The Climate, Land, Energy, Water (CLEW) and Ecosystem Nexus

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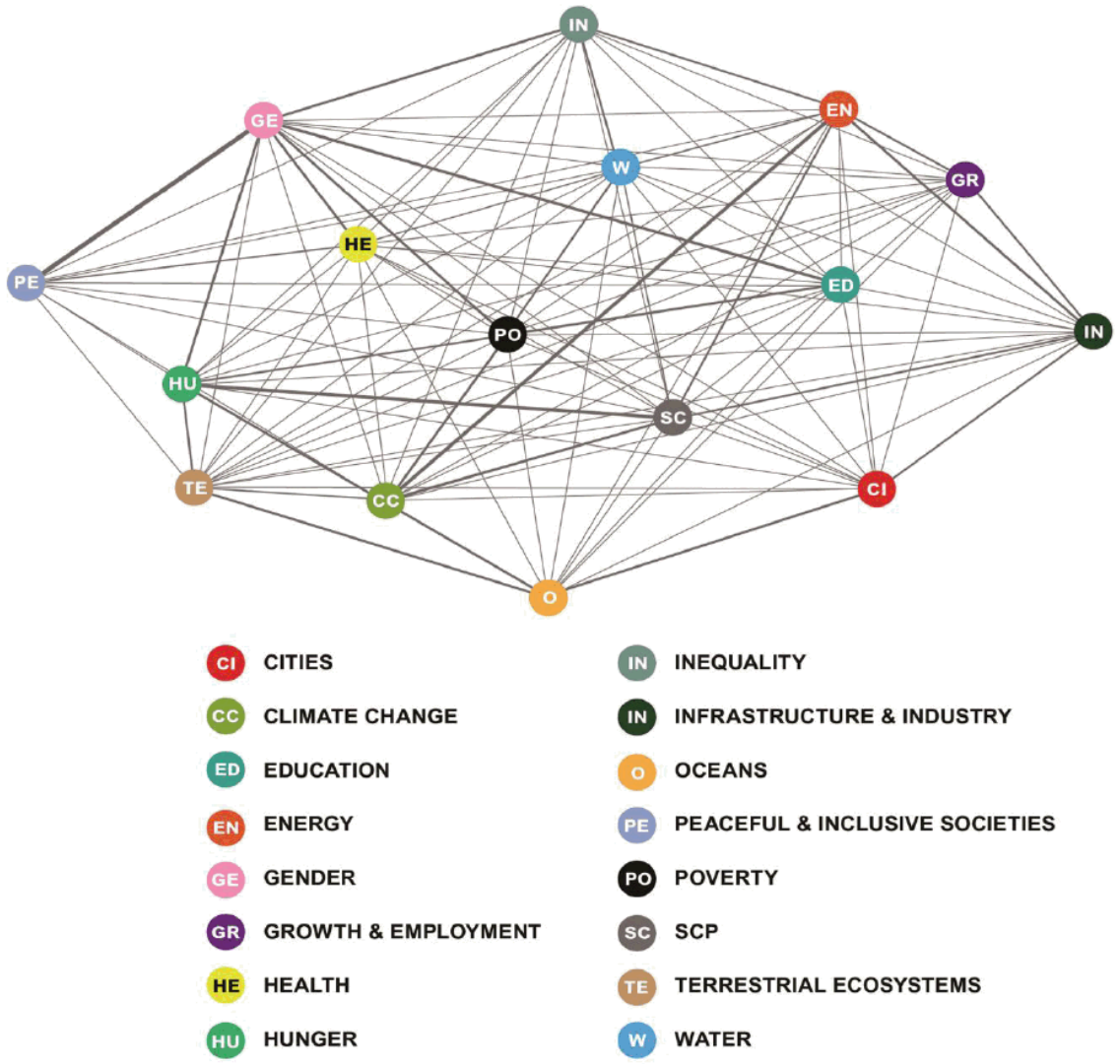
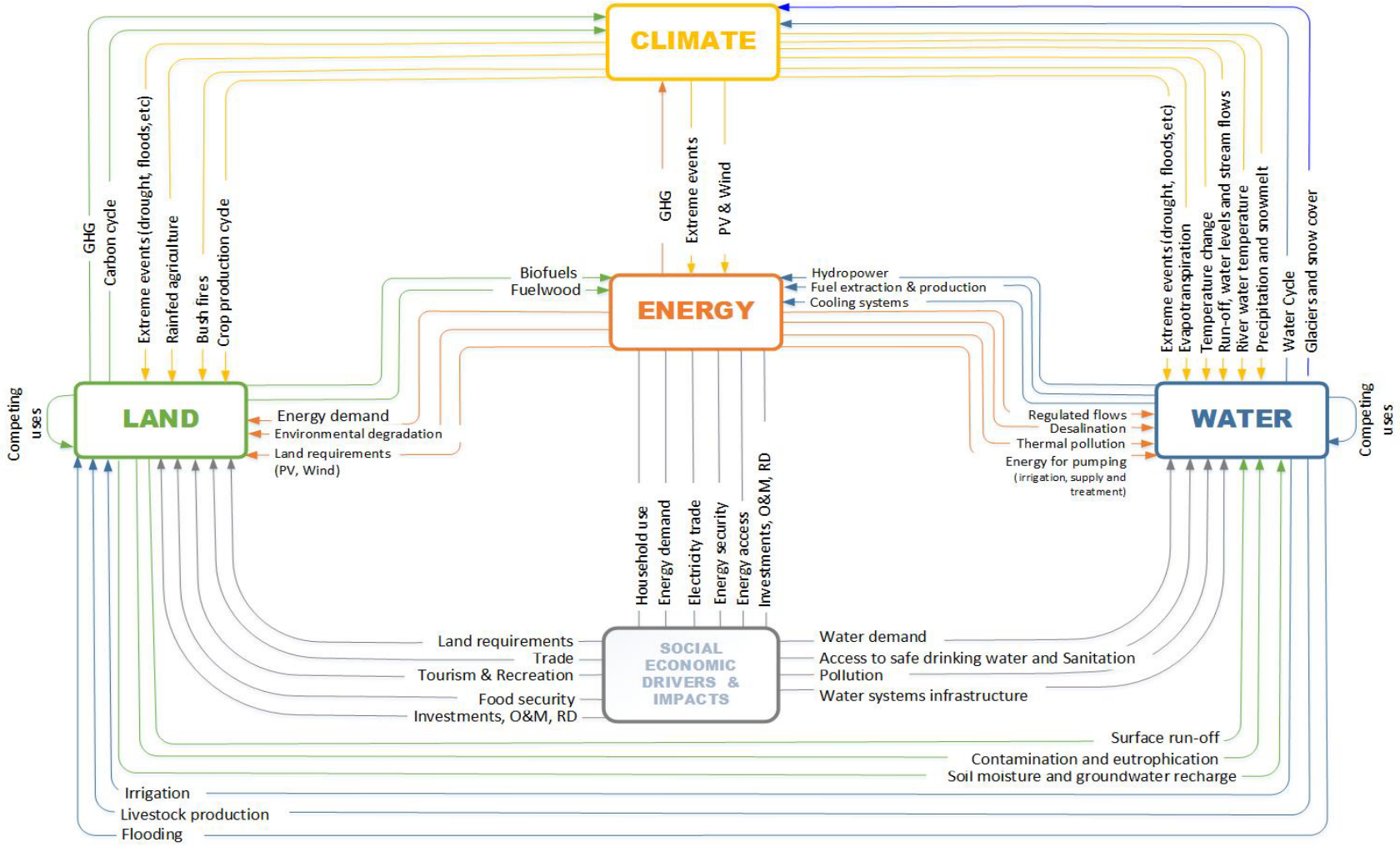
Integrated Modelling and Upskilling for Sustainable-Development

Agenda 2030 for sustainable development

- A plan of action for people, planet and prosperity
- Provides a powerful aspiration for improving our world – laying out where we collectively need to go and how to get there
- The SDGs are not 17 separate ambitions, but highly interlinked challenges that require coordinated action



The CLEWs framework and interlinkages ….



CLEWs and the SDGs

Housing (rural & urban)

11 SUSTAINABLE CITIES AND COMMUNITIES

1 NO POVERTY

Increased income, energy use & material consumption

Growth scenarios

8 DECENT WORK AND ECONOMIC GROWTH

2 ZERO HUNGER

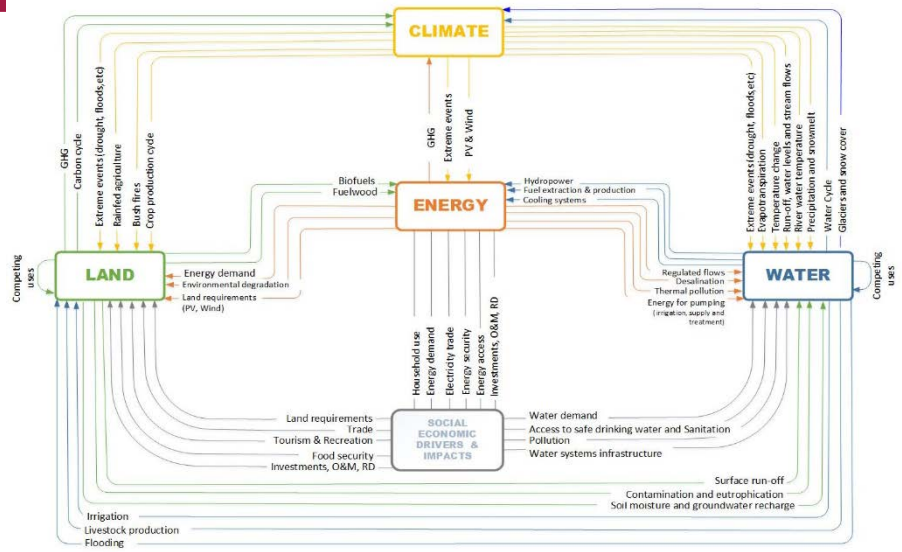
Demand for food

7 AFFORDABLE AND CLEAN ENERGY

Demand & source of energy

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Industrial production



12 RESPONSIBLE CONSUMPTION AND PRODUCTION

Assess alternative technologies & consumption patterns

Demand for clean water

6 CLEAN WATER AND SANITATION

17 PARTNERSHIPS FOR THE GOALS

Technology and investment options

15 LIFE ON LAND

Deforestation & land use

13 CLIMATE ACTION

Accounts for Carbon emissions

GLOBAL CLIMATE, LAND, ENERGY & WATER STRATEGIES

Water, energy and land-use are intimately interlinked and all affect the climate. Therefore, issues related to water, energy or land use cannot be dealt with in isolation and cannot be met sustainably without trade-offs between them. The CLEWS Model provides an integrated interdisciplinary framework supporting a clear understanding of those relationships.

The original model was developed by researchers from the Royal Institute of Technology (KTH) in Sweden in cooperation with the United Nations Division for Sustainable Development. For more information please visit: UN DESA

Comparing A BAU with a Carbon Tax

Welcome to the United Nations

COMPARE CLIMATE SCENARIOS

Use the dropdown menus to compare the emissions and energy produced by various industries under different scenarios from 2010 to 2050. All scenarios follow current assumptions for energy supply and renewable energy generation potentials.

CHOOSE SCENARIO: Baseline Scenario

This is the **business-as-usual** scenario. Greenhouse gas emissions are expected to **increase average temperature to between 4°C and 6°C**. Consumption and production grow according to trend and no new environmental regulations are considered.

CHOOSE SCENARIO: Carbon Tax Scenario

This scenario does not impose any limit on the use of fossil fuels but incorporates a **global carbon tax** increasing from US $1 per ton CO_2 eq. in 2016 to US $25 in 2050.

guide

trade-offs

emissions & use

energy supply

CUMULATIVE AMOUNTS, 2010 TO 2050

How much water is consumed?

1,850 km³ — baseline value

Annual average is 142% of 2010 values

How much CO_2 is produced?

1,552 CO_2 eq

Annual average is 123% of 2010 values

What is the total investment in energy and material production?

$228,071 billion 2010 USD

Annual average is 8.1% of global GDP

CUMULATIVE AMOUNTS, 2010 TO 2050

How much water is consumed?

1,879 km³

Annual average is 144% of 2010 values

How much CO_2 is produced?

1,452 CO_2 eq

Annual average is 115% of 2010 values

What is the total investment in energy and material production?

$233,864 billion 2010 USD

Annual average is 8.3% of global GDP

Comparing A BAU with a 2’C Target

Welcome to the United Nations

COMPARE CLIMATE SCENARIOS

Use the dropdown menus to compare the emissions and energy produced by various industries under different scenarios from 2010 to 2050. All scenarios follow current assumptions for energy supply and renewable energy generation potentials.

CHOOSE SCENARIO: Baseline Scenario

This is the **business-as-usual** scenario. Greenhouse gas emissions are expected to **increase average temperature to between 4°C and 6°C**. Consumption and production grow according to trend and no new environmental regulations are considered.

CHOOSE SCENARIO: 2 degrees Scenario

This scenario poses a limit on use of fossil fuels such that **average global temperature does not increase above 2°C**.

guide

trade-offs

emissions & use

energy supply

CUMULATIVE AMOUNTS, 2010 TO 2050

How much water is consumed?

1,850 km³ — baseline value

Annual average is 142% of 2010 values

How much CO_2 is produced?

1,552 CO_2 eq

Annual average is 123% of 2010 values

What is the total investment in energy and material production?

$228,071 billion 2010 USD

Annual average is 8.1% of global GDP

CUMULATIVE AMOUNTS, 2010 TO 2050

How much water is consumed?

2,454 km³

Annual average is 189% of 2010 values

How much CO_2 is produced?

1,052 CO_2 eq

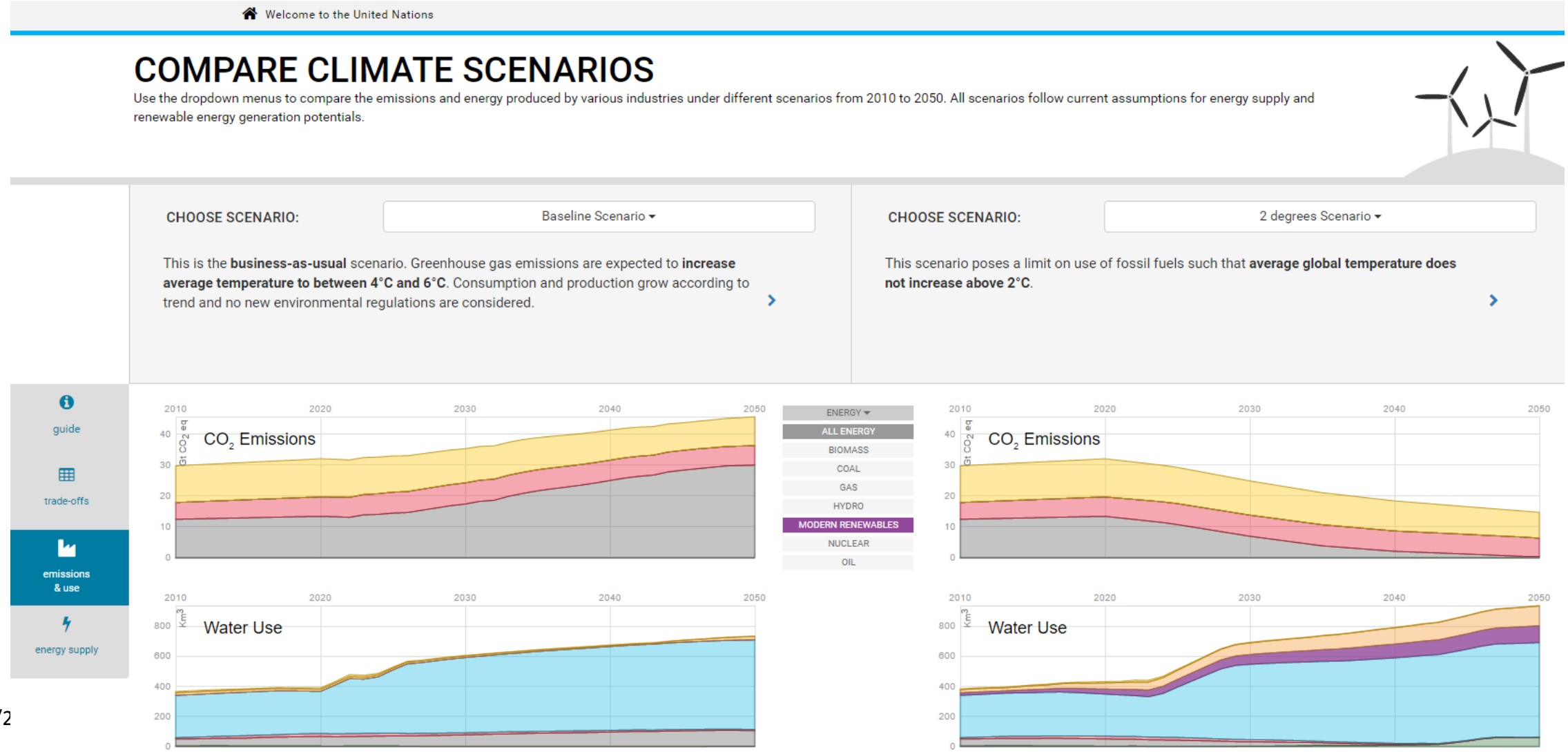
Annual average is 83% of 2010 values

What is the total investment in energy and material production?

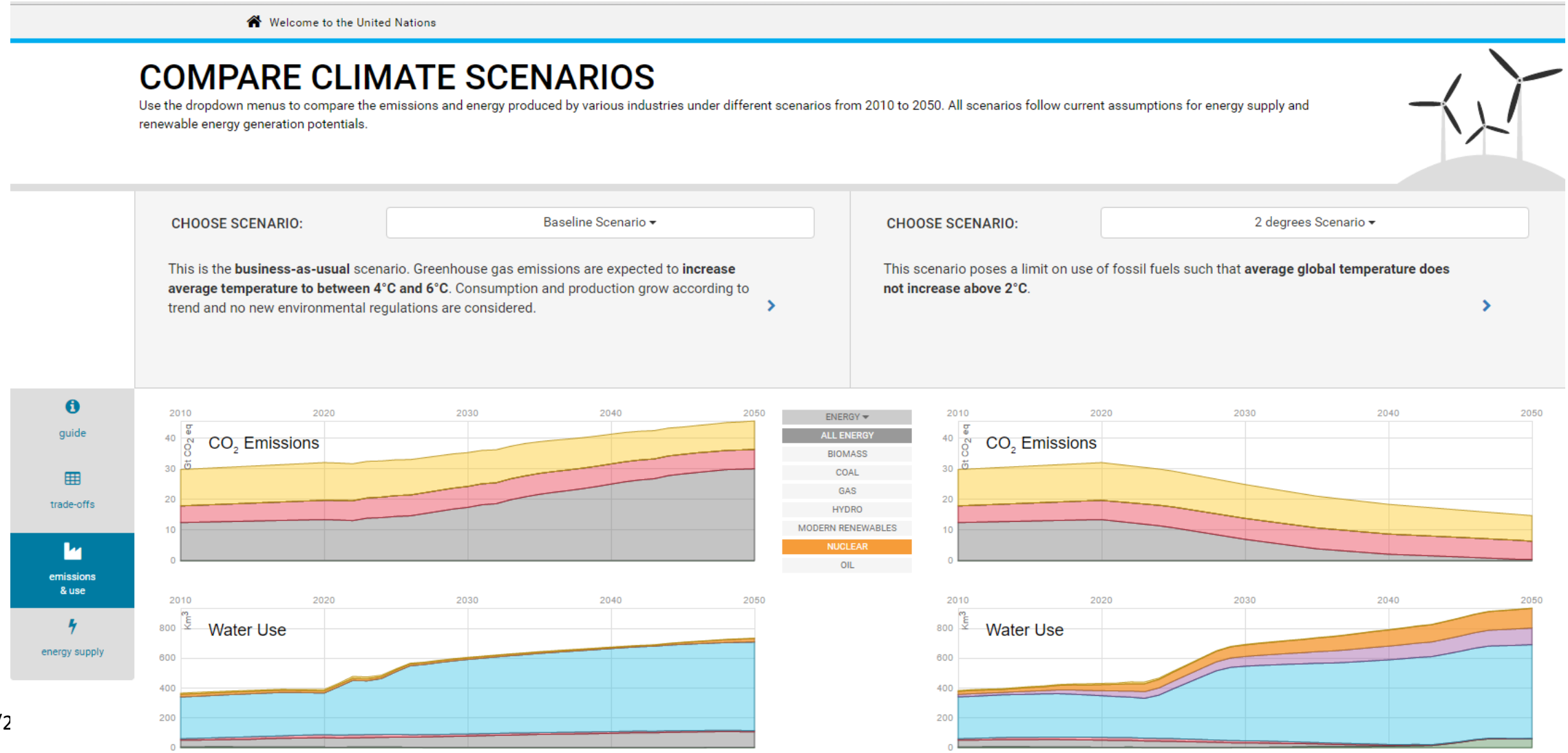
$256,257 billion 2010 USD

Annual average is 9.2% of global GDP

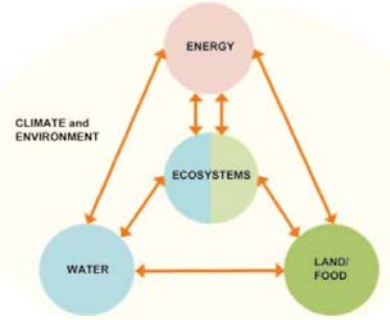
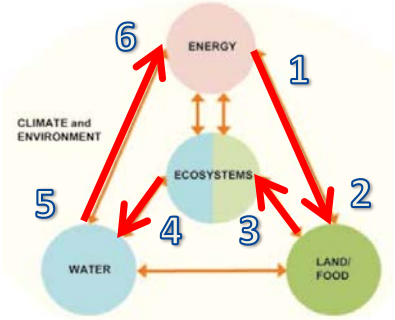
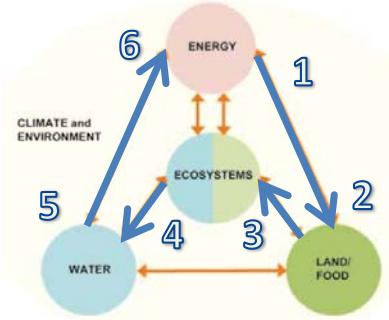
Technology and Water …

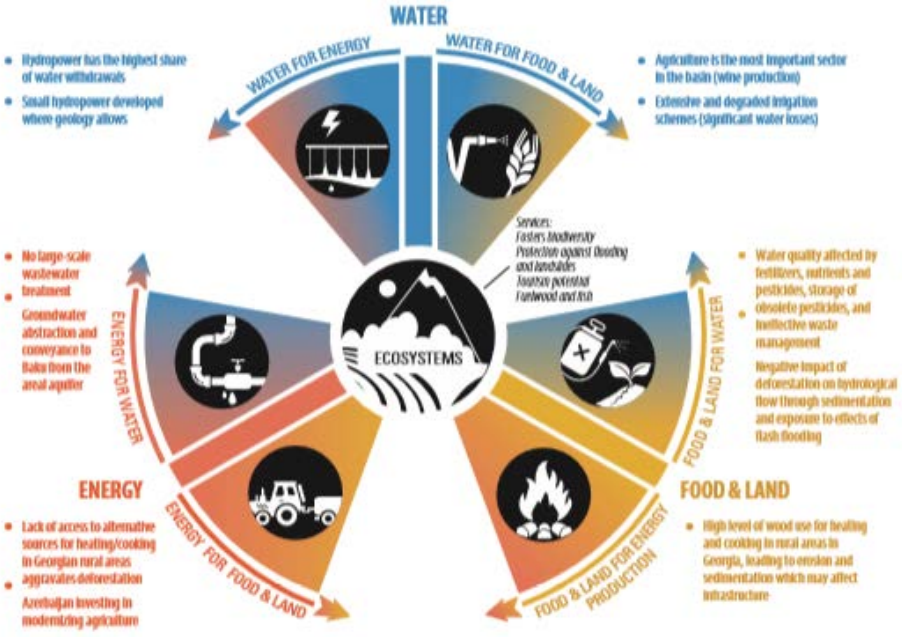


Technology and Water …



Transboundary assessments

Nexus interaction diagram	Impacts of fuelwood use	Nexus solution – modern energy
		



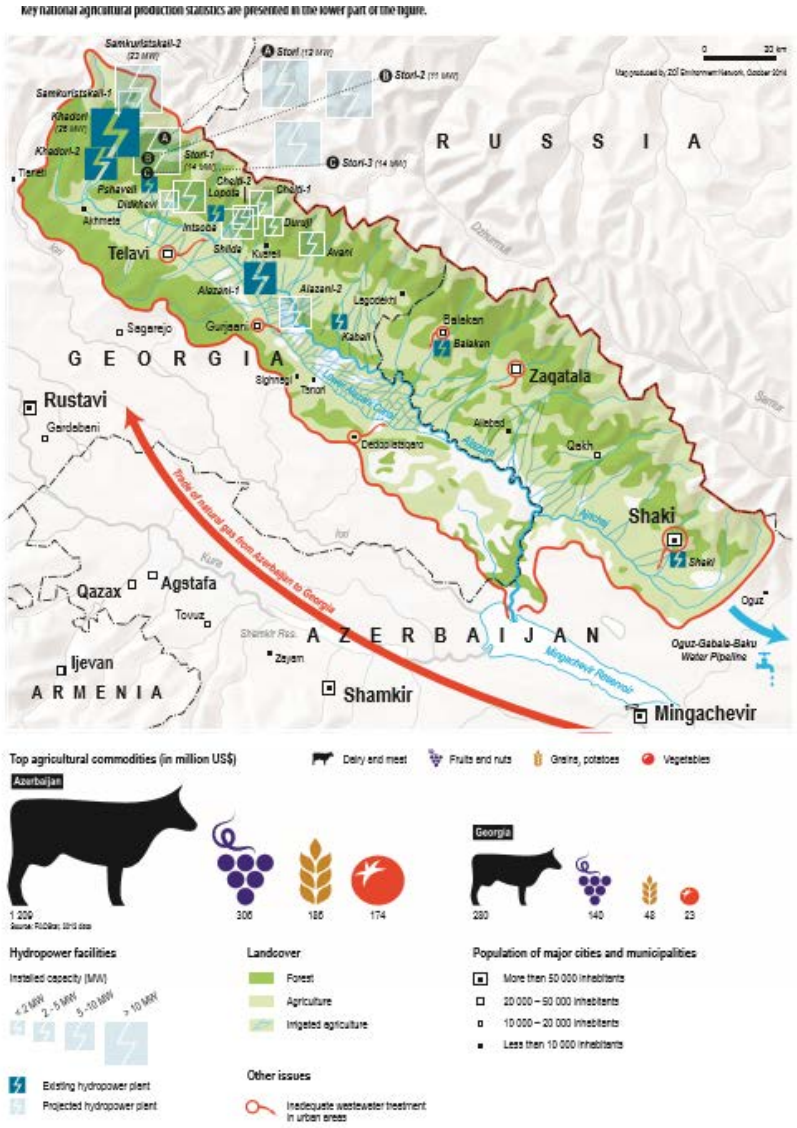


FIGURE 21
Key indicators describing the resources and socio-economics of the Sava countries

SAVA BASIN

River length	River basin area	Water use
945 km	97,713 km²	4,069 million m³/year

	SLOVENIA	CROATIA	BOSNIA AND HERZEGOVINA	SERBIA	MONTENEGRO
TOTAL RENEWABLE FRESHWATER RESOURCES	Sava basin share: 18,600 million m³/year; 31,870 million m³/year of which, water withdrawal 942 million m³; Agriculture 0.2% Industry 82.3% Municipal 17.6%	37,300 million m³/year; 105,500 of which, water withdrawal 629 million m³; Agriculture 1.4% Industry 13.7% Municipal 85%	35,500 million m³/year; 37,500 million m³/year of which, water withdrawal 329 million m³; Agriculture [no data] Industry 14.8% Municipal no data	8,400; 162,200 of which, water withdrawal 4,121 million m³; Agriculture 1.9% Industry 81.6% Municipal 16.6%	19,700 million m³/year of which, water withdrawal 161 million m³; Agriculture 1.1% Industry 39% Municipal 59.9%
INSTALLED ELECTRICITY GENERATING CAPACITY & HYDROPOWER	3.4 million kW of which Hydropower 1.3 million kW * Hydropower 37% Fossil fuels 36% Nuclear 21% Other renewables 6%	4.2 million kW of which Hydropower 2.1 million kW * Hydropower 51% Fossil fuels 45% Other renewables 4%	4.3 million kW of which Hydropower 2.15 million kW Hydropower 50% Fossil fuels 50%	8.8 million kW of which Hydropower 2.8 million kW * Hydropower 32% Fossil fuels 63% Other renewables 5%	0.9 million kW of which Hydropower 0.7 million kW Hydropower 76% Fossil fuels 24% * including pumped storage
AGRICULTURAL LAND	4,900 km² of which 1% is irrigated	13,600 km² of which 1% is irrigated	21,500 km² [No irrigated land (or negligible)]	51,200 km² of which 0,5 % irrigated	5,200 km² [No irrigated land (or negligible)]
GROSS DOMESTIC PRODUCT	$$$$$$$$$$ 48,000 million USD	$$$$$$$$$$ $$ 57,900 million USD	$$$$ 17,800 million USD	$$$$$$$$$$ 45,500 million USD	$ 4,400 million USD
POPULATION	2 million of which 1,220 thousand people in the Sava basin (61 %)	4.3 million 2,150 thousands (50 %)	3.8 million 2,850 thousands (75 %)	7.2 million 1,800 thousands (25 %)	600,000

Sources: FAO Aquastat; US EIA International Energy Statistics; International Sava River Basin Commission; Wood Bank, 2015.
* United Nations administered territory under Security Council Resolution 1244 (1999).

FIGURE 24
Future trends among nexus linkages in the Sava Basin

BASIN TRENDS	
PRECIPITATION	↘
TEMPERATURE	↗
ECOSYSTEM SERVICES	↘
POPULATION	↘
ECONOMY (medium term)	↗

↗ RISE ↗↗ SIGNIFICANT RISE ↘ DROP BY 2030

NATIONAL TRENDS	SLOVENIA	CROATIA	BOSNIA AND HERZEGOVINA	MONTENEGRO	SERBIA
WATER FOR FOOD & LAND Irrigation needs	↗↗	↗↗	↗	↗	↗↗
WATER FOR ENERGY Electricity generation needs, cooling	↗↗	↗	↗↗	↗	↗↗
ENERGY FOR WATER Treat, move and store water	↗	↗	↗	↗	↗
ENERGY FOR FOOD & LAND Grow, store, process and move food	↗	↗	↗	↗	↘
FOOD & LAND FOR ENERGY Food-energy competition for water, biofuel production	↗	↗	↗	↗	↗
IMPACT OF FOOD & LAND ON WATER RESOURCE Water pollution, agricultural use	↗	↗	↗	↗	↗

Uganda

Aim: to quantify the resilience of large scale hydro expansion using a CLEWS assessment.

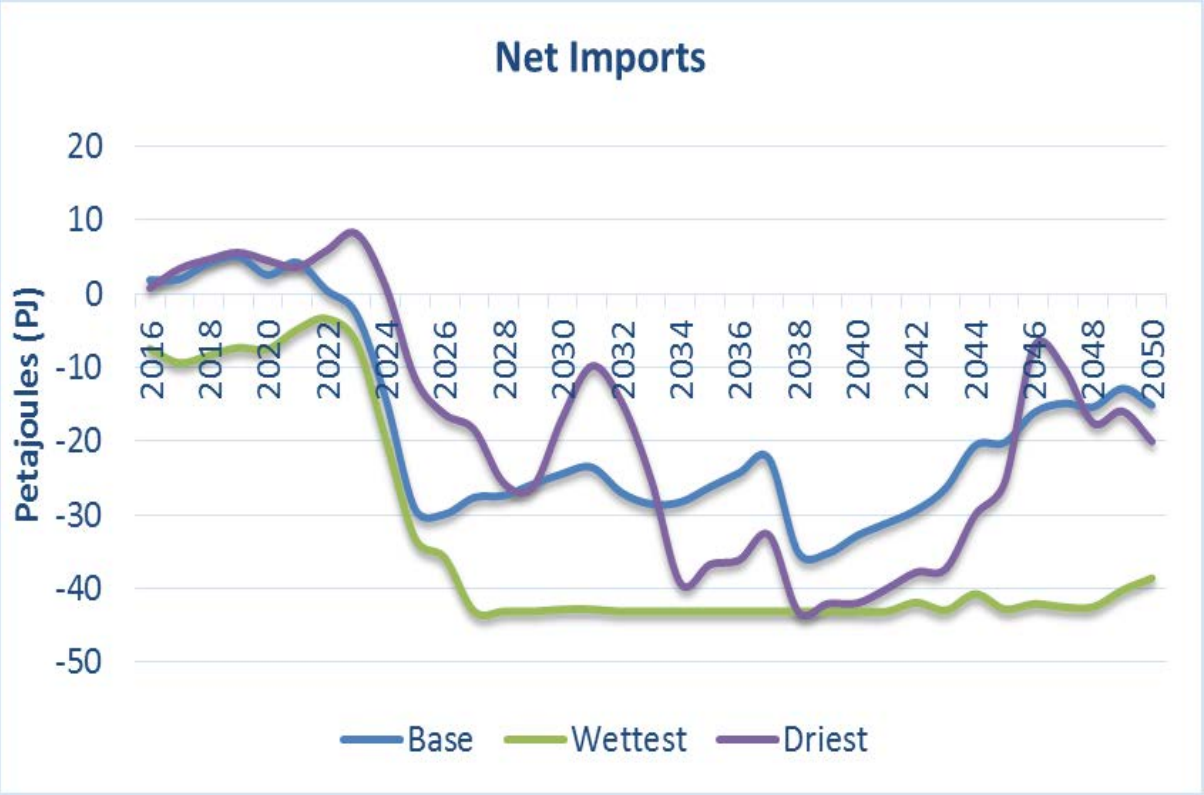
How: by assessing global climate change, regional power expansion and local demands a “CLEWS approach” may provide new insight

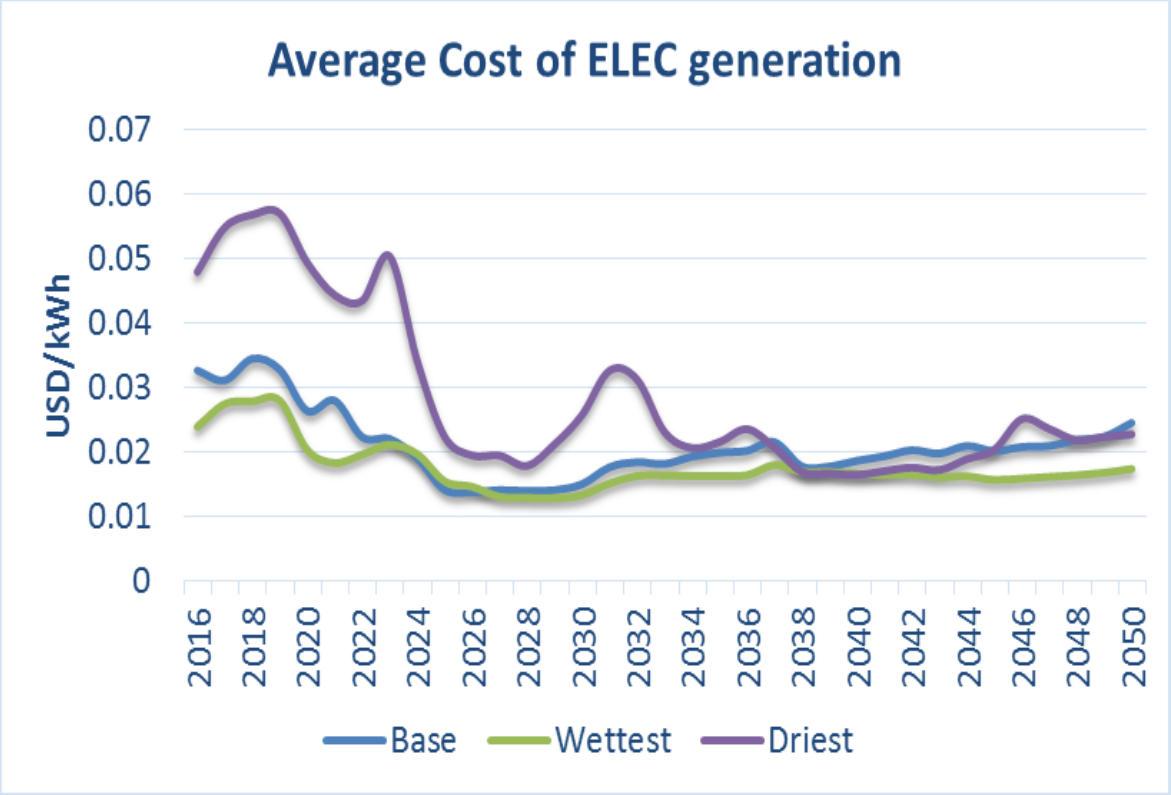
Why: Hydro investments need to be undertaken in the context of local water and regional power needs

- Ethiopia is expanding its hydro system rapidly, potentially stranding Uganda’s expansion and trade potential
- Climate change (with associated water withdrawals) may change production potential
- Local water requirements may grow in the future

Uganda

Resilience of Africa Energy infrastructure to Climate Change : Uganda as part of the East African Power Pool



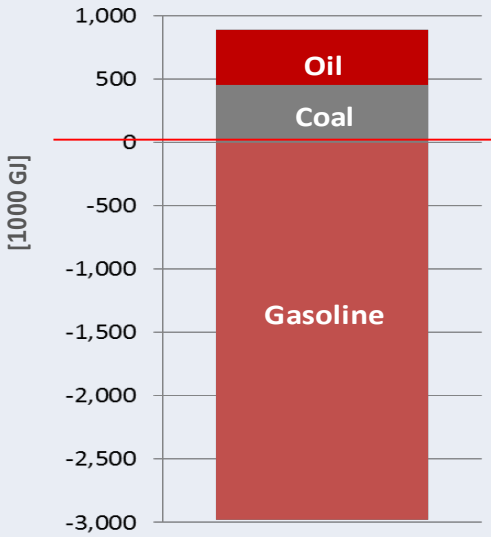


Mauritius

- Main revenue has been tourism and sugar exports
  - Expiration of EU agreement and collapse of revenue from the latter.
- Diversification away from sugar cane to food crops and vegetables
- Sugar cane production and refining – staple industry
- Bagasse from refining – cogeneration of heat and electricity
  - Reduction in sugar production led to lower electricity generation from bagasse
- Consequent increase in fuel imports – coincided with increase in international fuel prices
- Irrigation requirements higher for food crops-vegetables than for sugar cane
  - Increased water demand

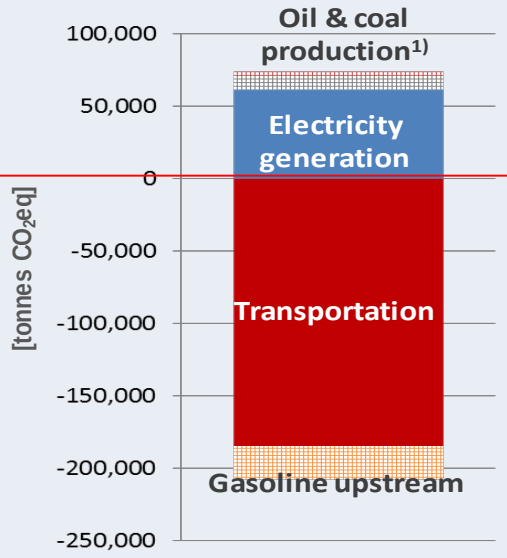
Impact of shifting two major sugar refineries to produce 2nd generation ethanol

Reduced fuel imports



Overall energy import dependence decreases: Gasoline imports are reduced as ethanol replaces gasoline as a motor fuel. Some bagasse is diverted from electricity generation to ethanol production and needs to be substituted by higher imports of coal and distillate oil.

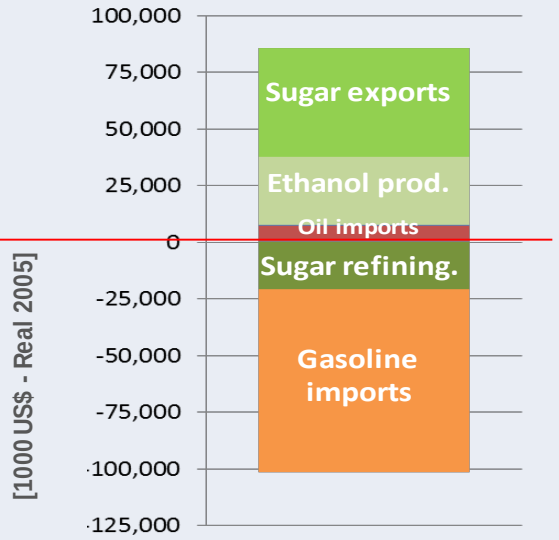
Reduced greenhouse gas emissions



Total greenhouse gas emissions are reduced: Tailpipe and upstream emissions are reduced as gasoline is replaced by ethanol. The increased use of coal and distillate oil (in place of bagasse) for electricity generation results in smaller additional emissions.

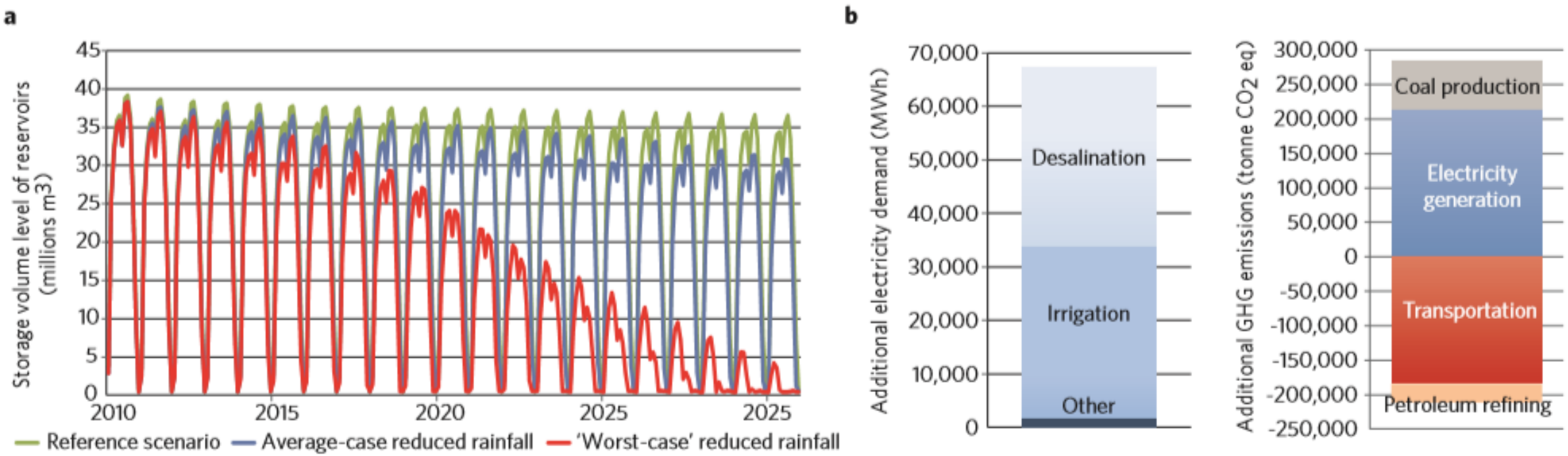
1) Indirect emissions

Reduced expenditures



Domestic ethanol production has economic benefits: As some of the sugar is converted to ethanol, the expenditures for sugar refining and gasoline imports are reduced. This outweighs the reduced sugar export earnings and the costs associated with ethanol production and the increases in oil and coal imports.

Impact of climate change in a CLEWs framework



Punjab, India

Punjab has only 1.5% of India's land, but its rice and wheat production accounts for 50% of the grain the government purchases and distributes to feed more than 400 million poor Indians.

- Groundwater is being **withdrawn faster than it can be replenished**
  - **No restriction** on landowners' rights to pump water on their own land.
  - Government-set prices **incentivises planting of water-intensive crops**
  - Electricity is **provided for free** to farmers
- **Water levels drop** and increased pumping is putting additional stress on an already fragile and overtaxed electricity grid.
  - Excessive pumping not only leads to over-exploitation of aquifers it also leads to high electricity demand.
  - **Irrigation accounts for about 15–20% of India's total electricity use**.

Urban CLEWs
– New York City: pilot CLEWs city study

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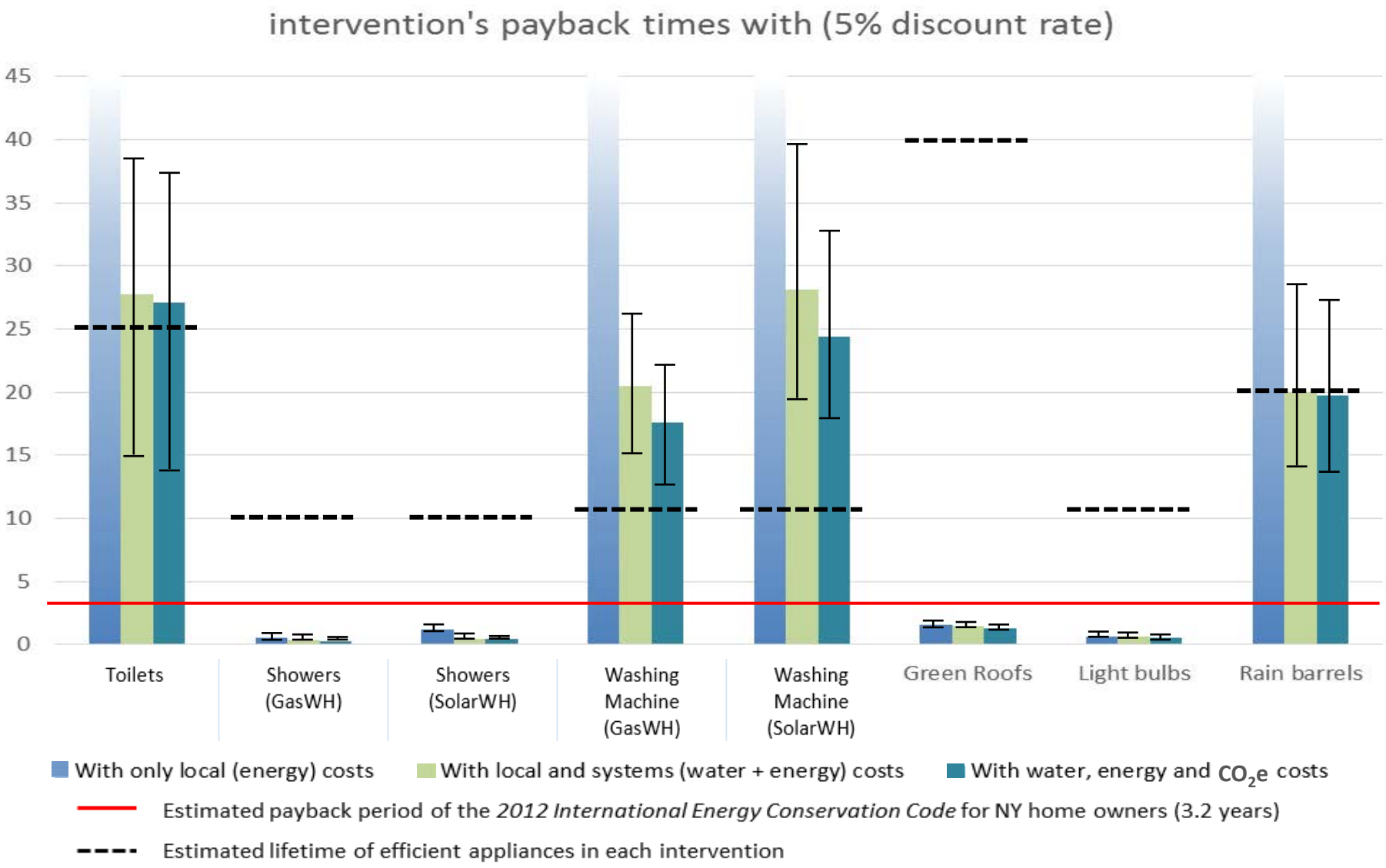
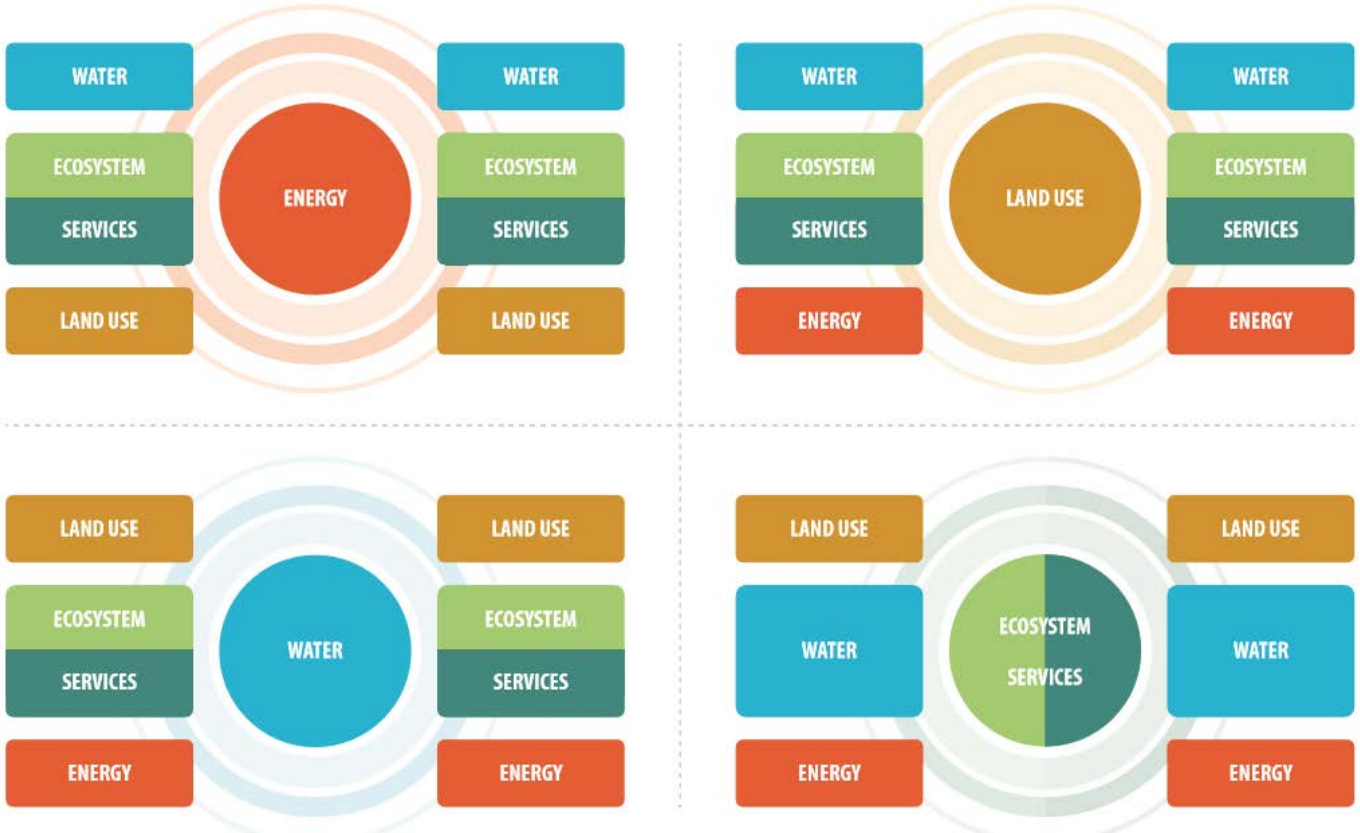
Numerical results: economics of interventions



Capacity building and communication ….



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Considering the energy, water and food nexus: Towards an integrated modelling approach

Morgan Bazilian [a,*], Holger Rogner [b], Mark Howells [c], Sebastian Hermann [c], Douglas Arent [d], Dolf Gielen [e], Pasquale Steduto [f], Alexander Mueller [f], Paul Komor [g], Richard S.J. Tol [h], Kandeh K. Yumkella [a]

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ABSTRACT

The areas of energy, water and food policy have numerous interwoven concerns ranging from ensuring access to services, to environmental impacts to price volatility. These issues manifest in very different ways in each of the three "spheres", but often the impacts are closely related. Identifying these interrelationships *a priori* is of great importance to help target synergies and avoid potential tensions. Systems thinking is required to address such a wide swath of possible topics. This paper briefly describes some of the linkages at a high-level of aggregation – primarily from a developing country perspective – and via case studies, to arrive at some promising directions for addressing the nexus. To ses the nexus, nvironmental d jointly the

water
MDPI

Article

A Methodology to Assess the Water Energy Food Ecosystems Nexus in Transboundary River Basins

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† The views expressed in this article are those of the authors and do not necessarily reflect the views of the United Nations Economic Commission for Europe or its Member States.

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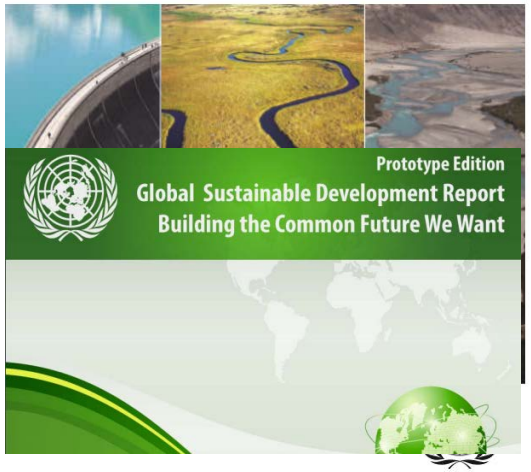
Integrated analysis of climate change, land-use, energy and water strategies

Mark Howells[1]*, Sebastian Hermann[1]*, Manuel Welsch[1], Morgan Bazilian[1], Rebecka Segerström[1], Thomas Alfstad[2], Dolf Gielen[3], Holger Rogner[4], Guenther Fischer[4], Harrij van Velthuizen[4], David Wiberg[4], Charles Young[5], R. Alexander Roehrl[6], Alexander Mueller[7], Pasquale Steduto[7] and Indoomatee Ramma[8]

Land, energy and water are our most precious resources, but the manner and extent to which they are exploited contributes to climate change. Meanwhile, the systems that provide these resources are themselves highly vulnerable to changes in climate. Efficient resource management is therefore of great importance, both for mitigation and for adaptation purposes. We postulate that the lack of integration in resource assessments and policy-making leads to inconsistent strategies and inefficient use of resources. We present CLEWs (climate, land-use, energy and water strategies), a new paradigm for resource assessments that we believe can help to remedy some of these shortcomings.

UNECE

Reconciling resource uses in transboundary basins: assessment of the water-food-energy-ecosystems nexus



WATER-ENERGY NEXUS

Assessing integrated systems

The various supply chains that deliver the services society needs are often managed in silos. Research now shows the advantages of integrated management.

Mark Howells and H-Holger Rogner

Living in the beautiful cities of Stockholm and Vienna we note, with some irritation, occasional interruptions to their scenic walkways. Striving to provide services, a street might get torn up several times within a few months. First to do sewage repairs, then to lay new high-capacity data cables and finally to increase the capacity of the gas mains — efforts that might cost three times more tax money than if these activities were coordinated. And this is just an example at local level — globally it can be worse. Our societies are simply not organized to undertake integrated planning and action[1]. We spend far more than we need to deliver the services societies demand. Writing in *Environmental Science and Technology*, Bartos and Chester[2] show the missed opportunities from the lack of integrated water-energy management in the state of Arizona, USA.

The delivery systems of society's services consist of a chain of activity. They originate from natural resources and ecosystems. These are extracted, processed and transported to provide products and services. Those chains are shaped by economics, technology and policies — notably to ensure secure supplies.

Society's 'delivery chains' have traditionally been managed individually. Initially, interactions between many chains were largely inconsequential — their supplies were abundant and our demand was small. For practical reasons, separate management also allows for delineated responsibility and focused planning. Hence, at all governmental levels, we find authorities for energy, water, agriculture and so on, each tasked with their own sectoral mandates. Such mandates often do not include any assessments of the impacts of action in one sector on others. A notable exception is the European Commission's Strategic Environmental Assessments. These assessments are required for certain types of public plans and programmes (for example, on land use, transport, waste and water management, energy and agriculture)[3].

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