Potential global biofuel production and its implications on CO_2 in air, water and soil.

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Agenda

- Problems on our planet
- Ostensible Solutions for climate
- Growing oil plants on bad soil
- Long time fixation of carbon in the soil as Terra Preta, Reduction of CO_2 in air and water
- Simulation of the replacement of fossil oil and coal by plant oil and solar thermal power plants
- Résumé

Problems on our planet

- Fossil energy carrier are limited and partly beyond maximal extraction
- Burning of fossil energy enhances CO_2-level in air and water

  → Causing more and stronger storms, heavier rain, longer droughts

  → seashells are losing their shell → collapse of food chains

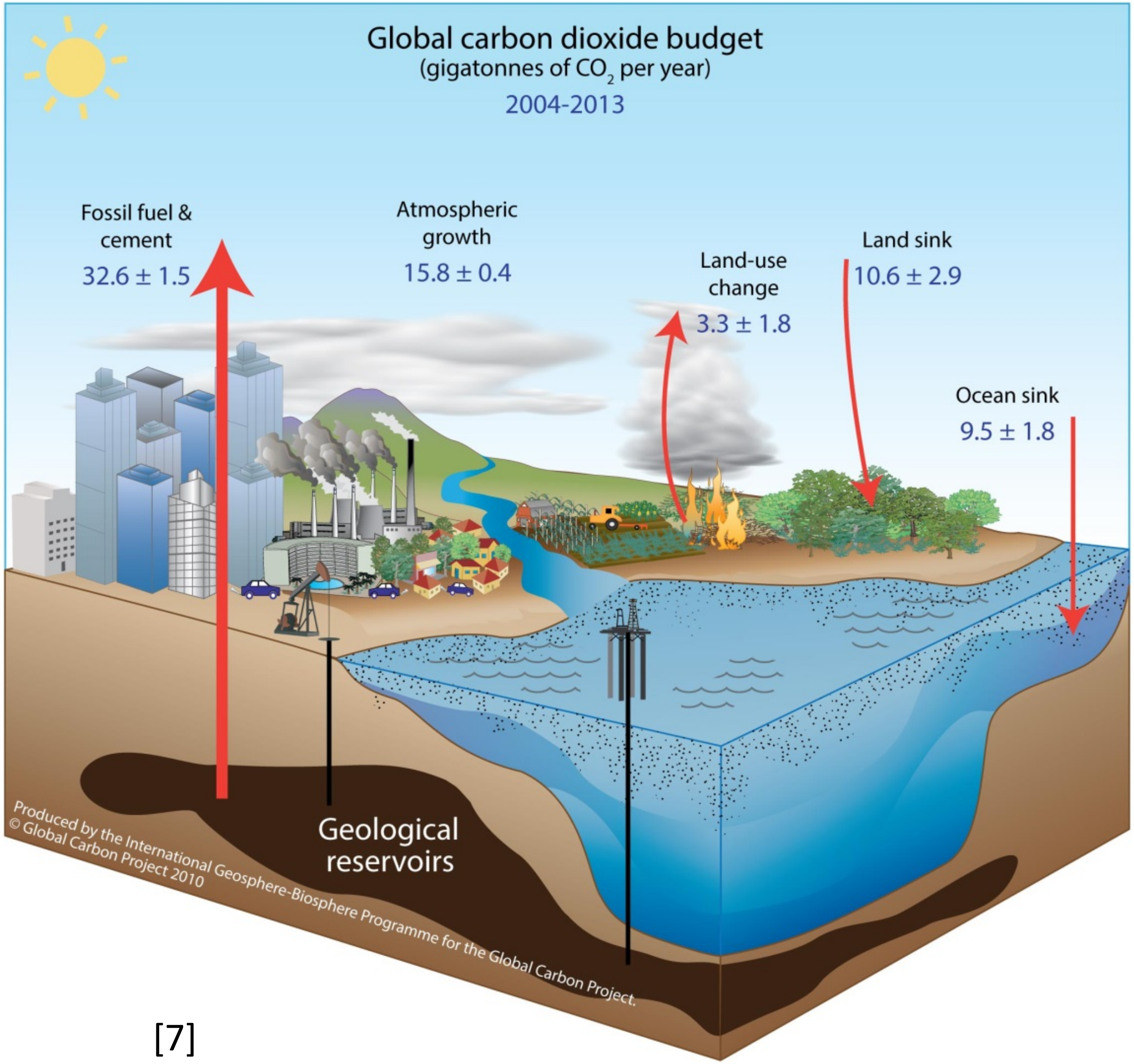
  → Rising sea level flood river deltas,

  habitat for some hundred million people
- Destruction of forests, degradation of soil → more CO_2 to the air
- Depletion of humus → lose of fertility → risk of global hunger
- Depletion of mineral resources like V, Mo, Cr and **most important PO_4**

Problems on our planet

- Nearly 800 million people worldwide are starving, mostly in developing countries.
- More than 2 billion people have no access to pure fresh water.

  Because of melting Himalaya glaciers this will soon be much more.
- Global Safety risks, → many million war and climate fugitives
- Every year huge areas of arable land are destroyed caused by wrong treatment, too much cattle, deep ploughing, wrong irrigation, use of mineral fertilzer, etc.
- Tropical rainforest is destroyed to grow sugar cane (in Brazil) or palm oil (in Malaysia, Indonesia) for the production of biofuels.



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29% of fossil CO_2-Emissions are bound by the oceans,

33% enhance growth of forests

38% rise CO_2-level in the air

Plus further 10% from deforestation and land-use change

Ostensible Solutions for climate change

- Adaption and mitigation are discussed.
  - Reduce solar input by SO_2 release in the high atmosphere.
  - Paint roofs white to reflect more sunlight.
  - Carbon Capture and Storage.
  - Breed plants, which can survive hotter climate.
  - CO_2 absorption by marine life and deposition on the sea floor.
  - CO_2 washing with amine or $NaHCO_3$.
  - Plant trillions of trees (good, but they will release CO_2 after cutting them down).
- All this will not reduce CO_2 fast enough if ever and emission will continue.
- Reduction of emission by 3%/year would be necessary
  → That has never be realized and CO_2-content will rise.

An Energethical Solution for Avoiding Climate Change and Peak-Oil.

- We need something that **replaces fossil oil** and coal.
- It should **reduce the carbon dioxide** in the air.
- It may not use land, which is now used for food production.
- It should not destroy rainforests.
- It should restore the degraded soil and give additional food.
- If a project can reduce hunger and scarcity of water,
  it is favorable to other concepts.

How much oil is needed?

- Crude oil world production in 2015: 29 billion Barrel = 4612 billion liter
- Oil yield of different plants in L/ha Produced in t/year

Oil palm	4.000 – 6.000	10 Mio.
Cocos nut	9.500 – 12.000 fruits/ha	4,8 Mio. (1996)
Jatropha curcas	750 – 10.000	
Soya oil	640 plus protein	38,8 Mio.
Castor bean (Rizinus)	…….	0,75 Mio.
European plants for oil	L/ha	
Raps	1500	3,6 Mio.
Sunflowers	1500 ?	11,5 Mio.
Leindotter	700 – 1050 in between wheat possible, covers soil	
Olive tree	4-6 L/tree	

- ….. There are 3500 different oil plants on earth

How much oil is needed?

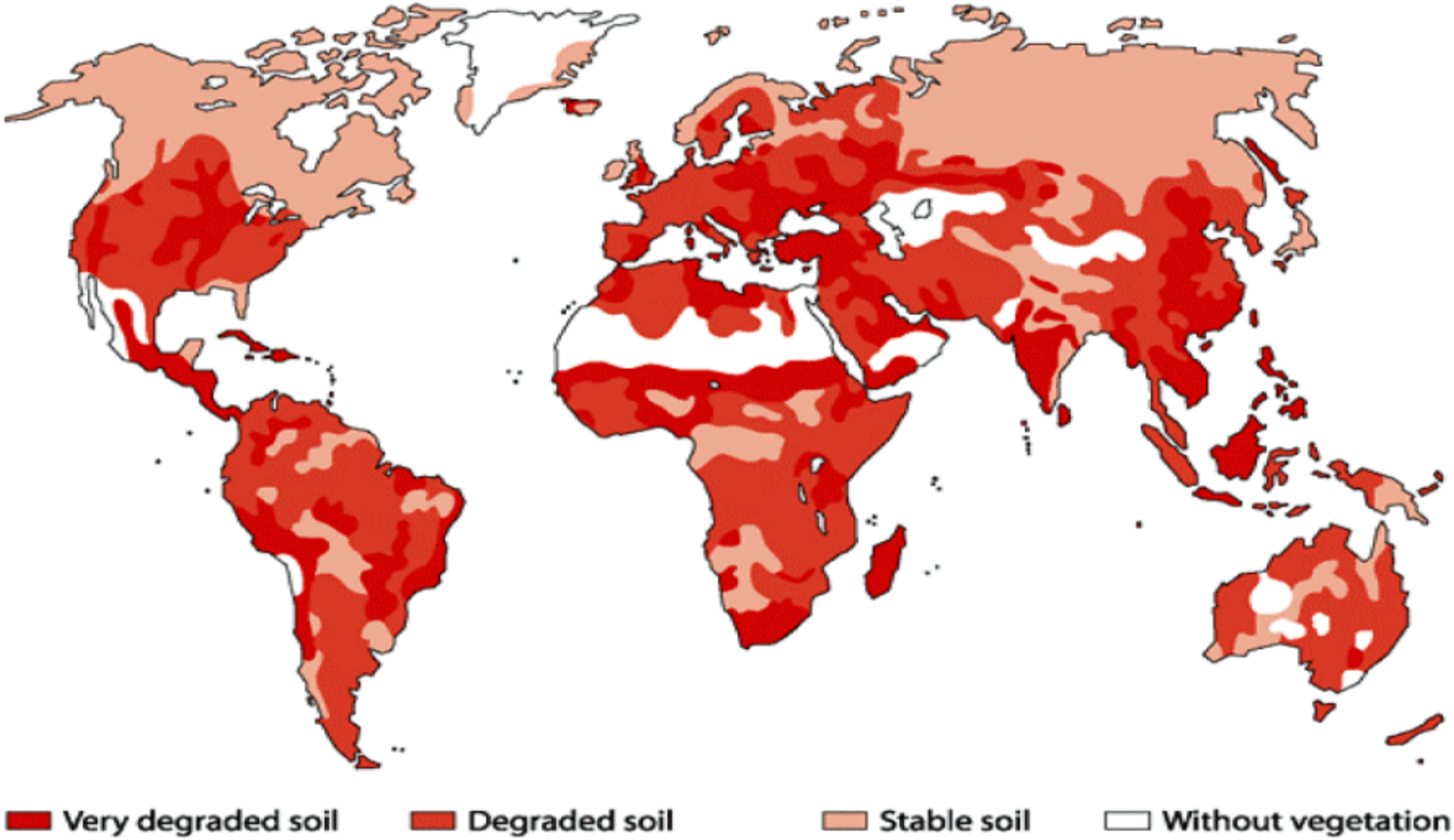
- Oil yield: Palm oil, Jatropha curcas : 4,000 – 10,000 $liter/hectar$
- Production area if all fossil oil should be replaced:

$$4.612 \cdot 10^{12}\ liter/4200\ liter/ha = 1{,}1 \cdot 10^{9}\ ha = 11\ million\ km^{2}$$

- For comparison: Worldwide we have made 20 million km^2 degraded land and 36 million km^2 deserts.
- During the last 1000 years 10 million km² were degraded.

Bio-diesel from Jatropha plantations on degraded land

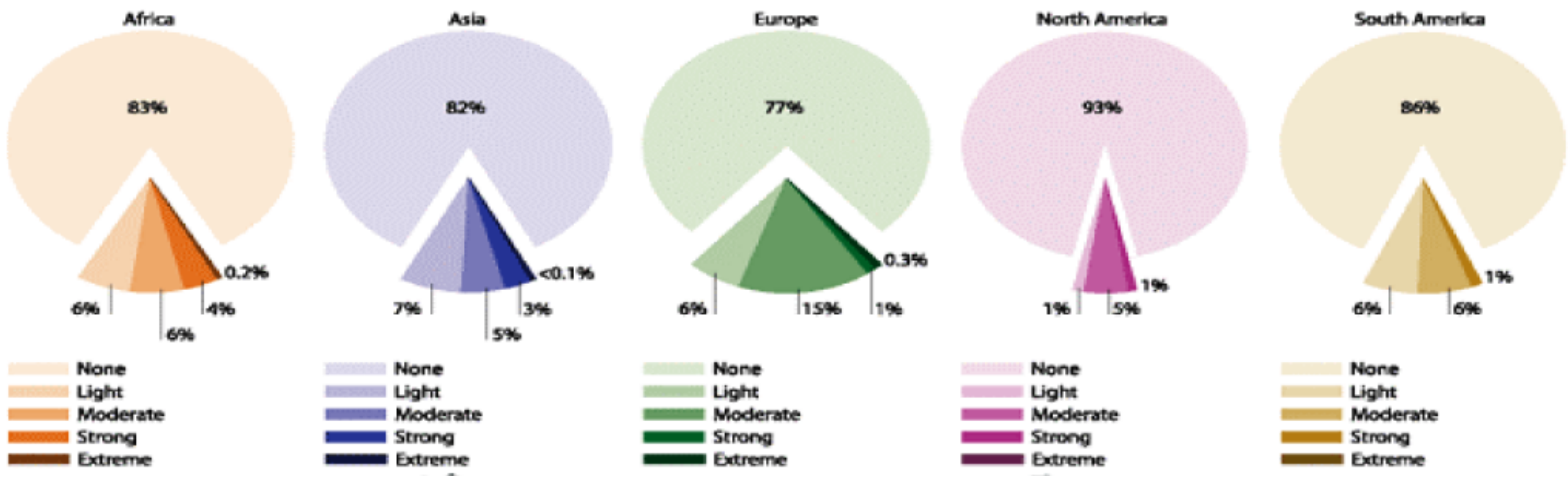
Prof. Dr. K. Becker and Dr. G. Francis



Distribution of degraded land in the different continents (Source UNEP)

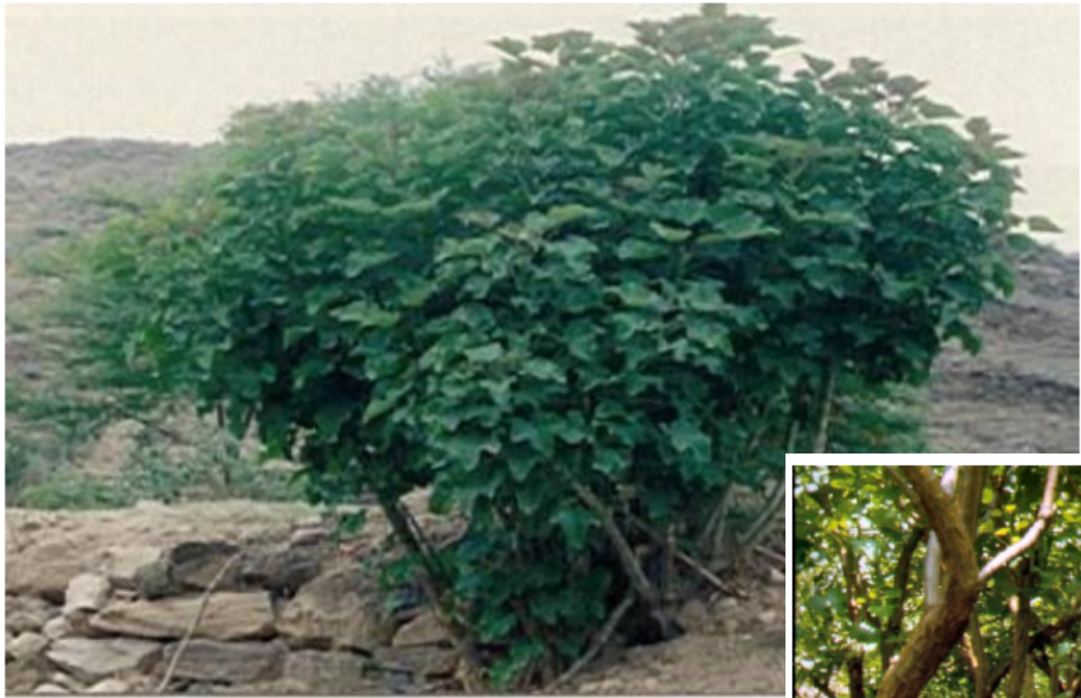
2000 million ha land has been degraded in 3000 years,

that is 15% of the earth‘s land area



Land used for cereals, vegetables and fruits:
Land used for cattle:

For example Jatropha curcas



Vigorously growing Jatropha plant on rocky substrate

Vegetables intercropped between rows of Jatropha plants – agro forest system (Photo: K. Becker)

How many workers are needed?

- One worker can plant, cut and harvest 5 - 8 ha .
- So he will get 25,000 – 40,000 liter/year.
- Number of workers: $1{,}1 \cdot 10^{9}\ ha/5\ ha/worker = 220$ million .
- If a family has 3 children, there are 550 million people.
- They need food, which is produced on additional

  0.5 ha/person, so 275 million ha arable land is added.

- 1090 + 275 million ha = 1365 million ha are to be planted.
  - This is less than 70% of the degraded land
    - which will be restored.

For example Jatropha curcas

- Jatropha curcas plantation in Madagascar, unripe, ripe and peeled nuts
- Reinhard K. Henning, The Jatropha System, An integrated approach of rural development

DaimlerChrysler jatropha biodiesel project in India

At the beginning

First plantings

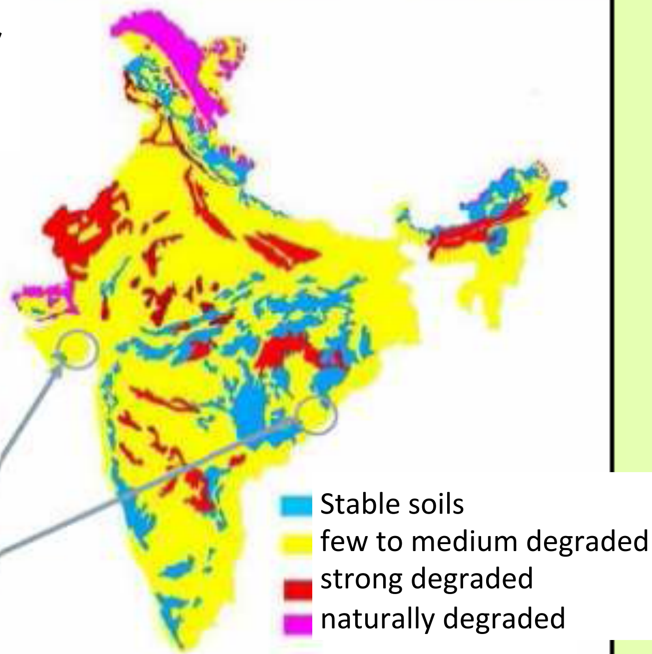
After some years

Driving with biodiesel

Quelle: DaimlerChrysler, Jatropha – Biodiesel from Eroded Soils, A Concept for Sustainable Mobility in Developing Countries, RBP/CF July 17, 2006

Degraded soils in India

- In India are 130 million hectare degraded land
- 33 million hectare are available for planting Jatropha curcas
- Political programs for recultivation are at work



Quelle: DaimlerChrysler, Jatropha – Biodiesel from Eroded Soils, A Concept for Sustainable Mobility in Developing Countries, RBP/CF July 17, 2006

How much water is needed?

- Example: Jatropha curcas
- Jatropha curcas grows with rainfall of at least 300 - 1000 mm on bad, but good drained soils. Survives 6 month without rain.
- No competition with food.
- Yield: 2500 to 5000 kg/ha (sometimes 10000 kg/ha) dried black seeds
- Oil content: 30% - 35% (up to 46% reported)
- Oil yield: 875 – 1500 Liter/ha on dry land
  (10000 Liter/ha reported from Jatrophacurcas-plantations.com
  5520 Liter/ha, dry Land, irrigated
  3600 Liter/ha, arid, irrigated from Biodieseltechnocrats.com)

$$\mathbf{600\ dm^3\ water/m^2 \cdot 10000 m^2\ /ha\ /1500 dm^3\ /ha\ oil = 4 m^3\ water/dm^3\ oil}$$

- Water must be cheap!

How to get enough water?

- Seawater desalination is possible in industrial scale.
- The remaining salt content for irrigation may not be higher than 25 mg salt/kg water (FAO).
- Energy demand for thermal desalination:

  ~50 kWh_{heat}/m^3 water and 2-3 $kWh_{el.}$ Energy /m^3 water

or

- Reverse Osmosis 4-5 $kWh_{el.}$ Energy /m^3 water

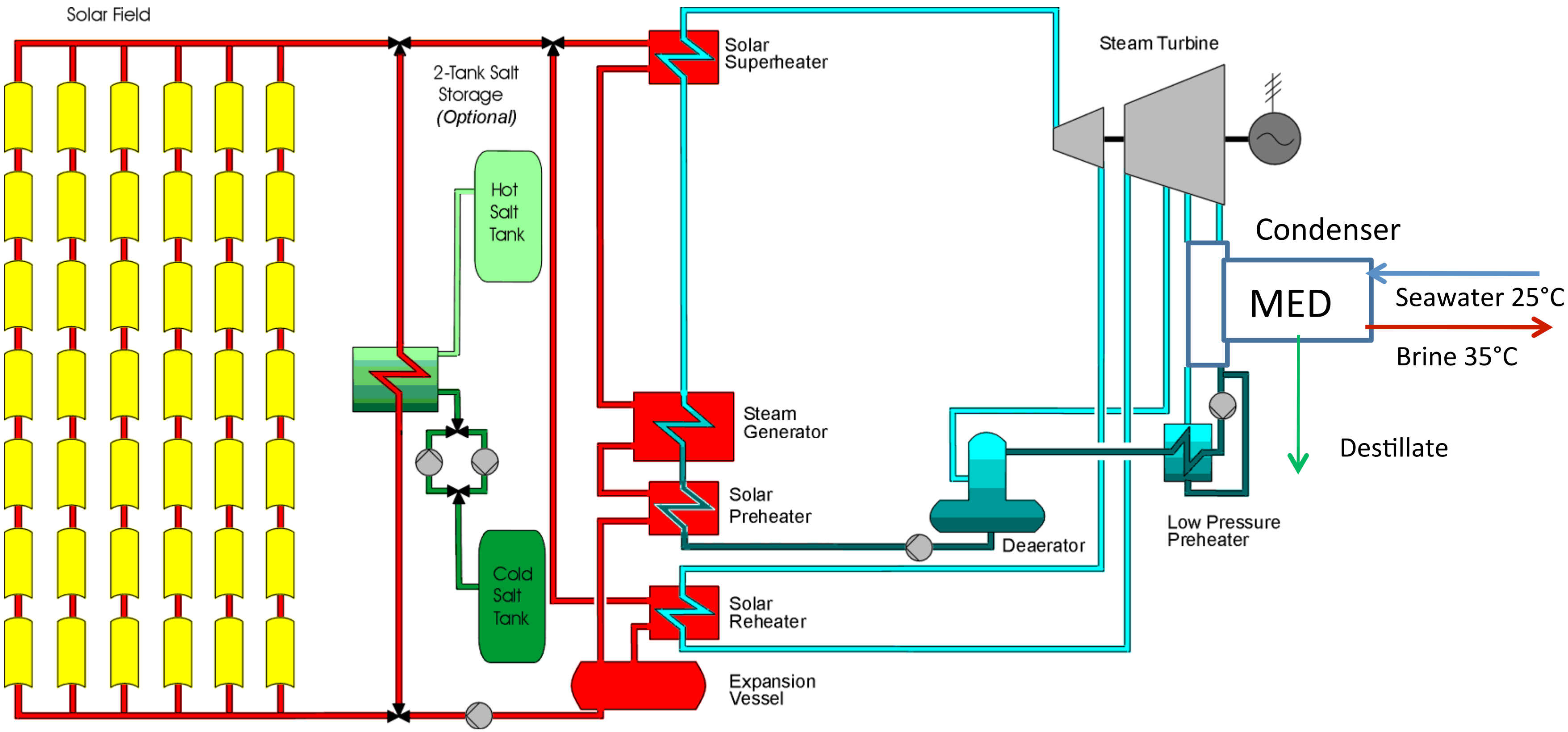
Desalination types, properties, energy demand

- Seawater desalination methods:
  - Reverse Osmosis (RO) needs high pressures pumps 4-5 $kWh_{el.}/m^3$,
    Membranes have to be replaced every 18 Month
    salt content: > 50 mg salt/kg water.
  - Multi stage flash evaporation (MSF)
    ~45-50 kWh_{th}/m^3 heat at 120°C, 2-3 $kWh_{el.}/m^3$
  - Multi effect distillation (MED)
    ~45-50 kWh_{th}/m^3 heat at 80°C, 2-3 $kWh_{el.}/m^3$
    salt content : < 25 mg salt/kg water.

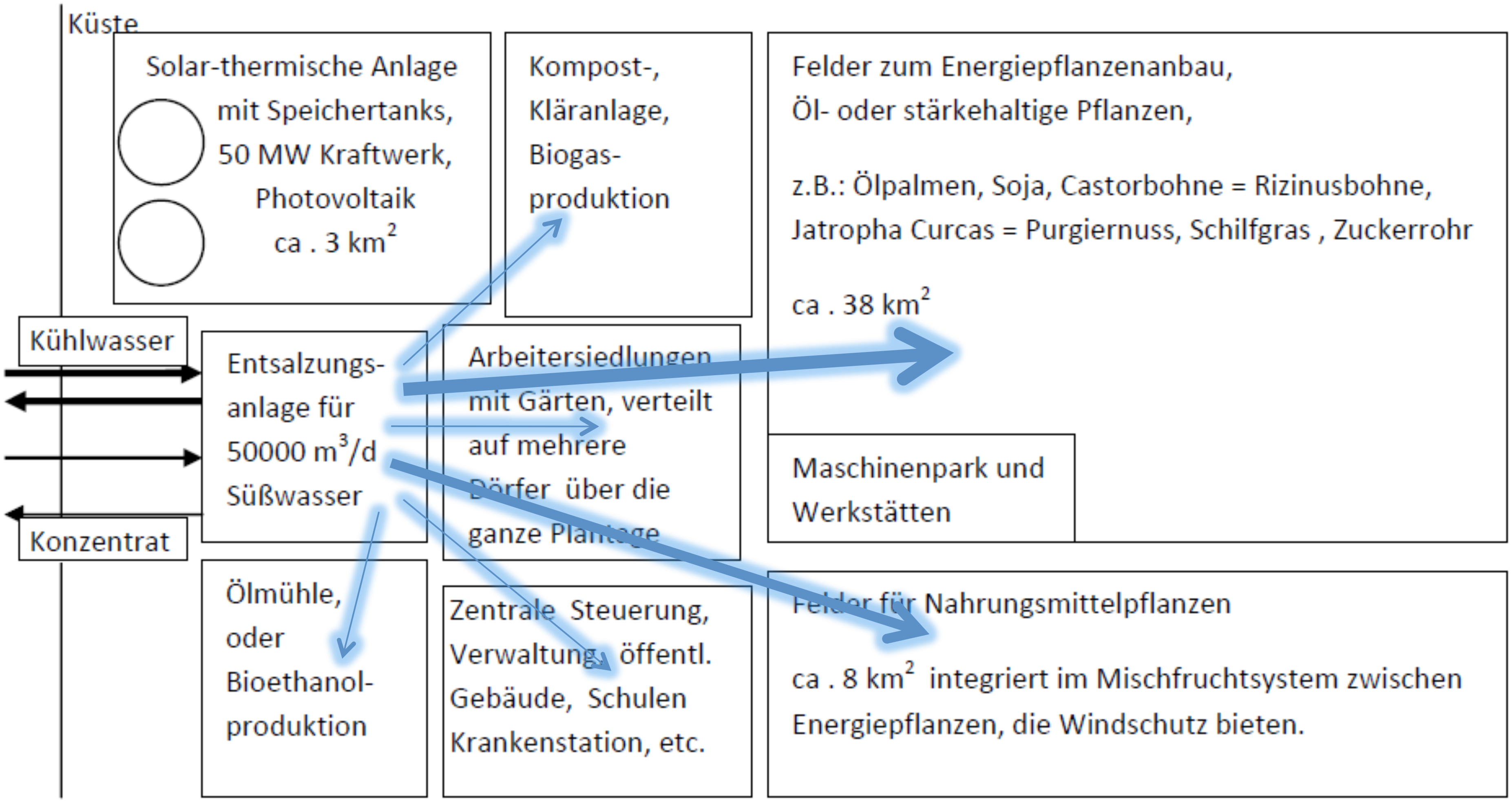
Energy supply

- Heat is abundant in deserts and tropical regions.
- Combination with solar thermal power plants.
- One 50 MW_{el} power plant (Andasol 1) has ca. 93 MW waste heat at 80°C
- With this it is possible to gain 50.000 m^3 per day fresh water (44,64 kWh/m^3).

Combined heat and power plant with thermal desalination



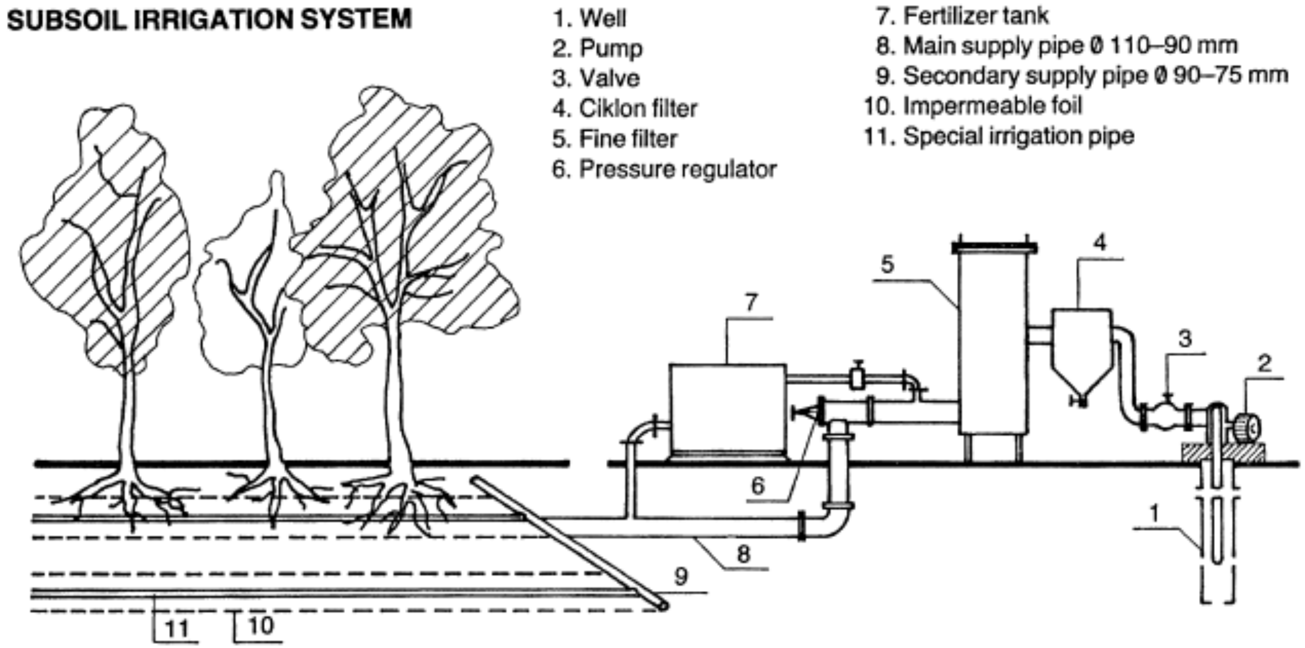
Concept of combined solar thermal power plant, desalination, irrigation and oil and food production



Efficient Irrigation

- Evaporation rates in tropic regions are very high. So efficient usage of water is necessary.
- Subsoil irrigation needs only 25% - 30% of the amount of water compared to sprinkler systems.
- For various crops up to 200 liter/($m^2 * a$) are necessary with usual irrigation.

- Yields are ca. 30% higher.
- Here we calculate with 400 $dm^3/(m^2 * a)$.



H.K. Barth, Sustainable and effective irrigation through a new subsoil irrigation system (SIS), Agricultural Water Management 40 (1999) 283-290

Carbon capture and storage **in biomass**

- The oil will be burned instead of fossil oil.
- Burning coal can be reduced (solar thermal power plant).
- Additional CO_2 will be bound in the biomass.
- 50 – 70 t/ha pruning can be harvested every year.
- Nearly 50% is carbon, taking > 91,6 t/ha CO_2 from the air.
- Converting this dried pruning to bio char by pyrolysis or HTC will release 1/3 of the carbon again.
- 16,6 t/ha bio char will be left to store it in the soil.
- This bio char can not be oxidized by microbes.
- Thus it stays in the soil for at least 2000 years.
- This Terra Preta makes soil more fertile and stores water.

Compensation for CO_2 releasing of the atmosphere

- 60 t/ha CO_2 are at least taken from the air.
- More is bound in the roots and the trunk.
- CO_2 bound in leaves will be reemitted after 2 years.
- If the planter gets 20 €/t CO_2, he receives 1200 €/ha
- This reduces the costs for plant oil 1200 € / 2500 liter =0.48 €/liter
- The final costs are 0.92 €-0.48 € = 0.44 €/liter
- This is only necessary for startup.
  After some years yields/ha are growing
- For comparison:
  crude oil was in 2014 at $US 88.94/br
  =88.94/1.2659/159 €/litre = 0,442 €/litre

Long time results

- 20 years with 16.6 t/ha bio char will enhance the carbon content of the soil to 33.2 $kg/m^{2.}$
- Additional 16.6 kg/m^2 will be bound in the humus as microbes.
- 50 kg/m^2 carbon in 15 cm soil means 50/300 = 16,67%
- Thus restoring fertility and water storage capability.
- Yields can be expected to rise at least 100%

Long time results

Left: compost

Right: compost with 15% bio char,
Source: Dr. Bruno Glaser,
University Halle/Saale

How much CO_2 is taken from the air?

- 50 kg/m^2 * 11 million km^2= $550*10^{12}$ kg C
- $550*10^{12}$ *44/12 kg CO_2 = $2016,7*10^{12}$ kg CO_2 will be bound in the soil in 20 years.
- Since 1850 we released

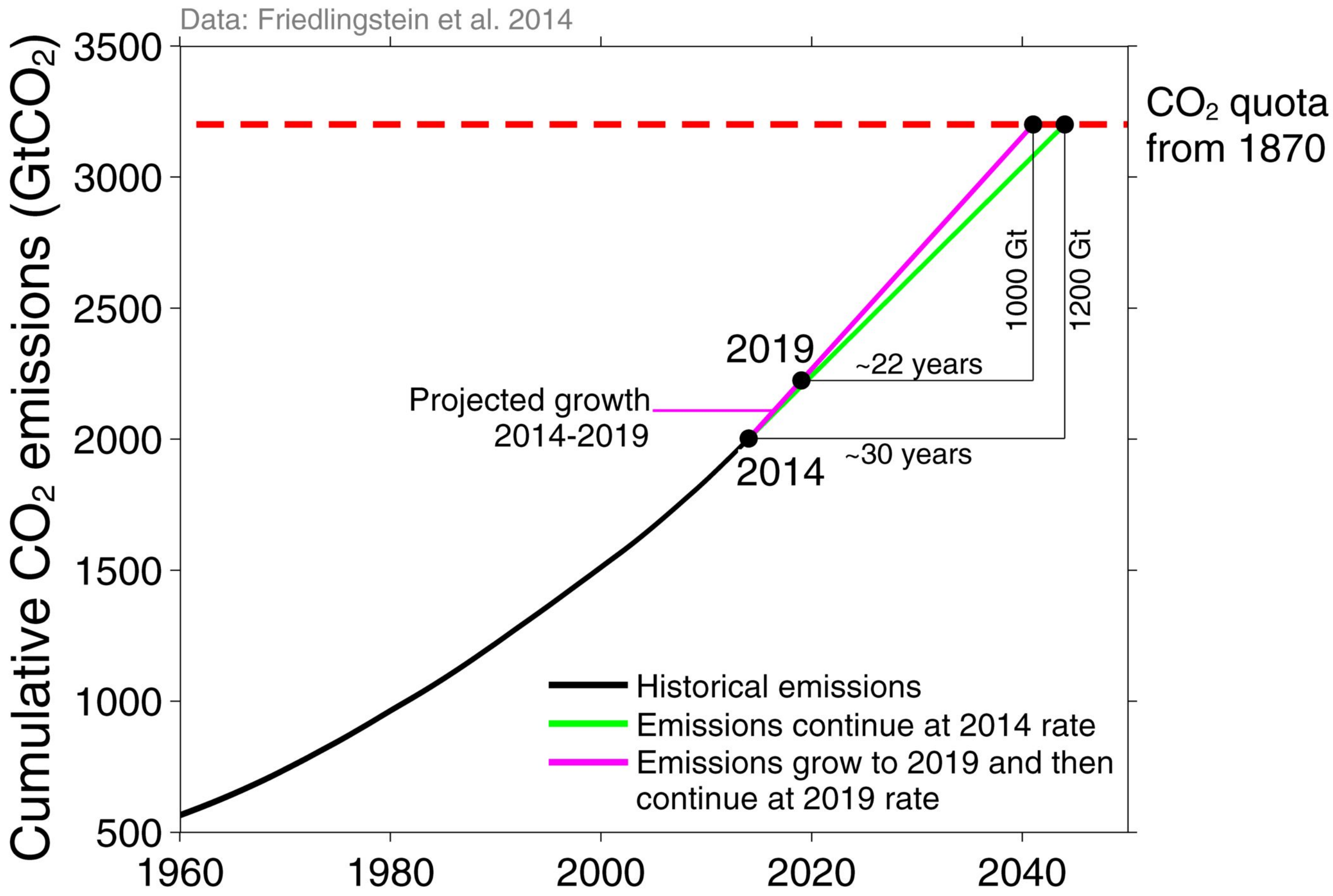
2000 billion t CO_2=$2*10^{15}$ kg CO_2

This implies no additional CO_2 is released.
All burning of fossil fuel is stopped immediately.

This is not possible, but we should start soon and replace every coal and nuclear power plant by a solar thermal power plant.

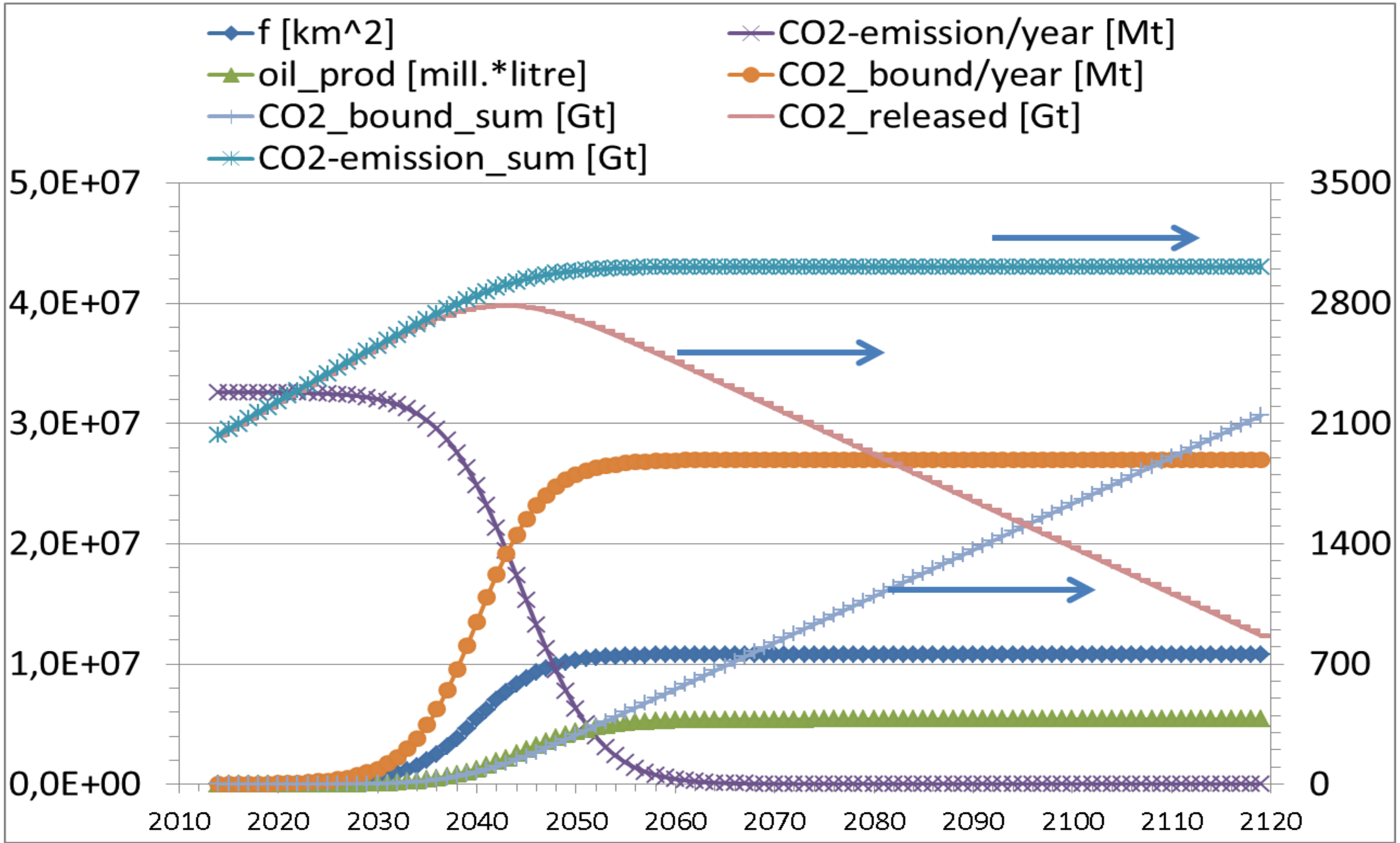
Planting of nearly 11 mill. km^2 will last some decades, while more CO2 will be emitted.

How much CO_2 is added to the air since 1870?



How long will the replacement last?

- If a natural growth is assumed, the area for plant oil production will look like this:



Resumé

- These plantations can deliver plant oil to replace the dwindling fossil oil.
- The trees will bind much more CO_2 than is bound in the oil and set free in burning the oil.
- Converting this biomass to bio char and building Terra Preta will help to enhance water storage capability and fertility of the degraded soils.
- CO_2-content in air and water can be reduced to pre-industrial level
- Between the energy plants food for 550 million people can be produced. Water scarcity is reduced.
- Education possibilities for these people are possible.
- The solution is sustainable and ethical.

Thank You for Your attention

Sources:

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8. Technology Review, July/Aug 2006

Recommended Books:

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- David R. Montgomery: Dreck, Warum unsere Zivilisation den Boden unter den Füßen verliert, oekom-verlag, 2010

What will this plant oil cost?

- Efficient usage of water and higher yield give 400% efficiency compared to sprinkler systems
- Water needed for 1 liter oil ~ 1.6 m^3
- Only 4/5 of the area will produce plant oil, 1/5 is needed for food production. Plus water supply of the workers and their families.

Costs of waste heat (0,95€/GJ) 0,00174 €/kWh * 50 kWh/m^3=	0,087 €
Electricity for pumps 3 kWh/m^3 * 0,05 €/kWh =	0,150 €
Costs for desalination installment /m^3 water	0,102 €
Costs for irrigation system /m^3 water	0,200 €
Maintenance and Personal /m^3 water	0,050 €
Total costs for water /m^3 without interest	0,589 €
Total costs for water /m^3 with interest (8%/a for 28 a)	1,37 €

What will this plant oil cost?

- Costs for water in plant oil: 5/4*1,6*0,59€ = 1,18 €/dm^3 oil

  for 2500 litre oil/ha. May be lower if yields are higher.

- Working costs:
  - One worker can harvest 30 kg/h, with 10-12,5 Liter oil
  - 10€ for 8h wage → 10€/80 liter -10€/100 liter → 0,1 -0,125€/ liter oil
  - In 50 weeks with 5 days a worker gains 2500 €
    for comparison : wage of a teacher in Ghana: 2500 €/a

Working costs per Litre oil=	0,100 €
Water costs per Litre oil (if necessary) =	1,180 €
Total costs per Litre oil without interest	1,28€
Water costs per Litre oil with interest =	€
Total costs per Litre oil with interest =	€