Water energy and food nexus, securing the future needs of Adelaide, South Australia.

By

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SUMMARY

Water energy and food (WEF) demand is set to grow considerably in the future and need for integration in this sector is critical because they are all interlinked. This study is to investigate Adelaide's residential water, energy and food consumptions to find future demand in WEF through efficient water management, sustainable energy use and dynamic food utilisation.

Adelaide's water supply is dependent on River Murray allocation, limited supplies, drought, and below average rainfall due to global climate change which brought competition for resources. In order to maximise our efficiency in using the limited resources, we need to understand the links within the WEF sector.

This study finds the city dwellers will drive the demand in WEF resources. To meet the growing needs of the city's population, available water needs to be used efficiently, energy use should be effective and dietary change towards less water intense food will reduce water and energy resource needs.

Demand for water energy and food is growing steadily, with constraints in availability over-exploitation of natural resources will eventually lead to resource depletion: global climate change is curtailing optimum utilisation of the energy.

WEF nexus policy should focus more towards integrated approach in securing future water needs, through efficient water management, sustainable energy usage and disciplined food utilisation, to form a synergy in a sheltered plan, critical for a sustainable future. Depleted natural resource will lead to scarcity; resulting in inflated water and energy price, food shortages and hyped power supply.

Key finding in this study is that the urban population are using potable water for outdoor use; there is energy wastage through inefficient appliances and water demand through over consumption of food and wastages has grown to an unsustainable level. Adelaide city's future WEF needs can be secured through a combined approach in water energy and food alliance. These are interrelated and complex: change in one sector will be felt across the other. The effect can be local, regional or transnational. This complex and dynamic issue needs an integrated nexus approach.

Overall, this research provides insight into city scale WEF management. Results indicate the need for the conservation arrangements, and formulation of a strategic plan and policy to reduce anticipated resource shortages in the near future.

DECLARATION

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Signed...

Dated: 8th June 2020

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LIST OF ABBREVATIONS

ABS	Australian Bureau of Statistics.
AEMO	Australian Energy Market Operator.
AER	Australian Energy Regulator.
CPI	Consumer Price Index.
DAWE	Department of Agriculture Water and Energy.
ESRI GIS	Environmental Systems Research Institute – Geographic Information System.
GHG	Green House Gas.
FSC	Food Supply Chain.
LSA	Life Cycle Assessment.
NEM	National Electricity Market.
SA	South Australia.
UNDP	United Nations Development Programme.
WEF	Water Energy Food.
WHO	World Health Organisation.

Chapter 1: Introduction

The Water Energy and Food (WEF) nexus concept has emerged as a phenomenon ever since United Nation initiated Sustainable Development Goal towards good health and well-being, declaring clean water, affordable clean energy and cost-effective nutritious food as necessity UNDP (2020). As Figure 1 shows, global climate change affecting social life, and population growth coupled with urban expansion, poses risk as competition for limited resource presents great challenges, due to the complexity of inter connection with in the sector (Aiko et al. 2015).

The rapid growth among emerging economies around the world is forcing rural inhabitants to migrate to urban areas to find jobs. As people migrate and settle in cities, demand for water, energy and food increases, putting more pressure on dwindling natural resources, therefore a degree of urgency is required to secure future WEF demands. Experts have predicted WEF demand is likely to escalate by 40 %, 50 % and 70 % respectively by 2030, causing food and water shortages. In addition energy consumption poses great challenges which should create a heightened focus by governments across the world and by the academic community (Zhang et al. 2019).

Adelaide is a growing cosmopolitan city consisting of more than 1.29 million people according to ABS census data (2018). Worldwide of 7.594 billion population, nearly 55.3 % live in urban dwellings and within a decade, nearly 60 % of the entire population will live in the cities. By 2030 there will be 550 cities with a million people or more living in urban centres, an increase of 67 % in 18 years. According to the United Nations report on World Cities (2018) there is also a big increase in megacity’s where population of more than 10 million people live.

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Figure 1: WEF frame work and key drivers. Source: (Aiko et al. 2015).

In order to meet the food demands of the rapidly increasing population, and with limited agricultural land to exploit, the available water resource is not sufficient, especially with global climate change curtailing optimum utilisation of the energy, it is therefore critical to have a secure plan and frame work for a growing city like Adelaide (Finley & Seiber 2014). WEF sector efficiency is linked with other sectors (Figure 2), integration through resilience, trade-off and synergy is critical. Energy is required to transport water, water is needed to produce energy and both water and energy is necessary to produce food, extensive change in one sector will impact the other, (Figure 1).

In regard to over exploitation of existing natural resources, it is widely accepted by experts, that faced with scarcity and disaster, a strategic and decisive long-term plan to manage and extend the life span of the existing natural resource is essential. It is a matter of time before it is realised that the strenuous task of dealing with the adversity is arduous, demand for water is increasing by the day, nature cannot meet the demands, either you face severe shortage or completely runout of the resource (Adnan 2013).

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Figure 2: WEF integration and link. Source: (Aiko et al. 2015).

Sao Paulo, one of the most populated south-eastern region of Brazil with an estimated population of 6.5 million, is faced severe water shortage in 2015. Cantareira reservoir, which supplies water to Sao Paulo city, was at an all-time low of 50 % capacity, with an extended drought, less than average rainfall, reduced water inflow and subsequent mismanagement of the water distribution. This forced the government to take drastic measures which includes water restrictions, and imposing fines on those who are drawing more water than previous years consumption (Scruggs 2015). Sao Paulo's situations should ring alarm bells to the rest of the world to foresee the disaster ahead and initiate a necessary proactive governance structure, policy initiatives, infrastructure investment, and capacity building through integrated water management system. To secure water for Adelaide's future, which should be the utmost priority, the city should learn from this example.

Case study: Detroit, Michigan (United States of America)

Detroit an industrial town in the State of Michigan, USA developed innovative WEF nexus by creating a community farm in a state-owned public place called D-Town. They established a water catchment network to be used for producing food in urban farm, generating compost from farm waste, using energy from solar power for pumping rain water, advocating food justice through food co- operative centre among the community, thus reducing the overall WEF footprint. Earth Works an urban farm, grows organic produce in its less than three-acre area, by collecting rain water from roof top gutters in its greenhouse farm (hoop house), using solar power for pumping water to irrigate the farm and produce is distributed to the local community. In both cases WEF footprint is reduced and an integrated approach is practiced. Larger benefits include low environmental impact, quality food production, and low resource use. This exhibits resilience and innovation by the Detroit community (Treemore-Spears et al. 2016) which can be replicated at an urban scale in Adelaide.

1.1. Australian Context

Australia is one of the most urbanised countries in the world, two thirds of the population live in cities: 75 % of the population in SA live in Adelaide. City dwellers will drive the WEF demand within a metropolitan city. Households made up of individual people are the building blocks, they are the second largest consumers of potable water in SA, third largest in energy consumption nationally and the main driver of food production, hence understanding water related energy use and food consumption, what type of food they eat, how much money they spend, their water and energy footprint in food production, are the key aspects to understand.

Australia has incurred the knock-on effect of climate change either by alteration or by naturally occurring phenomenon. The predicted increase in average temperature of between 0.3^0 to 1.0^0 centigrade by 2030 and between 0.6^0 to 2.5^0 centigrade by 2050 will follow extended drought, decrease in rainfall and unreliable rain events, leading to flooding and storm, increase in frequency of heat waves (Figure 3): such extreme weather events are cause for concern (Howe et al. 2005).

Infrastructure development in water related activity linking to mitigate climate change impacts is massive, particularly in water and energy nearly $2 billion worth of water relevant infrastructure was invested in Australia, focussing on metropolitan cities between 2006 and 2007: this amounts to the money spent in the past 100 years. The governments proposed $30 billion for the next 10 years to boost energy efficient climate adaptable supplies (Kenway et al. 2011), a resilient and efficient synergy is critical for WEF approach at the city scale in Adelaide.

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Figure 3: Average temperature in Australia for a century. Source: Bureau of Meteorology (2016).

1.2. Adelaide’s population

The greater Adelaide metropolitan area, with an estimated 1.33 million population (Table 1), live in an area covering 3200 square kilometres, about three quarters of the entire South Australian population live in metropolitan areas. Adelaide, which is the fifth most populous city in Australia, is situated between the Mount Lofty Ranges and the Gulf of St Vincent (Figure 4). The research area comprises five regions of Adelaide including inner metro. The state population is increasing by 1 % annually with 90 % of the growth in the capital city, and is expected to reach 1.72 million by 2040 from the current 1.37 million (Table 1). School age children 5-17 years, are set to rise from 290,000 at medium series increase, with the high series increase at 334,000 by 2041 as projected by The Department of Planning Transport and Infrastructure (2019). Leading industries are manufacturing, construction, defence, food and wine, water management, education and retail.

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Figure 4: Research location, Adelaide metropolitan area. Source: Department of planning, transport and infrastructure, Government of SA (2019).

Table 1: Adelaide population projection 2016 - 40. Source: Department of planning, transport and infrastructure, Government of SA (2019).

	Population projection for 30 June . . .				
Region	2016	2017	2018	2019	2020
Inner Metro PPR	224454	225901	227455	229283	231476
Adelaide - North PPR	429924	434364	439640	445552	452117
Adelaide - South PPR	362685	364898	367452	370345	373676
Adelaide - West PPR	233831	234988	236772	238893	241548
Adelaide Hills PPR	73164	73758	74374	75073	75820
Adelaide metro (Total)	1324058	1333909	1345693	1359146	1374637
	Population projection for 30 June . . .				
Region	2021	2022	2023	2024	2025
Inner Metro PPR	233928	236554	239374	242194	245007
Adelaide - North PPR	458939	465848	472870	479883	486883
Adelaide - South PPR	377260	380956	384767	388589	392415
Adelaide - West PPR	244483	247598	250810	254111	257496
Adelaide Hills PPR	76617	77434	78272	79119	79975
Adelaide metro (Total)	1391227	1408390	1426093	1443896	1461776
	Population projection for 30 June . . .				
Region	2026	2027	2028	2029	2030
Inner Metro PPR	247802	250690	253660	256715	259849
Adelaide - North PPR	493868	500837	507789	514724	521639
Adelaide - South PPR	396241	399965	403580	407075	410444
Adelaide - West PPR	260957	264472	268034	271637	275276
Adelaide Hills PPR	80838	81709	82587	83469	84354
Adelaide metro (Total)	1479706	1497673	1515650	1533620	1551562
	Population projection for 30 June . . .				
Region	2031	2032	2033	2034	2035
Inner Metro PPR	263070	266370	269746	273201	276737
Adelaide - North PPR	528532	535402	542252	549085	555902
Adelaide - South PPR	413675	416761	419699	422490	425131
Adelaide - West PPR	278946	282645	286370	290116	293885
Adelaide Hills PPR	85242	86132	87022	87914	88806
Adelaide metro (Total)	1569465	1587310	1605089	1622806	1640461
	Population projection for 30 June . . .				
Region	2036	2037	2038	2039	2040
Inner Metro PPR	280360	284067	287865	291756	295743
Adelaide - North PPR	562701	569486	576261	583031	589797
Adelaide - South PPR	427625	429972	432175	434236	436158
Adelaide - West PPR	297676	301492	305335	309204	313103
Adelaide Hills PPR	89699	90592	91487	92385	93285
Adelaide metro (Total)	1658061	1675609	1693123	1710612	1728086
Source: Department of planning, transport and infrastructure, Government of SA, 2019					

1.3. Research questions and objective

This study aims to answer questions related to complexity in the nexus approach. Understanding and developing integration in WEF structure will facilitate in securing the needs to a sustainable level for the future of Adelaide. We will discuss multiple key drivers which interfere in precluding a sustainable future.

Will quantifying the water related wastage in households and adopting towards water efficient smart appliances, utilising rain and recycled water, influence the outcome? What about the energy consumption for water distribution in cities and waste water recycling process? Will linking synergies in these sectors and management of water related energy use, scale down water dependence? How much food is produced and consumed in South Australia? And what kind of food is produced? How it is produced, packaged, transported and eventually sold to the end user. What impact does it has on environment? How much natural resource like water, human and financial resource does it require? How to prolong the future demand? It is a complex and complicated issue to deal with. The biggest problem the nations with growing economies and suppliers of products to these economies like Adelaide face, is the susceptibility in the near future as growth in urban population sets in. Having enormous disposable wealth to spend, stake holders' dietary patterns are changing, causing a slight disparity which will have repercussions on food supply and demand. Adelaide particularly will face ramifications.

In this study an effective use of water and conservation regime, challenges in synergies, key driving factors, methods to reduce consumption and trade-off are discussed in chapter 2. Efficient energy use, energy conservation and strategies to reduce dependency, developing synergies with the water and food sector is discussed in chapter 3. Demand management in food, social behaviour towards diet, economic, health and biodiversity impact, conservation, challenges in the nexus approach and uncertainties are discussed in chapter 4.

Lack of quantitative information related to the virtual water footprint in food production limited the outcome for a definitive elucidation. However, inter linking issues pertaining to water and energy is critical. The Primary objective of this study is to understand the use of water and energy, both internal and external driving factors as variables, highlighting specifics on stake holders' issues which are detrimental for the outcome and decreases susceptibility by optimising the linkage in WEF sectors in Adelaide.

1.4. Research Methodology

This study uses qualitative and quantitative analysis of data pertaining to WEF consumption and usage, establishing an interdisciplinary approach through WEF literature, using key words “water energy food nexus”, specific attention is given to limiting it to city scale.

The following methods were used.

- Scientific research database consisting of both peer reviewed as well as non-peer reviewed journal articles as primary source from Google Scholar, Flinders University library database, ScienceDirect, Web of Science, PubMed, ProQuest and Scopus.
- Key focus emphasis on inter connection between water and energy, strength and weakness of the pathway, statistical data pertaining to suburban food consumption are analysed.
- Australian food imports and consumer spending data were obtained from the Australian Bureau of Statistics, water usage data obtained from SA water.
- Energy generation and forecast data were obtained from AEMO, emphasis was on published articles on the city scale nexus with focus on population similar to Adelaide metropolitan area are compared.
- Overview of present food consumption through spending on eight major foods, historical and future trends, analysis of export and import data for the forecast. Calculation for water footprint in food production was obtained from literature (Mekonnen & Hoekstra, 2011b) and energy footprints for food production is obtained from (Mekonnen et al. 2015), food spending data was from the ABS.
- The WEF footprint was obtained through multiple government source and literature values incorporating both quantitative and qualitative data analysis: a multidisciplinary integrated approach encircled by demand management was used.
- Lack of quantitative information related to virtual water footprint in food production limited the outcome for a definitive conclusion. However, inter linking issues pertaining to water and energy is critical.

CHAPTER 2: WATER

2.1. Introduction

An over view of the present scenarios in Adelaide water consumption in the last years 10 years shows a consistent increase of 5 % per year (Figure 5), but receives annual precipitation of only 536 mm, limiting ground water recharge, Adelaide city's residential water is mainly sourced from River Murray allocation (82.95 %), SA Water provides water to residences, business and agriculture sector through pipe lines spanning across Mannum to Adelaide stretching across 60 Km in length. Sewage water is collected across Adelaide population through extensive network of 8700 Km pipe lines. It is processed at three major waste water treatment plant: Bolivar, Glenelg and Christies beach. The rest of the water for SA household is sourced from surface, ground and sea water through desalination according to The Department of Environment and Water (2019).

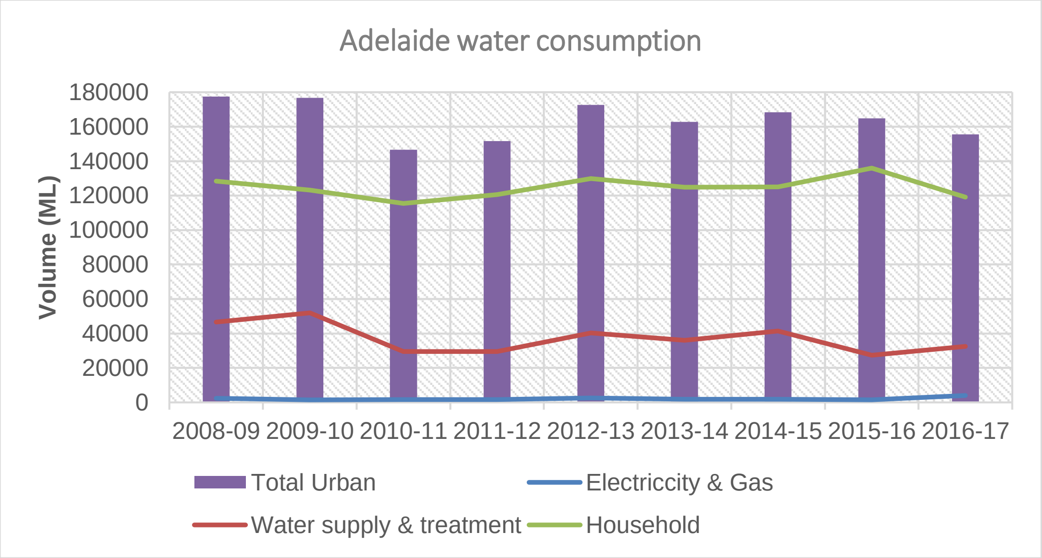

Figure 5: Adelaide water consumption trend. Graph generated from ABS (2017).

2.2. Methods to reduce water and results

South Australian households are the second highest users of the water allocated from River Murray, next only to agriculture at 135 GL in the year 2015-16, (Figure 6) which makes up nearly 13 % of the total allocated water for sector wise consumption. According to the EPA data (2018),17 % is used at sporting facilities, religious places, parklands, and open frontages.

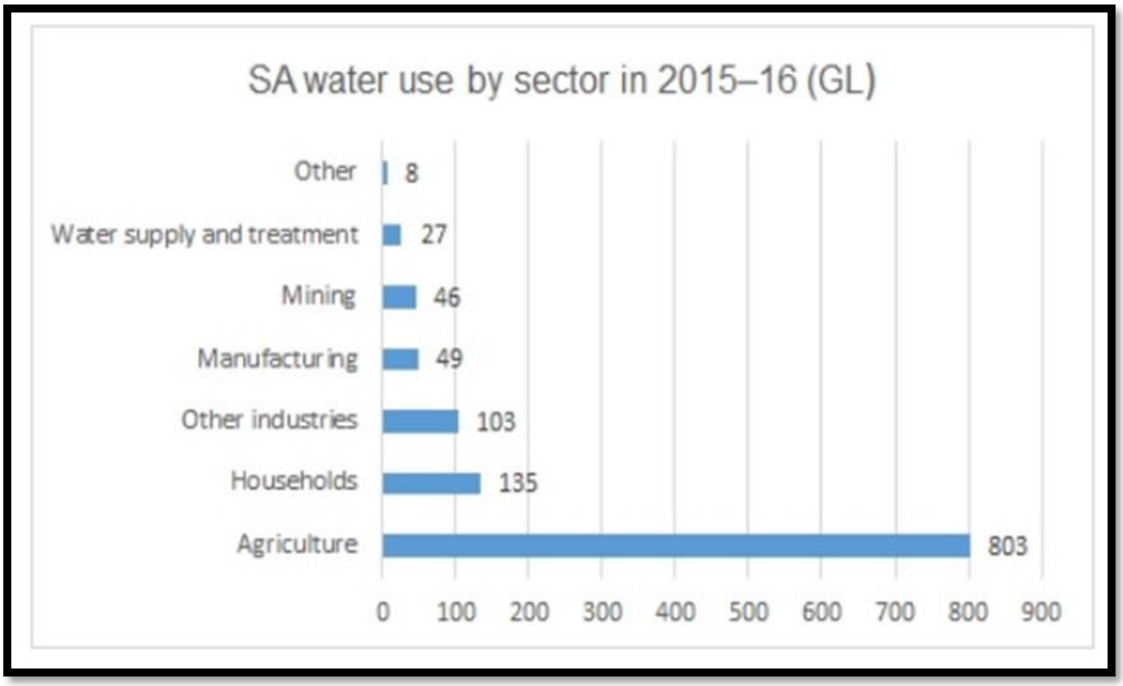

Figure 6: South Australian water use by sector. ABS (2017).

A comprehensive study to measure volume of indoor water used by households comprising 65 % of the Adelaide population by Goyder institute for water research spanning 15 months, starting from October 2012, concluded in March 2014 (Figure 7). Households were fitted with high resolution meters to identify general populations behaviour towards water usage. The study reveals that on average water used by the household is estimated at around 289 L/day in the year 2013 – 14. When this is broken down into the specific area of usage 48 L/day is used for showering, 28 L/day for toilets, washing machine 25 L/day, and for tap usage of 29 L/day which constitutes to 21 % a day (Arbon et al. 2014).

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Figure 7: Average water use per person in Adelaide. Source: (Arbon et al.2014).

According to the latest SA water data, most households use 40 % of their water outdoors accounting for more than 90,000 litres a year to water their garden according to the City of Norwood, Payneham and St Peters council (2019). Residential water use continues to raise in Adelaide (Figure 8), conservation through effective utilisation of rainwater outdoors and for gardening will reduce dependence on potable water supplied by the SA water network. Use of trigger nozzle activated hoses, drip feed irrigation methods, cleaning motor vehicles and fishing boats at commercial cleaning facilities where reclaimed water is efficiently recycled by automated cleaning systems will conserve water (Bawden 2009).

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Figure 8: Household demand per day in Adelaide. Source: (Bawden, 2009).

To conserve water for long term security of Adelaide it is essential to understand the household water usage and end user attitude: 11 % savings per year can be attained through various conservation techniques to resolve water issues to some extent for a water deprived city like Adelaide.

An estimation of minimum water savings.

1. Smart appliances & utility - 87 K litres (SA Water fact sheet)
2. Rain water usage - 95 KL litres (City of Norwood, Payneham and St Peters council (2019).
   Total population in Norwood, Payneham & St Peters = 37496 in 2016-17
   Savings per person - 95000/37496
   2.53 litres × 1324058 (Adelaide population served in 2016-17)
   = 3349KL
3. Storm water usage - 18000 ML Department for Environment Water (2017).
4. Leak & faulty equipment - 20 K litres, SA Water (2019)
   Total savings - 18003.35 ML or 15.11 %

Total water supplied to households = 119112 ML (2016-17)

= 18003.35/119112*100

= 15.11 %

Implementing and improving infrastructure throughout Adelaide city will potentially save up to 15 % water. However, a larger scale comprehensive cost and benefit analysis will provide monetary benefit. Population increase, exponential growth and inefficiencies continues to put squeeze on water supply.

2.3. Discussion.

Residential water uses and end user behaviour is critical for integrating city scale water management. By identifying key drivers future demand can be predicted and conservation techniques can be implemented (Cuddy et al. 2014), which are discussed below.

Efficient fixture and appliances.

Inefficient appliances are costing precious resource wastage: nearly 20,000 litres of water is wasted every year due to faulty and leaking plumbing related issues including toilet cistern leakage, estimated at 95,000 litre a year. According to the SA Water best practice fact sheet a modern four-star dual flush toilet can save up to 11Kl/year per person which often overlooked. In addition to replacing shower head and tap in business communities and public amenities where 40 % of the water is used for toilets, showering and washing, a saving of 1100 Kl a year (Table 1), can be achieved every year according to SA Water (2019).

Table 1: Water savings through smart appliances. Source: SA Water (2019).

Appliance type	Best practice flow rate	Non water Saving fixture	Water savings/person (kl/year)	Water savings($/person/year)
Toilet	4.5/3 dual flush (avg 3.3l/flush)	11 L/flush	11	$36.52
Hand Basin	4.5 L/min	18 L/min	20	$66.40
Shower (10min)	7 L/minute	18 L/min	40	$132.80
Shower (4 min)		18 L/min	16	$53.12

**calculation of water cost is based on 2014/15 second tier commercial water pricing of $3.32 per KL*

According to the government source water efficient appliances will save up to $2 billion dollars in 10 years, saving of $175 dollar per household in a year according to Department of Agriculture Water and Energy (2020). A modern day washing machine will save up to 50 litre of water per load, uses less detergent and energy compared to the older washing machines: an appropriate water level-based load, employing washed water for flushing the toilet and gardening will reduce the demand for potable water considerably (Bawden 2009).

Water sensitive gardens and land scaping.

Understanding the soil conditions in gardens will reduces water consumption. Knowledge of the local ecosystem, and stages of plant growth, will help the end users make choices in choosing plants which can tolerate extended draught conditions. In a city like Adelaide, a dry and arid place with annual precipitation of under 600 mm, moisture retention through organic soil conditioners, using clay-based soil additions like Kaolin and Bentonite, will help in retaining the moisture and will reduce water requirements for plant substantially: these key measures will reduce water wastage. Excessive watering, damaged pipes, faulty sprinklers, insensitive plant selection are some possible preventive actions which can be effectively adopted according to Water Corporation (2013).

Rain water harvesting.

Harvesting rain water for domestic purposes substantially reduces dependency on mains water (Figure 9), thus reducing water and energy bill. It also promotes the use of untreated water for drinking purpose, it is estimated that one in four people in Australia use rain water for drinking, and irrigating their gardens. Different states have various incentive schemes to encourage households to adopt to their needs. Rain water can supplement bore water to grow crops and vegetables. Chemical addition to remove pathogens will leave behind some protozoa and bacteria in the treated water, whereas rain water is consumed untreated with no presence of chemicals. As an environmental impact there is added benefit in reducing less dependency on mains water and in addition gardens are better off with rain water than mains water according to rain water harvesting guide (Combes, 2018).

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Figure 9: Annual water savings in Adelaide. Source: (Combes, 2018).

Storm water usage

South Australia experiences a volatile weather pattern, decline in rainfall due to climate change resulting in a 15 % to 30 % decrease. Extreme weather events like flooding, and extended draught would affect overall quantity and quality of water according to the Local Government Agency Strom Water Management (2018).

An experimental study has shown estimated savings of up to 6 GL per annum at the moment and an addition of 12 GL per annum can be saved, if government-initiated a good water strategy. This would need to be effectively put in place utilising storm water for watering gardens at public places, flushing toilets and storm water irrigation which will potentially save around 30 GL by 2025 according to water for good, an initiative from Government of South Australia (2010).

Residential water use continues to rise in Adelaide from 139 GL in 2009 to 152 GL in 2015. Experimental study showed savings of up to 30 GL can be attained, which can be utilised in energy sector to form a synergy.

CHAPTER 3: ENERGY

3.1. Introduction.

Energy demand in the last three decade among households has increased from 299 petajoules (PJ) to 467 PJ by the end of 2020 as residential occupants increased from 6 million to 10 million in Australia, similar trend continued in South Australia where residential energy soured from 25.4 PJ in 1990 to 29.9 PJ in 2019, a 15 % increase in less than three decades (Figure 13). Per capita consumption of 17 gigajoules (GJ) per year in 1990 increased to 20 GJ by 2020, an increase of almost 18 % (Harrington & Foster 2008).

Energy demand in urban sectors is growing at an increased pace. residential sector is the third largest consumer using 12 % of the energy. Energy use by water sectors is expected to grow by 200 % by 2030, increased energy use will inflate cost: households and water providers are the building blocks who drive the demand. One third of the total energy in Australia is used in water related industries (Kenway 2012). Energy demand has resulted in inflating the cost of electricity by 72 % and gas by 54% nationally, and with a 41 % overall increase in Adelaide (Swoboda 2014).

Water is an indispensable part of electricity generation and energy is essential to transport potable water, raw water treatment and energy is also required for water distribution. It is estimated that 7 % of the world energy is utilised in water providing companies: integration of both energy and water sectors is paramount (Retamal et al. 2009). Population increase and exponential growth has compounded the issue, we need to analyse the use of energy among households and water providers in Adelaide to understand the dynamics associated for a potential synergy and trade off to reduce dependency at the city scale.

3.2. Strategies for energy use and reduction.

Analysis of energy for residential sector for five years.

Table 2: Energy use by water suppliers for Adelaide. Source: (Cook, Hall & Gregory 2012).

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Energy for water distribution

A comprehensive study by the CSIRO involving major cities in Australia has provided an insight into energy consumption for years 2009-10 (Cook, Hall & Gregory 2012). Data were collected from participating utility companies across cities with the Adelaide data provided by SA water, the sole supplier of water to the entire state. The study area is limited to Adelaide metropolitan area. The energy data were obtained from the Australian Government, Department of the Environment and Energy: annual energy generation data for SA, was obtained from the Australian Energy Monitoring Organization (AEMO).

Desktop energy calculation for residence based on 2009-10 data (Cook, Hall & Gregory 2012)

Total water supplied (2009-10) = 139 GL

Energy for water supply & pumping = 336,363 GJ

Energy for 1GL = 336,363 GJ/139 GL

= 2419.88 GJ

Water supplied for subsequent year- Data obtained from ABS Water account, Australia (2017)

Energy required for water supply and pumping for one GL.

2013-14	2014-15	2015-16	2016-17
141.79 GL	145.36	152.00	135.85
141.79*2419.88	145.36*2419.88	152.10*2419.88	135.85*2419.88
343114.78 GJ	351753.75 GJ	367821.76 GJ	328740.69GJ

Water per capita for Adelaide: 2009 -10

Total volume supplied/ population served	Per capita consumption
139 GL / 1136156	(139*1000ML*1000000L/1136156)/365
Per Capita consumption -	335.18 Litres

Energy consumption for water related activity occurs at different stages of distribution, treatment, pumping, extraction and waste water treatment, consumption is dependent on length of distribution network, geological condition and infrastructure, potable water for Adelaide city comes from river Murray near Mannum, energy use is higher than Eastern States.

State initiative in infrastructure investment on wind energy has largely reduced gas-based energy generation by 2 %: considerable progress has materialised in the form of complete abrogation of coal powered electricity generation in South Australia, replaced by 31.3 % wind, 20.3 % solar energy respectively since 2010 (Table 3) (AEMO, NEM 2020). 34 % of the residents in SA contribute energy in the form of Photovoltaic (PV) energy an increase of 20.1 % in a year (Figure 10) (AEMO, NEM 2020).

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Figure 10: South Australian energy production. Source: (AEMO, NEM 2020).

Table 3: South Australian renewable energy generation. Source: (AEMO, NEM 2020).

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3.3. Discussion

Energy use by households.

Energy utilisation in Australia is growing at 2 % annually. In South Australia energy use increased by 15 % in three decades with household use constituting more than 26 % in the year 2009-10. A recent study in Adelaide and Melbourne revealed energy consumption directly corresponds to characteristics of the household and dwelling size. Older houses require more energy to heat/cool space, efficient modern appliances with low energy ratings will reduce dependence. Australian homes use 34 % of energy for space heating and 19 % for water heating (Figure 11). Adelaide's arid climatic conditions and geographic location require more energy compared with other Australian cities (Han & Karuppannan 2016). Energy demand for space heating can be reduced by investing in thermal efficiency of the dwellings. Capital investment through incentives and stringent thermal building standards for new buildings will reduce the long-term demand and GHG substantially (Morrissey et al. 2013).

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Figure 11: Household energy consumption in Australia (Han & Karuppan, 2016).

A comprehensive study by CSIRO in collaboration with states conducted an analysis, checking energy consumption every hour through smart meter. By estimating energy required to heat or cool a standard dwelling, based on scale of 1-10 using appliances with star ratings, it was found that homes with high efficiency appliances require less energy (Table 4). A 5 star space heating device will save 33 % and 7 star device will save 69 % energy, compared with 2.5 star rated appliance, therefore a standard home in Australia can reduce 42 % overall energy in addition to reduced GHG (Saman 2013). This establishes a synergy by installation of PV (solar) system on the roof top which can generate clean energy to meet the energy requirement, be self-sufficient in reducing the dependence on centralised power network, giving short term monetary benefit through tariff, and benefitting the environment in reduced GHG emissions and ecological benefit. These benefits outweigh the initial capital investment (Mountain & Szuster 2015).

Table 4: Annual Energy consumption for 2.5, 5 and 7.5-star homes. Data Source: (Saman 2013).

Star rating	2.5★		5★		7.5★	
Energy source	Electricity	Gas	Electricity	Gas	Electricity	Gas
Water heating	21240			22830		8640
Space heating	4693		3137		1411	
Space cooling	5172		3608		2567	
Cooking		2527		2246		1872
Lighting	1130		848		269	
Other appliances	11113		10883		10653	
Total energy consumption	45516	2527	19399	25076	15645	10512

According to The Australian Energy Regulator (AER) bench mark data table 5-6, there is scope to decrease the gap in household energy efficiency without reducing the comfort level. This will reduce environmental impact as well as long term economic benefit. AER's study through data analysis of more than 1000 household matched with meter readings from energy service providers, concludes that households without swimming pools use 2808 kwh less energy per year, electricity use increases as the building size increases along with more appliances, increase of 917 kWh for every additional person in the household (Table 5) (Tustin et al. 2012). Key findings of the study reveal household's present benchmark norm have not been attained for SA (Table 6).

Table 5: Household electricity use by mean, without and with pool. Source: (Tustin et al. 2012).

Household size		1	2	3	4	5	6
	Average pools = 7%						
Appliances	0	3,060	4,077	5,094	6,110	7,127	8,144
	1	4,123	5,140	6,157	7,174	8,190	9,207
	2	5,187	6,204	7,220	8,237	9,254	10,271
	3	6,250	7,267	8,284	9,300	10,317	11,334
	No pool						
Appliances	0	2,869	3,886	4,903	5,920	6,936	7,953
	1	3,933	4,949	5,966	6,983	8,000	9,017
	2	4,996	6,013	7,030	8,046	9,063	10,080
	3	6,059	7,076	8,093	9,110	10,127	11,143
	Pool						
Appliances	0	5,777	6,794	7,811	8,828	9,844	10,861
	1	6,841	7,857	8,874	9,891	10,908	11,925
	2	7,904	8,921	9,938	10,954	11,971	12,988
	3	8,967	9,984	11,001	12,018	13,035	14,051

Table 6: AER benchmark household electricity use without swimming pool (Tustin et al. 2012).

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Energy utilisation in water sector.

Quantifying energy usage in water sector will allow better understanding of essential infrastructure through careful investment. Integrating with the water and the food sector will empower a nexus approach which will be more economic. A demand management approach in the water and energy sector will be more effective through trade-off.

Energy utilisation by the water providers in Australian capital cities set to increase by nearly 200 % by 2030 including Adelaide: due to increase in population growth, topography and the water source. If the trend continues in the same direction, by 2030, government will have to adopt 300L/ cap due to reduction in yield, resulting in 25 % abatement in overall energy (Kenway et al. 2008).

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Figure 12: Energy consumption by water providers. Data source: (Cook, Hall & Gregory 2012).

Study reveals primary energy used per person continue to raise, ranging from 5 to 10 kW per person, unless imminent demand is managed aptly through management strategies, more likely to face inflated energy cost; due to more energy required to treat and transport water (Figure 12). Reducing the dependency and increasing reliability through efficient treatment process will reduce overall energy cost, GHD and carbon footprint. Generating power through effluent treatment and bio fuel treatment will lower energy dependence, savings in water treatment process will contribute a small portion towards a sustainable future for water stressed city like Adelaide (Svardal & Kroiss 2011).

Energy for water processing and delivery.

SA Water, the sole provider of potable drinking water to the entire state through centralised network of pipes from Mannum to Adelaide spanning 87 Km. Agriculture sector utilise more than 80 % of the total share, whereas 12 % is used by households. Energy consumption by water industries transpire for pumping raw water treatment and distribution to consumers is highly energy intensive, estimated to be around 2801 GJ/GL which is higher compared to other eastern states (Cook, Hall & Gregory 2012).

A study by Electric Power Research Institute (EPRI) in the United States of America has revealed, 4 % of the total energy is utilised by water sector to transport potable water from processing facilities to the customer, forecast to increase to 23 % by 2020 and 63 % beyond by 2050 (Copeland 2014), a similar trend is anticipated in Adelaide at 2.5% average increase in energy growth between 2009 – 2015, 15 % overall increase in three decades (Figure 13). Energy for collecting and treating waste water continue to rise in Adelaide, 60 % of the total energy is diverted for 6 waste water treatment plant, 30% energy needs are supplied through biogas which also reduces GHG, costing at 3271 GJ/GL for the entire process (Cook, Hall & Gregory 2012).

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Figure 13: SA residential energy consumptions (PJ). Source: (Harrington & Foster 2008).

Energy for desalination.

The challenge to meet the growing demand for water stressed city like Adelaide is to find new source for water, one such source is through Desalinating sea water to increase supply to meet the demand: as population is set to grow, urban residents and industries demand more fresh water, sea water is one option arguably the best but expensive option available at the moment. Thermal desalination plants consume more energy compared to reverse osmosis technology. Estimated energy consumption to operate a desalination plant is about 3 – 4 kWh/m^3 based on 50 % recovery of fresh water and emit CO_2 between 1.4 – 1.8 kg/ m^3 of fresh water produced (Elimelech & Phillip 2011).

Desalination and Environment.

Huge volumes of salt water from ocean is desalted everyday around the world to meet demand for potable water, estimated that nearly 9.92 million m^3 /day^{-1} fresh water is produced. Resulting in huge volumes of waste brine as a by-product. Thermal desalination process which produces multistage flash (MSF) pollutants, will contaminate marine environment by increasing the ocean temperature, turbidity, salinity and ocean current, its impact on marine species is enormous causing fish and aquatic species to migrate and alleviate molluscus, algae and nematods (Al-Mutaz 1991).

A recent study has projected that 25 million/m^3 of ocean water is processed at desalination plant and the majority of these plants are located in the arid regional countries, with limited resource in ground and surface water they will have to use expensive energy. Advancement in technology and anticipated decline in precipitation due to climate change is forcing many European countries, United States, China and Australia have several operational desalination plants in the nation, and have invested heavily in considerably large projects, an indication of the growth and positive trend around the world. Research studies and laboratory-based analysis have conclusive and a compelling case to portray that the waste and brine discharge to ocean containing toxic and contaminants will pose huge impact on ecology and marine environment of the ocean (Roberts, Johnston & Knott 2010).

CHAPTER 4: FOOD

4.1. Introduction South Australian food

The global food demand has opened up opportunities to export quality food products from South Australia to water stressed nations. Thus, agriculture has become a source of income in generating money to the state treasury. There are various elements attached as burdens; such as ground water salination, fall in water table level, or salt water intrusion, in addition to other environmental issues posing several questions along the way. In order to integrate a nexus approach, it is imperative to consider risk pertaining to food. For example, diary and meat products in South Australia’s imports risen steadily as shown in Table 7, SA is a net importer of processed food, confectionary, oil, fat, and seafood (Garnett 2014). While the demand for quality food raises, natural resource like water to produce food is not increasing as evidenced by reduced rainfall and extreme weather patterns due to the effect of global warming which poses threat and competition for limited available resource.

Table 7: Adelaide food imports. Data Source: Australian Government, Department of Foreign Affairs and Trade (2019).

Adelaide metropolitan city	2017 / 18		2012 / 13		Change ($m)
Industry	$m	Share % of import	$m	Share % of import	2012-13 to 2017 - 18
Agriculture, forestry and Fishing	91.6	1.5	103.9	1.9	-12.3
Food and accommodation services	124.4	2.1	118.2	2.1	6.2
Wholesale trade	298.1	4.9	203.1	3.6	95.1

4.2. Strategies for food use and conservation

Average spending on food per person in the year 2015 - 16 was $4739 which accounts for nearly 35 % of the total income, Table 8 provides details of items from 1988 – 2016, 33.9 % of the income is spent on fast food and meals out. Key driver for food demand is the economic advantage, because prosperity brings in more wealth, resulting in people having more disposable income to spend. With the increase in urban population growth, demand for food in urban areas has increased. Future demand is predicted based on trends, keeping in view across various groups measured within household income, and actual food price and food consumptions (Hogan 2017).

Table 8: Major food expenditure in Australia. Source: (Hogan 2017).

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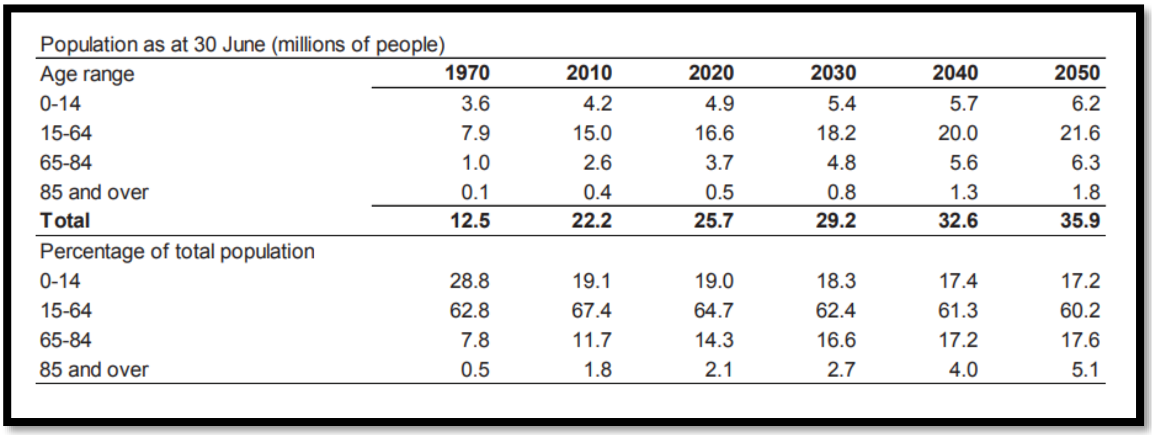
Household food consumptions is likely to increase in line with annual population growth predicted at 1.4 % per year by 2050. The Australian population is predicted to reach nearly 40 million in which 60 % of the increase is in 15 – 64 year age group as shown in Table 9. This demographic is certain to demand a higher portion of the food share, which will represent a challenging factor in food demand management (Swan 2010). Expected household spending on food is set to increase by 65 %, which equates to $160 billion by 2050.

Table 9: Age wise population forecast. Data Source: Treasury (2010).



Population as at 30 June (millions of people)						
Age range	**1970**	**2010**	**2020**	**2030**	**2040**	**2050**
0-14	3.6	4.2	4.9	5.4	5.7	6.2
15-64	7.9	15.0	16.6	18.2	20.0	21.6
65-84	1.0	2.6	3.7	4.8	5.6	6.3
85 and over	0.1	0.4	0.5	0.8	1.3	1.8
Total	**12.5**	**22.2**	**25.7**	**29.2**	**32.6**	**35.9**
Percentage of total population						
0-14	28.8	19.1	19.0	18.3	17.4	17.2
15-64	62.8	67.4	64.7	62.4	61.3	60.2
65-84	7.8	11.7	14.3	16.6	17.2	17.6
85 and over	0.5	1.8	2.1	2.7	4.0	5.1

Average food expenditure per person on 8 major foods.

Australian imports in the food sector have dramatically increased in the last 28 years from 1988 - 2016 by 20.5 %. Fast food, meat and seafood account for more than 47.6 % of the total money spent on food per household, Therefore, there is a need to reduce reliance on high intensity processed imported food and adopt methods to use less water intense industries with highly efficient locally available food products. Expenditure on food is the second largest cost on family income. Average expenditure for food per person rose in the last 28 years. However, cost rose sharply from then on, reaching its peak in 2015 – 2016 as shown in Figure 14 (Hogan 2017). A comprehensive sustainable resource utilisation is essential to meet the demand for food and to secure long-term future of the Adelaide population.

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Figure 14: Food expenditure per person. Source: (Hogan 2017).

4.3. Discussion

The Australian population is ethnically diverse and the majority of people, nearly 90 % of its population out of which 25.415 million, live in urban settings, 22,759 million people live in cities, and 77 % of SA people live in Adelaide metropolitan areas: Therefore, urban dwellers will determine and shape Australian food demand as well as global food demand, this is especially true of the five growing economies with which Australia has Free Trade Agreement for both import and export in the food sector. Demand from the domestic population as well as global needs is set to increase rapidly. Australia is self-sufficient in securing domestic demand; however, exports 70 % of unprocessed agricultural produce as grain, wheat, beef, sheep and dairy products in 2011 – 12 worth $19.2 billion. High water intense meat and dairy products import is a cause for concern that needs to be reduced in order to lower water over consumption (Di Nunzio 2014).

There is more than one reason for these increases in food demand. Major causes are the natural increase in Australia's population due to exponential growth, economic growth enabling large disposable income to spend, deviation from traditional dietary habits leaning towards heavily processed fast foods, growth of the mega metropolitan cities, and urbanisation. Concern for dwindling natural resource which requires immediate focus and demands a responsive action plan to overcome these problems (Cole et al. 2018). According to ABS (2012) reports, imports have increased at an average rate of nearly 5 % from 1992 – 2012. A 0.5 % increase in a year's spending, which is likely will escalate total household food spending towards $140 billion by 2050, from $92 billion in 2015 - 16 according to a government study (Hogan 2017). Adelaide remains a net importer of processed seafood since early 2000, particularly of high-end products, such as frozen and canned fish (ABS 2012).

Balanced food diet and redressing over consumption.

Among other food wastage, such as discarding food without consumption, over eating beyond what is required to sustain the human body has become a major phenomenon, particularly among wealthy Western developed nations. The term 'luxus consumption' has been coined to describe an extreme pattern of excessive eating where young men and women indulge in over eating and use chemical laxatives to get rid of the food they have eaten (Blair & Sobal 2006): In The United States of America, it is estimated that 5000 calories per day is consumed by these young men and women, which amounts to a million calories a year just for one person, this habit is contributing towards food waste and obesity among population, In addition to impacting environment and ecology through resource, time and material wastage as land fill. Moreover. There are psychological and health ramifications, since overweight condition may leads to depression, anxiety, low self-esteem , risk of chronic disease and fatality among obese people. (Blair & Sobal 2006).

As already stated, South Australia is a net importer of heavily processed food. Therefore, dietary change would help to conserve both energy and water by adopting to a diet of food grown using less water and energy resource. Furthermore, reducing consumption of pork, beef, poultry and dairy products from 50 % to 25 % and substituting with bread and cereal in the diet would result in a net reduction in consumption of 44.3 kg/per person annually. Moreover, by including 9.7 kg bread and cereal per person in a year, there would be a reduction in natural resource dependence as well as lower environmental impact and health benefits for the population (Ridoutt, Hendrie & Noakes 2017).

Food waste reduction.

One of a the key global challenges facing world food authority is to reduce unrivalled the large scale food wastages in the Food Supply Chain (FSC),(McCarthy & Liu 2017). Minimising the avoidable food wastage and reducing the surplus is a simple yet effective option, enabling distribution of excess food to those who are hindered by lack of food due to poverty. Efforts in converting food waste into biofuel and animal feed is also a potent and useful way to utilise wastage and conserve available resources.

Australian households too dispose of a great deal of edible food, with an estimated $2.9 billion worth of food discard to land fill every year. Landfills are a major source of unnecessary methane gas production (CH_4), which is an atmospheric pollutant and a significant cause of climate change. Household wastage of food is avoidable through contemporary technology, innovation and public education, as the key for sustainable food strategy can be adopted through participation from the local community, and policy initiation by providing incentives for private and public support (McCarthy & Liu 2017). Managing waste effectively will have a decisive effect on environment and will benefit society, as it can be financially rewarding in addition to promoting positive influence towards the global fight against poverty.

Quantifying the amount of food waste and putting a financial value on it will help raise a lot of awareness. Nearly half of all edible food produced is wasted before it reaches consumers, particularly in the developed world according to Papargyropoulou et al. (2014), the amount of food waste in Europe and North America can feed the world’s hungry three times over, A staggering 1.3 billion tons of food is wasted every year.

Food waste is attributed to four causes, all occurring at initial stages even before it reaches consumers. Poor harvesting technology, inadequate and poor transport, inefficient storage conditions, and extreme weather conditions, are the primary causes of FSC wastage. For example, in 2007 nearly $750 billion worth of food was wasted at various stages of FSC as shown in Figure 15.Due to this problem, the financial implications are significant and form a threat to a sustainable future (Papargyropoulou et al. 2014).

In addition to adverse environmental impact, water and energy are needed to produce food, containing 24 % water and 2 % energy, which in turn produces GHG emissions up to 31 % (Castell-Perez et al. 2017). However, converting food waste and municipal solid waste (MSW) into energy through biochemical conversion technologies a viable solution. Furthermore, organic land fill can be turned into compost and fertiliser for agriculture and growing organic produce (Franchetti 2013).

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Figure 15: Food waste structure. Source: Papargyropoulou et al. 2014)

Food waste on environment

Food waste disposal through land filling produces the greenhouse gases, methane and carbon dioxide, as a natural process of decomposition. The estimated global production of methane gas through decomposition of organic waste from land fill and industrial waste, amounts to 30 – 70 × 10^6 T/year or 6 % to 18 % of the total CH_4 (methane) gas that is generated by all processes on the earth (Bingemer & Crutzen 1987). The volume of methane gas released is greater than gas emission from coal mining and industrial gas leakage combined together. These greenhouse gas potentially speed up atmospheric temperature (global warming) by trapping heat from the sun far greater than

CO_2. Thus, this sector contributes more than 3 % towards global GHG emissions (Adhikari, Barrington & Martinez 2006). Consequently, activities pertaining to production of food, such as agriculture, processing, manufacturing, transporting of produce, storage and refrigeration of food, and distribution to the retail sector are contributing to the climate change. Agriculture and livestock are the two key sectors which contributes 40 % of GHG emissions, which can be reduced through managing waste and renewable energy practices (Papargyropoulou et al. 2014). Otherwise, the effect of food waste on natural resources through depletion of water and energy, and damage to the environment will have decisive economic and social ramifications.

Irrigation management.

Food production through agriculture is a quite dynamic and complex issue to resolve, however integrating an issue-based approach will help reduce the dependency.

Traditional Irrigation practices of growing regular agrarian crops where yields are relatively low compared to the volume of water used, need to be replaced by a methodical approach in water use, yield, application and water distribution proportional to the required depth for the crops. A study by Juan et al. (1996) based on irrigation techniques with rotation of crops and water availability-based crops, demonstrated agricultural practices that yielded high income, with crops requiring less water, that were rotated during times of limited water availability.

Climate plays an important role in determining the outcome of agricultural programs. Some critical input in terms of the variability is dependent on rainfall, type of soil, weather condition, evapotranspiration and irrigation methods, which are all critical for the outcome (Juan et al. 1996). A recent meta-analysis by Zhao et al. (2020) comparing more than 200 effective crops in China has revealed increase in yield by 20 % a result of strategic crop rotation as shown in Figure 16. The climate of this province of China is similar to the Adelaide region with an annual rain fall of 400 – 500 mm, and the yield is dependent on soil properties, topography, average temperature and irrigation practices. A rise in yield of 20 % will increase profit by more than 50 % for the farmers, which is profound in terms of economic gain (Zhao et al. 2020).

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Figure 16: Yield savings through crop rotation. Source: (Zhao.et.al. 2020).

Reducing Virtual water and creating green space.

An indication of the global water footprint to produce primary crops is estimated to be around 7404 (Gm^3)/year. This amount includes 78 % green and 12 % of blue water respectively on top of 10 % grey water, which includes 1328 Gm^3 from the developed world (Hoekstra et al. 2011). This trend is expected to grow annually, with farming influence in terms of GHG emissions of CO_2, N_2O and CH_4 resulting in global discharge of 4518.9 Mt of CO_2 affecting the environment (Munesue, Masui & Fushima 2015). According to Hoekstra et al (2011), water footprint to produce primary crop throughout its FSC will continue to raise. Australia exports 89 Gm^3 year and is a net importer of processed food (Mekonnen & Hoekstra 2011).

Urban scale energy conservation can be realised by reducing transport energy, because the demand for food in urban centres is separated by distance from the food production source. Therefore, energy and time is required to transport food to the urban markets and there will be an effect on the environment (GHG emissions) as well as food wastage. A reduction in energy needs can be attained through developing an improved network of FSC from raw production to end of product life cycle, through WEF (Water-Energy-Food) integrated approach, food production to disposition, recycling and converting waste into energy through decentralised infrastructure development (Treemore-Spears et al. 2016).

One solution to reduce spatial distance required to transport food involves the establishment of green space and organic, community garden in urban public places (Treemore-Spears et al. 2016). Community produce gardens can help manage waste by growing food using reclaimed water from households for irrigation, with clean energy (wind and solar) providing power and infrastructure, and employing active citizen participation to help support families and sustainability in cities. Thus a synergy in WEF is achieved, while also benefitting societies, self-sufficiency and the environment (Treemore-Spears et al. 2016). Such an approach would be highly appropriate for Adelaide and other urban centres with temperature climate and fertile soils. However, these solutions require coordinated infrastructure development, public expenditure, stake holder’s awareness, and planning to achieve the aims of a successful local project. Above all, programs utilising the WEF concept require vision and determination from dedicated stakeholders who want to live more sustainably.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

The integrated approach in Water Energy Food nexus is a complex and dynamic contention. Adelaide's population is predicted to reach 1.75 million by 2040, with exponential growth, economic prosperity and climate change bringing increased competition for water, energy and food resources. However, availability of water is predicted to decline, while demand for energy and food will increase. Therefore, integrating the WEF sector through nexus approach is vital for a sustainable future.

This research implications for governments, planners and food security authorities is the need for their recognition that city dwellers in Australia can determine and drive management of resource consumption and conservation initiative for a sustainable future. However, the effectiveness of programs and interventions to secure the future of Adelaide will depend on stake holder engagement and proactive participation in adopting more effective water saving techniques, efficient energy saving regimes and improved utilisation of food. Sustainable urban water schemes can be realised by embracing alternative water resources in households through decentralised conservation programs (rain-water) and by technology adaptations (smart appliances). Centralised sub-urban scale storm water usage can reduce resource extraction and will lower the energy footprint and these advances can have a positive effect in preserving valuable resources. Recovered water can then be utilised in the food sector, so that Integration of the three WEF sectors is achieved, establishing a synergy.

The combined effects of climate change, over population and urbanization poses a serious threat, to Adelaide's future as a clean, liveable and modern city. Therefore, initiatives in reducing reliance on fossil fuel-based on eco-friendly, renewable energy generation are needed to lower environmental and ecological impact. Stake holder's performance (social change) in food and dietary switch will conserve embodied water and energy. Social change through citizen participation, engagement and education about the importance of conserving food and the benefits of a healthy diet will protect water and energy resources. In addition, synergy in the form of generating energy through food and agriculture waste will reduce fossil fuel dependency and improve recycling of waste.

This study further envisages more energy conservation in Adelaide households through 5 star and 7.5 star-rated efficient appliances, and thermal efficiency of urban dwellings which would contribute to household savings and reduce further fossil fuel energy dependence. In less than a decade of focussed government policy, it could be possible using renewable wind and solar energy, backed up by battery storage, to abrogate coal-based energy generation in South Australia. These two key stone renewables are expected to have significant impact on overall environment, ecological and economic benefit for South Australians. These steps in the energy sector need to be joined with food and water sectors by developing a synergy, by establishing community gardens in public green space, and utilising reclaimed water to produce food. Visionary governance and policy formulation is vital if such recommendations are to succeed. For the future, research into biofuel energy generation would help reduce further the energy use for transportation and water extraction from ground water.

Recommendations

The following recommendations are proposed to gain further understanding of the nexus approach in an urban scale.

- Investment in improving the older buildings to be more efficient through subsidies.
- Creating green space in public places, centralised sub-urban water conservation through networking of reclaimed water, growing organic food through reclaimed water for household use and community market.
- Centralised network to grow food through storm water, energy generation through biofuel which can be utilised for irrigating urban scale crop production.
- Dietary improvement for the population to improve health and conserve water, consuming mainly vegetables and protein-based grains, rather than fast foods and water intense, animal-based food products.

Further research

- Quantifying water footprint associated with food manufacturing and conservation measures for Adelaide city.
- Economic viability and cost analysis for energy generation through wastes (food, agriculture and municipal sewage waste).
- Comprehensive cost and benefit analysis to quantify water footprint by water processing companies to produce energy through biofuel (Chapter 3.3. energy for water processing).
- Adelaide cities food import and export virtual water footprint analysis. Up to date survey of food and nutrition habits at city scale to determine effective resource utilisation.
- Life Cycle Assessment of all packaged food products to identify water and energy used throughout its cycle. Analysis will help in identifying drawbacks and manage food products to a sustainable level at city scale. Critical for WEF nexus integration.

Limitations

- Inadequacy in South Australian virtual water footprint for import and export data limits conclusive result, act as Impediment in quantifying virtual water and energy savings achieved through importing food products from water rich nations and exporting to water deprived nations such as like Middle Eastern countries. This limitation inhibits food management.
- Food analysis for Adelaide residents is based on National Nutrition Survey Data. Adelaide residents overall spending and consumption habits are similar to national data; hence assumption is made based on national data, which limits to conclusion; however, conservation regime, trade-off and synergy discussed in this study will sustain future needs at city scale.

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APPENDICES

Appendix A: Water consumption in SA 2008-2017. Source: ABS (2017).

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Appendix B: SA residential power consumption 1990 – 2020. Source: (Harrington & Foster 2008).

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Appendix C: Adelaide Food Imports 2010-2018. Source: Australian Government, Department of Foreign Affairs and Trade (2019).

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