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CARBON COST FOR SAFE WATER SUPPLY THROUGH ADVANCED TREATMENT OF RIVER WATER TO A COUNTRY TOWN

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ABSTRACT

Greenhouse gas emission from fossil fuel burning is causing global warming and climatic change, whose negative impact on economy, human development, environment and society will be manifested through water. Importance of Carbon Footprint Accounting (CFA) for climate change mitigation and adaptation are illustrated. CFA calculation process steps, methodology and mathematical equations that applies, are explained for Meadow Town Water Supply. MTWS's carbon footprint report reveals that fossil fuel- based grid electricity contributes to 97% of greenhouse gas emission. Carbon pollution reduction scheme (CPRS) or carbon emission trading (CET) is likely to increase prices of carbon and water usage prices in the future, if the current trend in energy consumption at water utilities continues. The challenge for the water utility engineers, scientists, operators, accountants and customers are to minimize the energy and carbon intensity of water supply services through diverse portfolio of measures.

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INTRODUCTION

Water is the basis of all life, human well-being and economic development. It links together all aspects of life on this planet- human and environmental health, ecosystem, food supply, energy, industry, transport, waste dilution and recreation. Water links Earth's atmosphere, land mass and oceans through the global water cycle- circulating through each of these domains, changing phase between solid, liquid and gas; supporting the biosphere and humans. Water is involved in all components of the climate system- atmosphere, hydrosphere, cryosphere, land surface and biosphere.

Anthropogenic emission of greenhouse (GHG) gases (Kyoto GHG: carbon dioxide, methane, nitrous oxide, hydro fluoro carbons and per fluoro carbons) has cause earth's surface and ocean temperature to increase that has increased evapo- transmission for ocean, soil, surface water and plants. As a result, the water vapour concentration in the atmosphere has increased and is causing increasing extreme events- more intense and variable precipitation, flooding, tropical storm, drought and wild fire.

Population growth, increasing consumption and climate change are three most important factors that threaten to exacerbate human security and development. Climate change is defined as 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods' (UNFCC, Article 1; UN, 1992). Most of the warming in the past 50 years is 'very likely' (more than 90% in probability)

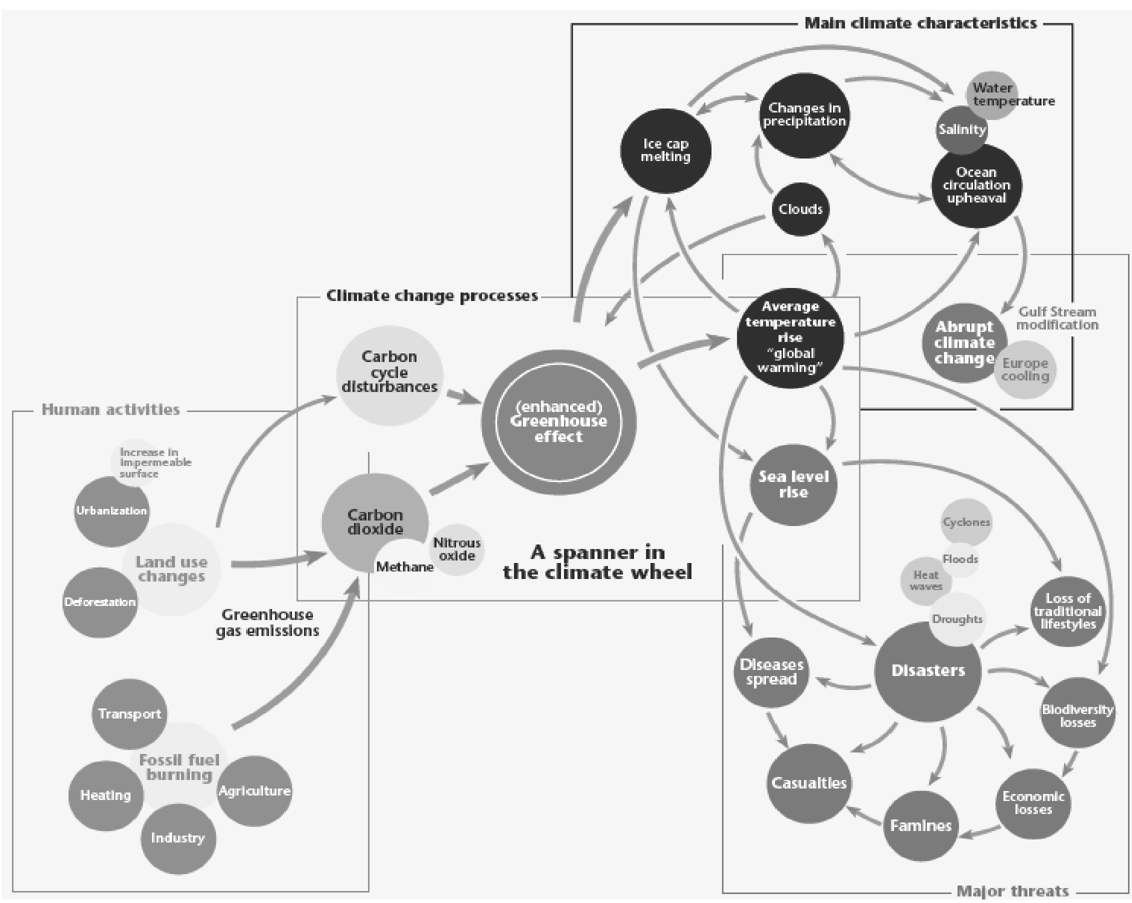

Figure 1: Water and Climate change processes, characteristics and threats[4]

due to the observed increase in greenhouse gas (GHG) concentrations from burning of fossil fuels and land use change (CSIRO, 2009; IPCC, 2008).

Water is the principal medium through which climate change will affect economic, social and environmental conditions (Fig. 1; UNESCO, 2009). The main impacts of climate change on humans and the environment occur through water.

If the current trend in fossil fuel consumption continues, it is estimated that Earth's temperature will rise by 5 degrees Celsius and sea level rise by 140 cm is plausible by 2100, with associated droughts, heat waves, floods and cyclones, causing for water utilities (CA, 2008).

- reduced freshwater supplies and increased customer demand for water
- increased algal blooms, taste, odour and toxicity in water
- higher incidence of bushfires, storms to impact water quality and infrastructure operation
- increase infrastructure failure from changed soil structure, stability and corrosion
- up to 34% increase in cost of supplying urban water supply (CSIRO Australia, 2007)[3]
- drought threatens water security, requiring costly water infrastructure projects such as $1.2 billion desalination plant in South- East Queensland to address current water supply problems
- increased evapotranspiration with associated increase in aridity and the severity of droughts
- increase in ground water salinity
- Reduced health of waterways due to lower environmental flows

Strategies and action to manage global warming and climate change are mitigation and adaptation. A fair and effective global agreement delivering deep cuts in emissions consistent with stabilizing concentrations of greenhouse gases at around 450 parts per million or lower would be in everyone's interests. Tackling climate change is the pro-growth strategy for the longer term, and it can be done in a way that does not cap the aspirations for growth of rich or poor countries. The Stern Review in 2006 concluded that by 2050 extreme weather could reduce global GDP by 1% and that, unabated climate change could cost the world at least 5% and up to more than 20% in GDP each year (Stern, 2007) . Economies that act earlier face lower long-term costs of around 15 per cent lower than with uniform international action (Australia, 2008; CA, 2008).

Water is both life and livelihood (Blue Gold) and is vital to economy, development, society and natural environment. In this paper, the process and calculation of GHG inventory, carbon footprint and carbon cost (applying the Australian Carbon Pollution Reduction Scheme (CPRS) framework), is described.

Meadow Town Water Supply (MTWS) facility

MTWS operates and manages the water supply for residential, commercial and industrial customers for around 41,000 population in the Meadow Town by carrying out the following activities (Fig. 2 and Table 1):

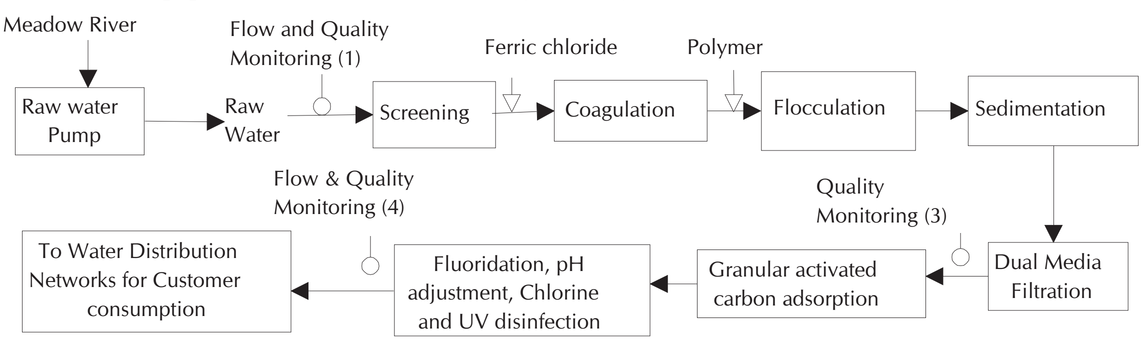

Figure 2: Meadow Town Water Supply Processes

Table 1: Controlling Corporation, Facilities and Identification of GHG Sources

Meadow town Water Supply	Corporation/Facility
60,000	Population
GE, F	Raw water transport from river
GE, F	Filtration
GE, F	Coagulation and Floculation
GE, F	Sedimentation
GE, F	Dissolve air floatation (DAF)
GE, F	Dual Media Filtration
GE, F	Fluoridation
GE, F	Granular activated carbon (GAC) adsorption
GE, F	Chlorine disinfection
GE, F	Dual media filter backwash wastewater treatment and disposal
GE, F	Potable water compliant Water Guidelines 2004 pumed to Reservoir
GE, F	DWQ quality and free chlorine monitoring in the distribution networks
GE, F	Rechlorination
GE, F	Potable water distribution to customers
F*	Transport fleet
GE, F	Offices, laboratory
GE, F*	Contractors

Note: GE: Grid electricity; **F**: Diesel for back-up generator; **F***: Liquid and gaseous fuel

1. extracts quality raw water from the Meadow River while complying with the environmental flow requirements of the river, which is monitored by the upstream river flow gauging station
2. carries out water treatment through screening, coagulation, flocculation, dissolved air floatation (DAF), sedimentation, dual media filtration, granular activated carbon (GAC) adsorption, chlorine disinfection, fluoridation and pH adjustment
3. treats dual media backwash and other process wastewater in the lagoon and discharges treated effluent into the Meadow River in compliance with the *Pollution Control Act*.
4. Measure, monitor, control and report drinking water quality (DWQ) in compliance with the World Health Organisation (WHO) and/ or the Australian Drinking Water Guidelines (ADWG) in Table 2 before pumping to the potable water reservoir for town water supply
5. Monitors and maintains total chlorine and minimum pressure of 20 meter head at customers' tap
6. Measure, monitor and control operation and instrumentation through Systems Control and Data Acquisition (SCADA) and Integrated Instrumentation and Control (IICATS)
7. Receives customer feedback, complaints relating drinking water supply; analyse data, identify root causes, take corrective and preventive action to address the issue or opportunities for improvement; and respond to customers in compliance with its Customer Service Policy, Charter and Protocol.

Scope of MTWS's Carbon Footprint Accounting (CFA)

For CFA, Scope 1 GHG emission (UNFCCC Category 1.A, 1B, 6) means emissions from fuel combusted, energy generated and used at MTWS facility site; Scope 2 GHG emission means energy produced by other corporation outside MTWS facility and used by MTWS; and Scope 3 GHG emission means GHG emissions that are generated in the wider economy as a consequence of a facility's activities but that are physically produced by another facility e.g. employees' business travels on a commercial airline.

For water utilities, 'production of energy' (Scope 1) normally means generation of renewable energy (gigajoule) from biogas cogeneration plants, hydro- electric plants, wind farm and solar panel and non- renewable energy from diesel generator for back up electricity supply.

For water utilities, 'consumption of energy' normally means use or disposal of energy) for operation of the facility (e.g. grid electricity for running motors, offices), transport fleet and losses in extraction, production and transmission.

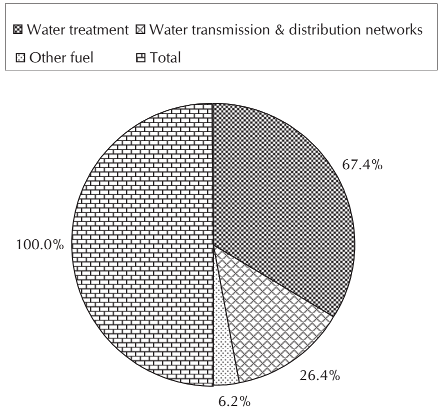

Figure 3: Energy demand for water treatment & networks (electricity) and transport & stationary (other fuel)

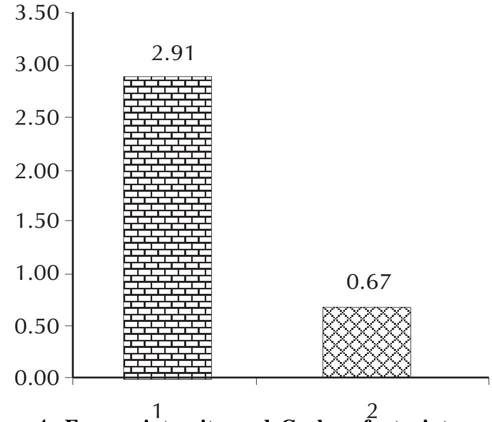

Figure 4: Energy intensity and Carbon footprint per ML water supply; 1 = Energy intensity, GJ/ML 2 = Carbon footprint, tonne CO_2-e/ML

For MTWS, the sources of GHG emissions are outlined in Table 1.

Exemption from CFA for MTWS

The following activities are exempted from the carbon footprint accounting (CFA) for MTWS:

1. All large infrastructure project contractors for MTWS that are independent corporations that hold full 'operational control over their activities including environmental, health and safety policies for MTWS projects.
2. Transporters, Handler and Processor for by- products for MTWS such as water treatment residual sludge, are independent private corporation
3. Scope 3 Emissions for MTWS such as processing of water treatment residual sludge, employees' business travels on a commercial airline

Table 2: MTWS's drinking water quality specification at customers' tap (Australian Drinking Water Guidelines (ADWG) 2004)

Characteristics	Health Guideline value (mg/L)	Characteristics	Aesthetic Guideline value
Microbiological quality		Other inorganic chemicals	
E. coli	0 Orgs/100mL	Aluminium (acid soluble)	0.02 mg/L
Disinfection agents and		Iron	0.03 mg/ L
inorganic by-products of disinfection			
Chlorine (Free)	5	Zinc	3 mg/L
Monochloramine	3	Physical characteristics	
Other inorganic chemicals		Turbidity	5 NTU
Antimony	0.003	pH	6.5 – 8.65
Cadmium	0.002	True colour	15 HU
Chromium (as Cr (VI))	0.05		
Cyanide	0.08		
Cooper	2		
Fluoride	0.9-1.5		
Lead	0.01		
Manganese	0.5		
Nitrate (as nitrate)	50		
Nitrite(as nitrite)	3		
Nickel	0.02		
Sulphate	500		
Organic disinfection by-products			
Trihalomethanes (total)	0.25		
Other organic compounds			
Acrylamide	0.0002		

Table 3: Process steps in preparing CFR

Step	Task	Explanation
1	Identifying key GHG sources	To focus effort, resources and priority for GHG sources that contributes most to the overall inventory or inventory uncertainty.1. Scope 2 grid electricity consumed 2. Scope 1 Fuel e.g. diesel, gasoline, E10, natural gas, LPG consumed
2	Determining appropriate GHG inventory estimation methodology	· Estimation methodology depends upon whether the source is 'key' or 'not key' and by data and resources available. · Tier 1 is the basic method (refer Table 2) · Tier 2 intermediate and Tier 3 most demanding in terms of complexity and data requirements. They are more accurate.
3	Data collection activities or Measurement and Monitoring (MandM) Program	· Focus on the collection of data needed to improve estimates of key GHG · establish and maintain good verification, documentation and checking procedures (QA/QC) to minimize errors · Develop comprehensive Annual Energy and GHG MandM program
4	GHG emission estimation	Emissions are estimated for GHG sources in Step 1 applying methodology chosen in Step 2
5	Estimation uncertainty and key GHG sources	Estimates of uncertainty are needed for all relevant source and sink categories, greenhouse gases, inventory totals and their trends.
6	Report inventory	Present the inventory in an as concise and clear way as possible to enable users to understand the data, methods and assumptions used in the inventory.

Table 4: CFR Parameters measurement and monitoring program (UNESCO, 2009)

Parameter	Unit	Minimum Frequency	Method (Example)
CO_2	mg/L	Continuous emission monitoring (CEM)	ISO 10396:2007 Stationary source emissions
N_2O	mg/L	CEM	ISO 11564:1998 Stationary source emissions
Gas velocity		CEM	ISO 14164:1999 Stationary source emissions.
CH_4 nitrogen	mg/L	CEM	US EPA Method 3C - Determination of carbon dioxide, methane, and oxygen from stationary sources (*i.e.,* landfills)
General testing for			ISO/IEC 17025:2005 General requirements for the competence of and calibration laboratories ISO 10012:2003 Measurement management systems- Requirements measurement processes and measuring equipment
Water flow	kL	Continuous	
Gaseous fuel (1 consumption	GJ or Nm^3 at a pressure of 101.323 kilopascals; and temperature of 15°C (Standard condition)		Indirect method- invoices and adjustment for financial year beginning Jul) and closing (30 Jun) stocks.
	Nm^3 at standard conditions		Direct measurement at point of consumption
Liquid fuels	Kilolitres (kL) at 15⁰C		Using bulk filling meters corrected to 15° C
Grid electricity consumption at facilities	GJ		Invoices or industry metering records.

Scientific methodology and legislative framework

In Australia, the *National Greenhouse and Energy Reporting Act 2007 (NGER Act;* Aus. Govt, 2007), NGER Regulation 2008 (Aus. Govt, 2007) and NGER (Measurement) Determination (MD) 2009 (NGER MD, 2009) provide the legal framework, technical guidelines and governance requirements for carbon footprint accounting.

For MTWS, Method 1 of the NGER MD 2009 for calculating GHG emission, energy consumption and energy production is applied, as MTWS does not carry out direct GHG emission monitoring and measurement from energy consumption.

Table 5: Carbon footprint calculation formulas for different energy sources (Aus. Govt, 2007)

Energy/ Fuel consumed	Energy content factor	Emission factor (Scope 1and 2), EF_i $(CO_2+CH_4+N_2O)$, Kg CO_2e/ GJ	GHG emission calculation formula
Gaseous fuels (i)			
Natural gas (pipeline) for stationary engine	39.3 X 10-3 GJ/m³	51.33	$Eij = \frac{Q_i \times EC_i \times EF_{ijoxec}}{1000}$
Natural gas (light duty transport)	39.3 X 10-3 GJ/m³	57.0	
Natural gas (heavy duty transport)	39.3 X 10-3 GJ/m³	53.6	E_{ij} is the GHG emission in CO_2-e ton type from each gaseous fuel type (i) in CO_2-e ton Q_i is the quantity of fuel type (i) combusted standard cubic metre, m³ or gigajoules. EC_i is the energy content factor (gigajoules per standard cubic metre) of fuel type (i)EF_{ijoxec} is the GHG emission factor (kilograms CO_2-e per gigajoule)
Liquid fuels			
Gasoline (stationary engine)	34.2 GJ/ kL	67.10	$Eij = \frac{Q_i \times EC_i \times EF_{ijoxec}}{1000}$
Gasoline (transport)	34.2 GJ/kl	66.92	
Diesel oil (stationary engine)	38.6 GJ/kl	69.50	E_{ij} is the GHG emission in CO_2 -e ton type from each liquid fuel type (i) in CO_2-e ton
Diesel oil (transport)	38.6 GJ/ kL	69.81	
Liquefied petroleum gas (stationary engine)	25.7 GJ/ kL	59.9	Q_i is the quantity (kilolitres, kL/ yr) of fuel type (i) combusted
Liquefied petroleum gas (transport)	26.2 GJ/ kL	60.2	EC_i is the energy content factor (gigajoules per kilolitre) of fuel type
Biodiesel (stationary engine)	34.6 GJ/ kL	0.26	(i)EF_{ij} is the GHG emission factor (kilograms CO_2-e per gigajoule)
Biodiesel (transport)	34.6 GJ/ kL	3.4	
Ethanol (stationary engine)	23.4 GJ/ kL	0.26	
Ethanol (transport)	23.4	3.4	
Grid electricity		089kg CO_2-e/kWh	Y = QXEF/100 Q = quantity of electricity purchased from the electricity grid during the year (kilowatt haur). EF - Scope 2 emission factor (kilogram CO_2-e emissions per kilowatt hour) = 0.89 kg CO_2-e/ kwh in South Australia

Carbon footprint accounting (CFA) principles

The following principles, at minimum, are applied for carbon footprint accounting for MTWS:

1. Transparency: There is sufficient and clear documentation such that individuals or groups other than the CFA compilers can understand and verify how the inventory was compiled.
2. Completeness: all identifiable GHG emission sources, energy production and consumption sources must be accounted for. Where elements are missing their absence should be clearly documented together with a justification for exclusion.
3. Consistency: Estimates for different inventory years, GHG emission sources, energy production and consumption categories are made using the same method and data sources in all years, as far as possible.
4. Comparability: GHG emissions, energy production and energy consumption is reported in a way that allows it to be compared with the CFA for another water utilities using the same method.

Table 6: Carbon footprint for Meadow Town Water Supply for research period

Average population in the MWS catchment for the research period	41,000	
Water supplied, ML	22,713	
Energy/ Emission	Energy consumption, GJ	Greenhouse gas emission, tonne CO_2-e
Scope 1		
Diesel (stationary engine)	1,006	69.9
Diesel (transport)	2,150	150.1
LPG (transport)	344	20.7
Gasoline: unleaded (transport)	2,586	173
Ethanol (as E10)	21	0.002
Scope 2		
Grid electricity in water treatment	43,068	10,647
Grid electricity in water transmission and distribution	16,843	4,168
Total (Scope 1 and Scope 2) energy consumption, GJ	66,018	
Total (Scope 1 and Scope 2) GHG emission, tonne CO_2-e		15,225
Energy intensity, GJ per ML drinking water supplied	2.9	
GHG emission intensity, tonne CO_2-e per ML drinking water supplied		0.67
Carbon cost $ per ML drinking water supplied @ $40/ tonne CO_2-e (refer Australian Government Carbon Pollution Reduction Scheme (CPRS) White Paper, 2008)	26.8	
Carbon cost as % of water usage price (@ $1,870/ ML drinking water in 2008-10)	1.4%	
Annual carbon footprint per capita for water supply, kg CO_2-e	90	
Annual carbon footprint cost $ per capita for water supply, kg CO_2-e	3.7	

5. Accuracy: Uncertainties in GHG emission, energy production and consumption must be minimised and any estimates must neither be over nor under estimates of the true values at a 95% confidence level.

Carbon footprint report preparation steps

To describe in simple terms, compilation of CFR is a six- step process as explained in Table 3.

Measurement and monitoring program for the CFR

Sampling, measurement and monitoring program and analytical methods for key CFA parameters is illustrated in Table 4.

Carbon Footprint or GHG inventory methodology

Meadow Town Water Supply consumes grid electricity, gaseous fuel (natural gas), liquid fuel (gasoline, diesel, LPG and ethanol). The energy content factor, Tier 1 GHG emission factor and the formula used to compile GHG inventory for MTWS is provided in Table 5.

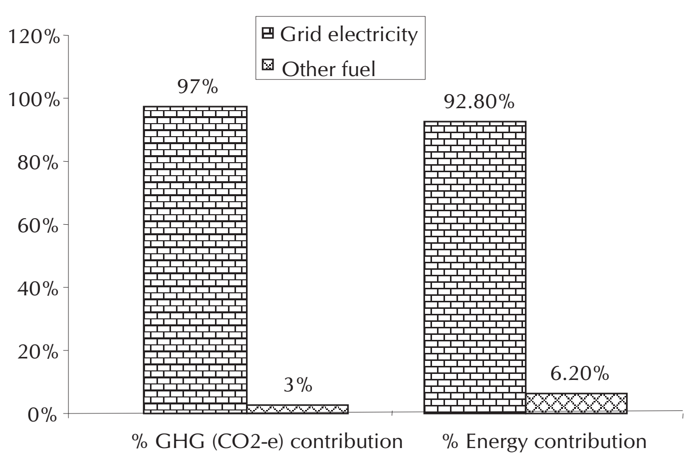

Figure 5: % Contribution to energy and Carbon emission of electricity and fuel

Analysis of carbon footprint for Meadow Town Water Supply

Over the research period (1 July 2003 to 30 June 2007), MTWS has consumed 66,018 GJ energy and emitted 4,169 tonne CO_2-e for supplying 22,713 ML potable drinking water to customers.

Grid electricity contributes 92.8% (water treatment 67.4%; transmission and distribution 26.4%) and other fossil fuels (diesel, LPG, gasoline and E10) of 6.2% in meeting total energy demand for MTWS of 43.068 GJ (Table 6, Fig. 3). Out of total grid electricity consumption of 59,911 GJ, water treatment incurs 72% and water transmission and distribution incurs remaining 28%.

Energy intensity and carbon footprint for water supplied by MWS are 2.91 G/ML and 0.67 tonne CO_2-e/ML (Table 6, Fig. 4).

Grid electricity contributes to 92.8% of energy demand and 97% of GHG emission. On the other hand, other fuels (diesel, gasoline, LPG and E10) contribute to 6.8% of energy demand and 3% of GHG emission (Fig. 5, Table 6). Therefore, there is scope for improvement in improving carbon footprint for MWS through alternate energy resourcing for MWS, such as biogas, natural gas, LPG.

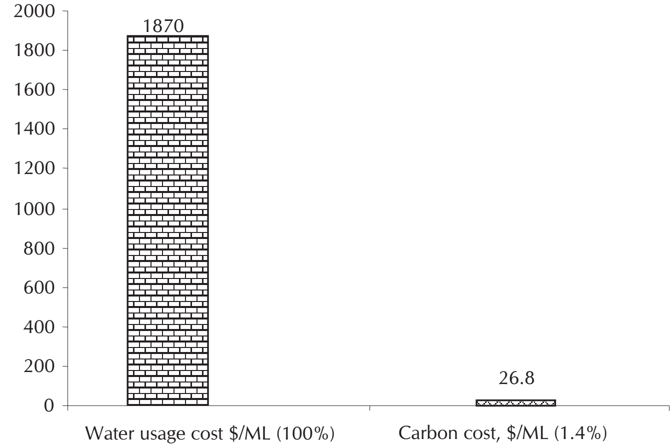

Figure 6: Water usage and Carbon cost for water supply to customer

Carbon pollution cost for MWS

The proposed carbon pollution reduction scheme (CPRS; CA, 2008) in Australia is a market- based cap and trade mechanism to reduce GHG emissions in the most cost- effective way. CPRS uses carbon pollution permit (CPP) as the measure of carbon footprint or greenhouse intensity of a process or activity. One CPP is equivalent to one tonne CO_2-e of GHG emission. CPP has personal property right with a unique identification number in the National Registry and are marked with the first year in which it can validly be surrendered (its 'vintage'). CPPs do not have an expiry date and are regulated as financial products for the purposes of the *Corporations Act 2001* and the *Australian Securities and Investments Commission Act 2001*, and normal GST rules applies to CPP transaction. CPRS obligations will not apply to emissions from combustion of biofuels and biogas for energy.

Under the CPRS, MWS shall require 3,806 CPPs annually. Considering a price cap of $40[5] per tonne CO_2e or CPP, annual carbon pollution cost for operating the Meadow Town Water Supply will be $152,250. Carbon pollution cost will increase the price of water by $26.8/ ML (1.4%) over and above the current water usage price of $1870/ ML (Fig. 6).

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