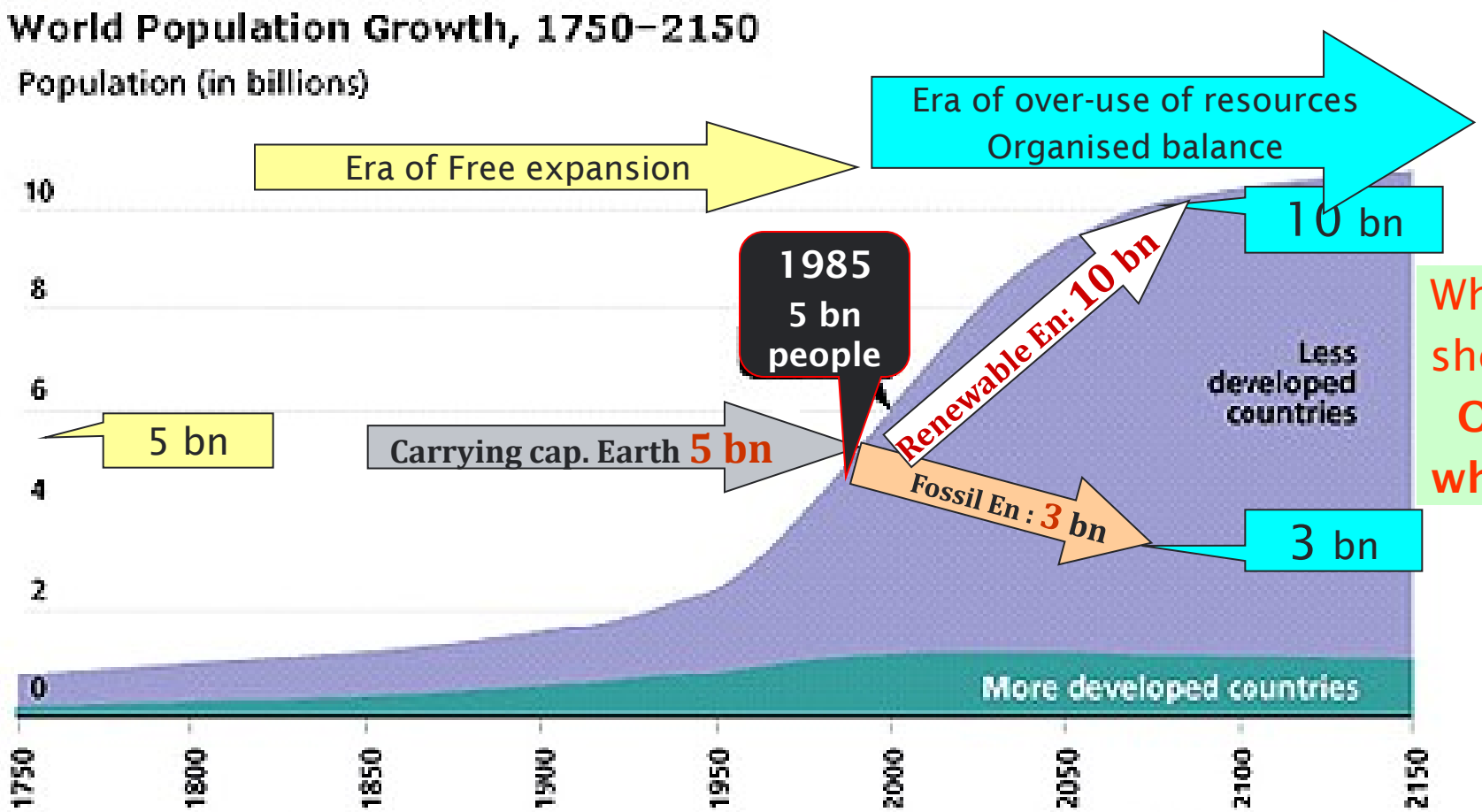


„invisible(?) hand“ of current market economy is degrading Earth’s carrying capacity Ostritz/Zittau, 9.8.2010

The 2 most important events in history of mankind:

(1) – 250,000 years: appearance of homo sapiens sapiens

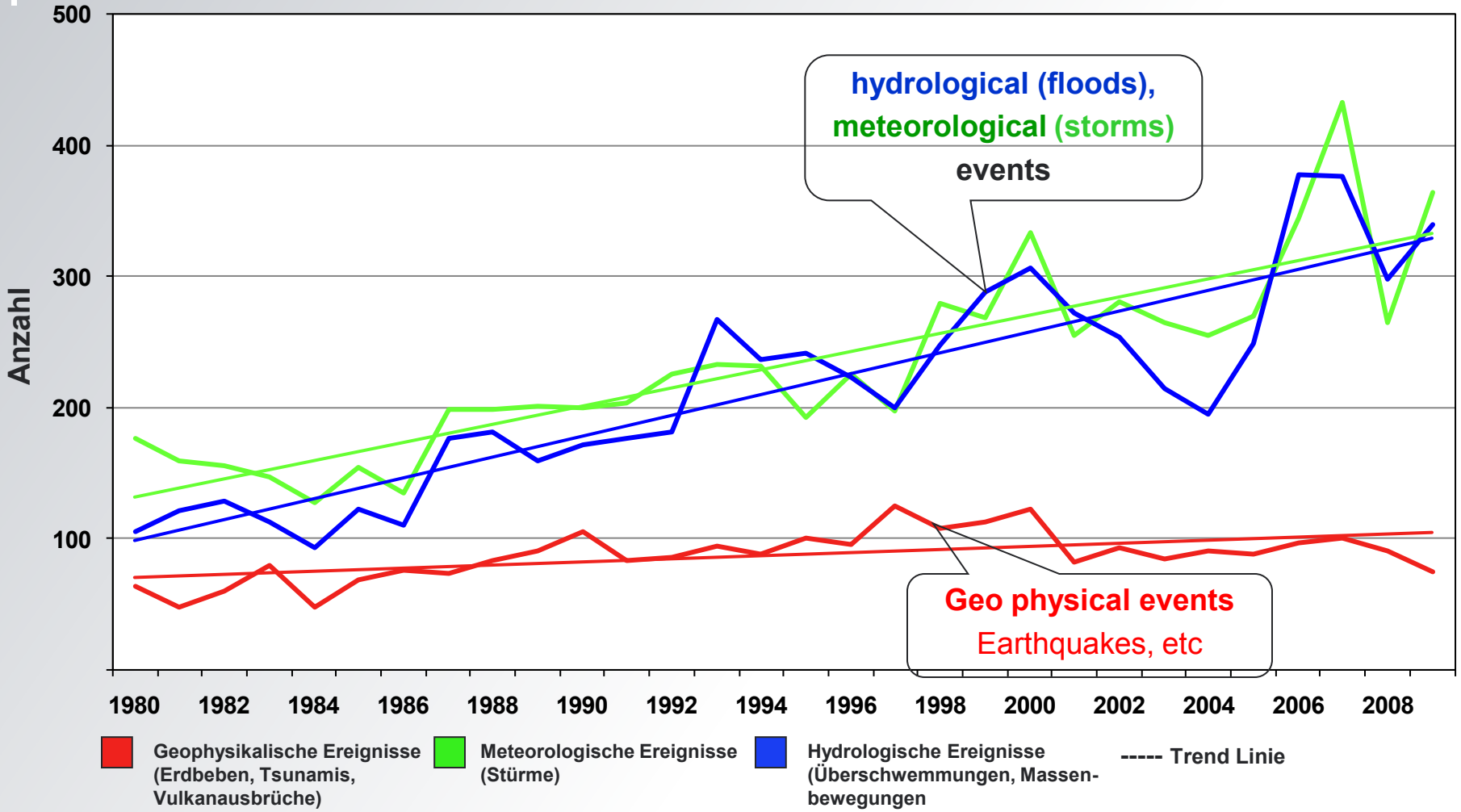
(2) 1985: No. of homo sapiens exceeds carrying capacity of planet Earth



Source: United Nations, *World Population Prospects, The 1998 Revision*; and estimates by the Population Reference Bureau.

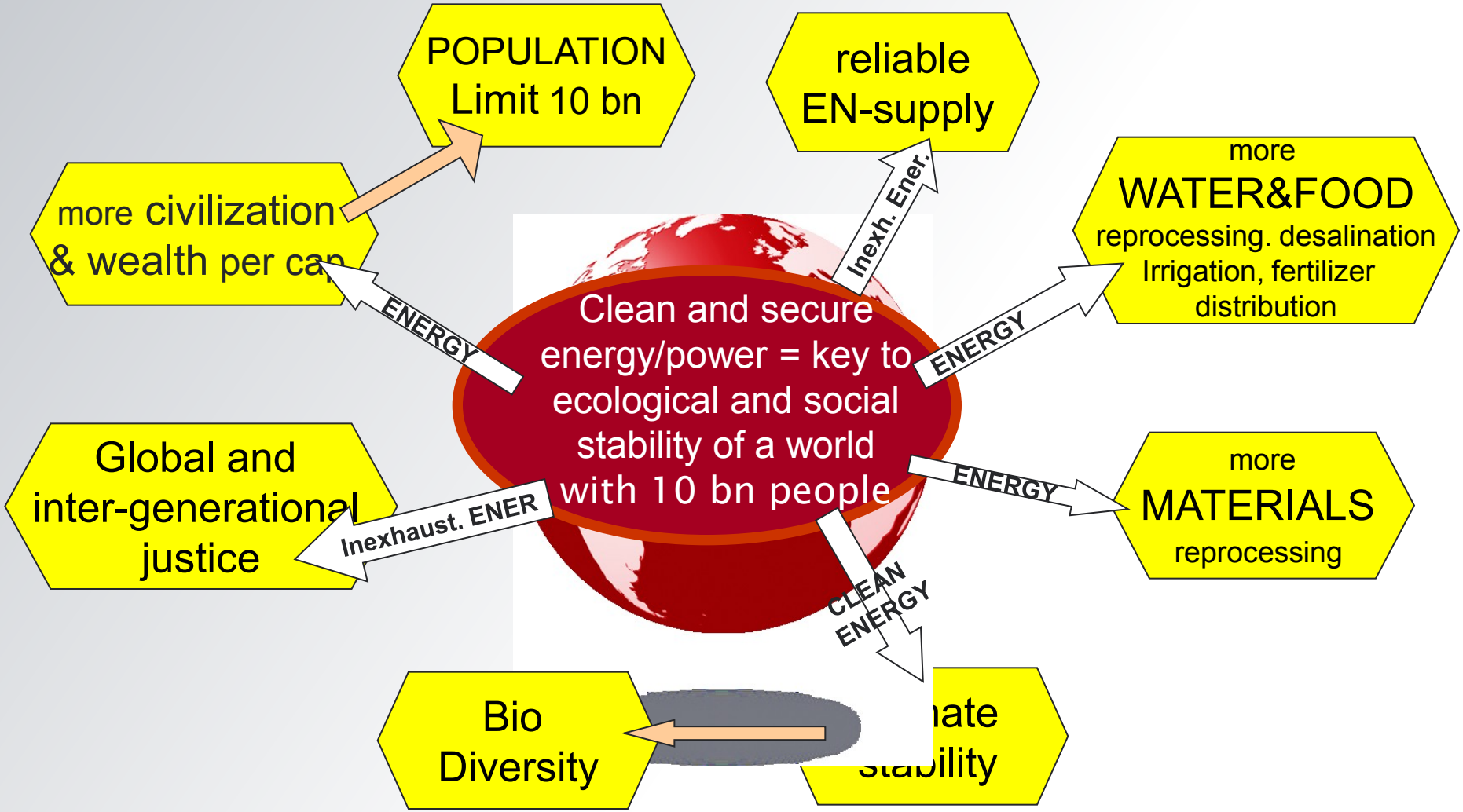
Who should go ?
Or
what else ?

Visible fist of capital economy:
Natural disaster events 1980 – 2009, global



A sustainable world for 10 bn people ?

HUMAN SECURITY Octet:



Organization of players for global sustainability:

"invisible hand of economy" : ➔ no alignment for sustainability

Principles of organization:

- National advantage

- Capital economy

main players

United Nations

National governments

Capital & investors

Sciences, S-community

Oil, Gas & Coal, big business

Civilization, Culture

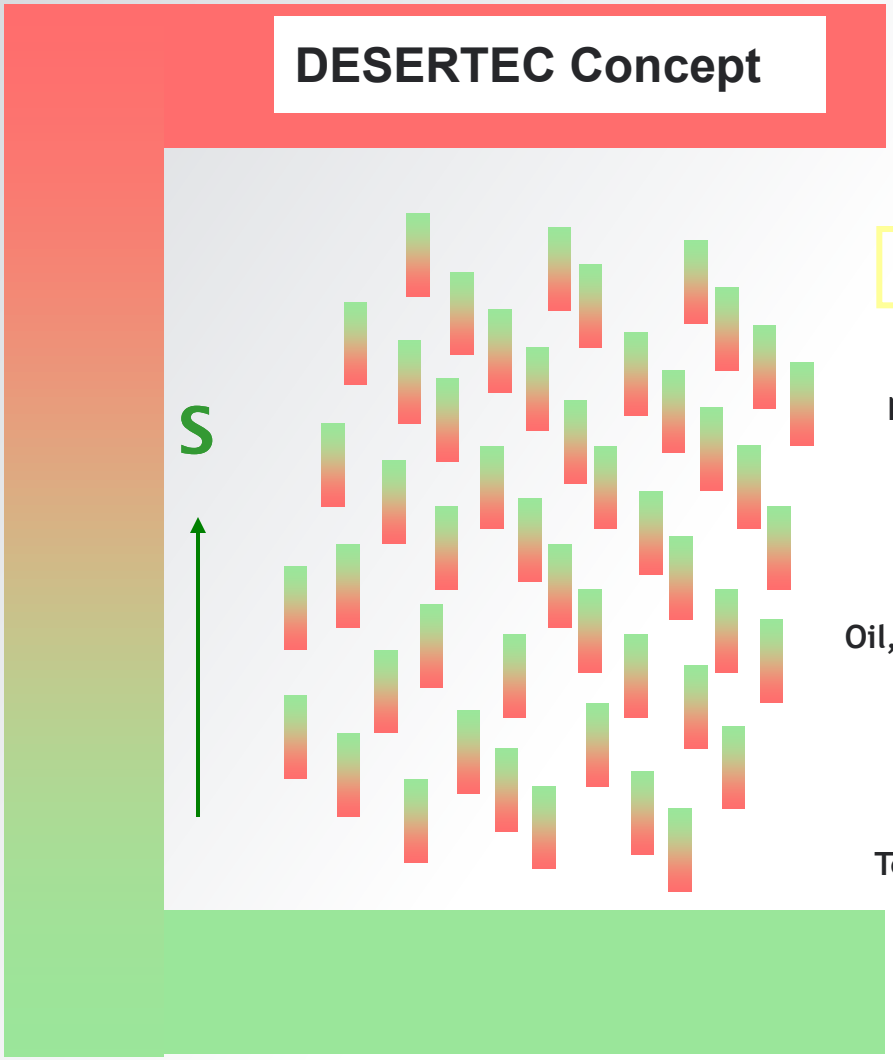
NGOs

Techno, Manufacturers

Organization of players for global sustainability:
➔ a solution model can align for sustainability

Principle of organization:

- strategy of survival for 10 bn people on Earth



main players

United Nations

National governments

Capital & investors

Sciences, S-community

Oil, Gas & Coal, big business

Civilization, Culture

NGOs

Techno, Manufacturers

How much power for 10 billion people like us ?

1.

2050 average power per person and year

5 MWh/y

Data 2006

World	3.1
OECD	8.6
USA	12.2
India	0.9
Germany	6.4

2.

2050 electro mobility per person and year

1 MWh/y

km/person:	10,000
Germany 2007:	13,000
person/car	2
Electr./100km:	20kWh

3.

World population 2050:
9 - 10 billion people

60 PWh/y

(+/- 20%)

2009: world:18 PWh/y
GERMANY : 0.5 PWh/y

in 2050: **50% as solar** power from DESERTS

DESERTEC for

30 PWh/y

4.

2500 solar hours per/y:

12,000
solar GigaWatt
collectors
globally

35 years, 1GW/day
Ready for that ?

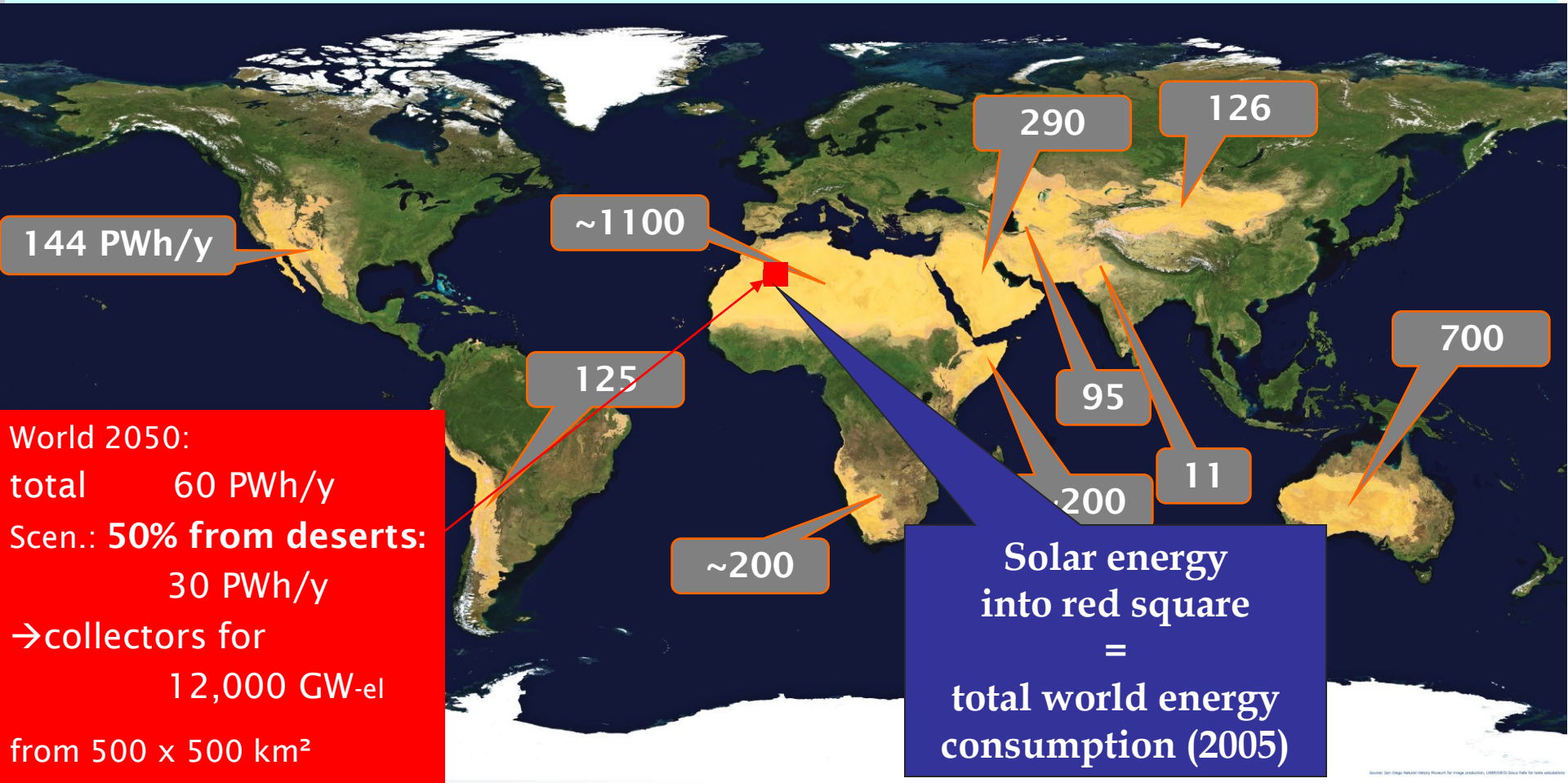
1 GW/day ~1-2 bn €/day ~ 35% of military expenses ~ 1% GNP industrial
Saving the planet will become largest business case of the decades ahead of us

Energy from DESERTS – a world-wide resource

Economic power potential: **3000 PWh/year** (1PWh= 1000 TWh)

present global demand (2008): 18 PWh/y

Source: Trieb et.al.,DLR, 2009



World 2050:

total 60 PWh/y

Scen.: **50% from deserts:**

30 PWh/y

→collectors for

12,000 GW-el

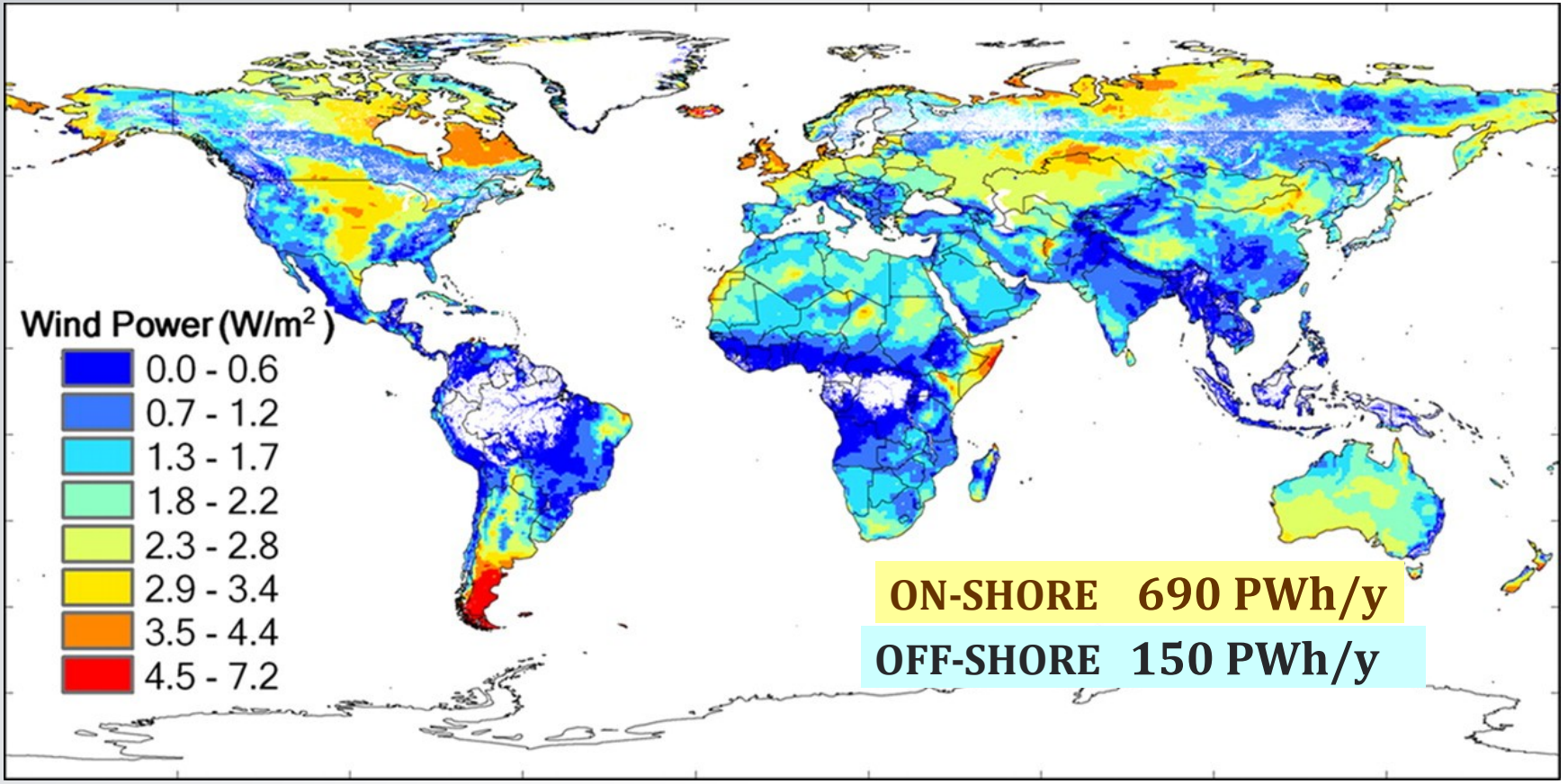
from 500 x 500 km²

= 1% of useful deserts

distributed over "10,000" sites

Wind – a world wide power resource

Global distribution of annual average onshore wind power potential (W/m2) for 2006 spatial limitations on placement, no limitations on capacity factors.



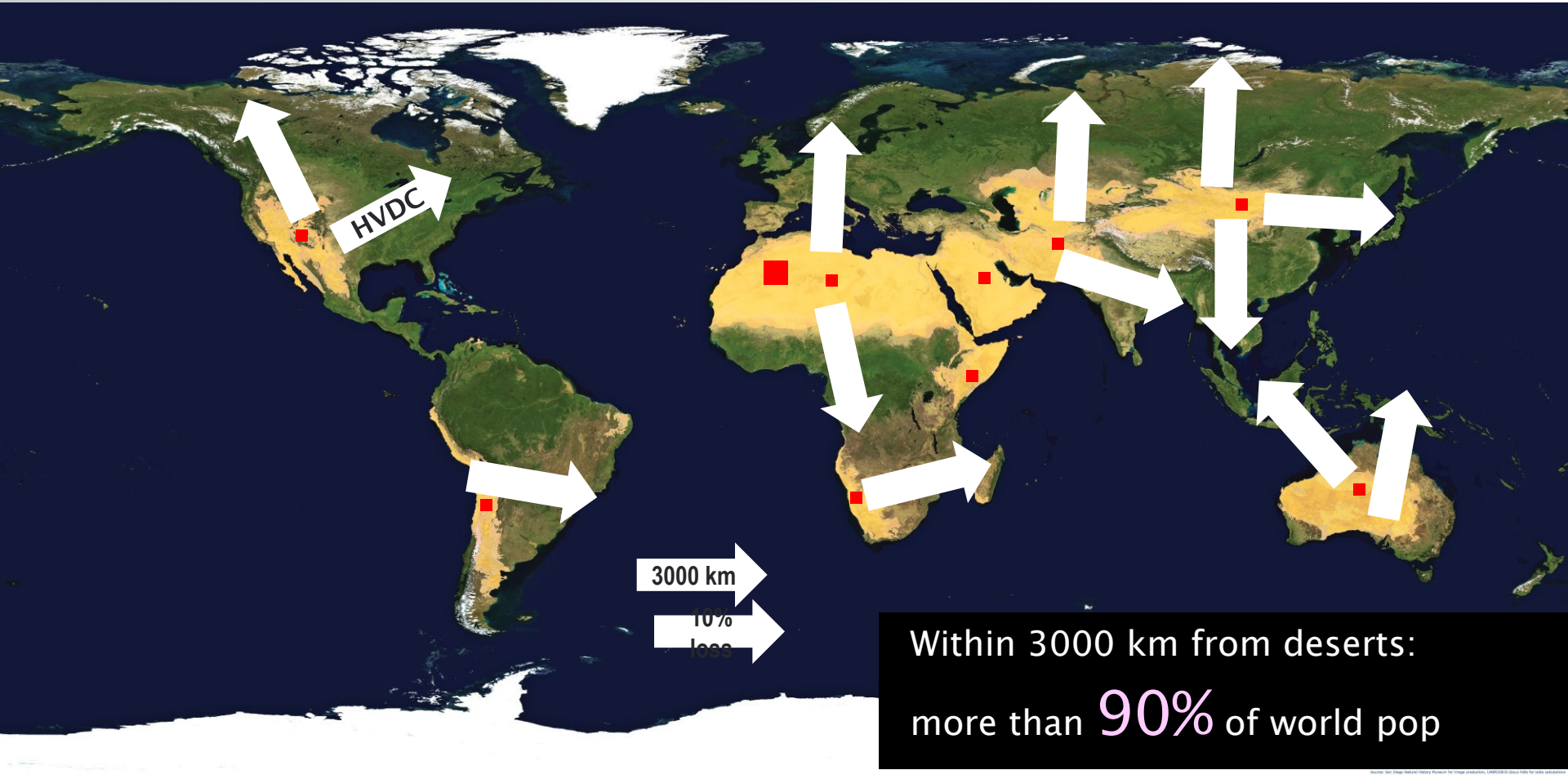
Lu X et al. PNAS 2009;106:10933-10938

PNAS

Transmission: from deserts to the people

5,000 solar GigaWatt transmission capac. from deserts

➔ HVDC super grid to a world with 10 billion people



Within 3000 km from deserts:

more than 90% of world pop

7. How to organize the transition ? – tipping points !!

➔ how much more CO2 compatible with $\Delta T < 2°$? ➔? (WBGU):

with 67% probability in 2050, equal emission rights per person, population as in 2010

World-wide: 720 Gt CO2

with emissions as in 2008

	remaining years
World	24
Japan	10
EU	11
USA	5
India	87
Indonesia	66
China	23

1. **24 year global CO2 exit**
trial & error? – NO!
strategy required
tough but feasible !

2. **"game over" for national solutions**

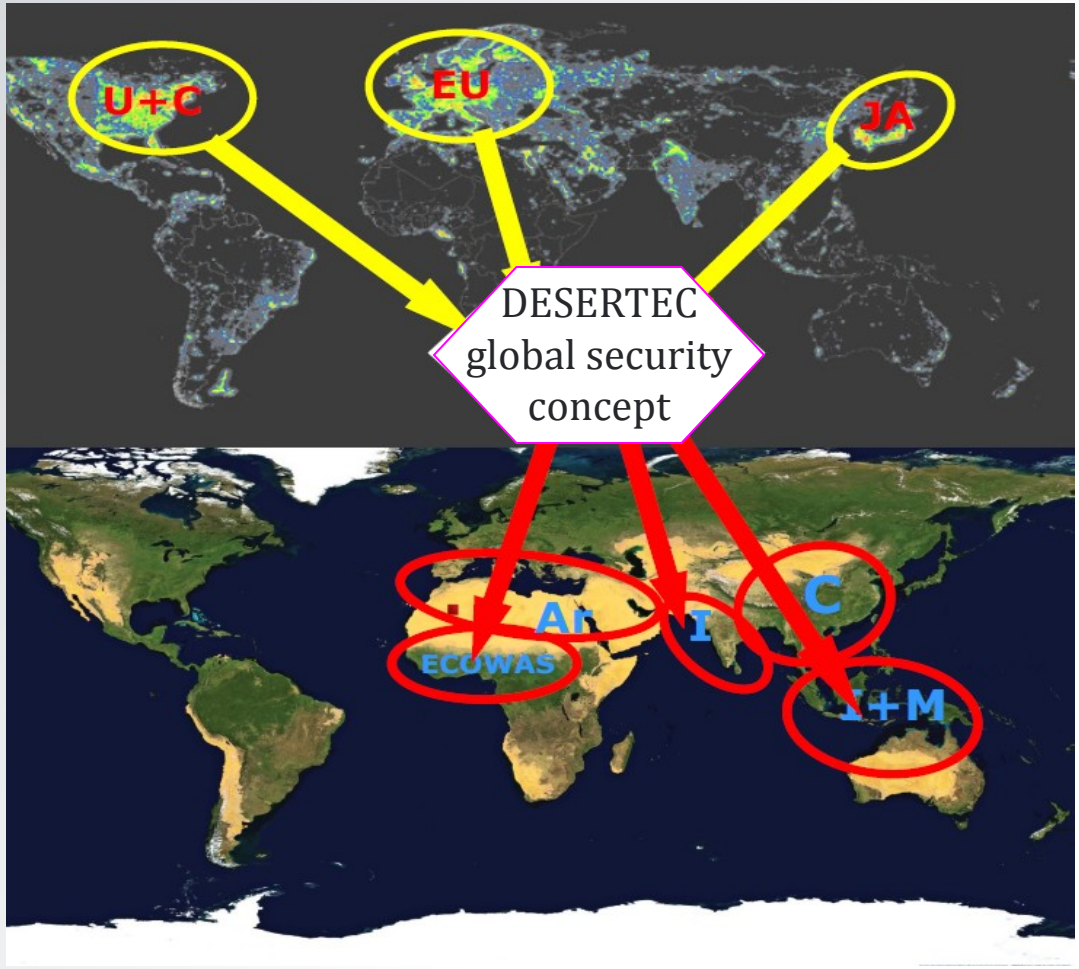
For industrial economies:
remaining time too short.
Never 50% reduction by 2020:
➔ climate crash or economic crash !

3. **late countries: remaining time ok**
but victims of „industrial" emissions

➔ ecological & economic security simultaneously only by north-south co-operation:

➔ new world order for sustainability : clever North-South Climate Alliances

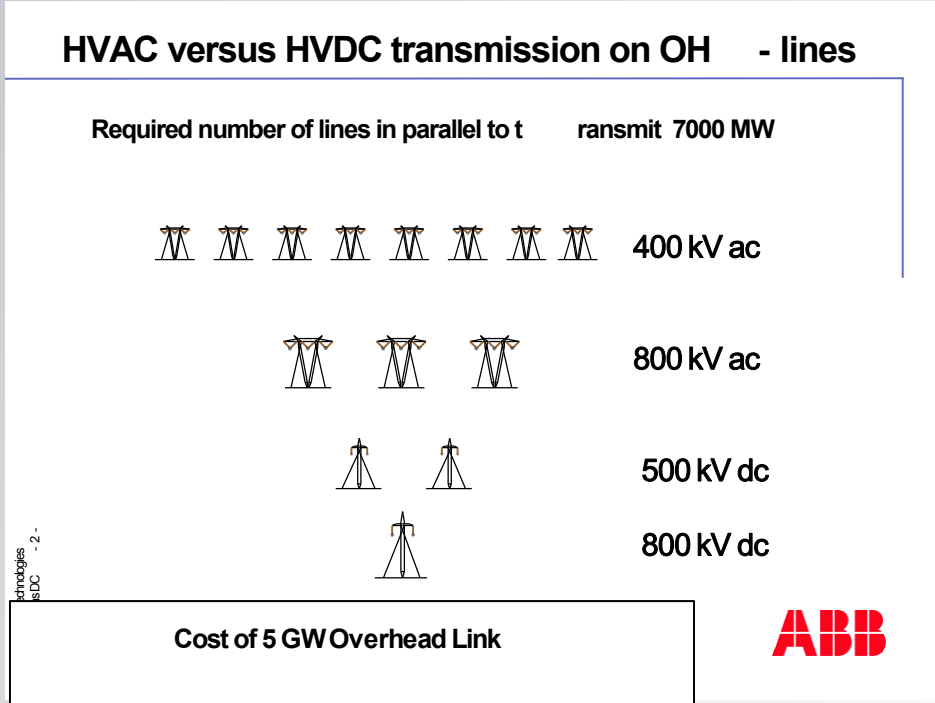
DESERTEC – alliances
pillars of the global solution model for energy and climate security

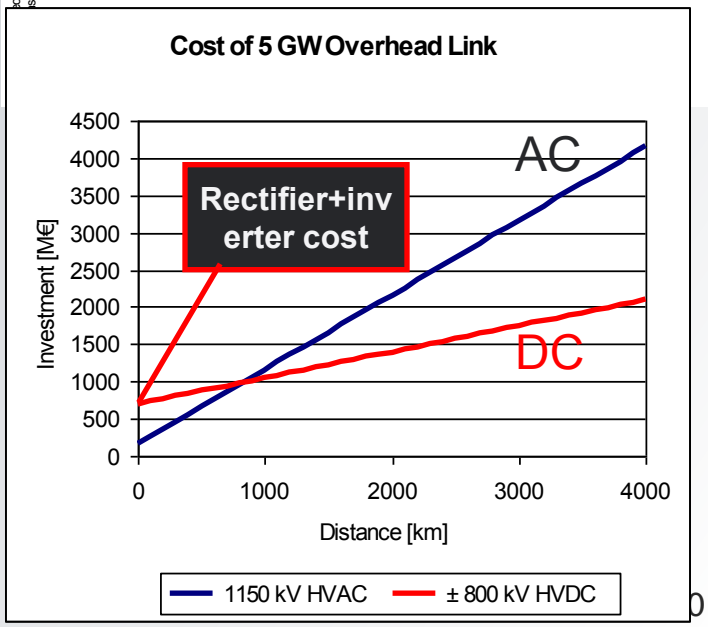


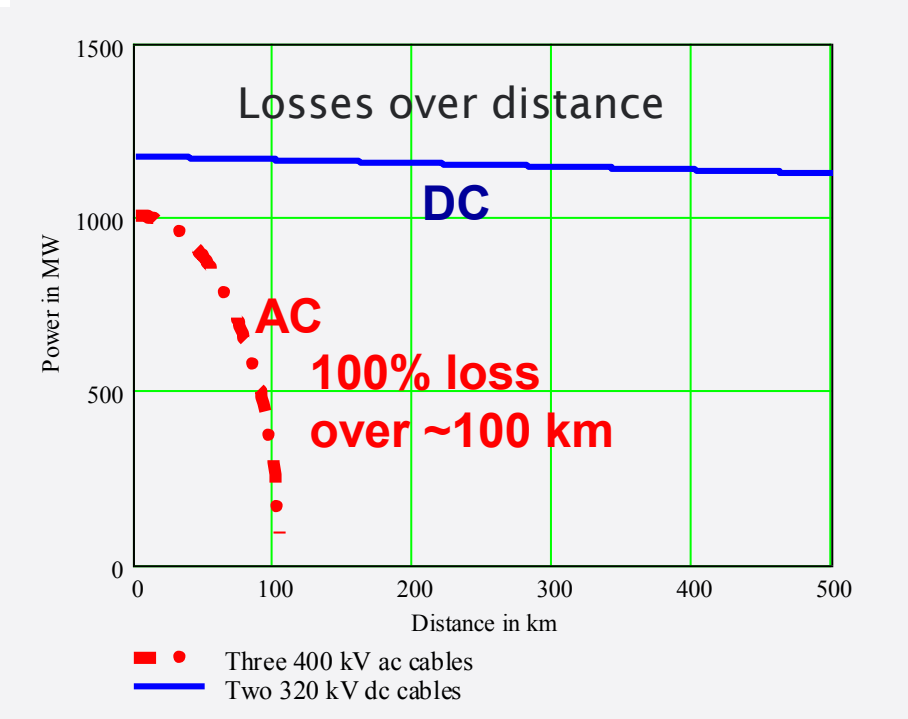
Low-loss long-distance transmission by HVDC

Loss = $\delta W/W \sim 1/U^2$

Cables, (under ground, submarine)
High capacity, AC impossible







In favor of DC over AC:

1. un-limited reach (cables, no rad.)
2. lower losses/km (always Vmax)
3. lower power line costs/GW
4. lower space demand/GW

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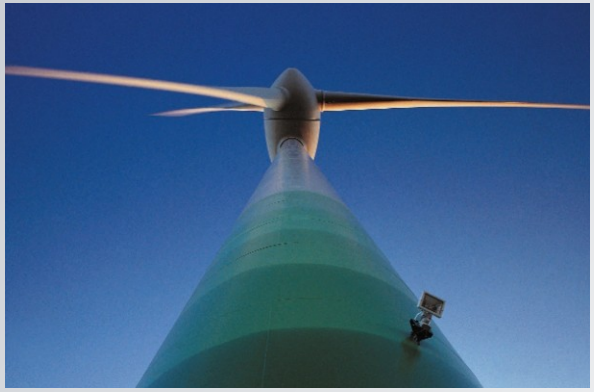
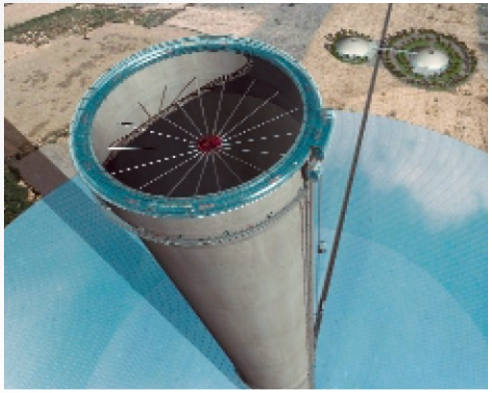
Wind Power (Enercon)



Hydropower (Tauernkraft)

Solar Chimney (SBP)



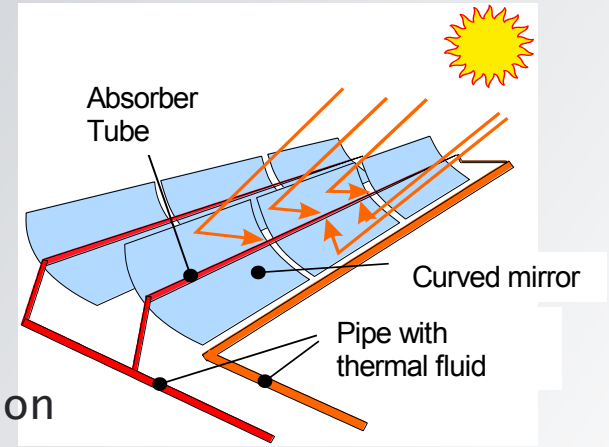
Photovoltaic (NREL)

Hot Dry Rock (Stadtwerke Urach)

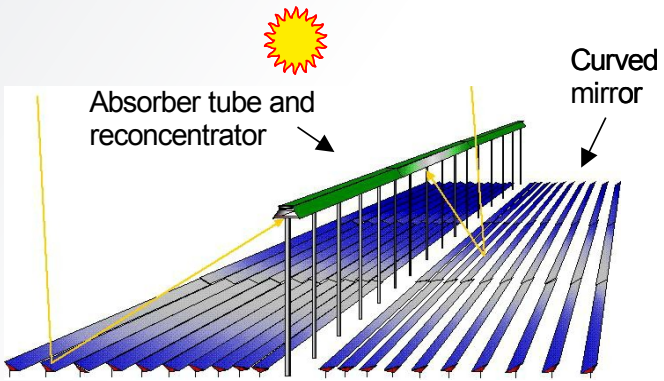
Biomass Power (NREL)

Concentrating solar collector technologies: basic layout schemes

Linear Concentration
conc: 100,
T: ~ 500° C

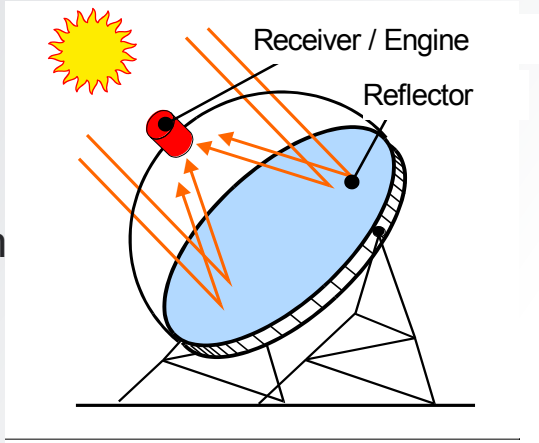


Parabolic Trough

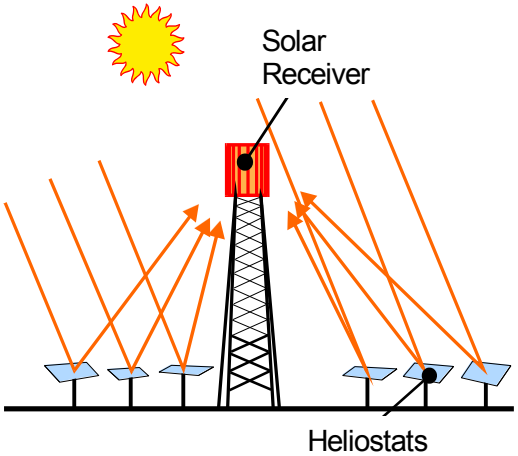


Linear Fresnel

Point Concentration
conc: 1000+,
T: ~ 1000° C



Dish/Engine



Central Receiver

Solar Power also at Night! Andasol 1: Andalusia, Spain, molten salt heat storage tank day+night operation

CSP:
Clean power on demand

Solar thermal power without water!

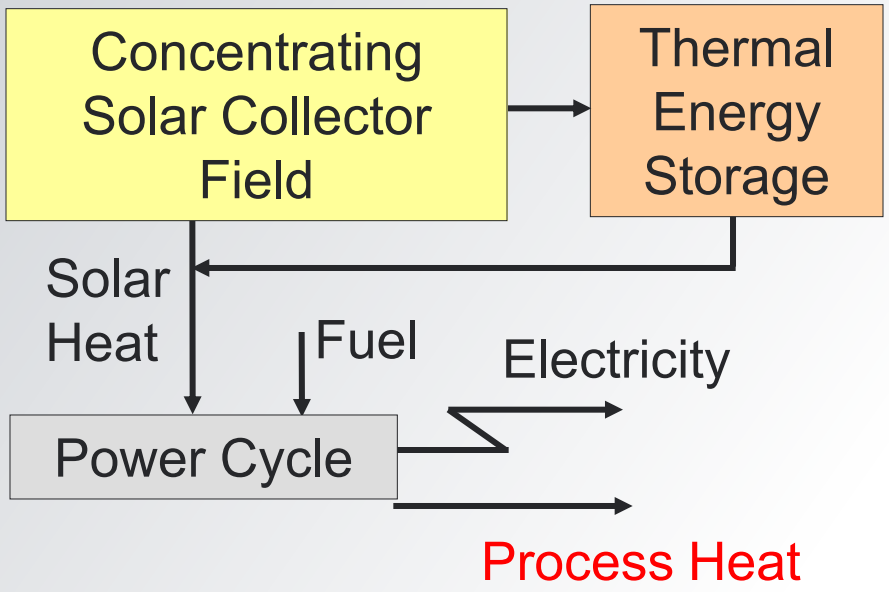
Here: Linear Fresnel Solar Steam Power Plant
1.5 MW, in Spain, March 2009

No water Consumption

Dry cooling
Dry cleaning

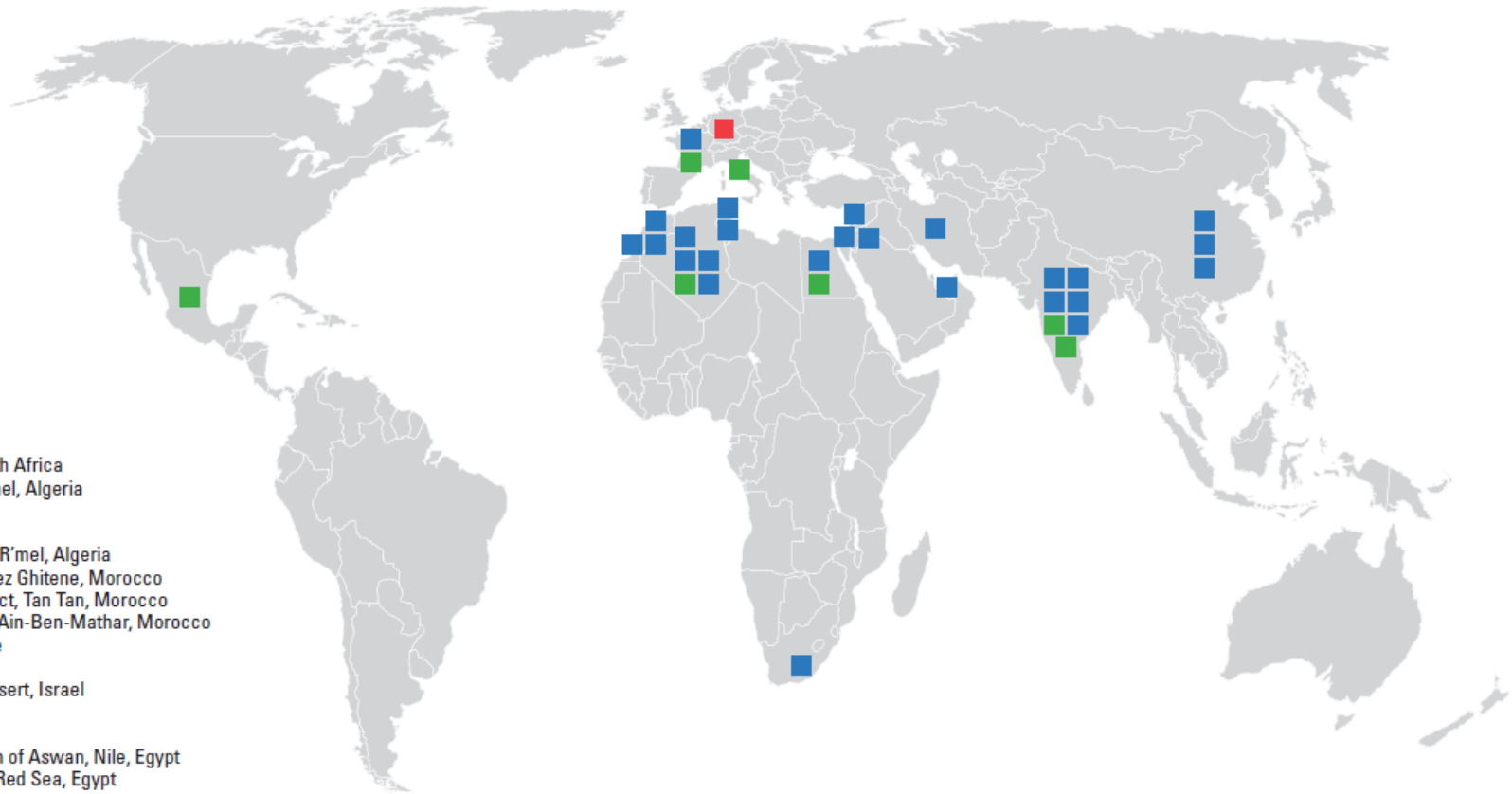
Or
Cooling by sea water as desalination

CSP Applications – Solar or Hybrid Electricity and Combined Heat & Power



- solar electricity
- integrated fossil fuel backup capacity, power on demand
- increased solar operating hours, reduced fuel input
- additional process heat for cooling, drying, seawater desalination, etc.

Map of CSP Worldwide plant locations



Operating

- Jülich, Jülich, Germany

Planning

- Upington, Upington, South Africa
- Hassi-R'mel II, Hassi-R'mel, Algeria
- Meghaïer, Algeria
- Naâma, Algeria
- Hassi-R'mel ISCC, Hassi-R'mel, Algeria
- Ouarzazate Project, Tamez Ghitene, Morocco
- Tan Tan CSP-Desal Project, Tan Tan, Morocco
- Ain-Ben-Mathar ISSC 2, Ain-Ben-Mathar, Morocco
- Thérmis, Thérmis, France
- Ashalim, Ashalim, Israel
- Negev Desert, Negev Desert, Israel
- Elmed CSP, Tunisia
- IPP-CSP Project, Tunisia
- Kom Ombo Project, North of Aswan, Nile, Egypt
- Marsa Alam, Hurghada, Red Sea, Egypt
- Shams 1, UAE
- Joan1, Ma'am, Jordan, Jordan
- Yazd ISCC, Luth Desert, Iran
- Bap Project, Bap, Jodpur, India
- Gujarat, India
- Rajasthan, India
- Rajasthan, India
- Uttar Pradesh, India
- Guangdong, China
- Ordos, Inner Mongolia, China
- Inner Mongolia, Xin Jiang, Tibet, China

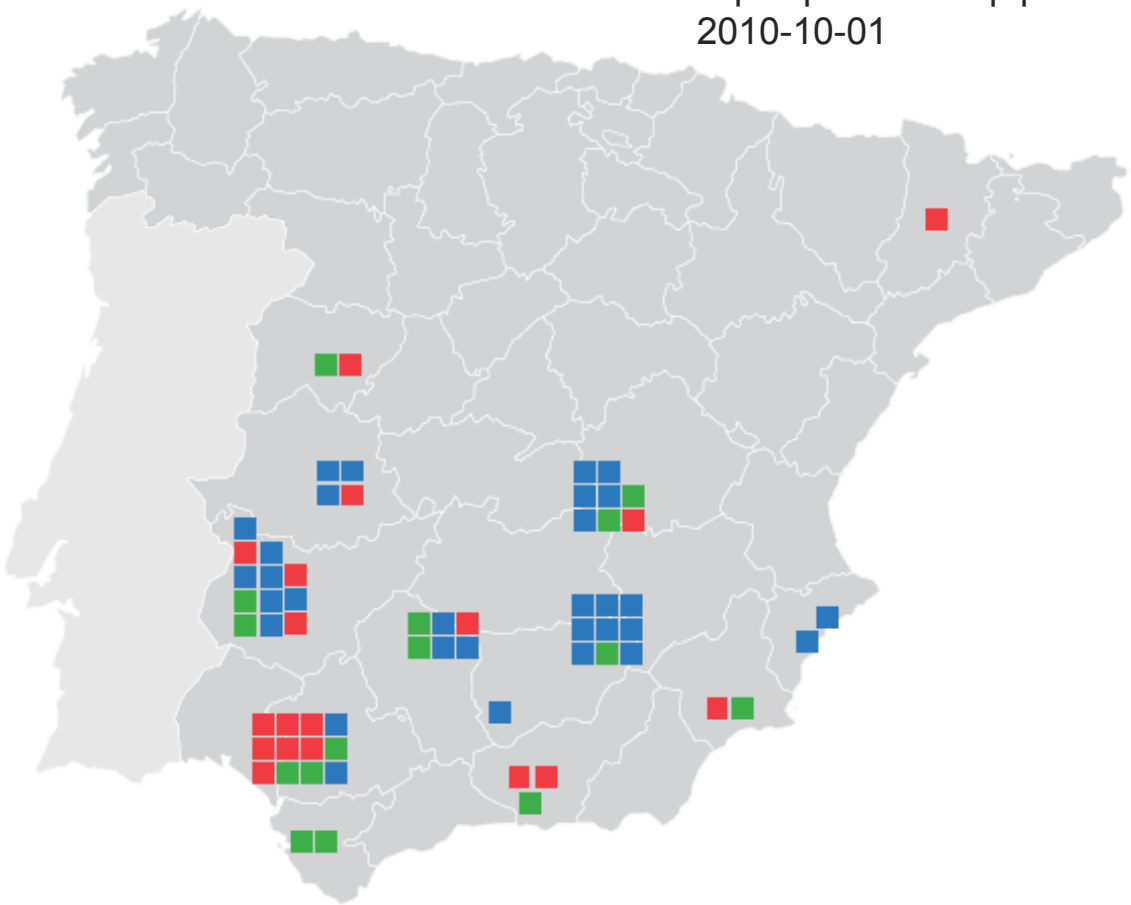
Under Construction

- Agua Prieta II Project, Sonara State, Mexico
- Ain-Ben-Mathar ISSC, Ain-Ben-Mathar, Morocco
- Archimedes Prototype Project, ENEL Power Station of Priolo, Siracusa, Sicilia, Italy
- PÉGASE, Thérmis, France
- Kuraymat ISCC, Kuraymat, Egypt
- Acme Rajasthan Solar Power, Jodhpur, Rajasthan, India
- Rajasthan Solar One, Rajasthan, India

http://www.csptoday.com/csp/csp-world-map.pdf
2010-10-01

CSP Spain plant locations

http://www.csptoday.com/csp/csp-world-map.pdf
2010-10-01



Operating

- Extresol 1, Torres de Miguel Sesmero, Badajoz
- La Risca (Alvarado 1), Alvarado, Badajoz
- PS20, Sanlucar la Mayor, Sevilla
- Solnova 1, Sanlucar la Mayor, Sevilla
- Solnova 3, Sanlucar la Mayor, Sevilla
- Envirodish, Sevilla
- Solnova 4, Sanlúcar la Mayor, Sevilla
- PS10, Sanlucar la Mayor, Sevilla
- Puertollano Ibersol, Puertollano, Ciudad Real, Castilla-La Mancha
- Andasol 1, Guadix, Granada
- Andasol 2, Guadix, Granada
- Puerto Errado I, Calasparra, Murcia
- Termosolar Borges S.L., Aigües Blanques, Lerida
- C.Solar Termoelectrica Caceres, Galisteo, Cáceres
- Central Solar Termoelectrica La Dehesa, La Garrovilla
- Solaben I, Logrosán, Cáceres

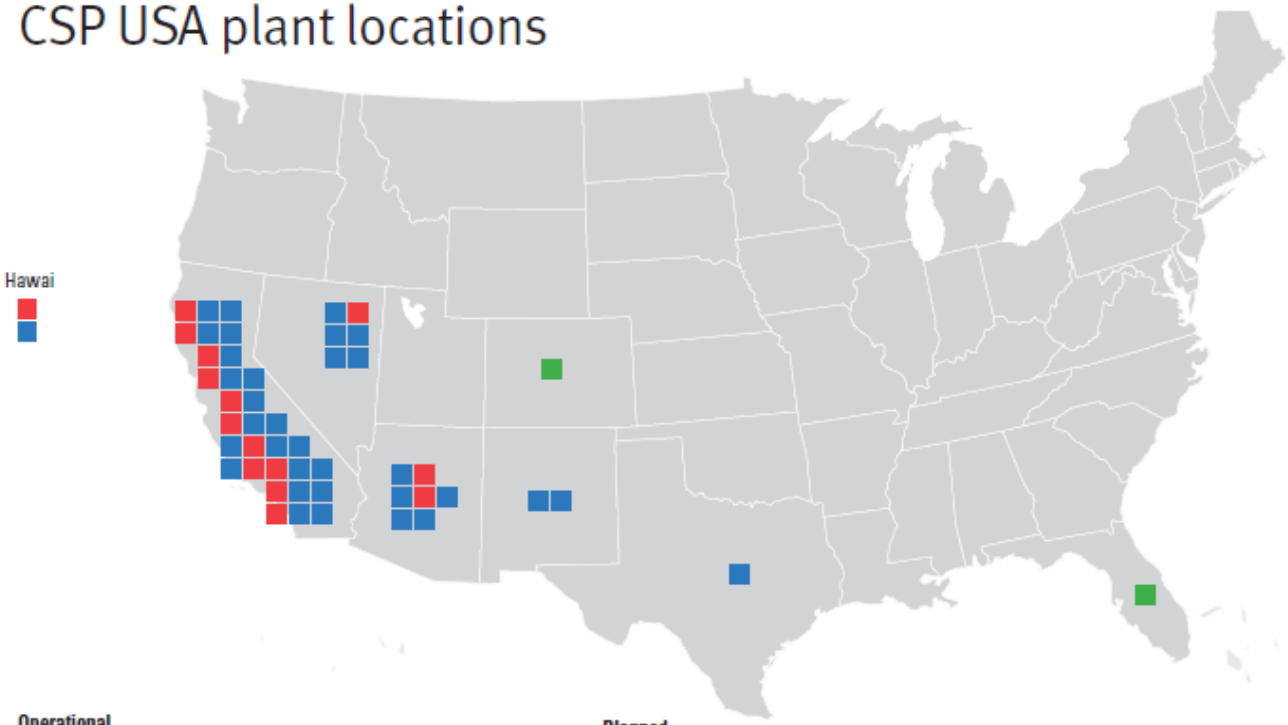
Planning

- C.Solar Termoelectrica "Astexol-2", Badajoz
- Casablanca, Talarrubias, Badajoz
- PL. Termosolar de Olivenza I, Olivenza, Badajoz
- C. Termosolar "La Africana", Fuente Palmera, Córdoba
- Extremasol 1, Villanueva de la Serena, Badajoz
- Termosol 1, Navalvillar de Pela, Badajoz
- Termosol 2, Navalvillar de Pela, Badajoz
- Solaben II, Logrosán, Cáceres
- Solaben III, Logrosán, Cáceres
- Solaben 6, Logrosán, Cáceres
- Pl. Termoelectrica de Consol Orellana, Orellana la Vieja, Badajoz
- Solarcor 1, El Carpio, Córdoba
- Extresol 3, Torre de Miguel Sesmero, Badajoz
- Arenales PS, Morón de la Frontera, Sevilla
- PL. Termosolar de Morón, Morón de la Frontera, Sevilla
- Helios 1, Ciudad Real, Castilla-La Mancha
- Helios 2, Ciudad Real, Castilla-La Mancha
- Manchasol 2, Alcázar de San Juan, Ciudad Real, Castilla-La Mancha
- Solarcor 2, El Carpio, Córdoba
- C.Solar Termoelectrica "ASTE - 1A", Alcázar de San Juan, Ciudad Real
- C.Solar Termoelectrica "ASTE - 1B", Alcázar de San Juan, Ciudad Real
- PL. Termosolar 10MW Puertollano, Ciudad Real, Castilla-La Mancha
- PL. Termosolar 10MW Puertollano, Ciudad Real, Castilla-La Mancha
- PL. Termosolar 10MW Puertollano, Ciudad Real, Castilla-La Mancha
- PL. Termosolar 8MW Puertollano, Ciudad Real, Castilla-La Mancha
- PL. Termosolar 10MW Puertollano, Ciudad Real, Castilla-La Mancha
- PL. Termosolar 10MW Puertollano, Ciudad Real, Castilla-La Mancha
- PL. Termosolar 14MW Puertollano, Ciudad Real, Castilla-La Mancha
- C.Solar Termoelectrica Enerstar Villena, Villena, Alicante
- C.Solar Termoelectrica Enerstar Villena, Villena, Alicante
- PL. Termosolar 990KW Casas de los Pinos, Villarobledo, Albacete
- Pl.Solar Termoelectrica, Espejo

Under Construction

- Andasol 3, Aldeire, Granada
- Arcosol 50 (Valle 1), San José del Valle, Cádiz
- Manchasol 1, Alcázar de San Juan, Ciudad Real, Castilla-La Mancha
- Renovalia, Albacete, Castilla-La Mancha
- PL. Termosolar 990KW Casas de los Pinos, Villarobledo, Albacete
- Termesol 50 (Valle 2), San José del Valle, Cádiz
- Puerto Errado 2, Calasparra, Murcia
- Extresol 2, Torre de Miguel Sesmero, Badajoz
- PL. Termoelectrtica de Palma del Rio I, Palma del Río, Córdoba
- PL. Termoelectrtica de Palma del Rio II, Palma del Rio, Córdoba
- HelioEnergy 1, Écija, Sevilla
- HelioEnergy 2, Écija, Seville
- Gemasolar (CTS Solar Tres), Fuentes de Andalucía, Sevilla
- Lebrija 1, Lebrija, Sevilla
- Central Solar Termoelectrica La Florida, Alvarado, Badajoz
- Termoelectrica de Majadas, Majadas de Tiétar, Cáceres

CSP USA plant locations



http://www.csptoday.com/csp/csp-world-map.pdf
2010-10-01

Operational

- Nevada Solar One, Boulder City, Nevada
- Maricopa Solar Project, Peoria, Arizona
- Saguaro Power Plant, Red Rock, Tucson, Arizona
- Holaniku, Keyhole Point, Kona, Hawai
- SEGS I, Dagett, Mojave Desert, California
- SEGS II, Dagett, Mojave Desert, California
- SEGS III, Kramer Junction, California
- SEGS IV, Kramer Junction, California
- SEGS V, Kramer Junction, California
- SEGS VI, Kramer Junction, California
- SEGS VII, Kramer Junction, California
- SEGS VIII, Harper Lake, California
- SEGS IX, Harper Lake, California
- Kimberlina, Bakersfield, California
- Ridgecrest Solar , Lancaster, California

Under Construction

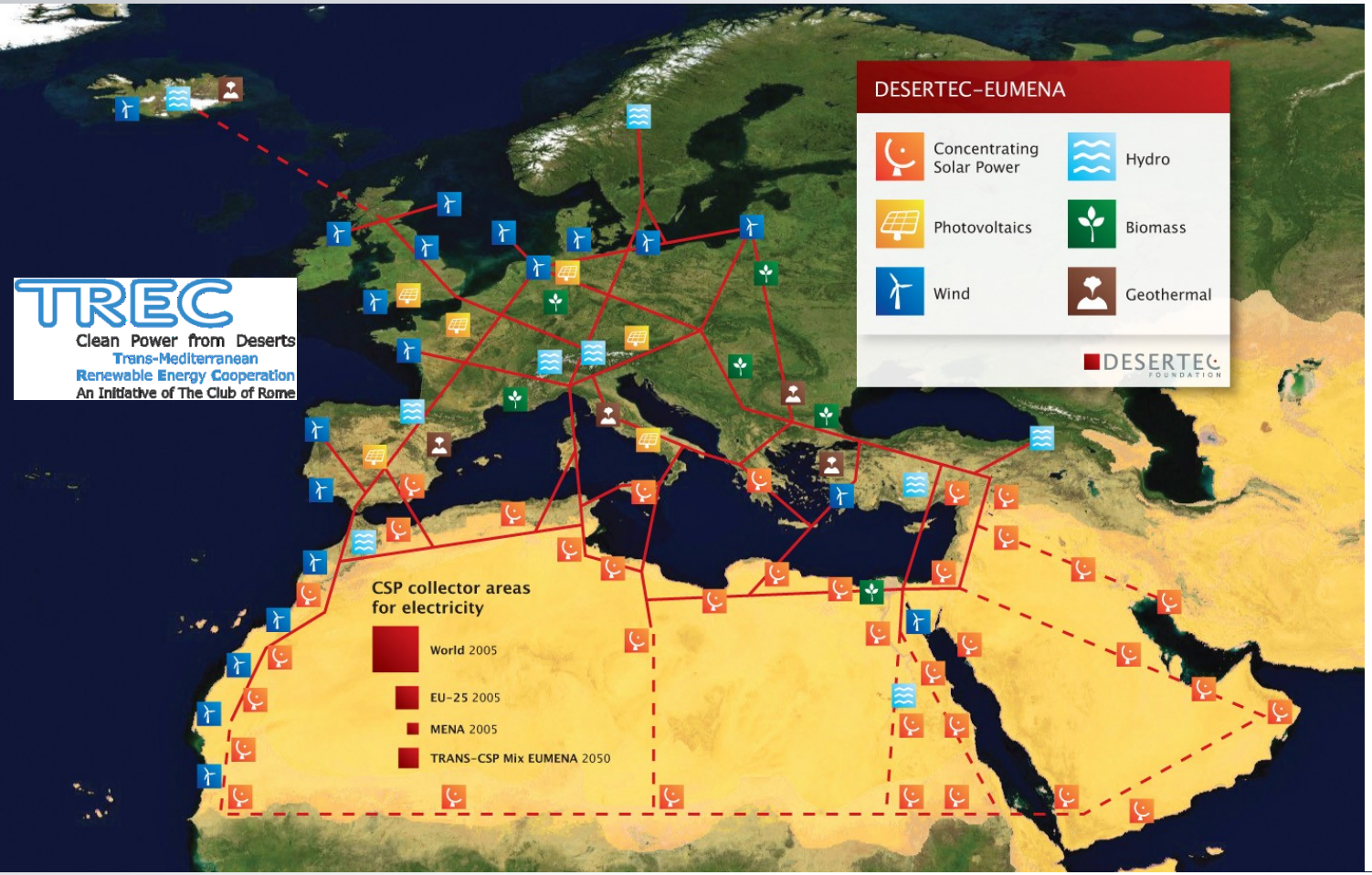
- Cameo Coal-Fired Hybrid Demonstration Project, Grand Junction, Colorado
- Martin Next Generation Solar Energy Center, Martin Country, Florid

Planned

- Santa Teresa New Mexico
- Kingman Project, Kingman, Arizona
- Sonoran Solar Energy Project, Maricopa County, Arizona
- Solana, Gila Bend, Arizona
- UA Tech Park Therman Storage Demonstration Project, Tucson, Arizona
- Amargosa Farm Road Solar Energy Project 1, Nye County, Nevada
- Amargosa Farm Road Solar Energy Project 2, Nye County, Nevada
- Crescent Dunes (Tonopah), Tonopah, Nye, Nevada
- Coyote Springs 1, Coyote Springs, Nevada
- Coyote Springs 2, Coyote Springs, Nevada
- Buckeye Landfill Project, Buckeye, Arizona
- Sun Power Tower, Santa Teresa, New Mexico
- Western Ranch, San Antonio, Texas
- Westside Solar Project, Kauai, Hawai
- Rice Solar Power Project, Rice, Mojave Desert, near Blythe
- Abengoa Mojave Solar Project, Harper Lake, San Bernardino Country, California
- Alpine Power Tower Project, Antelope Valley, Lancaster, California
- Beacon, Kern Country, California
- Blythe, Kern Country, California
- Ridgecrest, Kern Country, California
- San Joaquin Solar 1, Coalinga, California
- San Joaquin Solar 2, Coalinga, California
- SES I, Mojave Dessert, California
- SES- Solar 2, Imperial Country, California
- SES Solar One, Victorville, California
- Sky Trough Demonstration, Daggett, California
- Ft Irwin Solar Power Project, Ft. Irwin, California
- Gaskell Sun Power Tower I, Kern Country, California
- Gaskell Sun Power Tower II, Kern Country, California
- Genesis Solar Energy Project, Riverside Country, California
- Harper Lake Solar Plant, Harper Lake, California
- Mojave Solar Park, San Bernardino Country, California
- Palen, Deser Center, Riverside, California
- Palmdale Hybrid Gas-Solar Plant, Palmdale, California
- Victorville Hybrid Gas-Solar Plant, Victorville, California
- Ivanpah, Barstow, California

Step 1: DESERTEC – EU-MENA

case study for 1/7 of world pop: 12,000 → 1,600 GW solar collector capacity



DLR

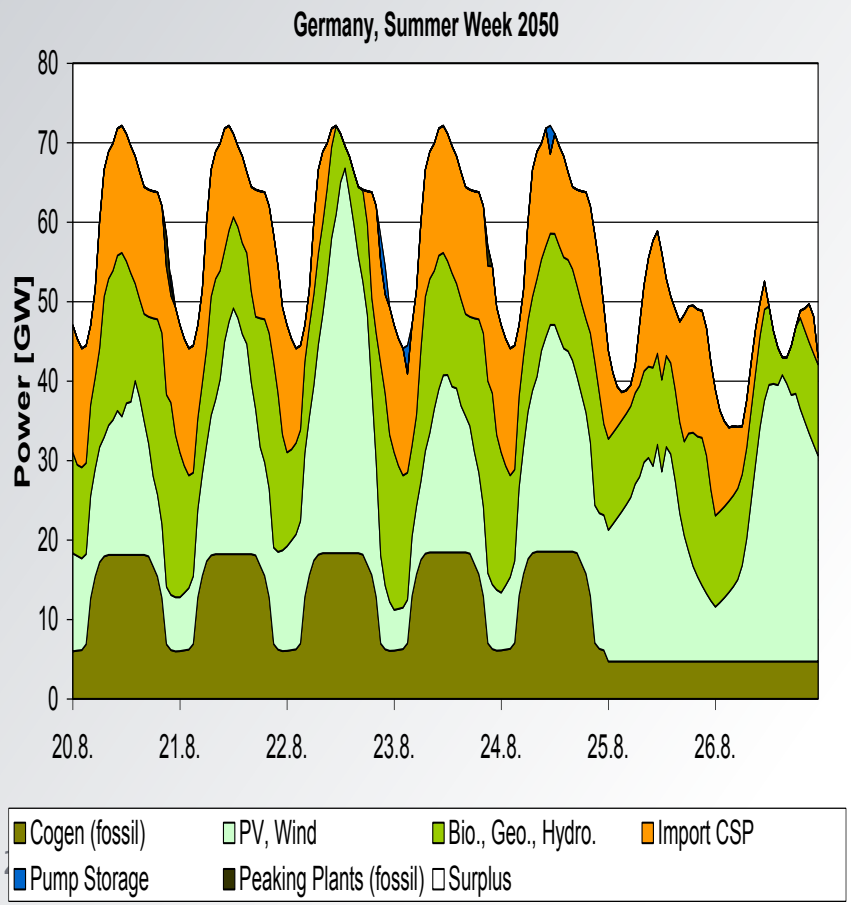
Studies by DLR for EUMENA region

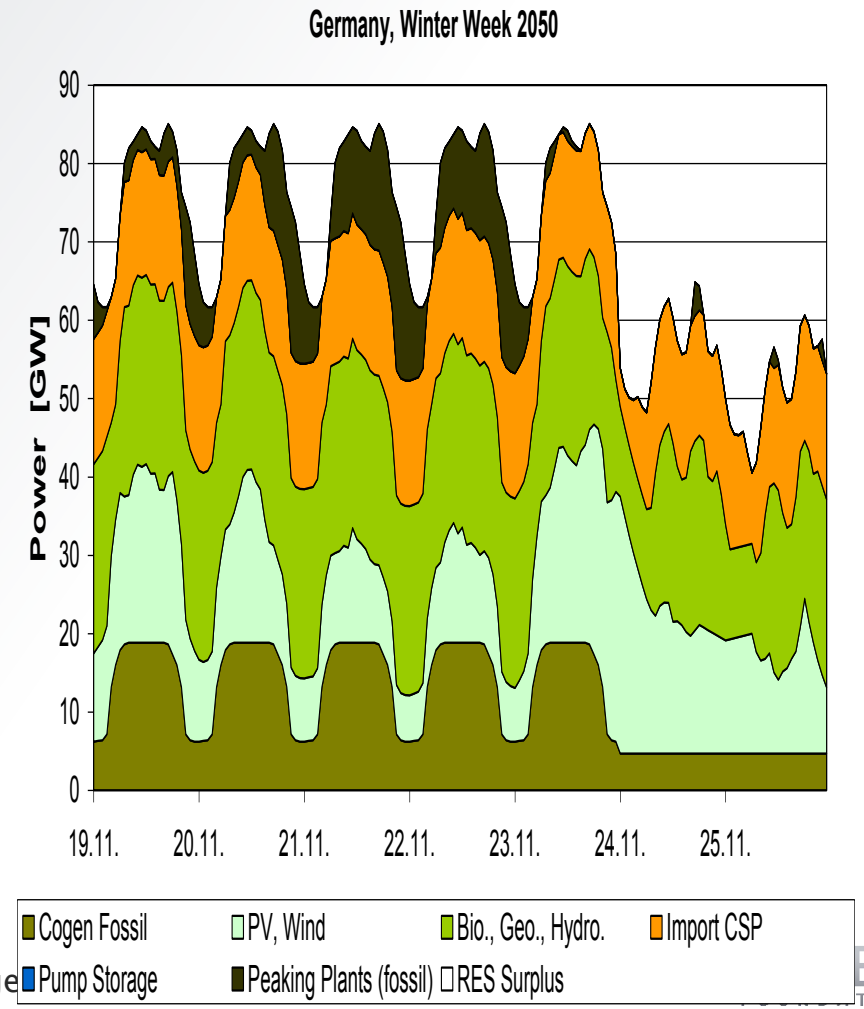
MED-CSP TRANS-CSP for German gov't

CLUB OF ROME
White Paper 2009
www.desertec.org

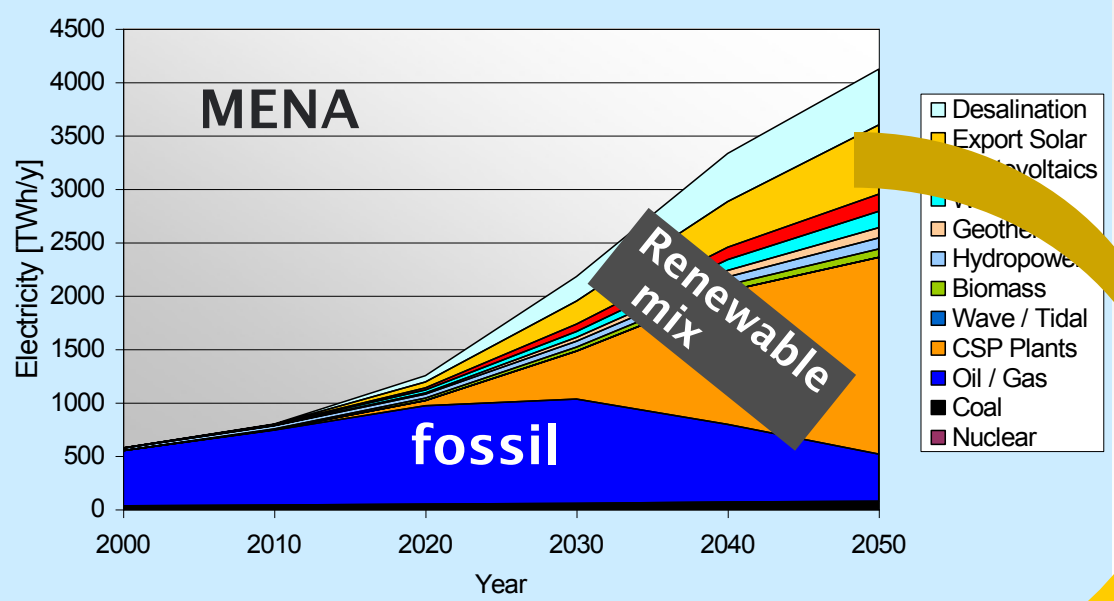
EU-MENA Mix : Firm Power on Demand

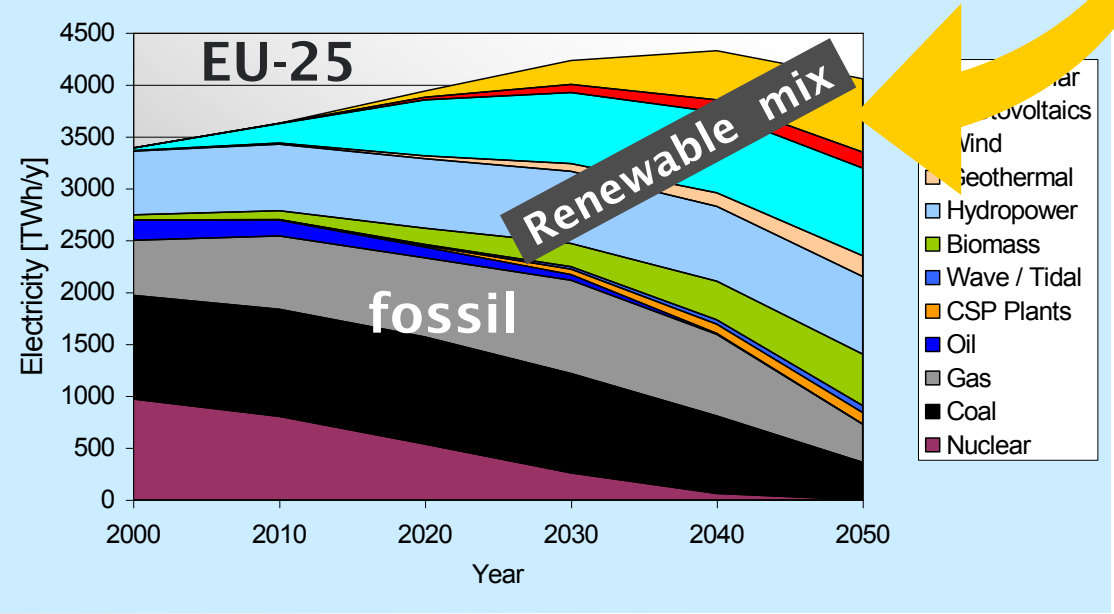
Hourly time series modelling of power supply in the TRANS-CSP scenario





transition mix 2000-2050

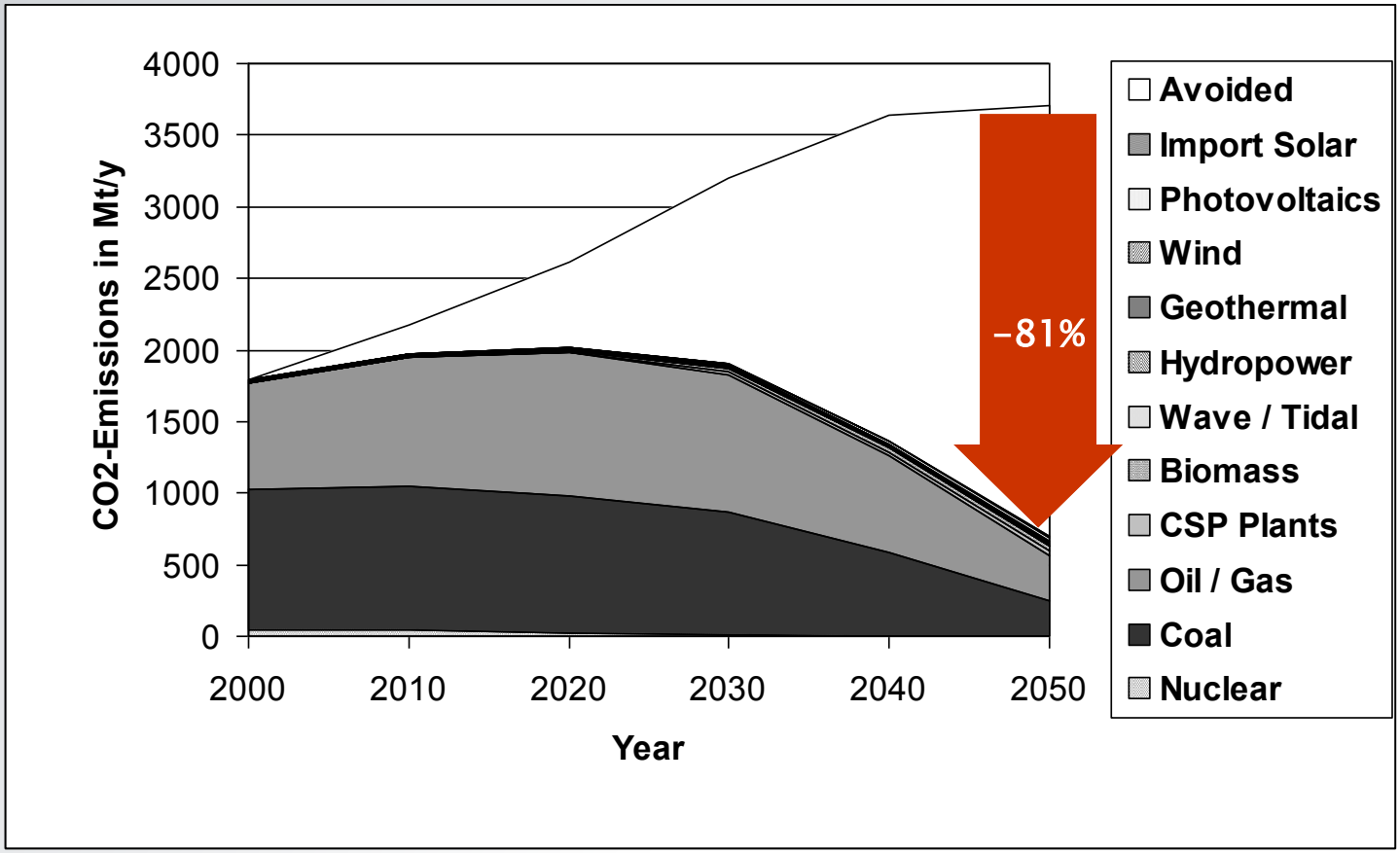




transmission MENA-Europe

The 15% CSP power import from Sahara deliver the necessary firm capacity for grid stability. „balancing power“.

Decarbonization in EUMENA,
compatible with climate goal ΔT<2°



Step 2: DESERTEC-Global

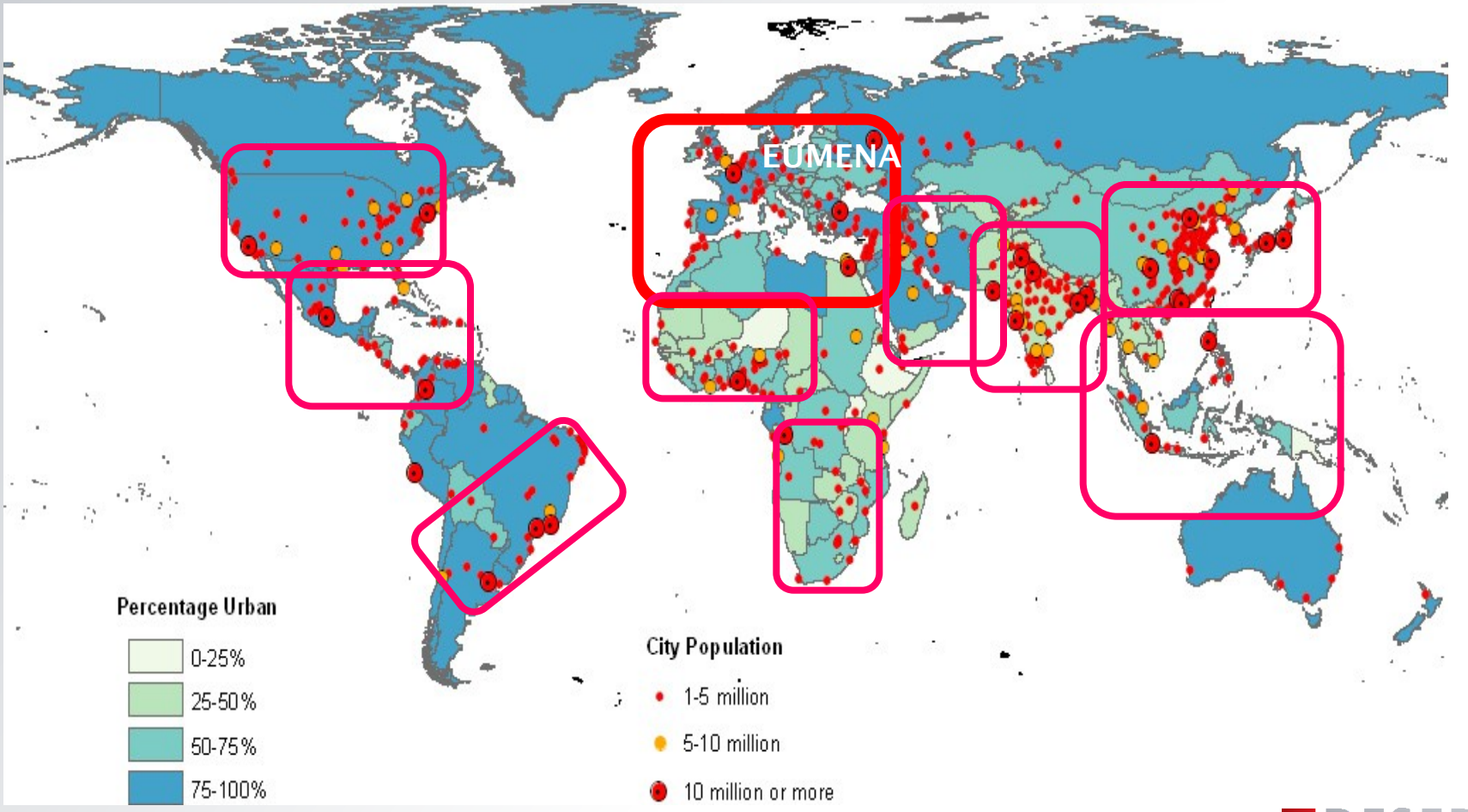
DESERTEC-EUMENA ➔ DESERTEC-GLOBAL

Mediterranean ➔ Global Solar Plan

DESERTEC develops Global Solar Plan

10 Important demand regions for DESERTEC

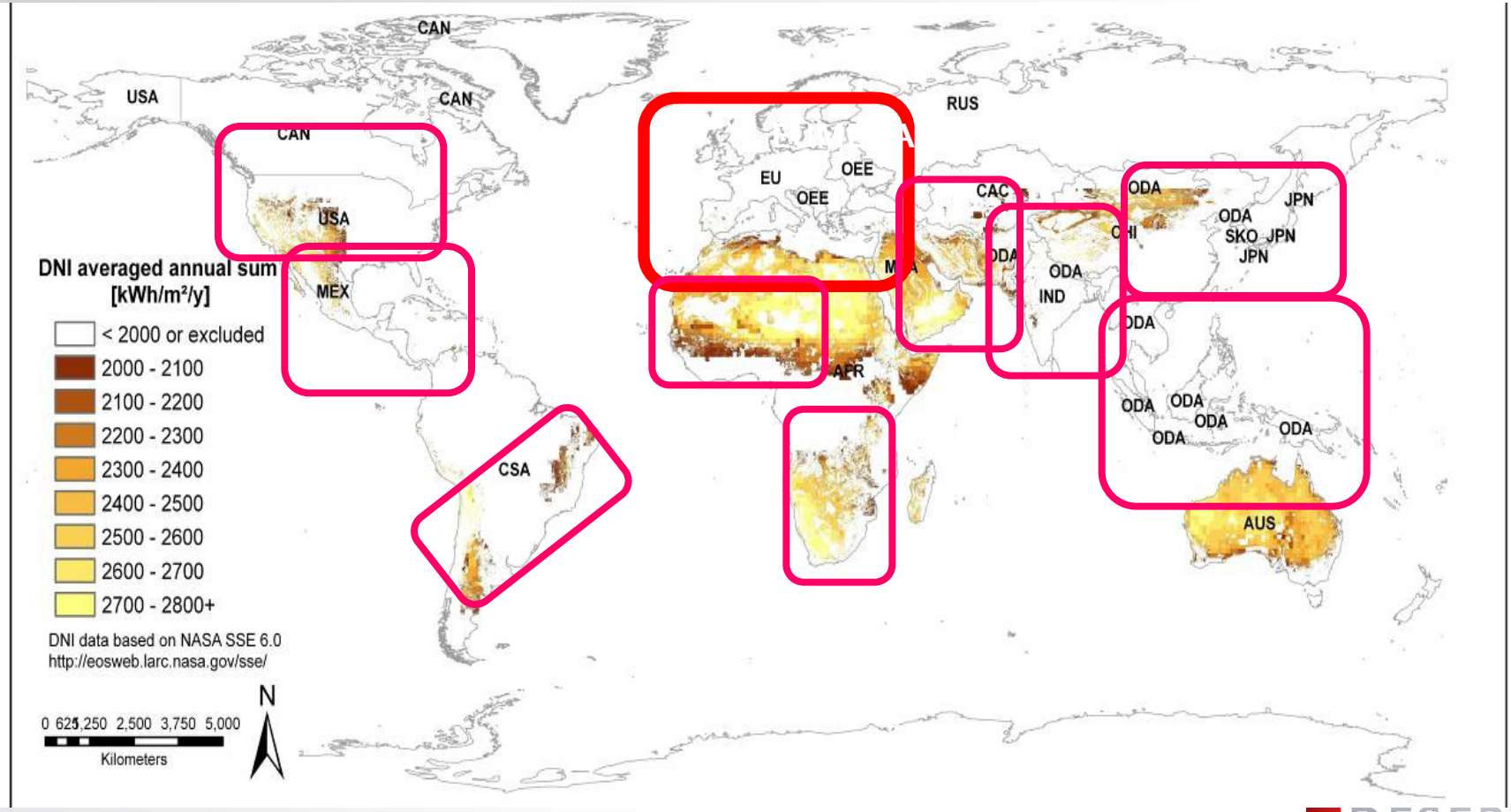
urban population expected for year 2025



DESERTEC proposes: Global Solar Plan

10 Important demand regions for DESERTEC

urban population expected for year 2025



How to achieve 24 year exit strategy ?

Phases of a clever global DESERTEC program

DESERTEC GLOBAL DEPLOYMENT PLAN

A rough implementation scheme:

Phase 1 6 years HIGH SPEED MARKET INTRODUCTION ~20 GW

2010 –2015 policy driven; external financial support (DELTA financing).

DELTA (DESERTEC–Δ) ~ 10 – 80 bn $

Phase 2 20 years COLLECTOR PRODUCTION SCALE UP

2016– 2035, market driven

3➔500 GW/year: +30% p.a., duplication in 2.5 years

Phase 3 30 years HIGH SPEED DEPLOYMENT

2020 – 2050, market driven

average **1.3 GW–coll/day**, investment ca. 3 bn €/day

Financing of phase 1 = key to success !

➔ ?? How much and who should pay DESERTEC-Δ??

How to finance CSP market introduction cost Δ

a coarse assessment

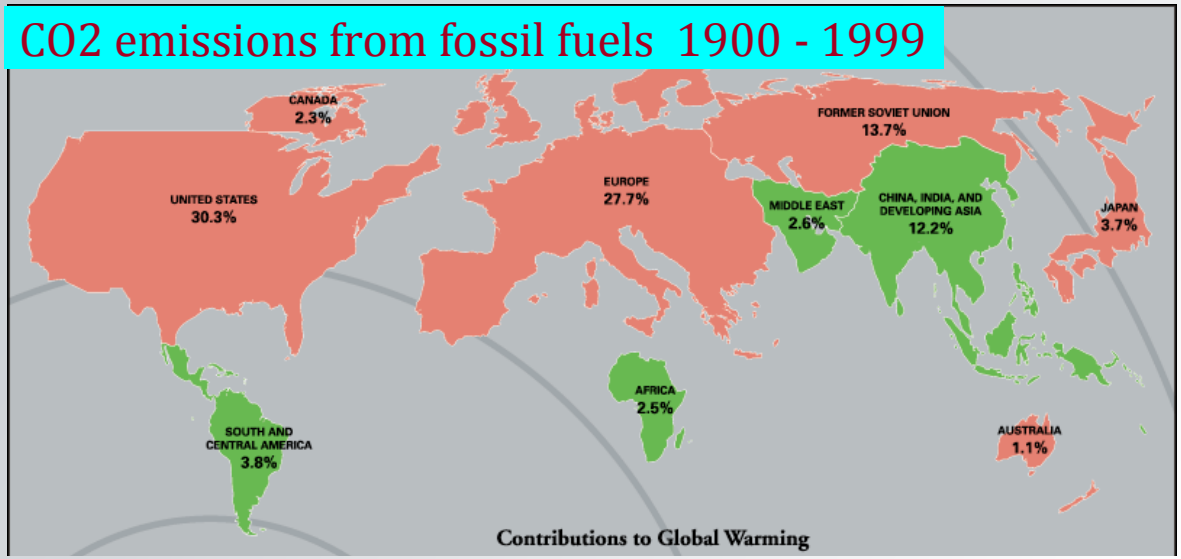
- Main uncertainty: development of fossil fuel cost.
- CSP capacity necessary for market introduction :

  ➔20 GW collectors, (<5 €/W) ➔ < 100 bn €
- Total incentive Δ: < 50% of investment ➔ < 50 bn €
- Cost of saving the climate: ➔ < 50 bn €

  Cost of saving a bank?

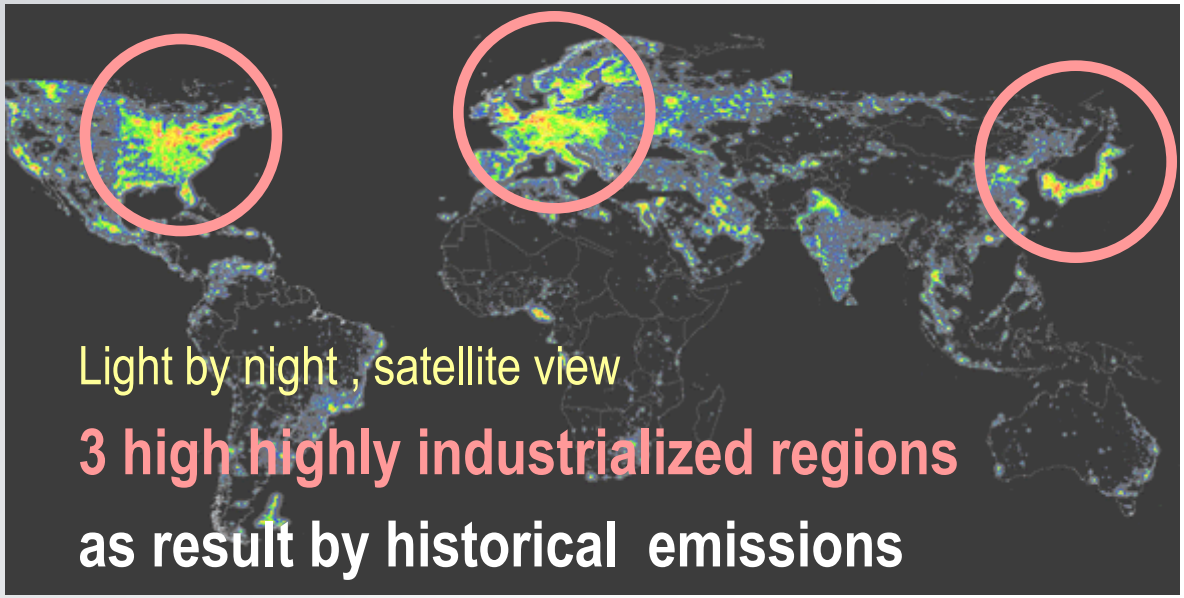
Who should pay ?

Historical CO2 ... ... have 2 implications



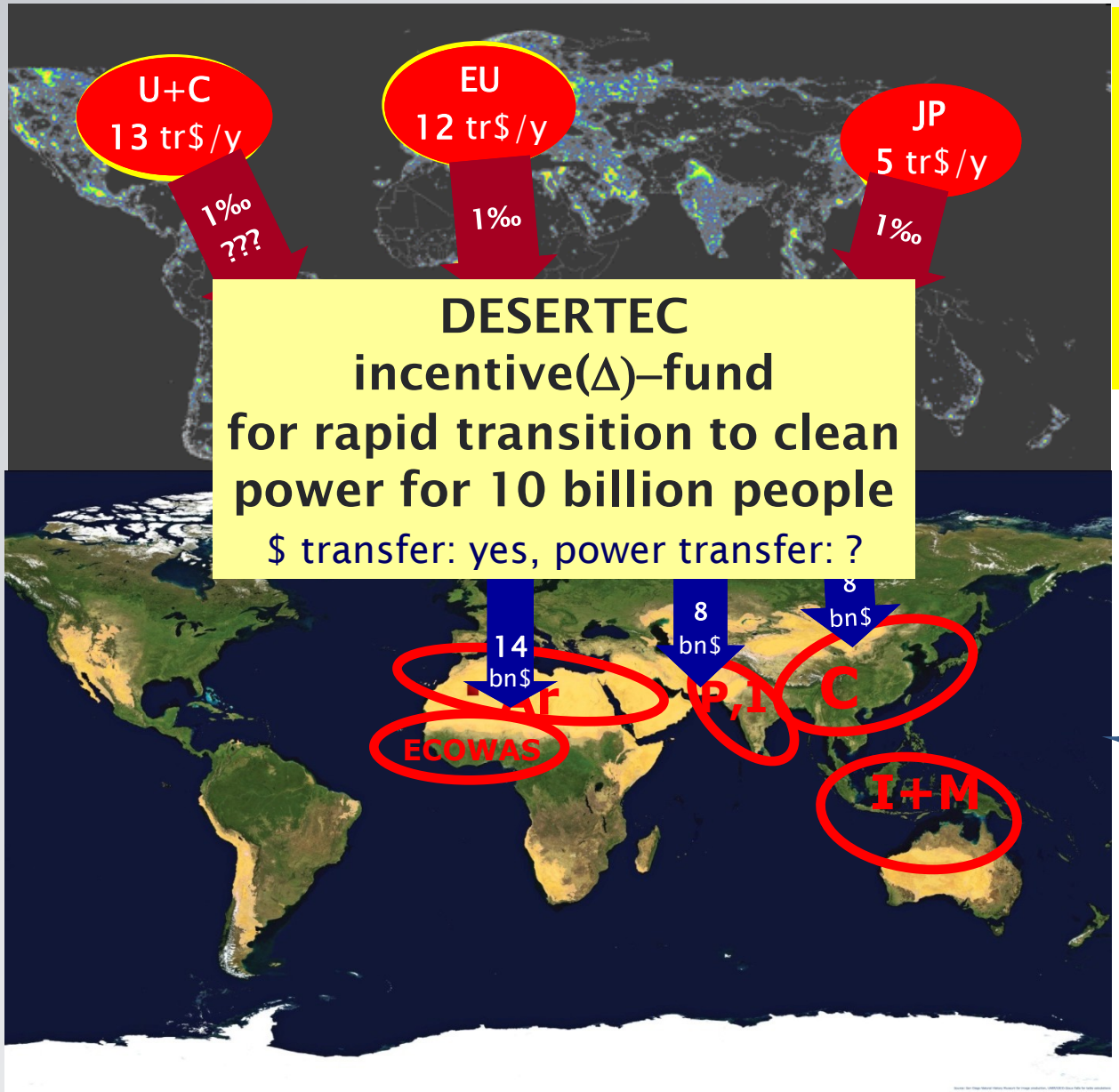
1. climate change
   = costs for all
2. industrialization
   = prosperity for few

3 early developed regions (EDR)
GNP per person
EDR: 34.200 $/y
LDR: 2.200 $/y



per person	
Hist. emissions	24 : 1
Present income	17 : 1

DESERTEC-Incentive(Δ) Fund for Human Security



3 industrialised regions
0.9 bn people:
total income advantage
31,000 bn $/y
mil. defence expenses
1,100 bn $/y

Desertec-Δ **10-80 bn $**

support for financing of *clean power from deserts* projects in

regions with rapidly growing power demand and good conditions for DESERTEC projects

DESERTEC FOUNDATION

A DESERTEC-Global Incentive Fund

for climate stability, energy security and more equitable development

➔ The DESERTEC Proposal:

With Δ–**money** of < 80bn$, as much(little) as

➔ 1 week global military spending, or

➔ ½ day GNP of industrialized world,

+ with 1% of global deserts

DESERTEC can ensure the availability of sufficient energy for

1. developed countries to continue
2. later developing countries to catch up ("Brot für die Welt")
3. stable climate for a world with 10 billion people.

In addition to climate conferences,

an emergency program for clean power implementation

with 10-80 bn $, and DESERTEC-Global Concept

Summary on DESERTEC

solution model for global climate and energy security

1. Clean Energy: commercial commodity AND basis of human security
2. The solar and wind energy resources for global energy and climate security are available, mainly in deserts
3. The necessary technologies (CSP, PV, HVDC) are developed and ready for large scale deployment
4. Powerful industry is getting involved (Dii GmbH))
5. The political goal of 2° limitation is now internationally accepted, but needs implementable enforcement plan
6. DESERTEC + D-alliances are a feasible solution model for the 2° goal
7. Time for national solutions is over
8. Clean energy for a sustainable world with 10 billion people is feasible

Thank you – gerhard.knies@desertec.org