The Abdus Salam International Centre for Theoretical Physics

2372-25

Joint ICTP-IAEA Workshop on Sustainable Energy Development: Pathways and Strategies after Rio+20

1 - 5 October 2012

Finding CLEWs
Exploring Sustainable Energy Developments: Looking at Climate-Land-Energy-Water Interactions
CLEWS Case Studies: Results and Lessons Learned

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Finding CLEWs

Exploring Sustainable Energy Developments:
Looking at Climate-Land-Energy-Water Interactions

CLEWS Case Studies:
Results and Lessons Learned

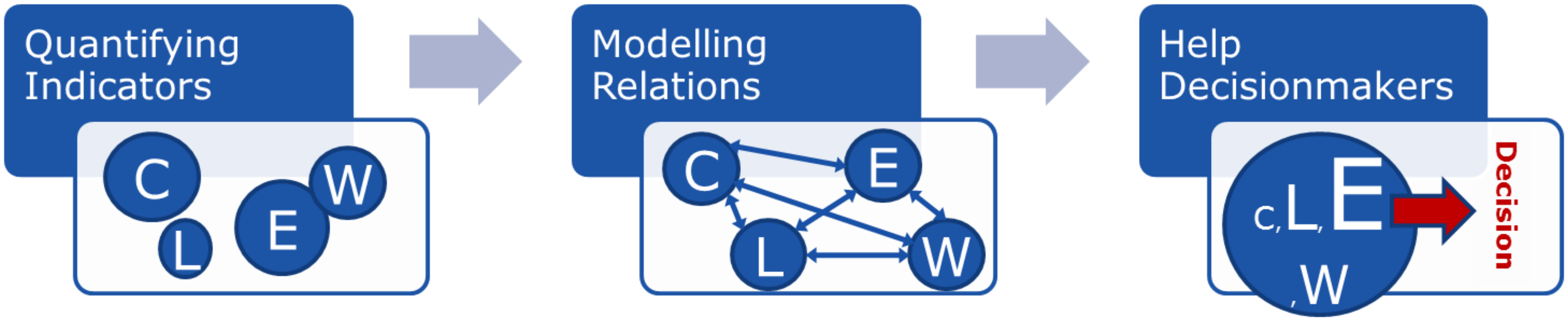
Joint ICTP-IAEA Workshop on Sustainable Energy Development:
Pathways and Strategies after Rio20

01-05 October, 2012, Trieste, Italy

Overview

1. Introduction & Set-up of a CLEW Case study
2. Mauritius – investigating the interdependent effects of local biofuel production
3. Burkina Faso – multidimensional resource shortage
4. Summary

The Aim of CLEW

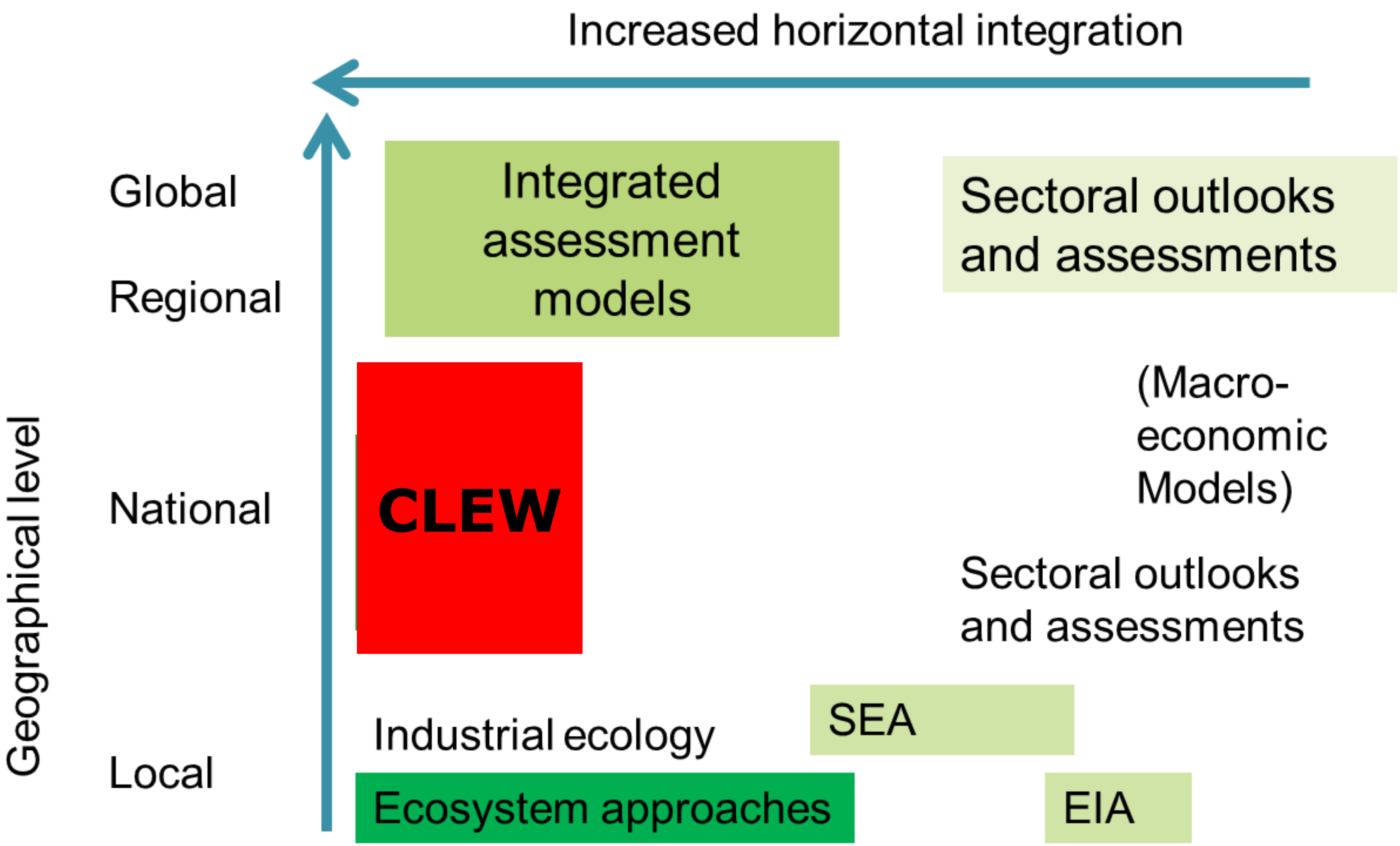


Country Specific …		
Priority Resources? Shortages? Substitutes?	Identifying Key Interrelations! What can be omitted?	What measures should be supported? Price mechanisms encouraged?
The three « access » goals (water, clean energy, food security) in practice - Everything has a cost/ opportunity cost: what priorities, and how are they determined?		

Horizontal integration: the Grail of sustainable development

- Lack of horizontal (cross-sector) integration long identified as a major cause for relative lack of progress on SD
  - Economic/ technical choices:
    - misses systemic links, feedbacks,
    - potentially adverse consequences
    - In the CLEW nexus, potential for adverse consequences important
    - Land use/ land use change as the meeting point of conflicting demands: integrated models critical
  - Institutional side (most important)
- Major links/feedbacks well identified a priori
  - See Bazilian et al. (2011), Energy Policy
- BUT relative importance of links varies across countries
  - Messages based on results from global models potentially misleading / not best guide to national policies
  - Actual strength of the feedbacks/links unknown where it matters most

CLEW tool as a crucial missing link



(shade of green: degree of Increased economic – biophysical integration)

Potential CLEW applications and levels of details

Increasingly challenging

- Prototype (not fully calibrated): awareness raising and capacity building in government
  - Common understanding of the « key » issues, of potential links/ feedbacks
- Full model: shared diagnosis platform
- Agreement on common baseline for different actors (e.g. ministries)
  - Improvement over traditional macro models by design: single actions are intrinsically "checked" regarding their effects on other sectors
  - Common understanding of trade-offs and synergies
- Platform for common (national) vision
  - Shared with broader public, interactive
  - "forces" clarification of priorities
    - Everything has a cost / opportunity cost
    - How do you value food security, energy security, access to water for all?

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International level: what can we learn from CLEW for the future?

- Strength of various interlinkages in different socio-geographical contexts
  - Typologies: constraints / limiting factors for development
  - Differentiated national (development) strategies / narratives
  - Needs other case studies!
- Risk-based strategies versus BAU+ strategies (e.g. CC mitigation)
  - Robust national strategies
  - Are incentives from international mechanisms right?
- The three « access » goals (water, clean energy, food security) in practice
  - What does it mean at the national level?
    - Everything has a cost/ opportunity cost: what priorities, and how are they determined?
  - "Aggregating back" to the global level: new story?
    - No "spatial" externalities (e.g. more land in Africa, more renewables elsewhere): does it change the conclusions?

How to set up a CLEW case study?

Intro

Mauritius

Burkina Faso

Summary

1. Geographic Extends (small scale vs. country or region)

2. Defining the "hot topics" and "constrains" - Formulating specific development targets

3. Looking into the future – defining key future developments and areas of intervention.

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Geographic Extend

Intro

Mauritius

Burkina Faso

Summary

Mauritius	Burkina Faso
- Small Islands – clear boarder - No water and electricity trade - ca. 2,000 km2 - BUT: large scale plantation - High resolution data available	- Land locked country - Water and electricity trade - 275,000km2 - BUT: small scale farmers - Mainly aggregate national data used

Defining “Hot Topics”

Mauritius	Burkina Faso
How can Energy Security be increased? (Under a clear set of boundary conditions and constrains)	Multidimensional Problem: • Food Security • Energy Access • Water Availability (against an annual population growth rate of 3%)

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Key future developments

Intro

Mauritius

Burkina Faso

Summary

Mauritius	Burkina Faso
Key Future "Thread": - Climate Mainly: **Possible natural RESOURCE REDUCTION**	Key Future "Thread": - Population Growth (and associated demand for resources) Mainly: **Strongly INCREASED CONSUMPTION**

Modelling Tools Used …

Water
Evaluation
And
Planning

WEAP

OSeMOSYS

LEAP

AEZ - The Land-Use Model

Case studies illustrating model integration

Intro

Mauritius

Burkina Faso

Summary

1. Mauritius
2. Burkina Faso

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 focussing on reducing dependence of fossil fuel and reducing GHG emission …**

Aim of the case study

Intro
Mauritius
Burkina Faso
Summary

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

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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Methodology

Intro

Mauritius

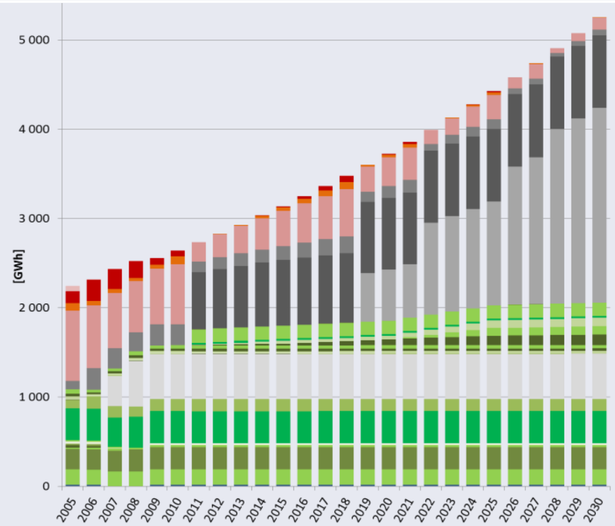
Burkina Faso

Summary

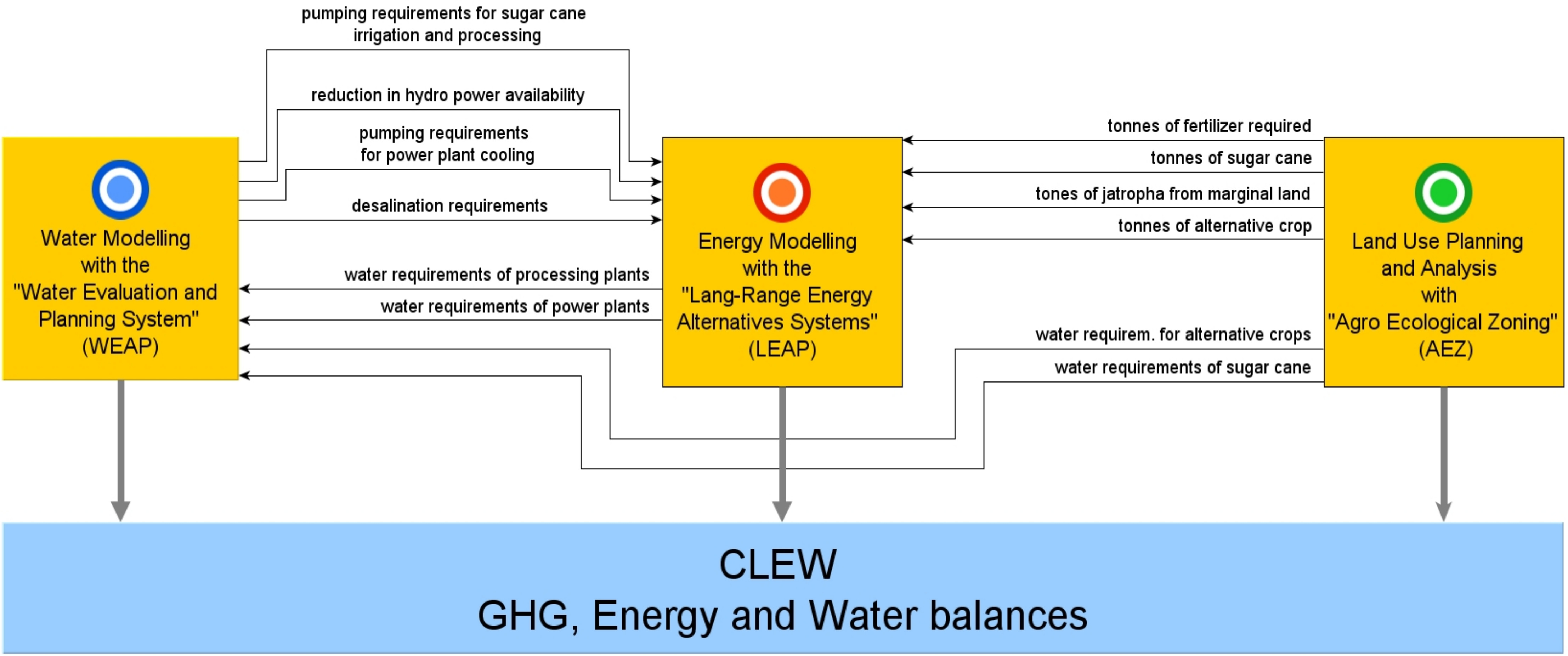
- Development and calibration of water, energy and land use model using 10 years data (1996- 2005)
  - WEAP - water
  - LEAP - energy
  - AEZ - land production planning

- 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 changes the local energy balance?
  - What are local and externally induced GHG emissions?

Modeling Tools Used

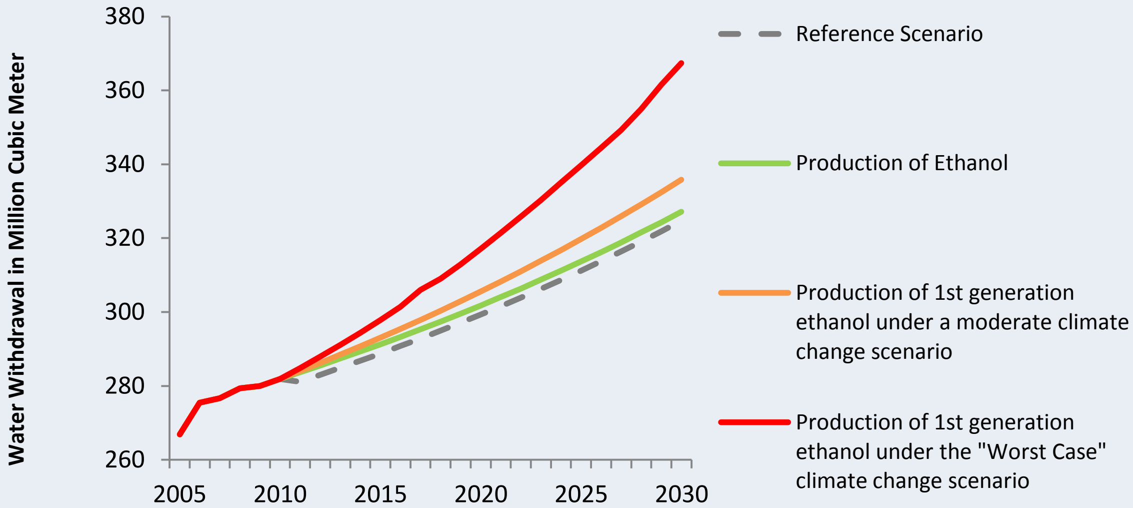
Energy	Water	Land Use
LEAP	Water Evaluation And Planning WEAP	AEZ
	**Water availabilty for each point in the system (on the island) under different conditions / szenarios**	**Grid map of Mauritius showing optimal crops, potential water use, and potential yield including a „Crop calendar“**

Case Study Mauritius – Model Interconnections:



OVERALL WATER WITHDRAWALs AND ENERGY DEMAND IN DIFFERENT CLEW SCENARIOS

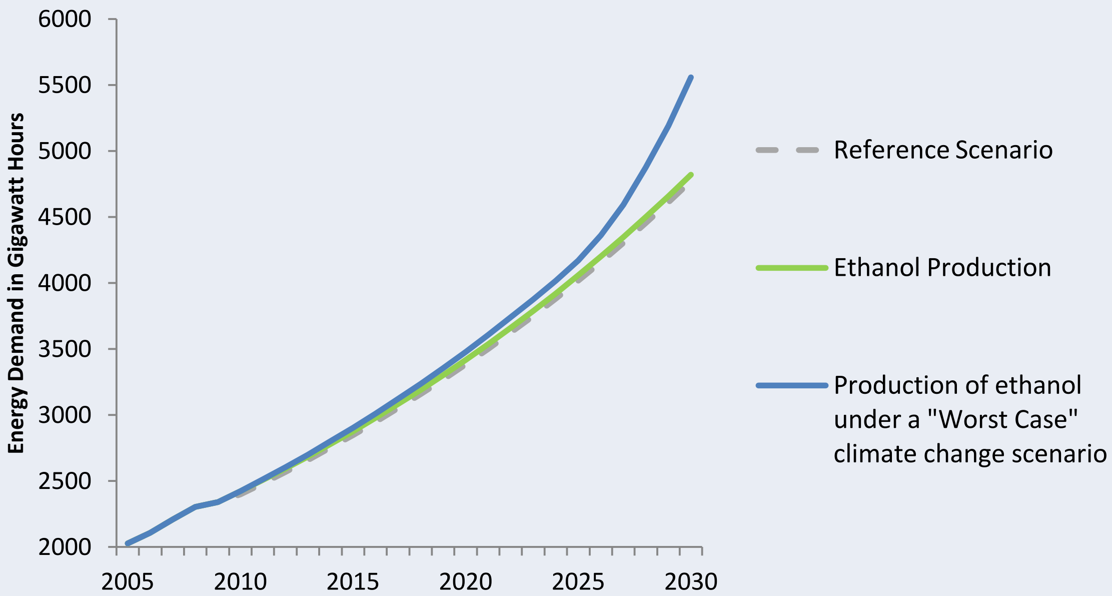
Mauritius Total Water Withdrawals Under Different Integrated CLEW Scenarios



Water withdrawals increase under climate change scenarios:

To compensate for reduced rainfall, irrigation will have to be expanded to previously rain-fed sugar plantations and farms. This leads to higher withdrawals. Of surface and ground water.

Mauritius Total Energy Demand Under Different Integrated CLEW Scenarios



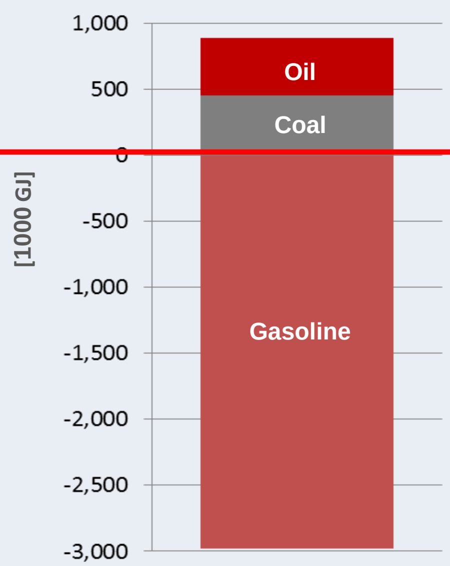
Increasing Energy demand for biofuel production:

Energy demand increases as demand for water pumping and desalination grows to meet demand as rainfall is reduced. .

THE IMPACT OF TRANSFORMING TWO SUGAR PROCESSING PLANTS TO PRODUCE 2nd GENERATION ETHANOL (PROJECTED FOR 2020)

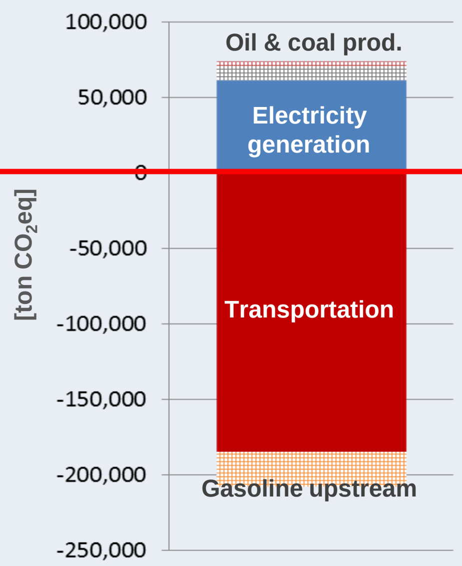
Baseline

Reduced fuel imports



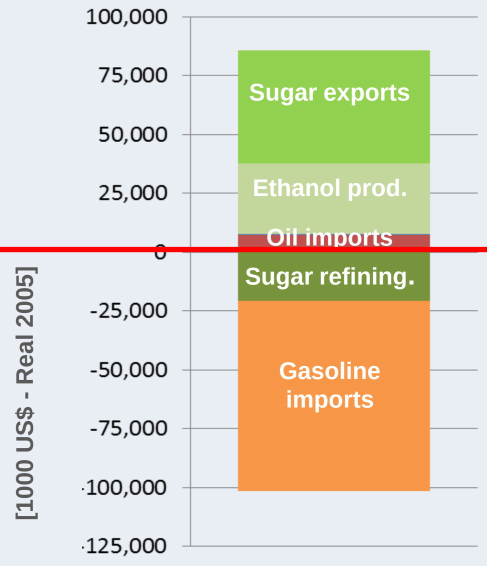
The import dependence decreases. Gasoline imports are reduced as ethanol replaces gasoline as a motor fuel. Some bagasse is diverted from electricity generation to ethanol production, which needs to be compensated for by increased imports of coal and distillate oil.

Reduced greenhouse gas emissions



Total greenhouse gas emissions are reduced. Tailpipe and upstream emissions are reduced as gasoline is replaced by ethanol. The increased use of coal and distillate oil (in place of bagasse) for electricity generation results in smaller additional emissions.

Reduced expenditures



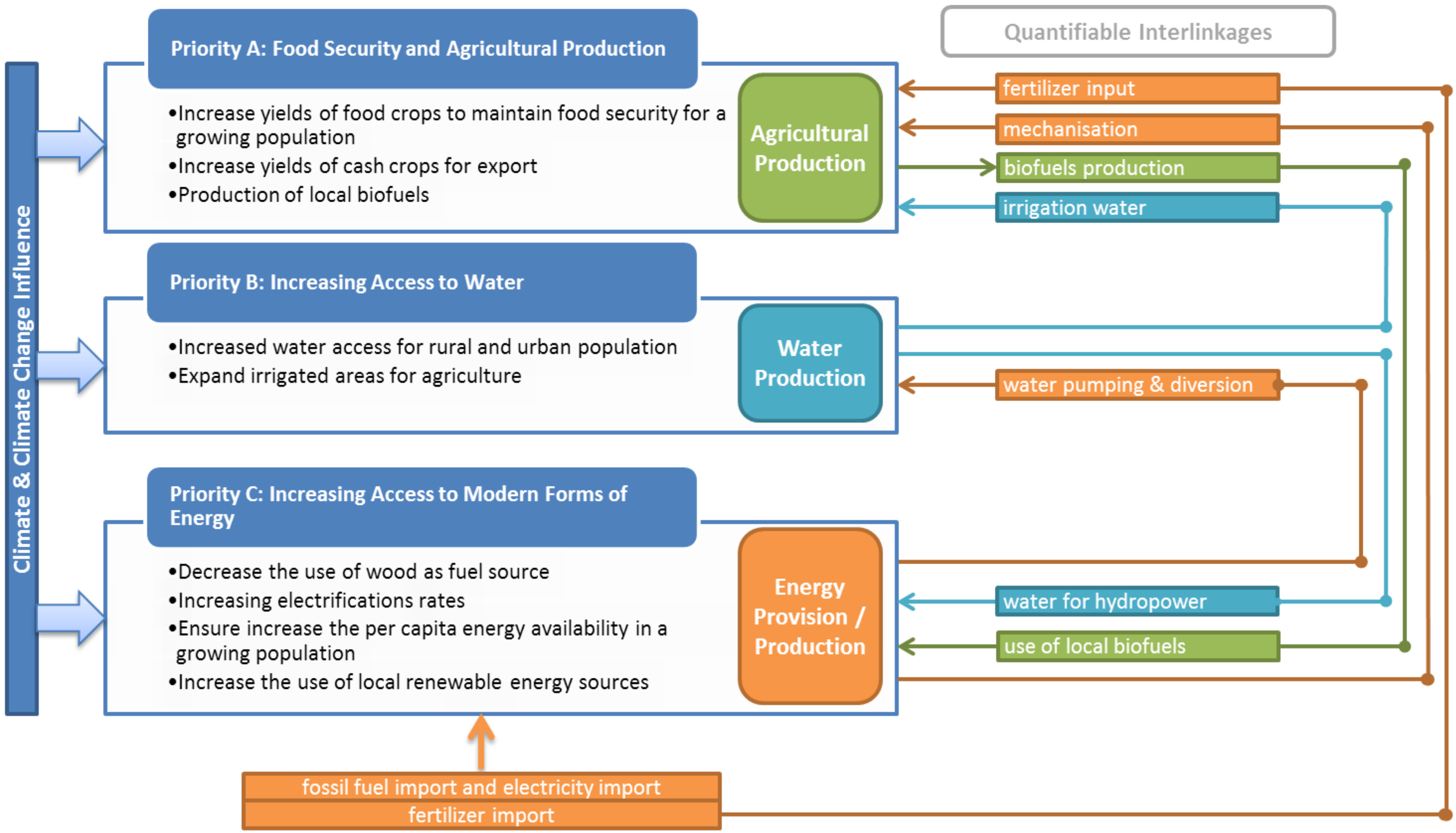
Ethanol production has an economic benefit. As some of the sugar is converted to ethanol, the expenditures for sugar refining and gasoline imports are reduced. This outweighs the reduced sugar export earnings and the costs associated with ethanol production and the increases in oil and coal imports.

Burkina Faso

Selected Socio-economic Indicators
Size: 274.2 thousand km²
Population: 17.25 million (estimated 2012)
Capital: Ouagadougou 2.08 million inhabitants (estimated 2012)
Neighbouring countries of Mali, Niger, Benin, Togo, Ghana, Ivory Coast
Climate change in the humid subtropical climate in the south, north dry savanna
Population growth 3.085% (estimated for 2011)
Urbanization: 26%
Illiteracy: 78%
Life expectancy: 53.7 years
Infant mortality rate: 8.81%

Burkina Faso CLEW Challenges

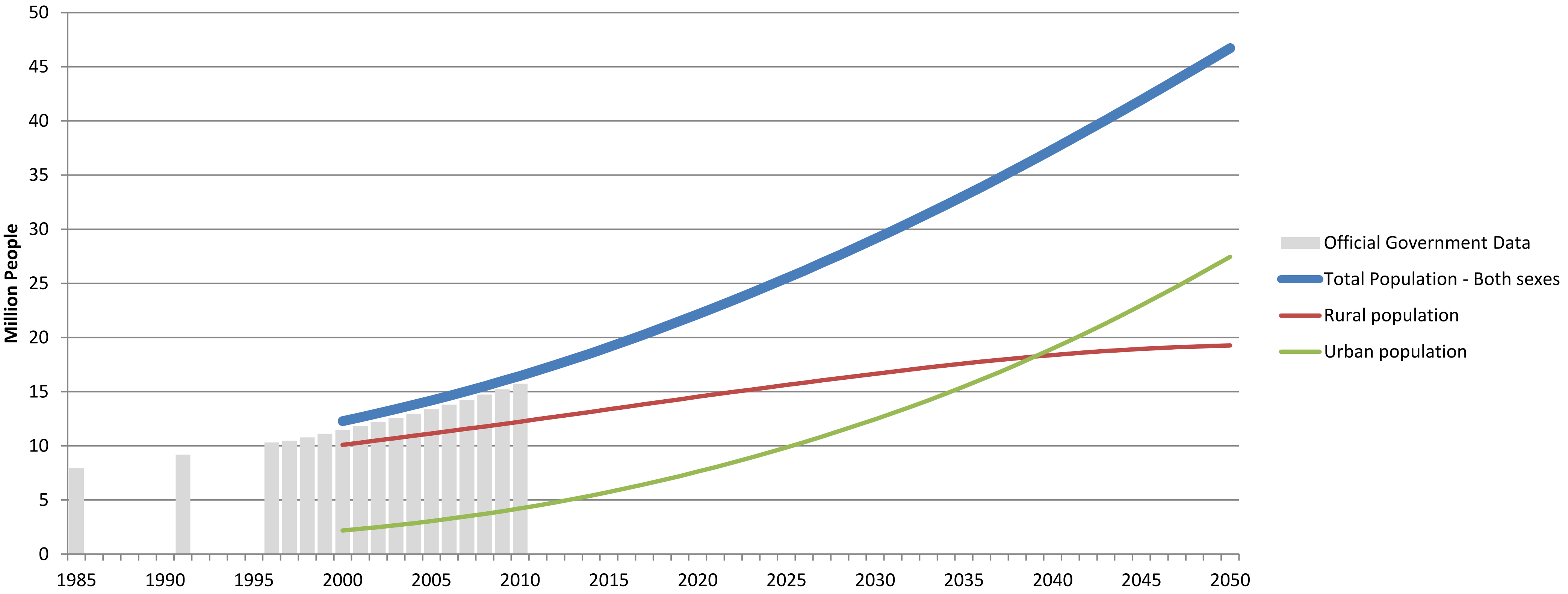
- Climate:
  - Low contribution to CC but potentially high vulnerability
- Land Use:
  - Growing food demand through increasing population and use of highly extensive agriculture
  - Dependence on one main export crop (cotton)
  - Continuous deforestation
- Energy:
  - No own fuel resource
  - high fuel import costs (due to landlocked situation)
  - Dependence on wood for as energy source
  - Low electrification rates
- Water:
  - Extremely dry areas of the country
  - Strong variability of rainfall (flooding and draughts)
  - low use of water for irrigation in the agriculture


Climate & Climate Change Influence
Priority A: Food Security and Agricultural Production
•Increase yields of food crops to maintain food security for a growing population
•Increase yields of cash crops for export
•Production of local biofuels
Agricultural Production
Priority B: Increasing Access to Water
•Increased water access for rural and urban population
•Expand irrigated areas for agriculture
Water Production
Priority C: Increasing Access to Modern Forms of Energy
•Decrease the use of wood as fuel source
•Increasing electrifications rates
•Ensure increase the per capita energy availability in a growing population
•Increase the use of local renewable energy sources
Energy Provision / Production
Quantifiable Interlinkages
fertilizer input
mechanisation
biofuels production
irrigation water
water pumping & diversion
water for hydropower
use of local biofuels
fossil fuel import and electricity import
fertilizer import

Intervention	Rationale	Influence on CLEWs
Intensifying the Agriculture in Burkina Faso	Burkina Faso Agriculture is highly extensive with low per hectare yields, low water and energy inputs. Increasing population and food demand (but also income generation with cash crops) will make an intensification of agriculture necessary in the future.	• Increase energy and water input per ha agricultural land • Medium to Long term benefits due to higher food production and possibly decreased agricultural land requirements • (interlinkages to biofuels)
Providing Modern Energy Services to the Population	Electrification Rates are very low in the country with large share of the population relying on traditional biomass. Bringing modern fuels and electricity to people is one of he governments main targets.	• Increased need for local electricity production or import • Reduction of use of wood resources (and associated secondary benefits: biodiversity, decreased soil degradation) • direct (GHG) emissions • (interlinkages to biofuels)
Increasing the Water Access for people and agriculture	Although increase over last decade access to drinking water needs to be increased in the country. Urban water demand will increase significantly in the next decades as urbanisation increase and population growth remains high. Irrigated agricultural land is expected to at least double within the next decade.	• Water demand will be limited by availability and is dependent on future climate • Intelligent irrigation will increase agricultural output and might lead to different land use option (crops). Irrigated biofuel crops are a controversial issue in this respect.
Introducing Biofuels in Burkina Faso	BF has very limited own energy resources and faces a growing energy demand in the future. Own biofuel production can increase energy security.	• Depending on the location biofuels might displace currently grown crops and might endanger food security. • If irrigated strong influences on the water balance is expected as well as on the energy balance of the crop (due to pumping / irrigation energy demand)

Projected CLEW Developments

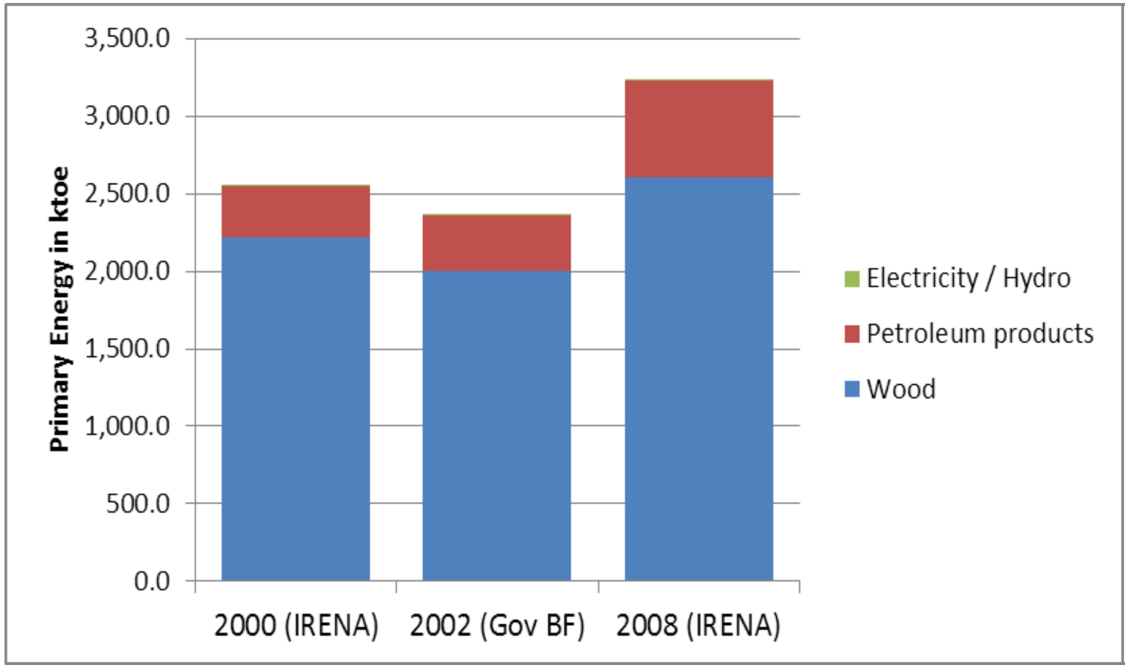
- Population -

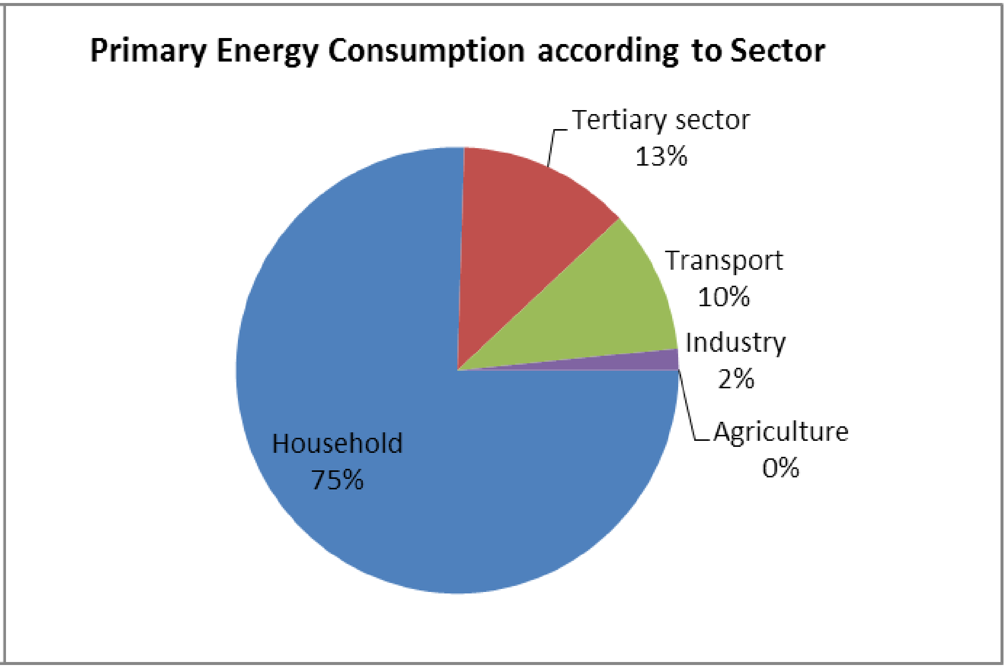


Burkina Faso currently has a population grow rate of 3% p.a. increasing stress on all CLEW resources in the country. According to official UN projection population will continue to grow might reach the 20 million mark in the year 2017 or 2018. Urbanisation will grow with effects on land uses and water and energy balances in the country.

Projected CLEW Developments

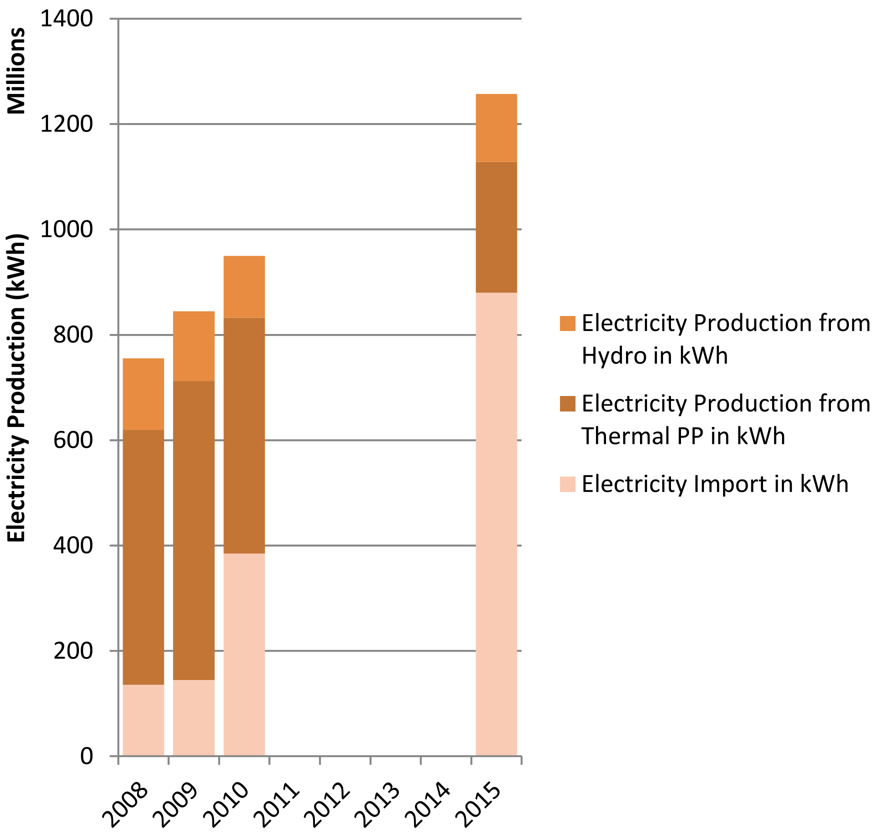
- Energy -

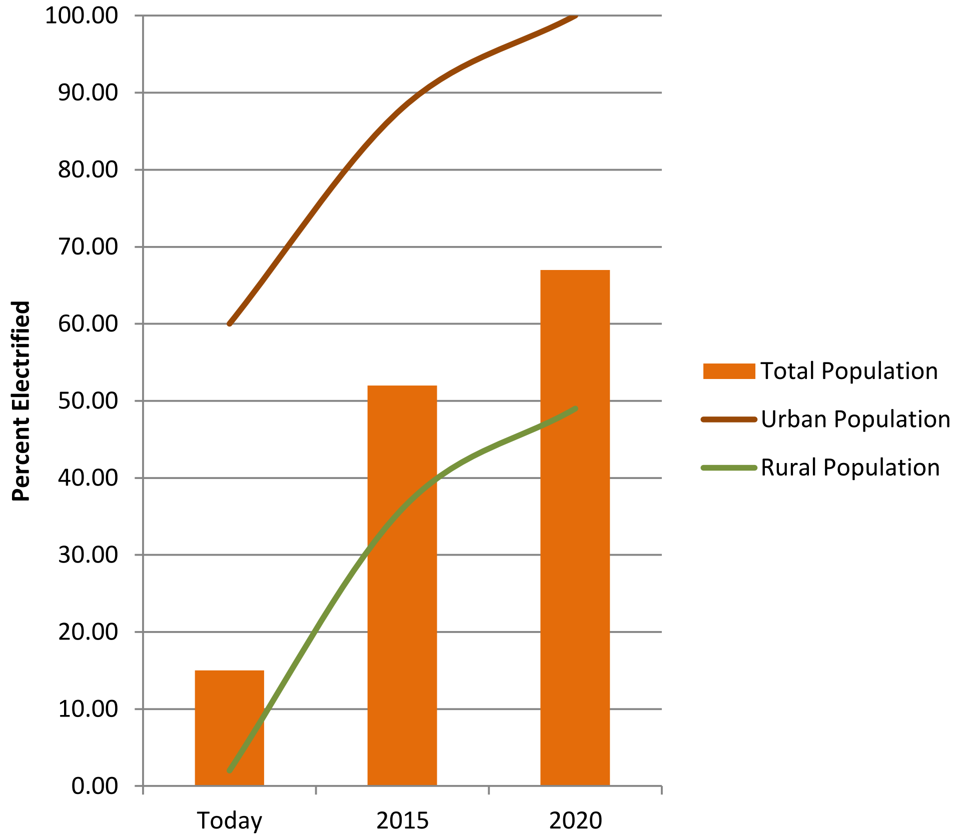




Projected CLEW Developments

- Electricity -



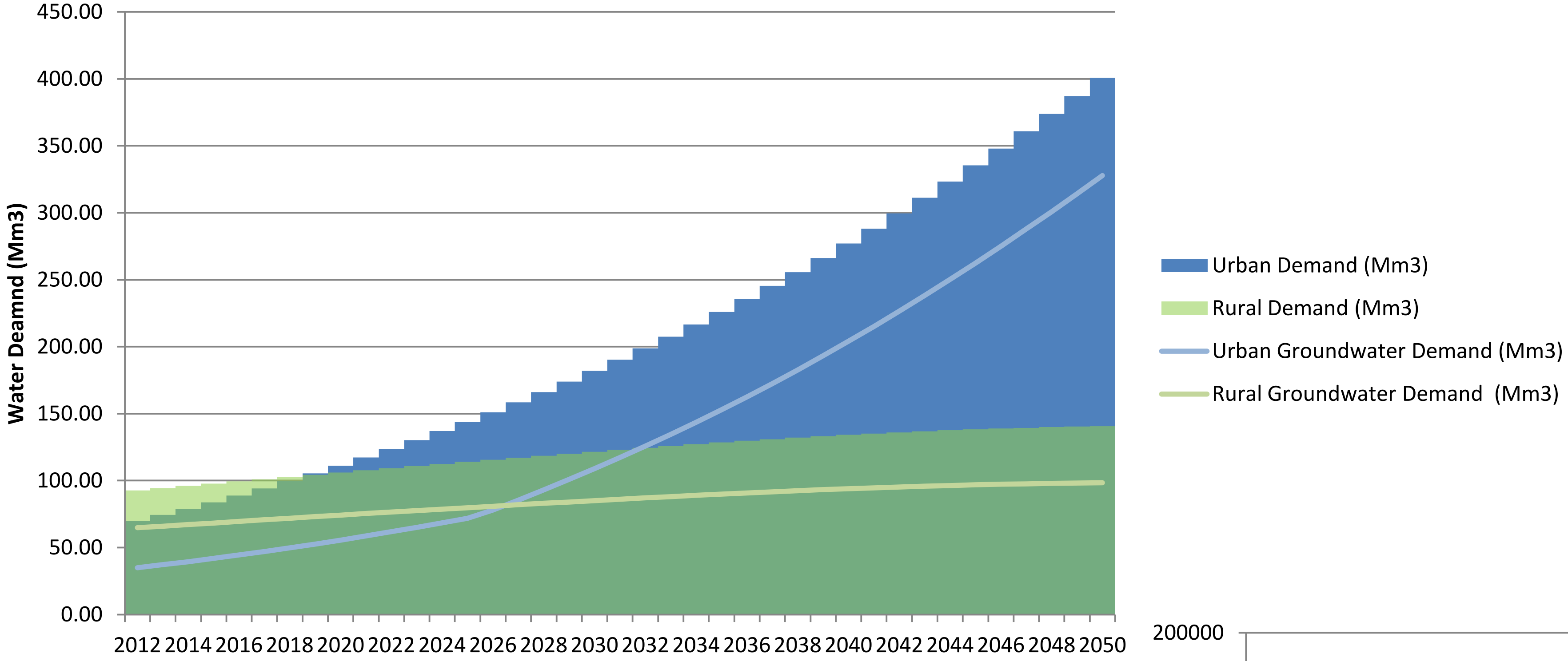


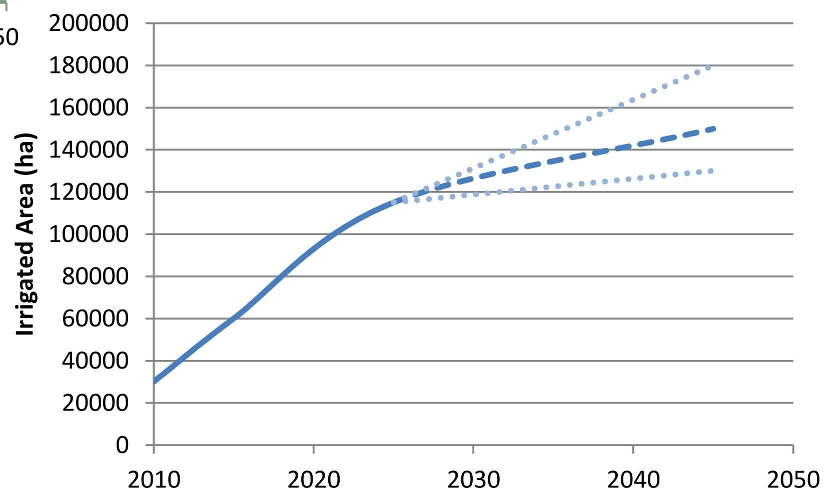
Projected Electricity production and import to the year 2015 – it is expected that electricity imports will be around 70% by 2015, while local production is reduced.

Governmental plans for electrification: Until 2020 67% of the population shall have access to electricity (100% in urban areas, 49% in rural areas).

Projected CLEW Developments

- Water -



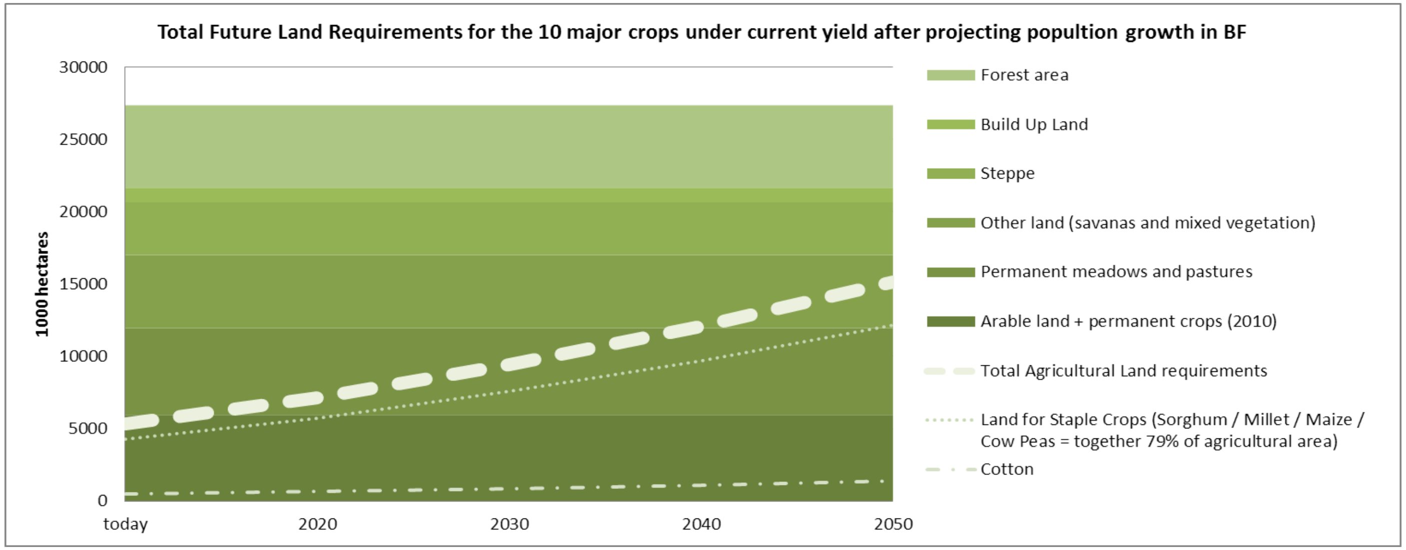


The Water sector is extremely vulnerable to climate change with strongly varying precipitation. Future population growth predominantly in urban areas as well as increased irrigation areas as planned by the government (right graph) will put an increasing stress in groundwater aquifers. (Water availability is to a large amount uncertain and includes “fossil” (not renewable) groundwater resources.

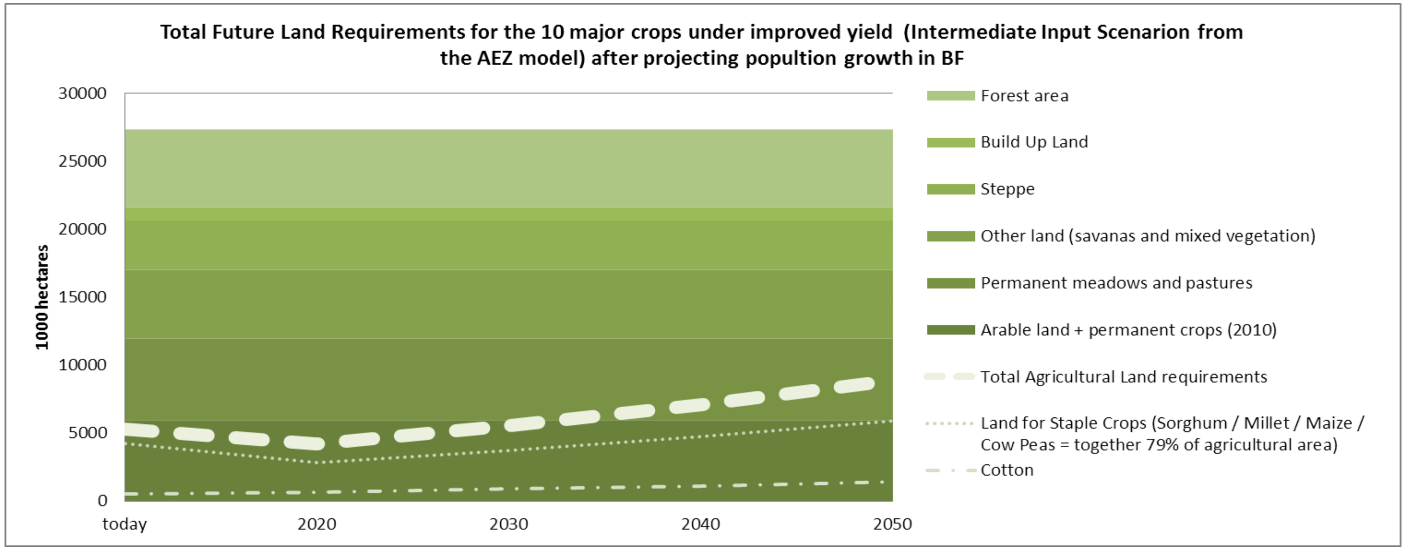
Projected CLEW Developments

- Land Use -

The agricultural land use projection based on constant yield per hectare assuming official population growth rates. In this scenario agricultural land in the order of 15 million ha (half of the land area) would be needed. This is amount of land would cut into the existing pasture land, and would with a high possibility also impact forest areas as other suitable land is scarce.



The agricultural land use projection based on increased yields. In this scenario energy and water input in the agriculture is increased to a so called "intermediate input level". Intensification of agriculture includes a higher mechanisation and more fossil fuel input but results in substantial higher yields and therefore a reduced land area.



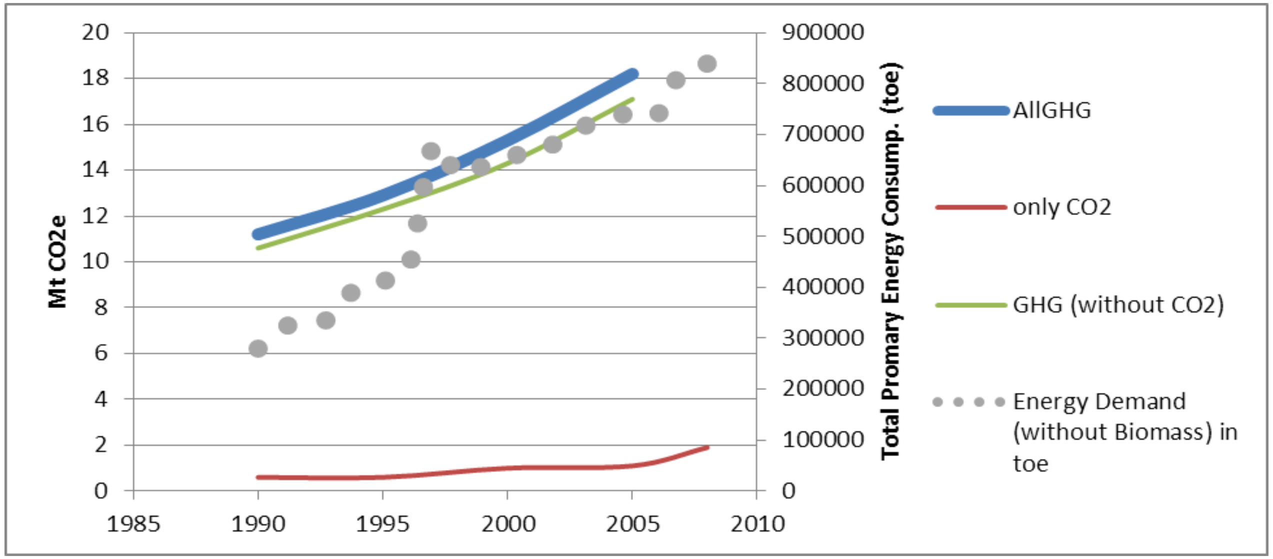
Projected CLEW Developments

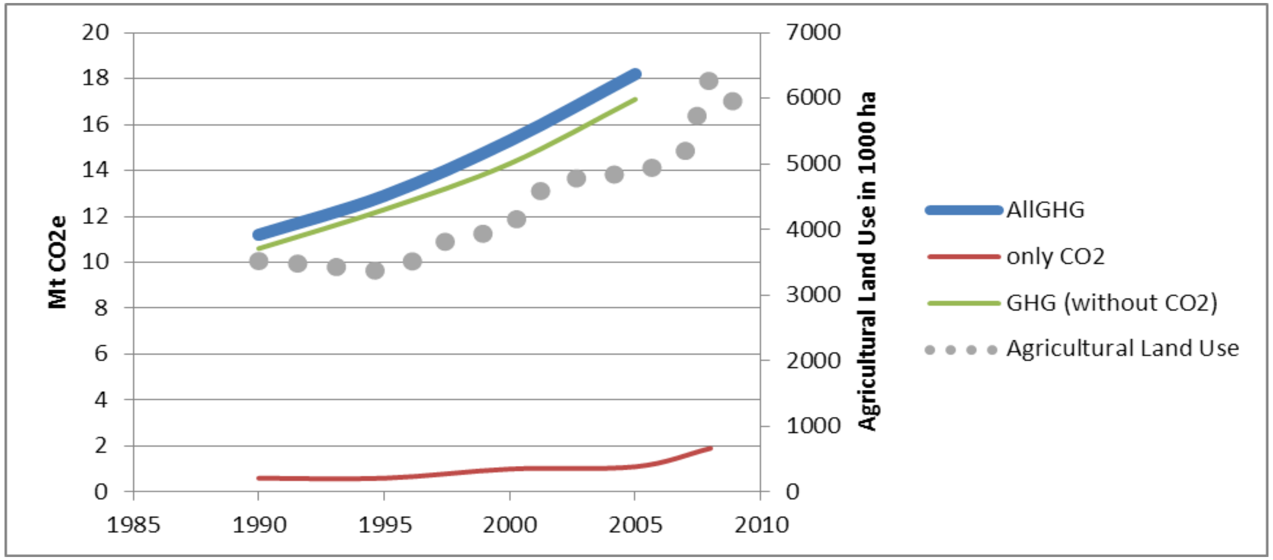
- GHG Emissions -

GHG emissions in Burkina Faso increase from 11.2 to 18.2 MtCO2e from 1995 – 2005. The bulk of the emissions (and emissions increase during this time) can be attributed to non-CO2 emission mainly from agriculture.

While both (agricultural land use and energy consumption) have both doubled in the same time, the share of CO2 from fossil fuel use has remained stable at 4 to 6% of total emissions only.

This results in the fact that an intensified agriculture which needs more fossil fuel input and mechanisation leads to overall decreased GHG emission as natural CO2 buffer can be created (forests and savannahs) while at the same time increasing food security.

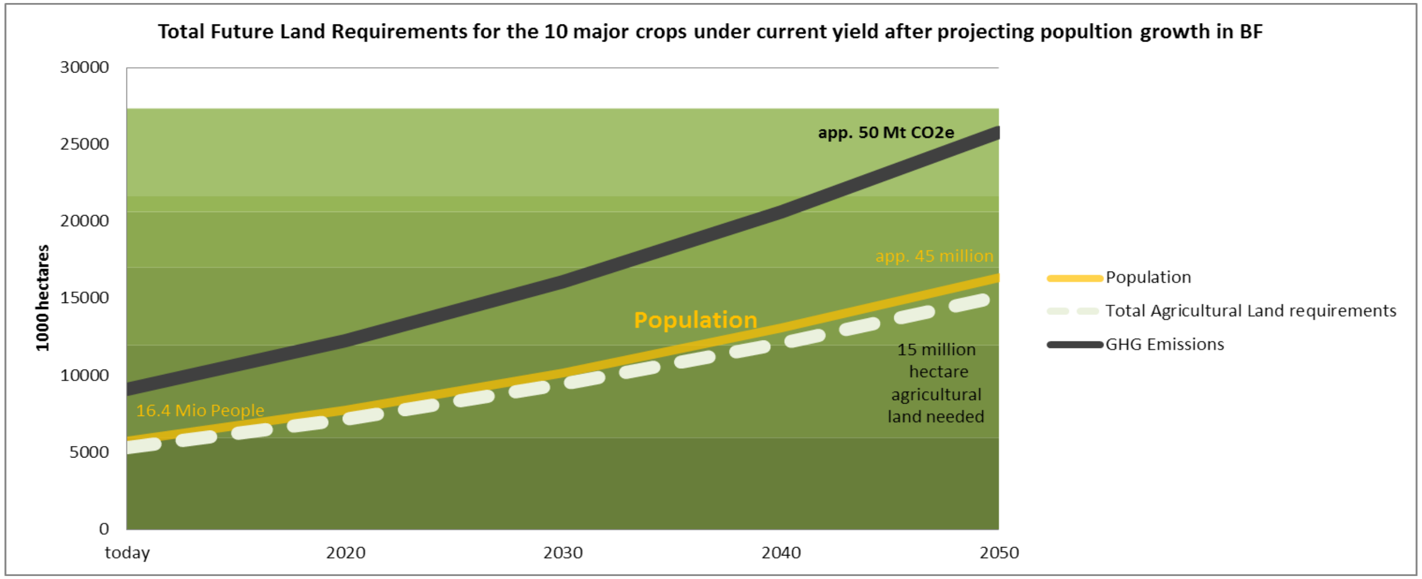




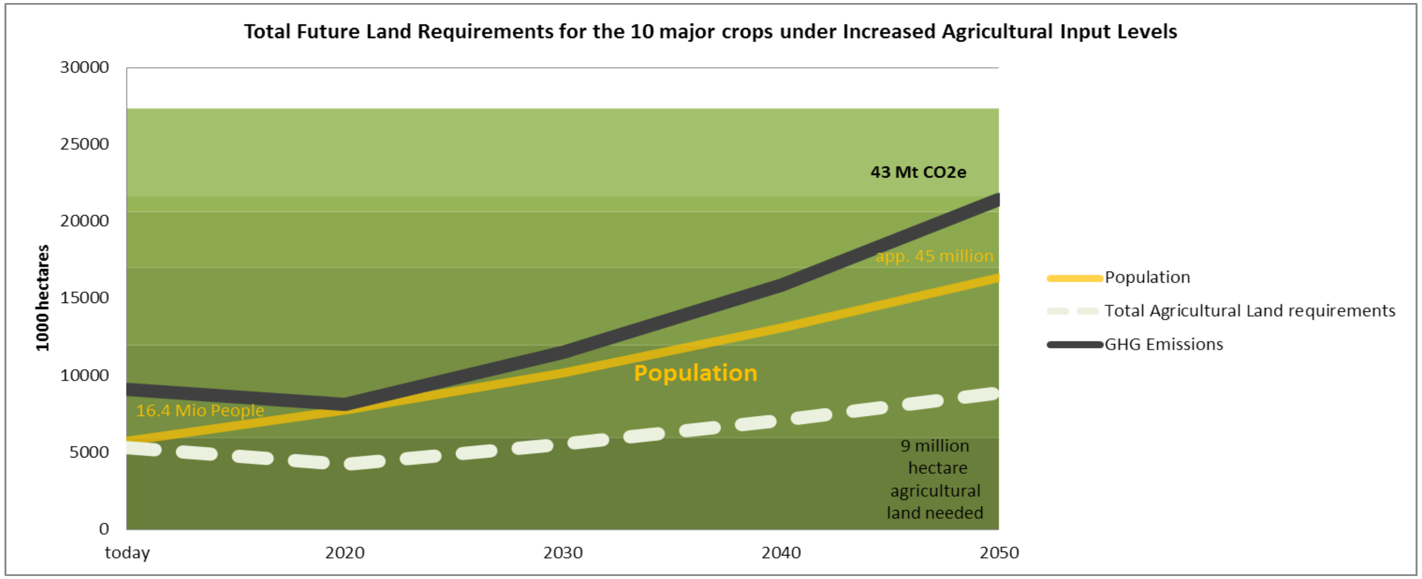
Projected CLEW Developments

- Land Use, Energy and GHG emissions -

Under current agricultural yields (which actually have been decreasing during the past decade). Necessary agricultural land area would constantly increase and result in overall growing GHG emissions – besides reaching into more and more unsuitable land and potentially would reduce remaining forest area.



Under a higher input agriculture yields could be increased drastically resulting in less agricultural area and less loss of forest and savannah. According to our calculations the GHG produced by increased amount of energy needed (approximately the 10fold in energy demand for the agricultural sector compared to today) for this scenario would be far less then the GHG emissions saved through reduced deforestation and overall reduced agricultural area.



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Biofuels - Jatropha

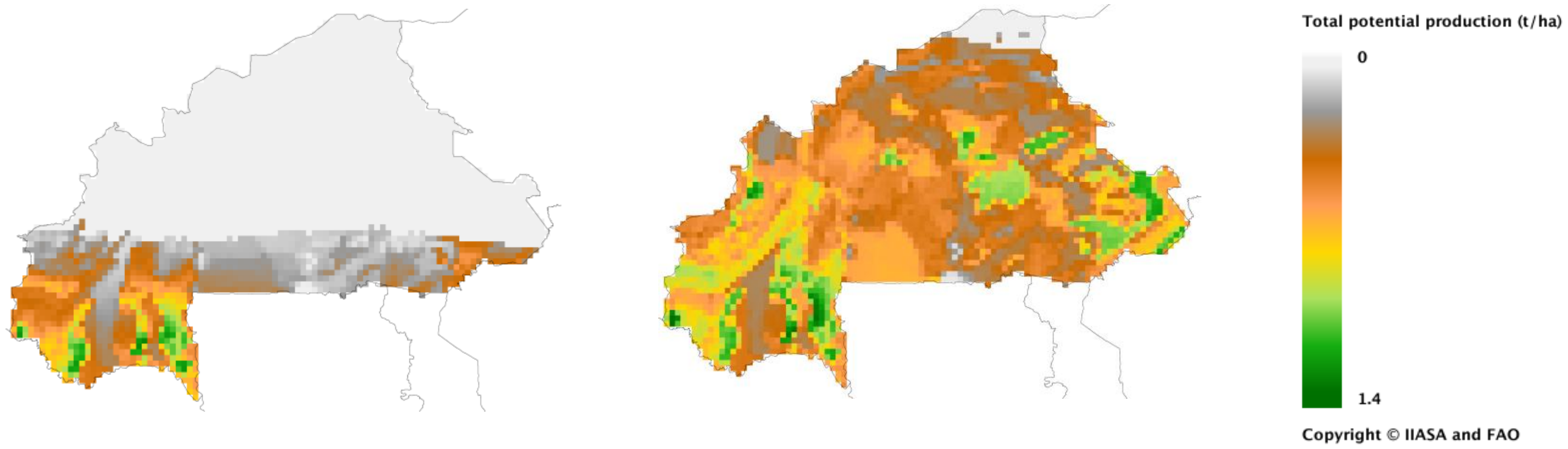
Climate - Land Use - Energy - Water

Intro

Mauritius

Burkina Faso

Summary

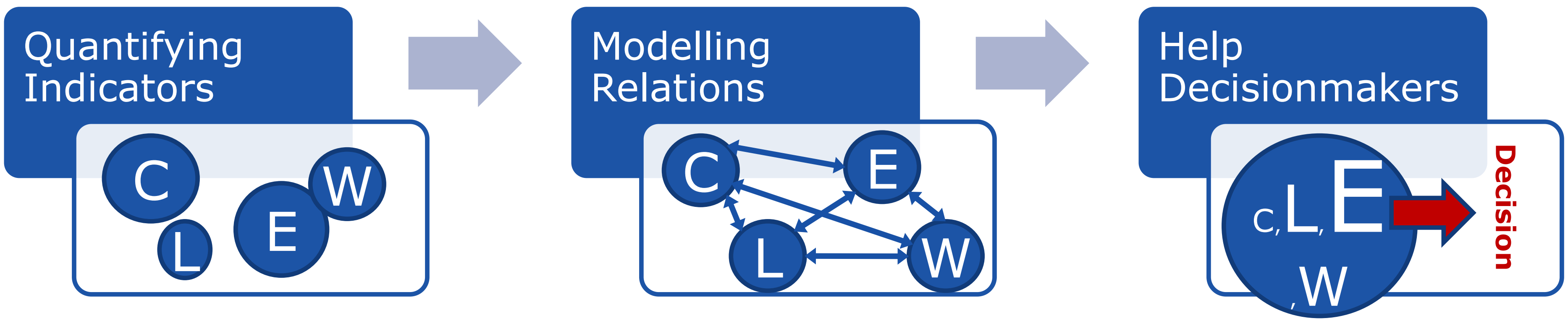


A first investigation using the AEZ land use model has shown that there are substantial differences in expected yields within Burkina Faso – especially under rain-fed conditions. If Jatropha is introduced a strong "tendency" to irrigation can be expected as yields in the country are considerably higher under irrigation.

Summary - The CLEW approach

- Develop clear indicators and quantify physical interrelations between CLEW resources
- Develop tools to assist decision makers to verify the effects on other CLEW resources
- Test the tools and calibrate them to different environments / situations / setups through data collection and Case Studies

	Energy	**Water**	**Land Use**
Models used	MESSAGE(IAEA) LEAP(SEI) OSeMOSYS(KTH)	WEAP(SEI)	AEZ(IIASA)
Output & Results for Integration	• Future optimal energy mix under different conditions, • Future GHG emissions • Costs	• Water availability under different CC and demand scenarios • Time depended water availability	• Crop Map (most suitable crops per area) • Future water demand in the agriculture • Energy and Fertilizer demand



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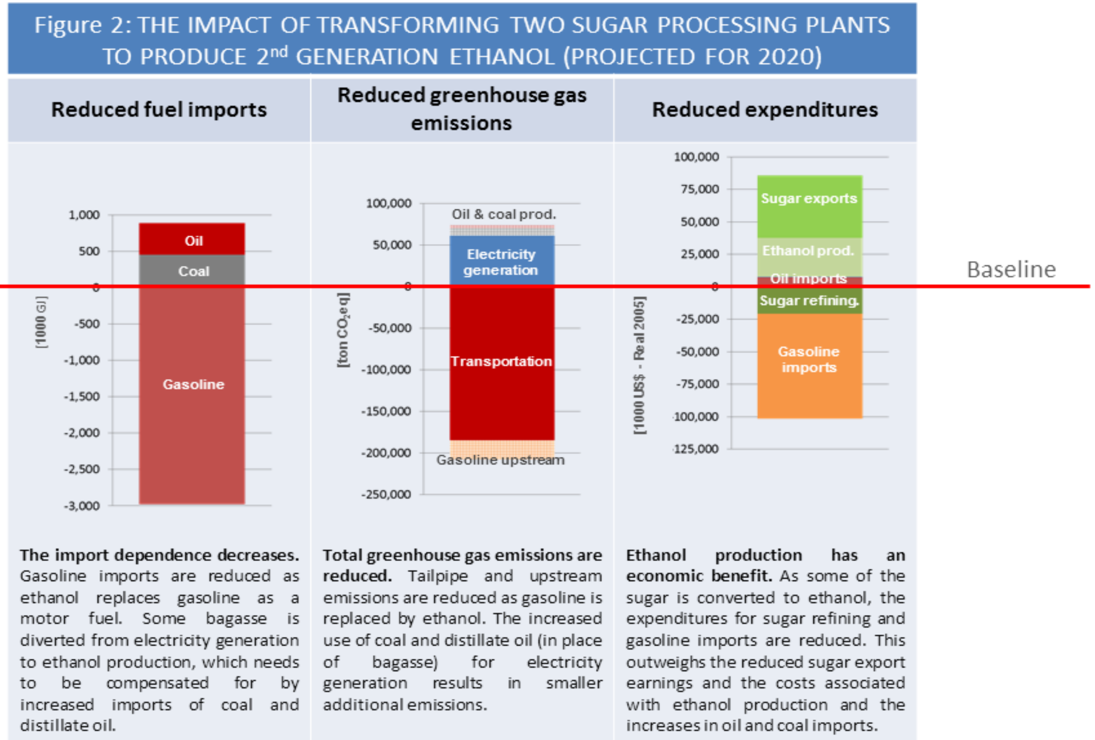
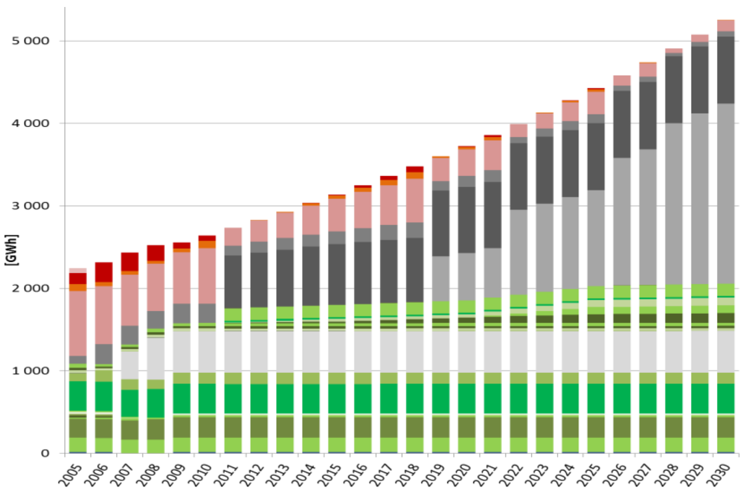
Current CLEW Case Studies (Mauritius)

Mauritius ….

…. the Government of Mauritius formulated a vision for making Mauritius a sustainable island focussing on reducing dependence of fossil fuel and reducing GHG emission.

The Mauritius-CLEW modelling framework was used to assess the energy, water and land-use system in the context of improved local energy generation (bioethanol from sugarcane) under different future climate change scenarios.





Left side:

A future energy scenario for Mauritius was developed outlining the potential for local biofuels under different scenarios. Overall GHG balances were made indicating for example that climate change effects will play a significant role through decreased water availability and increased groundwater pumping and desalination needs.

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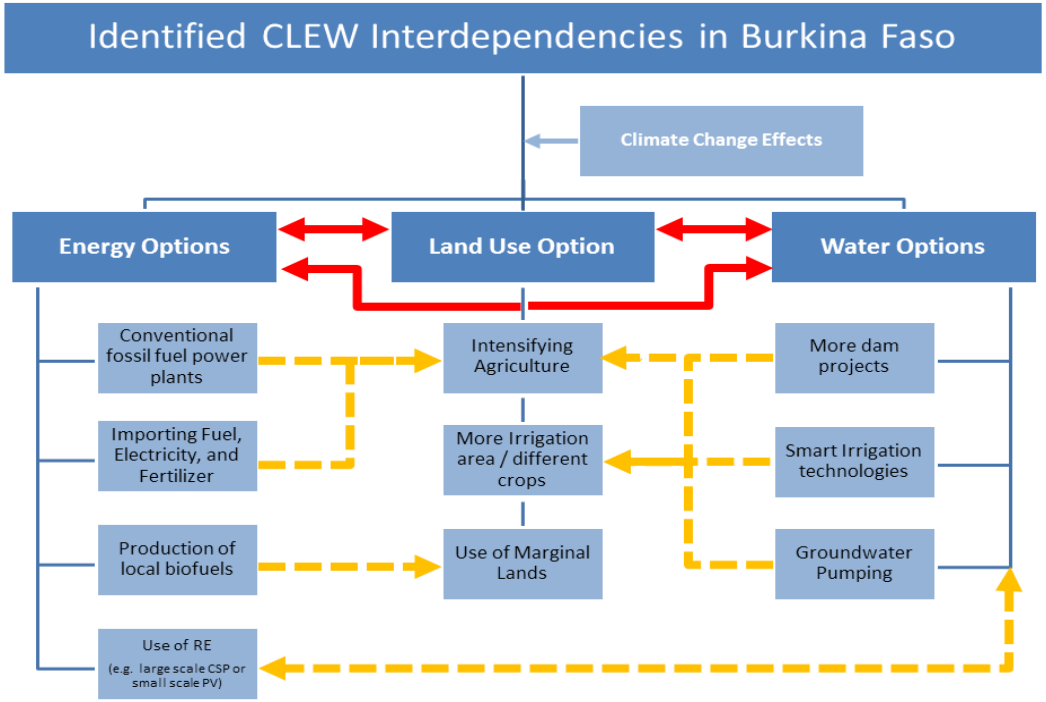
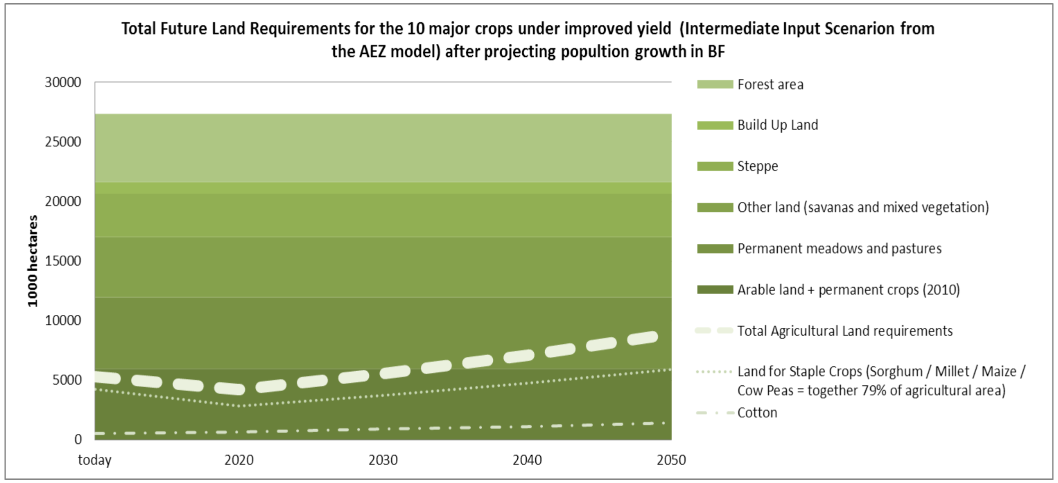
Current CLEW Case Studies (Burkina)

Burkina Faso ....
.... has to fight with a number of development challenges these include resource scarcity, population growth and vulnerability to climate change.
Our CLEW analysis looks into potential future development scenarios and what they mean for future LAND, ENERGY and WATER resources in the country, also taking into account possible Climate Change effects.





Left side:
Agricultural land use projection based on an in an intensified agricultural sector and improved increased yields.
In this scenario energy and water input in the agriculture is increased to a so called "intermediate input level". Intensification of agriculture includes a higher mechanisation and more fossil fuel input but results in increased yields catering for an increased population while approximately maintaining agricultural area.

Thank You

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