The water-energy-climate cycle: from vicious to virtuous?

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Outline

• The water-energy-climate cycle
• Vicious interactions
  • Water implications of energy generation
  • Energy/carbon implications of water services
• Virtuous interventions
  • Urban systems - energy (& water) saving
  • Appliances, buildings & city-scale systems
• Conclusions
Energy-water-climate cycle

- Climate
  - Mitigation
  - Variability
- Carbon
- Energy
  - Demand
- Water
  - Mitigation
  - Demand
- Adaptation

Exeter Centre for Water Systems
VICIOUS INTERACTIONS: Water implications of energy generation
Growth in energy demand

Notes:
1. OECD refers to North America, W. Europe, Japan, Korea, Australia and NZ
2. Transition Economies refers to FSU and Eastern European nations
3. Developing Countries is all other nations including China, India etc.

Source: IEA World Energy Outlook 2004
Global electricity generation by resource

Source: World Energy Council (2016)
Water consumption to generate power from different technologies

<table>
<thead>
<tr>
<th>Energy type</th>
<th>Water consumed (m³/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>0.001</td>
</tr>
<tr>
<td>Gas</td>
<td>1</td>
</tr>
<tr>
<td>Coal</td>
<td>2</td>
</tr>
<tr>
<td>Nuclear</td>
<td>2.5</td>
</tr>
<tr>
<td>Oil/Petrol</td>
<td>4</td>
</tr>
<tr>
<td>Hydropower</td>
<td>68</td>
</tr>
<tr>
<td>Bio-fuel, 1st gen. (corn, US)</td>
<td>184</td>
</tr>
<tr>
<td>Bio-fuel, 1st gen. (sugar, Brazil)</td>
<td>293</td>
</tr>
</tbody>
</table>

Sources: Henrik Larsen, DHI Water Policy, 2008
VICIOUS INTERACTIONS: Energy implications of water services
Growth in water demand

**Evolution of Global Water Use**
Withdrawal and Consumption by Sector

**Note:** Domestic water consumption in developed countries (500-800 litres per person per day) is about six times greater than in developing countries (60-150 litres per person per day).

# Energy consumption in water production

<table>
<thead>
<tr>
<th>Type of water supply</th>
<th>Approximate total energy footprint of water supply and treatment (kWh/m³)</th>
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</thead>
<tbody>
<tr>
<td>Surface water (rivers &amp; reservoirs)</td>
<td>0.5 - 4</td>
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<tr>
<td>Recycled water</td>
<td>1 - 6</td>
</tr>
<tr>
<td>Desalination</td>
<td>4 - 8</td>
</tr>
<tr>
<td>Bottled water</td>
<td>1000 - 4000</td>
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</tbody>
</table>

*Sources: Henrik Larsen, DHI Water Policy, 2008*
Energy consumption for UK water services

- UK water industry consumes over 8000 GWh energy annually to produce potable water and treat wastewater.
- This translates to over 5 million tonnes of CO₂ equivalent emissions. Of these:
  - 56% of these emissions derive from wastewater,
  - 39% from water supply and
  - 5% from administration/transport by the water industry.
UK average CO$_2$e emissions for water service and usage in the home

Total carbon emissions of 6.2 tCO$_2$e per Ml water for water in the home. This equates to 2.2 kg CO$_2$e daily per household.

EA (2008)
What should we prioritise?

• In the UK, we use 8 TWh electrical energy for water services
• Saving 30% equates to 2.4 TWh savings
• Water related energy use at home by customers is at least 60 TWh
• So users saving just 5% will have the same overall impact!
VIRTUOUS INTERVENTIONS: Appliances

climate

mitigation

carbon

adaptation

energy

water

variability

mitigation

demand
Micro-component based contributions to energy, water and CO$_2$e emissions

Water use & CO$_2$e emissions of household micro-components

Ultralow flush toilet (ULFT)

A pneumatic flush WC that uses a displaced air principle to operate.

- A sealable lid allows air to force waste from the bowl
- Requires only **1.5 litres** per flush and gives improved flushing and drainage performance.
- Looks and is used in the same way as a conventional WC
- Generates its own air and requires no ancillary equipment
- Is very low maintenance
Operation
Test rig experiments
Test rig experiments

Resource saving potential

• Average volume of current WCs: ~6 L
• Average volume of ULFT: 1.3 L
• Water saving: 86%
• Each ULFT flush (1.3 L) requires 500 J
• Each litre of water delivered requires 3200 J
• Net energy (and carbon) saving: 76%
• Ongoing data collection and analysis.
Propelair large scale trial

- Installation and monitoring study at University of Exeter (UoE) of >100 Propelair ULFTs
- Purpose is to record water saved, monitor potential sewer blockage and assess ‘real world performance’
VIRTUOUS INTERVENTIONS: Buildings

climate

mitigation

variability

adaptation

energy

water

demand

mitigation

mitigation

carbon

demand
Rainwater harvesting
Rainwater harvesting

Low energy RWH

Low energy RWH

A) Chamber connected to downpipe
B) Illustration of chamber discharging to downpipe
C) Illustration of chamber being pumped empty
Low energy RWH – lab testing
Low energy RMS – field trials

Zero energy RWH – lab testing
VIRTUOUS INTERVENTIONS:
Cities

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Energy and GHGs in wastewater treatment

- High energy use in wastewater treatment ↓ Carbon emissions
- Wastewater also a source of energy
- Significant direct emissions of CO$_2$, CH$_4$ and N$_2$O

GHGs from a conventional activated sludge wastewater treatment plant (arrow height proportional to CO$_2$e of emissions)
Energy and GHG reduction

- Study of an activated sludge wastewater treatment plant
- Investigate effects of modifying control
  - Flow rate adjustments
  - Choice of dissolved oxygen (DO) control strategy
  - Selection of DO setpoints
- 315 options evaluated

Based on IWA WWTP Benchmark Simulation Model (BSM2) + GHG emission extensions
Minimising net energy imported

Increase energy recovery to reduce carbon footprint?

Increasing energy recovery may increase net energy

Net energy may be reduced with a reduction in energy recovery

Don’t focus only on energy recovery!

Relationship between net energy imported and energy recovery

Conclusions

• Balance between top down and bottom up, plus small and large-scale solutions.
• Need a system wide, integrated approach.
• Prioritise combined mitigation & adaptation solutions (win-win).
• Engage & influence users.
• Encourage innovation – including in the house.
• Act now and work together to ensure that the vicious cycle of today becomes the virtuous cycle of tomorrow.
The ultimate water-energy solution?

Waterfall (1961), M.C. Escher