NEXUSES in a Resource Limited World

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بسم الله الرحمن الرحيم

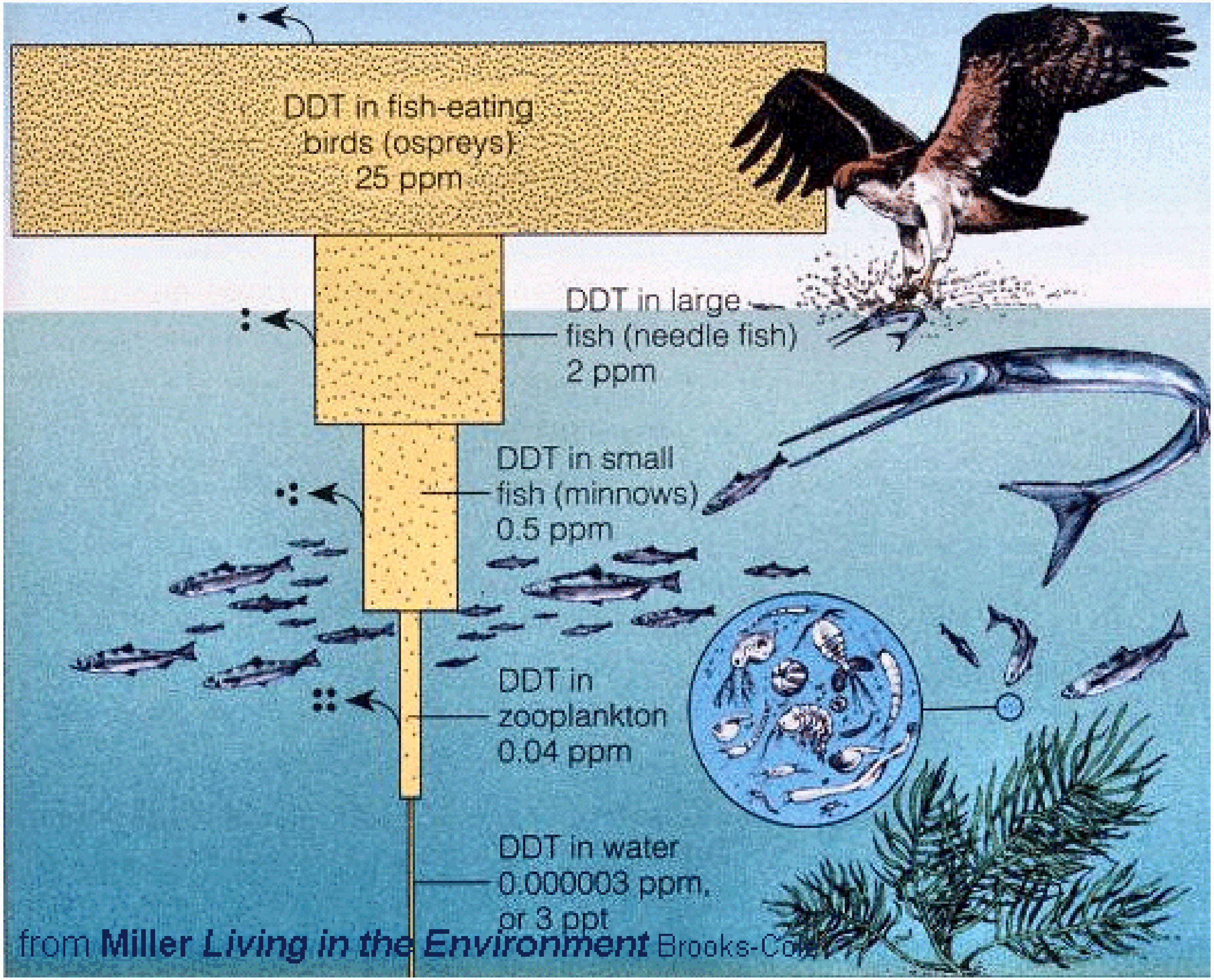
How Should we Understand the NEXUS?

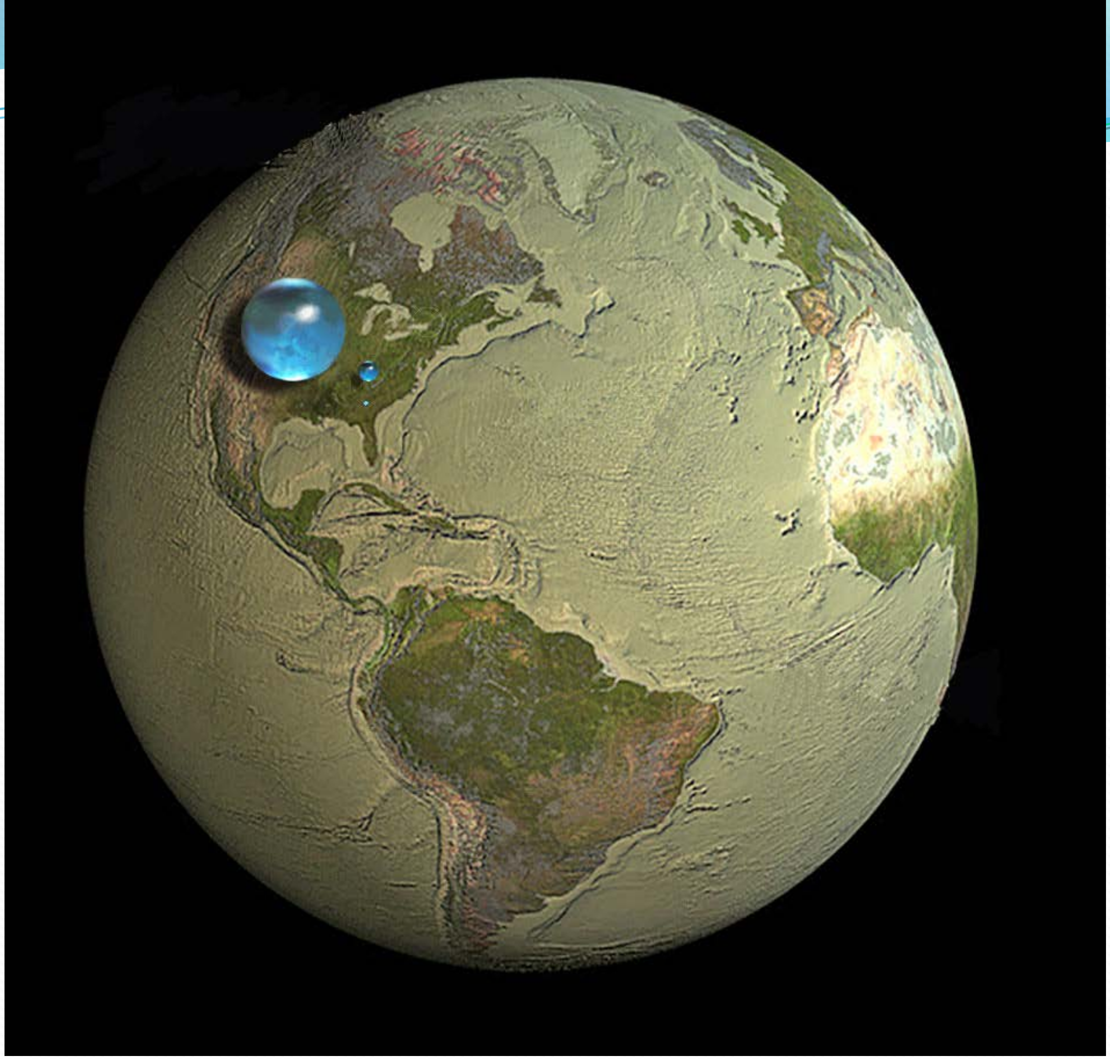
- NEXUS is an old Latin word which refers to the intricate interconnection of things.
- In today's resource-limited world nexus should be understood as the way the paired, tripled, quadrupled or multilateral interconnections between and among entities affect the way one element of the nexus responds to a certain input or action differently, in such a scale, quantitatively or qualitatively, in a chain of back and forth impacts and reactions that would not have happened if it was a lone responder to that certain input.

Then What's New if the Word is so Old?

- Neither the word nor the interconnections are new things. It is the intensity, scale and frequency in which these interconnection manifest themselves in an ecosystem which has started to demonstrate its limitations and invaded natural or ecological planetary boundaries.

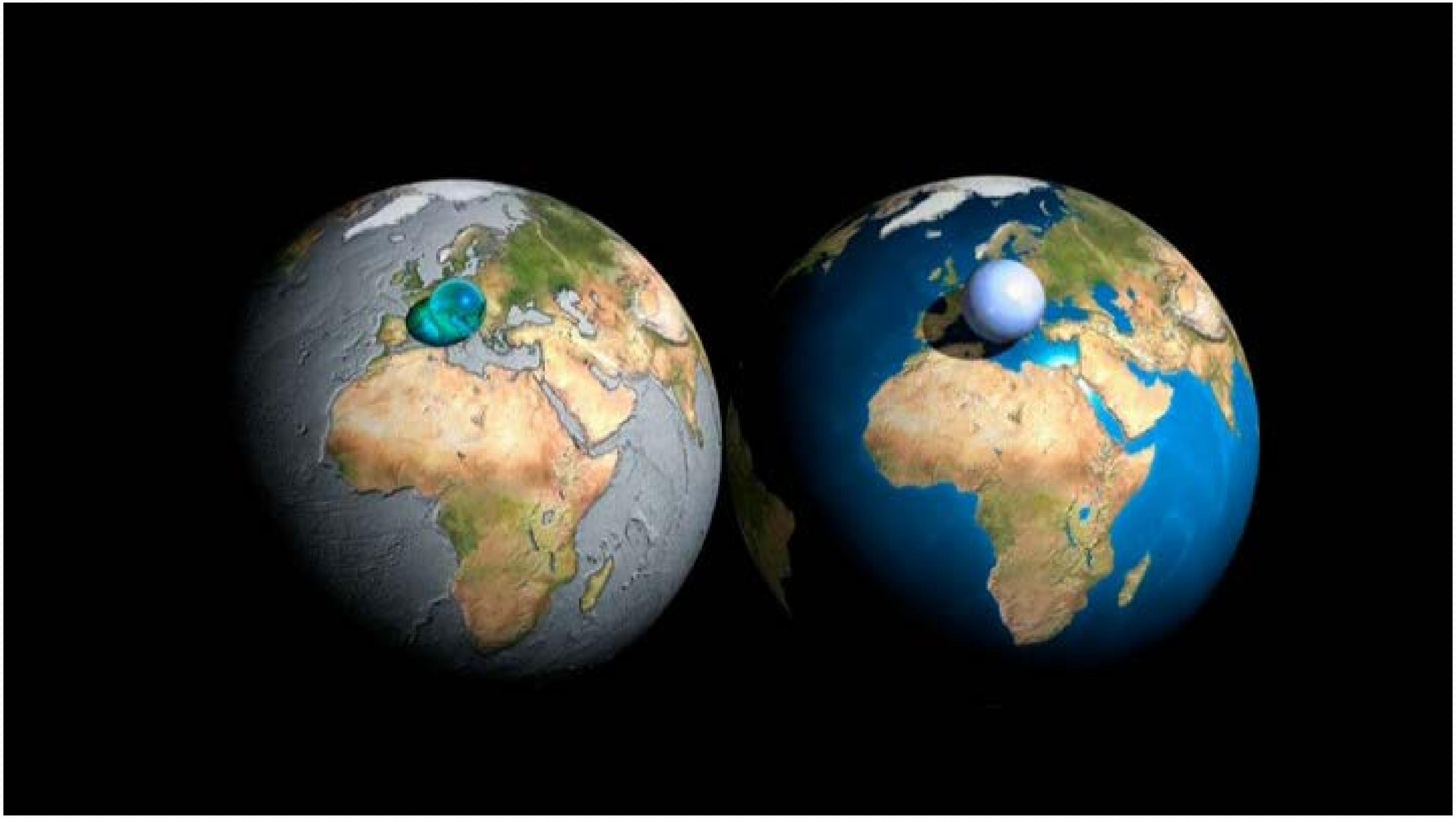
BIOACCUMULATION AND BIOMAGNIFICATION





All water on the planet (sphere over western U.S., 1384 Km in diameter)
Fresh liquid water in the ground, lakes, swamps, and rivers (sphere over Kentucky, 273 Km in diameter), and
Fresh-water lakes and rivers (the Tiny DOT over Georgia, 56 Km in diameter).

Earth, Water and Air



Water vapor accounts for roughly 0.25% of the atmosphere by mass
Diameter of Atmospheric Sphere in one bar pressure is 2000 km

Let Me Define A New Sphere! Anthroposphere?

World Population	7.5E+09
Avg. Weight in Kg (to make the layer one micron thick)	68
Total Weight in Kg	5.1E+11
Approx. Density	1
Human Volume in Liters	5.1E+11
Human Volume in Km3	0.51
Human Layer in Meters	9.999E-07
Human Layer in Microns	0.9998744

Anthroposphere : Thickness of Human Layer on planet earth,
Defined By: Bahram Taheri, 2014)
The Real magnitude of the Human Layer now is 0.7 microns.
In other words, at a population of around 10 billion people,
the thickness of this layer will reach to the critical value of about 1 micron!
At this thickness, the average per capita renewable fresh water will cross the scarcity level!

SWOT

- The competition between and among the elements of the nexus in their paired, tripled, quadrupled, and higher order multilateral links and related multi-dimensional spaces,
  - pose a great business, security and sustainability challenge on one hand,
  - while offering huge and untapped business opportunities on the other.

NEXUS Implementation Levels

- A thorough understanding of these complex and intertwined relations, not only can improve the short and long-term resource security and resiliency, but also its systematic study and analysis is a must in moving towards sustainability in multiple levels from policy development, adoption of strategies, transitional innovations all the way down to small enterprise management and kindergarten education.
- It is further a must in addressing our inter-generational responsibility in the need for assuring the enhancement, properness, continuity and more importantly the feasibility of our response measures.

Yet, another Scale!

- 100 B USD Pledge
- 73 T USD Economy
- More than 200 leaders committed
- The current state of climate affairs

Nothing but magnifies the importance of the role for scientists and what they can do in helping in:

- informed policy development
- addressing resource limitation
- needed decoupling between development and resources use, in which the energy is only one of the components, of course a major one.

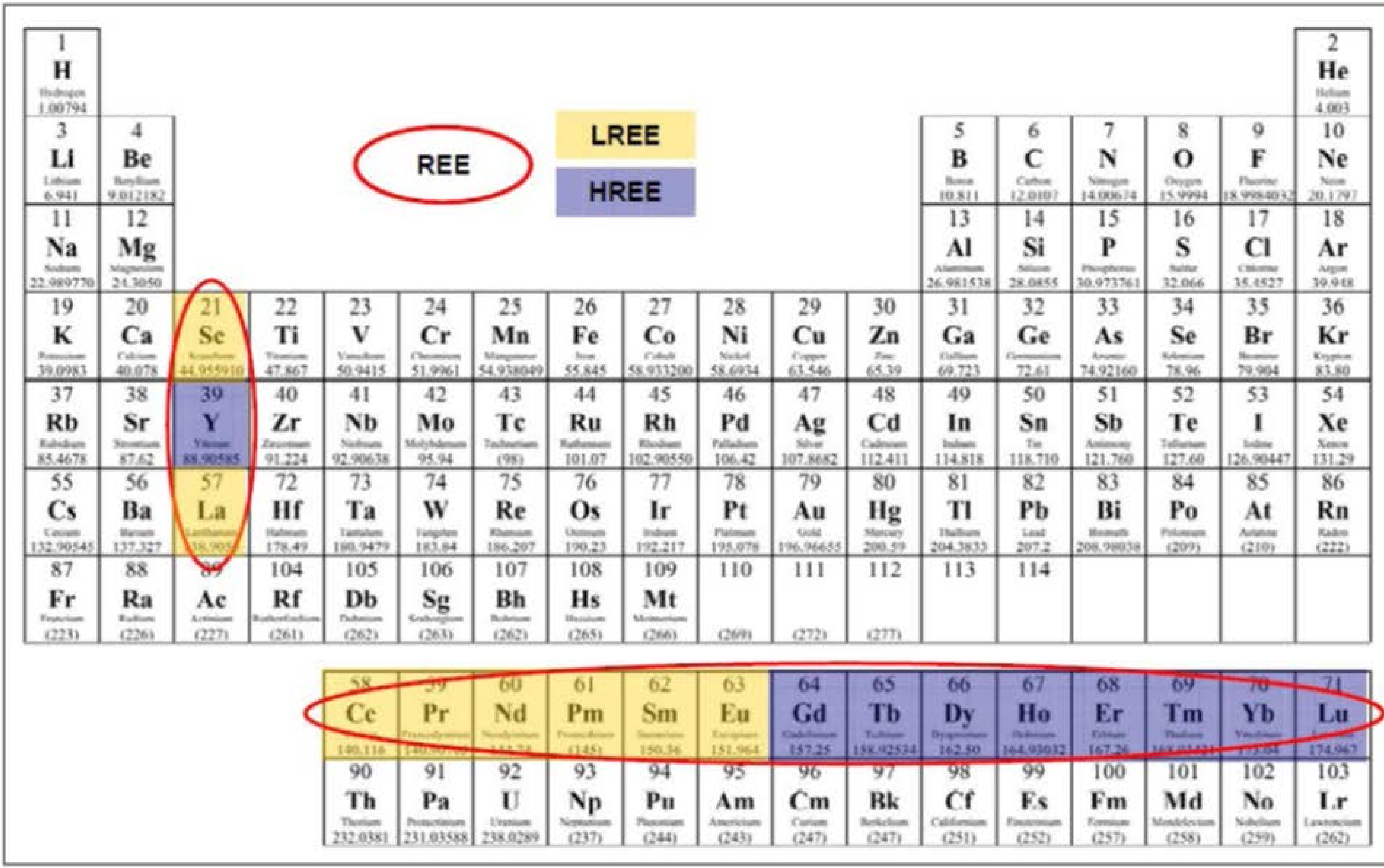
A Disruptive Change!

- Providing water has always required energy and producing energy by man has always needed water.
- In the past, there was always a balance between what the man could or could not do. However, the introduction of fossil energy in the dawn of industrial revolution and drilling of the first oil well in Pennsylvania in 1859 has had an enormous enhancing and compounding effect on the competitive performance of man over any other element in nature including the fossil fuel production and its exploitation.
- It is this intrinsic bouncing back and compounding impact which bears the fertile seeds of nonlinear, unpredictable and disruptive changes which is acting like the enemy within.

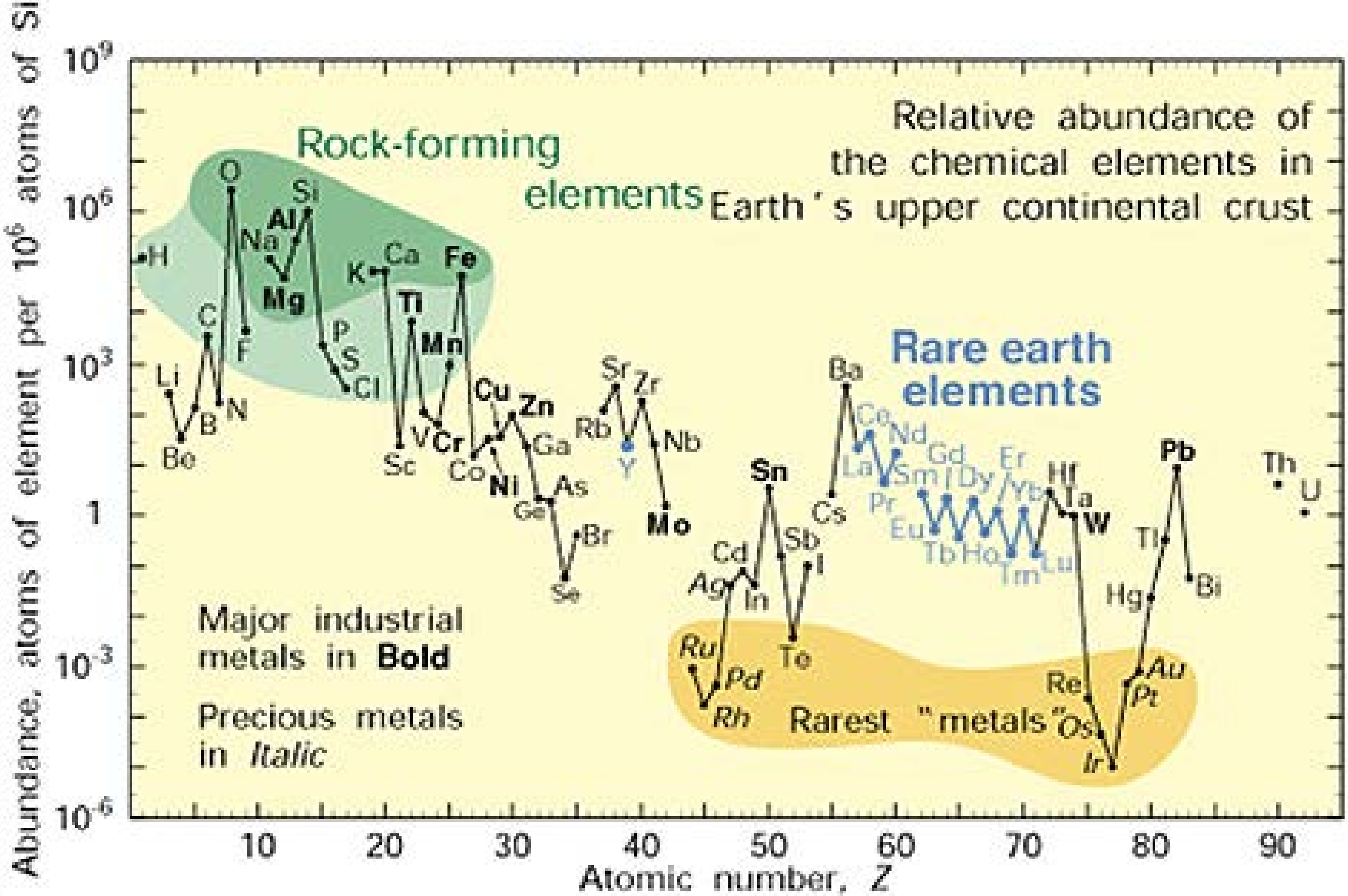
NEXUS and the Axiom of Conservation of Misery

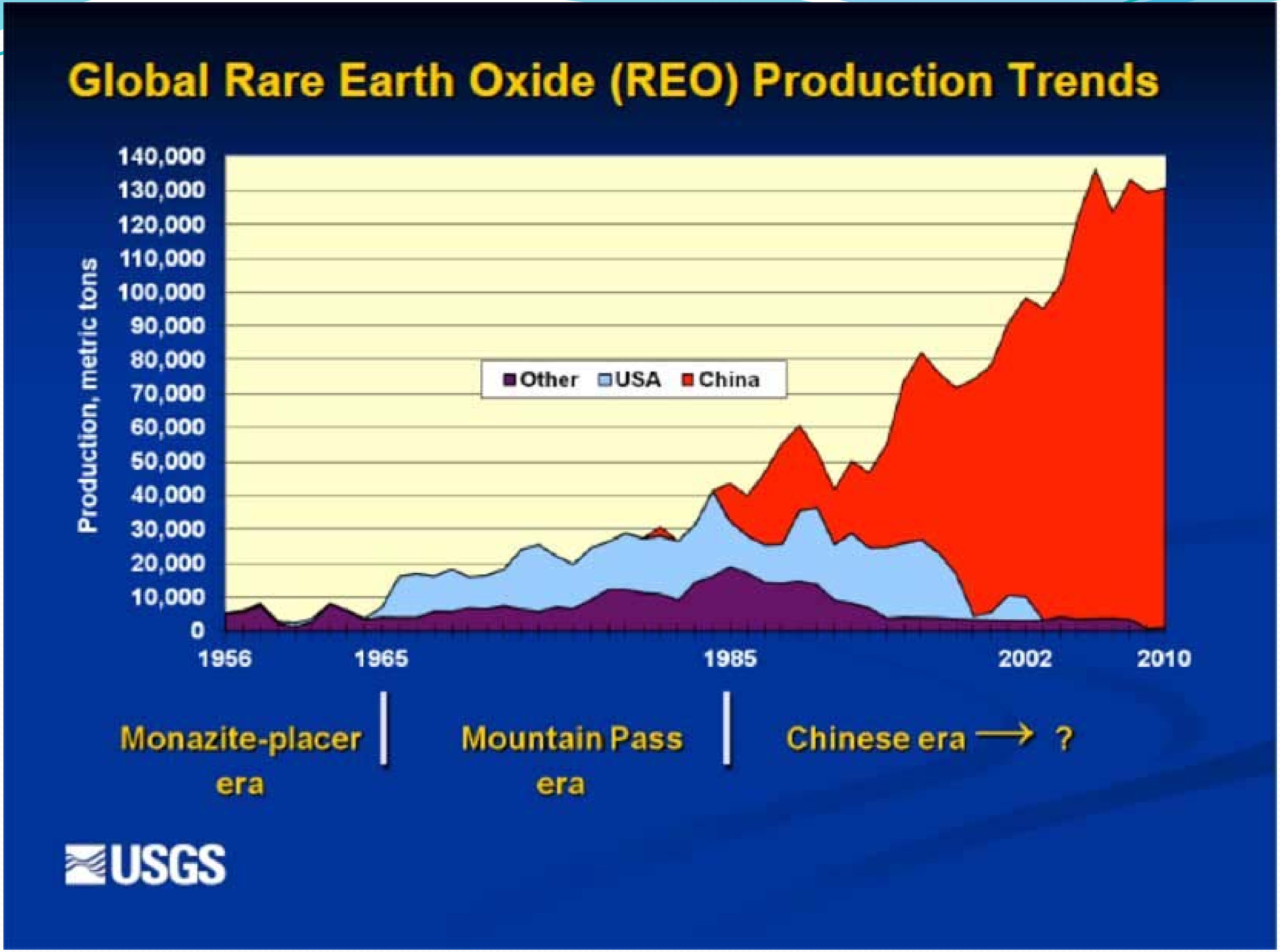
- While renewable energy reduces greenhouse gas emissions tremendously and has little carbon footprint of its own, it has a higher water footprint and amplifies the water stress and puts more strain on water security and hence food security.
- So, the carbon footprint reduction comes at the price of a higher water footprint. The renewable energy has also a high dependency on another very rare natural resource, namely the rare elements (LREEs and HREEs).
- Moreover, it is not only the global warming and GHG emissions which puts the planet at risk; it is the nature of this unprecedented superiority of the energy resource rich man which is working to the man's detriment.

Rare Earth Elements



Relative Abundance of REEs





Global Rare Earth Oxide (REO) Production Trends
140,000
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Production, metric tons
Other
USA
China
1956
1965
1985
2002
2010
Monazite-placer era
Mountain Pass era
Chinese era → ?
USGS

Two-Way Vectors

- One very important aspect which is fundamentally overlooked in the current NEXUS studies is that there is a huge difference between e.g.
  - the water-Energy nexus from the point of view of an observer standing on the water point relative to
  - the energy-water nexus from the point of view of an observer standing on the energy point.

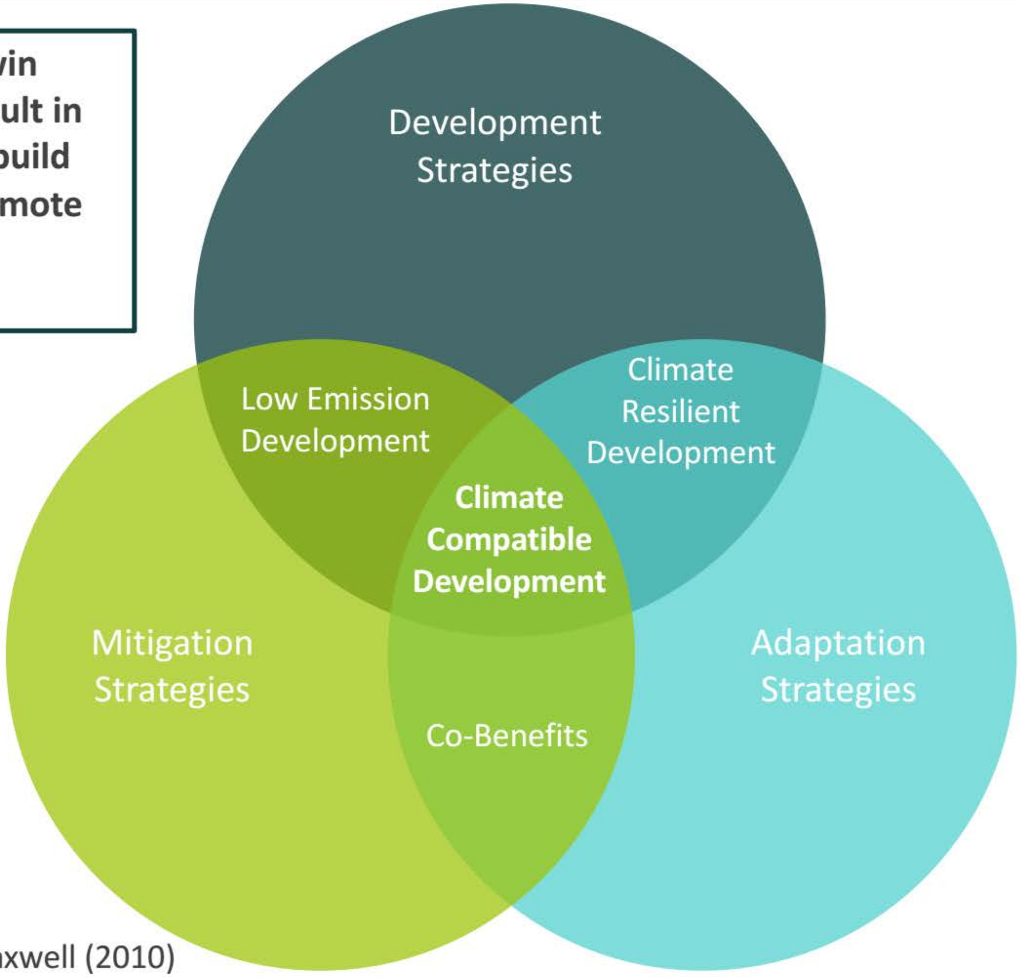
  Understanding this has a high systemic value in analyzing and understanding the causes of errors and shortcomings in our policy development or designing our response measures.

A Proposal for the Way Forward

- We need to develop a general framework for multilateral scientific cooperation under a systemic methodology:
  - to analyze and understand the changing nature of existing NEXUSES under the current conditions and boundary driven forces and restrictions (Proper Cognitive Steps),
  - the different prioritized attributes of each nexus element,
  - the positive and negative synergies and the way this newly developing science should be one of the pillars for:
    - policy and strategy development,
    - development of new methodologies,
    - new technologies,
    - new jobs,
    - new life-styles,
    - new awareness
    - and a new way of comprehending and preserving of the planet.

Need to strengthen the link between mitigation and adaptation in climate policies

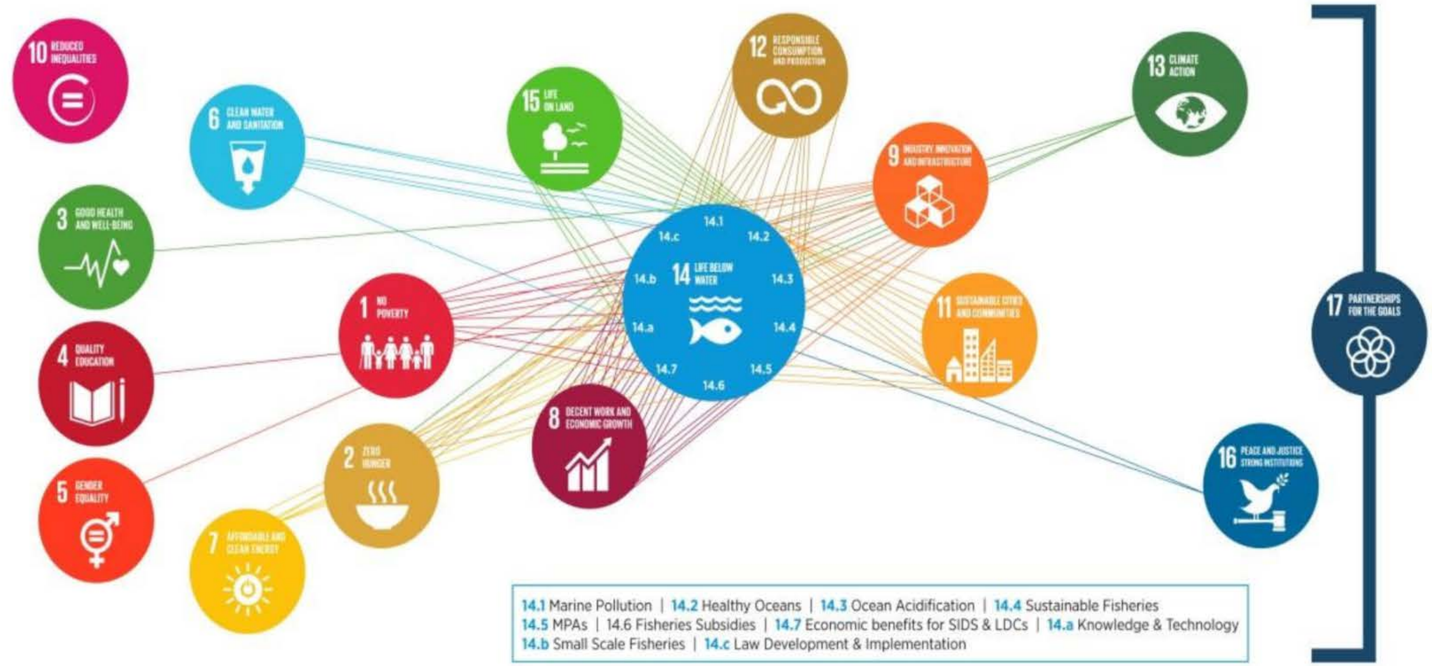
Search for triple win strategies that result in lower emissions, build resilience and promote development simultaneously

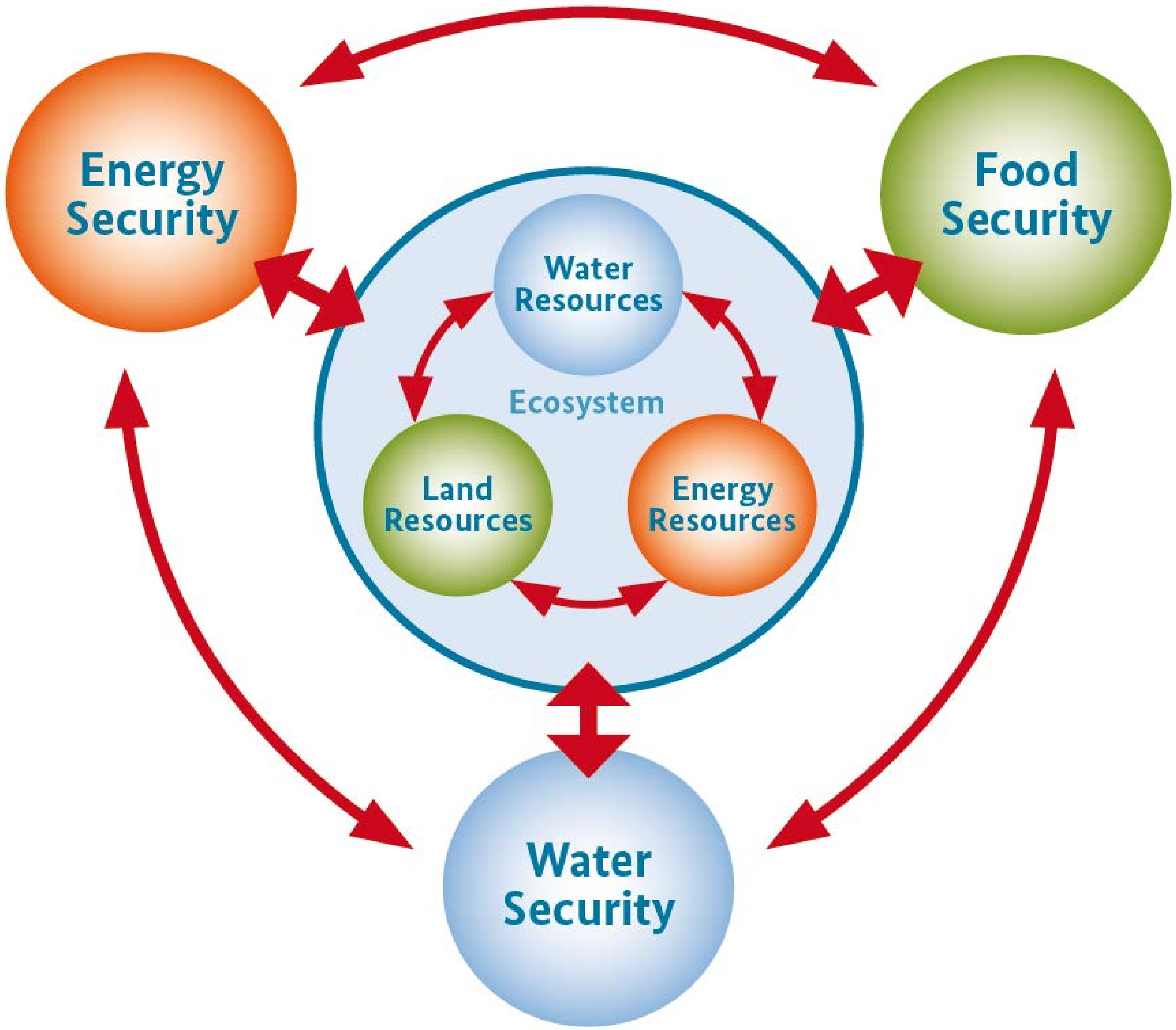


Source: Mitchell y Maxwell (2010)


NO POVERTY
2 NO HUNGER
3 GOOD HEALTH
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 CLEAN ENERGY
8 GOOD JOBS AND ECONOMIC GROWTH
9 INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION
13 PROTECT THE PLANET
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE AND JUSTICE
17 PARTNERSHIPS FOR THE GOALS
THE GLOBAL GOALS

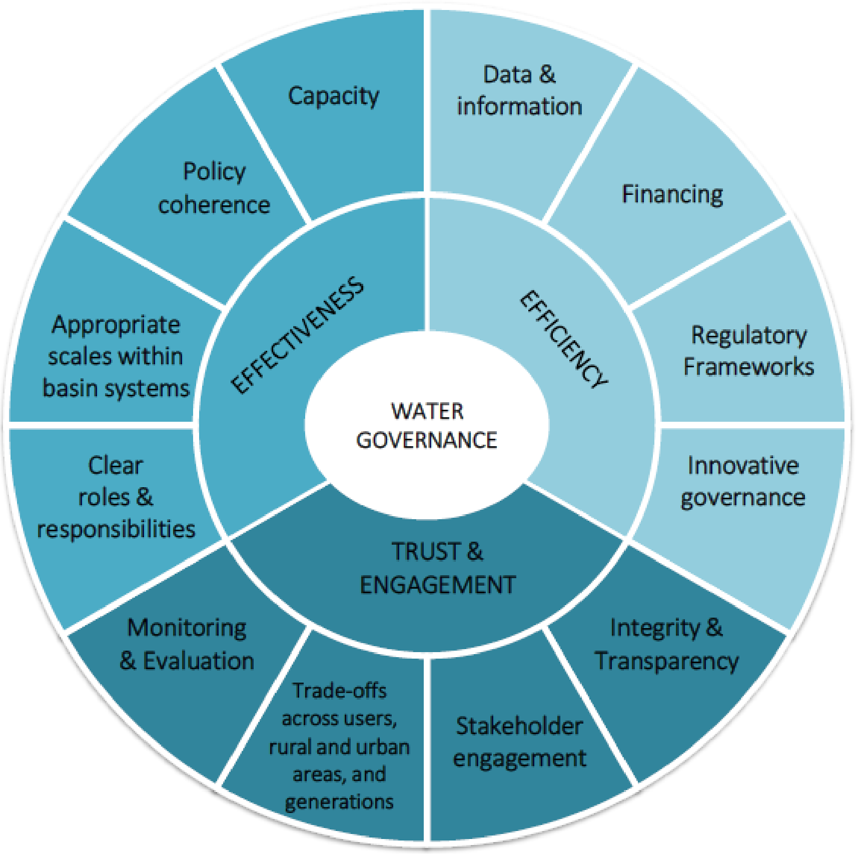
Climate action interacts with many other sector goals



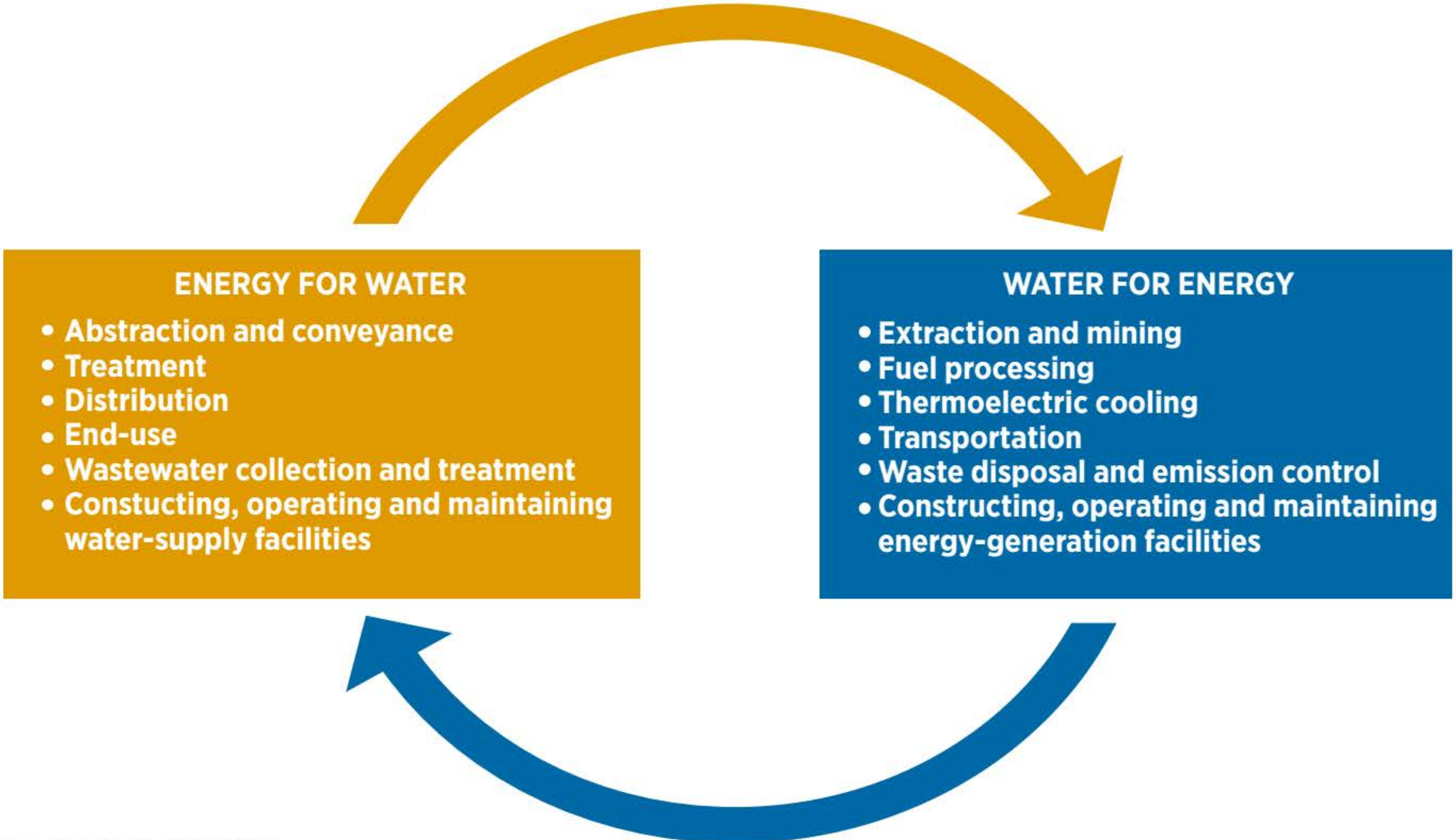

Energy Security
Food Security
Water Resources
Ecosystem
Land Resources
Energy Resources
Water Security

How Much will this Change? If at the Center we had written Energy rather than water!

Overview of OECD Principles on Water Governance



Some of Water & Energy NEXUS Interactions (Is everything written here?



Source: World Bank, 2013

What About:

- e.g. these topics?
  - Hydropower,
  - Pump and Storage Dams,
  - Water for Biofuels,
  - water pollution as a result of energy production
  - Water pollution because of offshore drilling and offshore production,
- e.g. also in case of energy for water
  - desalination,
  - cloud seeding,
  - Virtual water trade?
  - Etc., etc., etc!

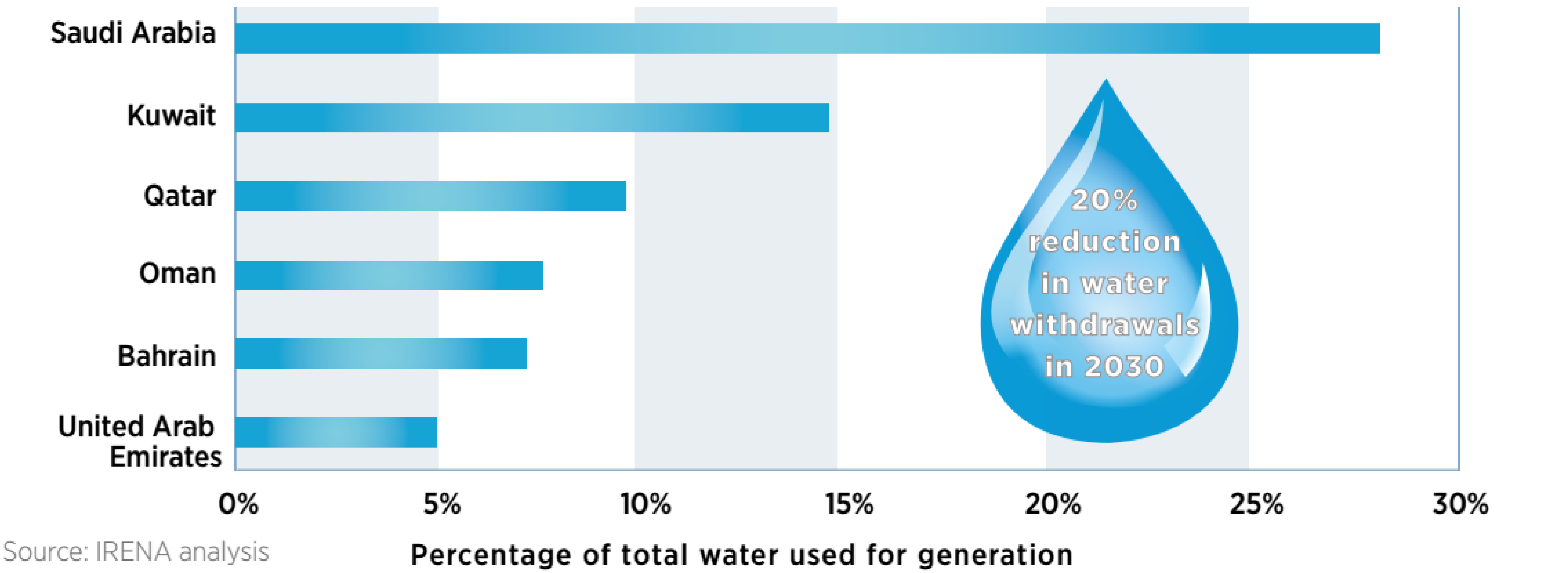
Reciprocal Water-Energy Risk-Impacts Examples

	RISKS	IMPACTS
Water-related risks to energy security	Shifts in water availability and quality due to natural or human-made reasons (including regulatory restrictions on water use for energy production/ fuel extraction)	• Reduced reliability of supply and reliance on more expensive forms of generation • Possibility of economic pricing of water and therefore higher costs of energy production • Reduced availability of water for fuel extraction and processing stages, leading to reduced outputs
	Increase in energy demand for water production, treatment and distribution	Strains on the energy system and reduced efficiencies given the different demand profiles for water and energy

Reciprocal Water-Energy Risk-Impacts Examples

Energy-related risks to water security	• Limited or unreliable access to affordable energy necessary to extract water • Re-allocation of water resources from other end-uses to energy	• Disruption in water supply to end-users or diversion of resources away from other core activities such as agriculture • Changes in delivery cost of water due to fluctuating costs of energy inputs
	Contamination of water resources due to energy extraction and transformation processes	Water resources, including for drinking purposes, rendered unsuitable due to contamination, often requiring additional treatment

Water Use % for Power Generation in Some Middle Eastern Countries

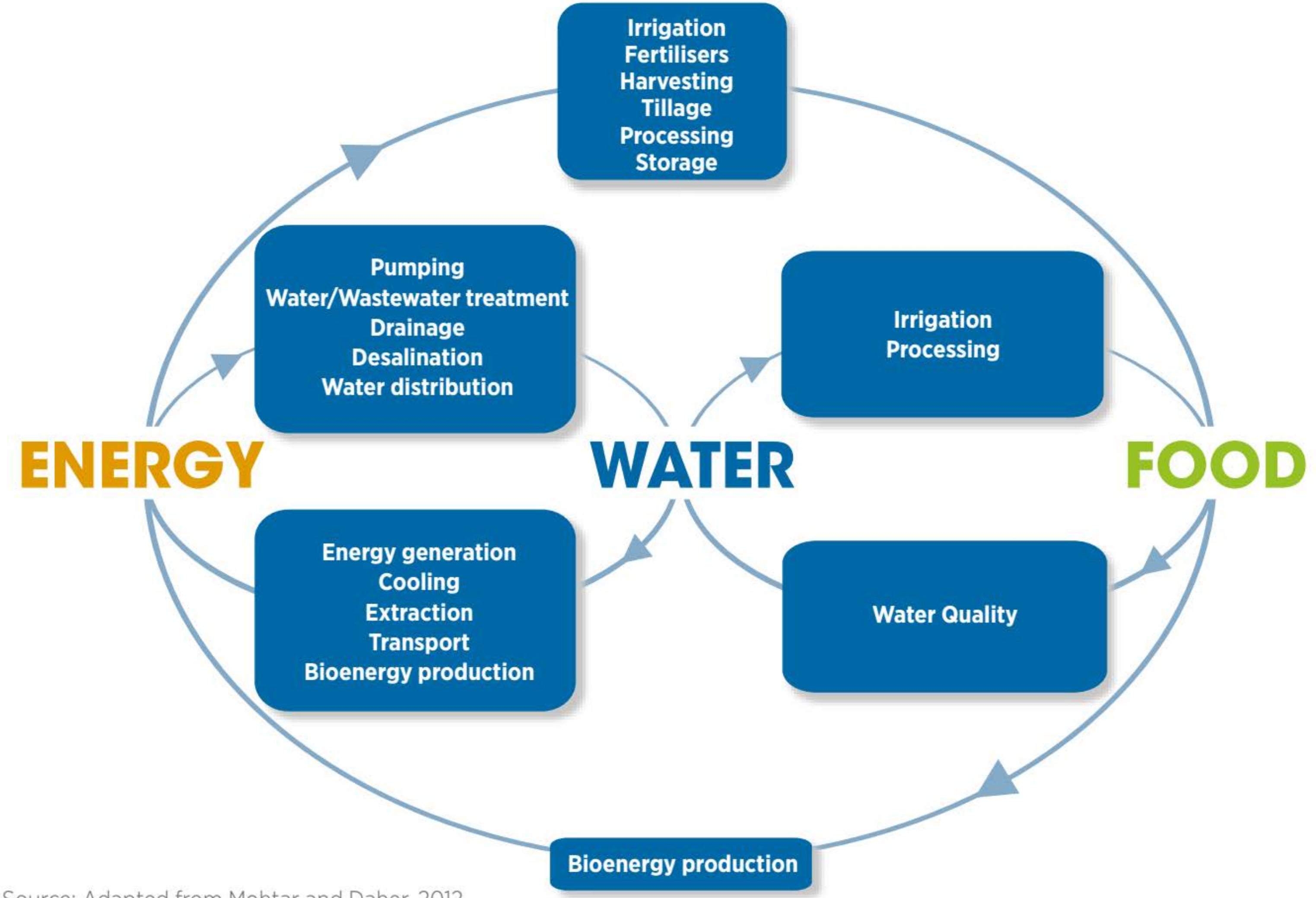


Source: IRENA

Hydropower in Iran

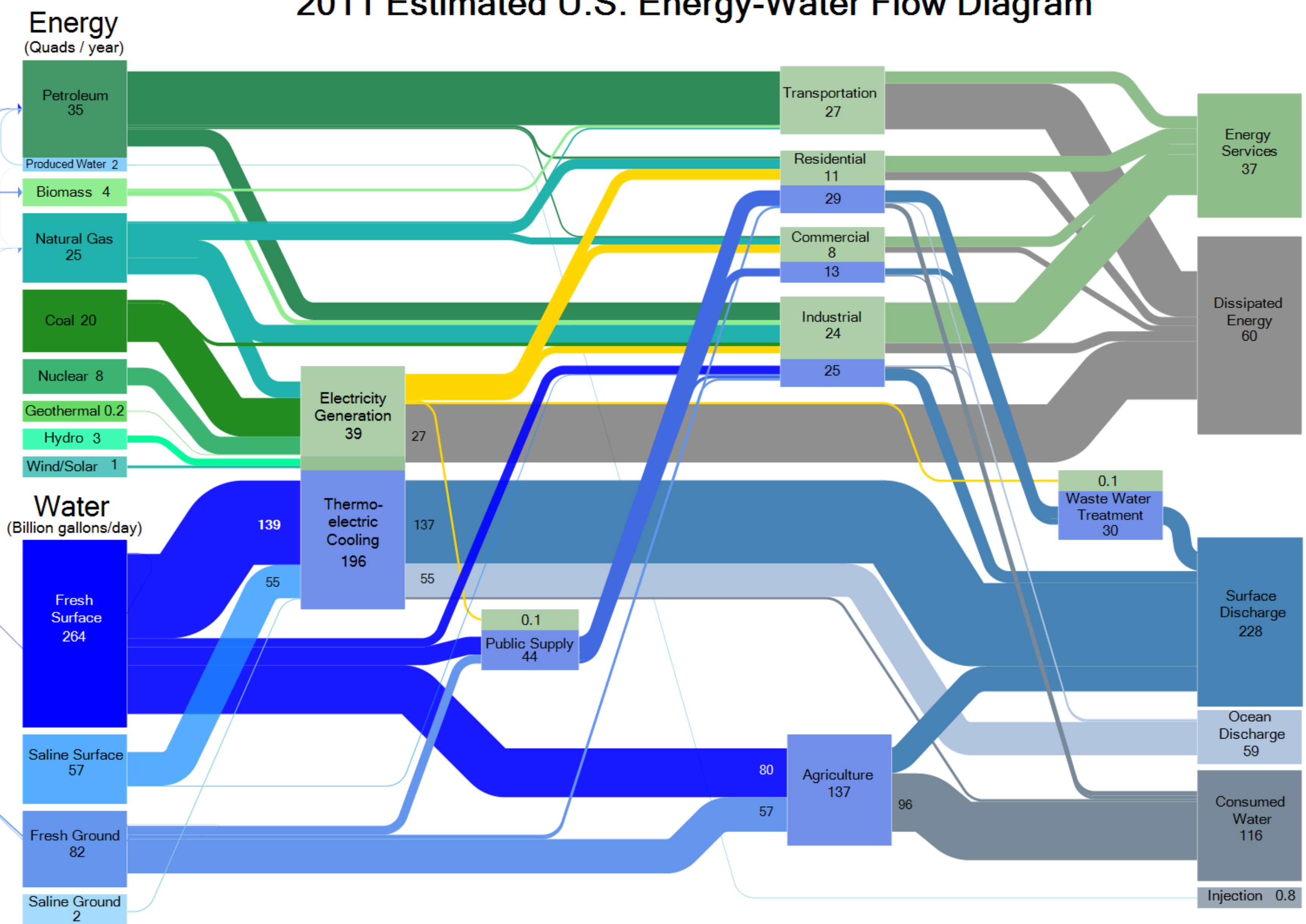
About 90% of energy supply of Iran comes from fossil fuel and 10% is obtained from water (About 6-8 BCM is used in producing energy from water). Since future energy supply will depend on the availability of land, wind, and water (Hoekstra, 2017), the understanding of WF of all different forms of energy covering both fossil and renewable resources in Iran is necessary.

Some of the Different NEXUS Interactions Among Water, Energy and Food. How complete or how well this is prioritized?



Source: Adapted from Mohtar and Daher, 2012

2011 Estimated U.S. Energy-Water Flow Diagram



Energy reported in Quads/year. Water reported in Billion Gallons/Day.

The Element of Soil

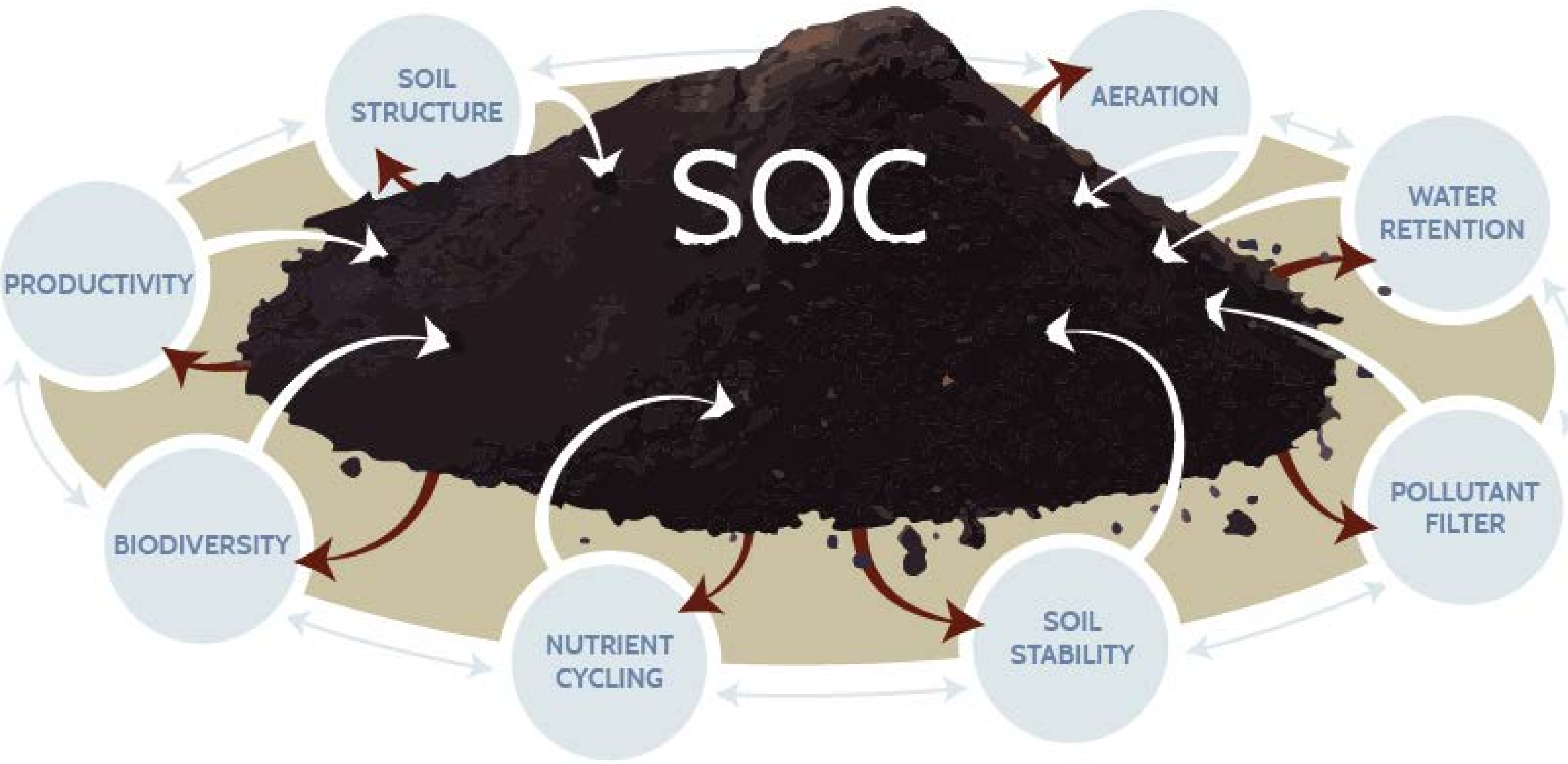
VGSSM action areas, defined by FAO

1. *Minimize soil erosion*
2. *Enhance SOM*
3. *Foster nutrient balances*
4. *Prevent soil salinization*
5. *Minimize contamination*
6. *Minimize soil acidification*
7. *Enhance soil biodiversity*
8. *Minimize soil sealing*
9. *Mitigate soil compaction*
10. *Improve soil water*

Each area has different technical requirements and implementation conditions in the field, thus requires different technical approaches

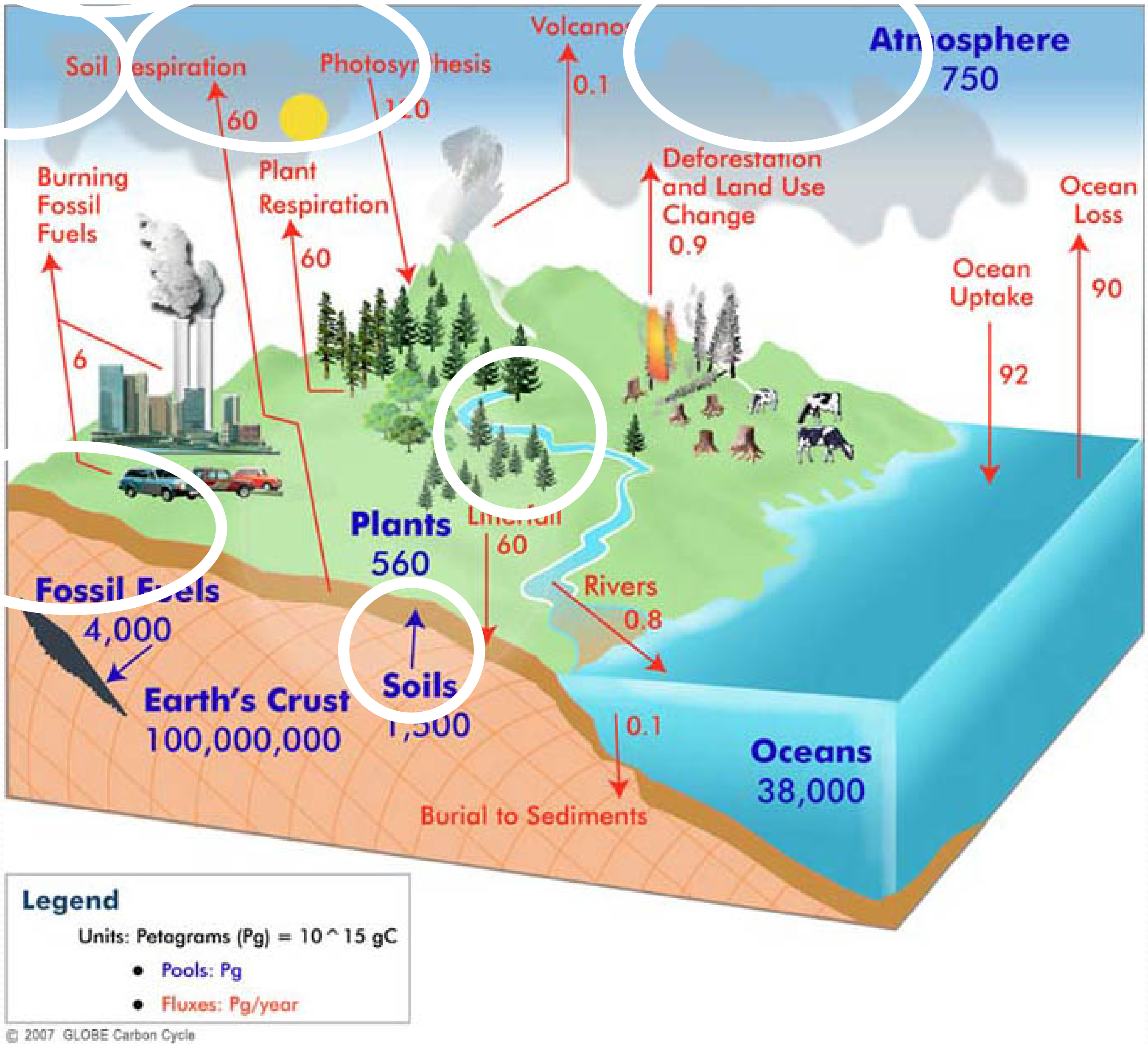
Role of Soil Organic Carbon (SOC)

Critical functions, a very important mechanism for both mitigation and adaptation through carbon sequestration



380 ppm

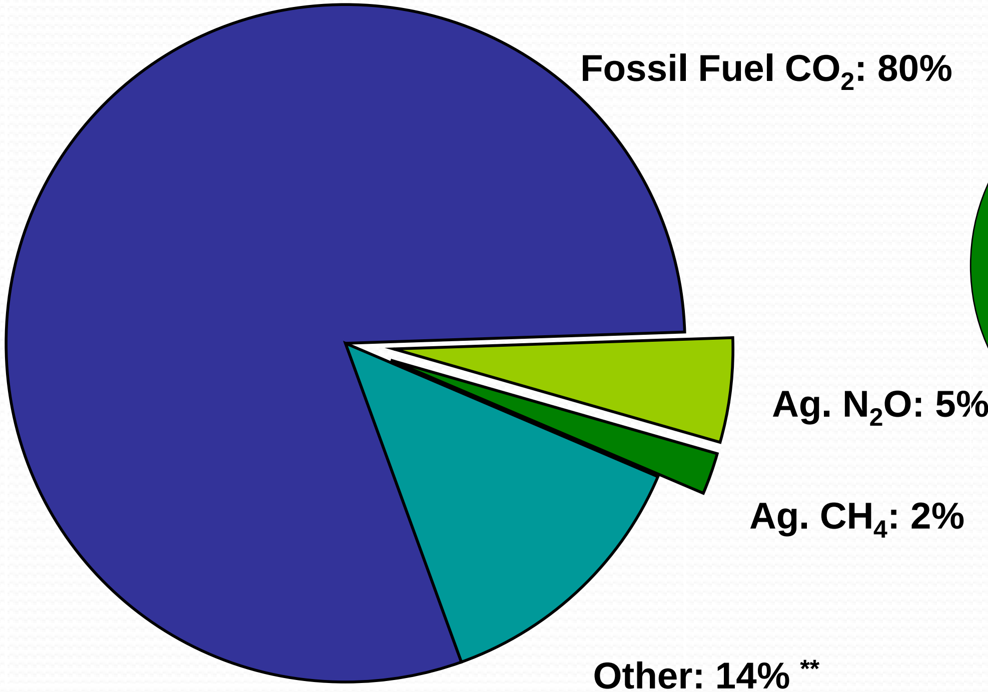
Carbon Balance and Transfer within the Planet's Elements



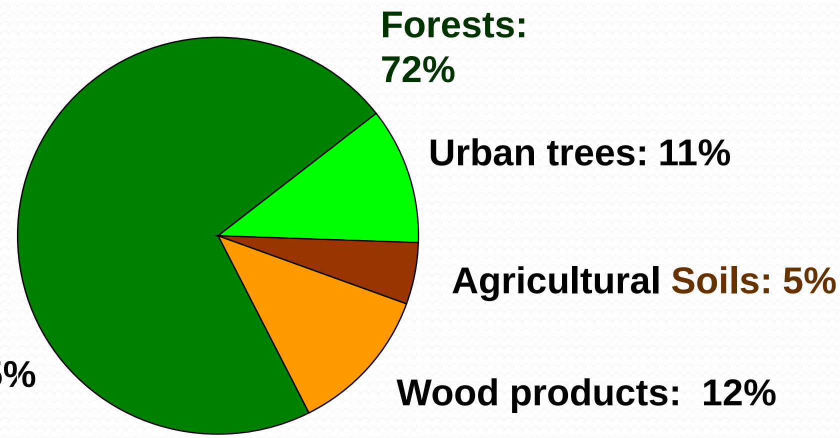
In the US:

Agriculture is responsible for 7 % of GHG emissions
While Carbon sequestration offsets 11 % of U.S. emissions

U.S. GHG Emissions:
7,260 million metric tons CO_2e



U.S. Carbon Sequestration:
828.5 million metric tons CO_2e

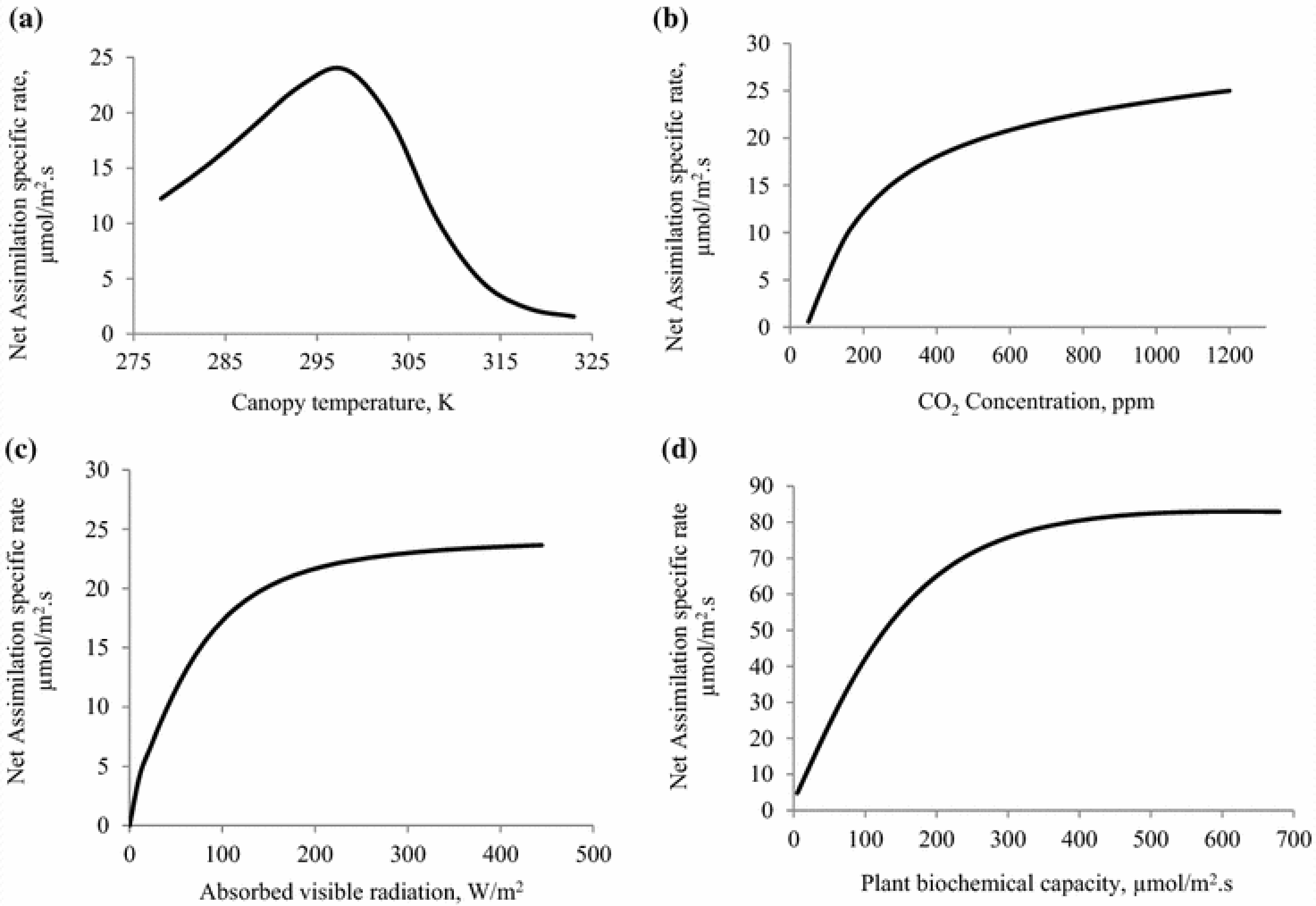


Source: US EPA. 2007. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2005 an AGRAGate

CO2 Impact on Food

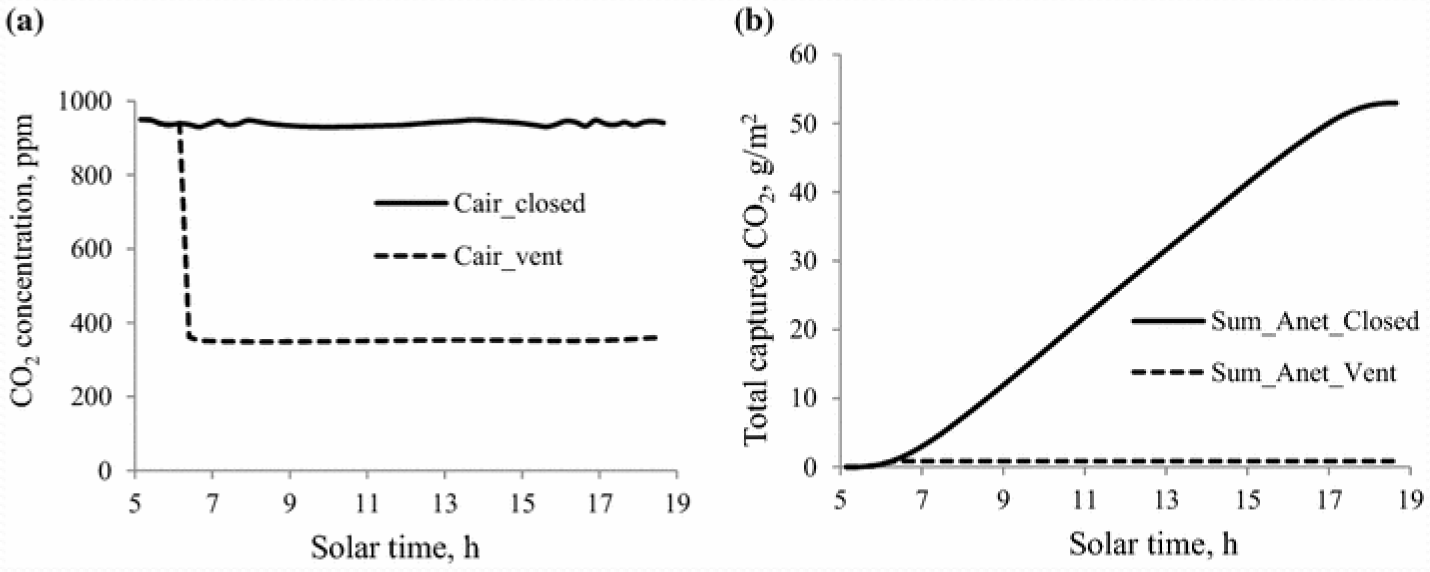
- Carbon dioxide enrichment results in:
  - heavier transplants
  - can be used to accelerate the growth,
  - as well as improving the quality of the transplants (Tremblay and Gosselin 1998)
  - Carbon dioxide may increase sugar translocation in the roots
  - as well as facilitating the movement of nitrogen and carbon compounds directed towards the development of new roots (Tremblay and Gosselin 1998)
  - CO_2 supplementation shortens the nursery period and results in sturdier, higher quality plants (Tremblay and Gosselin 1998).

Photosynthesis and CO2 Concentration

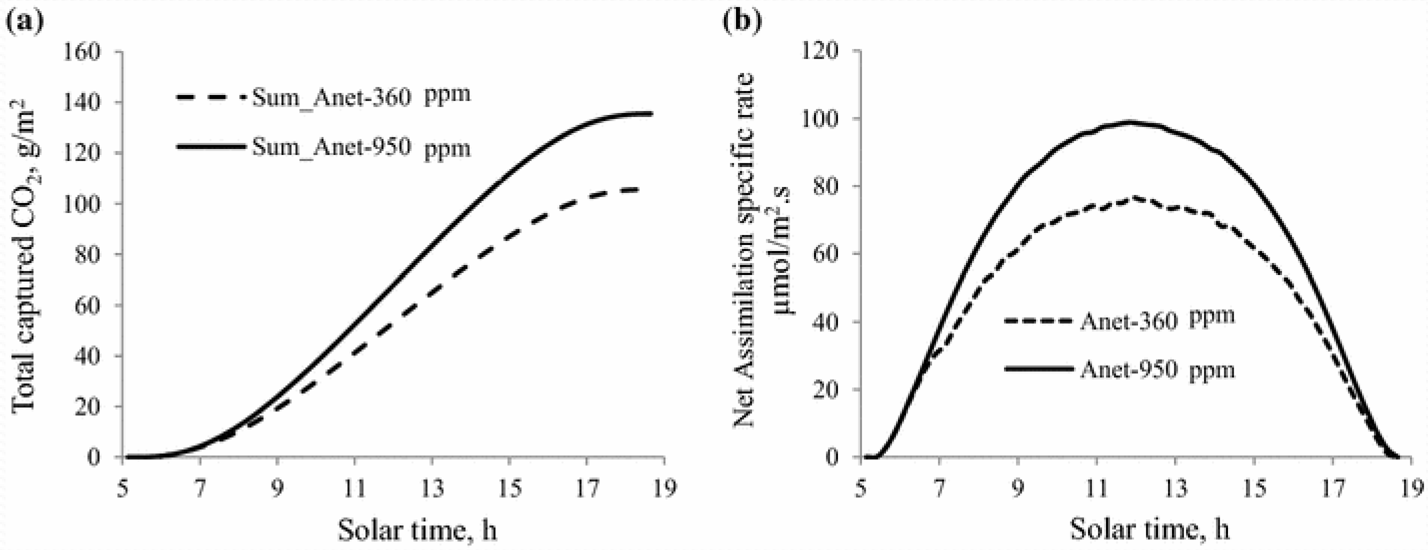


Reference: M. Efat et al, next 4 slides

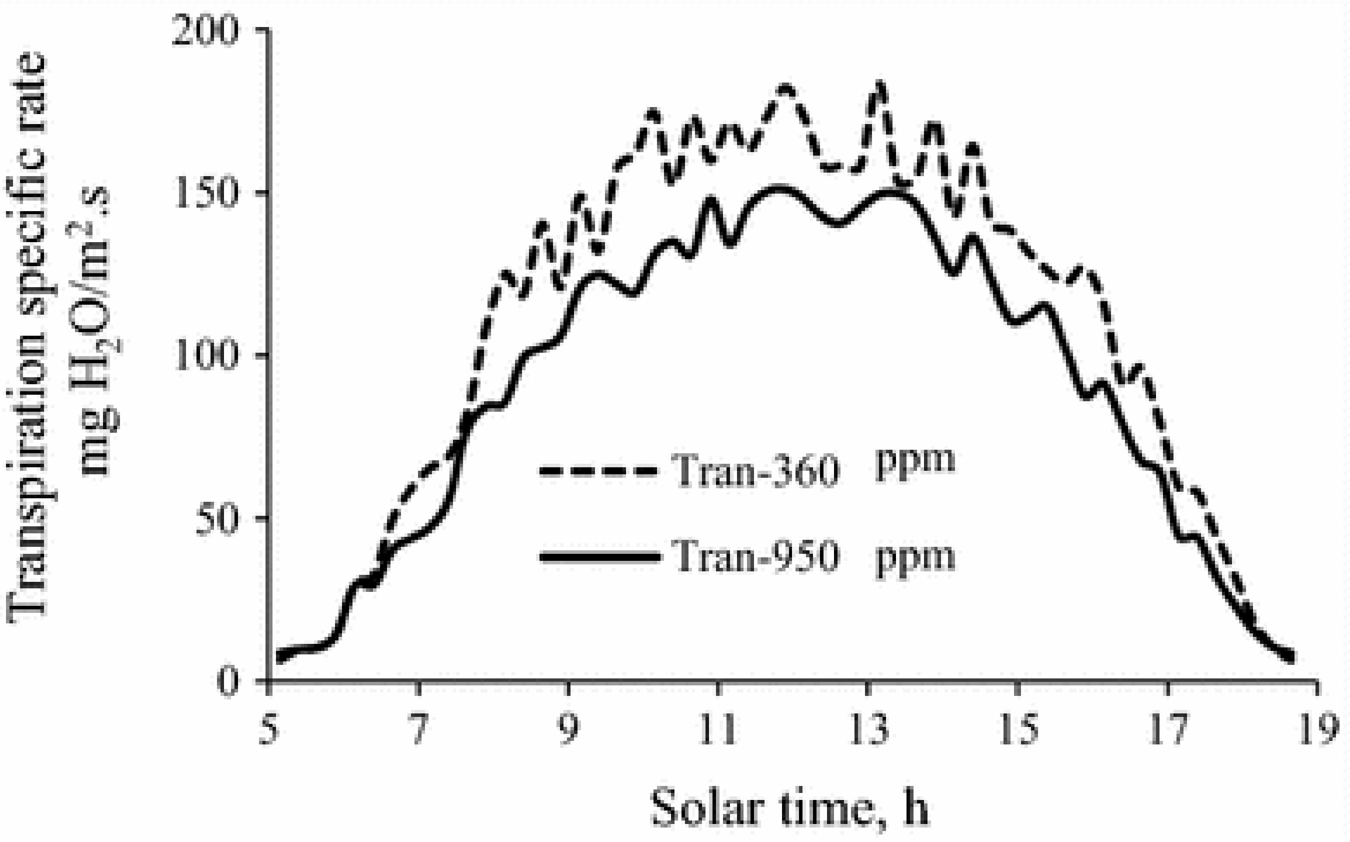
Closed vs Vented
CO2 Concentration and Sequestration



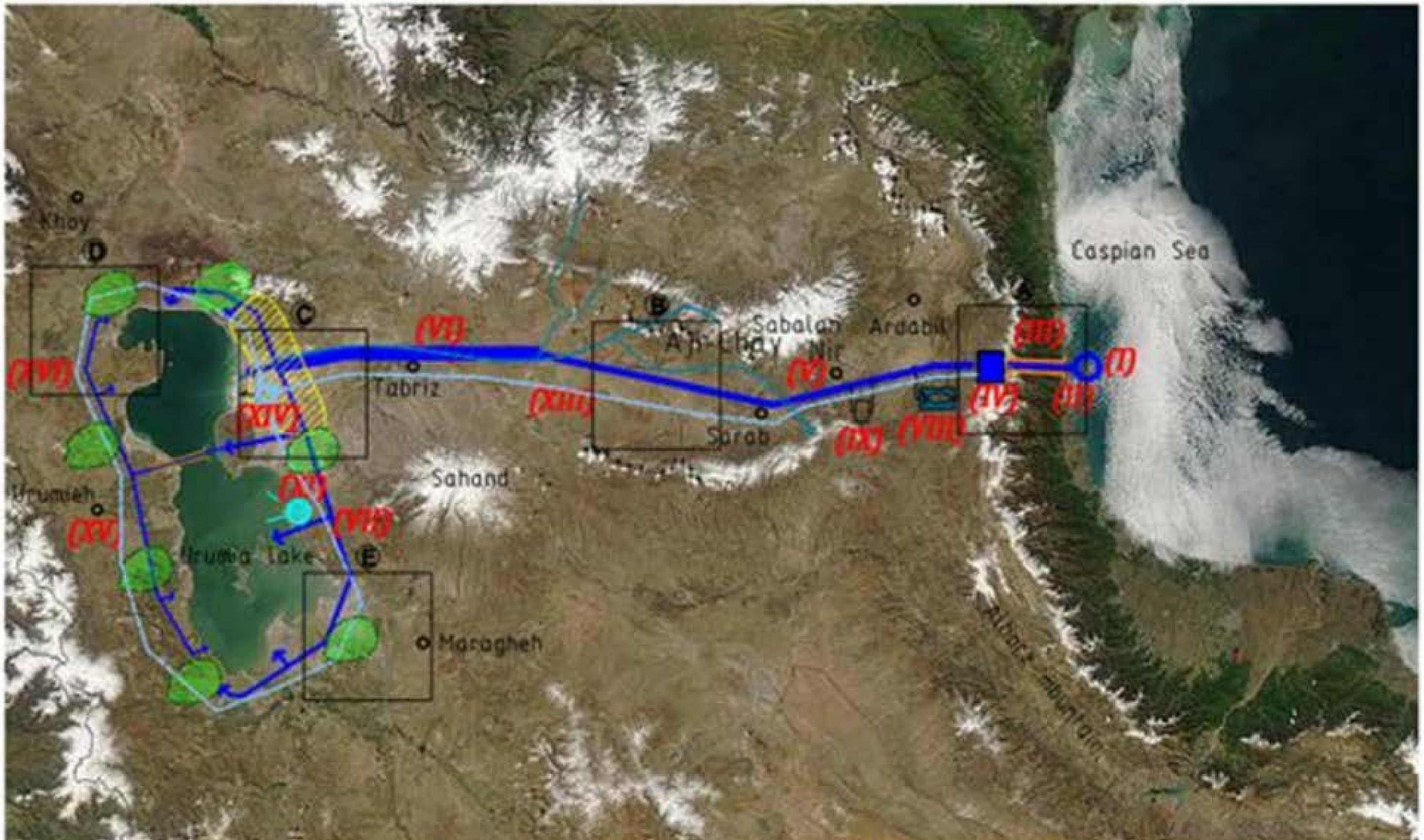
CO2 Assimilation Rate



Transpiration vs CO2 Concentration

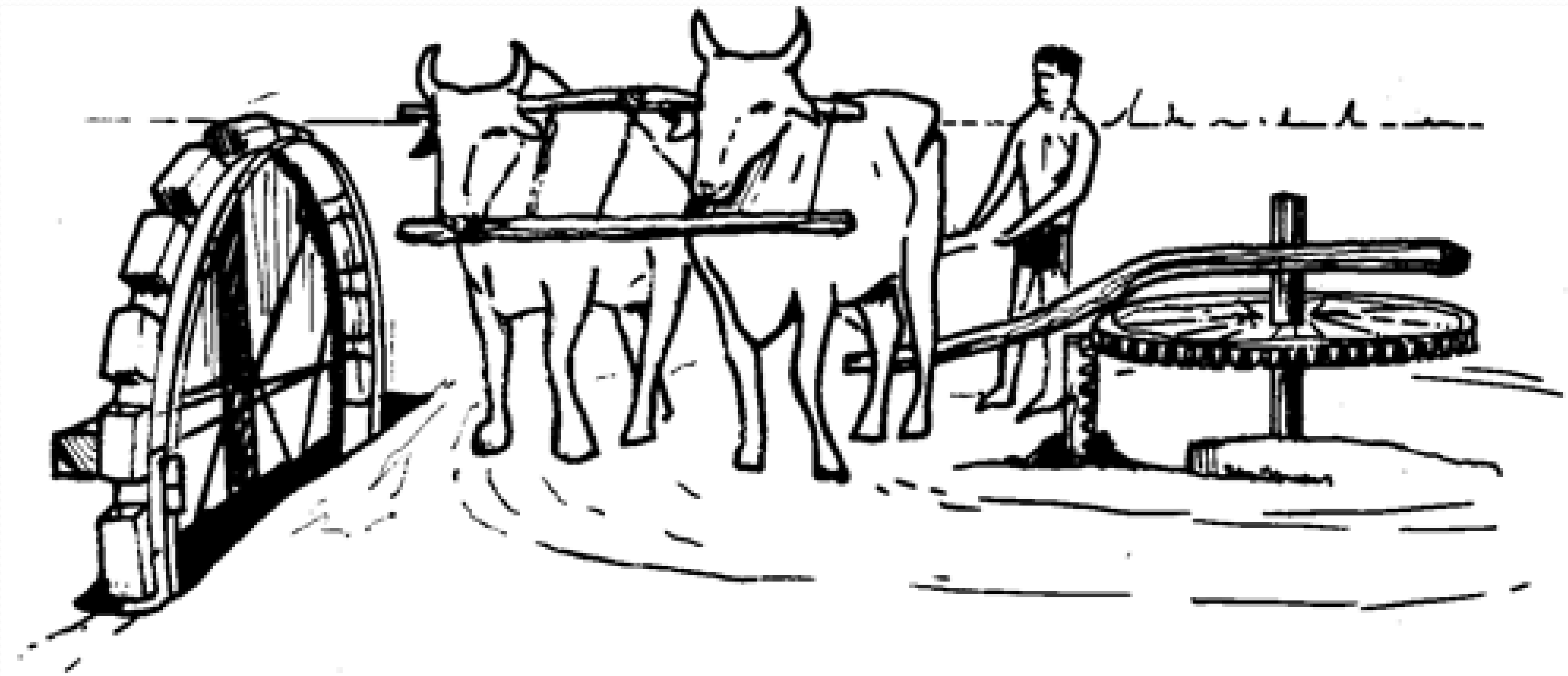


Brief Cost Estimate



How Were We Used to Produce Water and Food?

Cows Were Even Smarter Choices. They Produced also Milk and Meat



Energy Yield Needs to be Checked Alongside Water Yield in our Farms

	MJ/ha	MJ/ha	Energy
Produce	Energy Input	Energy Yield	Yield Ratio
Barley	**25656**	**49800**	**1.94**
Wheat	**32493**	**48517**	**1.49**

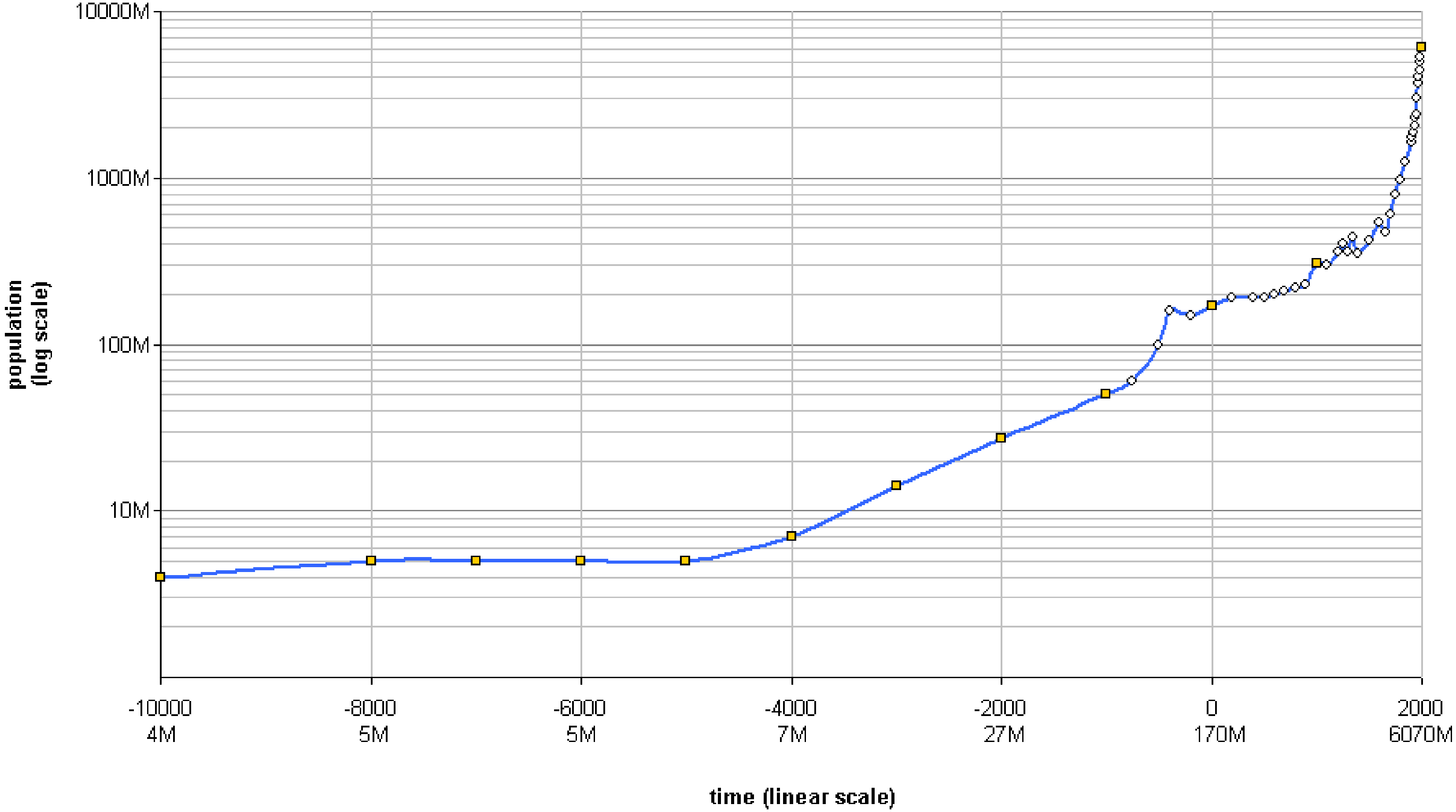
S.M. Ziaei, et al., Jan. 2015

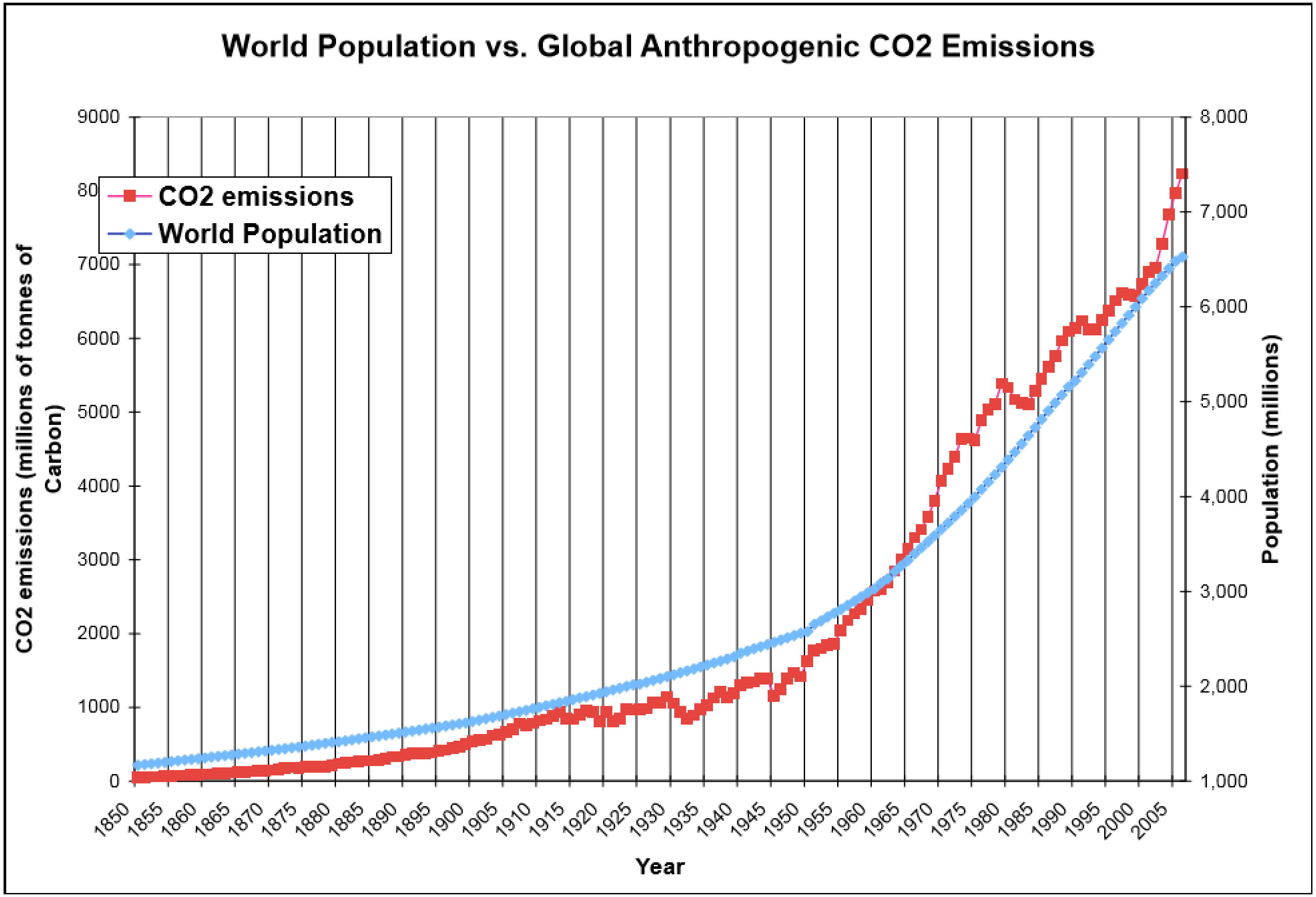
- 60 to 90% of energy use in today's world agriculture is from non-renewable sources
- In the case of Iran, it is 80%

What Happened Around 4200 B.C.

- Copper 4200 B.C.
- Silver 4000 B.C.
- Lead 3500 B.C.
- Bronze Age 2300-700 B.C.
- Tin 1750 B.C.
- Iron 1500 B.C.
- First Record of Windmills 1185 A.D.
- Steam Engine 1712 A.D.
- Petroleum became a major industry following the oil discovery at Oil Creek Pennsylvania in **1859**

Estimated world population figures, 10,000 BC–2000 CE (in log y scale)

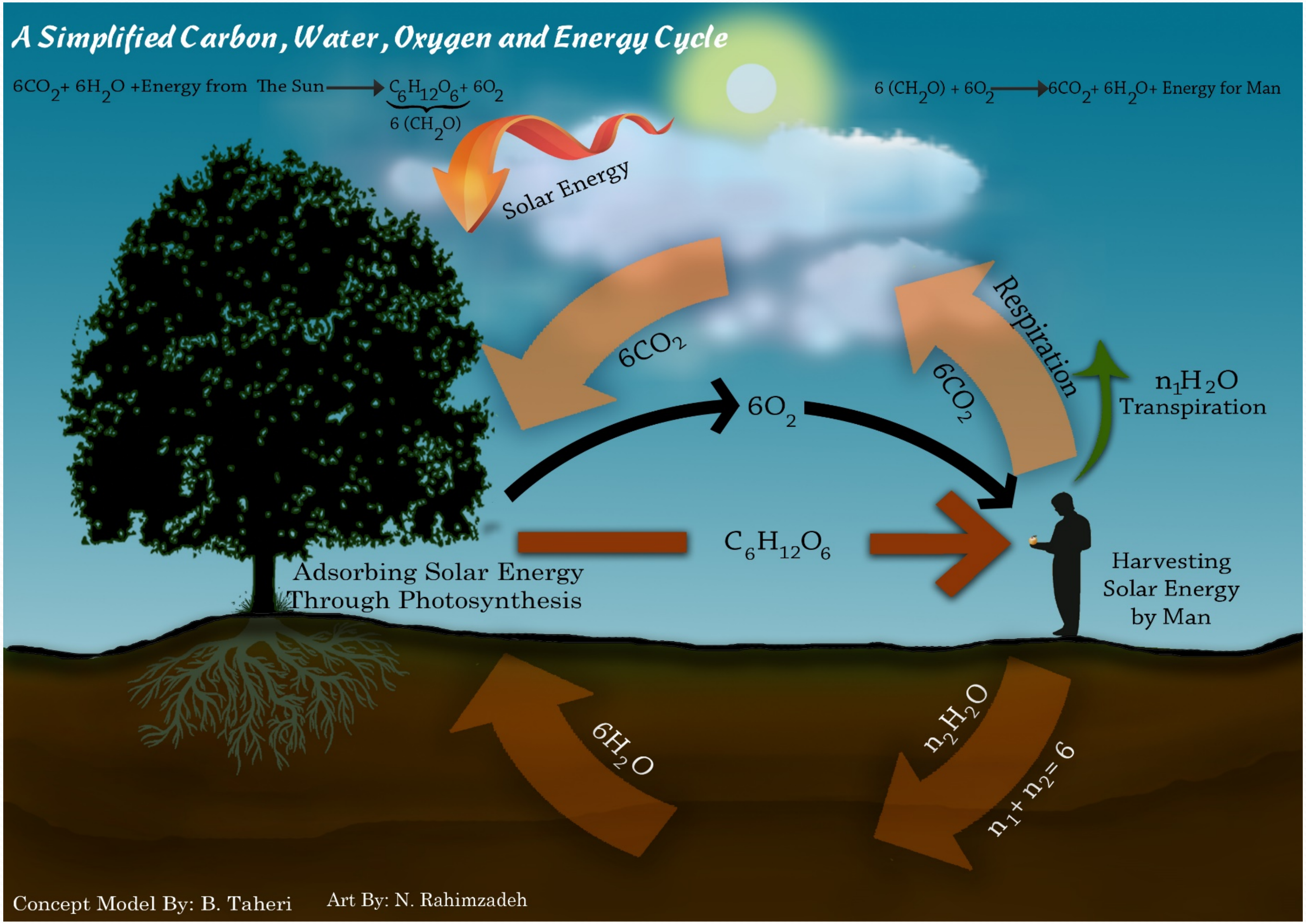



World Population vs. Global Anthropogenic CO2 Emissions
CO2 emissions
World Population
CO2 emissions (millions of tonnes of Carbon)
Population (millions)
Year
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
1850
1855
1860
1865
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005

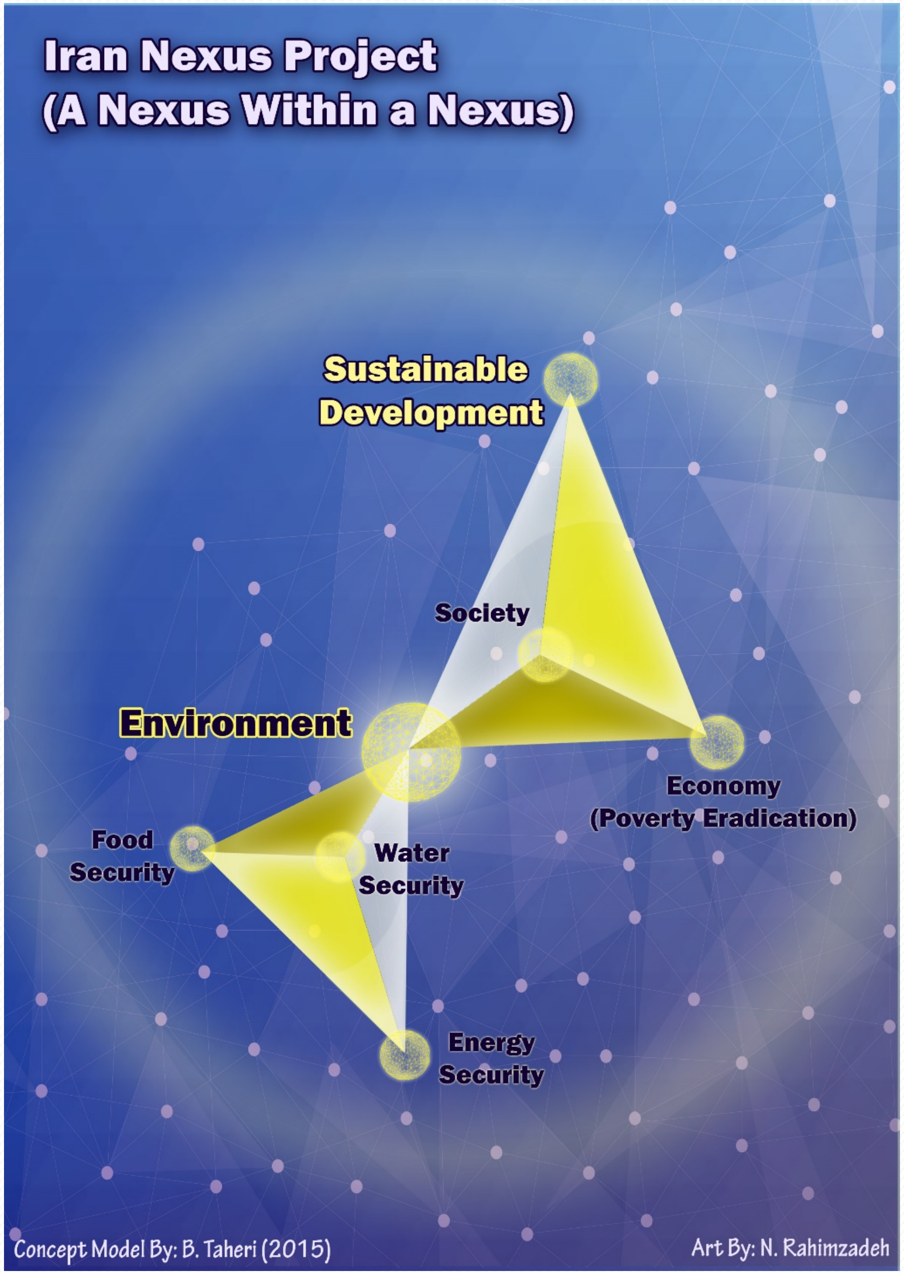
Efficiency in cogeneration

- In Denmark, the multifuel-fired Avedøreværket CHP Plant just outside Copenhagen can achieve a net electric efficiency as high as 49%. The overall plant efficiency with cogeneration of electricity and district heating can reach as much as 94%.

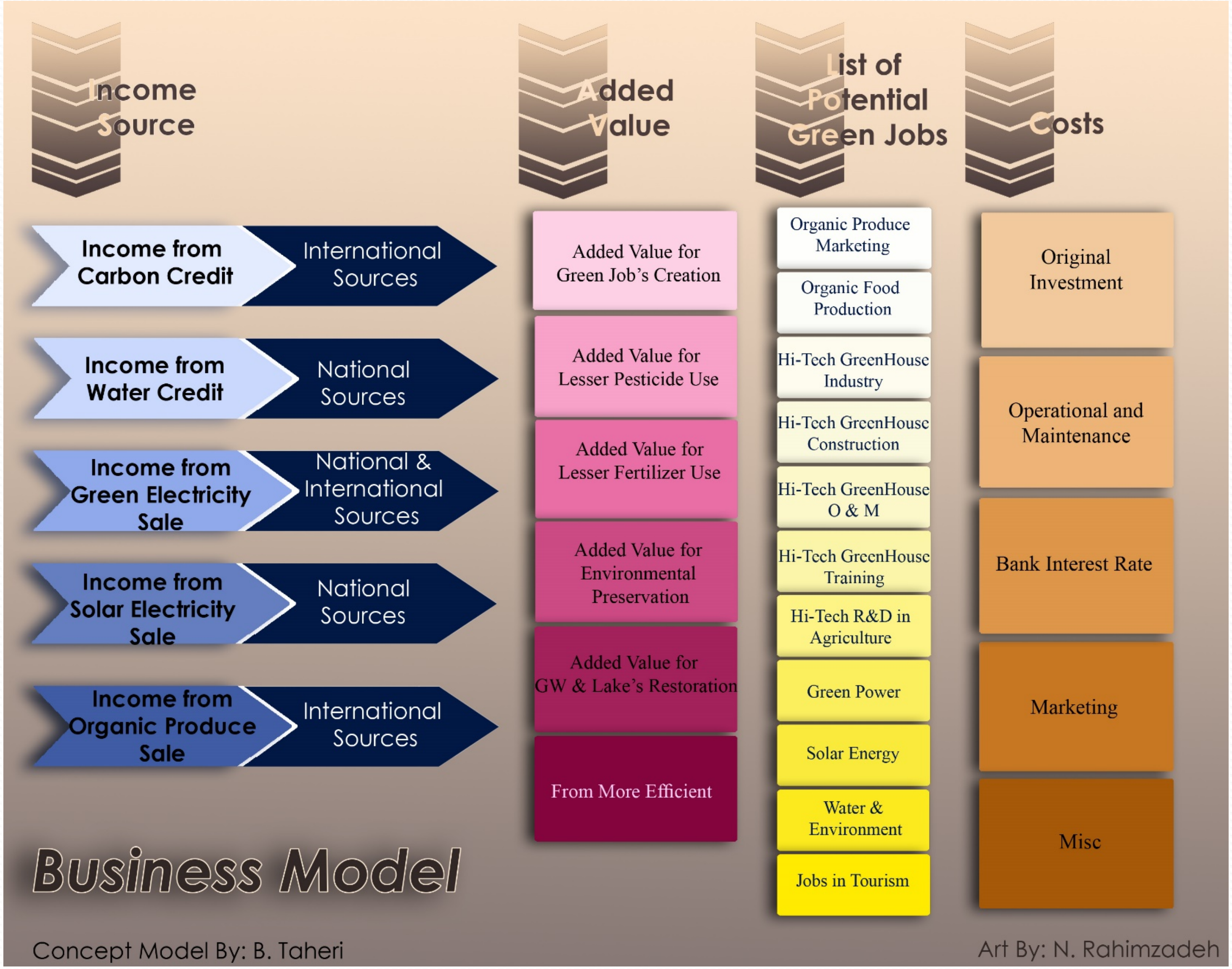
A Super-Simplified Conceptual Model Showing the Base-NEXUS among Energy, Water, Food, Soil, Air, Environment & Climate



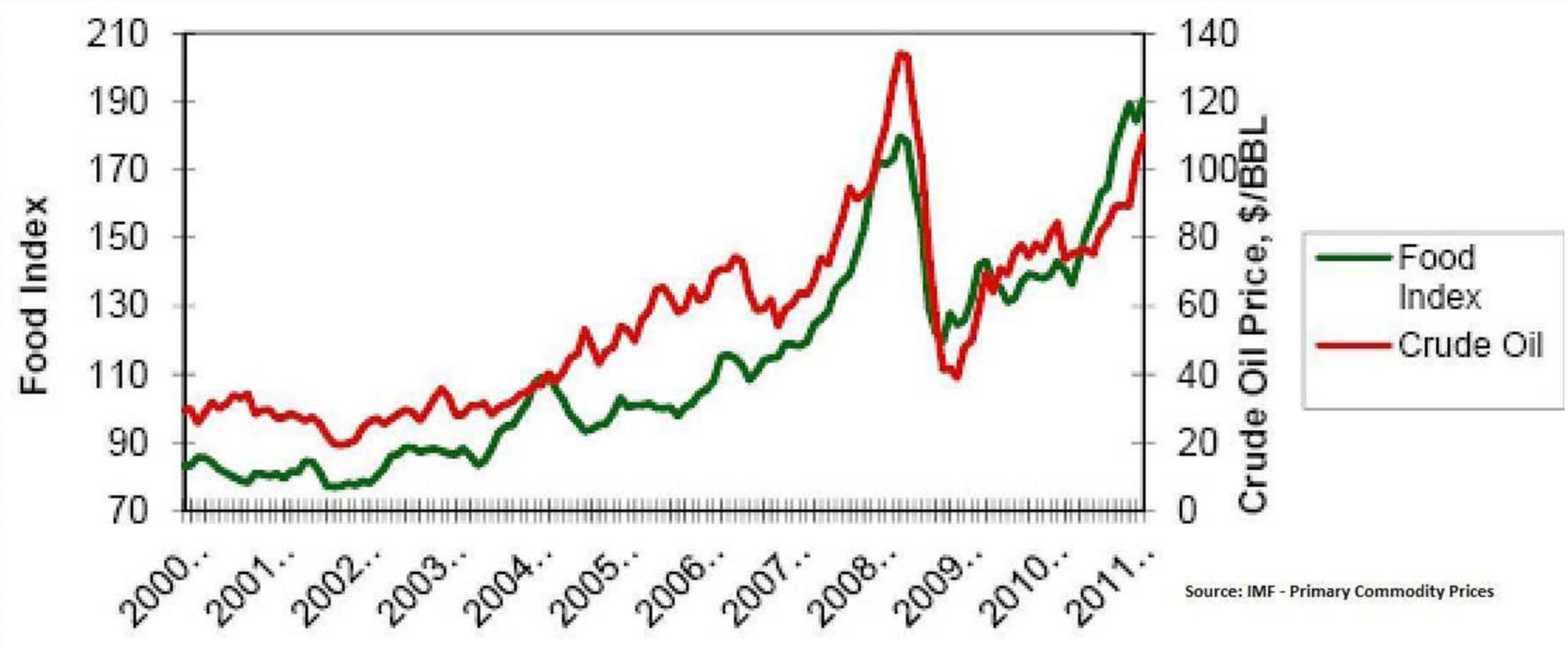
A 3-way Interaction, 7-Element NEXUS Model



NEXUS Technology's Business Model Simplified for Astana Future Energy Forum



Food versus Oil



Food, water and energy

Food security:

- 925 million people go hungry
- Around 1 billion people suffer from the 'hidden hunger'
- World population is increasing by 6 million per month
- An extra billion tonnes of cereals will be needed by 2030 (FAO)

Water security:

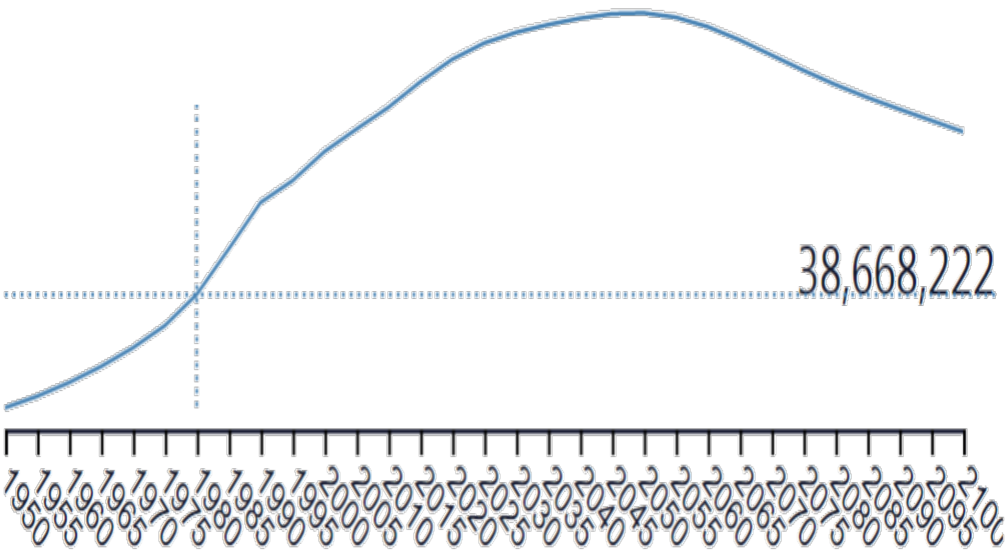
- 1.2 billion people live in areas affected by physical water scarcity
- 1.6 billion people live in areas affected by economic water scarcity
- 884 million people lack access to clean water
- Poor quality water in Middle East and North Africa costs from 0.5% to 2.5% of GDP.

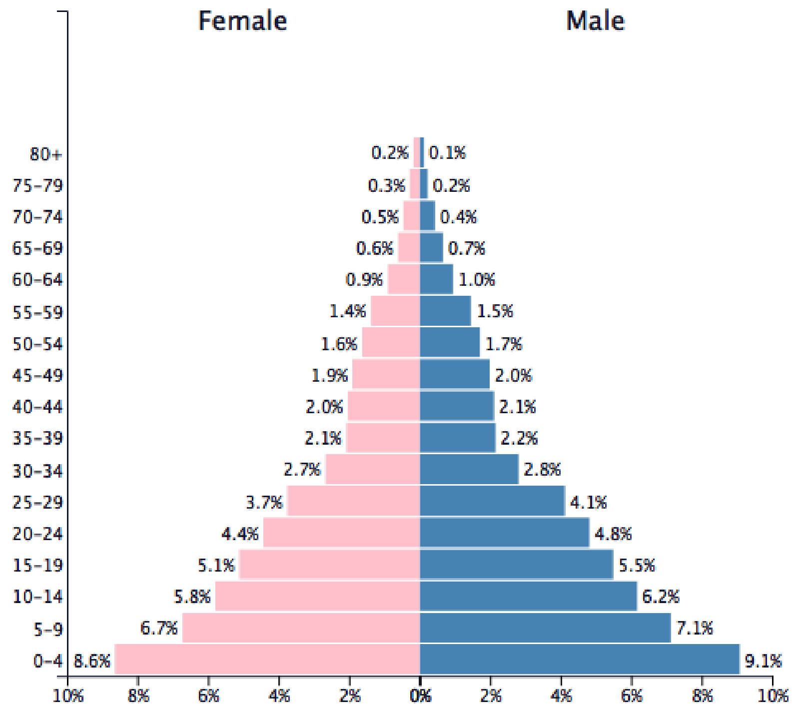
Energy security:

- Currently, 1.4bn people do not have sufficient electricity.
- It is estimated that in 2030 1.2bn people will still lack access to electricity

Source: FAO (2010) / WEO 2010/UNICEF 2010

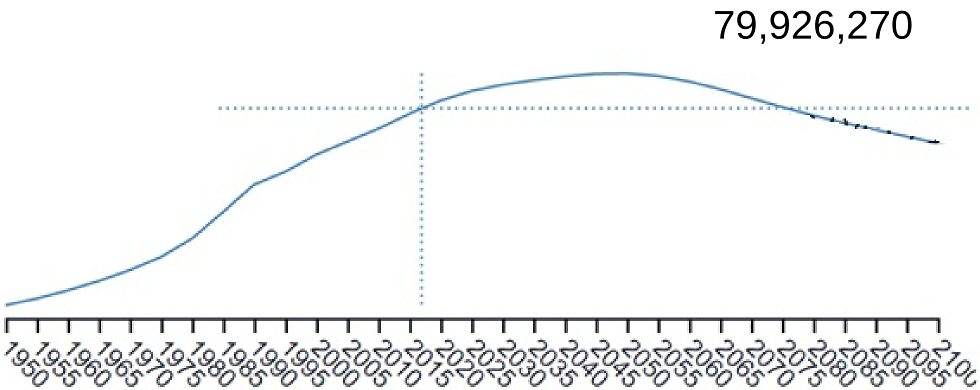
Population and population pyramid in 1980

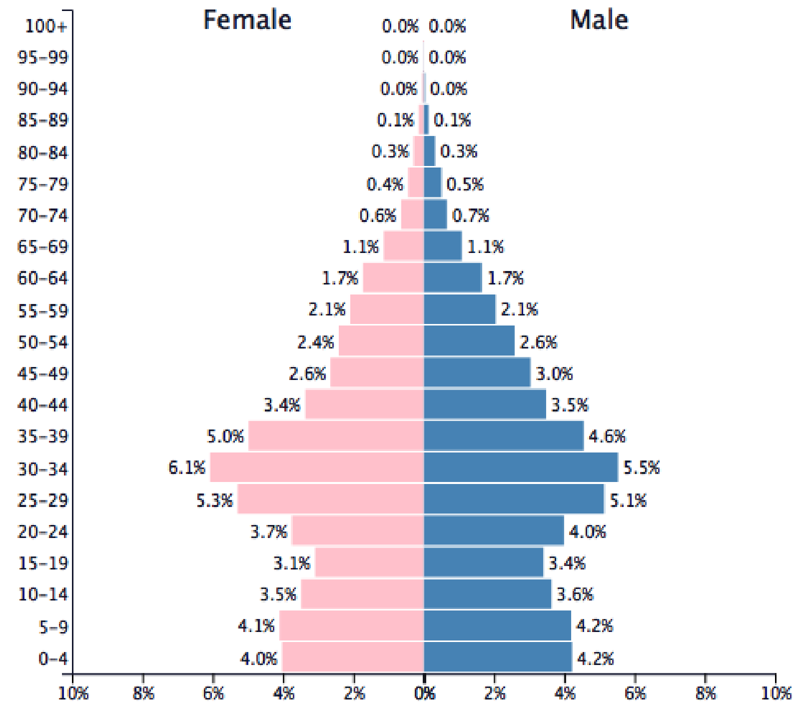




Source: PopulationPyramid.net

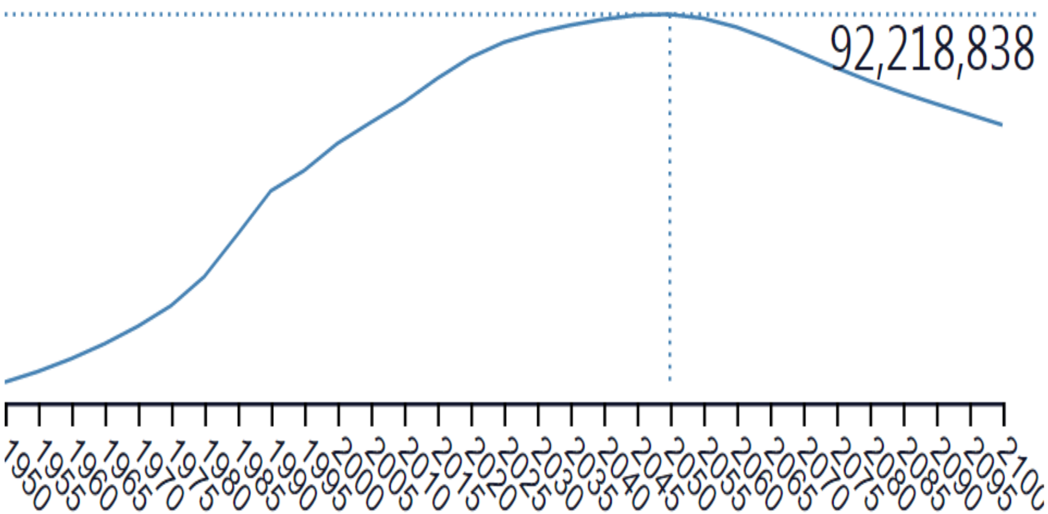
Population and population pyramid in 2017

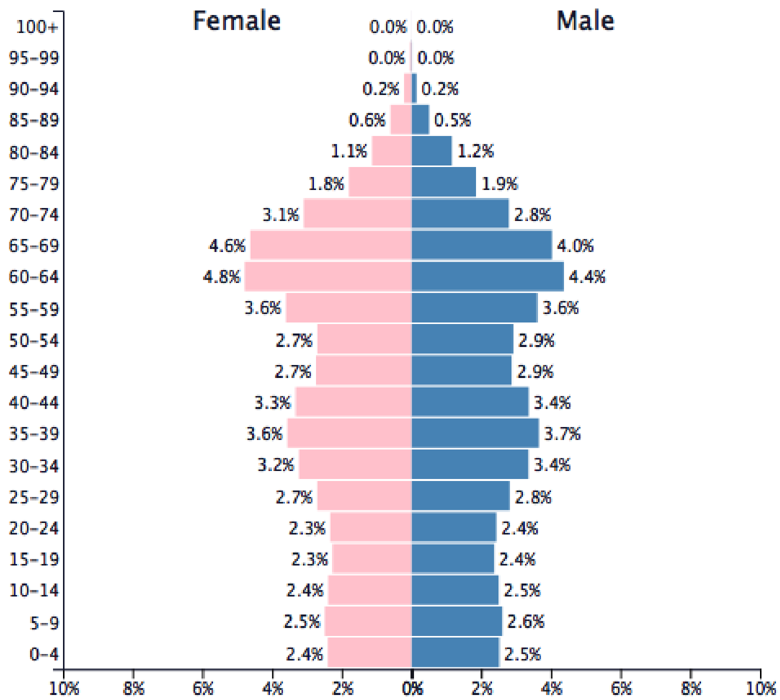




Source: PopulationPyramid.net

Population and population pyramid in 2050

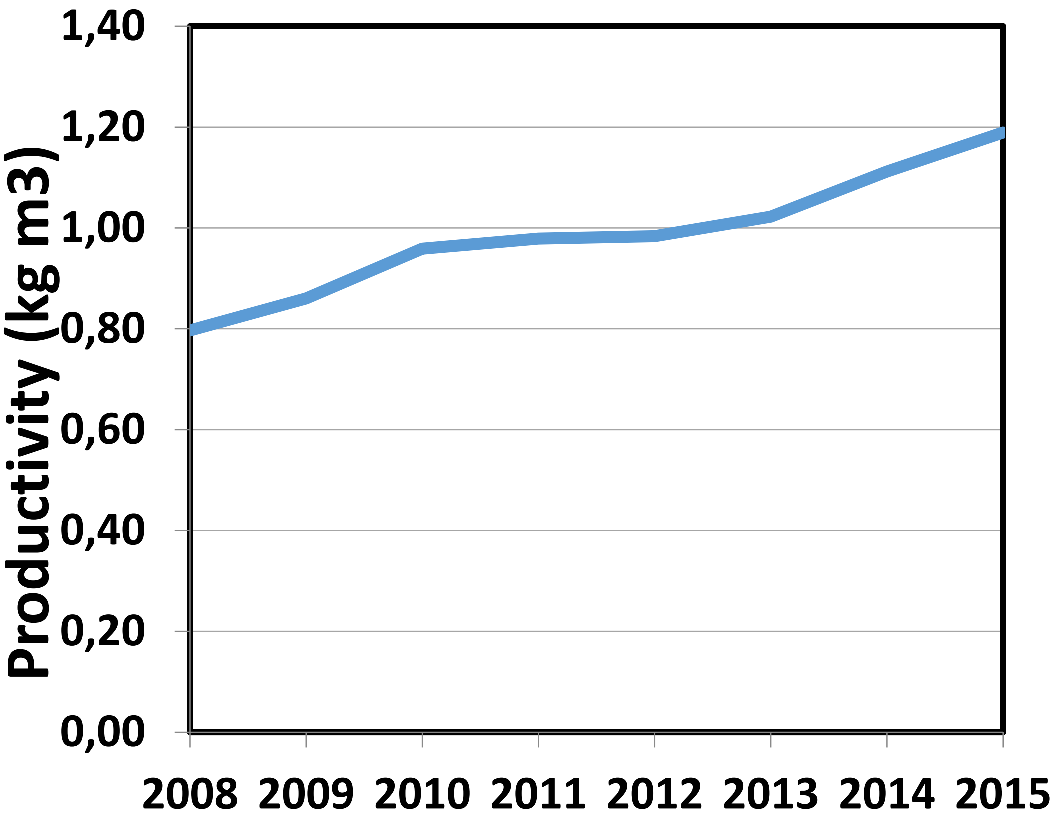




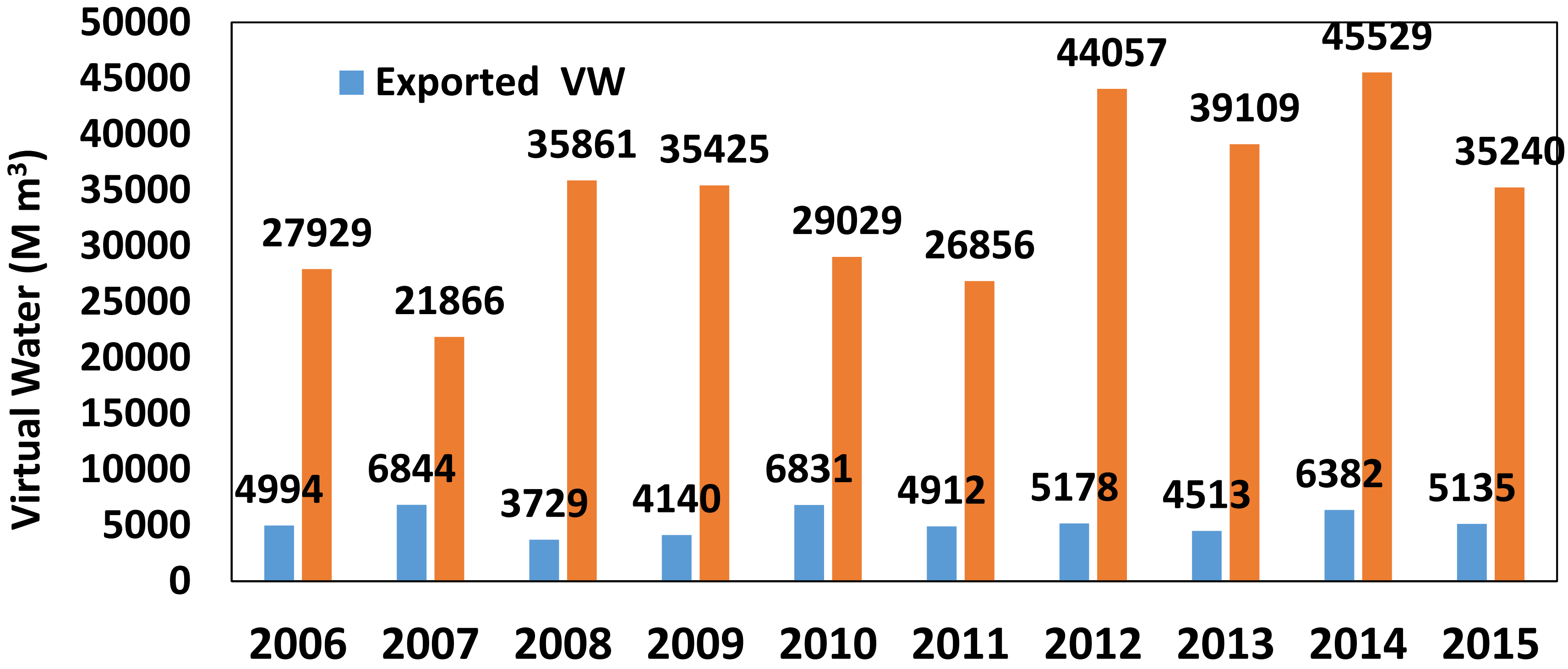
Source: PopulationPyramid.net

Temporal variation in mean water productivity over the period of 2008 to 2015.

years	total production	water use in agriculture	productivity	Percentage change
	Million ton	MCM	kg/m^3	
2008	62.14	78	0.8	-
2009	67.09	78	0.86	8
2010	74.79	78	0.96	11
2011	73.41	75	0.98	2
2012	73.77	75	0.98	0
2013	76.67	75	1.02	4
2014	83.38	75	1.11	9
2015	89.2	75	1.19	7



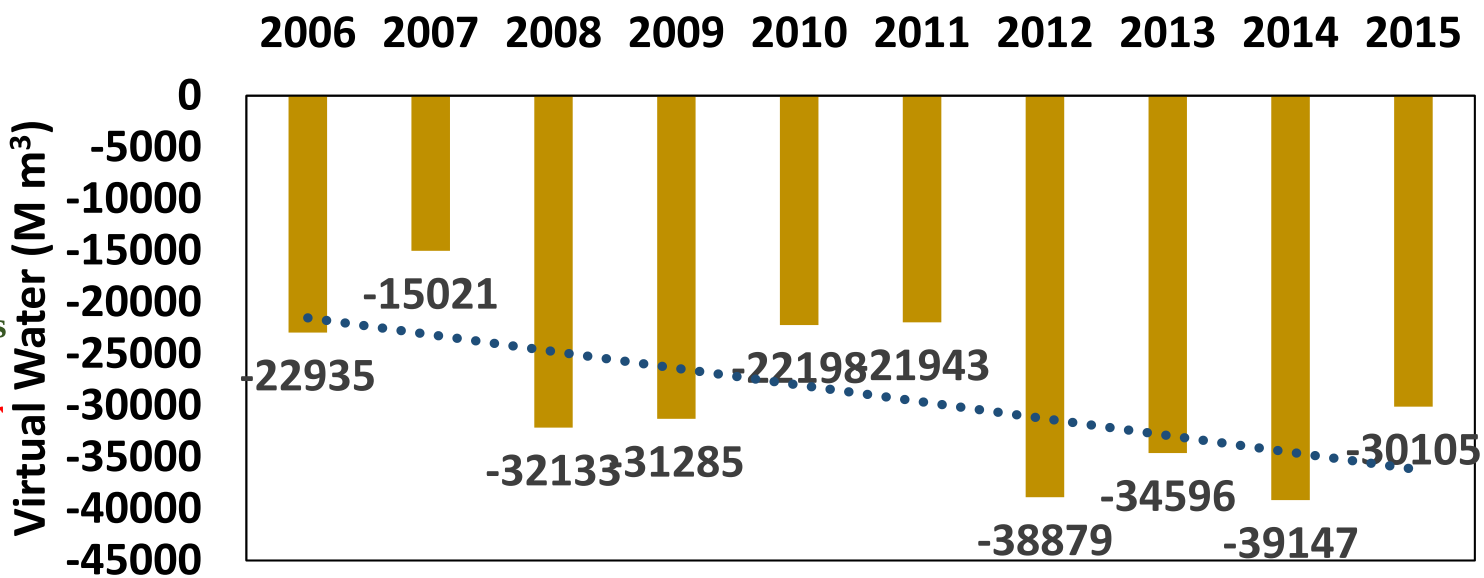
Agricultural Virtual Water Balance in Iran



Note: Processed Food, Livestock, poultry and aquatic products are not included.

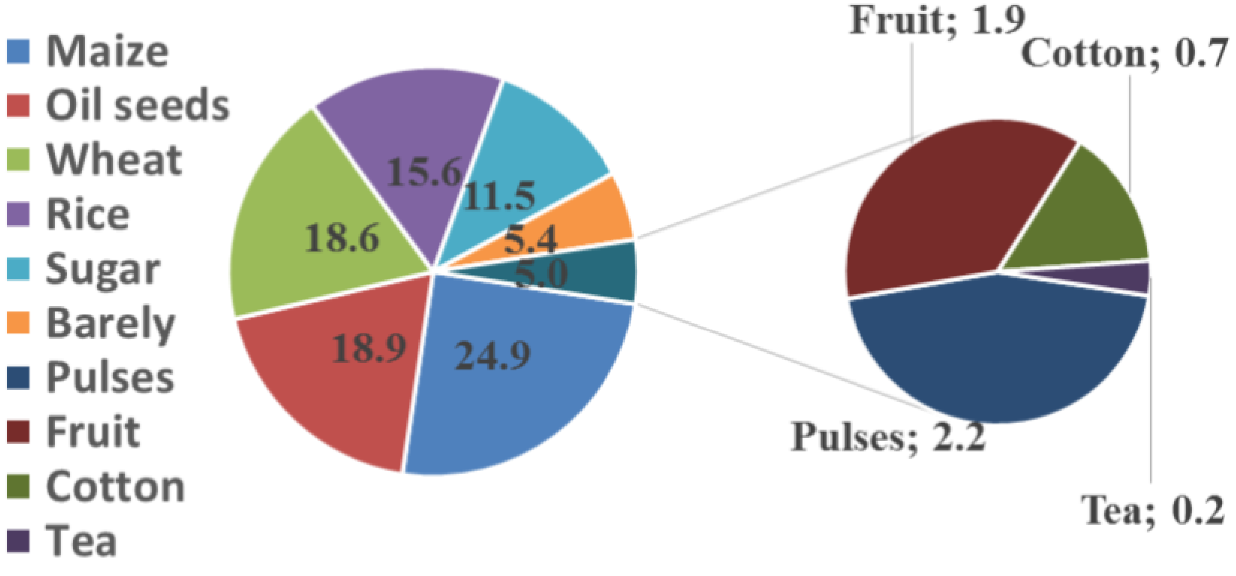
Net import of agricultural VW per year during 2006-2015

The net VW exchange is negative which means Iran is the virtual water importer.



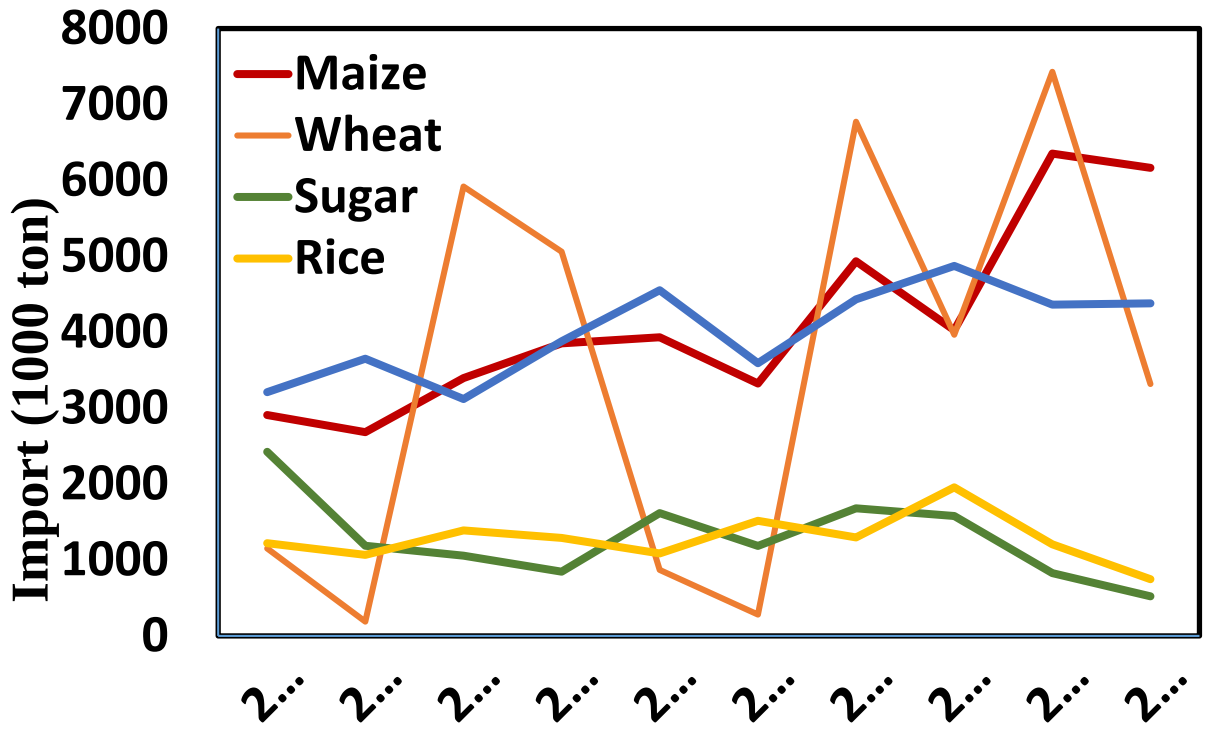
Note: Food manufactured, Livestock, poultry and aquatic products are not considered.

Share of different crops in VW import during 2006-2015

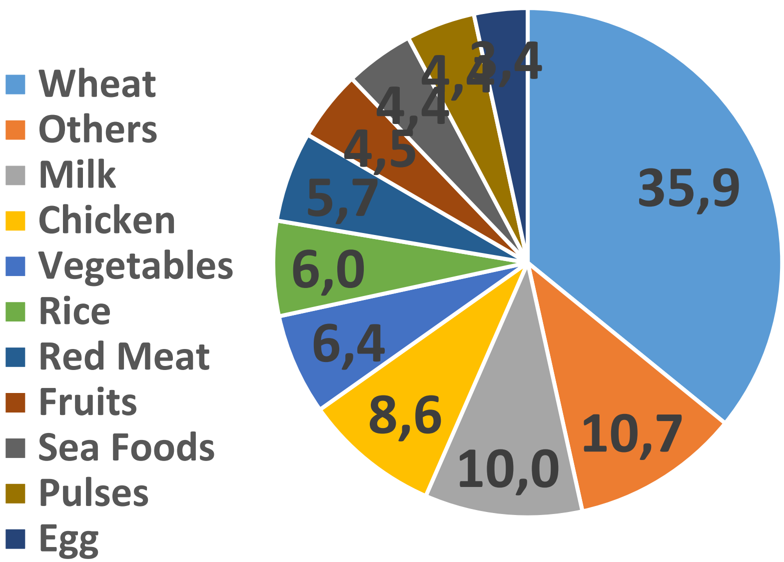


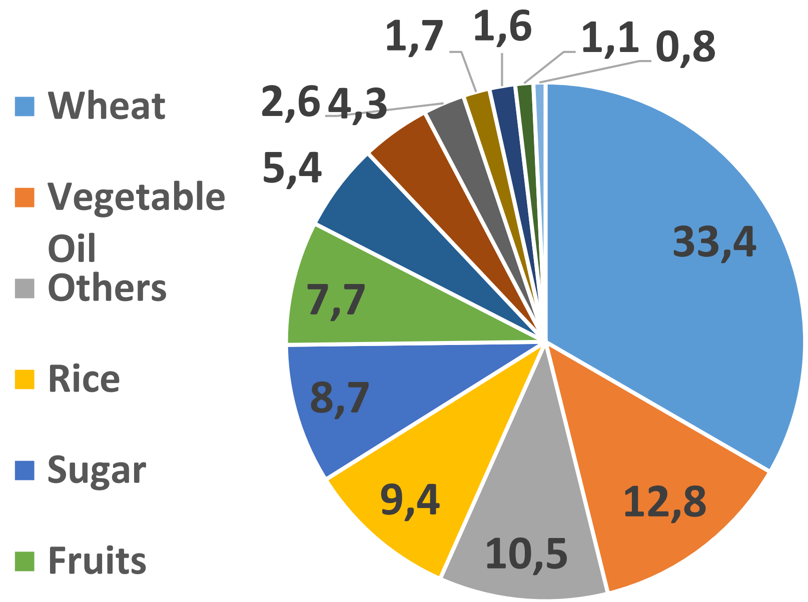
Note: Processed Food, Livestock, poultry and aquatic products are not included.

Variation of import for top-5 crops during 2006-2015.



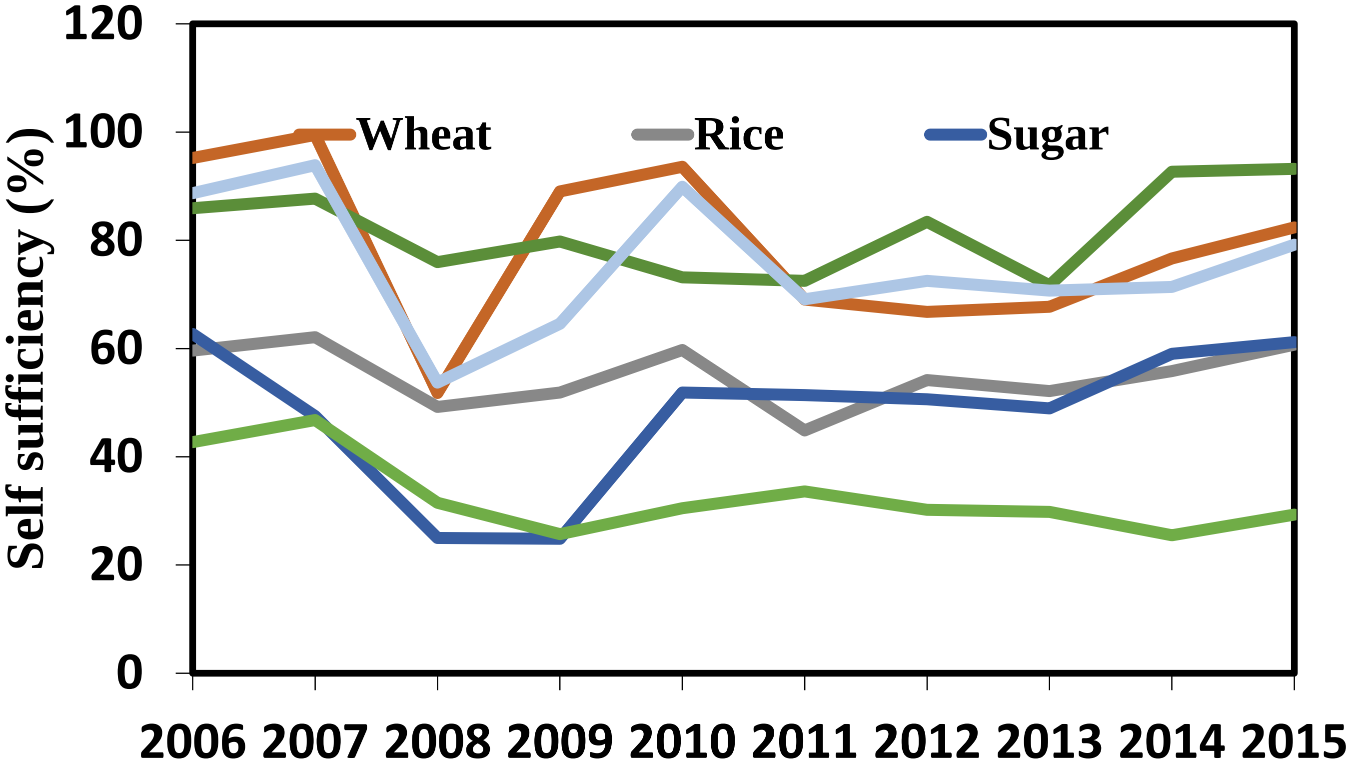
Percent share of products in the supply of daily protein in Iran



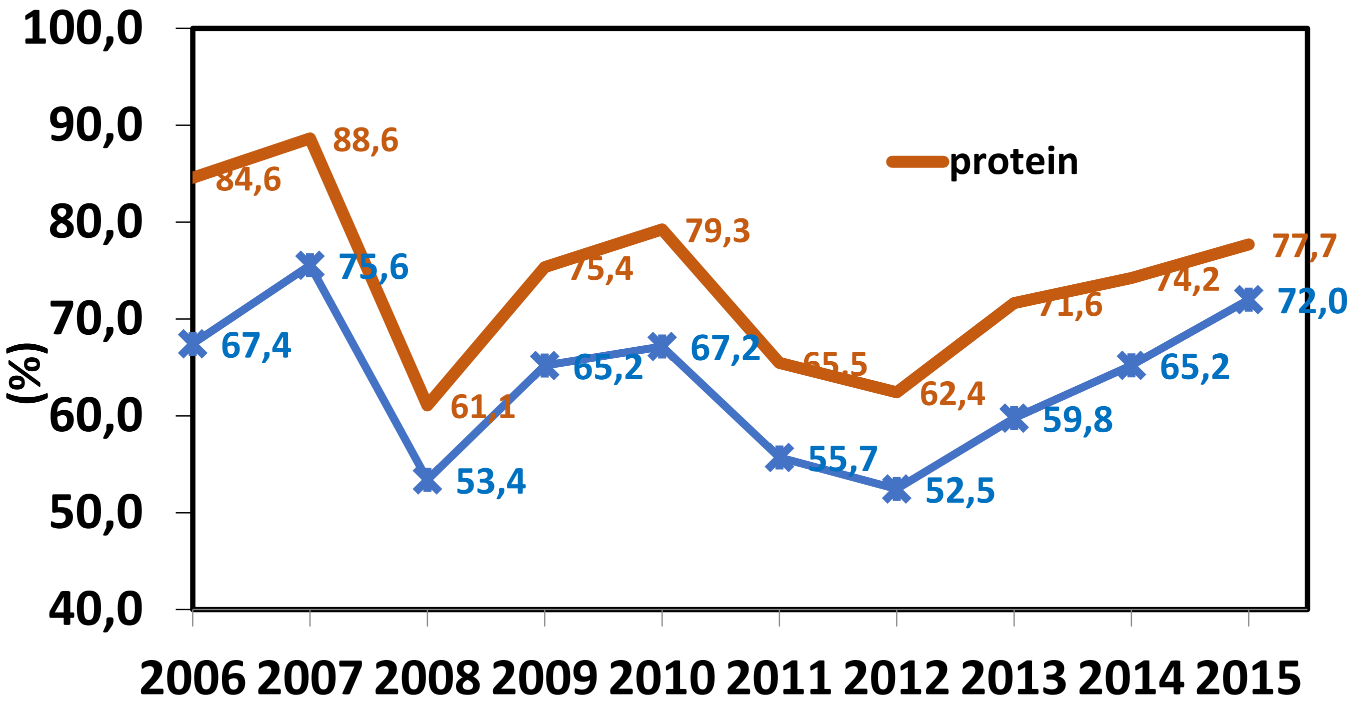


Percent share of products in the supply of daily Calorie in Iran

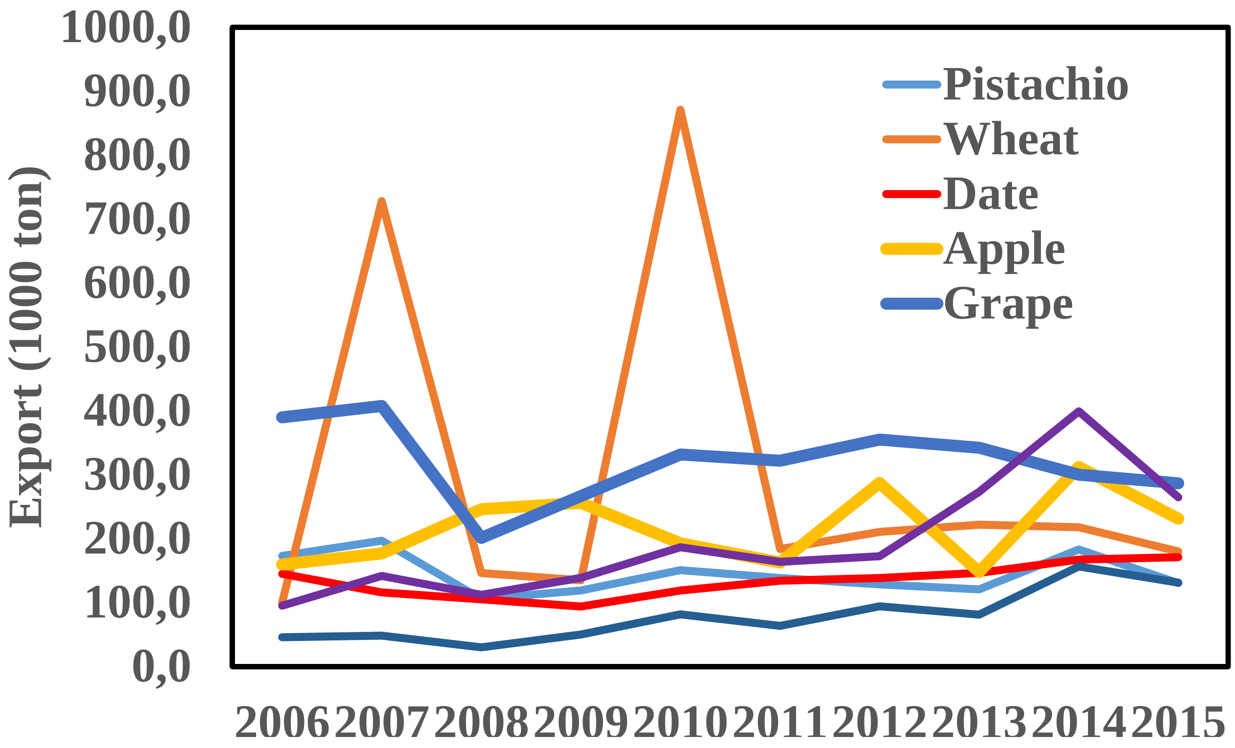
Trend in self-sufficiency of main agricultural crops during 2006-2015



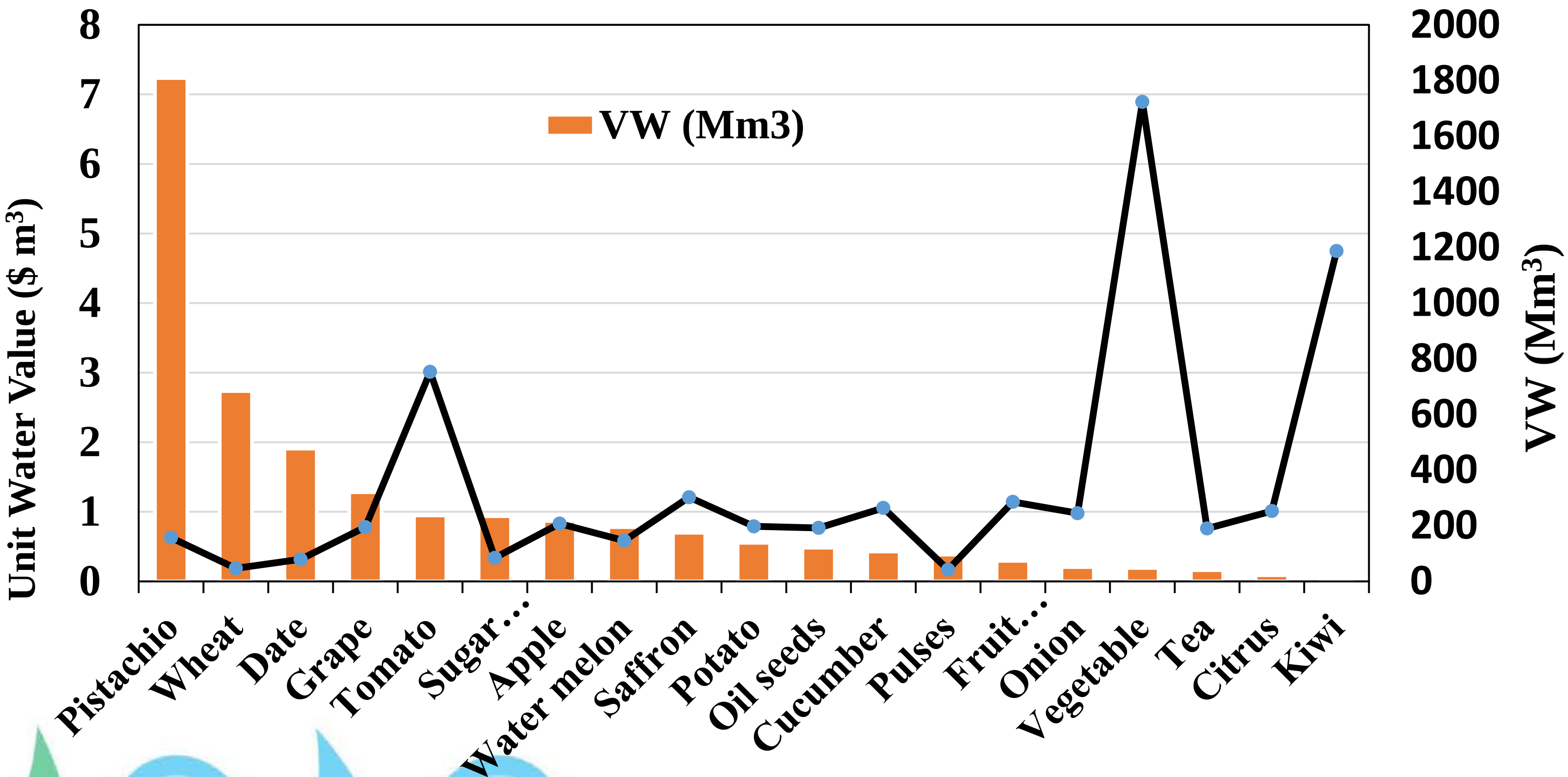
Temporal variation of Self-sufficiency in supply of Calorie (Energy) and Protein during 2006-2015



Trend of export of some crops (have high contribution in export) during 2006-2015.



Average unit water value in USD and exported virtual water of crops during 2006-2015



The average virtual land for main imported crops during 2010 to 2014

Imported Virtual land (1000 ha)	Crop
1549	Wheat
732	Maize
511	Rice
518	Barely
189	Sugar

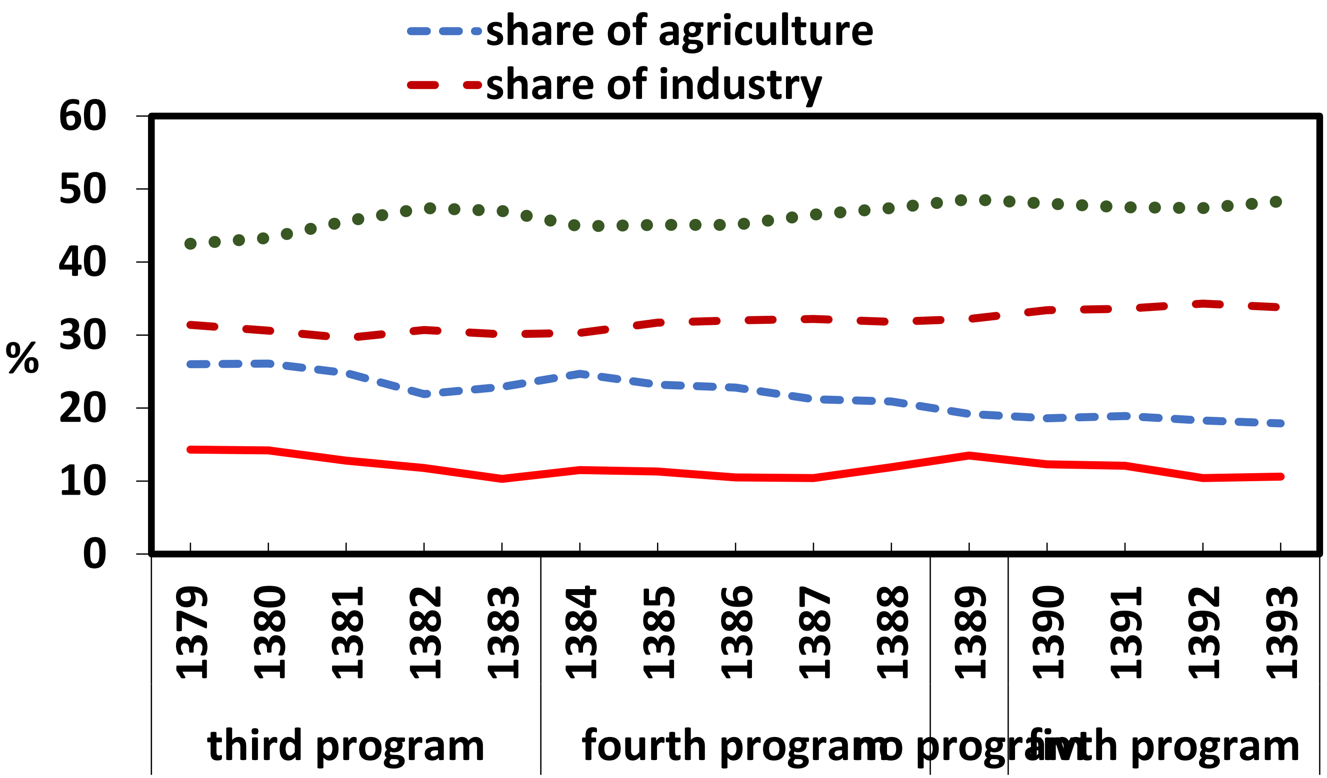
The average virtual land equivalent of imported crops is equivalent to 25% of the average cultivated agricultural land in Iran (during 2010 to 2014).

The average virtual land of exported crops is equivalent to 2.8% of the average cultivated agricultural land in Iran (during 2010 to 2014).

The average virtual land for main exported crops during 2010 to 2014

Exported virtual land (1000 ha)	Crop
207.2	Pistachio
28.2	Date
19.6	Apple
2.8	Kiwi
15.2	Potato
5.5	Onion
20.9	Water melon
38.6	Saffron
30.2	Grape

Unemployment rate and Share of different sectors in Iranian active population 1990-2005



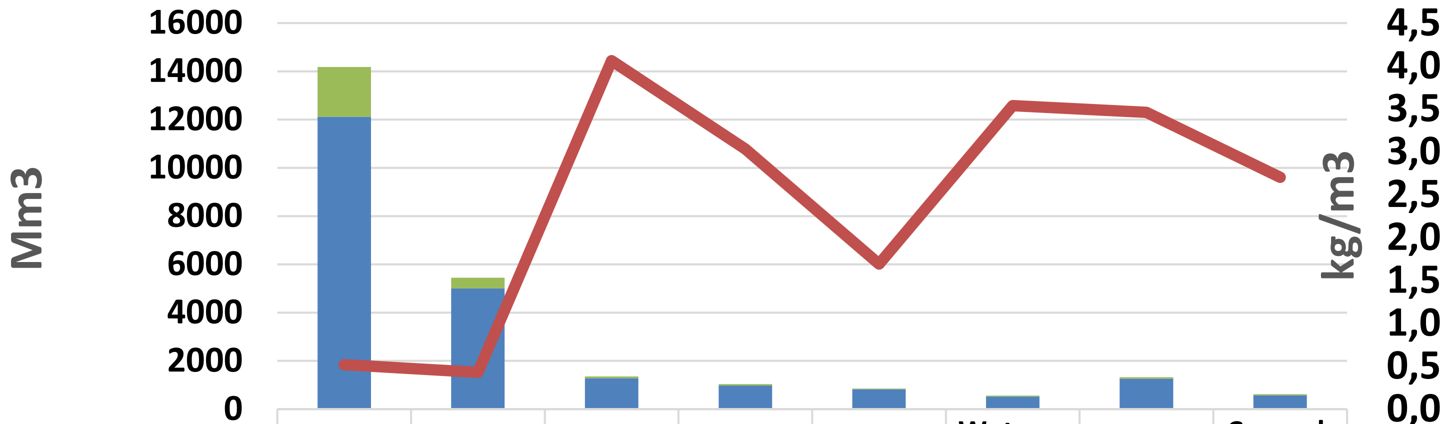
The average of virtual labor of main imported crops during 2010 to 2014

virtual labor (1000 man-day)	Crop
27,895	Wheat
13,183	Maize
35,790	Rice
8,281	Barley
24,610	Sugar
109,759	Total

Labor for the main exported crops during 2010 to 2014

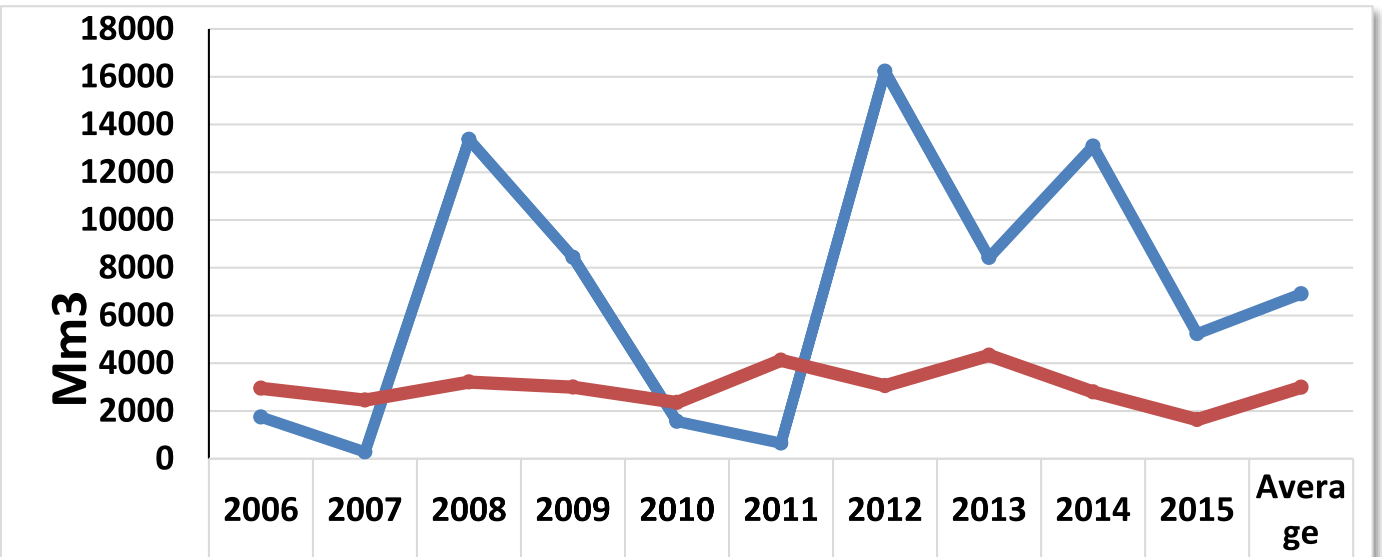
Exported virtual labor (1000 man-day)	Crop
35,227	Pistachio
2,731	Date
3,022	Apple
250	Kiwi
990	Potato
463	Onion
831	Water melon
10,409	Saffron
3,259	Grape
57,182	Total

Crops water use and water productivity



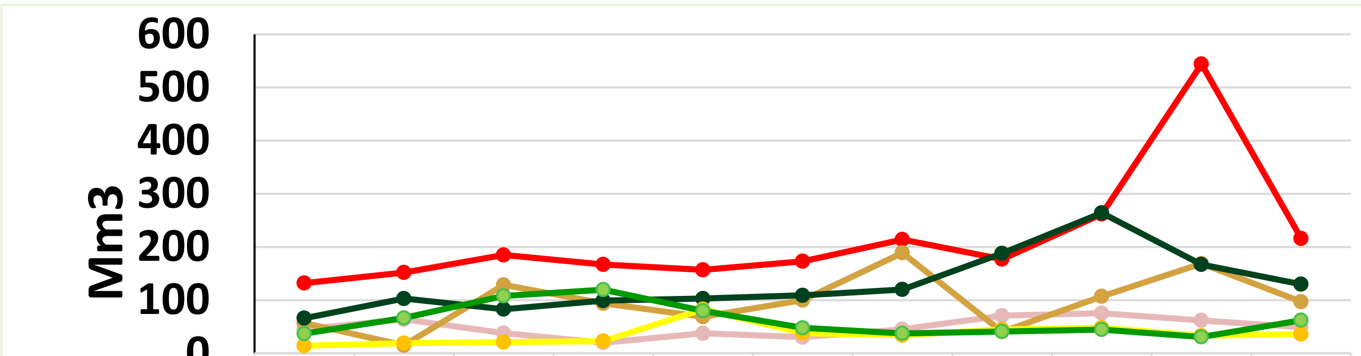
	Wheat	Rice	potato	onion	tomato	Watermelon	Melon	Cucumbers
Green water	2061	444	73	58	25	40	61	48
blue water	12116	5000	1287	979	828	522	1262	576
water productivity	0,52	0,43	4,06	3,03	1,69	3,54	3,46	2,70

Virtual water “Import”



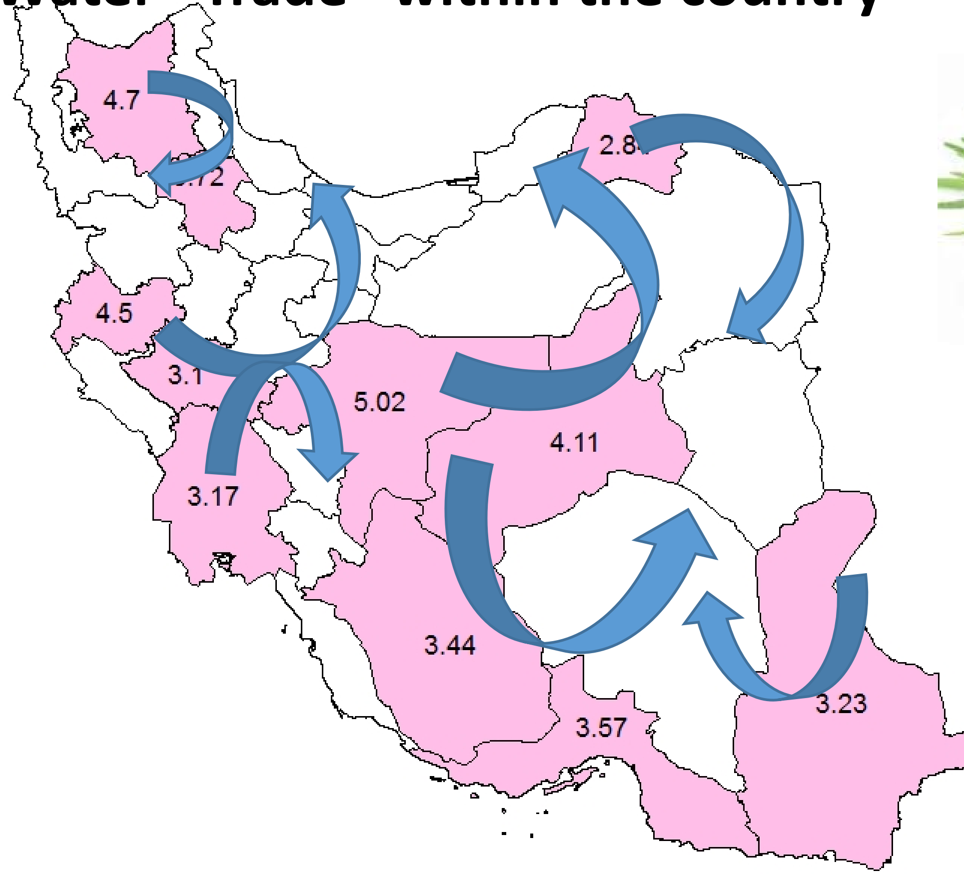
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Average
Wheat	1741	282	13370	8432	1559	650	16227	8422	13091	5233	6901
Rice	2952	2453	3210	2994	2353	4121	3056	4330	2796	1634	2990

Virtual water “Export”

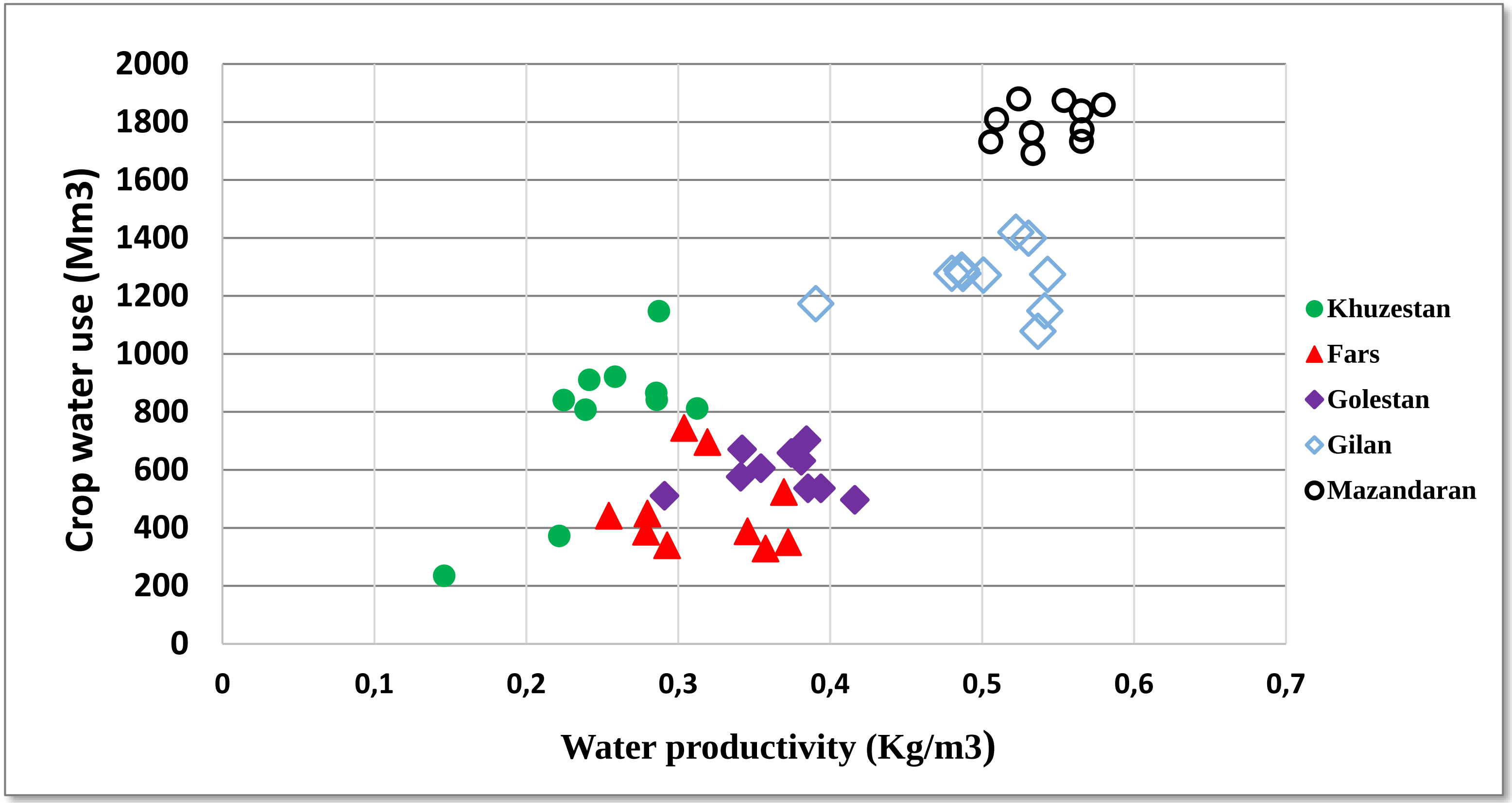


	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Average
onion	45,4	63,8	38,1	20	37,5	30,4	45,3	70,8	75,4	61,9	49
tomato	132	152	185	167	157	173	214	177	262	544	216
potato	57	15	128,6	94	68,7	100	189	40,5	107	168,7	97
watermelon	66	103	83	99	103	109	120	188	264	167	130
melon	14	19	21	23	83	38	34	45	48	33	36
Cucumbers	37	66	108	120	80	48	37	41	45	31	62

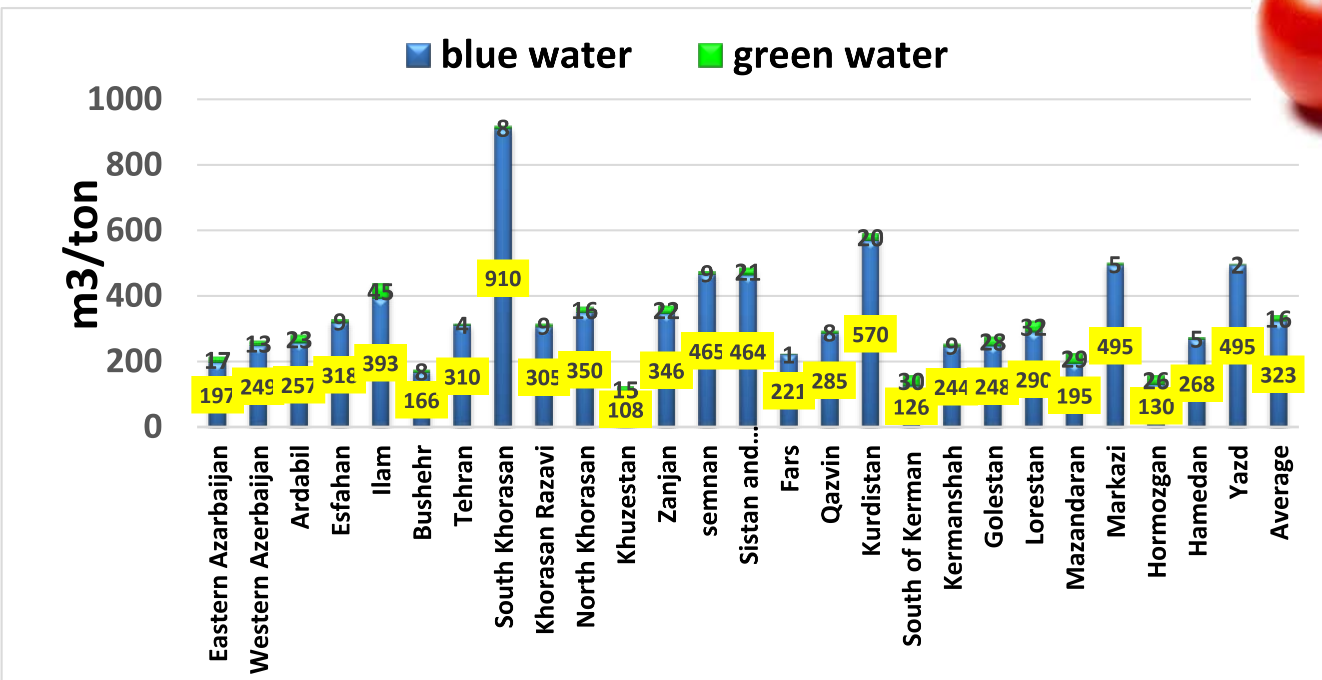
Onion Virtual-Water "Trade" within the country



Crop water use and water productivity -Rice



Tomato Virtual Water based on the applied water



Iran's favourable geographical location, abundance of natural resources and young population offer great potential for strong economic growth

- Iran is **favourably located** in the centre of promising growth markets.
- Economic power shifts towards China, Asia in general and the MENA region.

- Iran has an abundance of natural resources.
- It has **the largest proven natural gas** reserves and the 4^{th} largest proven **petroleum reserves.**

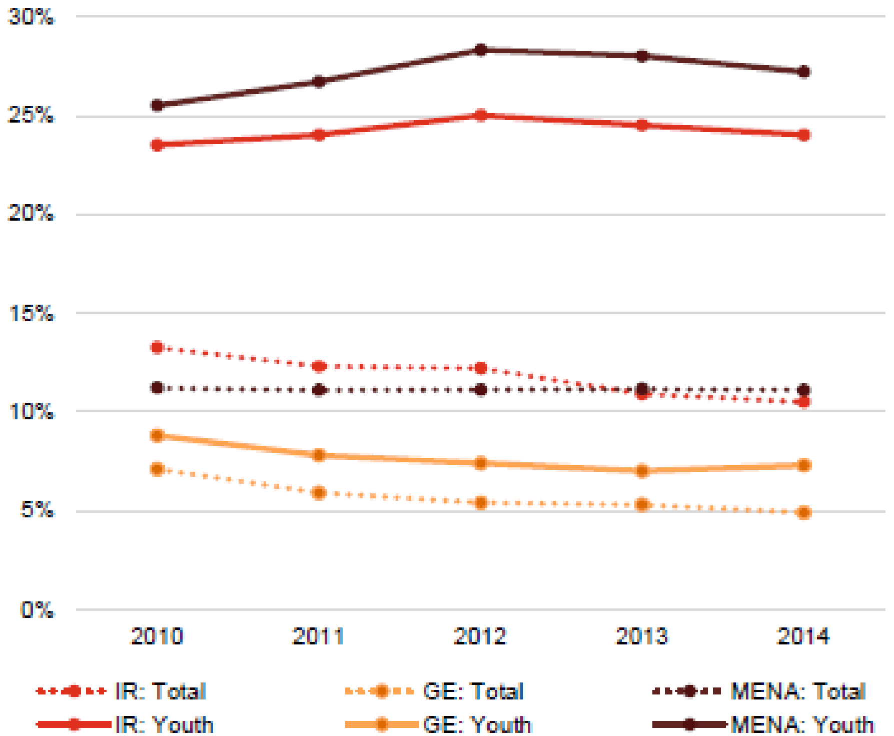
- Iran's **population** is rather **young**, with 18,7% aged 15-24 versus for example 11,2% in the European Union or 10,6% in Germany.

- Iran is **among the world's top:**
  - 15 automobile manufacturers
  - 15 steel producers and
  - 5 cement producers.
- In 2012 Iran was ranked as the world's 17th largest producer of scientific papers.

Iranian Youth as an Opportunity for the RE + EE Job Market

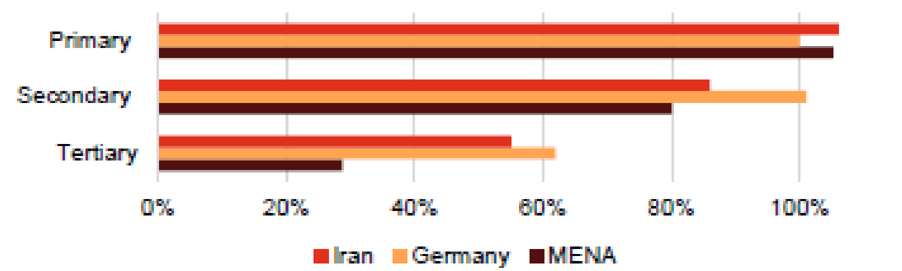
Despite education levels comparable to Germany, Iranian unemployment, especially amongst the youth, is very high

Total and youth* unemployment development



* % of unemployed labour force aged 15-24

Education levels*
(Gross, 2011/2012)



* Can exceed 100% due to inclusion of over- and under-aged students because of early or late school entrance and grade repetition. Not all MENA member states are included as data was not available.

Observations

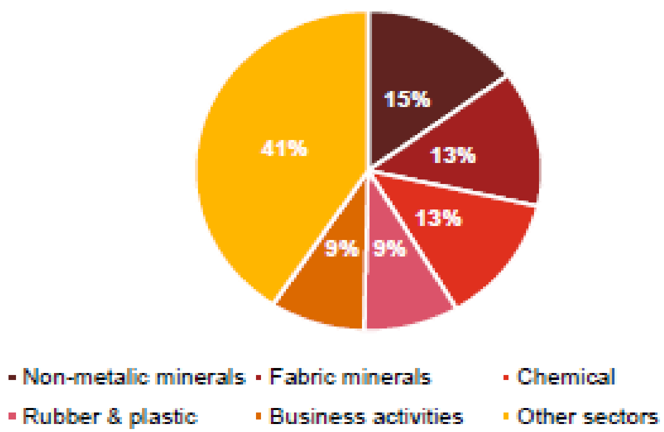
- Despite substantial improvements concerning unemployment in recent years, **youth unemployment** still is as high as 24% in 2013/2014.
- This is especially dramatic due to Iran's **demographic profile** with a relatively high share of youth population (over 60% of Iran's population being under 30).
- Iran shows **education levels similar to Germany**, with tertiary education levels being substantially higher than the MENA average.

Source: World Bank, PwC Analysis

Innovation Will Play a Role in the Iranian GDP and RE + EE Are Excellent Candidates

While SMEs play a major role in job creation, innovation and economic expansion, Iran's SMEs can further increase their contribution to GDP

Sectoral distribution of SMEs in Iran (2014)



***SMEs increase economic outputs* (2014)**

SME contribution to private enterprises	SME contribution to GDP	SME contribution to employment
Iran: 95 % of total enterprises (<10 employees)	Iran: 20% of gross value added (GDP contribution)	Iran: 80% of total employment
EU: 99.8% of total enterprises (10<employees<250)	EU: 58.1% of gross value added (output minus intermediate consumption)	EU: 66,8% of total employment

Observations

- In Iran there is a considerable mismatch between small and micro enterprises (**95% of all businesses in Iran are micro-enterprises** with 1-9 employees compared to the EU where 99,8% of SMEs employ more than 10 employees) with a **significant lower contribution of its SMEs to GDP** compared to the EU.
- **SME's drive a dynamic innovative economy**: they increase research and development, create big innovations and economic expansion and increase foreign investment.
- Also, supporting SMEs can have a **positive impact on innovation and exports.**

Source: Iran International Magazine No.70 (2014), European Commission (2014), PwC Analysis

Primary energy consumption (MTOE) from 2004 to 2013

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Iran	166.1	177.3	193.7	207.8	217.2	227	227.4	237.6	238.8	243.9
Change %		6.7	9.2	7.3	4.5	4.5	0.2	4.5	0.5	2.1
Germany	337.2	333.2	339.6	324.6	326.9	307.8	322.5	307.5	317.1	325
Change %		-1.2	1.9	-4.4	0.7	-5.8	4.8	-4.7	3.1	2.5

Iran INDC, 4% + 8%, 17.5 and 52.5 BUSD Price Tab

Source: BP 2014

CO_2 emissions per GDP, using purchasing power parity in kilograms CO_2 / US dollar, using 2005 prices in Iran and selected regions

Regions	1990	1995	2000	2005	2010	2011	2012	Change 1990-2012
World	0.54	0.49	0.45	o.43	0.40	0.39	0.38	-27.9%
EU-28	0.42	0.37	0.32	0.30	0.26	0.25	0.25	-40.9%
US	0.59	0.55	0.49	0.44	0.40	0.38	0.36	-39.7%
China	1.38	1.07	0.79	0.81	0.65	0.65	0.62	-55.2%
Iran	0.41	0.49	0.50	0.51	0.49	0.49	0.51	23.3

Source: IEA 2014

Carbon Intensity using Market Exchange Rates (Metric Tons of Carbon Dioxide per Thousand U.S. Dollars, Year 2005)

Country	2007	2008	2009	2010	2011	Change(%) 2007-2011
World	0.59933	0.6015	0.61455	0.61647	0.61209	2.1
Germany	0.2789	0.27552	0.27232	0.27006	0.25935	-7.0
Iran	2.08577	2.19763	2.47088	2.42185	2.47036	18.4

Source: US EIA, 2013

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Thank You!