THE WATER-ENERGY NEXUS: A COMPREHENSIVE ANALYSIS IN THE CONTEXT OF NEW SOUTH WALES

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Certificate of Authorship/ Originality

I certify that the work in this thesis has not previously been submitted for a degree, nor has it been submitted as part of the requirements for a degree, except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Candidate

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Marsh, D. & Sharma, D. 2007, *A framework for assessing integrated water and energy management scenarios*, Proceedings of the International Conference on Adaptive and Integrated Water Management, Basel Switzerland (full peer reviewed)

Marsh, D. & Sharma, D. 2007, *Energy-water nexus: an integrated modelling approach*, International Energy Journal Vol 8, pp235-242 (full peer reviewed)

Marsh, D. & Sharma, D. 2006, *A framework to enhance the effectiveness of water management strategies*, Proceedings of the 3rd International Young Water Researchers Conference, Singapore (peer reviewed abstract)

Marsh, D. & Sharma, D. 2006, *Water-energy nexus: a review of existing models*, Proceedings of the 1st Australian Young Water Professionals Conference, Sydney Australia (peer reviewed abstract)

Marsh, D. & Sharma, D. 2005, *Water-energy nexus: identifying the issues*, Proceedings of the Environmental Research Event Conference, Hobart Australia (full peer reviewed)

Marsh, D. & Sharma, D. 2003, *Water industry reform: some performance issues*, Proceedings of the Global Developments in Water Industry Performance Benchmarking Conference, Perth Australia

List of Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics;
ABS	Australian Bureau of Statistics
AC	Alternating current
ACA	Australian Coal Association
ACCC	Australian Competition and Consumer Commission
AEMO	Australian Energy Market Operator
AES	Allen partial elasticity of substitution
AG	Agriculture
AGA	Australian Gas Association
ANCID	Australian National Committee on Irrigation and Drainage
ANZSIC	Australian and New Zealand Standard Industrial Classification
AP6	Asia-Pacific Partnership on Clean Development and Climate
AQAL	All quadrants all levels
AWEA	American Wind Energy Association
AWRC	Australian Water Resources Council
BIGCC	Biomass integrated gasification combined cycle
BMP	Basic metals & products
BRW	Bulk & retail water
BWR	Boiling water reactor
CAEP	Central Asian Energy Pool
CARE	Centre for Agricultural and Regional Economics, University of New England
CAS	Conventional activated sludge
(CC)GT	(Combined cycle) gas turbine
CF	Coal fired
CG	Cogeneration
CHEM	Chemicals
CHP	Combined heat and power
COAG	Council of Australian Governments
COAL	Coal mining
COD	Chemical oxygen demand
CONST	Construction
CoV	Coefficient of variation
CCSD	Cooperative Research Centre for Coal in Sustainable Development
CSG	Coal seam gas
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DC	Direct current
DECC	NSW Department of Environment and Climate Change
DEEP	Desalination Economic Evaluation Program
DESAL	Desalination
DLWC	NSW Department of Land and Water Conservation
DWE	NSW Department of Water and Energy

E	Employment
EEI	Energy efficiency improvement
ELCOM	Electricity Commission of NSW
EPA	Environment Protection Authority
EPRI	Electric Power Institute
ESAA	Energy Supply Association of Australia (previously Electricity Supply Association of Australia)
EU	European Union
FBT	Food, beverages & tobacco
FEMP	Federal Energy Management Program
FMP	Fabricated metal products
GAD	Government administration & defence
GAMS	General Algebraic Modelling System
GAS	Retail gas supply
GDP	Gross domestic product
GGAS	Greenhouse Gas Emissions Trading Scheme
GRIT	Generation of Regional Input-Output Tables
GT	Gas turbine
GWh	Gigawatt hour
HDR	Hot dry rock
HEC	Hydro-Electric Commission
HWR	Heavy water reactors
HYDRO	Hydropower
IAEA	International Atomic Energy Agency
IC	Internal combustion
ICT	Information, communication and technology
IDW	Irrigation & drainage water
IGCC	Integrated Gasification Combined Cycle
IMP	Integral Methodological Pluralism
IPART	Independent Pricing and Regulatory Tribunal
IPCC	Intergovernmental Panel on Climate Change
ISU	Instream Use
kL	Kilolitre
LCA	Life cycle assessment
LWR	Light water reactor
MBR	Membrane bioreactors
MCE	Ministerial Council on Energy
MES	Morishima elasticities of substitution
ML	Megalitre
MM	Miscellaneous manufacturing
MMS	Modular modelling system
MRET	Mandatory Renewable Energy Target
MWh	Megawatt hour
MWSDB	Metropolitan Water Sewerage and Drainage Board

N	Income
NCC	National Competition Council
NCP	National Competition Policy
NEC	National Electricity Code
NECA	National Electricity Code Administrator
NEM	National Electricity Market
NEMMCO	National Electricity Market Management Company
NETS	National Emissions Trading Scheme
NETT	National Emissions Trading Taskforce
NGMC	National Grid Management Council
NIEIR	National Institute of Economic and Industry Research
NMMP	Non-metallic mineral products
NSW	New South Wales
NWC	National Water Commission
NWI	National Water Initiative
O	Economic output
OCGT	Open cycle gas turbine
OCS	Other commercial services
OLS	Ordinary least square
OME	Other machinery & equipment
OMS	Other mining & services to mining
OR	Other renewables
OXY-CF	Oxygen fired pulverised fuel
PCP	Petroleum & coal products NEC
PE	Primary Energy
PFW	Produced formation water
PIU	Performance and Innovation Unit, Cabinet Office, UK Government
PJ	Petajoule
PR	Petroleum refining
PRS	Power reservoir system
PV	Photovoltaics
PWR	Pressurised water reactor
RAS	Rows and Sums
RECYCLE	Recycled water
RO	Reverse osmosis
RW	Raw Water
SBP	Supply based pricing
SBR	Sequencing batch reactor
SC	Supercritical
SEEG	Société d'Eau et d'Electricité du Gabon
SEW	Sewerage
TCFL	Textile, clothing, footwear & leather
TE	Transport equipment
TGET	Task Group on Emissions Trading
TS	Transport & storage

UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USC	Ultrasupercritical
USAID	U.S. Agency for International Development
VFP	Voluntary fallowing program
WEST	Water-Energy Sustainability Tool
WPP	Wood, paper & printing products
WRT	Wholesale & retail trade
WSAA	Water Services Association of Australia

Abstract

Water and electricity are fundamentally linked. Policy reforms in both industries, however, do not appear to acknowledge the links nor consider their wider implications. This is clearly unhelpful, particularly as policy makers attempt to develop effective responses to water and energy issues, underpinned by prevailing drought conditions and impending climate change. Against this backdrop, this research has comprehensively analysed the links between water and electricity – termed water-energy nexus – in the context of New South Wales. For this purpose, this research has developed an integrated methodological framework. The philosophical guidance for the development of this framework is provided by Integral Theory, and its analytical foundations rest on a suite of research methods including historical analysis, input-output analysis, analysis of price elasticities, and long-term scenario analysis.

This research suggests that the historical and inextricable links between water and electricity, in the absence of integrated policies, has given rise to water-energy trade-offs. In the electricity industry, water-intensive coal-fired power stations that dominate base-load capacity in the National Electricity Market has resulted in intra- and inter-jurisdictional water sharing trade-offs. Intermediate and peak demand technologies, suchas gas-fired, cogeneration and renewables, however, would significantly reduce the industry's water consumption and carbon emissions. Drought and climate change adaptation responses in the water industry are likely to further increase electricity demand andpotentially contribute to climate change, due to policies that encourage investment in energy-intensive technologies, such as desalination, advanced wastewater treatment and rainwater tanks. Increasing electricity costs due to water shortages and the introduction of emissions trading will futher increase water and electricity prices for end users. Demand management strategies in both industries will assist in curbing price increases, however, their effectiveness is lessened by investment in water- and energy-intensive technologies in both industries.

The analysis also demonstrates that strategies to reduce water and electricity consumption of 'other' production sectors in New South Wales is overwhelmingly dependent on how deeply a particular sector is embedded in the economy, in terms of its contribution to economic output, income generation and employment growth. Regulation, demand management programs, and water pricing policies, for example, that reduce the water and energy intensity of agriculture and key manufacturing sectors are likely to benefit the wider economy and the Environment.

The future implications of the water-energy nexus are examined through long-term scenario analysis for New South Wales for 2031. The analysis demonstrates how policy decisions shape the domain for making philosophical choices by society - in terms of the balance between relying on alternative technologies and market arrangements, with differing implications for water and electricity use, and for instigating behavioural change. Based on these findings, this research puts forward a range of recommendations, essentially arguing for reorienting existing institutional arrangements, government measures and industry activities in a way that would encourage integration between the water and energy policies.

Although the context of this research is New South Wales, the findings are equally relevant for other Australian states, which share the same national water and energy policy frameworks. Further, the concepts and frameworks developed in this research are also of value to other countries and regions that are faced with the task of designing appropriate policy responses to redress their water and energy challenges.