The NeXus of – Water, Food, Energy
Project at TUM

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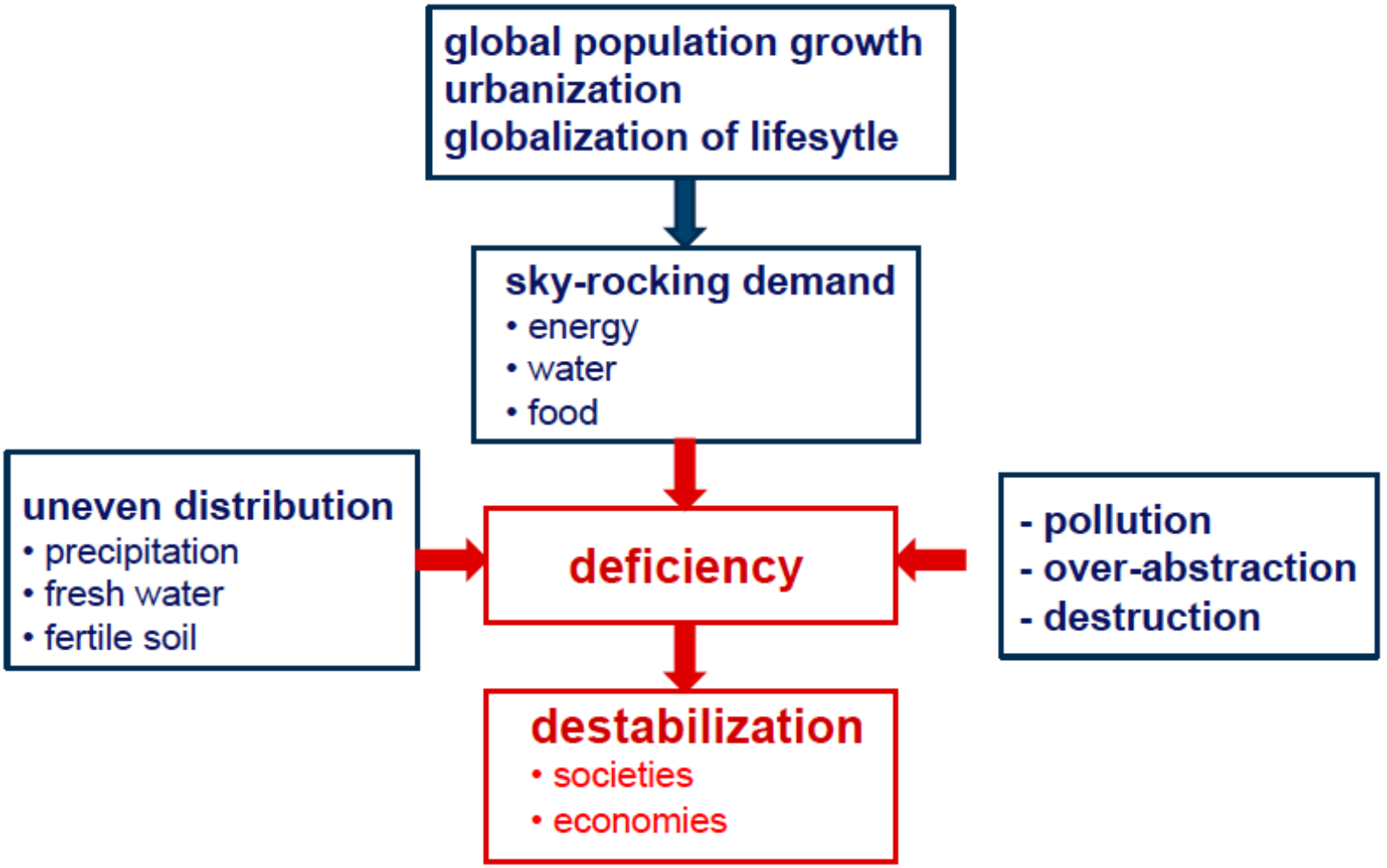
THE PROBLEM



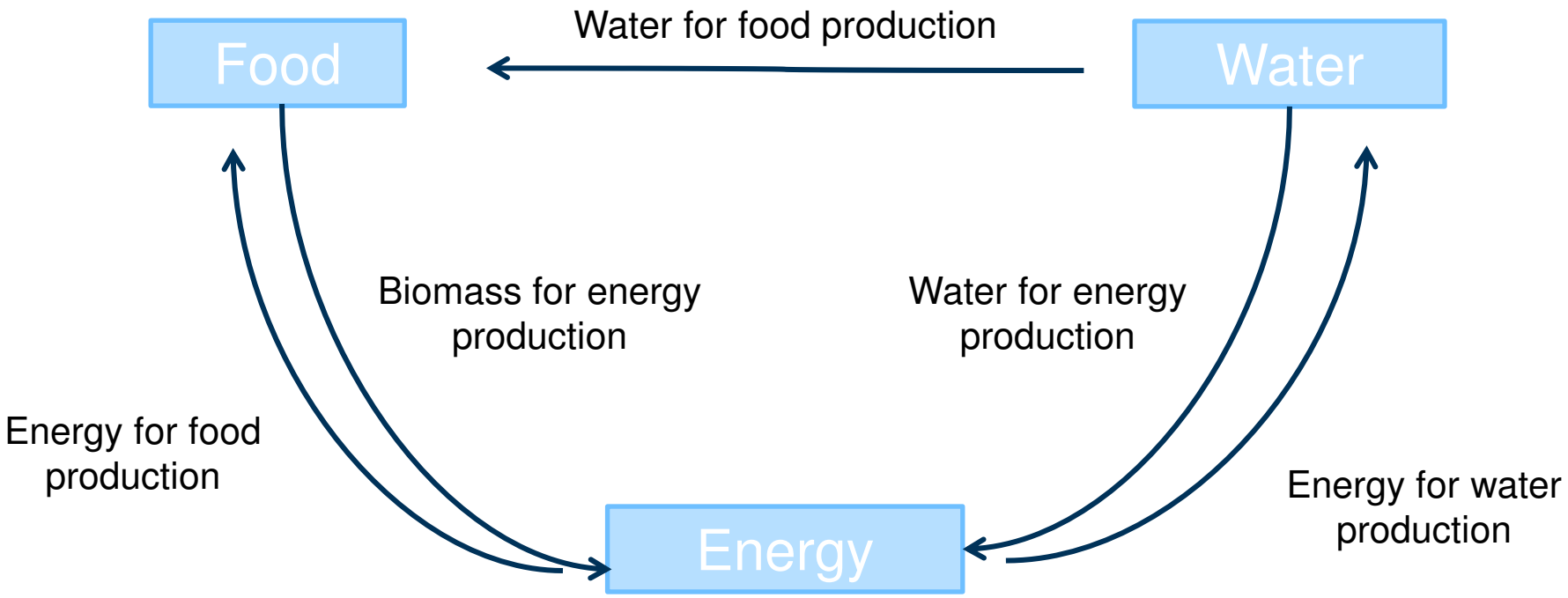
Courtesy: Prof. P. Wilderer

WATER FOOD ENERGY NEXUS

All three sectors are deeply intertwined

Therefore trade-offs are needed between energy, food and water in terms of resource allocation and planning.

The dependencies between the three fields:

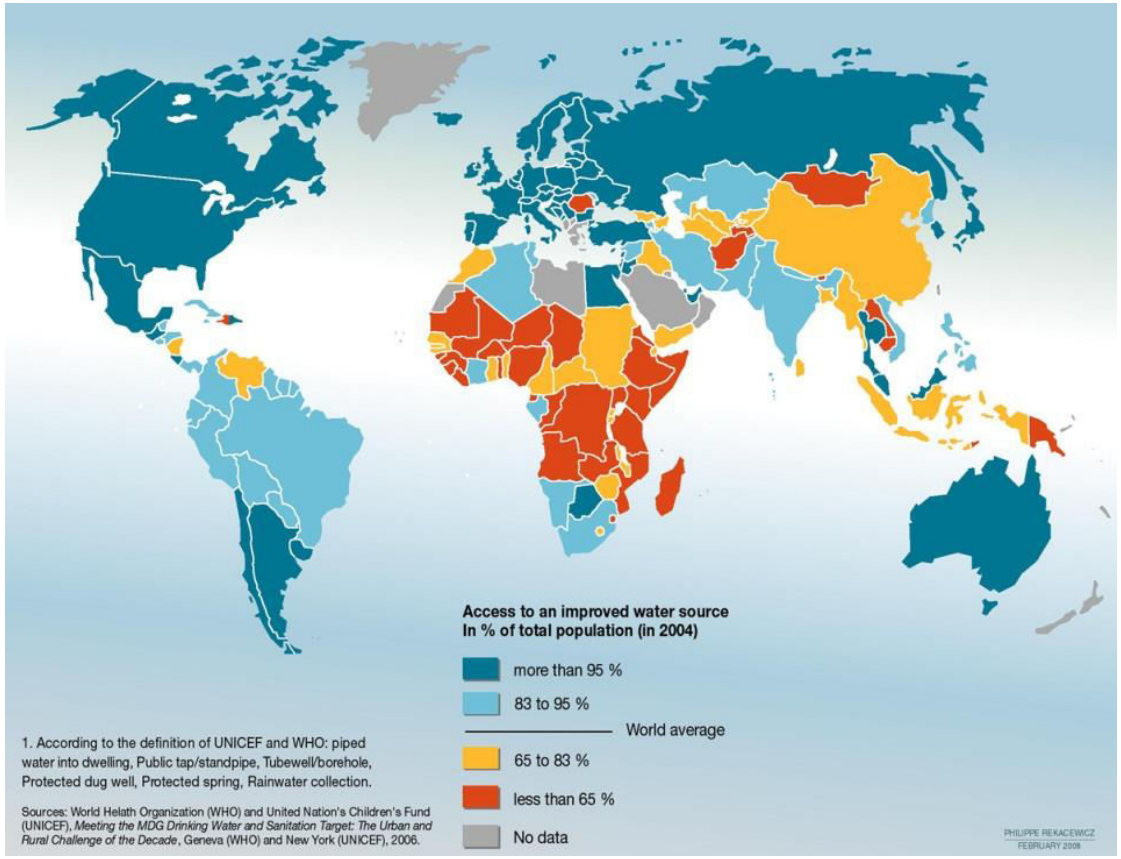


WATER RESOURCES

Since September 2010 the right to water and sanitation is a human right

Water security is defined in the Millenium Development Goals

However, there are 884 million people lacking access to safe drinking water and more than 2.6 billion miss a basic sanitation

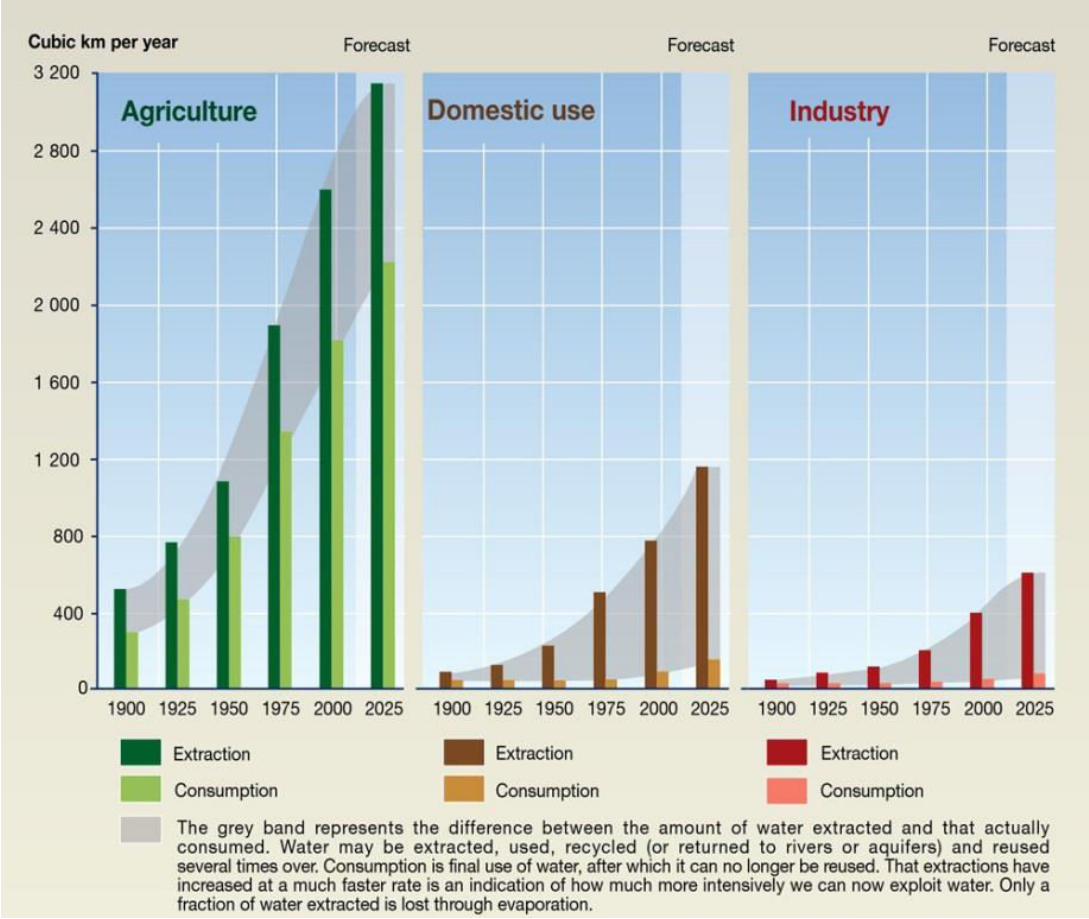


Source: WHO/UNICEF, Meeting the Drinking Water and Sanitation Target: The Urban and Rural Challenge of the Decade, 2006

WATER RESOURCES

Annual global freshwater withdrawal has grown from 3,790 km³ in 1995 to 4,430 km³ in 2000

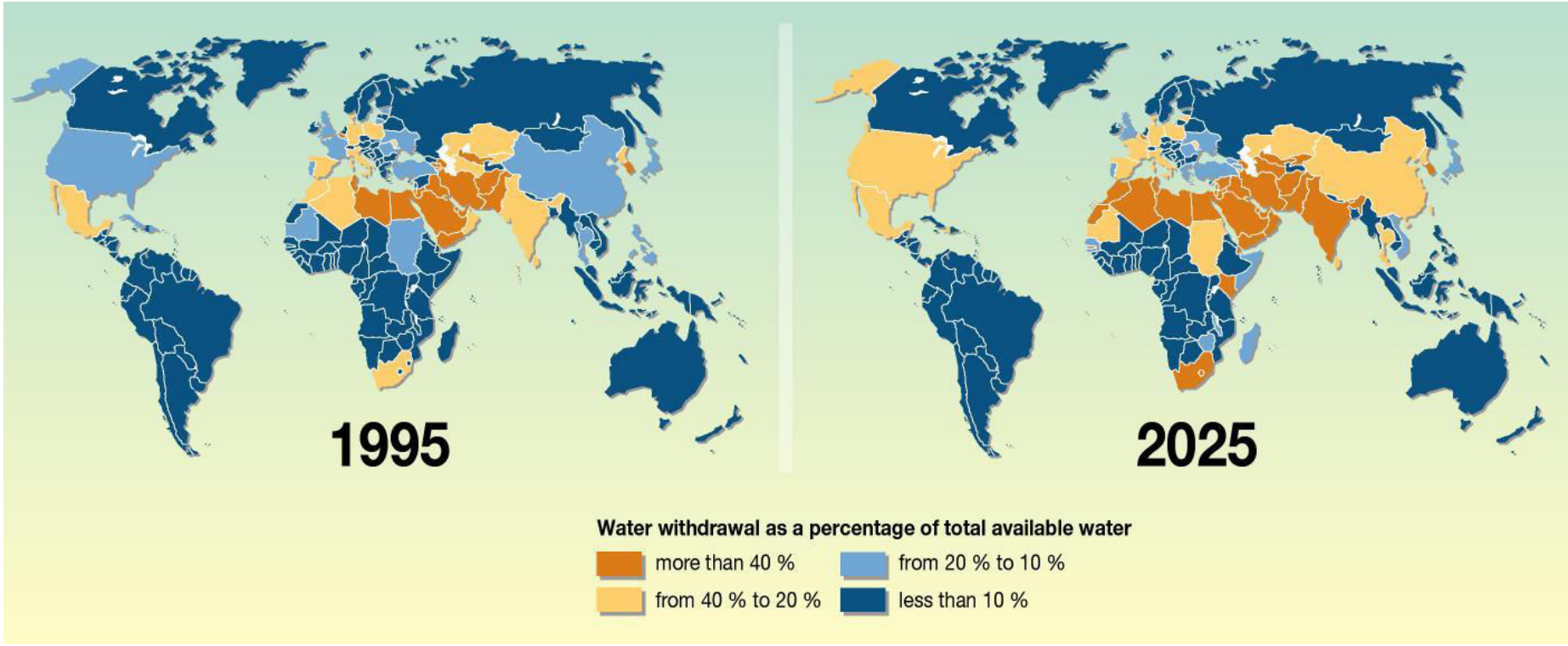
It is expected to grow about 10-12% every 10 years, reaching approximately 5,240 km³ by 2025



Source: Igor A. Shiklomanov, SHI St. Petersburg and UNESCO Paris, 1999.

WATER RESOURCES

Due to growing population, climate change, abstraction and pollution, water stress will be dramatically amplified



Source: http://www.unep.org/dewa/assessments/ecosystems/water/vitalwater/21.htm#21b

FOOD AND AGRICULTURE

Adequate food security is a human right

Global food production is sufficient to “feed the world”

However, food distribution in the world is very uneven

Today, roughly 1 billion people are undernourished

Scarcity and degradation of land and water pose a growing threat to food security

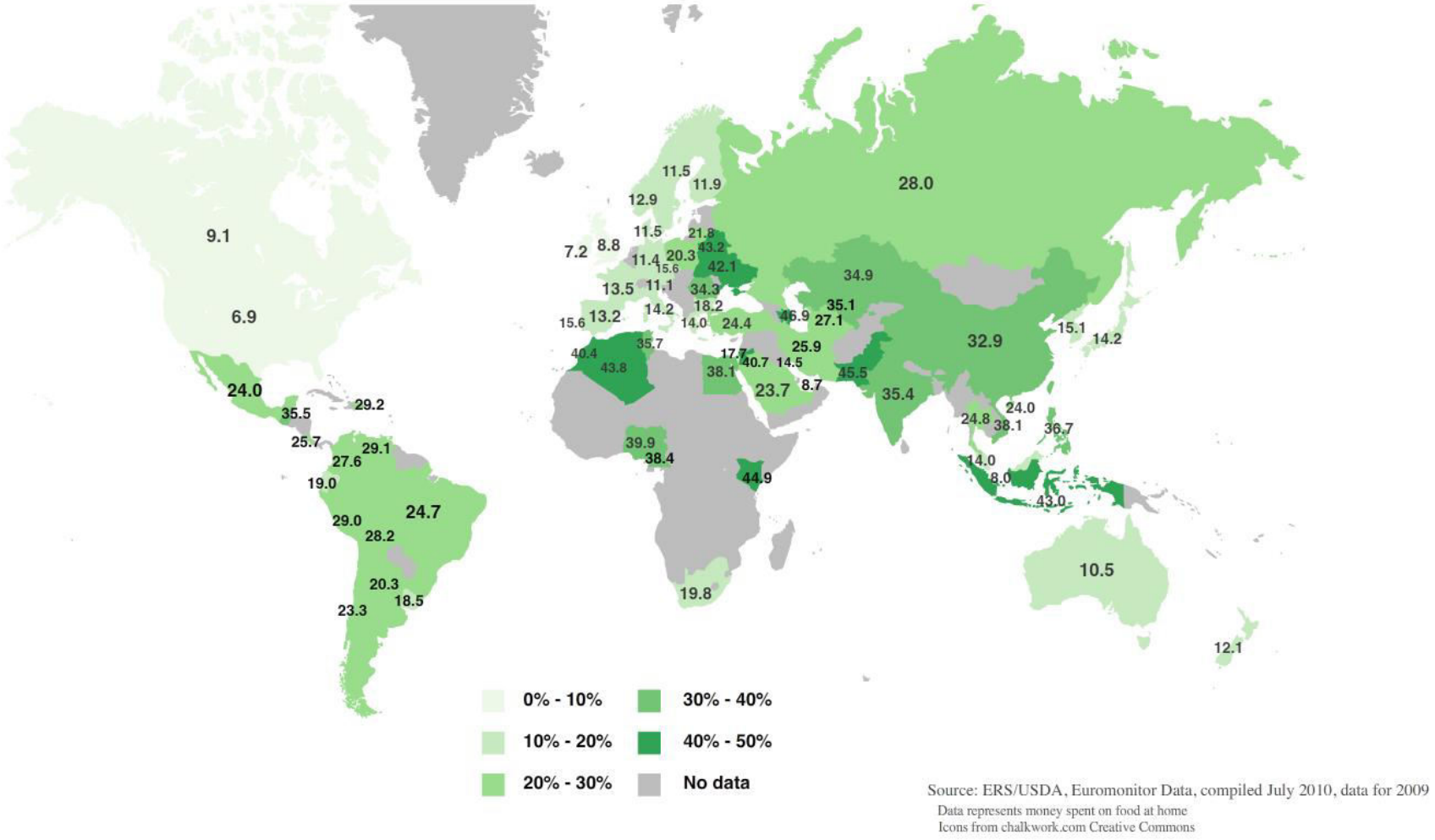
Feeding a global population of 9 billion people in 2050 requires a 70% increase in total food production

Poverty and under-nourishment will grow with the uncertainty of food supply

High market volatility and high domestic food prices create a threat to the food security of poor consumers

FOOD AND AGRICULTURE

Total expenditures spent on food in different countries



Source: ERS/USDA, Euromonitor Data, compiled July 2010, data for 2009.

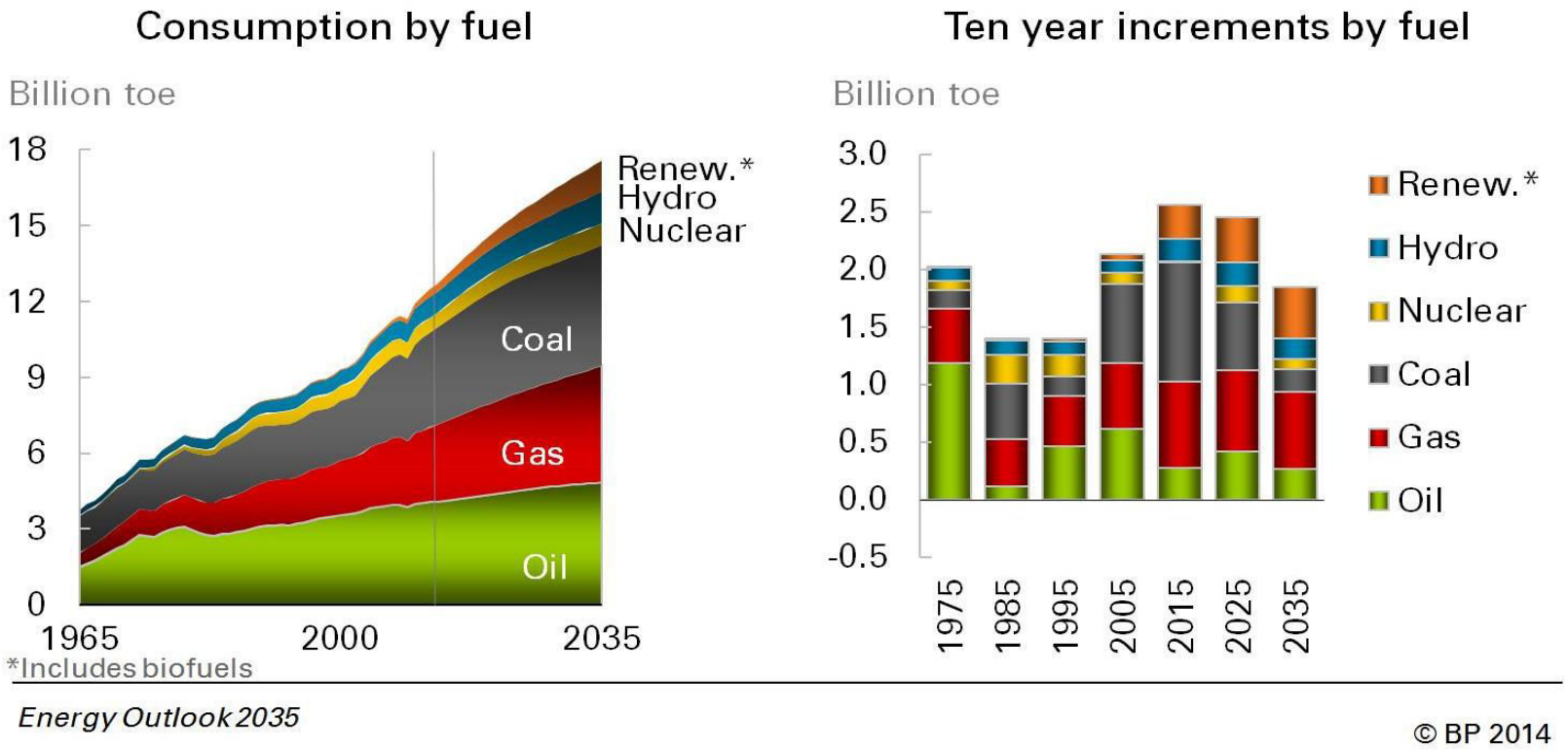
ENERGY

The total world energy supply in 2010 was 140,168 TWh

85% of which are covered by fossil fuels

Global Energy demand requires an increase of 39% in energy production until 2030

Almost all (96%) of this growth is in non-OECD countries



Source: BP Energy Outlook 2035, Washington DC, 2014

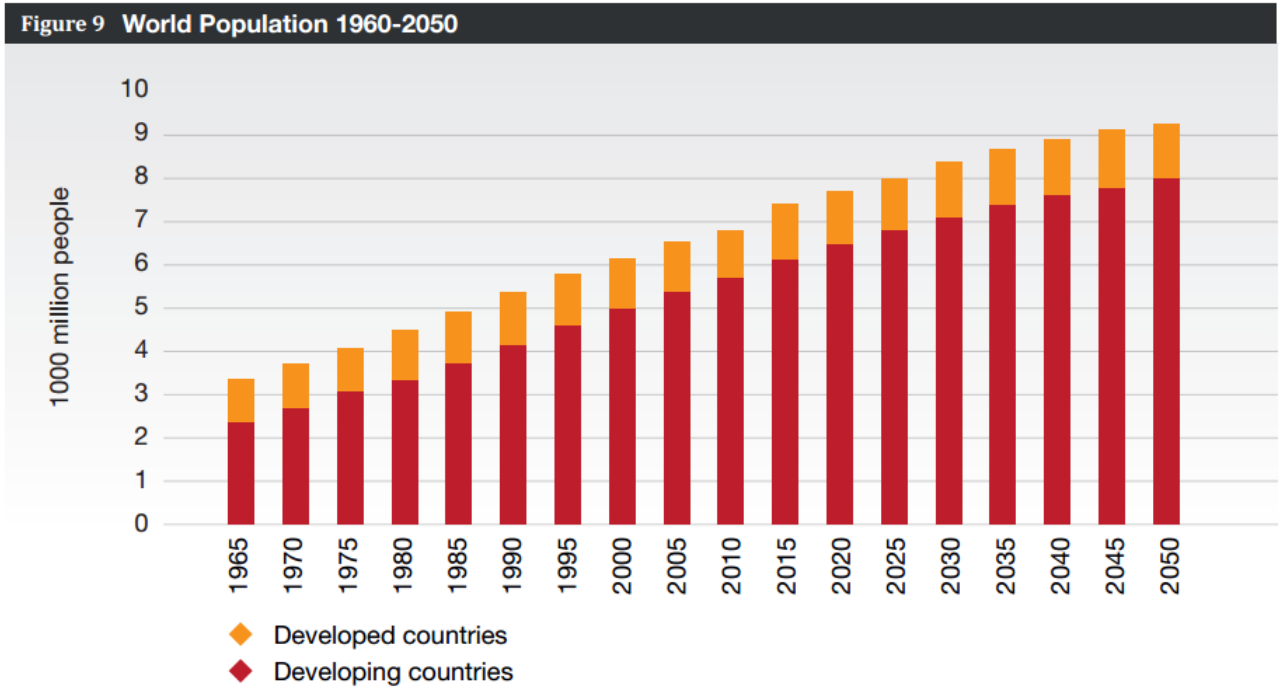
NEXUS IMPORTANCE

Water, Food and energy are basic necessities for robust economies and stable political systems

Nowadays there are already big problems and risks

Driven by population growth and economic development, global food, water and energy requirements are expected to increase significantly

There will be a trend for population concentration in cities mostly in “new cities” which are planned in traditional ways with overcome concepts



Source: World Economic Forum Water Initiative, edited by D. Waughray (2010). Water Security: The Water-Food-Energy-Climate Nexus, based on United Nations Population Division, UN-DESA, UN Revision 2008

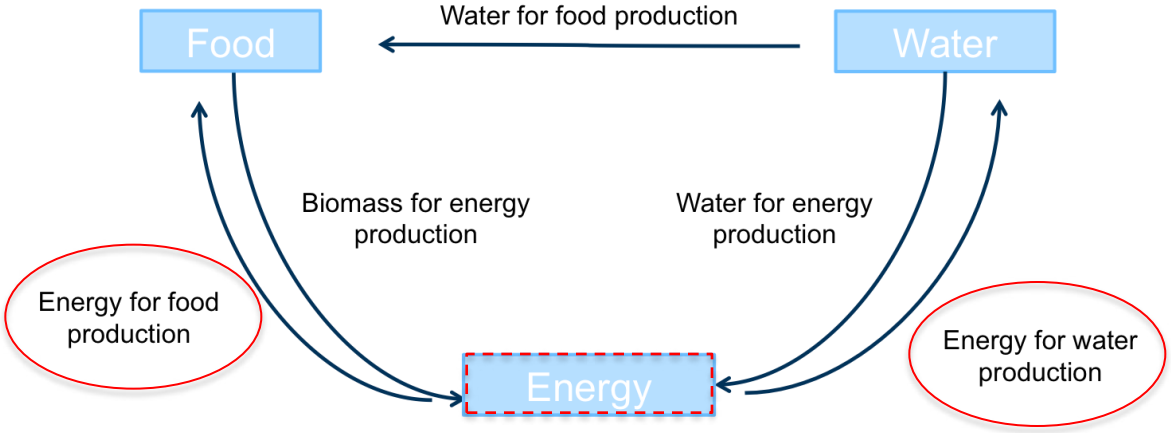
ENERGY FOR FOOD AND WATER

Energy for food production

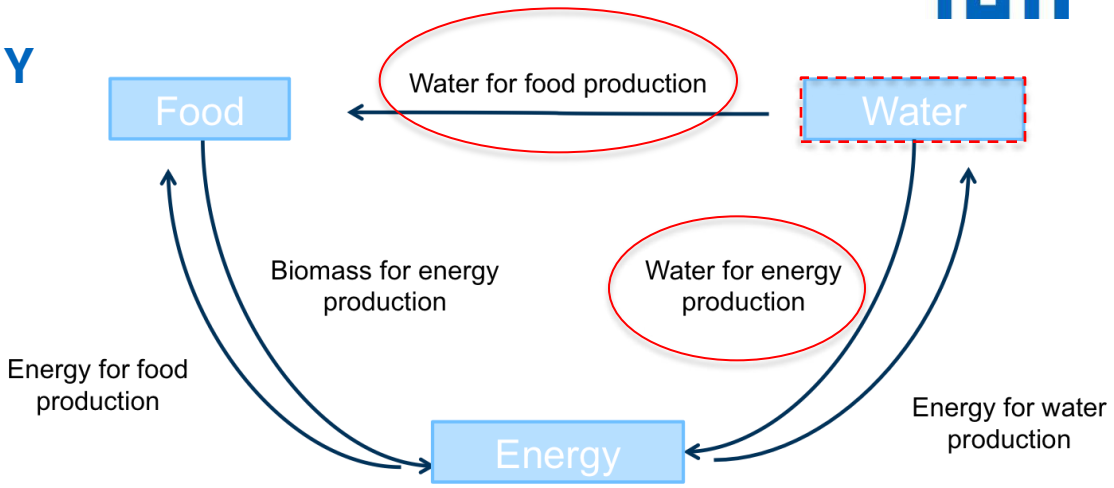
- Production of fertilizers (global consumption 1999: 141,4 million tons)
- Operation of machines
- Irrigation
- Operation of production facilities
- Storage and cooling
- Distribution
- Residential energy use for food preparation and clean up

Energy for water production

- Pumping and extraction of water
- Water treatment
- Transport and storage
- Desalination
- Waste water treatment



WATER FOR FOOD AND ENERGY



Water for food production

- Irrigation of agricultural areas (70% of water consumption)
- In 2000 40% of irrigated crops were located in areas of “medium-high”, “high”, or “extremely high” water stress
- Irrigation of feed crops for milk and meat production
- Food processing

Water for energy production

- About 8% of water withdrawals used during energy production
- Cooling of thermoelectric power-plants (e.g. coal or nuclear power-plants)
- Discharge through hydroelectric power-plants
- Fuel production - water is used to extract and refine
- Shale Gas Production – water is used in drilling, completion and fracturing
- Biofuel production – irrigation of biofuel acreage (e.g. 1/3 of corn in the USA is used for ethanol production)

THE ROLE OF CLIMATE CHANGE

Energy and food production are major drivers of climate change

- Electricity and heat production contribute 27% of greenhouse gases
- Agriculture contributes 15%
- Land use change and forestry contribute 14%

Energy and food production are subject to impacts of climate change

- Further drying of already water-scarce regions
- Loss of glacial water storage
- Effects of more extreme events
- Shut-down of power-plants due to draughts

MITIGATION APPROACHES

Increasing resource productivity

- Rainwater harvesting
- Desalination based on renewable energy
- Photovoltaic water pumps
- Second or third generation biofuels (e.g. based on algae)
- Genetic engineering/breeding (e.g. draught resistant crops)
- Aerobic seeding of rice to reduce water and energy demand

Using waste as a resource in multi-use systems

- Wastes, residues and by-products can be source for other products
- Productive sanitation with wastewater reuse
- Wastewater-energy integration
- Reusing waste products instead of discharging them

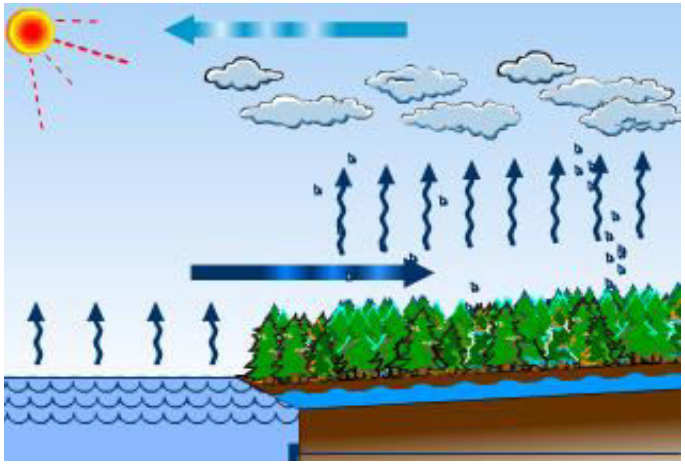
Novel technologies are required due to time pressure. Three possible ideas are presented:

- The Biotic Pump concept of Gorshkov and Makarieva
- Engineered condensation
- Vertical Farming and Roof top Farming:
  - decreases land demand in peri-urban areas
  - reduces costs for storage and transportation
  - conserves groundwater while making use of municipal wastewater

MITIGATION APPROACHES – ENGINEERING SOLUTIONS

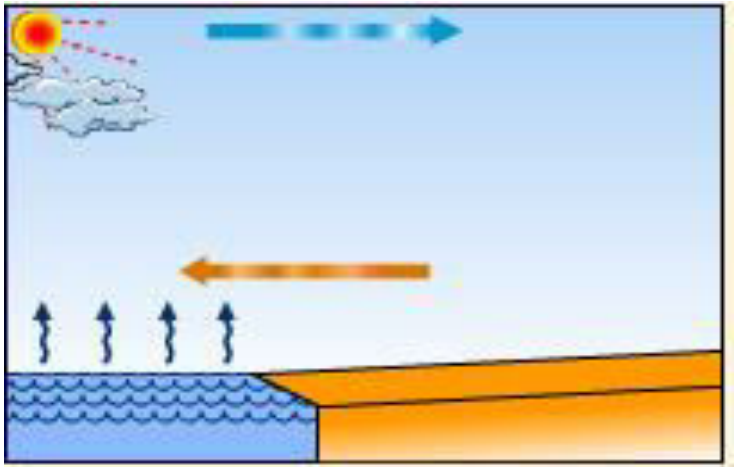
The Biotic Pump concept of Gorshkov and Makarieva

auto-regulation of forest ecosystem

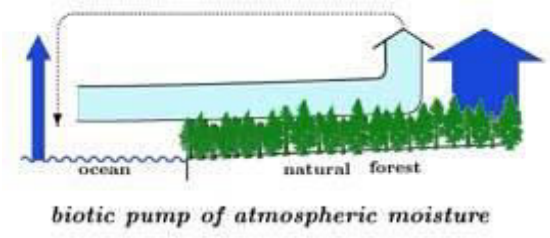


water vapor transport due to condensation induced pressure drop

desertification after clear-cut



evaporation over sea



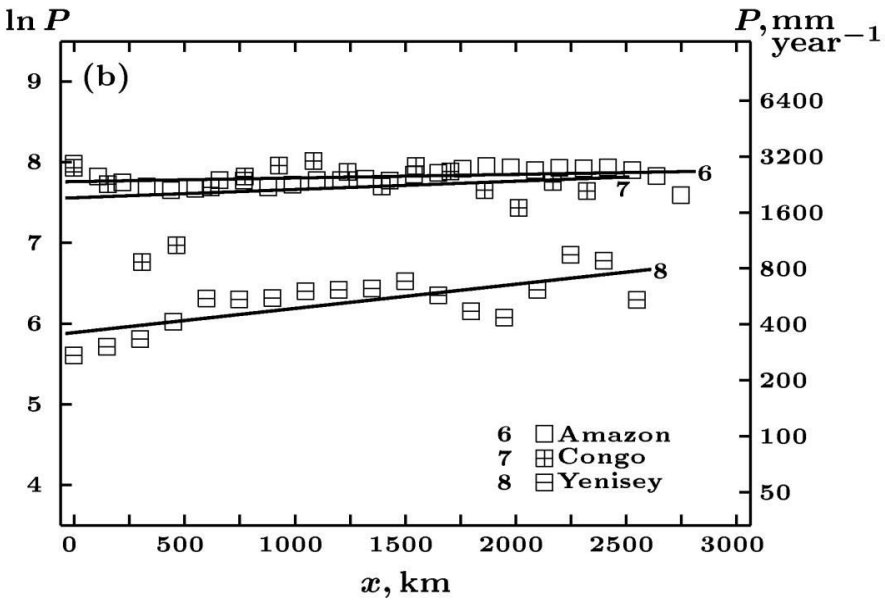
biotic pump of atmospheric moisture

evapo-transpiration over forest followed by precipitation

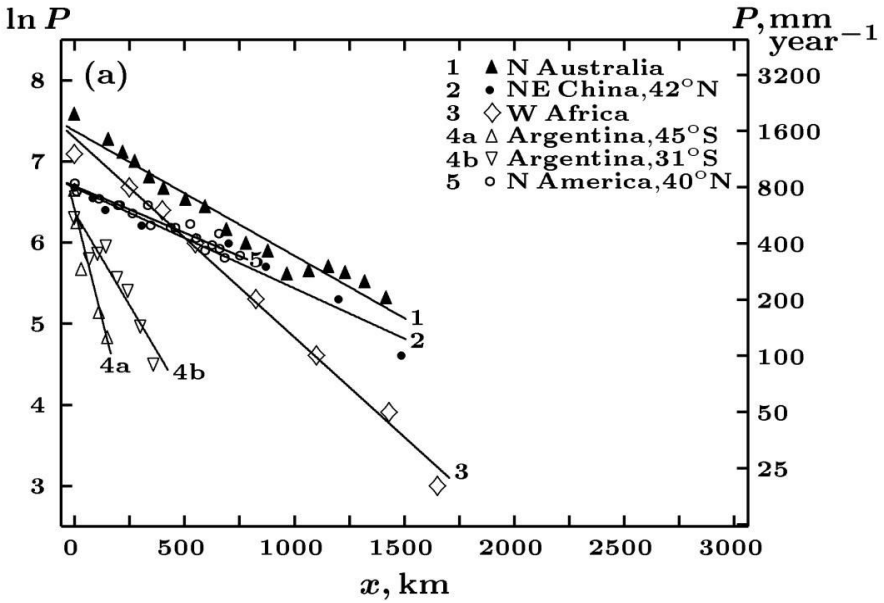
Courtesy: Prof. P. Wilderer

MITIGATION APPROACHES – ENGINEERING SOLUTIONS

The Biotic Pump concept of Gorshkov and Makarieva



forest ecosystem intact

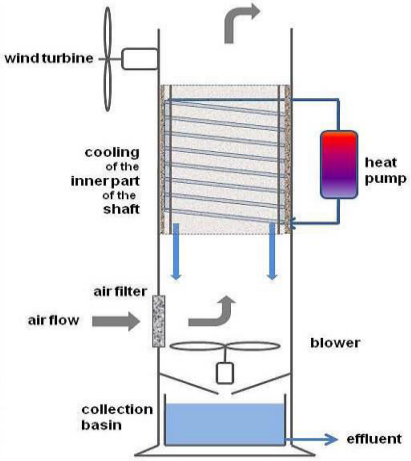


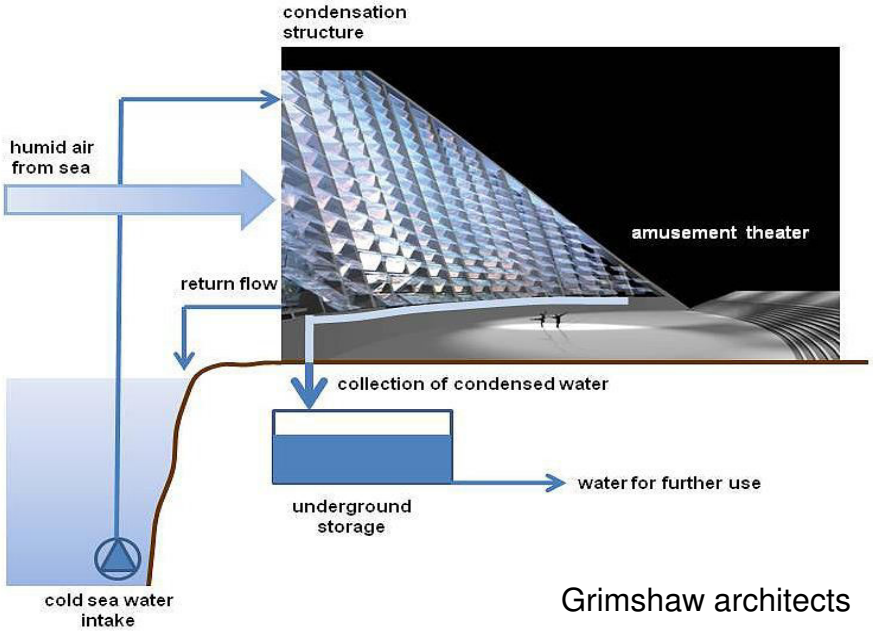
clear-cut dominates

Courtesy: Prof. P. Wilderer

MITIGATION APPROACHES – ENGINEERING SOLUTIONS

Engineered Condensation





Grimshaw architects

Courtesy: Prof. P. Wilderer

MITIGATION APPROACHES – ENGINEERING SOLUTIONS

Vertical Farming

Courtesy: Prof. P. Wilderer

MITIGATION APPROACHES – ENGINEERING SOLUTIONS

Vertical Farming

Growth of leafy vegetables for human consumption

Purified wastewater

- **Installation costs: ca. 30,000 Euro** (olympic swiming pool size)
- **Yield: 22 t/year of leafy vegetables**
- **<u>Purification requirements:</u>**
  - Elimination of particles incl. pathogens
  - Extended COD removal
  - Nutrient can be left in

Courtesy: Prof. P. Wilderer

EDUCATIONAL SENSIBILIZATION FOR THE NEXUS TOPIC

“Integrate the principles of sustainable development into country policies and programes and reverse the loss of environmental resources”
(Target 7.A Millenium Development Goals)

To face such enormous problems and tasks we need to train our administrative officers, scientists, industrial staff etc. to know more about these problems and about the link between the water, food and energy related topics – the Nexus of water, food and energy!

The project “NeXus of water, food, energy” at TUM develops a network of highly qualified and interested scientists and institutions. It is backed by a DAAD-funded thematic partnership in order to bundle the necessary capacity for addressing some of the main scientific questions of the nexus and to create a nucleus in the fields of water, food and energy. The final result will be a NeXus master course among the strategic partners.

DAAD NEXUS PROJECT - PARTNERS

- Danish Technical University (Denmark)
- Cairo University (Egypt)
- Helwan University (Egypt)
- Addis Ababa University (Ethiopia)
- Ludwig-Maximilian- Universität München (Germany)
- National Technical University of Athens (Greece)
- Swiss Federal Institute of Technology Lausanne (Switzerland)
- Ardhi University (Tanzania)
- Colorado School of Mines (USA)

DAAD NEXUS PROJECT – PARTNERS AND STRATEGY

Focus on one of the most essential grand challenges of the near future is addressed by TUM:

→ the nexus of **water**, **food** and **energy**

→ the initiative intends to build up an interdisciplinary network on the nexus topic in education and following in research and administration

DAAD provides funding of mobility for scientific staff and students:

→ to build up a thematic network

Research between TUM and

→Euro-Tech partners from **Switzerland** and **Denmark,** NTUA from Athens/**Greek**

→**USA**: National Science Foundation Engineering Research Center ReNUWIt:
partner institutions include → Stanford University, → University of California at Berkeley, → Colorado School of Mines and → New Mexico State University

→**Helwan University, Egypt,** → **Cairo University, Egypt** → Addis Ababa University, **Ethiopia** and
→ Ardhi University, **Tanzania**,

DAAD NEXUS PROJECT - GOALS

- Within the project we develop a new qualification certificate within the Master Course Environmental Engineering and Sustainable Recourses Management, first at TUM followed by the partner universities:
  The courses which are required for the certificate should give a deeper insight into the upcoming problems of water and water-use as well as possible solutions. Lecture contents will overcome nowadays faculty borders and mediate a trans disciplinary NeXus education

- With the help of the academic network between the partners and with joint Master- and Bachelor theses we want to initialize a trans disciplinary research on the NeXus topic in one of the areas in the world where an integrated NeXus view is essential and where we have long-term and well established contacts

- In the future even staff of the ministries and administration of our partner countries shall participate in the Master Course and by this we want to establish permanent contacts between these countries and TUM

DAAD NEXUS PROJECT – MASTER EDUCATION GOALS

Mediating a sound base for water, food and energy related competences. Not to be experts in all three fields but to understand the interrelation of these fields having a clear origin in the resource water

How can we possibly achieve this goal:

- There is no current and accepted education in the NeXus field neither are we experts in such education. We all originate from a water related field of expertise and therefore represent the necessary fundamentals but not the principles of the NeXus
- We could choose to elaborate such principles from a theoretical point of view or we could try to approach these by relevant and demonstrative project work (which is our primary interest)

DAAD NEXUS PROJECT – MASTER EDUCATION CONTRIBUTIONS

- Due to the broad NeXus topic import of lectures by partner universities into the planned NeXus master course is vital:
  → the courses shall enable the students a holistic view on the NeXus topic, especially for the interrelation of water-food-energy by conducting project work in Africa

- To address the NeXus topic in the master course we both need the practical and scientific experience of our African partners as well as the specific research and educational skills of the partners from Europe and USA

- The courses shall be setup in a modular way and thus can be used as a whole or in parts for the curricula in our partner universities

- Students attending the course or single lectures or summer schools:
  → coming from all partner universities
  → interested in the seminal NeXus topics

DAAD NEXUS PROJECT – MASTER COURSE STRUCTURE

CIVIL AND ENVIRONMENTAL ENGINEERING

Field of Study 1

Field of Study 2

Field of Study 3

NEXUS

SUSTAINABLE RESOURCES MANAGEMENT

DAAD NEXUS PROJECT – MASTER COURSE STRUCTURE

Carefully selected CASE STUDIES for interdisciplinary group work**. WEB interaction with partner students on** CASE STUDIES is **enforced. A common basic knowledge over all Nexus related fields is thought in summer schools and in the first semester accounting for different bachelor educations.**

1st Semester

Nexus related equalizing basic lectures

2nd Semester

Nexus related master lectures

3rd Semester

Nexus related master lectures

4th Semester

Interdisciplinary Master Thesis

CASE STUDIES

FIELD OF STUDY IN CIVIL/ENV ENGRG
OR
SUSTAINABLE RES MANAGEMENT

OUTLOOK INTO RESEARCH

NimaNex is a research project at TUM based on three pillars: A regional climate module (CLI-NEX), a water resources/hydrologic module (HY-NEX) and an energy and reservoir management module (MA-NEX) and integrates perfectly in the aim to lead students and researchers to NeXus areas.

Under **CLI-NEX**, the future changes of the NRB of Africa will be comprehensively assessed by simulating future climate of NRB using a stand-alone regional climate model (RCM), and also a RCM coupled with a land surface scheme (LSS). Using an ensemble, multi-climate modeling approach on the complex feedbacks between land-atmosphere, the effects of climate change based on the 4th Assessment report, SRES (Special Report on Emissions Scenarios) and the latest, Coupled Model Intercomparison Project Phase 5 (CMIP5)'s new scenarios, called RCP (Representative Concentration Pathways) climate projections of IPCC's (Intergovernmental Panel of Climate change) GCMs (General Circulation Models), climate anomaly (El Niño and La Niña) and landuse changes (LUC) will be simulated.

HY-NEX applies the climate projections of CLI-NEX to assess the availability of surface and ground water under the effects of climate change, LUC, irrigation management, and societal changes such as population growth. In some sense, CLI-NEX and HY-NEX will be loosely coupled together. HY-NEX will be more strongly coupled to **MAN-NEX** as the demand for water among competing users will affect agricultural productivity and population growth.

Thank you!

The NeXus of – Water, Food, Energy

funded by DAAD

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