

Saving water and carbon: Combined Water *and* Power (CWP) – a distributed technology opportunity for Melbourne.

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Abstract.

In responding to the current and future demands for water within a city such as Melbourne we are already witnessing a change of paradigm about the engineering of water systems. Strategies to reduce demand, by technology and behaviour change, are complemented by new approaches to supply based on a distributed systems approach. That new approach encompasses greater reuse of waste water. However expansion of treatment of waste streams is limited by the context of the 'water crisis' – global warming. Any expansion of the water supply that adds to CO₂ production is unacceptable.

At the same time as the shift to distributed systems thinking in water a similar shift is occurring in energy supply and consumption. The potential for grid-connected micro-generation of electricity from renewable or low-carbon sources is widely recognised as a significant element in a future sustainable energy system.¹

In this context there is the potential for the development of modular small-scale gas-fired combined heat and power (CHP) systems, delivering electricity to the grid and cleaning local supplies of waste water through distillation. Such systems could be both efficient in energy terms and in terms of CO₂ production.

Constructing a pilot unit should not be difficult as it would combine established technologies - a simple example of the idea of recombinant innovation². A network of these combined water and power (CWP) systems could be efficiently serviced in the way that distributed small-scale CHP units are organised in countries such as Finland, through on-line sensors reporting operational data to a central service agency.

A shift in thinking about water: 'Distributed systems' and 'everywhere is a catchment'.

Water is a typical *distributed* resource. It arrives (when it does) as rain falling over the ground (and of course over the sea). It flows under gravity into creeks, drains, gutters, underground aquifers, lakes, dams and the ocean.

In the past we have divided this distributed resource into (broadly) *three classes*: 'fresh (or useable) water', 'storm water' and 'waste' water:

- The first class - fresh, usable water - falls and is collected in 'nature', within what we have come to refer to as catchments, travelling through rivers and streams to some natural or artificial containment, which enables it to be collected for human consumption – as potable water in cities and towns, and also for agriculture in the country.
- The second, storm water, is that which falls 'out of nature', on pavements, roofs and other surfaces within the bounds of human settlements.
- Finally, used fresh water ends up as waste-water (or sewerage), forming the *third class*.

We have devised engineering systems for each of these classes of water:

- Pressurised reticulation of fresh useable water to enable its consumption for residential, commercial and industrial purposes. (The extraction of water for irrigation for agricultural production is a special case of these engineering systems)
- Storm drains for the evacuation of 'un-useable' storm water (ultimately, to the sea).
- Sewers (pipes and pumps) and treatment plants for waste water.

This classification system, and the development of the appropriate engineering solutions, made sense historically. Some (high) proportion of fresh water use is for direct, and indirect, human ingestion and health and quality control is vital. Run-off from human settlements is often contaminated, from air pollution, waste, animal faeces, the break-down products of tyres, paint and so on. Rain water retained within human settlements can provide a breeding ground for mosquitoes and other diseases. Human sewerage poses a real threat for human health. Solutions for safely de-contaminating waste water (before discharging it to the ocean or other aquifers) have been fundamental for social progress, for human development.

This successful three-tiered classification of useable (fresh) water, storm water and waste water, and the three distinct engineering systems developed to keep them separate, has worked well for most of history, during times when fresh-water (as rain) has been plentiful and consumption demands relatively low (compared to stocks available in catchments).

However, as we now know, in many parts of the world *that historical period has passed*. In Australia, in many of the areas we made our settlements (usually because of the ready availability of fresh water) supply has become scarce relative to

¹ See, for example: Micro-generation Strategy 2006. Department of Trade and Industry, UK DTI/Pub 8243/1k/03/06/NP. URN 06/993

² See: Ryan, C. *Digital Eco-Sense: Sustainability and ICT – a new terrain for innovation*. Chapter 15. 2004. Lab 3000. Melbourne. ISBN 0-975-67431-5

demand. Even though there have been significant reductions in residential consumption and there are programs to reduce consumption in commercial and industrial sectors, Melbourne's supply is challenged by growing population, by economic growth and the effects of prolonged drought. Projections of climate change suggest that the shortage of supply will become an endemic pattern. (An increase in the frequency significant climatic events complicates this picture, so that a progressive drying of the continent will, in all probability, be punctuated by excessive floods.)

The old engineering and development approaches are no longer adequate; a *new paradigm* of distributed water systems is slowly emerging:

- Fresh useable water from the old reticulation system will be more restricted to classes of use which require high quality supply.
- Storm water will be retained and matched to appropriate classes of use; various levels of cleaning and purifying will be used to extend that range of uses.
- The generation of waste water will be minimised by efficient use-technologies and changes in behaviour.
- Some waste water (loosely divided into 'grey' and 'black') will be cleaned and purified to appropriate levels for various uses.
- Other sources of fresh water may be developed, notably from the desalination of sea water.

Engineering and plumbing systems are changing as well to accommodate, for example:

- Localised rainwater storage and distribution
- Mutli-pipe systems for different water quality
- Black-water /grey-water mining and treatment
- New methods for efficiently delivering water to landscapes and agriculture
- Monitoring and feedback systems for controlling water delivery

The technology of the new water paradigm involves rain water tanks and large bladder storage systems; grey water plumbing; simple cleaning systems - settling tanks, physical filters, reed beds, worm colonies; complex cleaning systems - high pressure pumps and reverse osmosis filters; smart sensors for systems monitoring; new information based services for maintenance of efficient and high quality systems.

New challenges for the New Paradigm.

This new emerging paradigm faces some difficult challenges, there are many important trade-offs to be considered; possibly the most significant of which is **energy**.

The movement of water through all our reticulation and waste system is inherently energy intensive; water is heavy and moving it around, pumping and treating the supply requires considerable energy - for most cities this is somewhere in the vicinity of 6% of the total electricity supply³. Increasing supply through treating waste water or through desalination can add considerably to this total energy demand. Technologies for water treatment require additional pumping and the most common treatment/desalination system - reverse osmosis - requires considerable pressures to force water through filters. In such systems, producing 1000 litre of water can consume between 3 and 6kWh of electricity, so meeting any significant proportion of current water consumption (around 130kilres per capita per year) via such filtration systems would thus add considerably to future energy demand. (It is estimated that Perth will use some 180GWh of electricity to supply about 17% of its annual water consumption⁴.)

Given the projected link between current water supply problems and global warming, any solution to shortfalls that drives up greenhouse gas production raises serious political and ethical issues. For this reason a number of State governments are developing plans to address the greenhouse issues of increasing water supply, for instance by using renewable energy. But those same governments are already under considerable pressure to greatly reduce the carbon content of the existing energy supply, which will require expansion of renewable generation and substitution of gas for coal just to deal with the targets for existing energy demands (Victoria having set a target of 60% reduction in CO2 emissions by 2050).

Distributed energy systems are also the new way of planning a secure, sustainable supply.

Strategies for achieving 60-80% reduction in CO2 from energy systems, in countries that have committed to such targets, place great emphasis on increasing energy-use efficiency, expanding the diversity of forms of energy and moving to distributed generation. A pattern of grid-connected distributed electricity generation can be more efficient and effective. It supports the utilisation of diverse energy sources (solar, wind, geothermal, tidal, biomass, etc), reduces distribution losses and provides greater security in the face of increased threats to infrastructure from changing weather patterns and extreme

³ This is based on US department of energy data. From Melbourne Water data, supply of water uses 108kWh/ML and sewerage, 704 kWh/ML

⁴ Knight, D; MacGill, I; Passey, R. *The sustainability of desalination plants in Australia*. Centre for Energy and Environmental Markets, UNSW. 2007.

weather events. Many European countries are planning for a significant increase in distributed 'micro-generation' (25-100kW) much of which will involve Combined Heat and Power (CHP) systems.

CHP systems, use biomass, or gas, to generate electricity. They are inherently more efficient because they utilise their waste heat directly to displace heat, say for homes or offices, that would have come from burning gas or biomass, or from electricity. CHP can be thought of as generating electricity and delivering free heat, or generating heat and delivering free electricity.

CHP is not greatly utilised in Australia because our electricity generation (from coal or gas) tends to be from centralised large scale plants which waste vast amounts of heat for which there is little local value. Also, in contrast to Europe, there is only a relatively small demand for heating of buildings. (Much of Europe has well established 'district heating' systems, based on CHP, where heat is piped to homes, offices and public buildings.)

From CHP to CWP (Combined Water and Power)

Australia's need for treating, cleaning or desalinating water changes the local conditions in terms of the potential for CHP. The heat from a CHP unit can be used to *distil* water – the oldest and most established process of water purification. A distillation CHP unit - CWP - could use biomass to deliver a carbon neutral source of electricity and pure water. However the simplest and most flexible system for a city such as Melbourne would be to use gas; Victoria is committed to increasing the proportion of its electricity generated from gas as this produces roughly half the CO₂ that would be generated by the equivalent use of coal⁵.

Around the world there are many large plants which use waste heat, from the generation of electricity or other manufacturing processes to desalinate sea water. Such systems are built at the scale to supply towns and cities and combined heat and power systems are typically 20-25% more efficient than separate electricity generation and desalination. But such large scale systems (typically delivering many tens of mega litres per day) have little to offer for the treatment of storm water or waste water re-use in a distributed system or for the volumes of waste/storm water collected from office buildings, or city blocks, or from roadways, or residential communities.

Small scale (e.g 50-100kW)CWP units could be used to match the distributed nature of water sources needing need purification), using available natural gas and generating electricity to be fed into the grid. The overall efficiency of such a system (measured say in terms of CO₂ output) would be high compared to alternative water delivery systems because of the use of gas, the utilisation of the waste heat and the lower grid losses of distributed micro-generation.

The most significant advantage of a gas-fired CWP unit is that each part of it involves simple established technology. There are many engines that run efficiently on gas (from standard automobile engines to turbines); coupling them to an electric generator is technically simple, as is feeding the power produced into the grid. The distillation process may take some practical development, but around 2 billion litres of fresh water are distilled every day from waste heat on board ocean liners⁶, so the process of adapting existing distillation systems to the selected engine should not be too difficult.

⁵ The most efficient large scale gas-fired generators use the heat from their generator turbines to create steam to generate additional electricity. They still lose over 40% of their energy as waste heat.

⁶ This has been pointed out by Anthony Kitchener of the Melbourne research engineering company, SVW Pty Ltd.