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WEF Nexus School 2023

WEF Nexus Concept

Dr. Peter Nasr

Adjunct Faculty

The American University in Cairo

Exchange, Training, and Scholarships Pillar activities are implemented in cooperation with:





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Outline

- Water, Energy and Food relation
- Energy and water relation
- Embedded water in energy
- Water's role in Energy Value chain
 - Gas and Liquid Fuel – water consumption
 - Electricity industry – water consumption
 - Domestic water – Energy consumption
- WEF Nexus Levels
- WEF Nexus Global level
- WEF Nexus Regional level
- WEF Nexus Assessment



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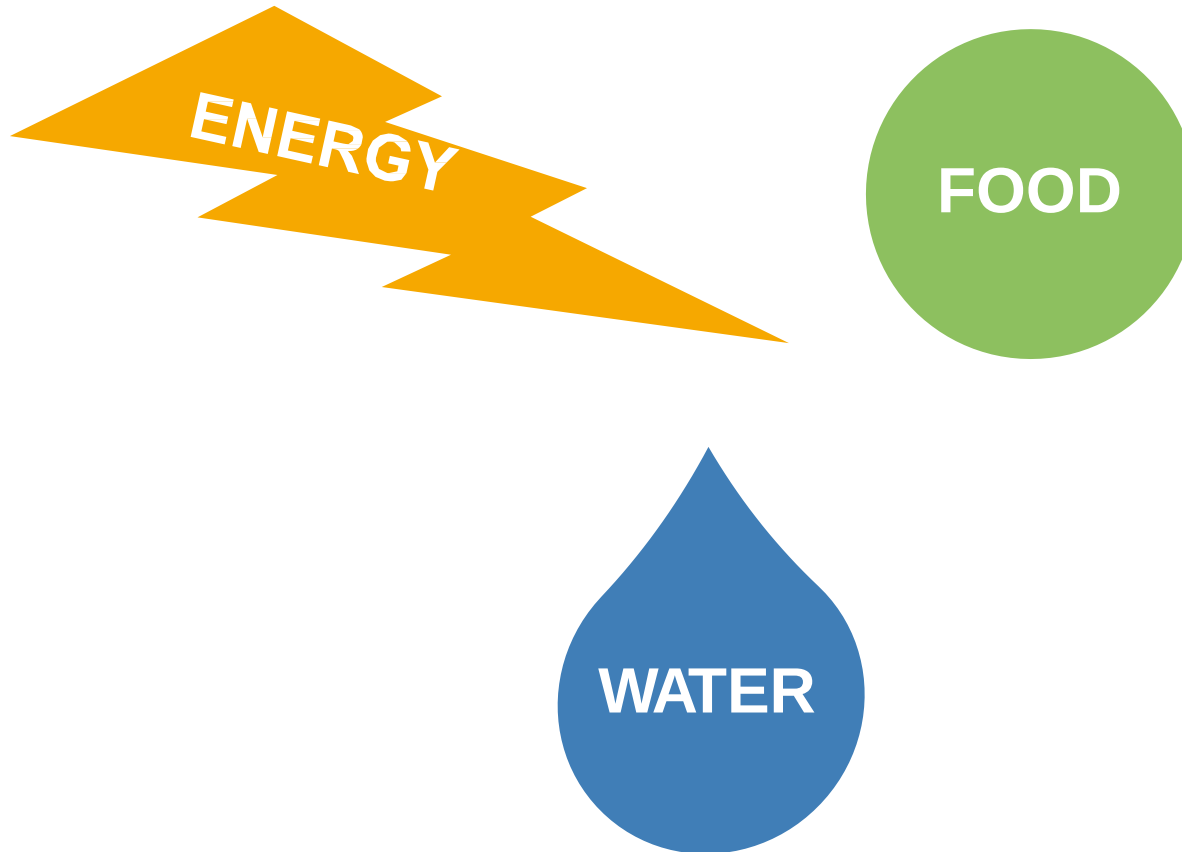


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Water-Energy-Food Nexus



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**Water is needed to
cool power plants**





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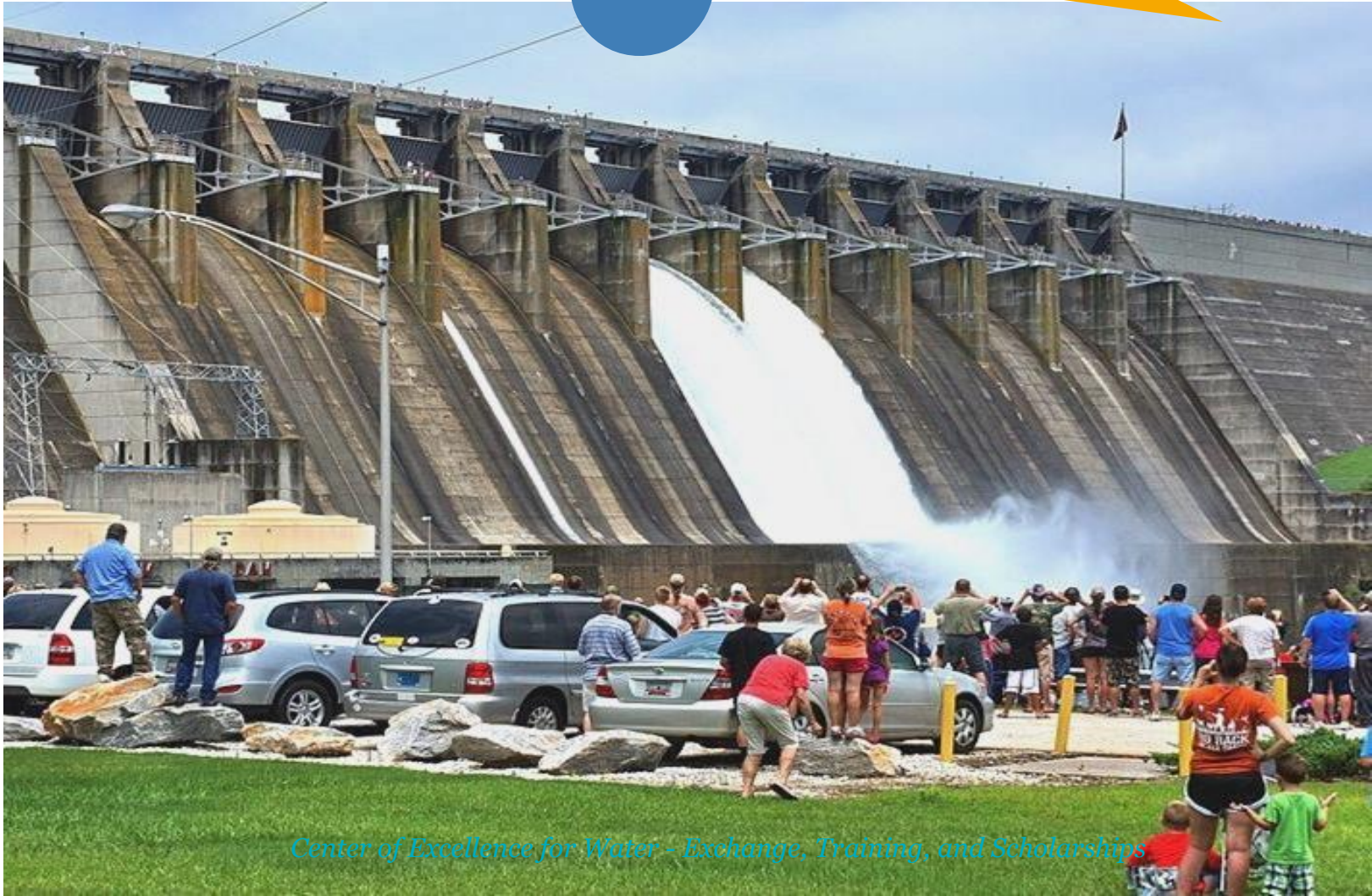


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Water is needed to
run turbines



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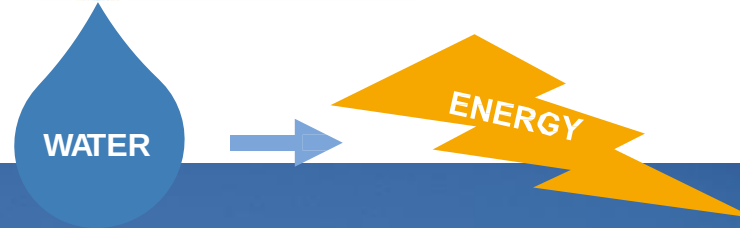


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**Water is needed
to produce biofuel**





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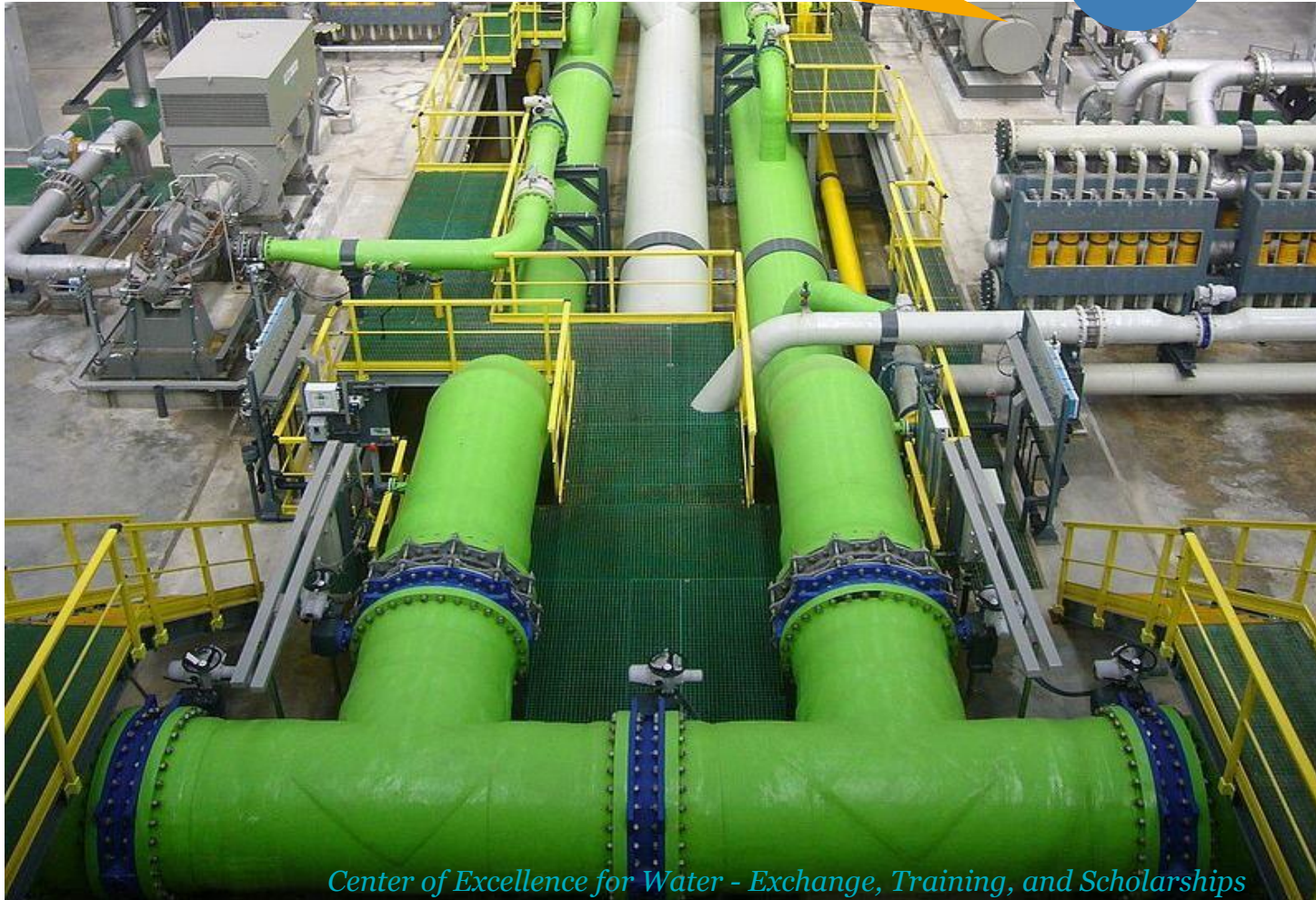
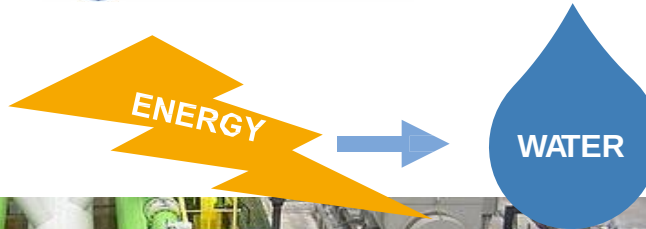


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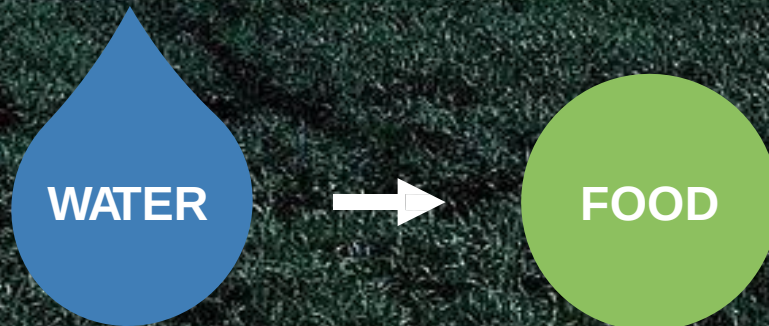
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**We need energy to
treat or desalinate water**



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We need water to irrigate crops





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Energy for food supply chain



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Maize is used to produce biofuel





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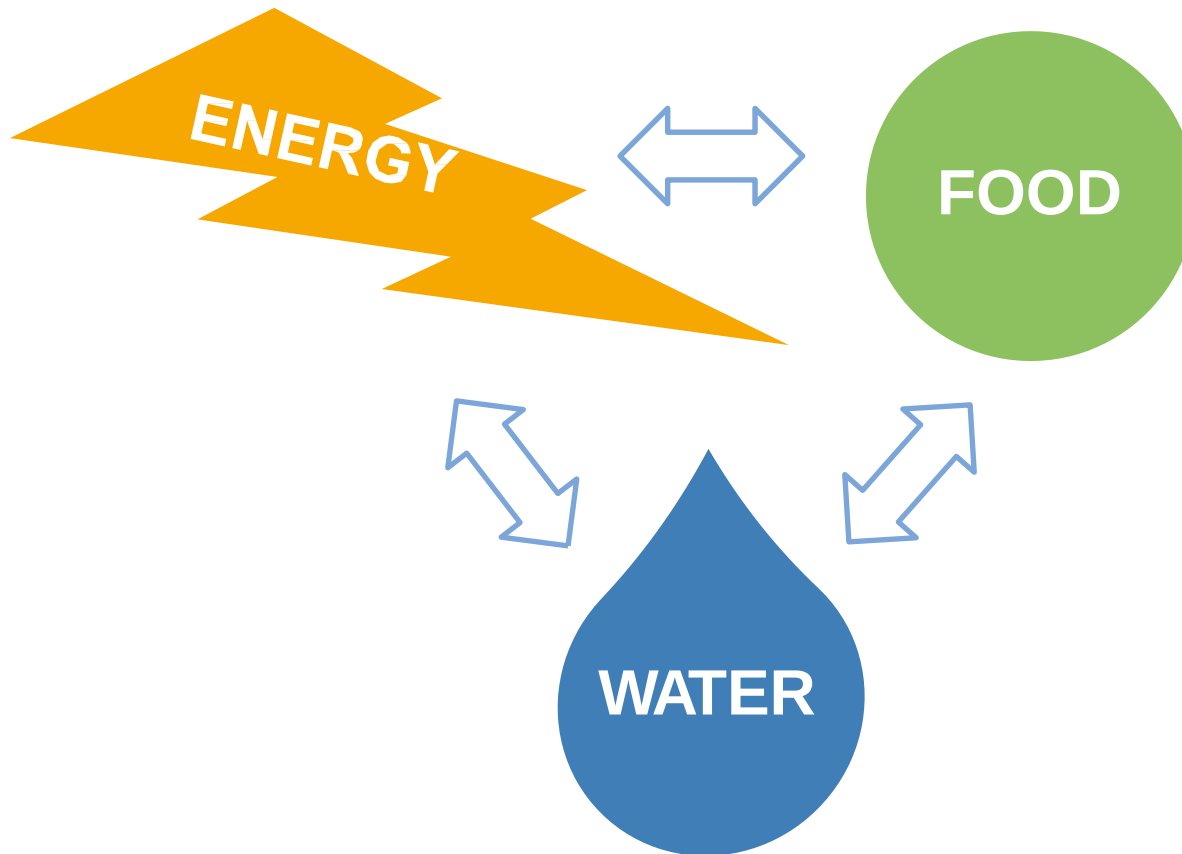


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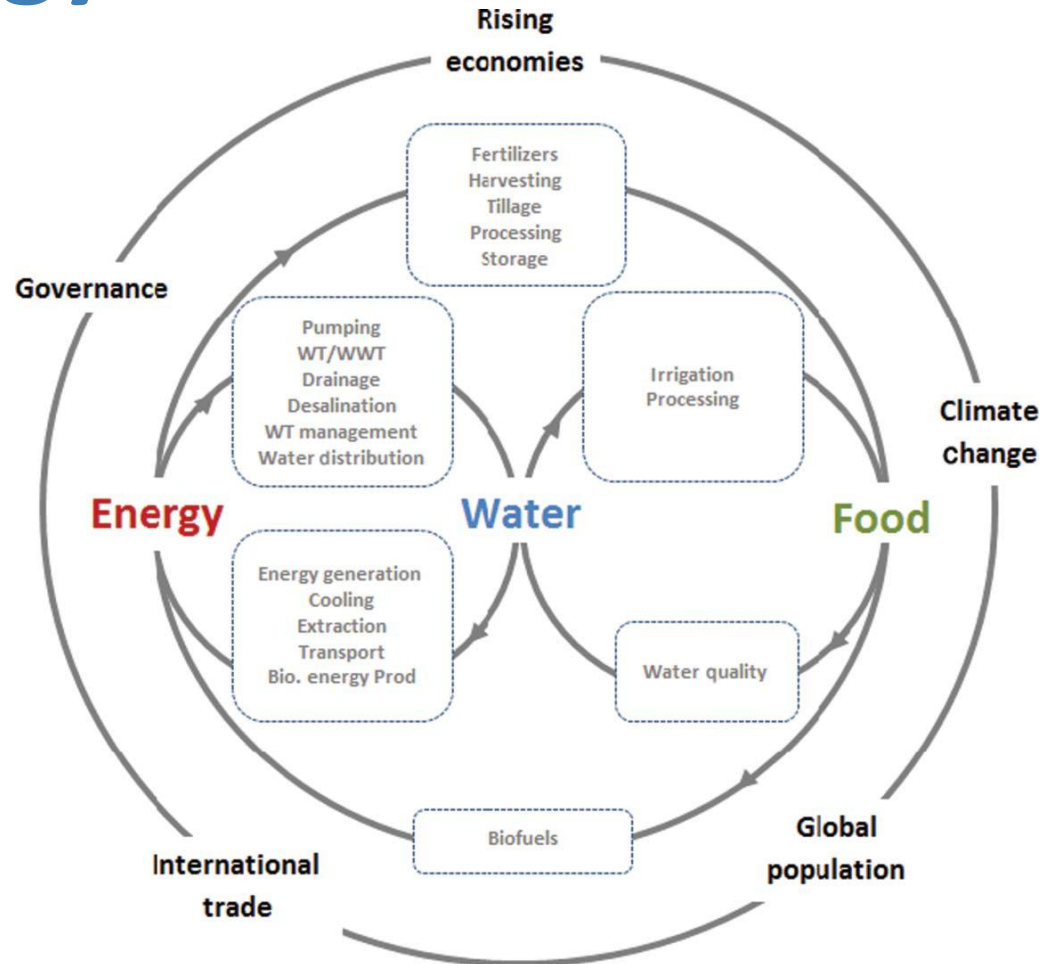
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Water-Energy-Food Nexus

- conceptual framework of the nexus
- linkages between water, energy, and food
- the factors that affect the nexus
 - rising economies
 - climate change
 - global population
 - International trade
 - governance





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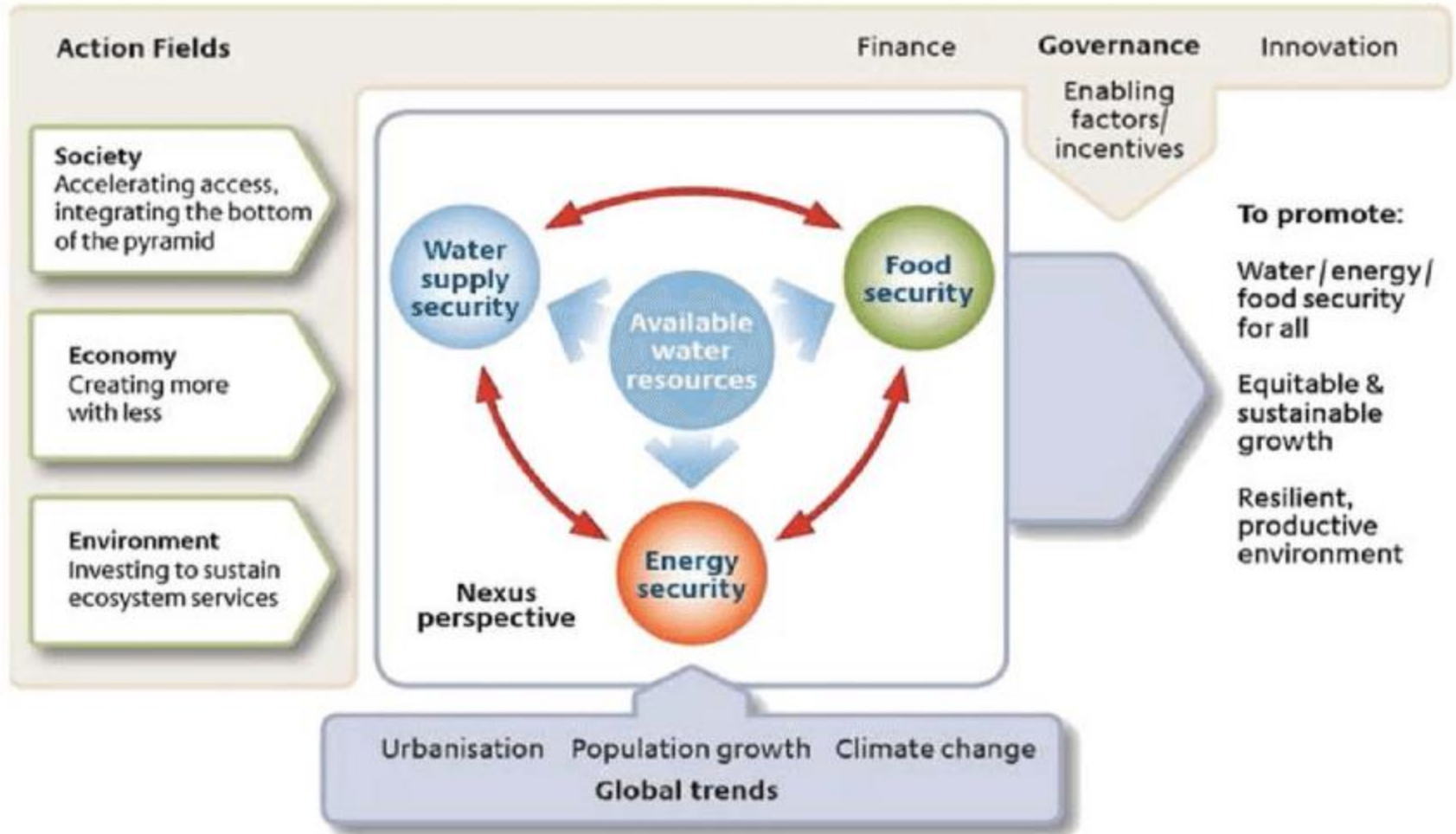


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Water-Energy-Food Nexus



WEF nexus framework presented at the Bonn Conference (Hoff 2011)

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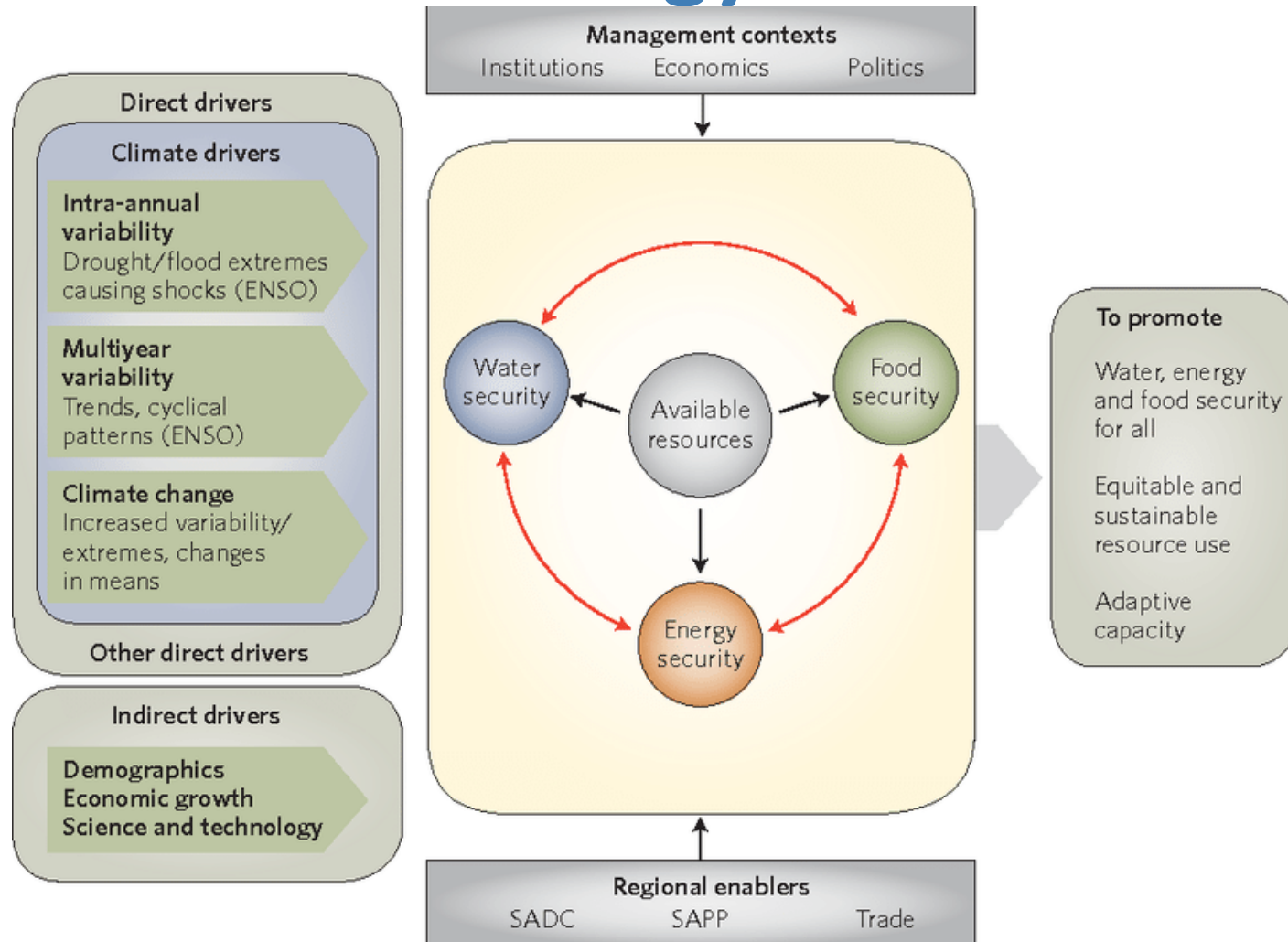


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Water-Energy-Food Nexus



The WEF nexus framework proposed by Conway et al. (2015)

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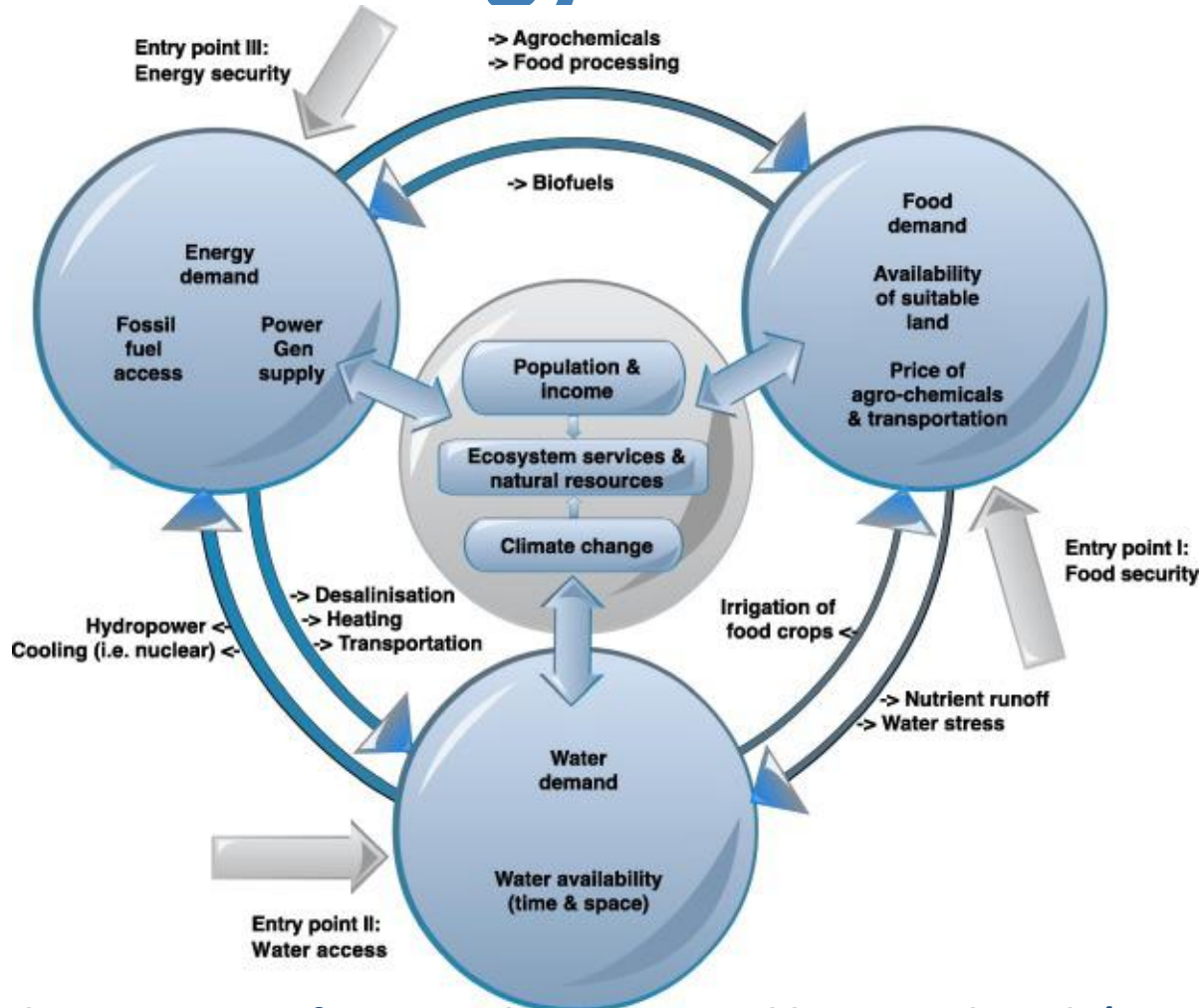


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Water-Energy-Food Nexus



The WEF nexus framework as proposed by Smajgl et al. (2016)

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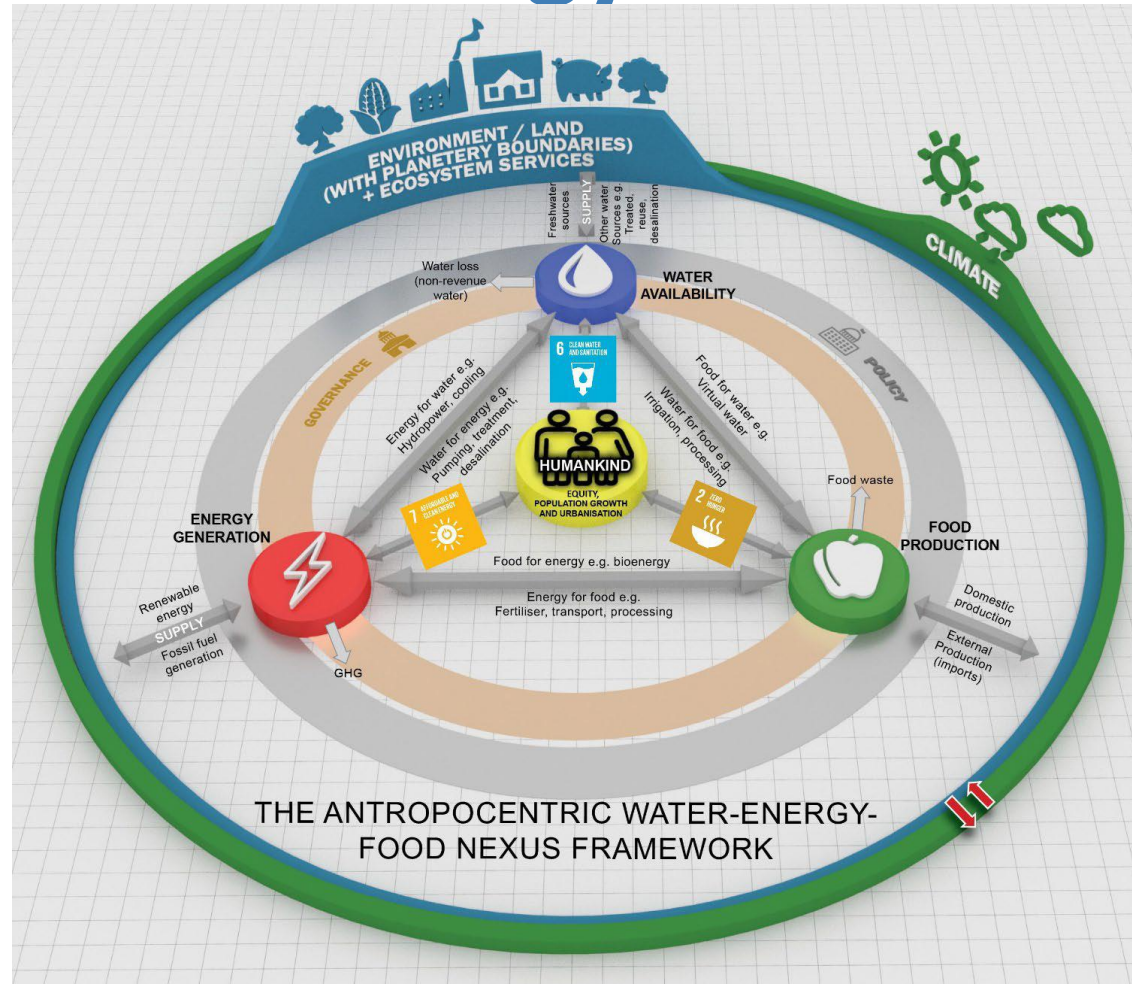


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Water-Energy-Food Nexus



The Anthropocentric WEF Nexus Framework

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WEF Nexus

- <https://www.youtube.com/watch?v=vBJGumr9NMY>



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Why WEF Nexus?

A nexus approach help:

- enhance water, energy and food security
- increases efficiency of each resource
- reduces trade-offs
- builds synergies
- improves governance across sectors



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WEF Nexus

Through a cross-sectoral and dynamic perspective
A Nexus approach helps us:

- to **better understand** the complex and dynamic interrelationships between water, energy and food
- to **use and manage** our limited resources sustainably
- to **think of the impacts** a decision in one sector can have not only on that sector, but on others
- to **anticipate potential trade-offs and synergies**, we can then design, appraise and prioritise response options that are viable across different sectors



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Energy and Water



Energy for Water	Water for Energy
Pumping	Cooling
Sewage treatment	Hydropower
Transport	Biofuel
Desalination	Heating



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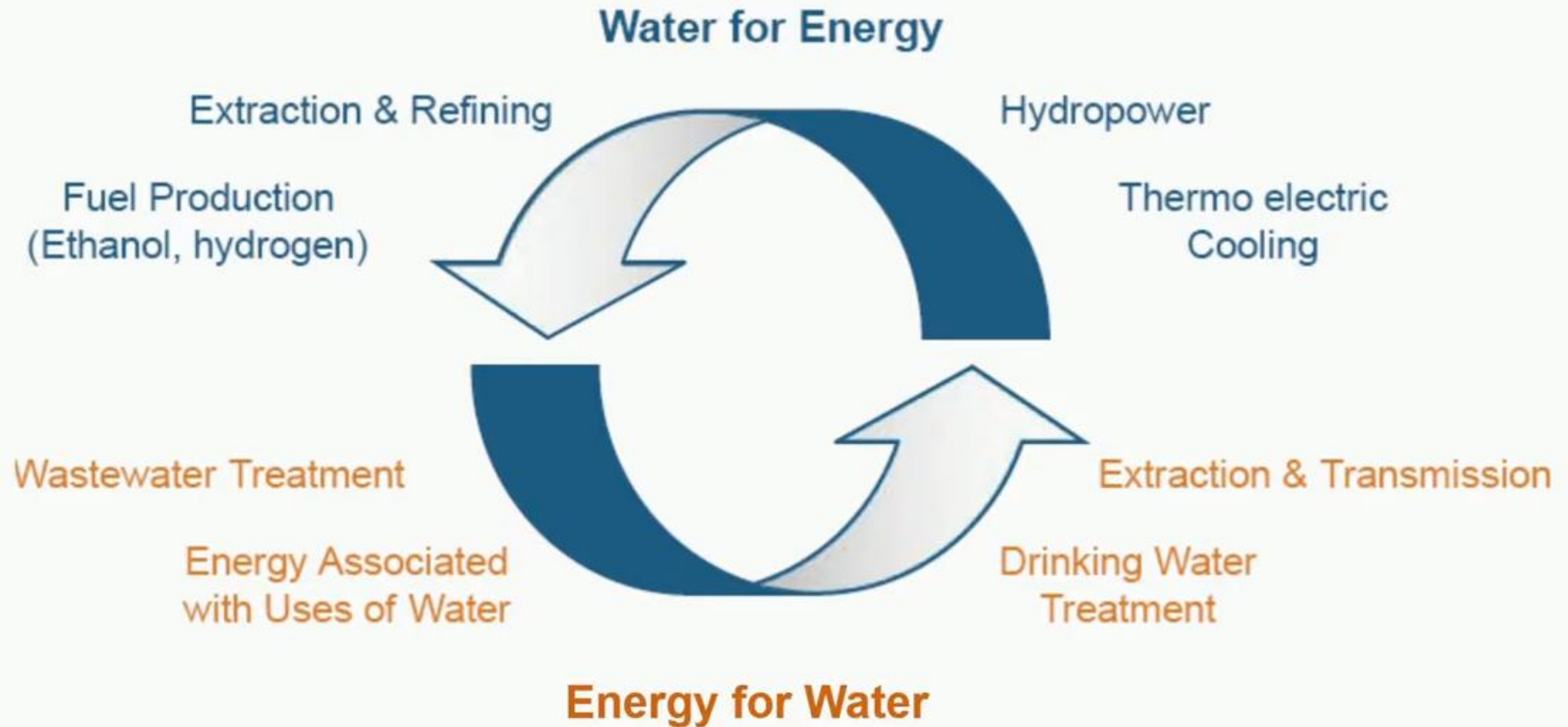


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Energy and Water





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Energy and Water

- Water for Energy
 - Freshwater is required for each step
 - Energy Extraction and production
 - Refining and processing
 - Transportation and storage
 - Electric-power generation
 - Today, energy uses about 8% of all freshwater withdrawn worldwide and around 40% of freshwater in some developed countries
 - Water withdrawn for energy is much higher than water consumption due to high water requirement for cooling power plants



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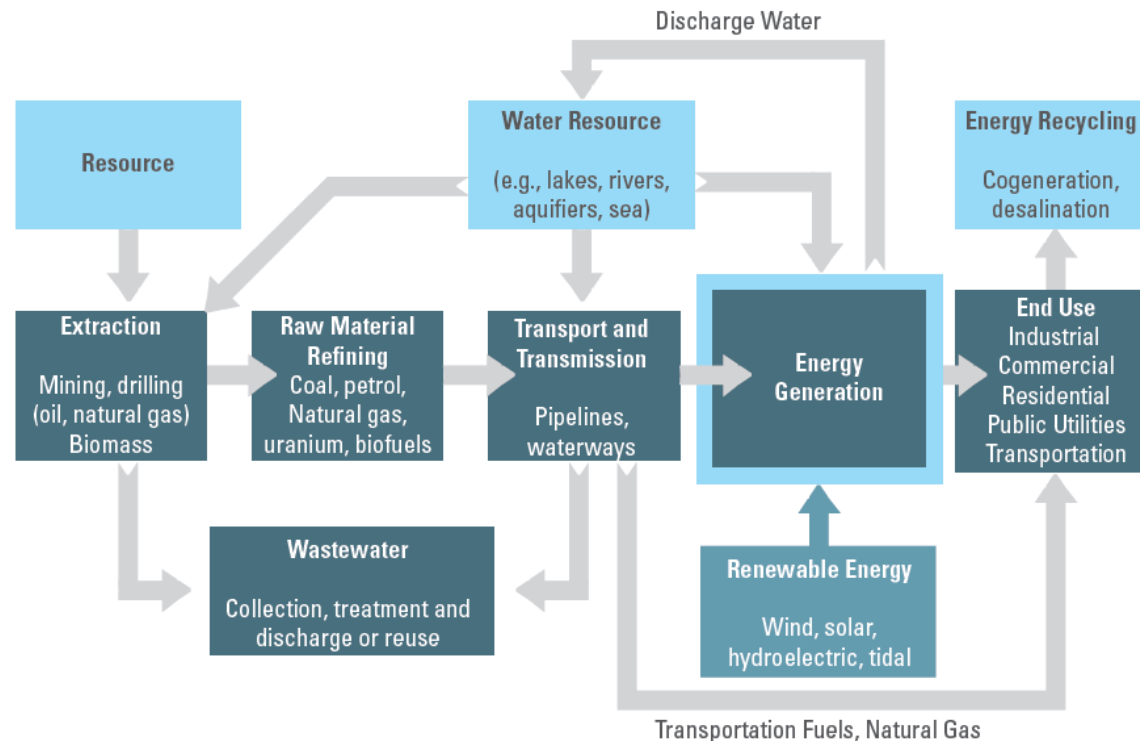
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Embedded water in Energy Production

- Energy production is the 2nd largest user of water (after agriculture)
- Globally, 90% of power generation is water-intensive
- 80% of global electricity is produced by thermal power generation
- 75% of all industrial water withdrawals are for power production



Water use in energy production



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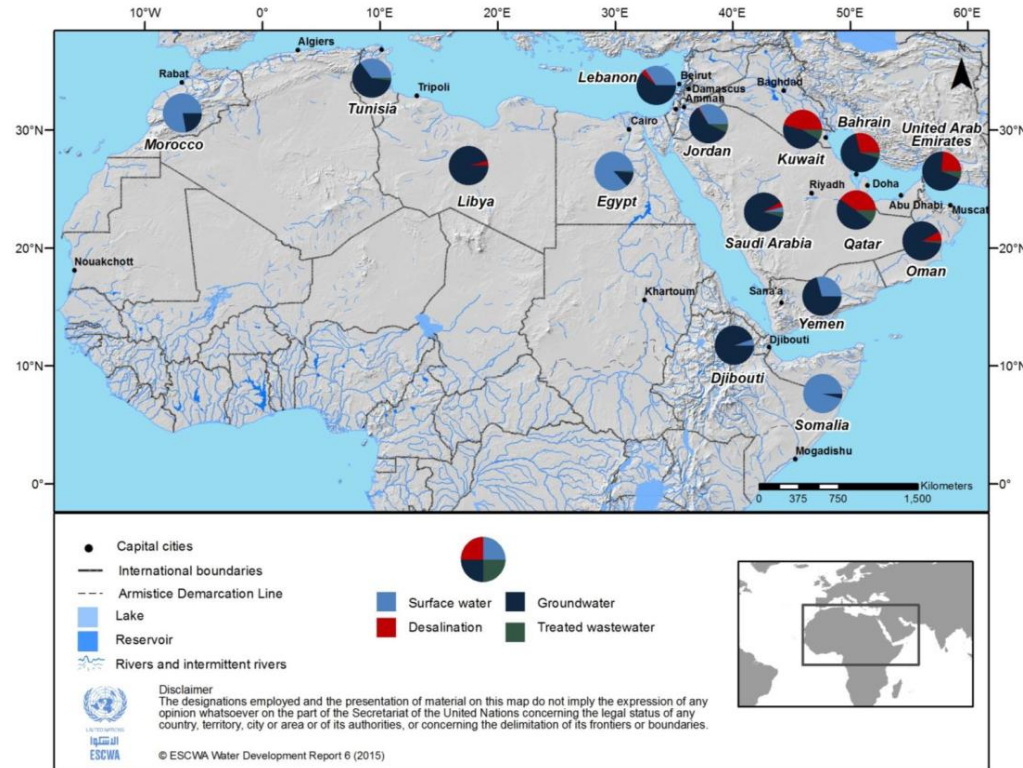
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Energy and Water

- Jordanian water sector accounts for **~15% of total annual electricity generated**
- Saudi Arabia: Groundwater pumping accounts for **10% of total fuel consumption**
- Libya: Groundwater pumping accounts for **14% of total fuel consumption**
- Bahrain: **30% of total energy use is for desalination**





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Water footprint for Energy Sources

Energy Source	Water footprint (m ³ /GJ)	Remarks
Crude oil	1.058	highest energy production rate and the highest water consumption rate
Coal	0.164	Energy gained from coal is less than in that from oil
Uranium	0.086	Uranium is increasing with time
Biomass	9.1 (for Maize)	Energy of the poor



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Water's Role in Energy Value chain

- Water's role in the energy value chain varies depending on the type of energy
- The energy value chain is divided into three components.
 1. **Production** of energy raw materials,
 2. **Transformation** of the raw material into a form usable by the consumer
 3. **Delivery** to the final consumer



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Water for Gas and Liquid Fuel – Value Chain

Gas and Liquid Fuels Value Chain—Water Consumption

Raw Materials

Transformation

Delivery to Customer

Oil

Traditional Oil:
3-7 Liters per GJ

Enhanced Oil Recovery:
50-9,000 Liters per GJ

Oil Sands:
70-1,800 liters per GJ

Oil Refining

25-65 liters per GJ

Biofuels

Corn: 9,000-100,000 liters per GJ
Soy: 50,000-270,000 liters per GJ

Ethanol: 47-50 liters per GJ
Biodiesel: 14 liters per GJ

Coal

5-70 liters per GJ

Coal-to-liquids

140-220 liters per GJ

Shale Gas

36 -54 liters per GJ

Natural Gas Processing

7 liters per GJ

**Delivery of Natural Gas
and Liquid Fuels to
Customer Involves
Minimal Water
Consumption**

Source 2



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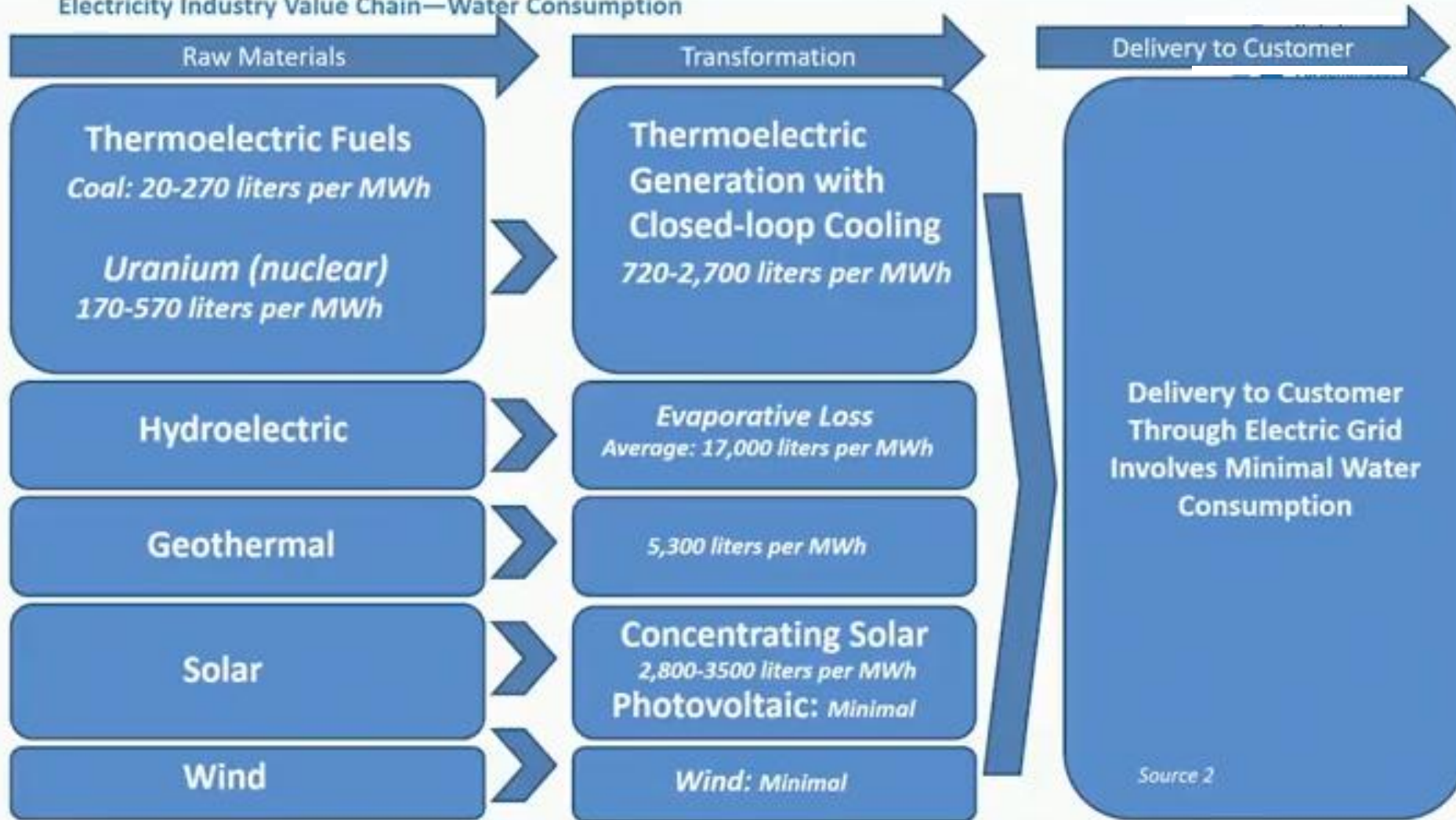
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Water for Electricity— Value Chain

Electricity Industry Value Chain—Water Consumption





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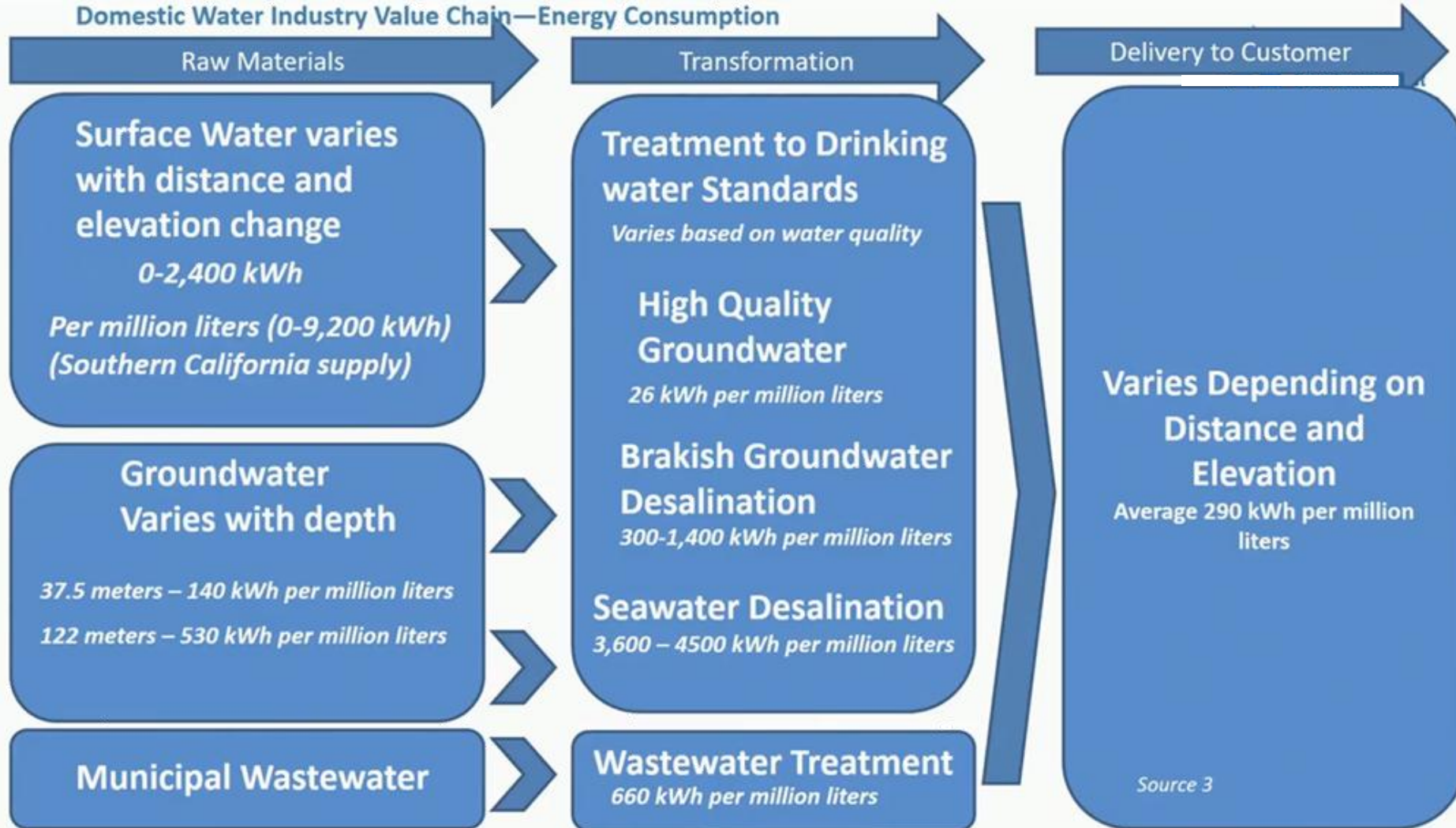
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Energy for Water– Value Chain

Domestic Water Industry Value Chain—Energy Consumption





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Energy and Food



Energy for Food	Food for Energy
Producing fertilizers	Biofuels
Agriculture processes	
Food Processing	



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Food and Water



Food for Water	Water for Food
Irrigation	
Processing	

BREAK



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WEF Nexus Levels

Global Level

- Large scale
- SDGs and MDGs

Regional Level

- Group of countries sharing borders
- Ex: Nile Basin countries, MENA region, Europe, Latin America

Local Level

- Community
- Village



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- <https://www.youtube.com/watch?v=Ol4MAsrYKVE>



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WEF Nexus at Global Level



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WEF Nexus at Global Level

- Global Change and Challenges
 - Climate change and variability,
 - resource use patterns,
 - globalization in terms of economic enterprise,
 - environmental change,
 - population growth
 - Fulfilling human aspirations for quality of life,
 - meaningful education,
 - Productive rewarding work
 - sustainable natural resources use

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WEF Nexus at Global Level

- Applications of system Integration (Examples):
 - Coastal Zone Management
 - Marine Spatial Planning
 - Ecosystem-Based Management
 - Biofuel Production and consumption
 - System integration of Virtual Water
 - Energy Integration



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Virtual Water

- The countries not growing a certain crop, or a certain product, would like to import it and other countries who have access to water to produce, they would like to export. This export and import process of products should be also seen from the virtual water point of view
- So, the water security in a certain country does not mean self-sufficiency, does not mean that they have to have enough water for all the products, but it means, that they have to secure the resources, to give the people access to the products that include water in its supply chain. That is why integration at a global level is encouraged.

Virtual Water

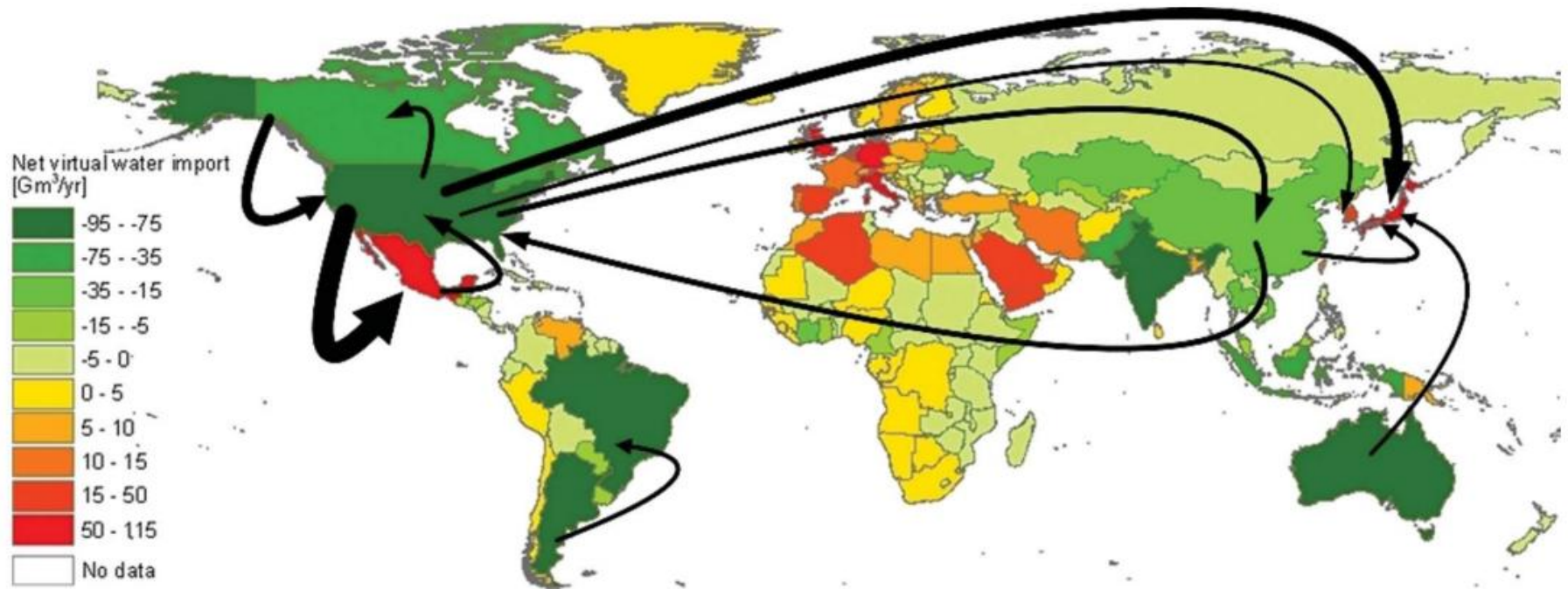


Fig. 2 Virtual water balance per country related to trade in agricultural and industrial products over the period 1996–2005. Net exporters are shown in green and net importers in red. The arrows show the biggest gross international virtual water flows ($>15 \text{ GM}^3/\text{yr}$); the fatter the arrow, the bigger the virtual water flow.

Source: Mekonnen, M.M. and Hoekstra, A.Y. (2011).^[15]



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Biofuel

- Unexpected Impacts of Biofuel
 - Positive and negative global impacts
 - Affects planetary boundaries (ex: climate change, land use and nutrient cycle)





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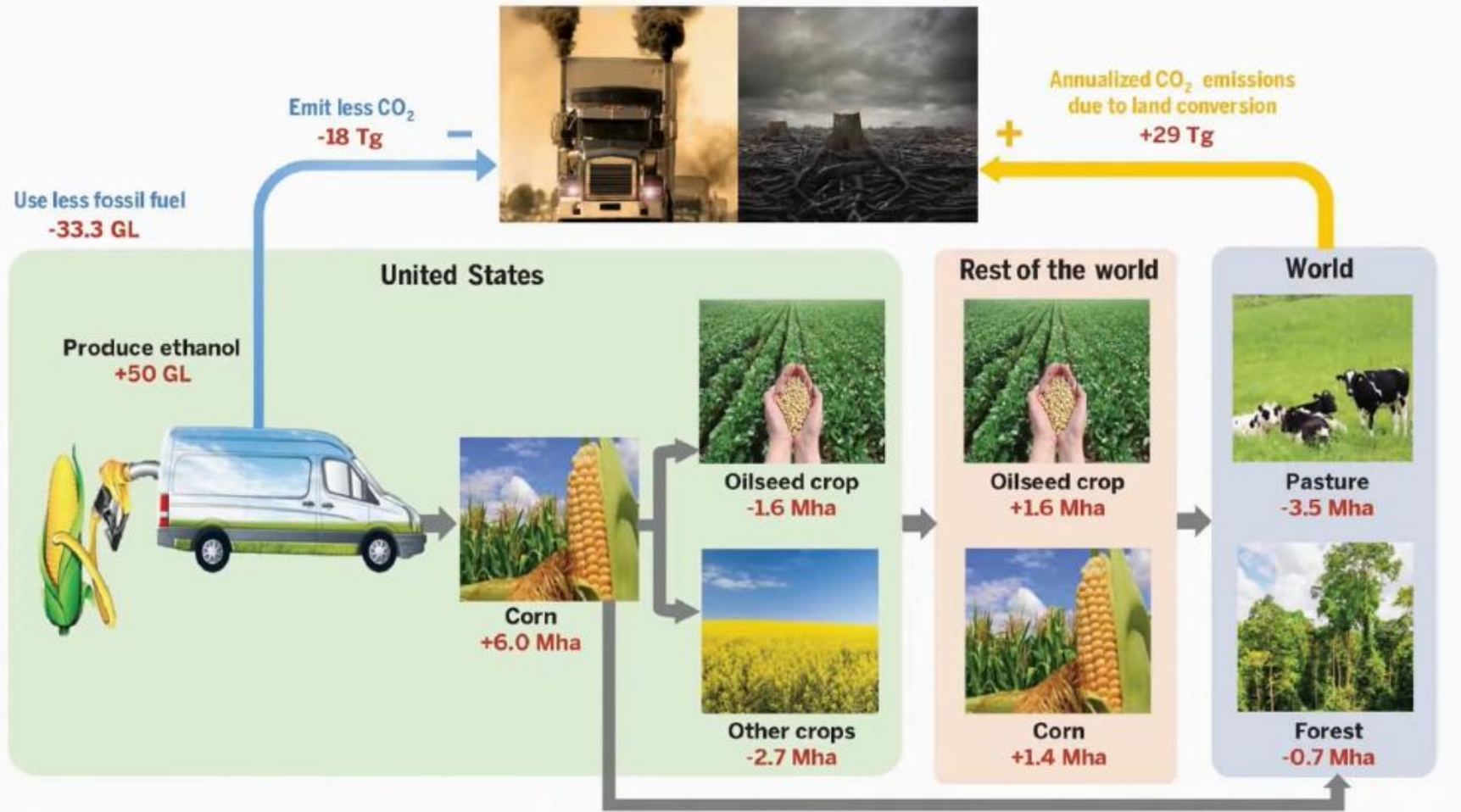
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Biofuel - from corn

CO₂ emissions





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Energy Integration

Europe (The world's largest importer of energy)

Europe depends on the rest of the world for its energy. The European Union, the world's second largest economy, consumes one fifth of the world's energy, but has very few reserves of its own



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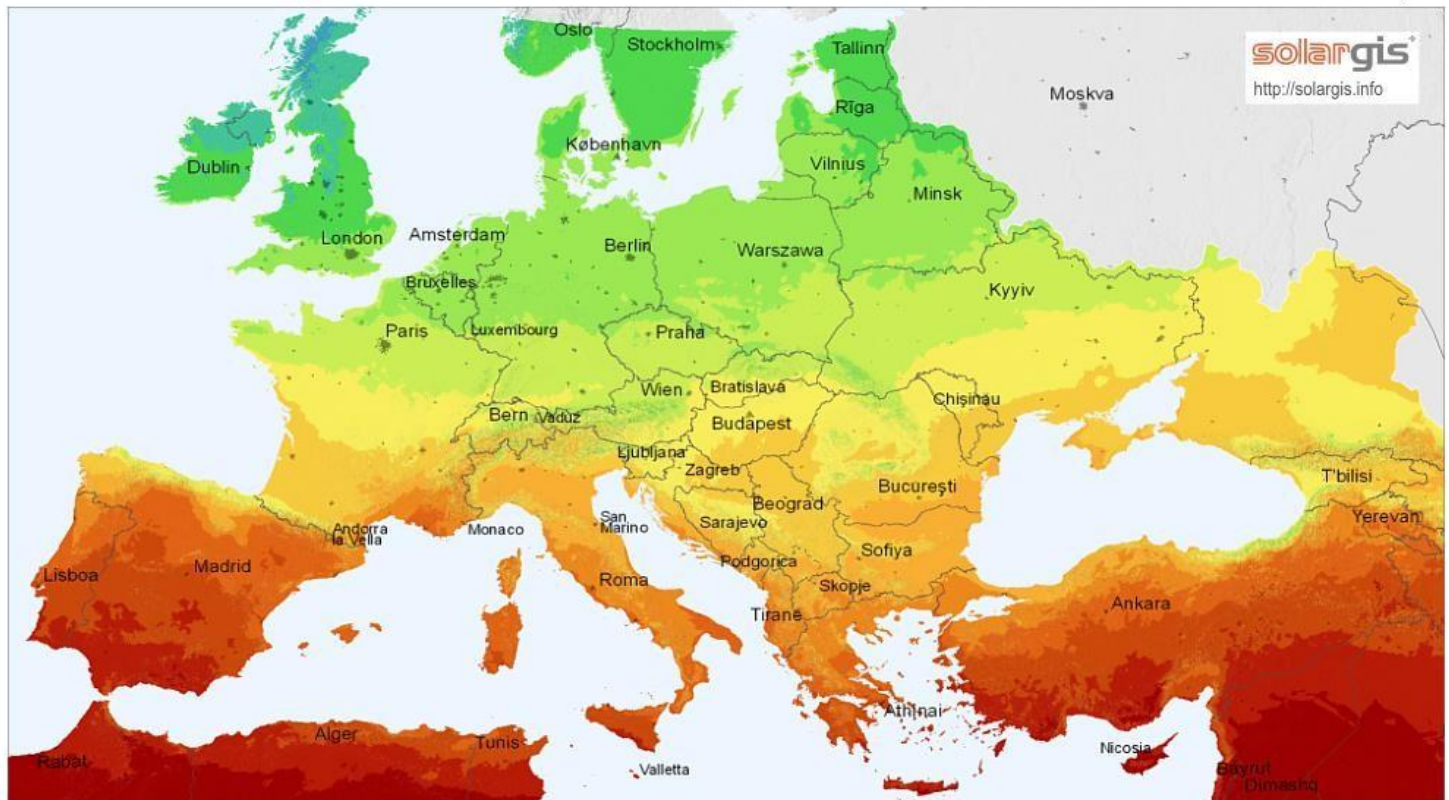
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Energy Integration

Solar Map of Europe

Global horizontal irradiation

Europe



Average annual sum (4/2004 - 3/2010)



0 250 500 km

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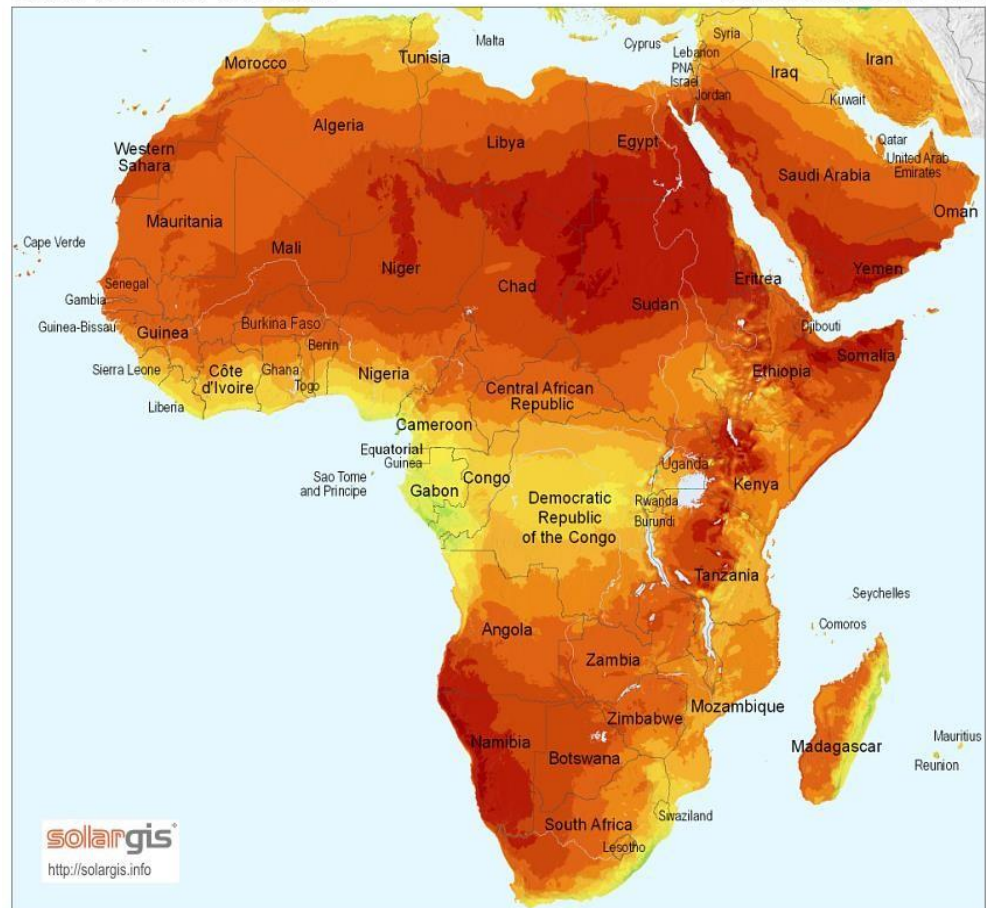
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Energy Integration

- Solar Radiation in Africa and Middle East

Global horizontal irradiation

Africa and Middle East



Average annual sum (4/2004 - 3/2010)





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Energy Integration

- Euro-Mediterranean Collaboration (DeserTec)





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WEF Nexus Levels

Global Level

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WEF Nexus at Regional Level



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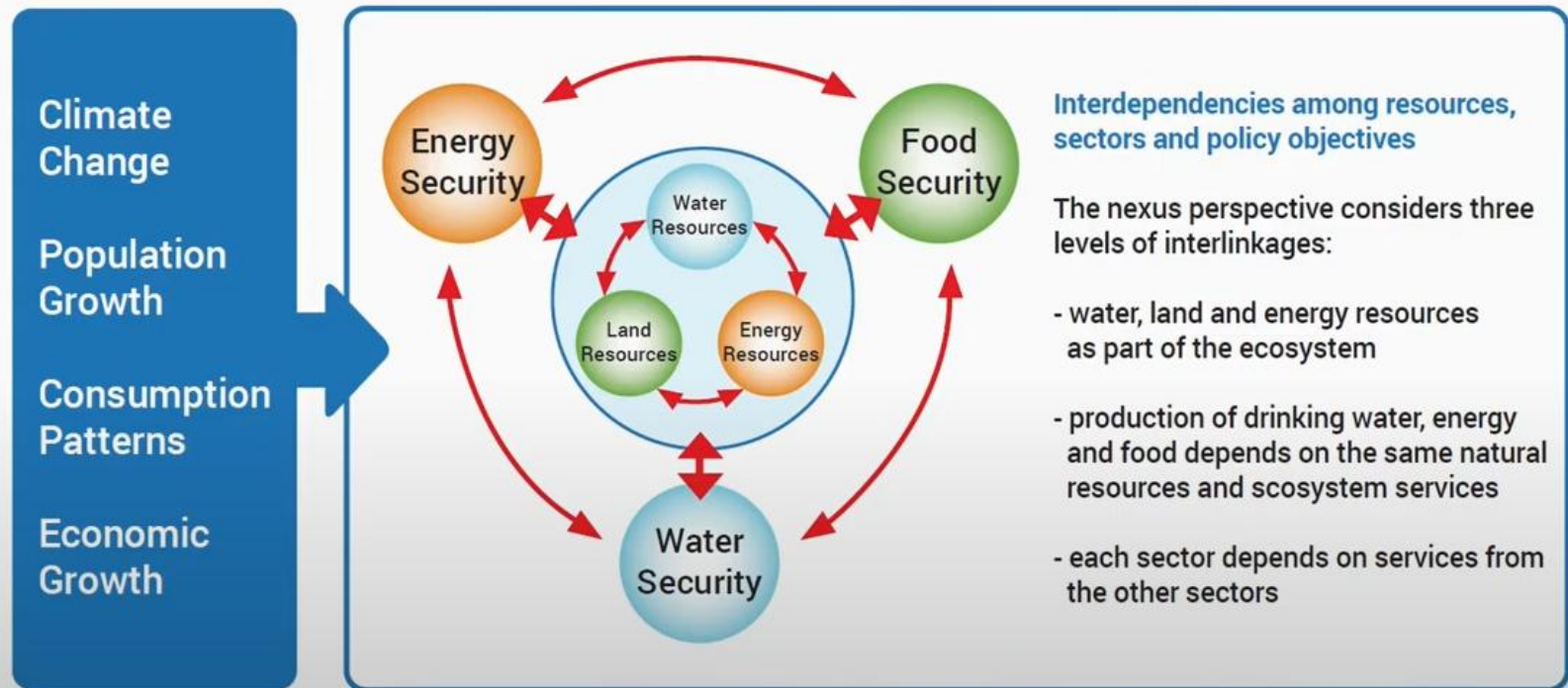


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WEF Nexus at Regional Level

- Stress on the WEF in the Arab Region

The WEF Security Nexus





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WEF Nexus at Regional Level

- WEF Challenges in the Arab Region
 - population has doubled in 30 years (170 million inhabitants in 1980 to more than 350 million in 2010)
 - Water Energy and food sectors are highly subsidized where the subsidy system works in favor of the rich rather than the poor (Ex: gas subsidy for big vs. small cars)
 - Extreme weather events like precipitation shifts, increasing temperatures, rising sea level are consequences of the climate change and are expected to impact the WEF Nexus



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WEF Nexus at Regional Level

- Institution Development in the Arab Region
 - shared domain between water, agriculture, climate, energy, finance and municipalities
 - It is important to develop and implement systematic approaches where all stakeholders are equally integrated
 - Data and information sharing and coordination are very important for collaboration



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WEF Nexus at Regional Level

- Governance models of Nexus Mainstreaming
 - One body already active in developing strategies related to WEF nexus can be the focal point for preparing a comprehensive WEF nexus strategy
 - Other possible models
 - Shared governance
 - High level governance (ex. Arab league)
 - Private public partnership



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WEF Nexus at Regional Level

- Financial Resources
 - Identifying stakeholders, including public and private sector and foreign aid
 - Climate change fund
 - Budgeting and establishing financial responsibilities for stakeholders can be the most critical and challenging aspect of negotiations in implementing WEF nexus



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WEF Nexus at Regional Level

- Are current policies Effective?
 - Arab region was the first to develop a regional strategy for Sustainable Consumption and Production (SCP)
 - Most SCP policies are supply oriented (rather than demand oriented), like improving efficiency of power generation or building of new desalination plants



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WEF Nexus at Regional Level

- Building Capacity at Institutional and Policy Level
 - Generating dialogue for tradeoff
 - There are no win-win solutions, so compromises and tradeoffs are needed (Ex: river connecting countries and dam)
 - There are main areas, on which capacity building for decision makers should be focused

Assessment of WEF Nexus (WEF Nexus index)



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Selection of Indicators

- An indicator “is the operational representation of an attribute (quality, characteristic, property) of a given system, by a quantitative or qualitative variable, including its value, related to a reference value”
- Several indicators currently exist for each of the three individual resources within the WEF nexus
- Many of these sector-specific indicators are reported upon by the World Bank, the UN, however, often describe **isolated** components of sector-specific information, **neglecting the interconnections or dependencies between the resources**





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Why Composite Indicator?

- Summaries complex or multi-dimensional issues, in view of supporting decision-makers
- Are easier to interpret than trying to find a trend in many separate indicators
- Facilitate the task of ranking countries on complex issues in a benchmarking exercise
- Assess the progress of countries over time on complex issues
- Reduce the size of a set of indicators or include more information within the existing size limit
- Place issues of countries' performance and progress at the centre of the policy arena
- Facilitate communication with ordinary citizens and promote accountability





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Selection of Indicators

- The proposed WEF Nexus Index will be based on indicators representing the three interdependent resources
- Indicators for the development of a WEF Nexus Index have been selected based on their relevance regarding:
 - “**access to**”
 - “**availability of**”water, energy and food at a national level



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Indicators selected to constitute the WEF Nexus Index

- The WEF index is made up of
 - three pillars
 - six sub-pillars
 - 21 indicators
 - 7 water-related
 - 6 energy-related
 - 8 food-related

p.01 Water Sub-Index	sp.01 Access	ind.01	People using at least basic drinking water services (% of population)
		ind.02	Percentage of people using safely managed sanitation services (% of population)
		ind.03	Degree of integrated water resources management implementation (0-100)
	sp.02 Availability	ind.04	Annual freshwater withdrawals, total (% of internal resources)
		ind.05	Renewable internal freshwater resources per capita (m ³ per capita)
		ind.06	Environmental flow requirements (10 ⁶ m ³ /annum)
		ind.07	Average precipitation in depth (mm per year)
p.02 Energy Sub-Index	sp.03 Access	ind.08	Access to electricity (% of population)
		ind.09	Renewable energy consumption (% of total final energy consumption)
		ind.10	Renewable electricity output (% of total electricity output)
		ind.11	CO ₂ emissions (metric tons per capita)
	sp.04 Availability	ind.12	Electric power consumption (kWh per capita)
		ind.13	Energy imports, net (% of energy use)
p.03 Food Sub-Index	sp.05 Access	ind.14	Prevalence of undernourishment (% of population)
		ind.15	Prevalence of severe wasting, weight for height (% of children under 5)
		ind.16	Percentage of children under 5 years of age who are stunted
		ind.17	Prevalence of obesity in the adult population (18 years and older)
	sp.06 Availability	ind.18	Average protein supply (g/caput/day)
		ind.19	Cereal yield (kg per hectare)
		ind.20	Average dietary energy supply adequacy (%)
		ind.21	Average value of food production (I\$ per caput)



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Challenges in measuring the WEF Nexus

- The three resource sectors **have different units of measurement** (Water is generally measured in m^3 , energy in kWh, while food in various ways, i.e. calories, value, etc.)
- **Spatial extent** of the assessment, which can vary from a household level to a city, catchment, province, country or regional scale
- **How the data are obtained** is also important
- Incorporation of **virtual water**
- **Trans-boundary** water catchments





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Aggregation of Indicators

Indicator	Indicator weight in index	Sub-pillar	Sub-pillar weight in index	Pillar	Pillar weight in index	Sub-index	Sub-index weight in index
ind.01	0.056	sp.01	0.167	p.01	0.333	si.01	1.000
ind.02	0.056						
ind.03	0.056						
ind.04	0.042	sp.02	0.167	p.01	0.333	si.01	1.000
ind.05	0.042						
ind.06	0.042						
ind.07	0.042						
ind.08	0.083	sp.03	0.167	p.02	0.333	si.01	1.000
ind.09	0.028						
ind.10	0.028						
ind.11	0.028	sp.04	0.167	p.02	0.333	si.01	1.000
ind.12	0.083						
ind.13	0.083						
ind.14	0.056	sp.05	0.167	p.03	0.333	si.01	1.000
ind.15	0.028						
ind.16	0.028						
ind.17	0.056	sp.06	0.167	p.03	0.333	si.01	1.000
ind.18	0.042						
ind.19	0.042						
ind.20	0.042						
ind.21	0.042						

By providing equal weighting across the three pillars it is implied that SDGs 2, 6 and 7 are equally important.

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WEF Nexus Video

- <https://wefnexusindex.org/>
- widgets.figshare.com/articles/19335626/embed?show_title=0



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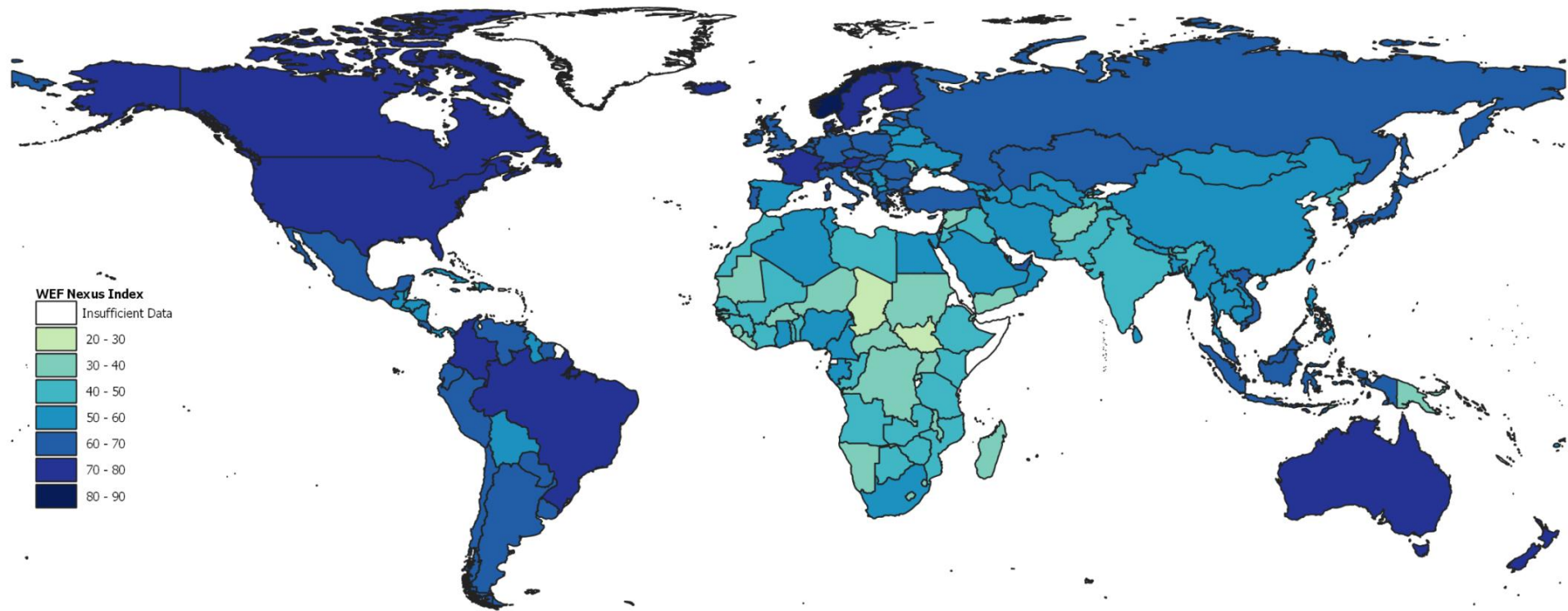


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Results





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WEF Nexus Index for the twenty top and bottom ranked countries

Rank	Country	WEF Nexus Index
1	Norway	80.88
2	New Zealand	77.29
3	Sweden	76.87
4	Iceland	76.57
5	Canada	75.51
6	Denmark	75.32
7	Australia	74.10
8	Austria	74.06
9	Finland	72.83
10	Brazil	72.75
11	United States of America	72.67
12	France	71.74
13	Switzerland	71.19
14	Colombia	70.12
15	Paraguay	69.99
16	Croatia	68.96
17	United Kingdom	68.53
18	Malaysia	67.79
19	Argentina	67.63
20	Uruguay	67.52

Rank	Country	WEF Nexus Index
151	Lesotho	37.93
152	Malawi	37.75
153	Rwanda	37.62
154	Uganda	36.27
155	Afghanistan	36.14
156	Timor-Leste	36.08
157	Liberia	36.03
158	Burkina Faso	35.74
159	Guinea-Bissau	35.18
160	Solomon Islands	35.05
161	Comoros	34.31
162	Yemen, Rep.	33.98
163	Namibia	33.39
164	Central African Republic	33.15
165	Madagascar	32.94
166	Mauritania	32.54
167	Djibouti	32.13
168	Papua New Guinea	32.00
169	South Sudan	26.97
170	Chad	26.96



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WEF Nexus Index

- Interactive website:

<https://wefnexusindex.org/>



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