Mathematical Material Flow Analysis of Water-Related Energy in a Brisbane Household System Quantification and Understanding

Steven Kenway
Total Water Cycle Management Planning

Science Forum, 19-20 June 2012
Overview / Key Messages

Why do it?
• Household water-related energy is substantial. Understanding will shape scenarios and monitoring.

How was it done?
• Construct a detailed model that can simultaneously address (i) household and (ii) city-scale influences.
• Calibrate and validate the model for a single household…. Then scenario analysis

Findings from one household?
• 35% of ghg emissions are “water-related”
• significant scope to reduce this…..behaviour is key
• some water-reducing strategies can increase ghg.
It's desalinate or die

Dry Downs to tap into Wivenhoe, says report

GOVERNMENT bureaucrats want to let another 180,000 people tap into Wivenhoe Dam's dwindling supplies.

A yet-to-be-released report recommends linking Toowoomba and surrounding areas to a pipeline from Wivenhoe Dam and the Peopleswater Dam.

The pipeline will take up to 5,000 megalitres of water a year - more than four times the dam's present capacity.

The pipeline is designed to provide long-term water security and will be fast-tracked to reduce the risk of emergency water supplies and Toowoomba's dam runs dry as predicted.

In early 2009, the pipeline would be operational.

Amanda Gearing

Progress of pipeline strikes rock bottom

Tuck Thompson

CONSTRUCTION of the pipeline which will deliver recycled water to Brisbane's parched dam is moving at a snail's pace, having progressed only 500m of its 20km journey in the past fortnight.

The Government, however, remains optimistic that the pipeline will be completed this year - despite the rate of progress having to be increased ten-fold if it is to be finished by the due date.

Infrastructure Minister Anna Bligh, who reviewed the project yesterday, said it was "very pleased" with the progress, which is already two months behind schedule.

"Work here is really starting to ramp up," Ms Bligh said.

The first step of the $1.7 billion project will move treated water from Bundamba to the Swanbank power station to over 20 million litres a day from the Wivenhoe Dam.

The work is being done in the so-called "common corridor" shared by the Southern Regional pipeline, which will carry water to Brisbane from a desalination plant in Queens. Southern regional executive director Graham Thompson said the work is expected to be finished by the end of April, a month before the deadline.

That leaves 30 months to complete.

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THE WATER CRISIS

Courier Mail, Feb 1, 2007

Greg Stoltz
GOLD COAST BUREAU CHIEF

PEOPLE will die unless the State Government rushes through the Gold Coast desalination plant, claims Premier Peter Beattie.

Visiting the Gold Coast yesterday, Mr Beattie brushed off a one-year delay in the desalination plant as "the green light".

He also dismissed concerns that the decision to proceed with the controversial desalination plant may be premature.

"We've got to build this plant," Mr Beattie said.

"If we don't build this plant, the people of the Gold Coast are going to be suffering," he said.

Mr Beattie said the project was a "no brainer".

"The water crisis is at hand," he said.

"If we don't get water, we're going to be in trouble," he said.

Mr Beattie also rejected claims that the plant would be a "white elephant".

"I don't believe we're going to build a white elephant," he said.

"We're going to build a water grid."
Australian urban water capital expenditure – major cities

Kenway and Lant 2011, using WSAA 2009 data
The motivation….an emerging problem…

Population serviced in 2007 is 12.5 million. 2030 figure assumes 225 L/p.d residential consumption and that climate change will not adversely affect existing water yields.

Kenway et al 2008a
## Major gaps in water-energy knowledge identified by literature review

<table>
<thead>
<tr>
<th>Research Objective</th>
<th>Dimension</th>
<th>Scale</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Technology</td>
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<tr>
<td>Water infrastructure impact on energy</td>
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<td>Water use impact - residential</td>
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</table>

- **More-studied**
- **Isolated studies**
- **Major research gap**

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Kenway et al 2011a *(Water Science and Technology)*
Water-related energy in the average Australian city.

Kenway, Lant, Priestley (Water and Climate, 2011b)
Water-related energy in the average Australian city.

- Resource loss
- Water use
- Water supply

13% electricity use, and 18% natural gas use = 9% Australia's primary energy = 8% Australia's GHG emissions

Kenway, Lant, Priestley (Water and Climate, 2011b)
Sectoral direct, and embedded primary energy use.....and water-related energy in cities (Australia 2007)
Building the Model

- Hot water system
  - Shower
  - Bath
  - Clothes washer
    - Taps indoor
      - Dish washer
        - Outdoor use
          - Toilet
            - Kettle
              - Aircon
                - Other energy
                  - Water supply
                  - Energy supply
                  - Wastewater

*Based on Kenway, Scheidegger, Larsen, Lant, Bader (Accepted 15 Feb 2012)*
First the demand for water

Based on Kenway, Scheidegger, Larsen, Lant, Bader (Accepted 15 Feb 2012)
Based on Kenway, Scheidegger, Larsen, Lant, Bader (Accepted 15 Feb 2012)
132 input parameters can characterise any hh.

642 output variables characterise all flows and costs. Either for a single hh, or a city comprised of multiple hh types, including sensitivities and uncertainties.

Summary of model structure
Collection of shower duration, flow, temperature frequency data –
ETH Zurich (Bits to Energy Laboratory Collaboration and use of amphiro)
## Input Parameters (21 of 132)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Description</th>
<th>Mean</th>
<th>STDV</th>
<th>Probability distribution</th>
<th>Probability (mean/minimum)</th>
<th>Probability (maximum/truncation)</th>
<th>lower boundary (truncation)</th>
<th>upper boundary (truncation)</th>
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</thead>
<tbody>
<tr>
<td>Parameters for the household</td>
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<td>0.03</td>
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<td>1.92</td>
<td>0.03</td>
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<td>Temperature cold water</td>
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<td>3.6</td>
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<td>5</td>
<td>tnormal</td>
<td>55</td>
<td>5</td>
<td>45</td>
<td>65</td>
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<td>[°C]</td>
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<tr>
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<td>3</td>
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<td>[m]</td>
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<td>1</td>
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<tr>
<td>[W/(m^2 °K)]</td>
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<td>Split of hot water system: share of gas use</td>
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<td>1</td>
<td>1</td>
<td></td>
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<tr>
<td>[-]</td>
<td>Number of standing times in hotwater pipe s</td>
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<td>uniform</td>
<td>1.27</td>
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Parameters for showers

<table>
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<th>Description</th>
<th>Mean</th>
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<td>[min]</td>
<td>Flow duration per shower for adults</td>
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<td>4</td>
<td>0.28</td>
<td>1</td>
<td>5.5</td>
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<tr>
<td>[l/min]</td>
<td>Flowrate per showers for adults</td>
<td>11</td>
<td>2</td>
<td>tnormal</td>
<td>11</td>
<td>2</td>
<td>3</td>
<td>25</td>
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<tr>
<td>[-]</td>
<td>Number of showers per adult per day</td>
<td>1.5</td>
<td>0.03</td>
<td>tnormal</td>
<td>1.5</td>
<td>0.03</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>[°C]</td>
<td>Temperature of showers for adults</td>
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<td>2</td>
<td>tnormal</td>
<td>41</td>
<td>2</td>
<td>30</td>
<td>45</td>
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</tbody>
</table>
Output results – water, energy, CO₂, costs

Based on Kenway, Scheidegger, Larsen, Lant, Bader (Accepted 15 Feb 2012)
Sensitivity analysis (local / partial)

What happens when the parameter changes 10%?

Based on Kenway, Scheidegger, Larsen, Lant, Bader (Accepted 15 Feb 2012 Energy and Buildings)
Uncertainty analysis – Average and Single day

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average day</th>
<th>Single day</th>
<th>Cumulative uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>P15 Heat coefficient hot water storage</td>
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<tr>
<td>P22 Flowrate per showers for adults</td>
<td>75%</td>
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<td></td>
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<tr>
<td>P24 Temperature of showers for adults</td>
<td>80%</td>
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</tr>
<tr>
<td>P43 Number of cycles warm front per day</td>
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<td></td>
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</tr>
<tr>
<td>P1 Number of adults per household</td>
<td></td>
<td></td>
<td>28%</td>
</tr>
<tr>
<td>P3 Temperature of cold water</td>
<td></td>
<td></td>
<td>44%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>59%</td>
</tr>
</tbody>
</table>

Based on Kenway, Scheidegger, Larsen, Lant, Bader (Accepted 15 Feb 2012)
Key Conclusions from one Household

• Water-related energy is 35% of my household energy use.
• There is a large opportunity to influence this.
• If I had an electric hot water system, this would be half my household ghg emissions.
• Water-related energy use and ghg emissions can be vastly different.
• Showers, washing machines, dishwashers and kettles deserve attention.
• Some water-savings initiatives could increase greenhouse gas emissions.
• Behavioural and economic factors are significant
Challenges at the water-energy-carbon intersection (PMSEIC 2010)

- Resilient pathways will simultaneously reduce GHG emissions, lower overall water demand, maintain overall environmental quality and allow living standards to continue to improve.

- **Recommendation 4 (of 5): Resilient Cities and Towns**
  - foster resilient, low-emission energy systems, water systems and built environments by focusing jointly on technological developments in supply and on adaptation in demand

- scope for a National Energy and Water Efficiency Target scheme to combine state and federal rebates, incentives and regulations (Section 5, Recommendation 1).
Example: washing machine

1980  150 l / Cycle
1985  110
1990  80
1993  50
2003  30

Slide source: Tove Larsen
Waterless clothes washers

Not a product endorsement
What could we achieve if we use all the elements of rainwater harvesting, water reuse, green roofs, urban agriculture, hydropower, evaporative cooling & thermal storage?

Source: Steve Moddemeyer 2009
Which is more sustainable?

A - Utility energy use

B – Water-related energy use
Example Cost Curve

Source: Seccombe and Walters 2010, AGIC: Accounting for Carbon in Infrastructure Strategies: Sydney Water’s Approach
Example Cost Curve

Highly system-specific

Levelised cost, $/t CO₂-e

Annualised average GHG savings, t CO₂-e

Biosequestr.

Hydro, solar, wind, biomass

Water distribution optimisation; aeration systems, variable speed drive pumps

Source: Seccombe and Walters 2010, AGIC: Accounting for Carbon in Infrastructure Strategies: Sydney Water’s Approach
Thanks contributing authors, Scheidegger, R., Larsen, T., Lant, P., and Bader, H-P., and reviewers; and
The University of Queensland and Urban Water Security Research Alliance, Swiss Federal Institute for Aquatic Science and Technology (Eawag), Australian-American Fulbright Commission and Lawrence Berkeley Laboratory for supporting the research.

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References

- Kenway, S. Scheidegger, R. Larsen, T. Lant, P. Bader, H-P. Water-related energy in households: a model designed to understand the current state and simulate possible measures. (Accepted 15 February 2012 in Energy and Buildings).
THANK YOU

www.urbanwateralliance.org.au