The Abdus Salam International Centre for Theoretical Physics

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Joint ICTP-IAEA Workshop on Uncovering Sustainable Development CLEWS; Modelling Climate, Land-use, Energy and Water (CLEW) Interactions

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An integrated case study of Mauritius

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Seeking CLEWS
Climate Land Energy Water Strategies

An integrated case study of Mauritius

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International Atomic Energy Agency

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- Introduction
- Background information on the climate, land, energy and water resources + policy measures
- Challenges facing Mauritius
- Aim of the case study
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- Different scenarios used
- Main findings
- Conclusion & next steps

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Introduction

Mauritius – pioneer for testing of CLEW modelling tool

- Small island with clear boundaries
- Producer and exporter of sugar (occupying 80 % cultivated land area)
- Dependent on fuel imports for its energy requirement
- Highly vulnerable to climate change
- Data availability

- Government vision for making Mauritius a sustainable island (MID policy) focussing on reducing dependence of fossil fuel and reducing GHG emission

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Background information

Mauritius is a small island (1865 km^2) with a middle-income economy

	% of GDP (2009)
Agriculture	5
Services& Tourism	68
Industry	27

Volcanic origin

Population 1.2 M

Population growth rate 0.9 %

Vulnerable to climate change –
cyclone , drought , heavy precipitation

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Mauritius - Background

Climate

Rainfall: 600 mm to 4000mm depending of elevation (0 - 828m) and position relative to the prevailing wind

2 seasons

Summer (Nov – April), rainier

Winter (May – Oct), cooler and dryer

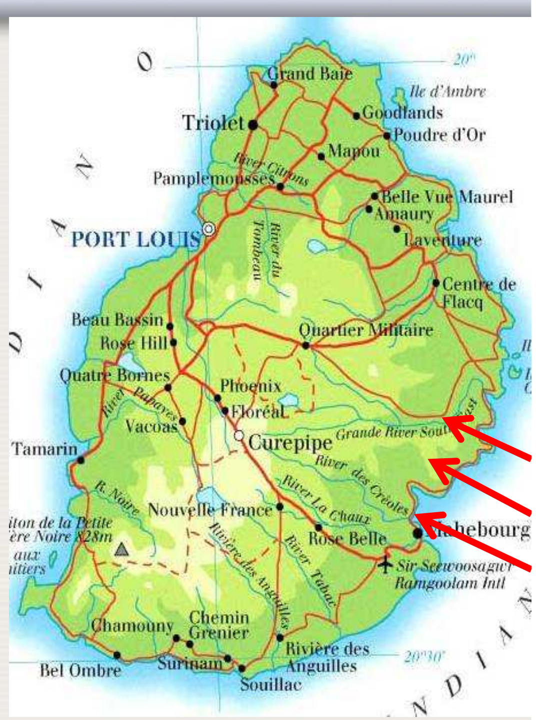
Average annual temperatures range 20 - 25 °C

Weather pattern is changing

7 out of 12 years declared as drought years

Recorded trend of a drop of 8 % of rainfall over past 30 years

Sugar cane suffering from water stress in North and west, requiring irrigation and thus increasing energy demand for water pumping



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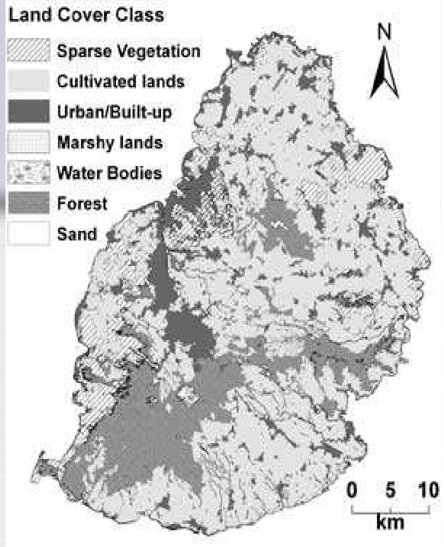
Land Use in Mauritius

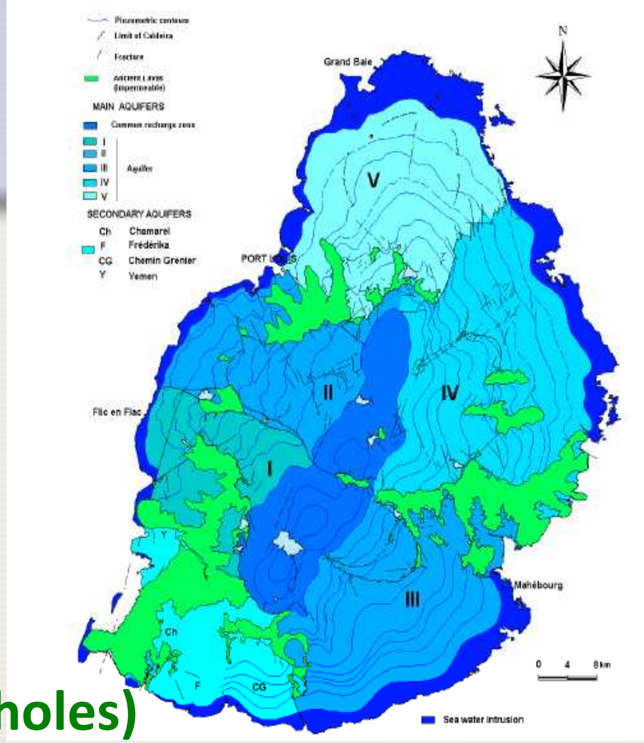
- Land area 186,500 ha - 57 % is cultivated
- Major crop - Sugar cane occupying 85 % of the cultivated area
- Reform of the sugar sector Following the EU sugar reform / 36 % drastic reduction in sugar price

-Regrouping small planters and intensification
-Diversifying for foodcrop for food security
-Ethanol production (Target 30 M litres by 2015 to replace gasoline)



- Limited land area, high pressure on agricultural land with increase in housing, infrastructural development and expanding tourism industry

Mauritius – Water sector



➢ **Average rainfall – 2100 mm per year**

Evapo-transpiration loss	**30%**
Surface runoff	**60 %**
Groundwater recharge	**10%**

Freshwater sources:

- **Surface water- Rivers (92) and reservoirs**
- **Ground water – 5 main aquifers (360 boreholes)**

➢ Groundwater supplies 50 % of the Domestic supply and 5 % for agriculture

➢ risk of sea water intrusion in case of increasing abstraction on coastal areas

Water Utilisation: 1 014Mm^3 (26 % of total precipitation)

Per capita consumption – 1083 m^3/head/year
Mauritius -classified as water stress country (UNDP)

Domestic, industry and tourism	**22%**
Agriculture	**48 %**
Hydropower	**28 %**

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Mauritius – Energy sector

Mauritius imports 82% of its energy requirement (oil, gasoline, gas, coal (27 %))

- Domestic energy resources (Hydro (6%)and burning of bagasse, a by-product of sugar processing (94%))
- Co-generation (coal and bagasse)at the sugar processing plants covers over 20% of its electricity needs.
- Energy demand increasing at rate of 5 % per year

MID " Maurice Ile Durable" Policy to shift from fossil fuels to "greener" sources of energy

Target 2025 , 35% self sufficiency in terms of electricity supply through use of renewable sources of energy and reduction of carbon emission

Renewable sources: Wind , Hydro, Solar, solid waste and bagasse

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Challenges facing Mauritius

- High and volatile of oil prices
- Dismantling of EU-ACP Sugar Protocol:36% decrease in sugar prices / loss of preferential market access
- Highly vulnerable to climate change and reduced rainfall leading to water scarcity
- High and volatile food prices – food insecurity
- Tourism and textile exports suffering from external factors

- Ensure continued economic development (hotels, IRS, new Industries)
- Achieve an increased degree of self-sufficiency in the energy sector
- Meet increasing water demand from agriculture, industry, tourism and growing urban population

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Despite clear inter-linkages among the resources, sectoral policies are still being developed through isolated policy processes, often leading to failure

Aim of the case study

Considering the policy goals to

- enhance energy security by increasing ethanol production
- ensure water supplies to sustain ethanol production
- maintain sugar exports

the CLEW modelling framework was used to assess the energy, water and land-use system in the context of different scenarios

1. Reduce gasoline imports by producing ethanol, displacing sugar exports

2. Considering different energy system alternatives and land use options (e.g. different crops) under uncertain future dryer climatic conditions (lower rainfall)

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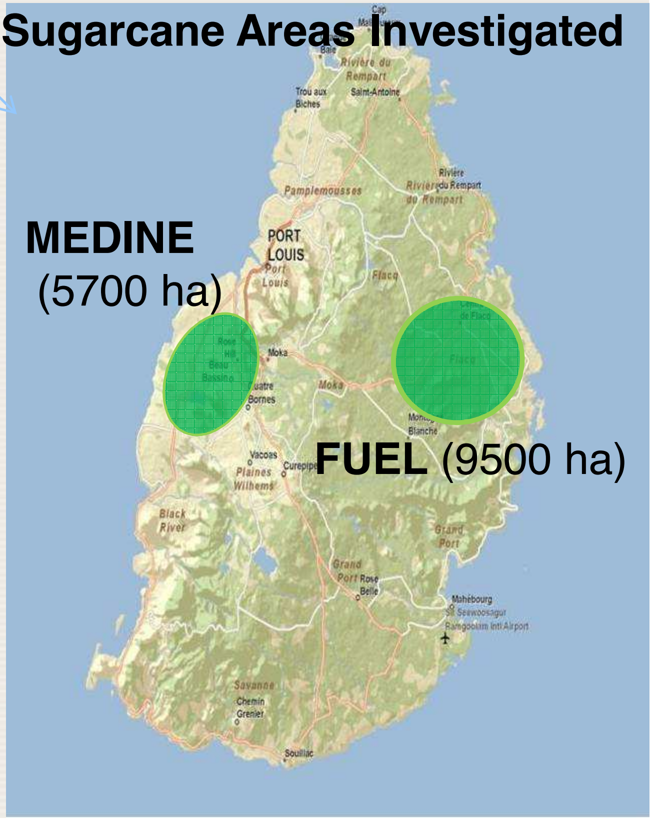
Assumptions

- The base year was 2005 and all scenarios are modelled to 2030
- The long-term oil price was 80 $ /barrel and sugar export market price was 0.42$/kg
- The discount rate was 5 %
- Two sugar processing plants are considered to convert ethanol production:
  - ✓ **West (Medine)** with lower rainfall and water scarcity, but limited electricity output
  - ✓ **East (F.U.E.L.)** with higher rainfall and electricity output



Scenarios Families investigated

BAU: Producing sugar and using waste bagasse for electricity generation

1. Maintaining sugar cane production

1	Converting sugar production to Gen 1 ethanol & electricity production (1st generation)
2	Use new process to increase ethanol yield (sugar cane used for Gen 1 ethanol production and bagasse used for Gen 2 (2nd generation) ethanol production)

2. Securing water supplies in a dryer future

A	**Maintain cane yields for sugar**
B	**Maintain Gen 1 ethanol production from sugar**
C	**Considering an alternative crop**

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Scenarios- summary

Characteristic	Cane to Sugar	Cane to ethanol (1st Gen)	Cane to ethanol (2nd Gen)	Alternative crop - ethanol
“Normal Rainfall Scenario”	BAU	1	2	
Water-stress scenarios	A	B		C

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Methodology

1. Development and calibration of water, energy and land use model using 10 years data (1996- 2005)
   - WEAP- water
   - LEAP - energy
   - AEZ – land production planning

2. Selective integration of the different models using common assumptions and "soft" linkages to calculate:
   - What are the changes in total costs?
   - What are the influences to the local water balance?
   - How chenges the local energy balance?
   - What are local and externally induced GHG emissions?

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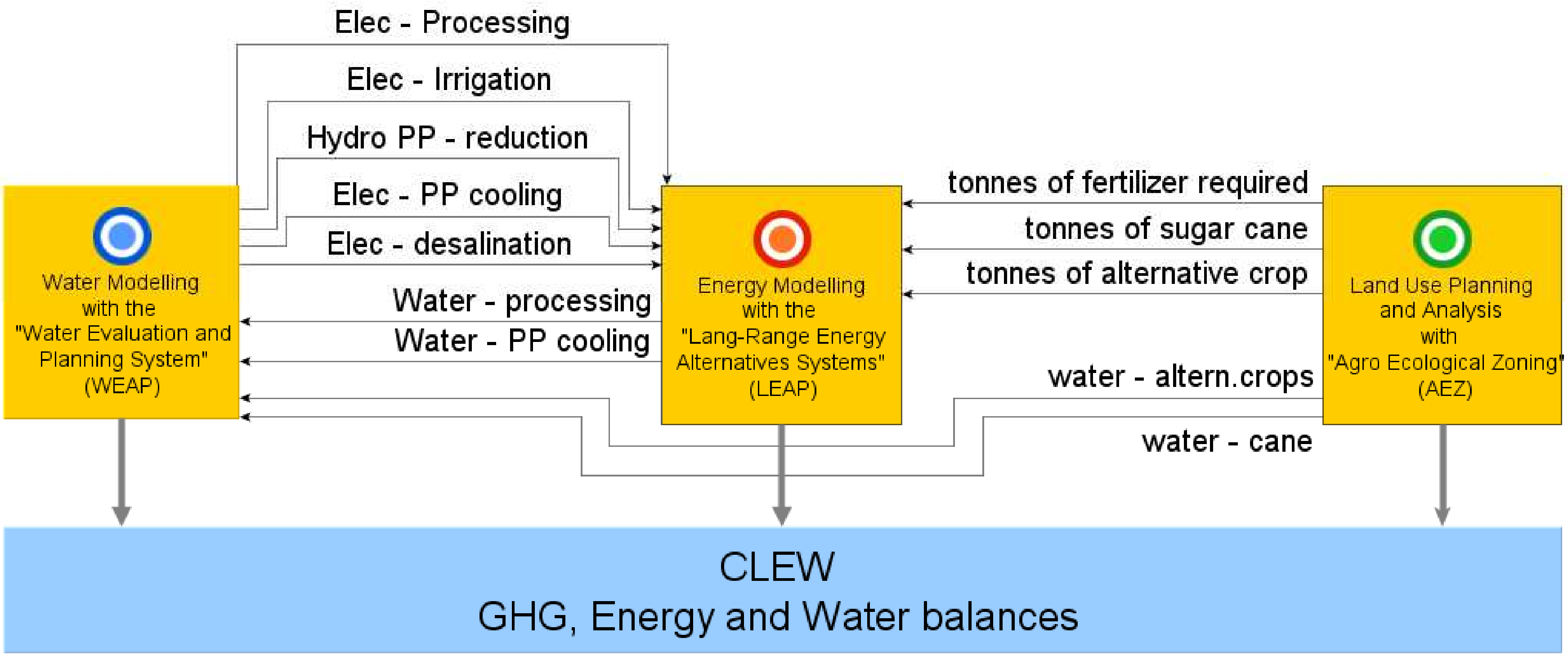
Model interactions



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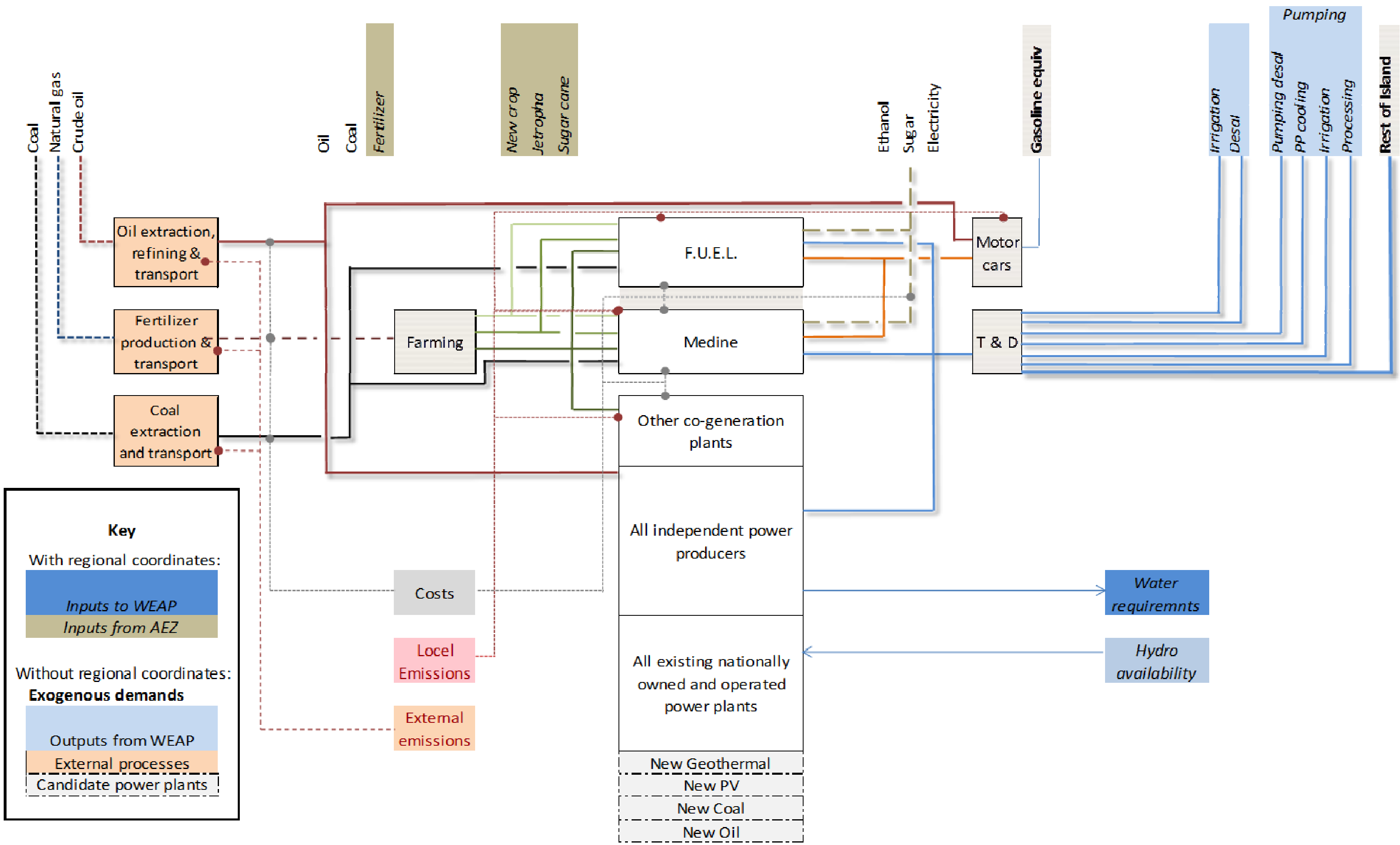
Detailed individual system models...

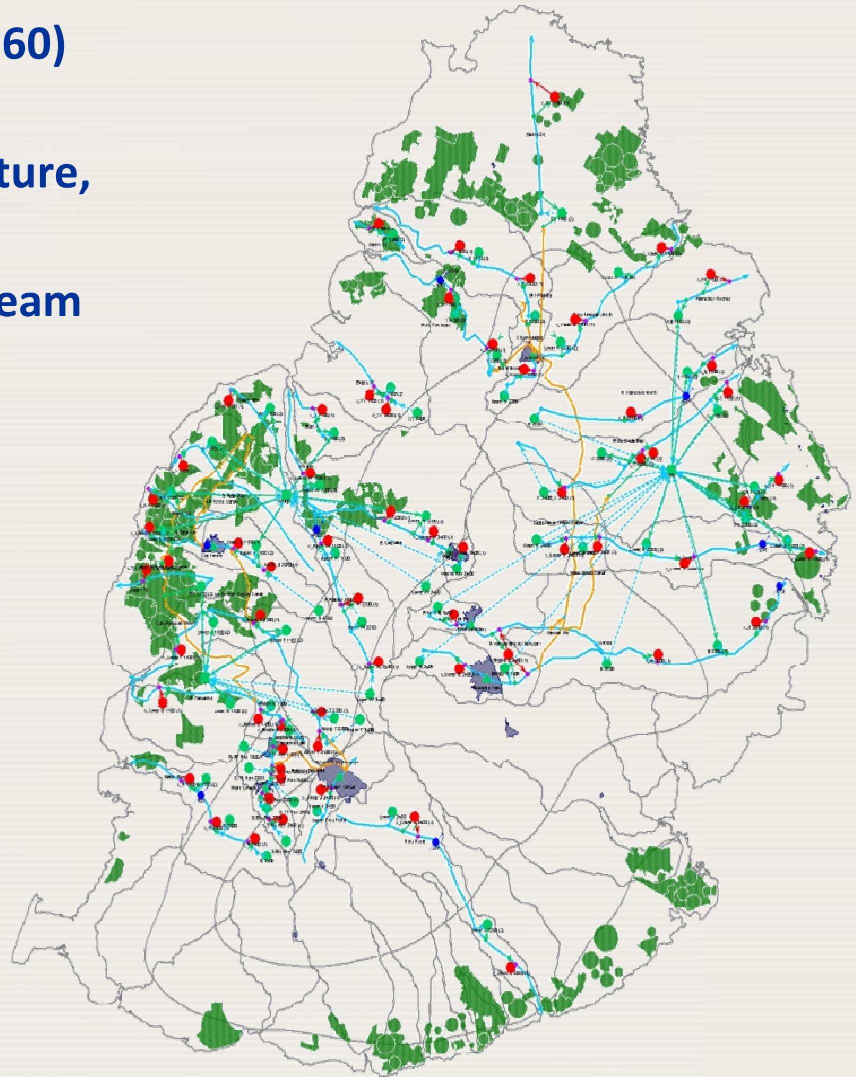


The Water Model …

Water
Evaluation
And
Planning

WEAP

- Definition of all Catchement areas (60)
- Real Climatic Data (1996 – 2005):Rainfall, min & max temperature, humidity ….
- All main rivers & reservoirs plus stream flow data and reservoirs levels
- Modelling of existing canals / distribution systems
- Using GIS: land cover classes to calculate evapotranspiration
- Water Demand data (urban and agricultural) according to national statistics and population density



Result: Water availabilty for each point in the system

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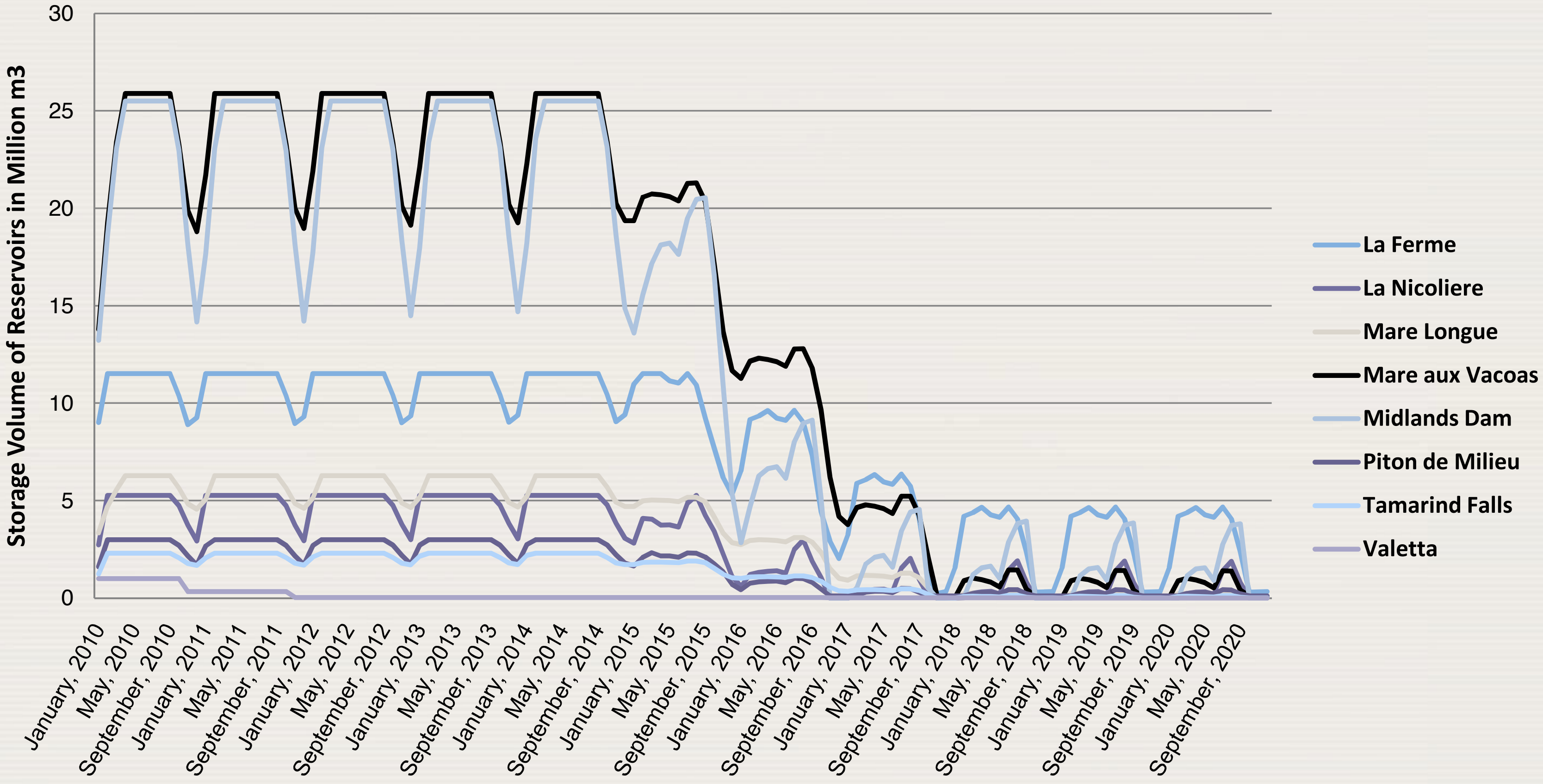
Results – Scenario B (40% rainfall reduction): Reservoir levels



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The Energy Model ...

Input Data:

- **Supply:**
  - All existing and planned power plants (capacities and plant factors)
  - Hydropower Plants and monthly production
  - Potential renewable energy targets
  - Energy production from bagasse
  - Oil and Coal imports
  - In the Scenarios: 1st & 2nd generation from biomass plus bioethanol production
- **Demand:**
  - from national statistics and official projections, assumptions for pumping water and desalination
  - Demand for ethanol production from sugar cane (1st and 2nd gen.)
  - Energy needs for fertilzer production

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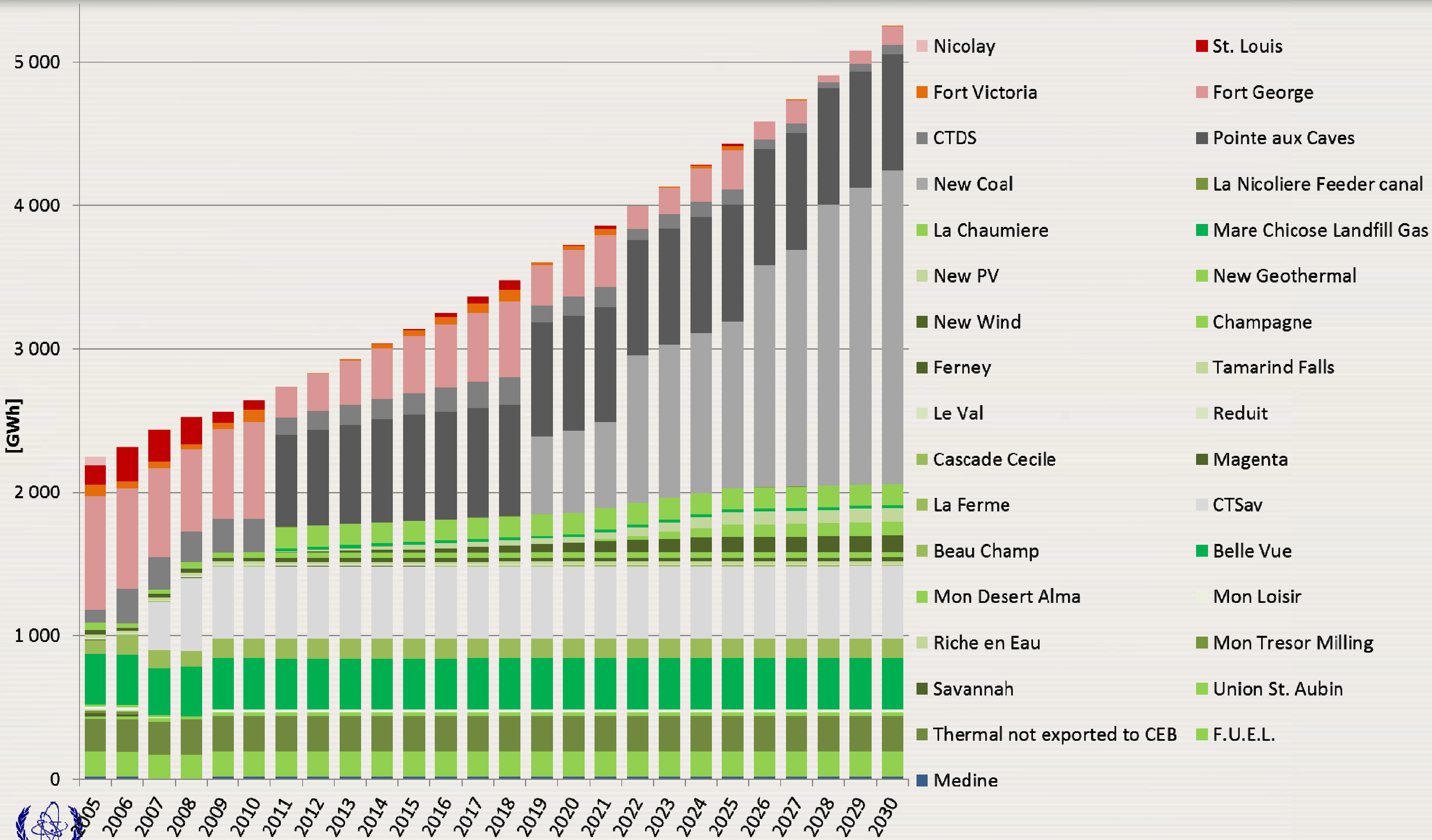
Results of the Business as Usual Scenario (BAU)



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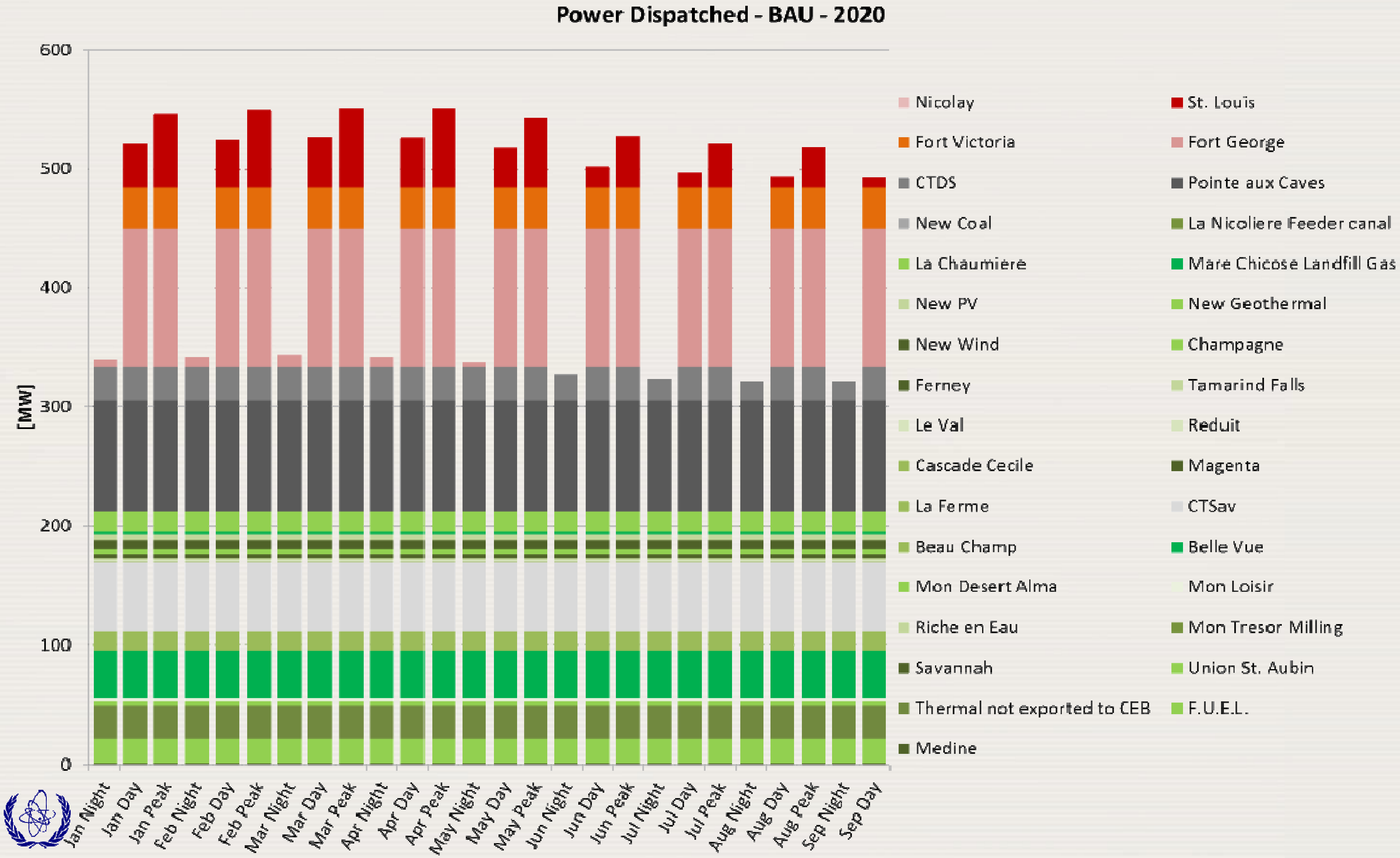
Results of the Business as Usual Scenario (BAU) - II



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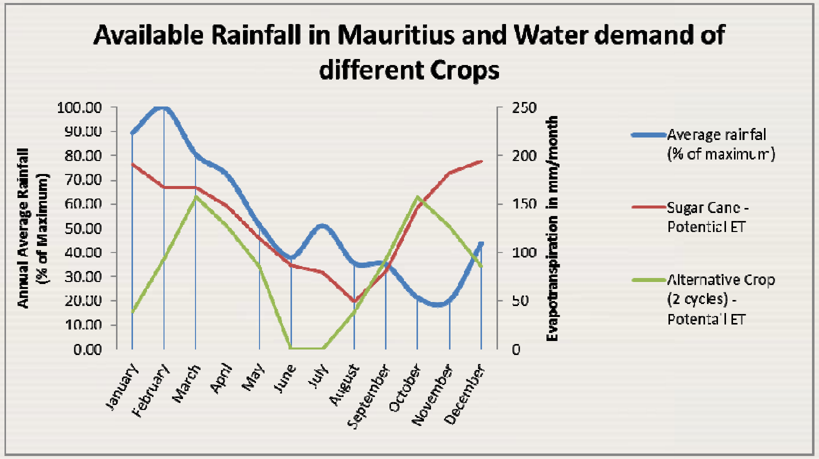
The Land Use Model ...

- **Input:**
  - **Climatic Data**
  - **Detailed soil map and data from soil profils**
  - **Slopes and marginal land**
  - **GIS data for landcover**
  - **Irrigated areas**
- **Output:**
  - **Grid map of Mauritius show optimal crops, potential water use, and potential yield**
  - **Crop calendar**



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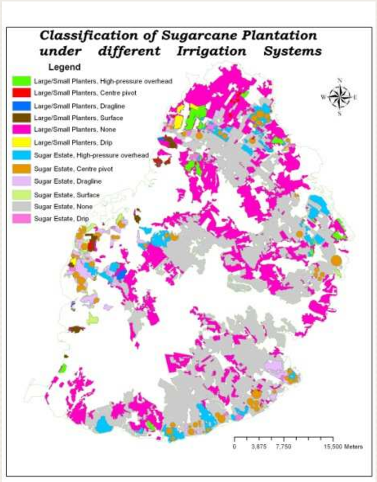
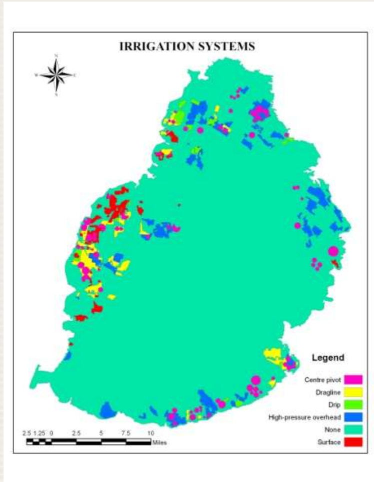
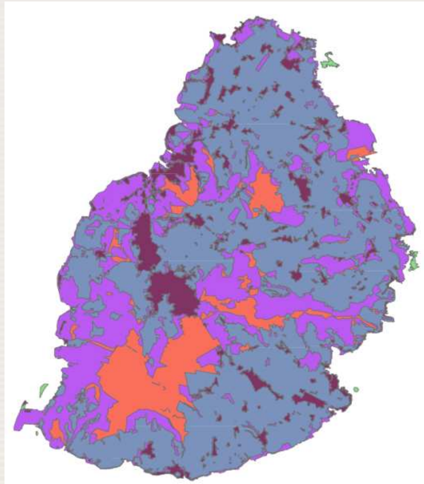
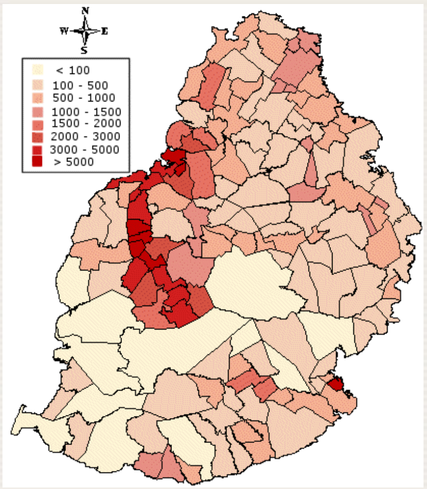
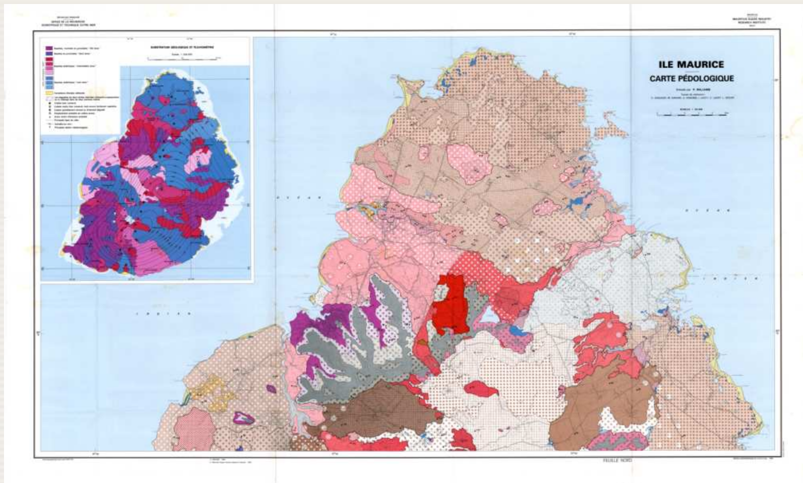
Maps used for AEZ ...





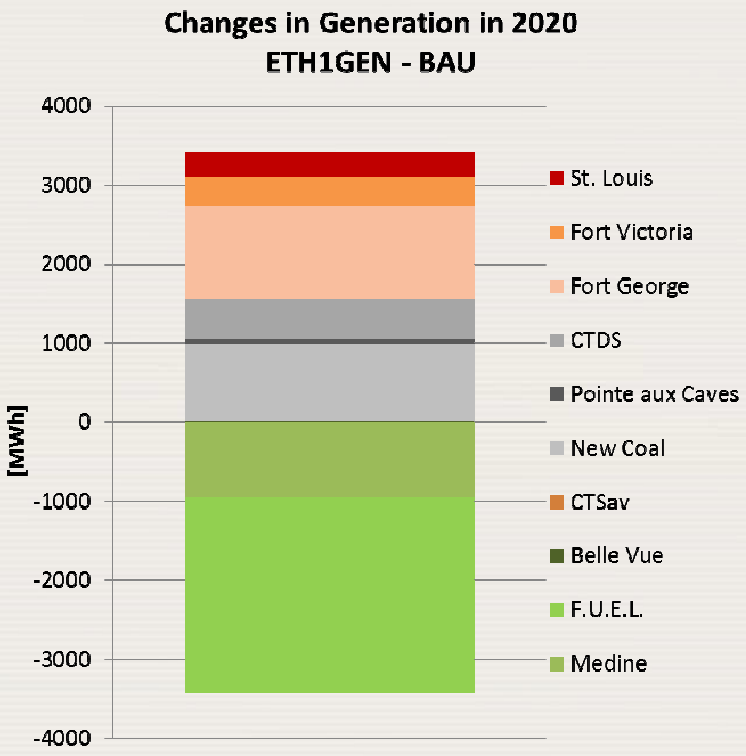


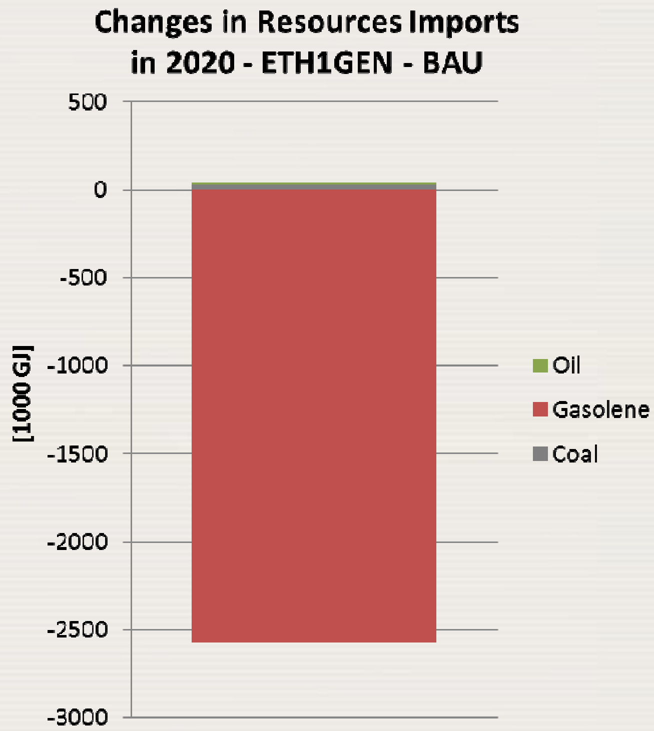




Results ..

Results – Scenario 1 (Ethanol 1st Gen.) - I





Produced Ethanol mainly used as transport fuel, leading to reduced oil import and ...

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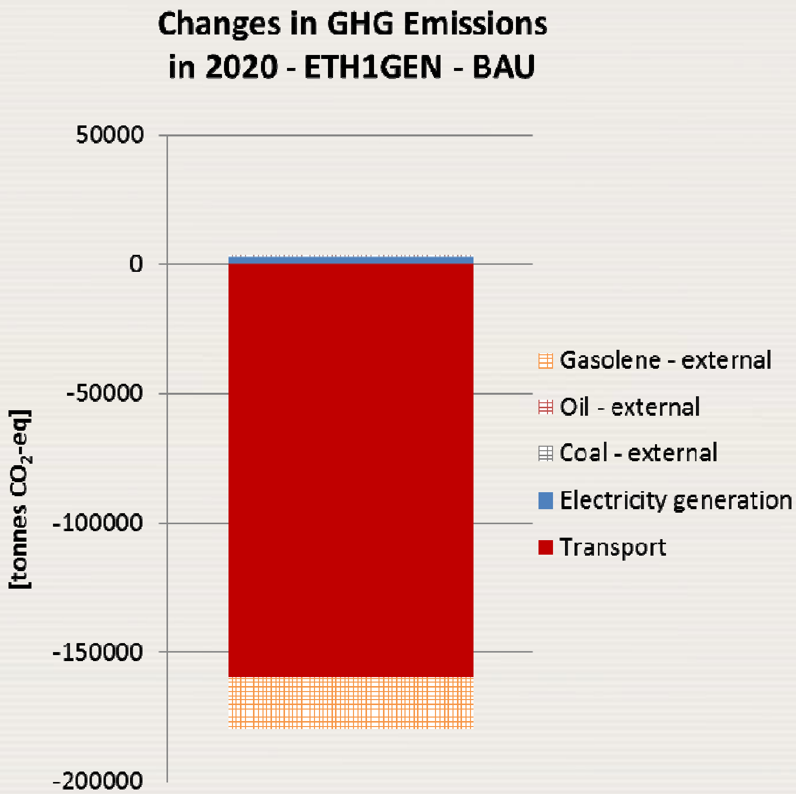
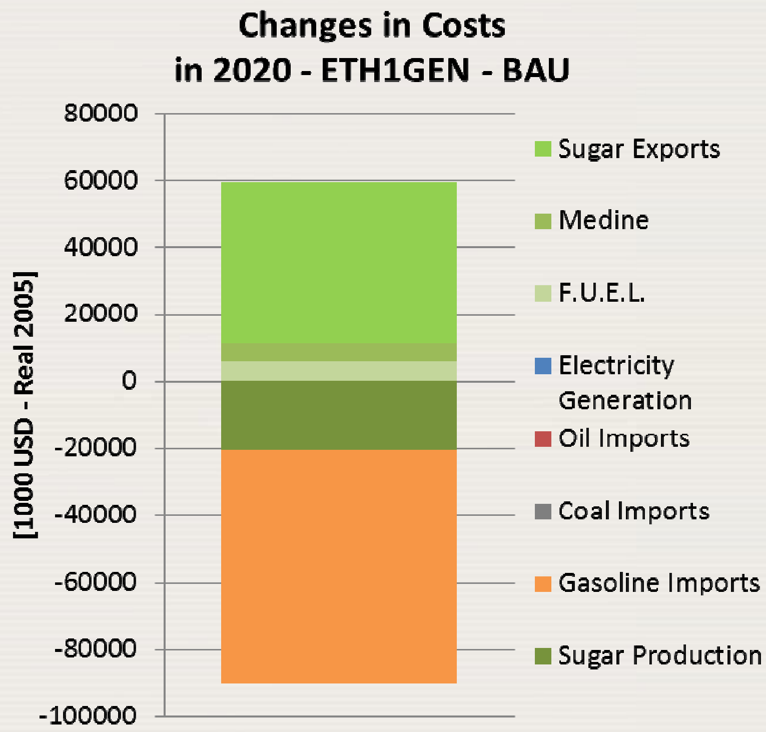
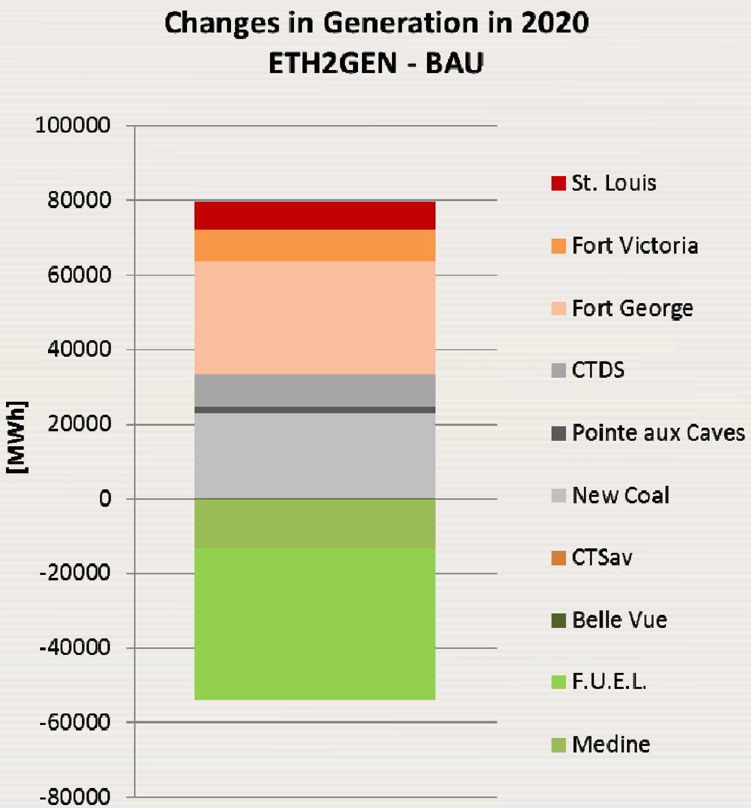
Results – Scenario 1 (Ethanol 1st Gen.) - II

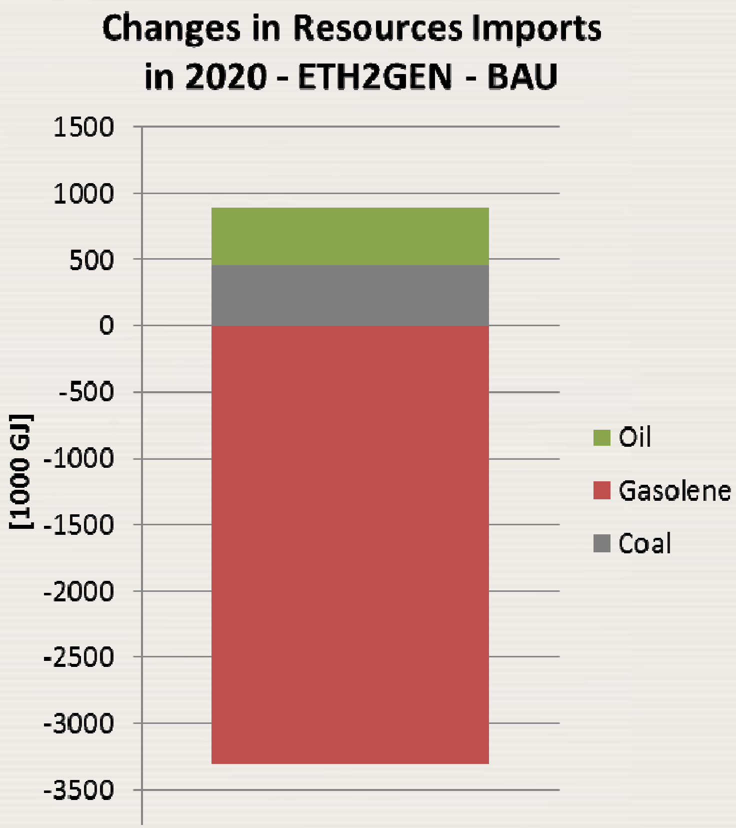




Produced Ethanol mainly used as transport fuel, leading to reduced oil import and reduced GHG emission in the transport sector.

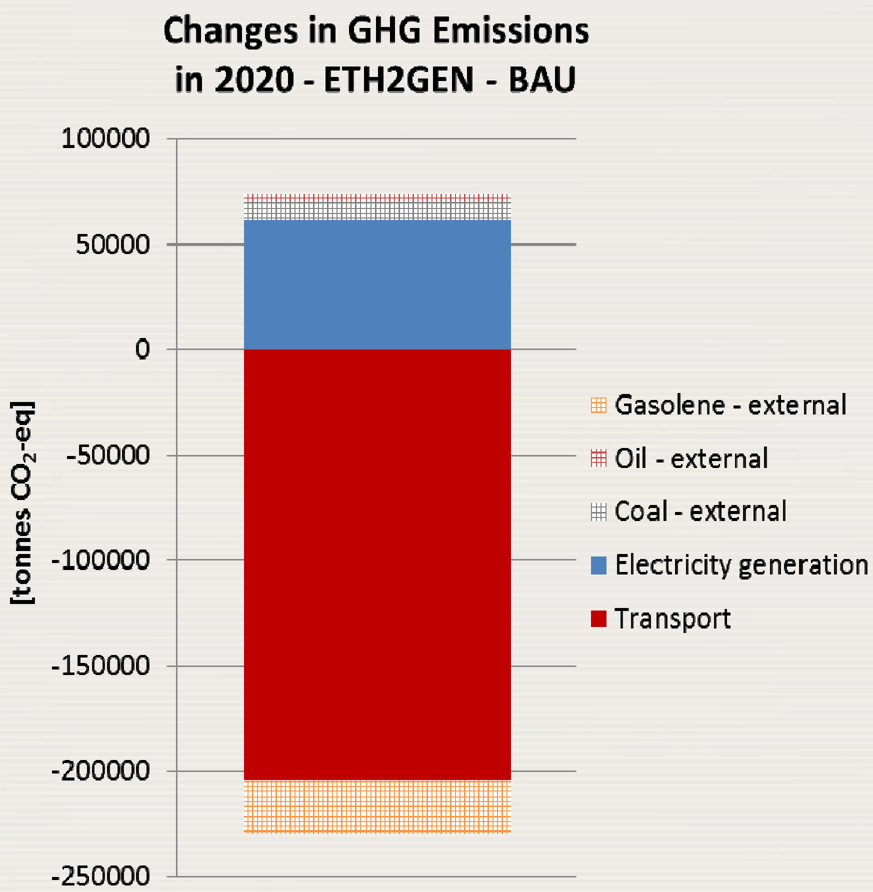
Results – Scenario 2 (Ethanol 2nd Gen.) – I

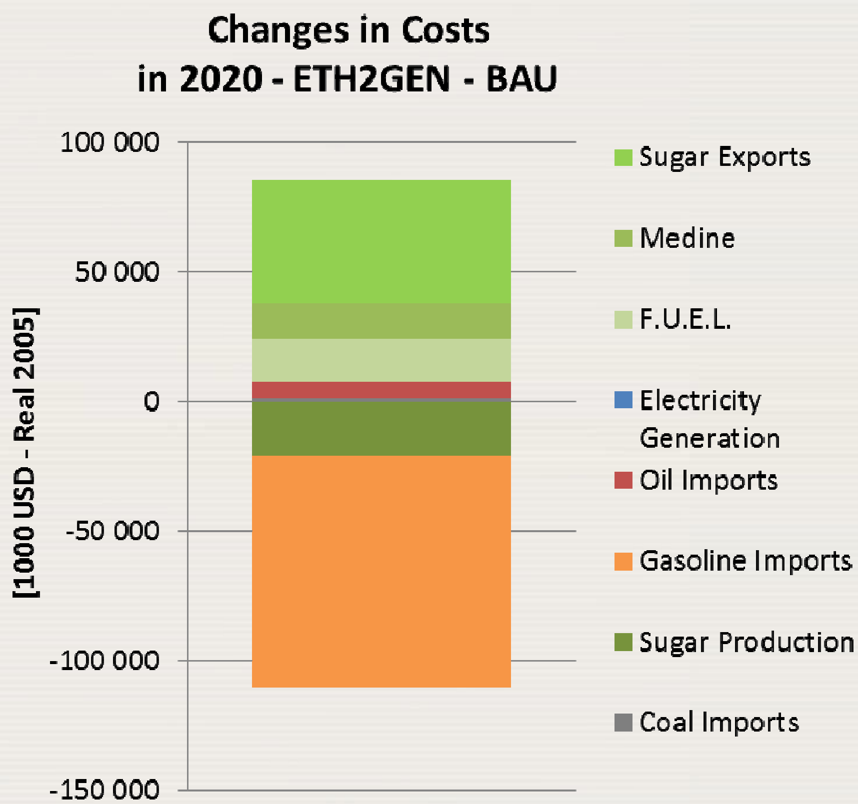




Much higher generation from coal (displacing bagasse). Lower gasoline imports offset by coal and oil imports for electricity generation.

Results – Scenario 2 (Ethanol 2nd Gen.) – II





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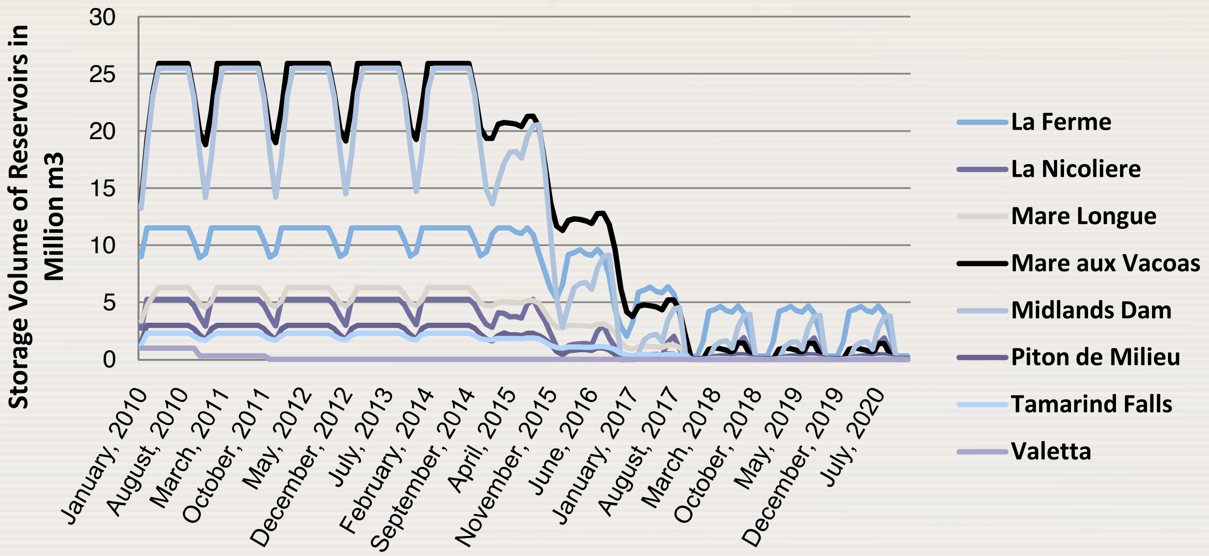
Much higher generation from coal (displacing bagasse). Lower gasoline imports offset by coal and oil imports for electricity generation.

Results – Scenario B (40% rainfall reduction)

- We assume a worst case scenario: What would happen when rainfall is reduced by 40%???
  - Where are water shortages?
  - Is desalination a solution? How much energy do we need?
  - Is groundwater pumping an option and what would be the required pumping energy?



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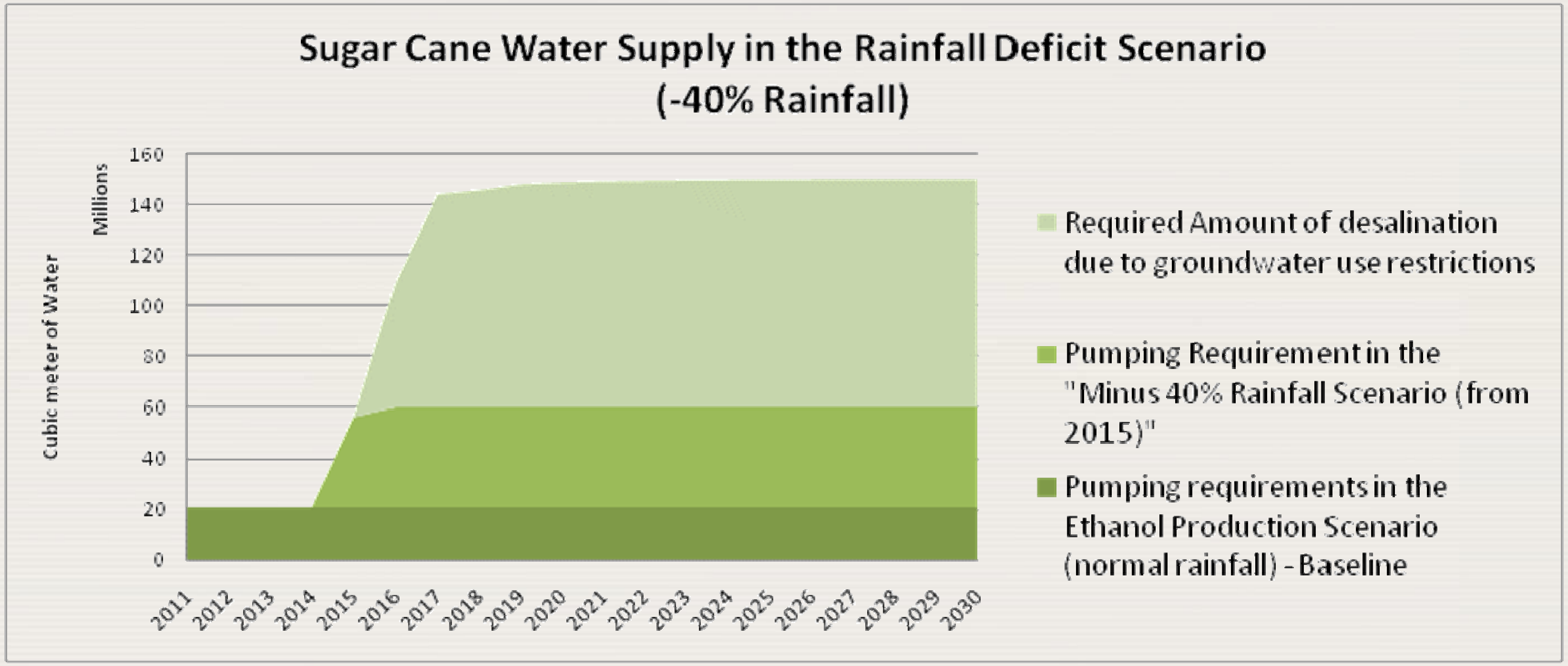
Results – Scenario B (40% rainfall reduction): Increased pumping demand

- Desalination and pumping requirements



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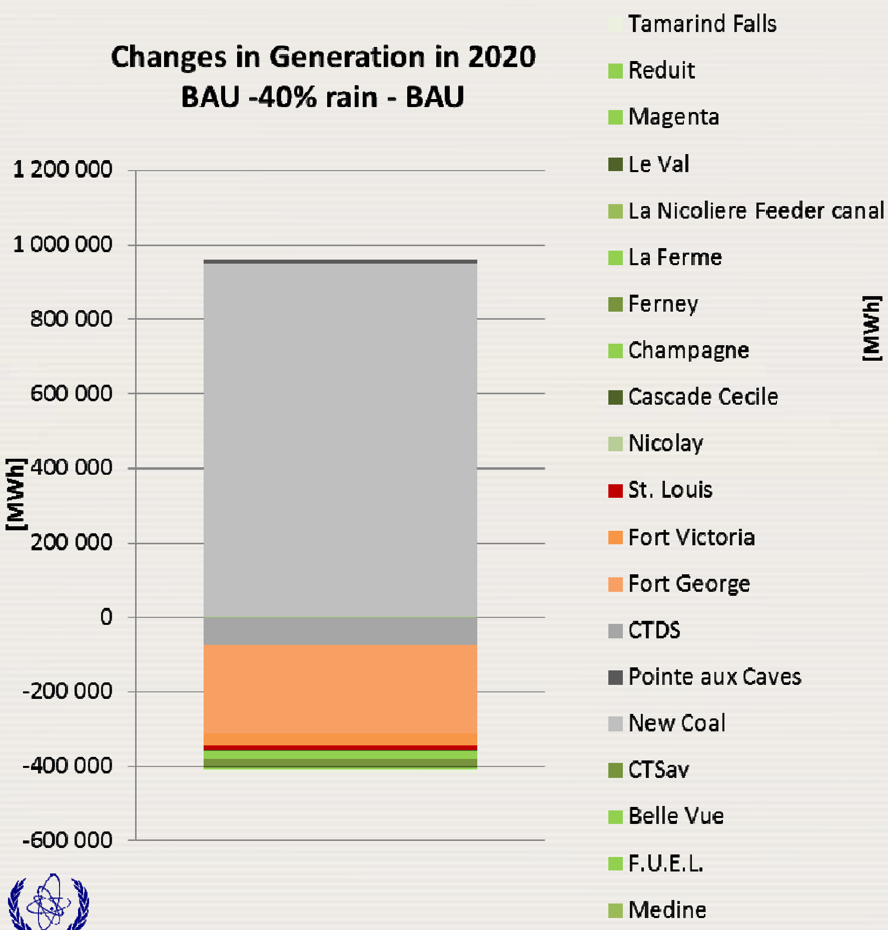
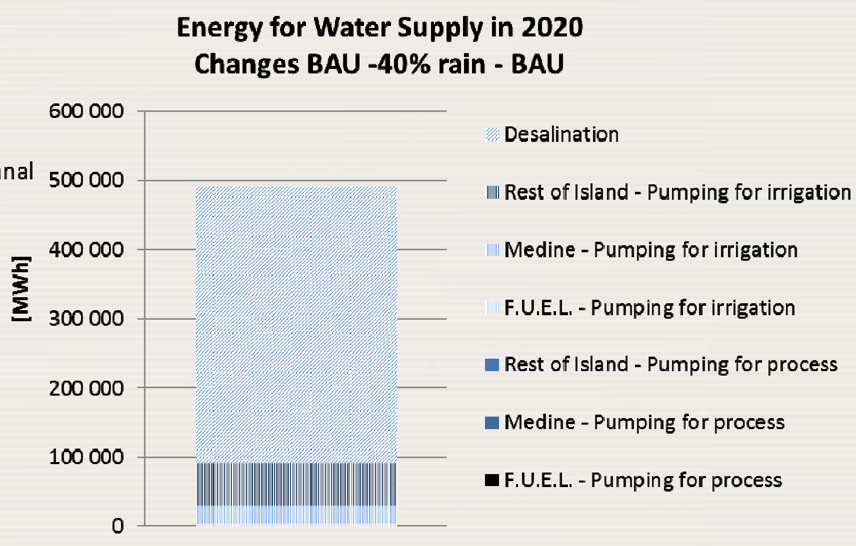
Results – Case A (40% rainfall reduction) - I





Significantly increased cost and energy demand because of pumping, irrigation and desalination.

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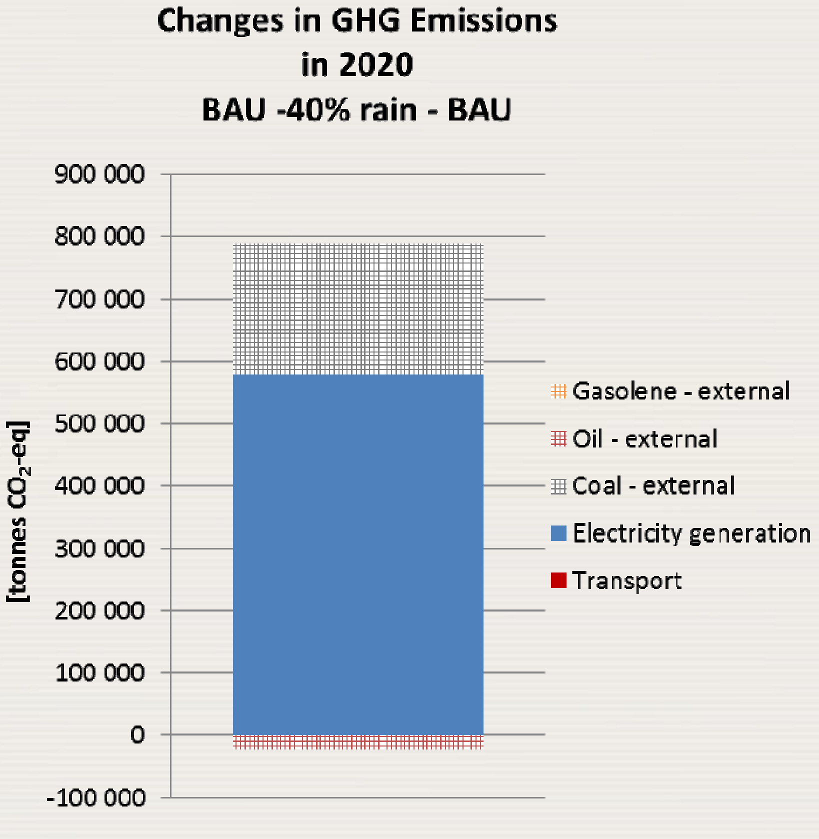
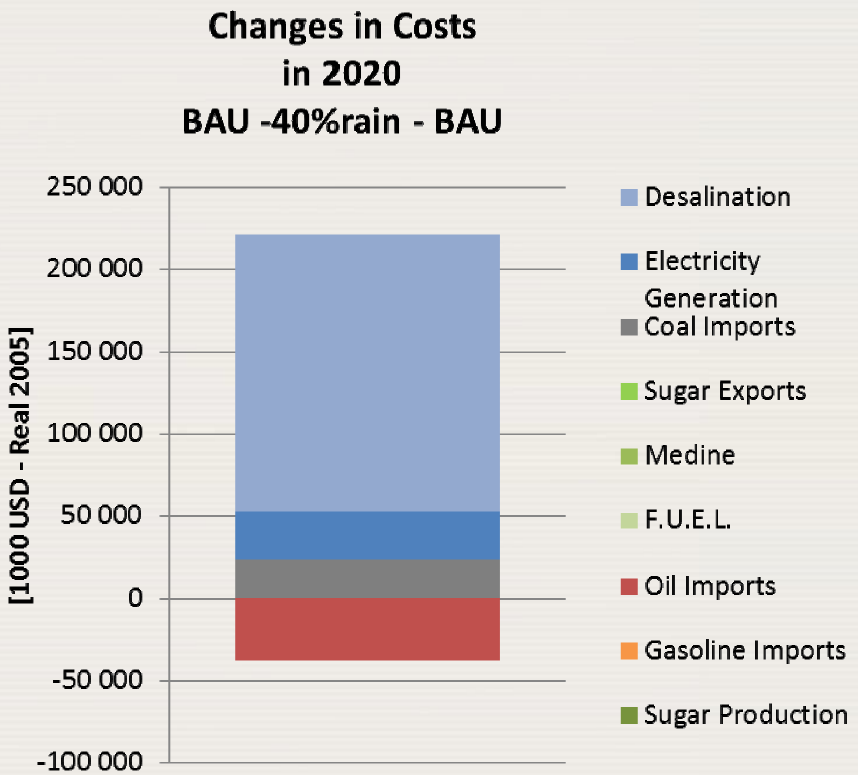
Results – Case A (40% rainfall reduction) - II





Significantly increased cost and energy demand because of pumping, irrigation and desalination.

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Results – Scenario B (40% rainfall reduction): Solution?

- **Identifying new crops suitable for new climatic conditions ...**
- **Finding new irrigation methods ...**

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Conclusions

- Interrelations are strong and important
- Ethanol outperforms sugar production under current assumptions from a GHG and economic point of view but certainly other factors play important roles
- Ethanol production technology:
  - 1st Gen and 2nd Gen ethanol production is low cost and better for the island's GHG balance (exchange of large amounts of transport fuels) but may increase island water demand through processing) and does not necessarily substitutes coal power plants for electricity
- New Crops:
  - Needs to be carefully chosen fit to rainfall conditions – AEZ and WEAP can help to match water availability to crop requirements ...
  - First results show that climate has a district influence on energy balance and economic value of different crops
- Significant improvements in GHG emissions & energy security are possible
- Clear role for desalination – especially in connection with "intermittent" low-carbon electricity generation (e.g. solar and wind)
- Concurrent mitigation and adaptation assessment meaning better economics

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Next steps

- Further develop the CLEW framework
  - Much closer look at seasonality, water storage and intermittency
  - Develop an optimization framework to determine ‘unpredictable’ outcomes
  - Consider effect of different attributes weightings
- Investigate water and energy efficiency options
- Use an MCDA approach to try and engage stakeholders
- Develop case studies on other scenarios
- Consider induced / indirect effects

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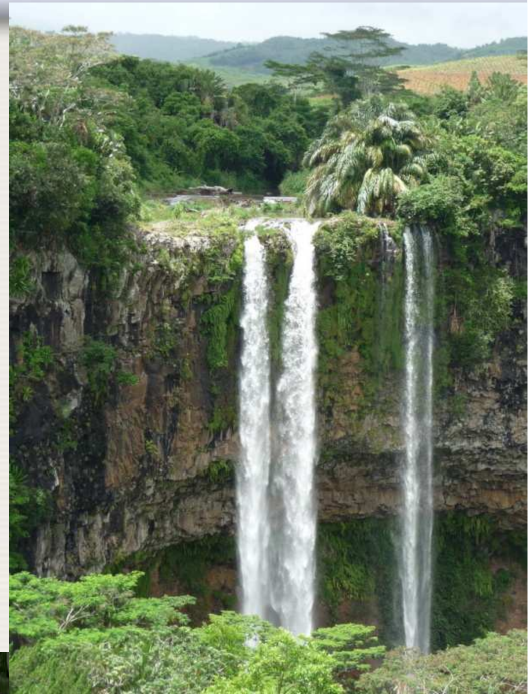
Thank you

Dissemination of the CLEW integrated system analysis **tool** and **training** to member states is essential to improve their national policies and transition to a sustainable green economy



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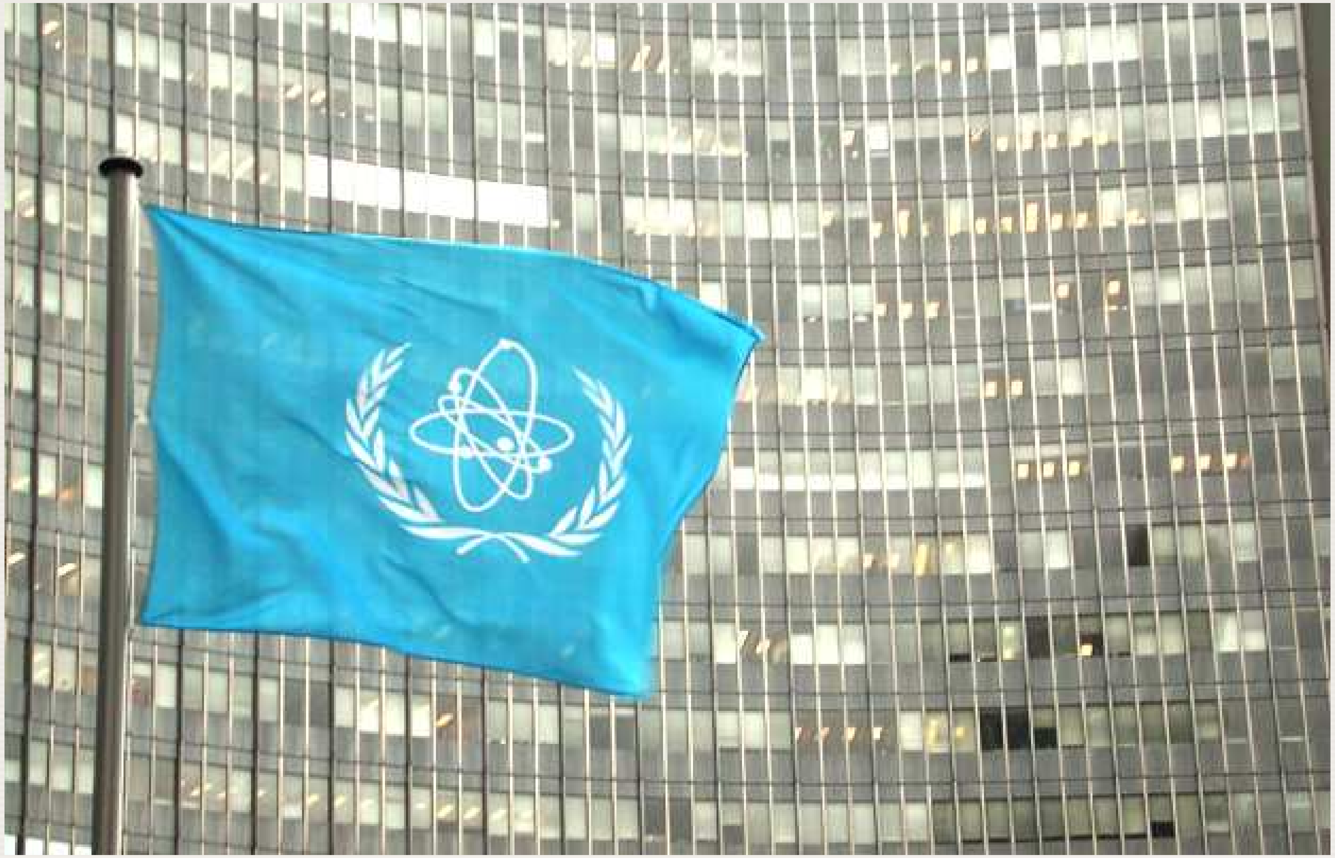

…atoms for peace.