The Global Energy Water Nexus: A Solution & Two Problems

Tony Allan

King’s College London & SOAS London

AAAS Washington 2011
Science Without Borders

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Setting the scene - how water and energy are interdependent.

Underscoring the significance of the nexus and the resulting tradeoffs.

The sustainable availability of water and energy will be dependent on how the nexus is understood, internalized and managed.
The water-energy security nexus is poorly understood.

It’s prominence has lagged the public profile of the global warming discourse.

There is a suite of

Global Uncertainties about Environmental and Economic Security and Sustainability

GUESS

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Two centuries of the Industrialisation of Agriculture, Manufacturing, Services and of Trade has done wonderful things for SOCIETY
Two centuries of the Industrialisation of Agriculture, Manufacturing, Services and of Trade has done wonderful things for society but has had very serious impacts on the global natural resources of land, energy, water and the atmosphere.

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Water
Lots of Water, but Not Always Where It Is Needed

One hundred and ten thousand cubic kilometers of precipitation, nearly 10 times the volume of Lake Superior, falls from the sky onto the earth’s land surface every year. This huge quantity would be enough to easily fulfill the requirements of everyone on the planet if the water arrived where and when people needed it. But much of it cannot be captured (top), and the rest is distributed unevenly (bottom).

WHERE DOES THE RAIN GO?

More than half of the precipitation that falls on land is never available for capture or storage because it evaporates from the ground or transpires from plants; this fraction is called green water. The remainder channels into so-called blue-water sources—rivers, lakes, wetlands and aquifers—that people can tap directly. Farm irrigation from these free-flowing bodies is the biggest single human use of freshwater. Cities and industries consume only tiny amounts of total freshwater resources, but the intense local demand they create often drains the surroundings of ready supplies.

WATER SUPPLIES TODAY

Much of the Americas and northern Eurasia enjoy abundant water supplies. But several regions are beset by greater or lesser degrees of “physical” scarcity—whereby demand exceeds local availability. Other areas, among them Central Africa, parts of the Indian subcontinent and Southeast Asia, contend with “economic” water scarcity, where lack of technical training, bad governments or weak finances limit access even though sufficient supplies are available.

Source: Scientific American 2009
Estimated annual global water use - average 1997-2001
Source; Hoekstra et al 2004

- 73% Soil water
- 12% Freshwater-irrigation
- 10% Freshwater-industry
- 5% Freshwater-domestic
Historical consumption of green and blue water - per head

- Primitive
- Hunting
- Primitive agricultural
- Advanced agricultural
- Industrial
- Technological

**m3 per day per capita**

- Transportation
- Services
- Industry
- Food/agriculture
- Food/agriculture

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Historical consumption of green & blue water - per head

- **m3 per day per capita**
  - **Years BP**
    - 500k
    - 50k
    - 5k
    - 500
    - 50

- **Log scale**

- **Half million years**
- **200 years**

- **Categories**
  - Transportation
  - Services
  - Industry
  - Food/agriculture
  - Food/agriculture

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Comparison of historical consumption of energy [1000 kcal/day] and water capita [m3/day]
Virtual water 'exports' and 'imports' - some industrialised, BRICS and less developed economies - 1997-2001 - cubic kilometres per year

35 economies

5 economies

165 economies

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### Virtual water content for selected products

**[m^3/ton]**

(Zimmer D., and D. Renault, 2003)

<table>
<thead>
<tr>
<th>Product</th>
<th>[m^3/ton]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>13,500</td>
</tr>
<tr>
<td>Pork</td>
<td>4,600</td>
</tr>
<tr>
<td>Poultry</td>
<td>4,100</td>
</tr>
<tr>
<td>Soybean</td>
<td>2,750</td>
</tr>
<tr>
<td>Eggs</td>
<td>2,700</td>
</tr>
<tr>
<td>Rice</td>
<td>1,400</td>
</tr>
<tr>
<td>Wheat</td>
<td>1,160</td>
</tr>
<tr>
<td>Milk</td>
<td>790</td>
</tr>
</tbody>
</table>

### Virtual water content of diets

**[m^3/person/day]**

(D. Renault, W.W. Wallender, 2000)

<table>
<thead>
<tr>
<th>Diet</th>
<th>[m^3/person/day]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diet 0 (reference USA)</td>
<td>5.4</td>
</tr>
<tr>
<td>Diet 1 25% reduction animal product</td>
<td>4.6</td>
</tr>
<tr>
<td>Diet 2 poultry replaces 50% beef</td>
<td>4.8</td>
</tr>
<tr>
<td>Diet 3 vegetal products replaces 50% red meat</td>
<td>4.4</td>
</tr>
<tr>
<td>Diet 4 50% reduction of animal products</td>
<td>3.4</td>
</tr>
<tr>
<td>Diet 5 vegetarian</td>
<td>2.6</td>
</tr>
<tr>
<td>Diet 6 Survival</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Figure 11. Water embedded in foods, per calorie of food. Data from: Chapagain and Hoekstra 2004 and the author's own calorie estimates.
The national water footprint per capita and the contribution of different consumption categories for some selected countries.
National water for domestic use
National water for food etc
Figure 10. Water intensity comparison of various diets. After: Renault and Wallender 2000.

Hoekstra et al

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Million litres available per person, per year

- Less than 0.5 - Extreme stress
- 0.5 to >1.0 - High stress
- 1.0 to >1.7 - Moderate stress
- 1.7 and over - No stress
- No data

SOURCE: Centre for Environmental Systems Research, University of Kassel

2070s

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Energy - Oil
synergies and outcomes of such use have not been equally well theorised.
Crude oil reserves

World Total: 1,055.3 Billion Barrels

- Saudi Arabia
- Iran
- Iraq
- Kuwait
- U.S.S.R.
- Emirates
- Mexico
- Libya
- Nigeria
- Venezuela
- Norway
- China
- Other

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The processes, synergies and outcomes have not been equally well theorised.

Natural gas – proved reserves 2008

Proved reserves at end 2008
Trillion cubic metres
The processes, synergies and outcomes of the use of water and energy have *not* been as well theorised as the small nexus.
The processes, synergies and outcomes of the use of water and energy have not been as well theorised as the small nexus.

Nor has an analytical framework been developed to capture the big nexus of water-food-trade-energy-climate change.

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The small nexus
The small nexus

The big nexus

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The small nexus
The big nexus
The mega nexus
The small nexus
Water – Food - Trade

The big nexus
Water-Food-Trade-Energy-CC

The mega nexus
Water-Food-Trade-Energy-CC-Finance

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Awareness of the energy/carbon-climate change element of the nexus has risen rapidly in the past three decades helped by concepts such as carbon footprints.

The water-food-trade element of the nexus has, over the same period been well conceptualised with ideas such as embedded water and water footprints.

It is only in the past decade, however, that the links between the industrialised and agricultural use of water and energy across the international political economy has been debated.

Major players in the world economy – big-oil, big-auto, big-ag, big-food and trading – have engaged
Widening of the security discourse

• Until the end of the Cold War, security was about sovereignty using hard economic and military power.
• Securitization was a process with few components:
  – Threats and threatened
  – Actors
  – Audience
• Environmental issues became security issues and we have the mega nexus.
• The outcome: many competing securities and a much wider agenda.

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# The main securities

<table>
<thead>
<tr>
<th>Security type</th>
<th>Group of environmental securities</th>
<th>Storyline</th>
<th>Means for achieving security</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water . Land . Food</td>
<td>Reliable supply</td>
<td>Accessibility to food</td>
<td>Sustainable intensification Local production &amp; trade. Behavior.</td>
</tr>
<tr>
<td>Energy</td>
<td>Reliable supply</td>
<td>Availability and sustainability</td>
<td>Local &amp; global resources &amp; trade</td>
</tr>
<tr>
<td>Climate</td>
<td>Life support system</td>
<td>Climate that enables life</td>
<td>CO2 reduction</td>
</tr>
<tr>
<td>Ecology</td>
<td>Life support system</td>
<td>Ecology v. food production &amp; polluting Industry</td>
<td>Environmental protection – sustainable consumption, diet &amp; reduced waste</td>
</tr>
<tr>
<td>Traditional</td>
<td>Not environmental</td>
<td>Protection of the nation AAAS 2011</td>
<td>Strong security capacity</td>
</tr>
</tbody>
</table>
A framework

Contextual variables

Water/Agriculture/Trade/Technology/Energy/CC/R&D/ Finance

Land  Water  Energy

Energy security  Climate security  Eco & Water security  Food security  Traditional security

Implications for policy and decision making process

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New political challenges for politicians

• Securities compete for limited resources.
• Decisions based not only on cost-benefit are now very politicized.
• Politicians and decision makers need to reconcile between conflicting securities and new uncertainties
New political challenges for experienced politicians

- Securities compete over same resources.
- Decisions based not only on cost-benefit are now very politicized.
- Politicians and decision makers need to reconcile between conflicting securities and new uncertainties.
- Politicians were invented to cope with uncertainty.
- Scientists like probability not uncertainty.
Challenges

• How can the competing discourses be reconciled?

• Who owns what, who does what, who controls what and who gets what?

• In FOOD security it is the private sector – locally and internationally

• In ENERGY security it was the private sector. It is no longer.
Differences – Energy & water sectors

Energy
Energy and water are different

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<thead>
<tr>
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<th>Energy</th>
<th>Water</th>
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<tr>
<td><strong>The resource</strong></td>
<td>Many non-renewables &amp; renewables</td>
<td>Almost all renewable</td>
</tr>
<tr>
<td><strong>Management &amp; impacts</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who owns?</td>
<td>Sovereign states &amp; Private sector</td>
<td>Private sector</td>
</tr>
<tr>
<td>Who operates?</td>
<td>NOCs &amp; Private sector</td>
<td>Private sector</td>
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<tr>
<td>Who trades?</td>
<td>Mainly Private sector</td>
<td>Private sector</td>
</tr>
<tr>
<td>Who controls?</td>
<td>States &amp; Private sector</td>
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</tr>
<tr>
<td>Who gets?</td>
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**Energy**

**Water**

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Energy and water are problematic in the nexus
Sometimes expensive – Sometimes scarce

| Energy for water security | Pumping water - 19% of energy consumption in California, 30% in some Indian states |
| Water for energy       | Cooling thermal
                        | Cooling nuclear
                        | Tar sands extraction |

Energy

Water
Energy can manufacture water
Water can generate energy
Not much is clean yet

<table>
<thead>
<tr>
<th>Technologies</th>
<th>Energy</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desalination dirty</td>
<td>&gt;&gt;&gt;&gt;&gt; Water</td>
<td></td>
</tr>
<tr>
<td>Desalination clean</td>
<td>&gt;&gt;&gt;&gt;&gt; Water</td>
<td></td>
</tr>
<tr>
<td>Electricity clean</td>
<td>Hydro</td>
<td></td>
</tr>
<tr>
<td>Oil substitute clean</td>
<td>Biofuels – 1\textsuperscript{st} generation</td>
<td></td>
</tr>
<tr>
<td>big water footprint</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil substitute clean</td>
<td>Biofuels – 2\textsuperscript{nd} &amp; 3\textsuperscript{rd} generation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Atmosphere and Solar</td>
<td></td>
</tr>
<tr>
<td>Electricity clean</td>
<td>Wind</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Solar thermal</td>
<td></td>
</tr>
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<td>Solar voltaic</td>
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Table 7. Average water footprint for fossil energy carriers, electricity from active solar space heat, electricity from wind energy, biomass produced in the Netherlands, Brazil, the United States and Zimbabwe (m³/GJ).

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<th>Primary energy carriers</th>
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<tr>
<td>Wind energy</td>
<td>0.00</td>
</tr>
<tr>
<td>Natural gas</td>
<td>0.04</td>
</tr>
<tr>
<td>Nuclear energy</td>
<td>0.09</td>
</tr>
<tr>
<td>Coal</td>
<td>0.16</td>
</tr>
<tr>
<td>Solar thermal energy</td>
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<td>Crude oil</td>
<td>1.06</td>
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<td>Biomass the Netherlands (average)</td>
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<td>Biomass US (average)</td>
<td>58.16</td>
</tr>
<tr>
<td>Biomass Brazil (average)</td>
<td>61.20</td>
</tr>
<tr>
<td>Biomass Zimbabwe (average)</td>
<td>142.62</td>
</tr>
<tr>
<td>Biomass (average the Netherlands, US, Brazil, Zimbabwe)</td>
<td>71.54</td>
</tr>
</tbody>
</table>

*Water footprint of bioenergy & other primary energy carriers, Gerben-Leenes, P. W., Hoekstra, A. Y., Van Der Mer, Th., 2008: Report 29, Delft: IHE*
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Example of trade-offs

This green energy needs substantial reliable water for cleaning the mirrors.

Example of a clean energy source
### Food-Water-Energy-Trade Nexus

Showing proportions of global water & global energy devoted to major activities

<table>
<thead>
<tr>
<th>Food production &amp; marketing chain</th>
<th>Other sectors and activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm</td>
<td>Other industry</td>
</tr>
<tr>
<td>Green water</td>
<td>55</td>
</tr>
<tr>
<td>Blue water</td>
<td>24</td>
</tr>
<tr>
<td>Blue water</td>
<td>3</td>
</tr>
<tr>
<td>Blue water</td>
<td>1</td>
</tr>
</tbody>
</table>

**Note:** Much of the blue water returns to the system. The returning quality is a big and hard to estimate issue.

### Energy

<table>
<thead>
<tr>
<th>Farm production &amp; food processing, transport &amp; marketing</th>
<th>Other industries</th>
<th>Transport</th>
<th>Domestic &amp; commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>32.2</td>
<td>27.3</td>
<td>21.5</td>
</tr>
<tr>
<td>Indirect Fuel &amp; Fertilizer &amp; electricity pesticides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>0.7</td>
<td>0.4</td>
<td>19.1</td>
</tr>
</tbody>
</table>

**Note:**
Uncertainty
is always part of
security and security politics

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Prices and price spikes
25 years doing the wrong thing extremely well
Food and food price spikes
Wheat prices on the other hand have been falling for 1000 years - agro [fertilizers & plant breeding etc] and other technological effects on yield plus transport, main increases came since 1945.

[UK wheat yields/ha - 1800 1t, 1900 2t, 1950 3t, 1990 9t]

There have been price spikes in the periods of wars and other crises - such as the UK adjusting to global pressures from US production 1830s. Also after the energy price spike in 1980 and in 1995 when the WTO was launched. And we have a price spikes now apparently also associated with the oil price and other commodity price surges.

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Still Below the Peak

Nominal wheat prices have risen to their highest levels in decades but, adjusted for inflation, they are still below the peak in the mid-'70s.

Wheat futures prices
Near month contracts

ADJUSTED FOR INFLATION

$25 a bushel

1 oil

2 oil

3 WTO/Dght/
Spec’n

Current
Soec’n/oil
price/
biofuels/
BRICS
Price spikes are important

They are moments when attention is focused
of
providers, politicians, the media and consumers

We are in the middle of such a window of
opportunity now.

The biggest one in my life so far and the most scary
because of
GLOBAL WARMING AND PEAK OIL

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How do we keep in place that which we have and provide sustainable entitlements for those who do not yet have?

We need an unprecedented level of creative and at the same time precautionary constructive engagement.

Thank you
Key messages

1. **Sustainable intensification** essential – roles for science, technology and improved farming

2. **Farmers** must deliver **high yields and stewardship**

3. **Energy sources** must be cleaned up

4. **Trade underpins** energy, water & environmental security

5. **Trade** must be **fair**

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Key messages - 2

6 Consumers are key – must eat sensibly & waste less

7 Socio-economic development is key

8 Private sector is key

9 Sound investment is key

10 Understanding the mega-nexus is key
Thank you