

2490-3

**Joint ICTP-IAEA Advancing Modelling of Climate, Land-use, Energy and
Water (CLEW) Interactions**

7 - 11 October 2013

Energy Systems Analysis and Planning Group

Fadiel Ahjum
*University of Cape Town
SOUTH AFRICA*

Energy Research Centre



University of Cape Town

Fadiel Ahjum

Energy Systems Analysis and Planning Group

www.erc.uct.ac.za

**Advancing modelling of Climate, Land-use, Energy and Water
(CLEW) Interactions**

IAEA, Trieste, 2013

Emerging Research Focus

<u>Energy</u>	<u>Water</u>	<u>Land</u>
<ul style="list-style-type: none">• Energy demand<ul style="list-style-type: none">• Energy for moving water• Energy for water treatment• Energy for heating water• Energy efficiency• Energy supply<ul style="list-style-type: none">• Energy from waste water treatment• Energy from pumped storage	<ul style="list-style-type: none">• Water demand<ul style="list-style-type: none">• Water for agriculture• Water for urban use• Water supply<ul style="list-style-type: none">• Water treatment• Storage• Augmentation• Climate change impacts	<ul style="list-style-type: none">• Land use for agriculture• Land-use for housing• Land use change<ul style="list-style-type: none">• Impacts on water and energy

South Africa at a glance...

52 million people.

GDP ~6000 USD per capita (2011).

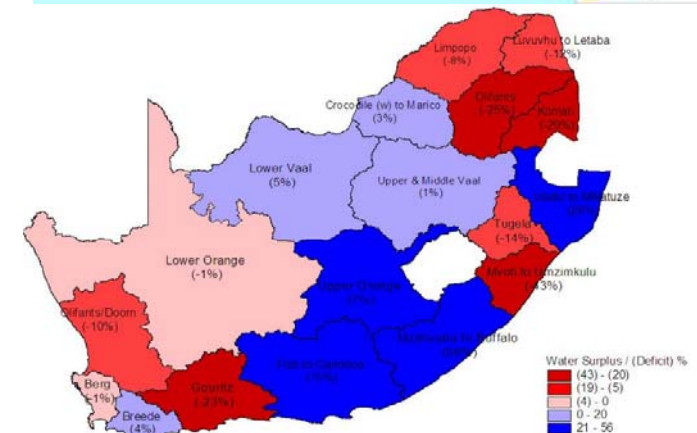
1.2 million m² (12%) of total land cover suitable for crop production.

60% of allocated water consumed for irrigated agriculture.

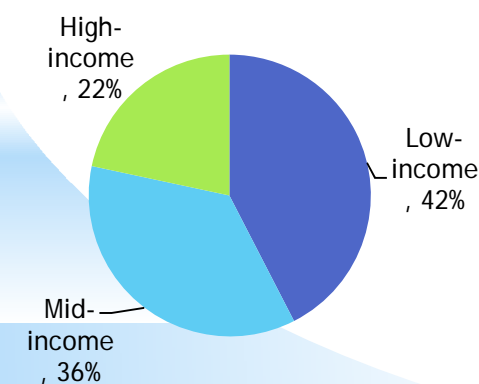
Increasing urbanisation of the population.

~90% of population with access to electricity.

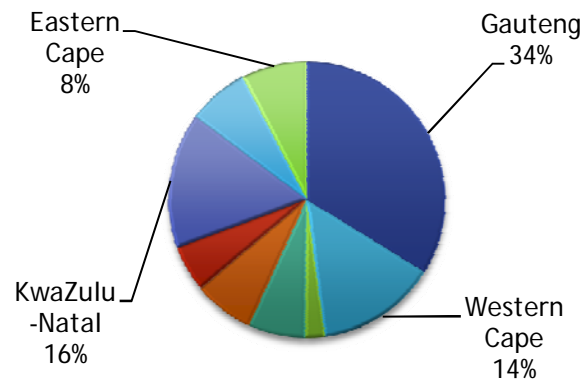
Increasing demand for housing and water and sanitation services.



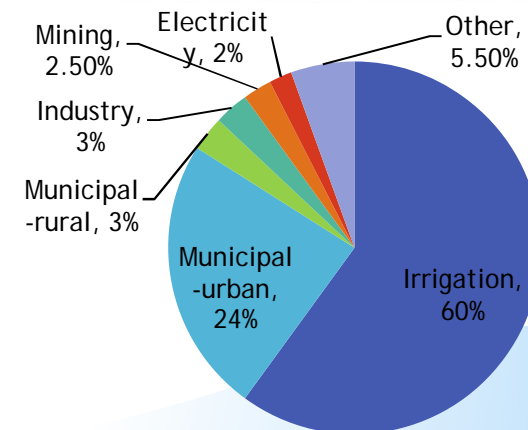
Water Management Areas: percentage surplus/deficit for the year 2000 (Source: NWRS)



Population distribution by Income



Provincial share of GDP



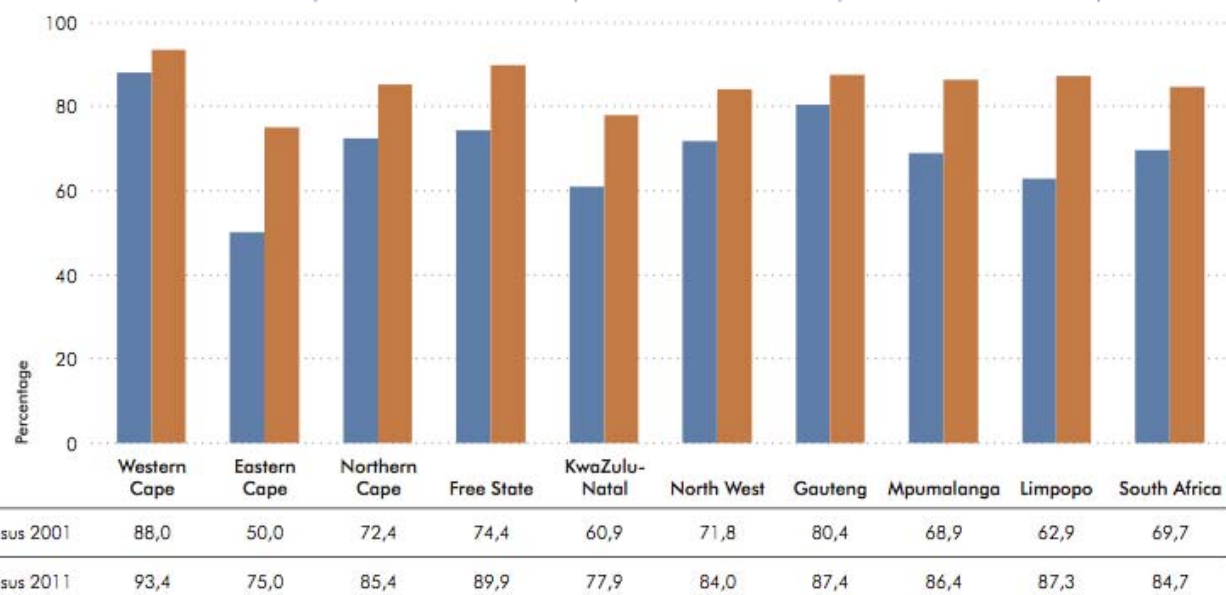
Estimate of sectorial water consumption

Access to basic services

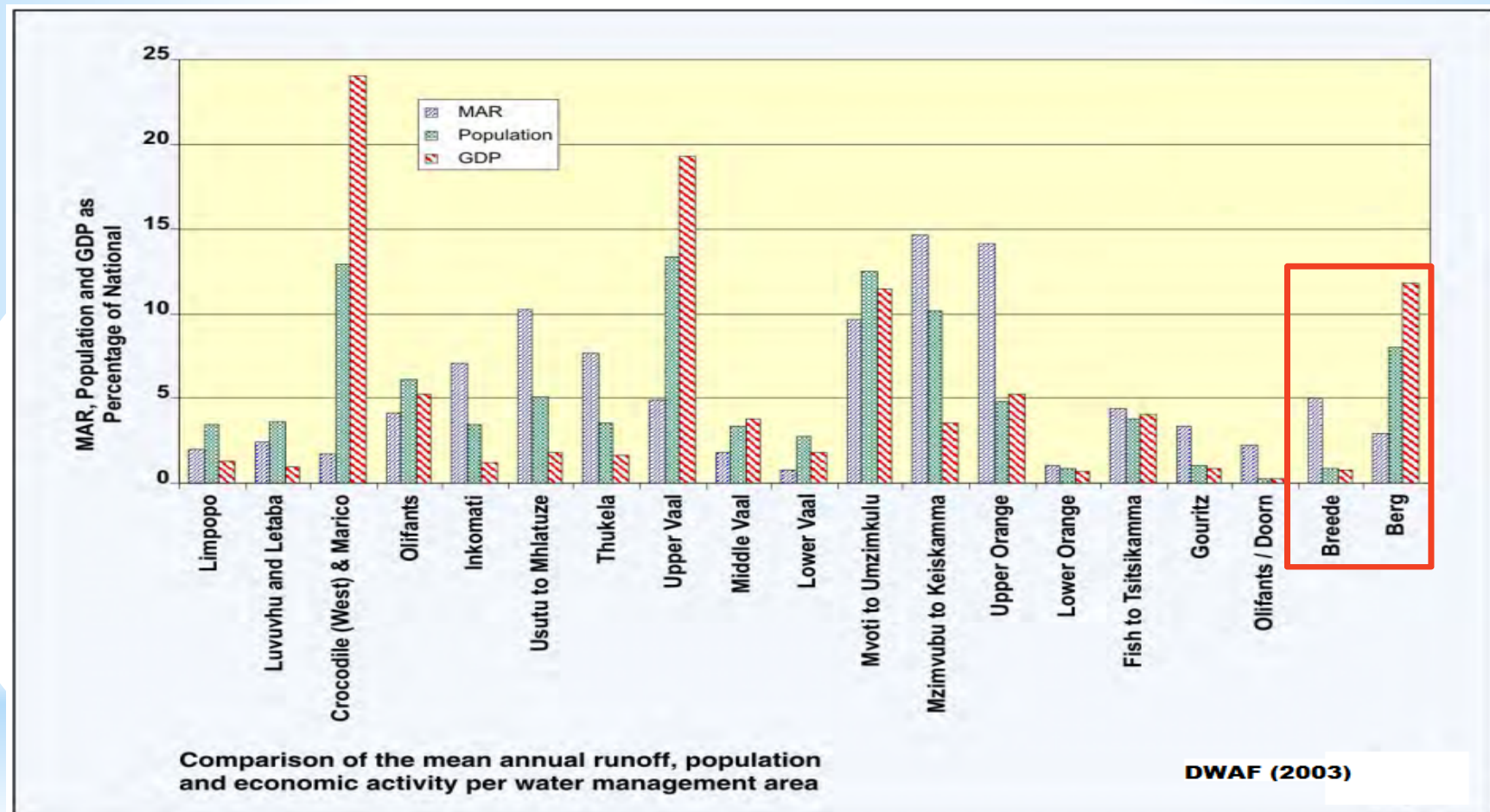
Water

	Piped (tap) water inside dwelling		Piped (tap) water inside yard		Piped (tap) water on community stand: distance less than 200m from dwelling		Piped (tap) water on community stand: distance greater than 200m from dwelling		No access to piped (tap) water	
	Census 2001	Census 2011	Census 2001	Census 2011	Census 2001	Census 2011	Census 2001	Census 2011	Census 2001	Census 2011
Western Cape	67,5	75,1	17,7	13,3	6,3	8,3	6,8	2,4	1,7	0,9
Eastern Cape	18,3	32,8	19,5	16,6	11,9	18,6	13,5	9,9	36,8	22,2
Northern Cape	34,3	45,8	37,7	32,3	10,9	12,8	11,1	6,6	6,0	2,6
Free State	22,8	44,8	47,7	44,3	13,7	6,2	11,4	2,6	4,4	2,2
KwaZulu-Natal	29,1	40,0	19,6	23,6	10,5	14,8	13,3	7,6	27,5	14,1
North West	18,7	29,3	35,5	40,0	16,0	14,3	16,4	8,0	13,4	8,4
Gauteng	46,4	62,1	36,4	27,3	7,0	6,0	7,3	2,8	2,9	1,8
Mpumalanga	19,8	35,7	36,7	36,0	12,8	9,2	16,4	6,6	14,3	12,6
Limpopo	9,7	18,4	29,2	33,9	16,1	20,5	23,1	13,2	21,9	14,0
South Africa	32,3	46,3	29,0	27,1	10,7	11,7	12,4	6,2	15,6	8,8

Electricity



Resources are regionally spatially and temporally dislocated from demand. At present CLEW modelling conducted at the ERC has focused on the Western Cape and the City of Cape Town in particular.

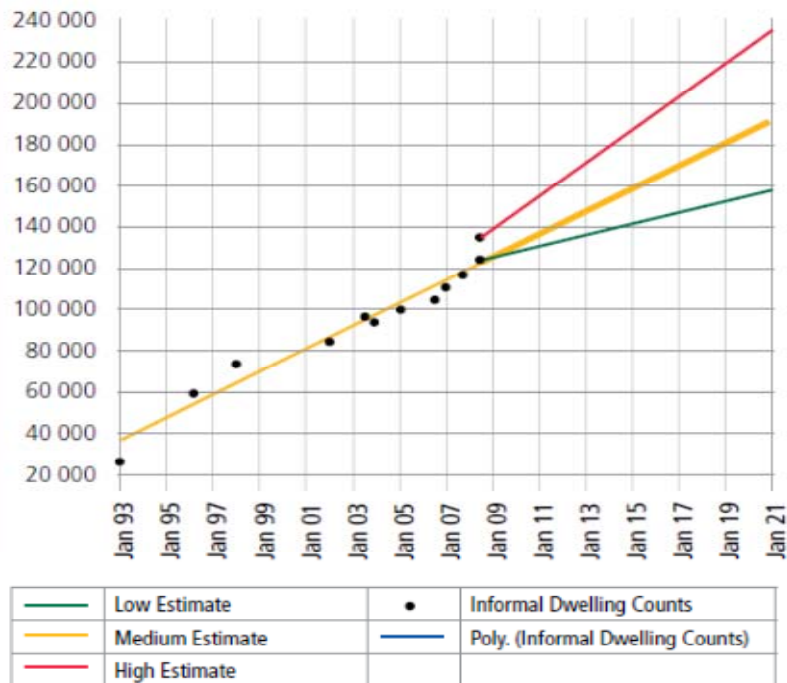


Western Cape

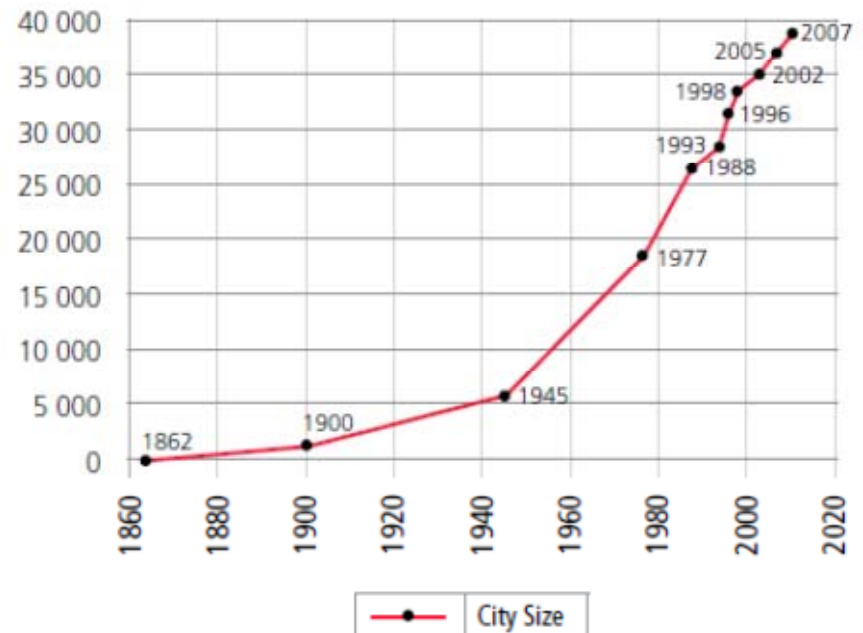
Population



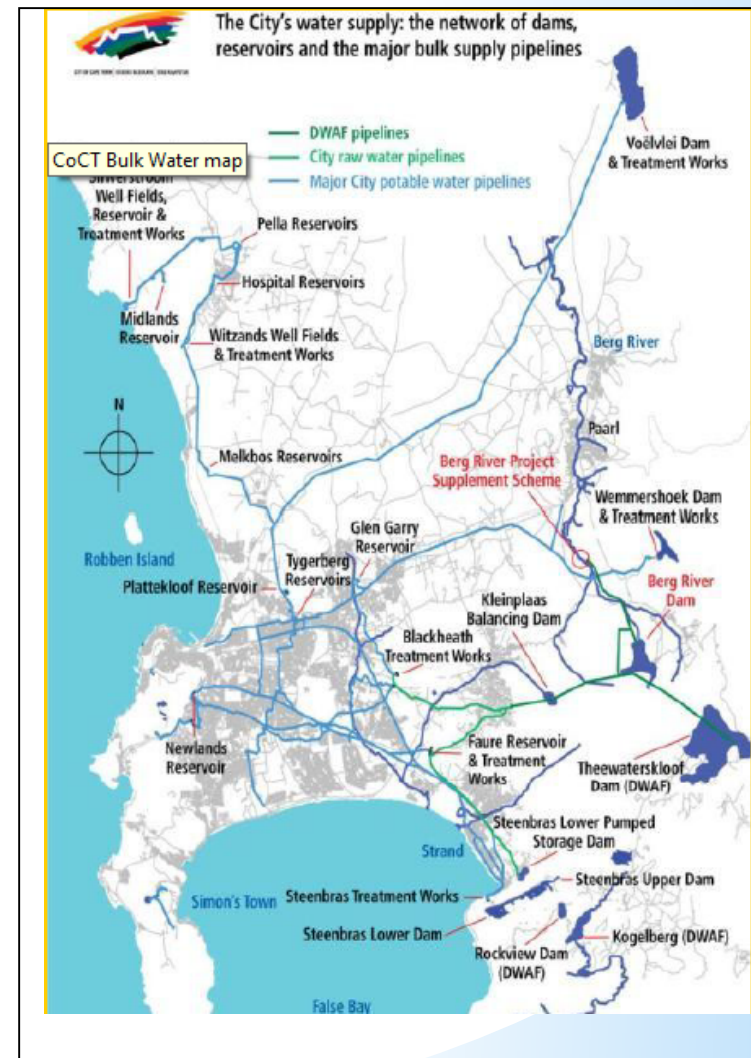
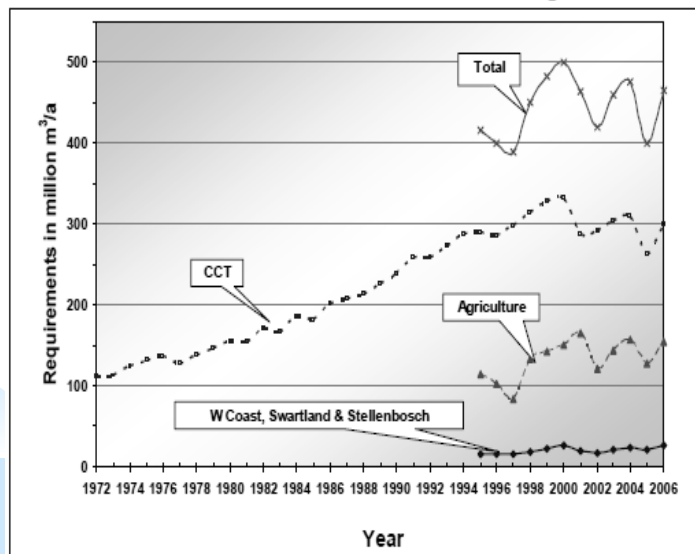
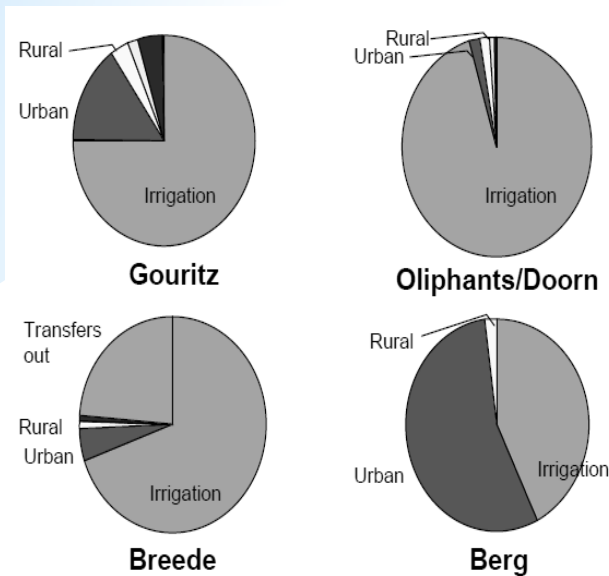
NUMBER OF INFORMAL DWELLINGS IN CAPE TOWN
(Corporate GIS counts)



POPULATION



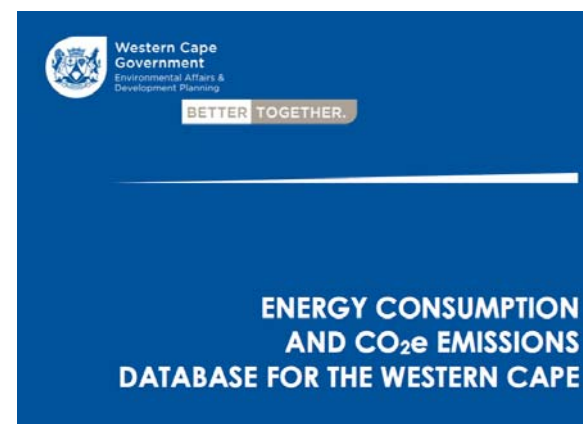
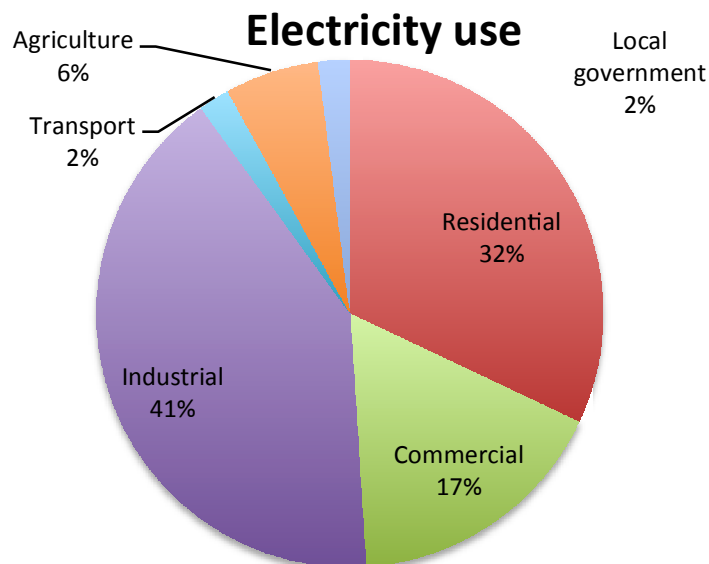
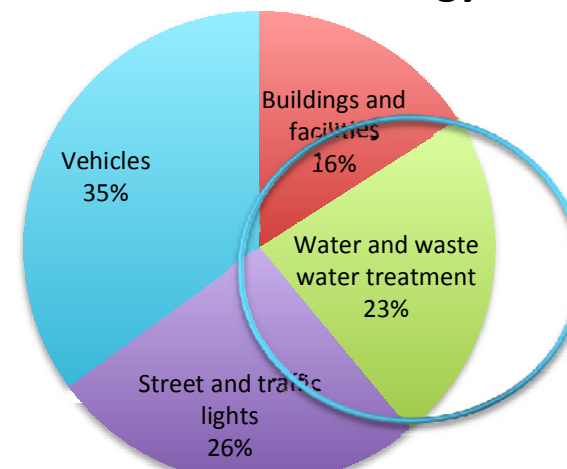
Water consumption



Energy consumption

	2009 TJ	% growth (2004-2009)
Provincial energy		
Residential	28703	8%
Commercial and public services	15659	12%
Industrial	112879	-1%
Transport	109027	5%
Agriculture	4689	-18%

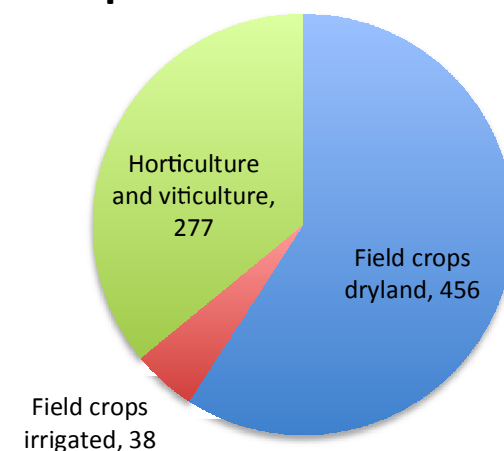
Local Government energy use



Land and agriculture

Field Crops	Planted hectares		Yield Tonnes/ha	
	Dry Land	Irrigated	Dry Land	Irrigated
Maize for Grain	36,513	2,067	2.81	4.44
Grain Sorghum	4,955	201	1.92	2.42
Other Summer Cereals	301	11	5.68	1.91
Wheat	220,284	10,754	2.44	3.49
Barley	43,974	3,461	2.25	4.9
Other Winter Cereals	40,229	1,958	2.02	2.12
Sunflower Seed	272	51	0.89	1.24
Other oil Seeds	18,305	497	1.14	1.3
Dry Beans	72	108	3.88	2.73
Other Legumes	1,655	6	0.58	2
Lucerne	39,290	13,751	2.09	8.96
Maizefor Silage	4,317	1,685	2.08	10.49
Teff	5,255	223	2.78	13.16
Other Fodder crops	36,981	3,668	4.97	5.12
Tobacco	1,036	8	0.09	2.38
Seeds	1,092	293	1.14	6.28
Other Field Crops	1,949	103	1.04	2.39

planted hectares



* High-value export crops are being produced in both the Berg and Breede River water catchments. This renders these regions as strategic pillars of the economy of the Western Cape province because of its multiplier effects. According to Eckert *et al* (1997), approximately 65% of all secondary industries are dependent on agriculture.

* Although water demand strategies have been implemented to curb the growth in urban water use, these strategies can only alleviate the problem; they cannot solve it.

* There is mounting pressure to reallocate water from agricultural use to urban use.

Energy modelling: LEAP

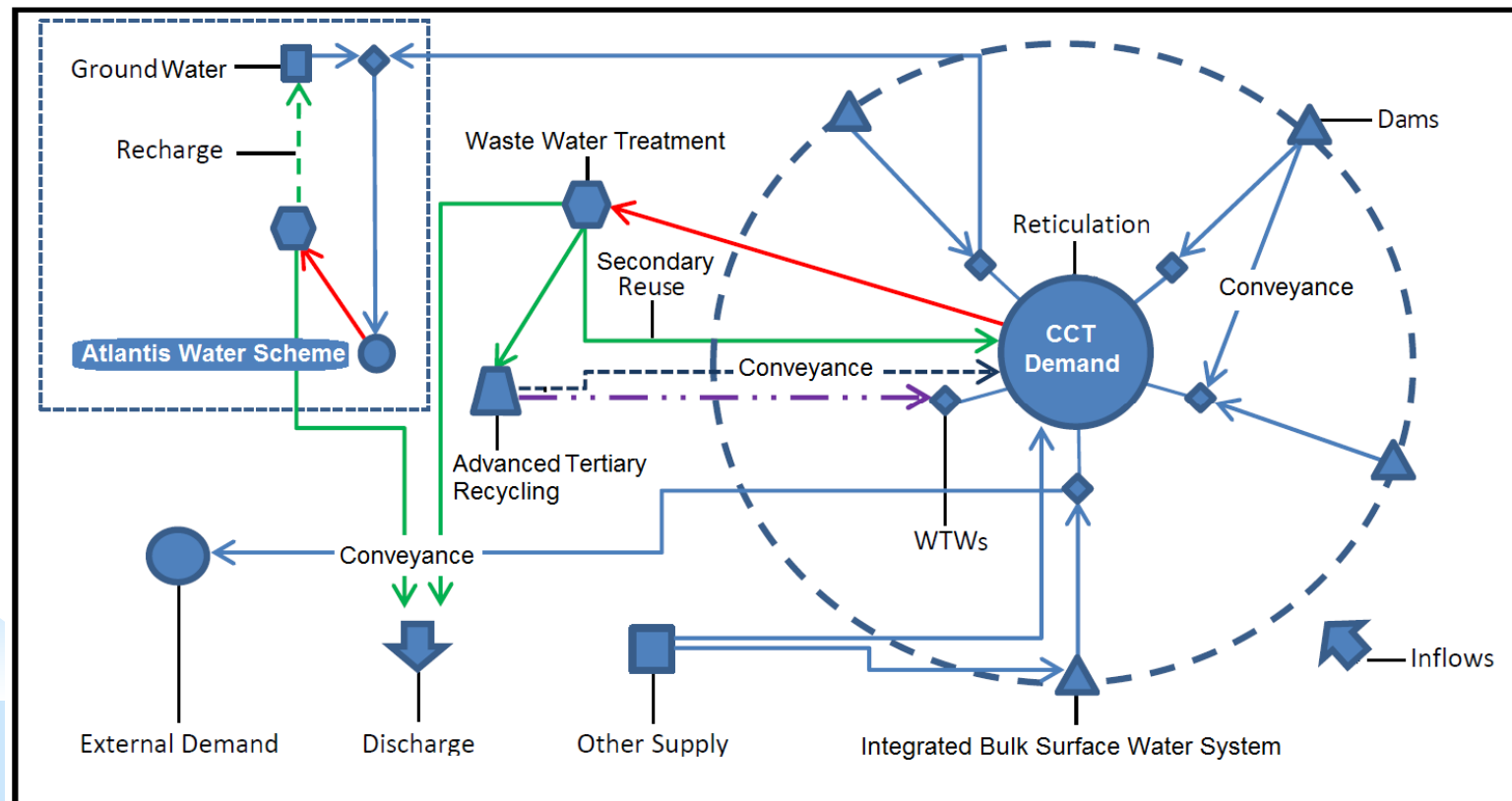
LEAP - CCT model with base year 2006/7

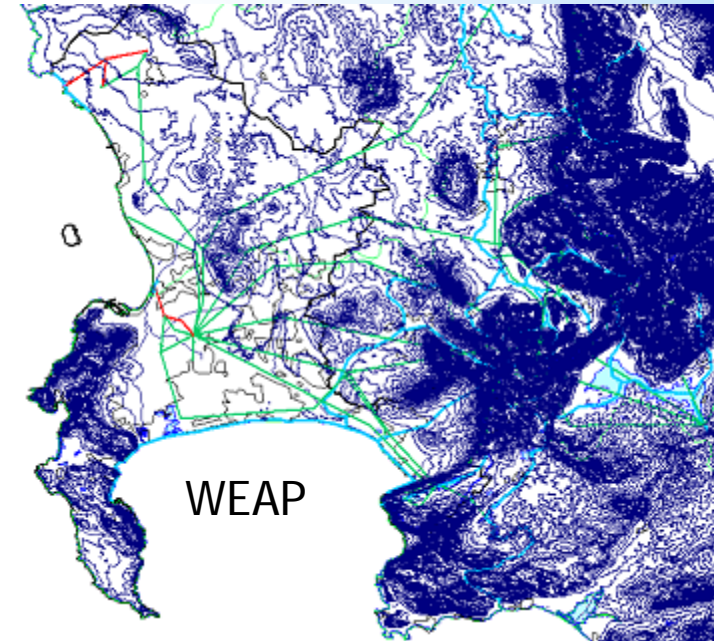
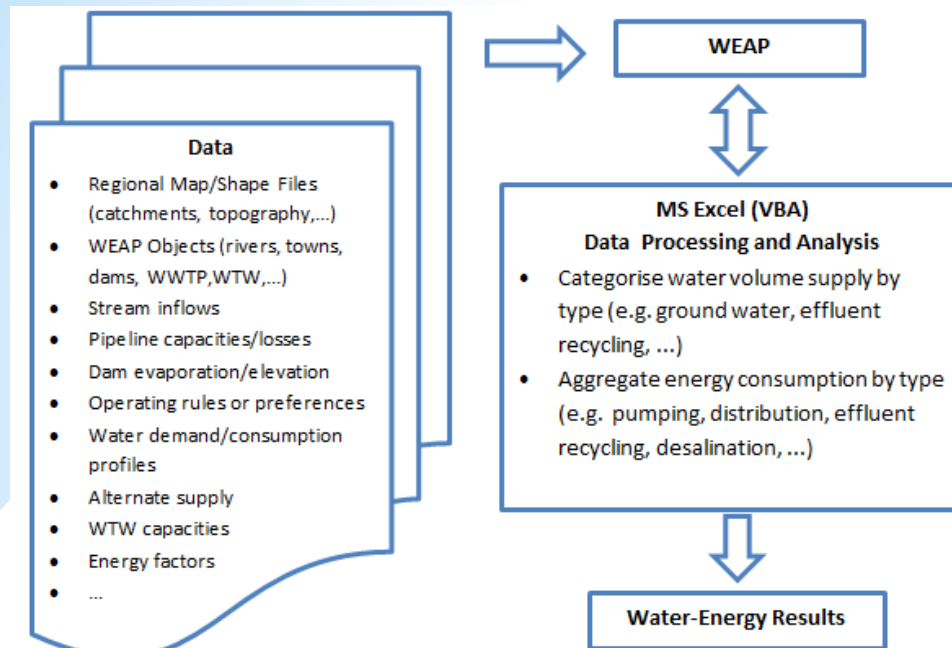
Sector	Disaggregation	End uses
Industry	Food and Bev, Textiles, Other	Process heat , electric end uses
Commerce	none	Lighting, water heating , space heating, HVAC, other
Residential	4 income groups, Electrified and non-electrified in lower 2	Lighting, cooking, water heating , space heating, refrigeration, other
Agriculture	None	Heat, irrigation , traction, electrical processes, other
Government	Street lighting, buildings, Waste water treatment, bulk water supply	Buildings as commercial

Model updates with recent 2011 census data are subject to the availability of student volunteers.

Water modelling: WEAP

Has focused on : exploration of the **energy consumption** for water and sanitation services for the City of Cape Town (CCT) with an emphasis on **water supply augmentation** options for the near future (2011-2030).





* Energy factors attributed to each stage of the urban cycle and summed by water transmission path according to:

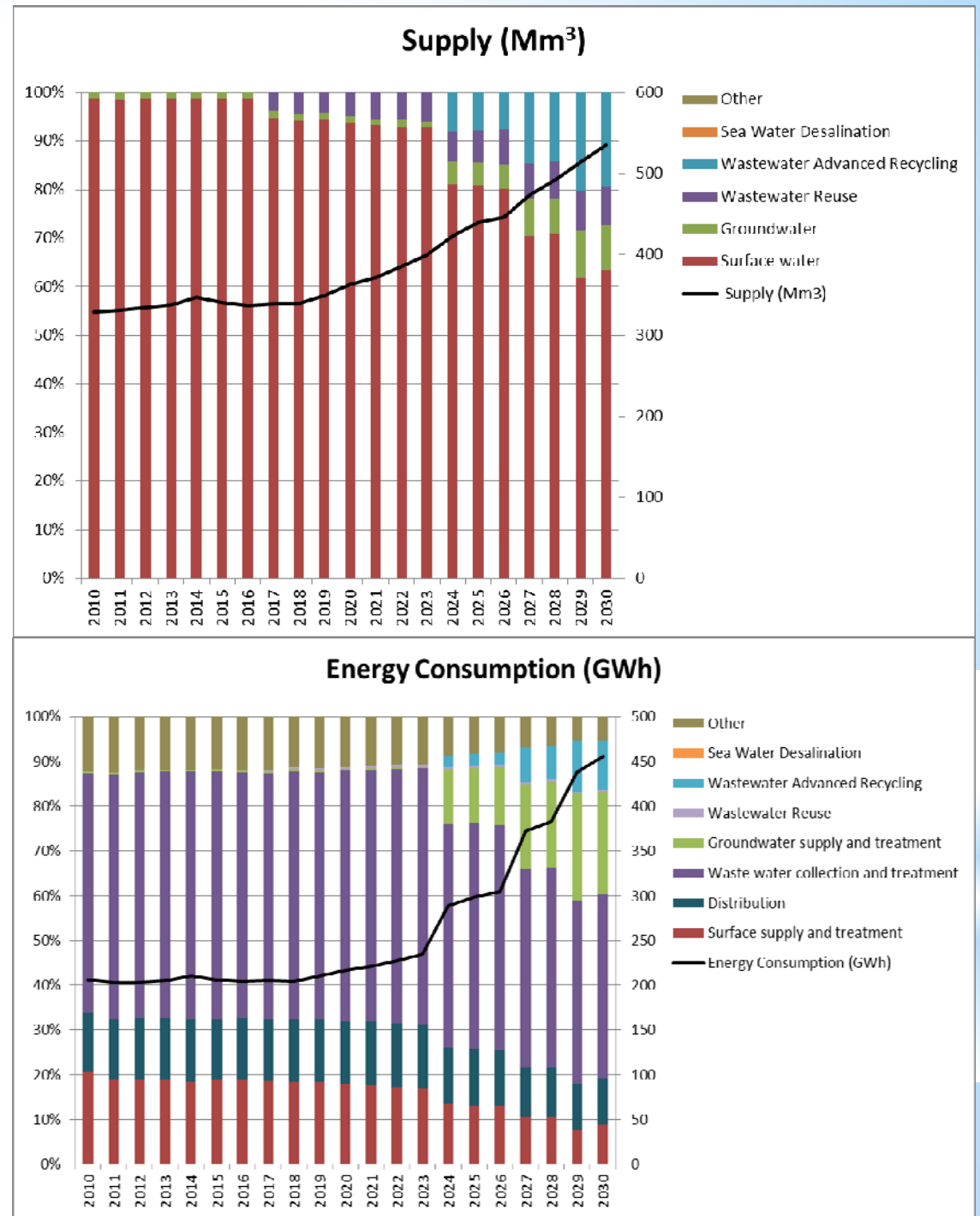
$$E(kWh) = \sum_{k=1}^n e_k s_k$$

* Energy data collated and categorised by stage (e.g waste water collection and treatment)

* Energy factors largely obtained from literature where topography and application were similar, empirical data and calculations (e.g. water conveyance pumping energy)

Sample Modelling Results: Timeline of Water Supply Portfolio and Associated Energy Consumption

- * The modelling process allows for: the examination of a mix of water supply options; and the associated energy consumption for the different stages for the urban water cycle.
- * For example, a scenario depicting an intervention orientated towards effluent reuse and recycling is illustrated.
- * In this case, by 2030, 20% of water supply is obtained from the advanced recycling of effluent with a further ca. 10% from the reuse of secondary treated effluent. Ground water also contributes 10% of supply.



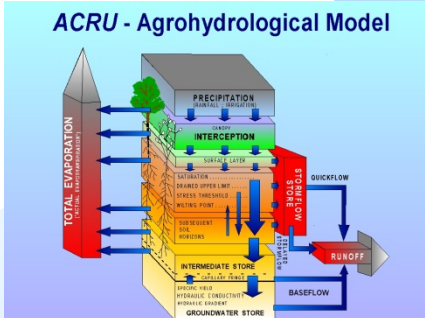
Modelling Implications

- * High growth in demand for water of ca. 3% per annum would require, in addition to WC/WDM measures, alternative water supplies.
- * This will result in an increase in energy intensity for water services in CCT with sea water desalination (SWD) potentially the most intensive (~70 % greater over the period than the reference “do nothing” case) with effluent recycling and additional surface water schemes the least (~20% - 30% greater).
- * The intervention that emphasises effluent recycling is comparable to the SWD schemes with regard to supply and dam storage but exhibits a lower urban water energy intensity. The energy intensity is 66% of that for the SWD interventions for the period 2011-2030.
- * Additional surface water schemes increases the vulnerability of the supply system to the impact climate on inflows to the dams while effluent recycling is sensitive to the volume of return flows.
- * Effluent recycling is a form of water conservation and therefore has greater applicability for the high growth scenario.
- * The SWD interventions provide improved security of supply at the cost of increased energy consumption.
- * Low growth in water demand of ca. 1% per annum with a concerted WC/WDM programme would require no additional supply interventions for the near future (2030).

Climate modelling

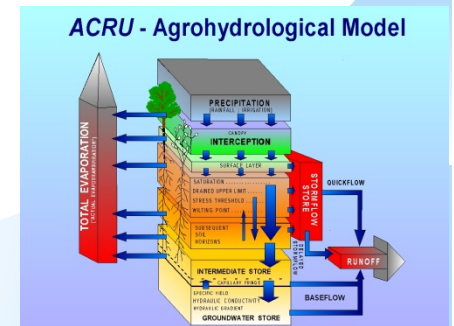
- * Climate Systems Analysis Group located at UCT performs regional climate modelling:

Managing climate risk for agriculture and water resources development in South Africa: Quantifying the costs, benefits and risks associated with planning and management alternatives (Louw et al. 2012).
- * Downscaling of the GCMs with the incorporation the ACRU agrohydrological modelling system. The ACRU model was developed locally for agricultural and water resource planning in KwaZulu Natal in the 1970s.
- * Revised modelling suggested that evaporation in the Berg and Breede catchments, in the near future (2011-2030), is unlikely to change whereas an increase of up to 10% is expected in the distant future (2046-2065).



The diagram illustrates the ACRU - Agrohydrological Model, a complex system for simulating water flow and storage. It shows a vertical cross-section of the land and subsurface. At the top, precipitation falls onto a canopy layer, followed by interception. Below this is the surface layer, which leads to infiltration. The model includes several storage components: a surface store (representing water on the ground), an intermediate store (representing water in the soil profile), and a groundwater store (representing water in the aquifer). Arrows indicate the movement of water between these stores and the atmosphere (evaporation and transpiration). The model also accounts for runoff, which is split into quickflow (surface runoff) and baseflow (groundwater discharge). The diagram is color-coded to represent different layers and processes, with a legend on the right side.

- Managing climate risk for agriculture and water resources development in South Africa: Quantifying the costs, benefits and risks associated with planning and management alternatives (Louw et al. 2012).*
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- ACRU - Agro



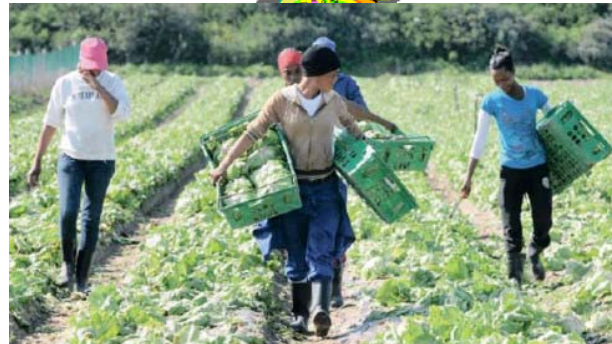
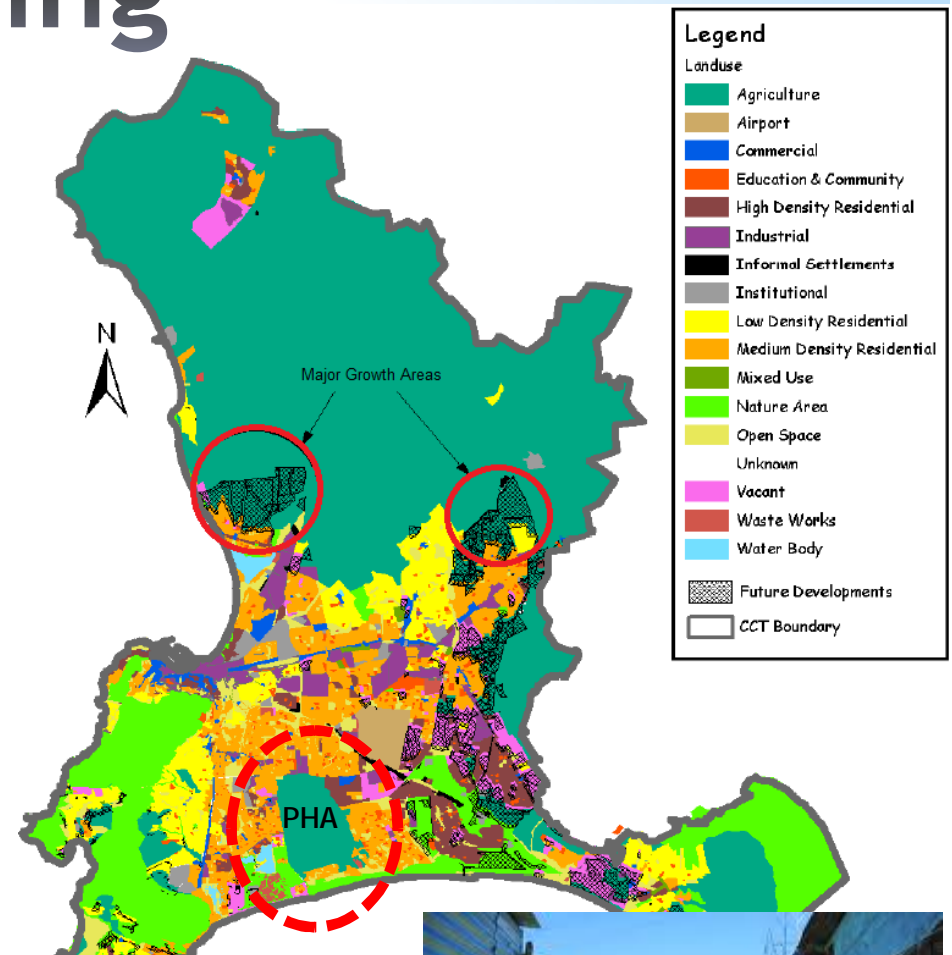
Land-use modelling

Initial focus on urban agriculture within Cape Town.

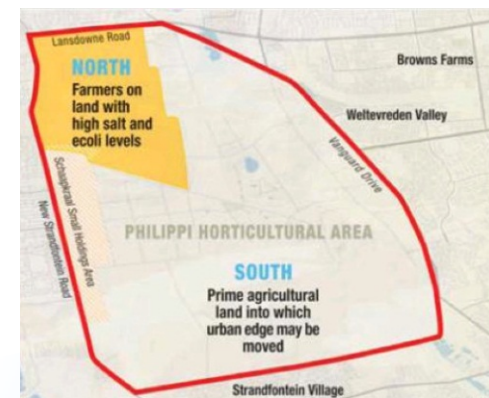
Project proposal: The Philippi Horticultural Area (PHA)

Examining CLEW tradeoffs in the context of urban food security vs low cost housing in the City of Cape Town.

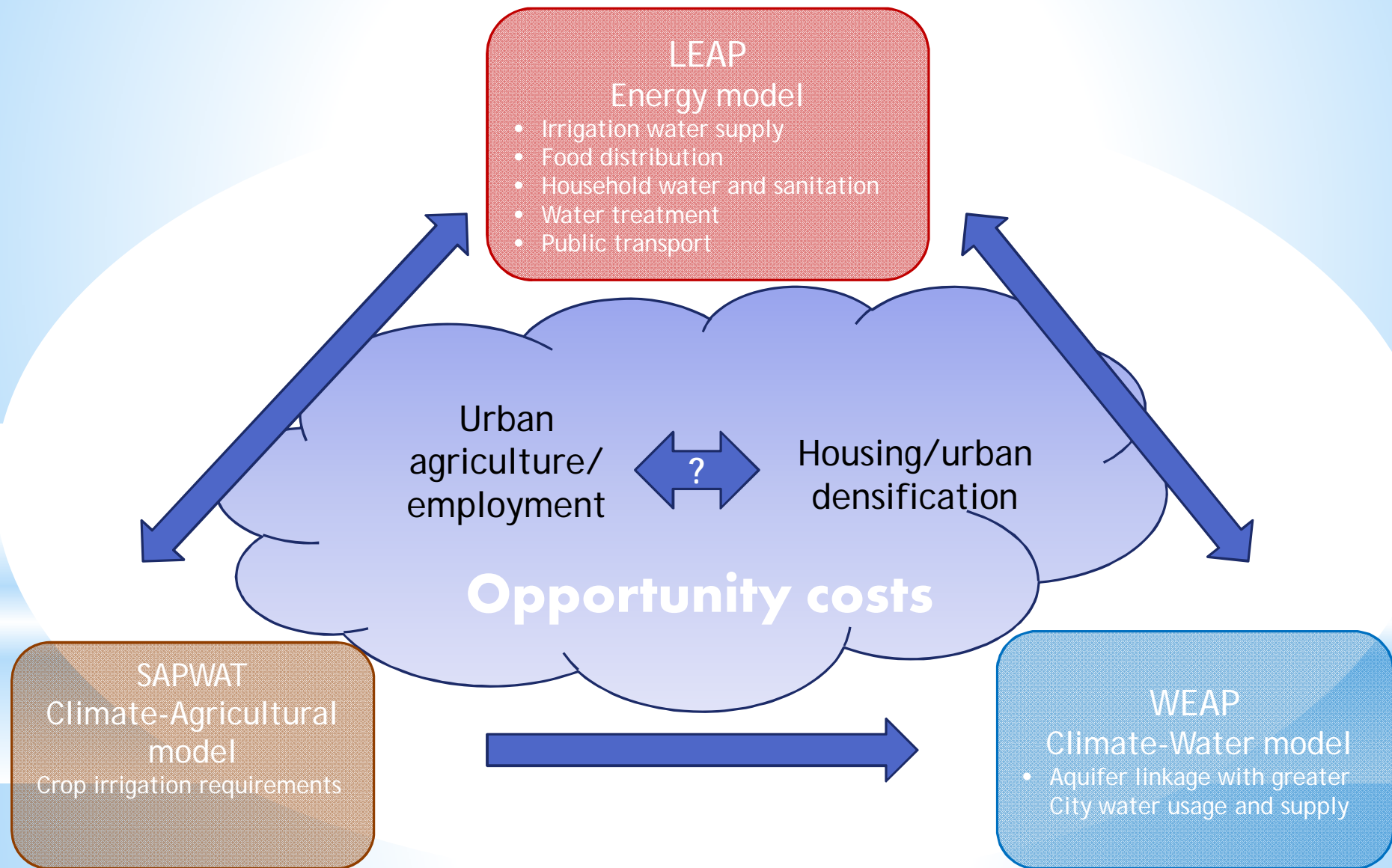
“The rapid growth of the City is associated with the urbanisation of poverty”



- The PHA covers an extent of 3000 ha with ~ 40% lying fallow.
- Provides 50%-70% of the City's vegetable produce via large retail outlets and direct sales to poor households.
- ~100 000 tonnes of fresh produce is grown in the PHA annually. This includes an estimated figure of over 2 000 tonnes of produce that is given free to farm workers in a year.
- 15-18 permanent low skilled labourers per 10 ha of vegetable production.
- Main supply of water is groundwater from the Cape Flats primary aquifer which is co-located.
- Water usage from aquifer estimated at between 5-19 Mm³/a.
- Water quality of aquifer varies from "poor" in the northern area - due to concentration of light industry and agricultural activity - to "good" in southern region where there is pressure to convert agricultural land to low income housing with full water and sanitation services.



PHA: CLEW project concept



PHA: CLEW project concept

SAPWAT is extensively applied in South Africa and was developed to establish a decision-making procedure for the estimation of crop irrigation requirements by irrigation engineers, planners and agriculturalists.

The irrigation requirement of crops is dominated by weather, particularly in the yearly and seasonal variation in the evaporative demand of the atmosphere as well as precipitation.

SAPWAT3 contains 50 years' daily weather data for each quaternary drainage region of South Africa, as well as the full set (3262 weather stations) of monthly CLIMWAT weather data (FAO Irrigation and Drainage paper 49).

<http://sapwat.org.za/>

The PHA CLEW concept proposes to examine the opportunity costs of land use change on the City's energy, water and land requirements for alternative scenarios:

- * Agricultural vs household water demands and the energy requirements for each alternative. That is, the resource impacts of relocating agricultural activity or housing development.
- * Urban densification vs food security for low income households.
- * Competition for groundwater from other sectors:
 - A potential municipal water scheme exploiting the aquifer;
 - City's potable water demand management programme encourages borehole abstraction from water customers.
- * PHA exists where the majority of the City's water and sanitation assets are located and where the predominantly gravity fed reticulation system can be exploited for potable water supply. Developments on the periphery may require increased water and sanitation pumping demands the northern growth corridor.
- * The housing alternative is well place to exploit the implementation the second phase of the City's BRT system reducing demand for private vehicle travel.
- * Potential pollution of the aquifer from neighbouring industrial growth and intensive non-optimal agricultural activity as future source of potable supply.

Other CLEW projects

*WORLD BANK

Energy-water nexus initiative: case study for South Africa.

Phase 1 underway incorporating regional water supply cost curves for the power sector in the ERC's South African TIMES (SATIM) model.

*BELMONT FORUM (PROPOSAL)

To use the existing SATIM energy system modelling framework to investigate the potential of biofuels to improve energy security and mitigate GHG emissions under water and land use constraints.

- Research biofuel crop characteristics and sites
- Model biofuel feedstock as primary sources
- Model production facilities
- Develop water supply cost curves for biofuel production zones
- Add land as a commodity to model and link to biofuel production
- Develop scenarios with land and water constraints

The end. Thank you.

