DECENTRALISED DEVELOPMENT: THE ECOVILLAGE AT CURRUMBIN

B Hood, E Gardner, R Barton, R Gardiner, C Beal, R Hyde, C Walton

Abstract

The Ecovillage at Currumbin is a 144 lot development in the Gold Coast hinterland which employs a range of strategies to enhance the sustainability of the community.

All the water was supplied by a combination of large (≥ 20 kL) rainwater tanks and recycled water from a cluster-scale sewage treatment/water reclamation plant. Despite the high specific energy use of the household scale rainwater pumps, the overall household electricity use was less than a third of that of an average Qld home. This factor reduced to a sixth when total energy (electricity and gas) was compared between housing types

Energy use of the sewage treatment and reclamation plant was ≤ 1.1 kWh/kL, less than that of an equivalent centralised plant (e.g. Pimpama Coomera) reflecting the low energy systems used to reduce organic load (septic tanks, recirculating textile filter).

With some minor optimisation, we believe the Ecovillage could be the first mainstream energy and water neutral community in Australia

Typical pedestrian friendly layout of The Ecovillage homes showing high communal open space with quality landscaping, climate adaptive housing and rainwater tanks.

Introduction

Decentralised technologies are an increasingly popular option for developments which cannot easily be connected to traditional water (and sewerage) services, or which promote sustainability and self sufficiency as a unique marketing feature. Whilst it is unlikely that decentralised developments can be "carbon copied" into mainstream urban development, many of their features such as rainwater tanks, water recycling, solar hot water systems and energy efficient housing construction are replicable. However it is important to separate often well-meaning sustainability claims from biophysical fact, if we are to move forward with confidence in arguing for a re-engineering of the water cycle of future urban developments. Thus, studies of the water and energy consumption of the Sustainable House in Sydney (Michael Mobbs), Healthy Home on the Gold Coast (Gardner *et al*., 2003) Research House in Rockhampton Qld. (Kele *et al*., 2006), and a cluster of houses at Silva Park (Beal *et al*., 2008) have all been important for informing the debate on sustainable housing.

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The most recent opportunity for scrutiny of the water/energy nexus is The Ecovillage at Currumbin (Qld), where the water supply and wastewater treatment services for 144 lots are wholly provided on site. Potable water is supplied by individual household rainwater tanks (20–45kL) whilst a communal sewage treatment/water reclamation plant (based on membrane filtration and UV disinfection) supplies non-potable water for toilet flushing, external household use and public open space irrigation. The water and energy consumptions are monitored at the development using a sophisticated installation of water and energy meters, most of which are networked to a central data server.

Materials and Methods

The Ecovillage at Currumbin is a development in the Gold Coast hinterland which employs a range of strategies to enhance the sustainability of the community. The 110 hectare site has been planned for 144 allotments, on which 40 houses have been constructed and occupied, some since 2008 (See Beal *et al*, 2008). A previous paper, (Lane and Gardner, 2009), has reported on Life Cycle Assessment of the decentralised technologies used.

The occupied residences studied in this report are a mixture of 1, 2 and 3 bedroom detached houses on community title blocks that vary in size from 400 – 1400 square metres. Housing design at The Ecovillage is climate adaptive and energy efficient with appliances like air conditioning and electric clothes dryers not permitted. To ensure compliance with a stated commitment to sustainability for the entire development, an extensive set of building guidelines stipulate the specification of materials, fixtures and fittings, and all designs must be approved by the Body Corporate prior to commencement of construction.

The site is not connected to water or sewerage mains, and all water services

The energy and water balances have been monitored and found to be almost neutral.

are supplied on site. 109 of the blocks are connected by a sewer network and recycled water treatment plant that provides reticulated Class A + recycled water to the residences for toilet flushing and external amenity use. Any excess recycled water is used for irrigation of common property through a zoned irrigation system. An onsite groundwater bore from a shallow aquifer also provides water for public open space irrigation. Each residence catches and stores rainwater which is used for all household potable purposes. Minimum volumes of the tank storage are stipulated in the Ecovillage Architectural and Landscape Code as described in Table 1, and these minimums can be met by any configuration of tank sizes.

The tanks are all above ground to minimise disturbance of the soil and water table on the site. Electric pumps provide the flows for the systems. 5000 litres of storage is also stipulated for fire fighting purposes at each home, and this can be incorporated in the main storage, or within a dedicated tank. This extra storage complements the recycled water main which handles firefighting flows that fulfil state guidelines on fire protection. Gas boosted solar hot water systems are specified for all houses. Each house has at least 1kW of grid connected photovoltaic generation capacity.

The flows of rainwater, recycled water and hot water were monitored by staff from Qld Department of Environment and Resource Management (DERM) on a monthly basis, by manual readings of the appropriate meters. Gas meters and energy meters for lights, rainwater pumping, general power outlets and photovoltaic generation were also read manually at the same time. All of these meters also connect to an integrated monitoring system (Ecovision) with a display on an internal screen in each

Table 1. Minimum rainwater storage volume requirements at the Ecovillage at Currumbin.

Lot type	Minimum storage volume	Stormwater detention gap
1 bedroom	22.5 kL	2.5 kL
2 bedroom	33.75 kL	3.5 kL
3 + bedroom	44.5 kL	4.5kL

house, which was installed under body corporate rules. Monitoring of houses at The Ecovillage began in April 2008 and each house completed since has been added to the monitoring regime. All data for each parameter reported in this study is collected from houses that have readings that cover at least 90 days of occupation. Data collected from a complementary study (Silva Park) covers the period from December 2005 to November 2009.

Silva Park is a 22 lot eco-friendly development in Brisbane where individual household rainwater and greywater systems reduce import/export of potable water/sewage respectively (Beal *et al* 2008, Gardner *et al* 2008). Individual household rainwater tanks (22KL) are connected to a large (150KL) communal tank which stores surplus water in wet weather and supplies potable water in extended dry periods. The communal tank in turn is connected to council mains water via a trickle top up supply. All internal water used by the homes is sourced from the rainwater tanks. All the tankwater is UV disinfected before use. Other features of Silva Park include individual greywater systems which subsurface irrigate a dedicated grassed area, with diversion to a local sewer system during extended wet weather. All toilet waste goes to this sewer, which only discharges into the council sewer during off peak times. For this analysis only 6 homes were available for mass balance studies.

Results and Discussion

Household water use

The average household water use at The Ecovillage is 196 L/person/day as shown in Figure 1, which seems quite high in comparison to reported consumption figures in the region. For example in 2008/09 the Gold Coast average is 185 L/p/d and a development at Pimpama Coomera, which has dual reticulation, used 156 L/p/d (Willis *et al*., 2009). In comparison Central South East Queensland (CSEQ) has a consumption of 134 L/p/d in 2008/09, whilst a decentralised development in western Brisbane, Silva Park, had a consumption of 121 L/p/day. This wide variety of figures is primarily a result of differing water restrictions in each of the regions. Central SEQ, which includes Brisbane, has been on Level 6 restrictions for most of the period, which has precluded almost all outside use of mains water. The Gold Coast had much lower restrictions over the same period and this is shown by the increase of the figures at these locations. The Ecovillage, being completely independent of the mains, has no restrictions and the residents utilise this freedom to irrigate the extensive vegetable gardens at almost every residence.

This increased **external** water use illustrated in Figure 2, shows The Ecovillage uses more than double the water of other reported values in SEQ. All of the water used externally at the Ecovillage is recycled water from the treatment plant on the site and is reticulated to the individual residences. This recycled water, therefore, is serving the dual function of improving amenity of the community by allowing unrestricted external use, and the second function of

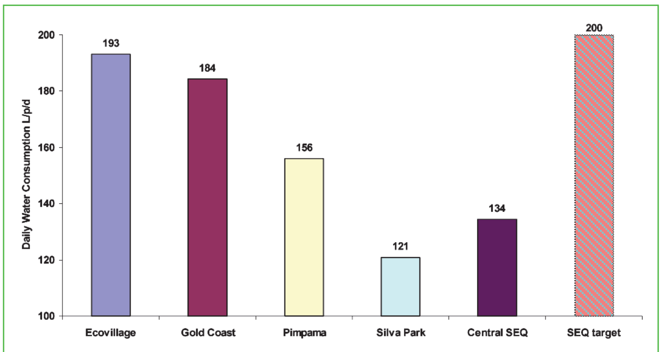

Figure 1. Total water use per person for The Ecovillage houses compared with similar data for other developments in the region. Also shown is the QWC target for SEQ after water restrictions are lifted.

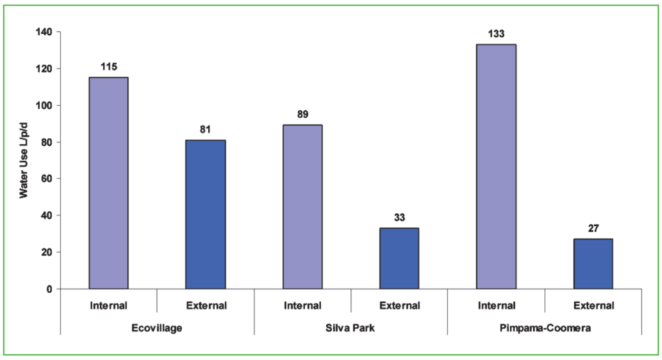

Figure 2. The comparison of internal and external water use at three decentralised developments in SEQ.

preventing the disposal of treated wastewater to waterways (or ground water), as in traditional systems.

The Pimpama Coomera development also has dual reticulation, however the system had not been switched to recycled water at the time of writing and the lower external usage may also reflect the impact of the use of rainwater tanks at this development for external irrigation. Further, promotion of the uses of recycled water had not been conducted in the community, so these values may reflect compliance with general restrictions in the area as reported by Willis *et al*., (2009). The flows of rainwater were not monitored at this site.

The figure at Silva Park includes data from December 2005 to November 2009, when lower levels of restrictions were in place. High usage at The Ecovillage may also reflect significant volumes of recycled water being used for construction purposes, establishment of gardens and landscaping features in this new development. Leakage of the recycled water connection points have also been noticed in a small number of occupied homes, and have been remedied as they occur by homeowners and Ecovillage staff.

The value for **internal** water use at The Ecovillage shown in Figure 2, includes 20 L/p/d for toilet flushing that is provided by recycled water. When indoor water use is compared with studies in other areas such as Yarra Valley (Roberts, 2005) or the Perth (Loh and Coughlan, 2003), the Ecovillage is well in front at 115L/p/d compared to 169 L/p/d and 155 L/p/d respectively. Locally, the contemporary study of Willis *et al*., 2009 at Pimpama Coomera reports a higher value of 133 L/p/d. These comparisons show that the residents of the Ecovillage are committed to conserving water resources, particularly inside the home. Water efficient appliances and fixtures such as taps, shower roses and washing machines are mandated by The Ecovillage Architectural and Landscape Code. The low value of 89 L/p/d at Silva Park reflects the low rainfall years of 2006 and 2007 as shown in Table 2, and the tight water restrictions for 2008, and for most of 2009.

All of the consumption figures, however, fall within the Queensland Water Commission's long term target which was revised from 230 L/p/d to 200 L/p/d in November 2009. The adoption of decentralised technologies such as rainwater tanks and decentralised scale recycling systems appears to show the way forward for incorporation into urban systems of the future. The important factor is the willingness of developers to consider the use of alternative sources of water for different purposes in the home, and to plan accordingly.

Table 2. Annual rainfall (mm) at weather stations near The Ecovillage and Silva Park.

Location	2006	2007	2008	2009 (exc Dec)	Long Term Ave	
The Ecovillage	1740	1140	1791	1438	1491	Coolangatta Airport
Silva Park	686	853	1234	1201	1175	Enoggera Reservoir

The tank volumes at The Ecovillage and Silva Park (15 - 45kL) are much larger than the currently "mandated" 5kL tanks for new homes, to reflect the utilisation of the rainwater in the residence for all end uses. Therefore these tanks easily meet the expected 70 kL/hh/yr target saving as stipulated in MP4.2 (DIP, 2008). Median lot sizes at these developments, at 930 m^2 and 1100 m^2 respectively, although larger than the average urban lot, are still within the upper ranges of urban developments. Pimpama Coomera for example has a median lot size of 628 m^2 but in general only has 5 kL tanks on a proportion of houses that were constructed after January 2007. Another important factor for rainwater collection is the connected roof area to ensure the tanks are adequately replenished during a variety of rain events. The Ecovillage homes have a median roof area of 142 m^2 and the Silva Park Homes 262m^2 which compare to the Queensland average for new houses of 236 m^2 (DEWHA, 2008). The inclusion of above ground tank storages has not adversely affected the amenity or aesthetic of the residences at these locations.

The breakdown of water source at The Ecovillage shows that 48% of the residents' water was sourced from rainwater with the remainder sourced from recycled water, compared to Silva Park with 82% of the total collected from rainwater. The total at Silva Park includes periods of drought during 2007, and the latter part of 2009. The supply shortfall at Silva Park was made up by mains water that is connected to the communal storage tank (Beal *et al*., 2008).

Table 3. The recycled water balance of The Ecovillage.

Sewage inflow	13.4 kL/d
Residential demand for RW*	9.3 kL/d
Public open space irrigation	18.3 kL/d
Reticulation leakage losses	2.2 kL/d
Total output RW (includes Bore)	29.8 kL/d
Bore augmentation for POS	16.4 kL/d
Irrigation area	7 ha POS**
Application Rate POS*	0.95 ML/ha/yr

***Public Open Space Irrigation for nursery, greenways & cropping*

** Recycled Water*

Total hot water use was measured at The Ecovillage and Silva Park, and values of 42 L/p/d and 41 L/p/d respectively were recorded over the corresponding periods. These values represent 36% and 46% of internal water use at the developments, and have substantial implications to energy use by houses.

Sewage and recycled water

The treatment and reuse of sewage at The Ecovillage is an important strategy in meeting the needs of the individual households, and the community as a whole. The recycled water treatment plant is regarded as a low energy plant, utilising septic tanks for primary treatment, oxidation by attached growth textile filter, and membrane filtration and ultraviolet sterilisation for final polishing. The sewerage reticulation network feeding this facility is largely gravity driven, further reducing energy requirements of the system. Recycled water is used in a number of applications where the use of high quality potable water is not necessary. The applications include toilet flushing, household irrigation, communal open space irrigation, plant nursery irrigation, crop irrigation and some usage in construction. To ensure continuity of supply to the residents and a substantial safety factor in the event of treatment system failure, 1 ML of buffering capacity and three 75 kL recycled water storage tanks are incorporated into the treatment facility.

The figures in Table 3 show that the volume of sewage recycled, 13.4 kL /d, is greater than the recycled water demand at the residences, 9.3 kL/d, so the residents' recycled water demand can be met without any addition from supplementary supply from groundwater. This excess recycled water is presently being augmented by groundwater for the irrigation requirements of extensive communal space (7 ha). There were also reticulation losses of 2.2 kL/day which have since been substantially reduced.

The specific energy of the recycled water at The Ecovillage, 1.1 kWh/Kl, compares favourably with the specific energy of the Gold Coast recycled water, 1.4 kWh/kL, inclusive of energy for membrane filtration and ultraviolet sterilisation (Kenway, 2008). This energy density also compares favourably with a traditional municipal design, because nitrogen is not reduced in the Ecovillage treatment process. It warrants noting that the figure for The Ecovillage includes the energy for pumping a further 16kL/day from the bore plus the energy for pumping over 18 kL/day water for irrigation of public open space If this extra energy were removed from the calculations the specific energy would decrease substantially, adding to the attraction of using this type of low energy treatment system in other developments. The use of 14 kW of roof mounted solar power panels to offset the electricity used by the plant (15 kWh/day) is further commitment by the developers to improving the sustainability of the Ecovillage. At present, the ability to monitor separate components of the energy usage at the plant is not in place. However, a study being undertaken by the Urban Research Water Alliance (http://www.urbanwateralliance.org.au/) is currently underway to fill this knowledge gap.

Recycled Water Quality

The quality of the recycled water at the Ecovillage is monitored as part of the licensing conditions, and the average results listed in Table 4 show that the recycled water treatment plant complies easily with the license conditions. The electrical conductivity, 634 μScm^{-1}, and the sodium absorption ratio (SAR) at 3.8 were recorded from supplementary monitoring by DERM staff. This water quality was attained through the use of rainwater as the principal water supply at the Ecovillage. Rainwater has very low conductivity and mineral loads and just the usual addition of salts by residents is reflected in the recycled water quality. The recycled water quality at the Ecovillage would be similar or better than that expected from a municipal treatment plant, especially those influenced by moderate potable water salinity (e.g. 350mg/L from Wivenhoe) or saline groundwater ingress into the sewerage system (e.g. Luggage Point).

Table 4. Water Quality test results for The Ecovillage recycled water.

Parameter	Units	Ecovillage (average)	Licence	Testing Frequency
Turbidity	NTU	0.3	< 2.0	Continuous
pH	-	7.0	6.0 – 8.5	Weekly
Free Cl_2	mg/L	1.4	> 1.0	Daily
Total Nitrogen	mg/L	12.5	< 15 (45 max)	Monthly
Total Phosphorus	mg/L	2.9	< 10 (30 max)	Monthly
Dissolved O_2	mg/L	7.3	> 2.0	Weekly
BOD	mg/L	< 3	< 10 (30 max)	Monthly
Suspended solids	mg/L	< 2	< 10 (30 max)	Monthly
E. coli	cfu/100mL	< 1	< 10	Weekly

Table 5. Household rainwater systems specifications.

	Average Pump Power Watts	PressureVessels/houses	UV
Ecovillage	700	6/33	No
Silva Park	630	0/6	40W
ISF	890	2/4	No

Specific energy of rainwater pumping

The energy to move water over the short distances that are found in decentralised systems is reported in Figure 3, and compares the energy required to supply a unit volume (1 kL) at each house.

Rainwater pumps at The Ecovillage have a median value of 1.4 kWh/kL which compares favourably with the other decentralised systems reported of 1.8 kWh/kL at Silva Park and 1.5 kWh/kL reported by the Institute for Sustainable Futures (ISF) (Retamal *et al*., 2009) for a number of residences in the Sydney region. The two values for Silva Park (1.8 and 5.1 kWh/kL) show the energy used by the system with and without ultraviolet sterilisation. Table 5 shows that the average pump sizes at these three systems are all less than 1kW. The decentralised systems when compared to traditional systems such as the Gold Coast potable supply are at an energy disadvantage. However when compared to the individual specific energies of systems such as the Purified Recycled Water (PRW) scheme and the seawater desalination plant at Tugun, the decentralised figures once again look favourable.

When the projected contributions of these new water sources are factored into the regional municipal water supply, a value of 1.2 kWh/kL is estimated for potable water supply across the region (Claydon, 2008), and systems such as The Ecovillage again look comparable. In future, such systems should provide an attractive solution for urban developments where centralised water and sewerage infrastructure can be supplemented by suitable decentralised technologies.

Further opportunities also exist to improve the specific energy of decentralised systems, through

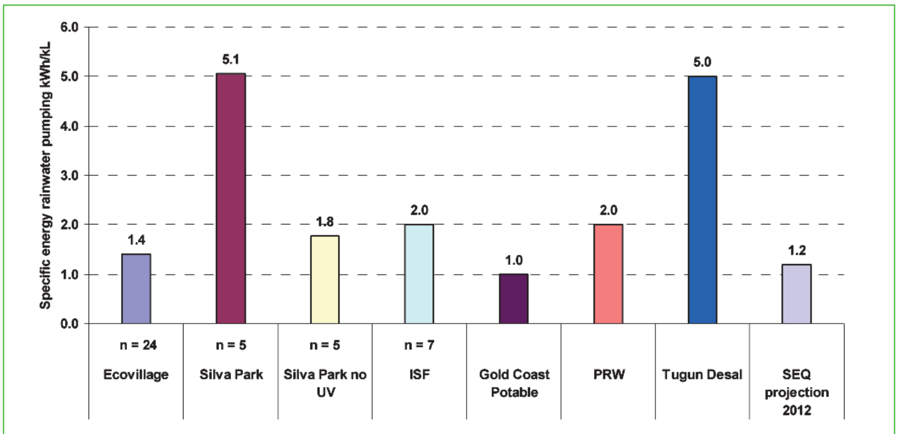

Figure 3. Comparison of specific energy for rainwater pumping with centralised municipal supply options.

optimisation of system design and components. Studies by Cunio and Sproul (2009) show that specific energies of rainwater pumps can be reduced to as low as 0.1 kWh/kL using 12 V DC pumps in low flow applications like toilet cistern valves. Retamal *et al*. (2009) also demonstrated the value of pressure vessels which reduced the energy consumption by a third for water supply systems supplying toilets, laundry and external taps. The pressure vessels reduced the number of pump starts per litre supplied noting that high transient energy use peaks occur during a "start up".

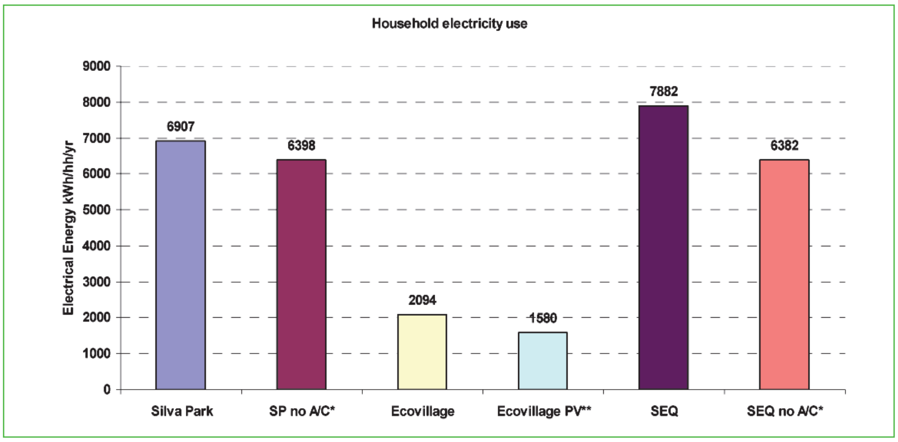

Figure 4. Household electricity use for The Ecovillage compared with similar data for other developments and regions * Air Conditioning, ** Photovoltaic generation.

Electrical Energy

The electrical energy consumption of the residents of The Ecovillage, as shown in Figure 4 is very low at a median of 2094 kWh/hh/yr in comparison to either Silva Park (6907 kWh/hh/yr) or SEQ (7882 kWh/hh/yr).

The principal energy saving strategies at The Ecovillage are set out clearly in the local community title documents and design guidelines which are distributed to new landholders. These codes specify the design of the building shell and choice of appliances for the owner. The first strategy that impacts the energy consumption is the banning of air conditioners at the site. Thermal comfort however is not abandoned by this practice as many other regulations in the code address the issue. Insulation, thermal mass, building orientation, shading of openings, cross ventilation and convection ventilation are all stipulated in the package. Often these codes have subsidiary benefits to other aspects of the energy consumption of the house such as lighting energy.

Energy for lighting is measured separately at the Ecovillage and a median value of 145kWh/hh/yr was recorded. The use of natural lighting and energy efficient compact fluorescent light are mandated at the site and help deliver the low lighting energy consumption at the site. Dark sky policies also minimise unnecessary external lighting to reduce energy use, neighbourhood impacts and disturbance to wildlife. The average value for lighting energy in Queensland is 973 kWh/hh/yr (Mills, 2009) but this figure includes incandescent and inefficient halogen lights, prohibited from sale after November 2009. Compact building sizes at the Ecovillage also contributes to the lower lighting energy needs with average house sizes of 155 m^2, compared with SEQ averages of 236 m^2.

Although rainwater systems utilise inefficient pumps for transferring water, pumping energy is a small proportion of the total electricity consumption of a household. Pumping energy at The Ecovillage is a median 87 kWh/hh/yr, or 4% of the total household electricity consumption. Silva Park is higher at 666 kWh/hh/yr (or 10 %) due to the use of ultraviolet sterilisation in the rainwater system.

The remainder of the electrical energy (1862 kWh/hh/yr) consumed at the Ecovillage is used by plug-in appliances. The local design codes encourage the use of efficient low energy appliances wherever possible, however a "grandfather" clause in the documentation allows the use of existing appliances until they are replaced. The major fixed appliances in each house, the oven and cook top, are gas appliances and the hot water system is a gas-boosted solar system. Electric clothes dryers are banned, and dishwashers are discouraged. Hence comparing electricity consumption with the surrounding region is difficult without adjustment to compensate for varying technology.

Figure 5 shows the theoretical set of standard appliances in Ecovillage houses compared to the reported averages of SEQ houses. The SEQ household data has been normalised by adjusting for household population density to 2.3 p/hh, equivalent to the Ecovillage. Average energy consumption figures were obtained for types and densities of appliances used in SEQ homes and these figures were then applied to a minimal set of the same appliances at The Ecovillage. The comparison shows that significant savings can be obtained using standard appliances (i.e. not necessarily

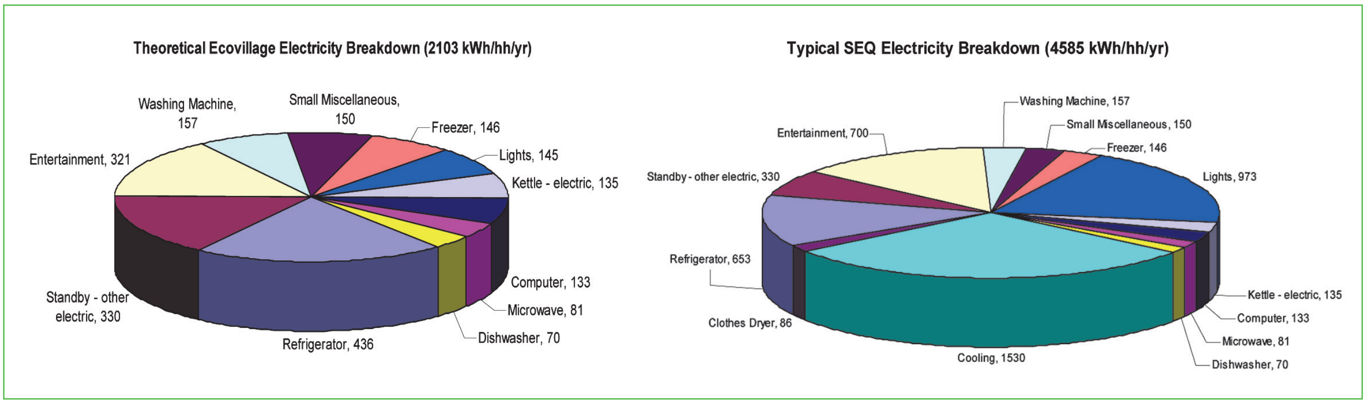

Figure 5. Partitioning of predicted electricity use at an Ecovillage home with an average home in Queensland. (data adapted from Mills 2009 and Newton and Tucker, 2009).

the most energy efficient) at an easily attainable density. For example, televisions at the Qld density of 2.4 units/hh means that there are more televisions than residents in the house at the Ecovillage, so the theoretical figure for Currumbin shows the energy consumption for a single television. When the theoretical figures of total appliance energy consumption (2023 kWh/hh/yr) in Figure 5 are compared with the measured value at the Ecovillage (1862 kWh/hh/yr), the comparison highlights the approach of consciously choosing energy saving appliances, and using all appliances frugally, substantial savings in energy usage can easily be obtained. The greatest savings are gained by the elimination of gross energy-using appliances, such as air conditioning. However, useful but incremental gains can be obtained by reducing the numbers of other appliances such as televisions or home entertainments systems. Importantly the lifestyle of the residents does not need to change greatly, as all appliance types are represented with the few exceptions of air conditioning and clothes dryers.

The other important contribution to the low value in the Ecovillage is the awareness of the residents of their own power use. Each house is fitted with a central monitoring system (Ecovision) that allows the consumers to see an actual value of energy or water use in real time. This allows the resident to actively manage their appliance usage and control their energy usage.

The Ecovillage has employed one last strategy to ensure that electrical energy usage is sustainable. Each residence has at least 1kW of roof mounted photovoltaic generation capacity mandated by the local development code. These solar panels are grid-connected to offset household electricity usage. The median generation value recorded was 1580 kWh/hh/yr (Figure 4) or 75% of the total electrical consumption. We believe this figure could easily be revised upwards if generation capacity were sized more closely to household size (similar to the rainwater tank sizing at the Ecovillage) as the generation to consumption ratios ranged from 0.2 to 1.8.

LPG consumption

The other energy source at The Ecovillage is liquefied petroleum gas (LPG) which provides energy for cooking and boosting the solar hot water system. Cooking included cooktops and ovens (and barbeques) and these uses would be expected to be the major end uses of LPG at the site. The gas is measured by a standard gas meter at each house but individual appliances are not measured separately. The results show a median Ecovillage consumption of 5309 MJ/hh/yr which is of a similar magnitude to the LPG consumption at Silva Park of 6050 MJ/hh/yr, which is surprising as the households at Silva Park use gas for both the cooktop only and for heating **all** of the hot water using an instantaneous hot water systems. The average consumption for Queensland homes using gas for water heating, cooking and space heating is 14400 MJ/hh/yr (Mills, 2009).

Analysis of this data shows that gas used for cooking can be estimated as 3300 MJ/hh/yr leaving a residual of 2000 MJ/hh/yr for boosting hot water systems at The Ecovillage. Applying this figure to the measured volume of hot water used at the Ecovillage shows solar boosting efficiency of only 43% compared to the 86% expected for SEQ (Mills, 2009). Direct contact with the residents has established that in several installations at the site, the solar hot water systems had been incorrectly installed, and hence gas boosting was dominant. Water temperature tempering valves had been incorrectly installed prior to the gas booster and the water, tempered to 45°C, was being subsequently heated to 60°C by gas boosting, increasing the consumption of gas unnecessarily.

This highlights the necessity for tradespeople to be trained in the installation of all of the alternative technologies that are utilised in this type of development. Professional building certifiers at both the development level and local government level need to be able to recognise faults of this type and report shortcomings, particularly if fixtures have been specifically installed to provide energy savings.

The overall energy consumption which combines electricity and LPG expressed as GJ/hh/yr are shown in Figure 6. The Ecovillage returns the low value of 13 GJ/hh/yr of total consumption, or 7 GJ/hh/yr when solar electricity generation is factored in to the value. This is much lower than Silva Park and SEQ values of 31 GJ/hh/yr and 43 GJ/hh/yr respectively.

The figure for Silva Park shows a good improvement on the average Queensland value and is an indication that even small gains can be made with only small changes in infrastructure design. These residences are much closer to the Queensland median in terms of size and appointment. However the residences at The Ecovillage being smaller, with carefully designed building shells and well selected appliances, display the greatest gain in this study, using less than a sixth of the energy of their counterparts in the broader community.

Even greater environmental gains are evident when the environmental implications of the energy consumption is

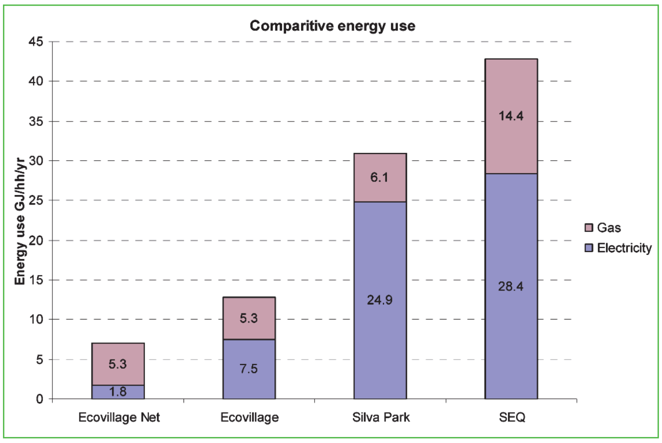

Figure 6. The total household energy consumption of The Ecovillage compared with Silva Park and SEQ.

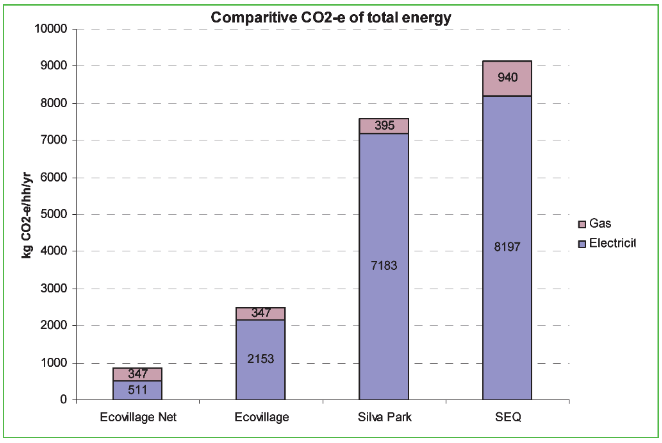

Figure 7. The household greenhouse gas generation of the Ecovillage compared with Silva Park and SEQ.

expressed as kg of CO_2- equivalent as shown in Figure 7.

The net value of greenhouse gas generated at The Ecovillage at 857 kg CO_2-e/hh/yr is over ten times less than the Queensland average of 9138 kg CO_2-e/hh/yr. This shows the clear advantage of photovoltaic generation compared to coal-based electrical generation that supplies most of Queensland electricity. The greenhouse gas density for coal generated electricity in Queensland of 0.3 kg CO_2-e/MJ is far greater than the 0.07 kg CO_2-e/MJ for LPG or the 0.06 kg CO_2-e/MJ for natural gas.

In a political and economic climate where carbon-based power generation is increasingly being imposted by regulation or financial penalties, renewable sources of power generation such as solar generation will become very attractive to the home owners of the future.

The goal for future development could be carbon neutrality (e.g. Newton and Tucker, 2009) and The Ecovillage is demonstrating some of the methods that can be utilised to attain this goal. With just a little optimisation of the systems, the Ecovillage itself is not far from this goal.

Conclusion

The preceding discussion has show that the range of technologies employed at The Ecovillage at Currumbin have had a significant impact on improving the sustainability of the development. These technologies are not new nor untested methods, but rather robust technologies used in combination to achieve beneficial outcomes. In the sub-tropical climate of South East Queensland rainwater tanks and recycled water used together can comfortably meet the needs of the residents without restriction, and easily comply with the usage targets of the regional authorities. Local energy consumption and generation has been well planned and the use of solar energy in two of the systems, water heating and electricity generation, has reduced the GHG production by a substantial amount. Importantly the residents' lifestyles have been minimally impacted by the reduction and type of energy using appliances within the household.

This development could well provide a benchmark for urban development in the future. This type of master planned development could be scaled to suit cluster scale development throughout the region and would suit both greenfield development and infill clusters. Moreover some of the technologies could be applied to high density development to reduce the need to upgrade or install increased capacity of centralised infrastructure such as water supply or power generation. Further research is recommended that examines environmental, economic and social outcomes that were not discussed in this study, particularly considering the expected increase in population in SEQ and other regions in the future. These preliminary results demonstrate that decentralised systems can compete favourably with centralised services in several aspects, and should provide a viable addition for water infrastructure for the continuing population expansion in SEQ which is expected to require 745,000 new dwellings by 2031 (SEQ Regional Plan - http://www.dip.qld.gov.au/regional-planning/regional-plan-2009-2031.html.).

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The Authors

At the time of writing, **Barry Hood** was the scientist in charge of The Ecovillage project. He is currently the Technical and Design Manager of GBG Wastewater Management P/L.

E A (Ted) Gardner is the Principal Scientist (email ted.gardner@ derm.qld.gov.au) of the Urban Water Cycle Science unit in the Department of Environment and Resource Management (DERM) , Queensland. and an Adjunct Professor at the Queensland University of Technology.

Ryan Barton and **Richard Gardiner** are a scientist and technician respectively in DERM. **Dr Cara Beal** (formerly a DERM scientist) is now a Research Fellow at Griffith University

Richard Hyde is a Professor of Architectural Science in the Faculty of Architecture, Design & Planning, University of Sydney, and **Chris Walton** is a Director of Land Matters P/L , the developer of The Ecovillage at Currumbin.

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