eperdoc Documentation

Release 1.0.a

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Aug 18, 2022

CONTENTS

CHAPTER

ONE

ABBREVIATIONS

Abbreviations	Description
ARESEP	Regulatory Authority of Public Services
AYA	Costa Rican Institute of Aqueducts and Sewers
BCCR	Central Bank of Costa Rica
CANATRAC	National Cargo Transport Chamber
CENCE	National Center of Energy Control
CIGEFI	Center for Geophysical Research
CNFL	National Company of Light and Power
CTP	Public Transportation Council
dESA	division of Energy System (from KTH)
DRAT	Arenal Tempisque Irrigation Project
ETSAP	Energy Technology Systems Analysis Program
ICE	Costa Rican Electricity Institute
IEA	International Energy Agency
IMN	National Meteorological Institute
INCOFER	Costa Rican Railway Institute
IPCC	Intergovernmental Panel on Climate Change
HACIENDA	Ministry of Finance
KTH	Royal Institute of Technology - Analysis
MOPT	Ministry of Public Infrastructure and Transportation
PACUMME	Water Supply for the Middle basin of the Tempisque River and Coastal Communities
RITEVE	Techical Vehicular Revision
RECOPE	Costa Rican Oil Refinery

CHAPTER

TWO

1. INTRODUCTION

2.1 1.1 Projects overview

The creation of CLEW-CR is part of the ”Development and assessment of decarbonization pathways to inform dialogue with Costa Rica regarding the updating process of Nationally Determined Contribution (NDC)” project, which was contracted by the World Bank Group for the Directorate of Climate Change (DCC) of the Ministry of Environment and Energy in Costa Rica (MINAE). This project involved the development of land-use and water models of Costa Rica, and the integration of them with a pre-existing energy model, all of them developed in the Open Source energy Modelling System (OSeMOSYS). The CLEW-CR team is composed by researchers from the University of Costa Rica (UCR) and the Royal Institute of Technology (KTH) in Stockholm.

The energy module of CLEW-CR started as part of the “Deep Decarbonization Pathways Project in Latin America and the Caribbean (DDPP-LAC)” project, which is coordinated by the Institute for Sustainable Development and International Relations (IDDRI) and the Inter-American Development Bank (IADB). The project involves six different teams, and each team is formed by experts from a Latin American (LA) country (Argentina, Colombia, Costa Rica, Ecuador, Mexico, and Peru) and experts from other countries (France, USA, Sweden and Brazil). The main purpose of these alliances is to transfer capacities from one country to another, while engaging with policy makers to address a modeling aspect of local importance.

In addition, the development of this energy module has been supported by the project “Assessing Options to Decarbonize the Transport Sector under Technological Uncertainty: The Case of Costa Rica”. This work was contracted by the Interamerican Development Bank (IADB) for the DCC-MINAE. The project aimed at developing a framework to evaluate mitigation actions in the Costa Rican transport sector that contribute to achieve the deep decarbonization, considering its uncertainty and socioeconomic impact, and implementing it in OSeMOSYS-CR to evaluate multiple climate actions towards a clean transport sector.

2.2 1.2 Motivation and problem statement

Costa Rica is a Latin American country worldwide known for its environmental protection, political, social and economic stability, and renewable electricity generation. Despite these achievements, there are many challenges to tackle in order to decarbonise its economy. The CLEWCR model aims at supporting policymakers in Costa Rica to understand the most suitable strategies to achieve a deep decarbonization in the land-use, energy, transport and water treatment sectors. In order to achieve this, CLEWCR presents two typical scenarios of interest: a BAU scenario representing current trends of actions and policies, and a National Decarbonization Plan (NDP) policy decarbonization scenario.

In addition, the CLEWCR model aims at representing the main interconnections between the Climate, Land, Energy and Water sectors and the society needs, i.e., the CLEWs nexus. The framework consists of an existing energy model, two new land and water models and the inclusion of climate variables such as precipitation. While each modeling frameworks characterize the corresponding sectors, their integration allow a broader, economy-wide assessment of different policy measures as the CLEW model captures their interactions and optimizes the overall cost of the system subject to restrictions.

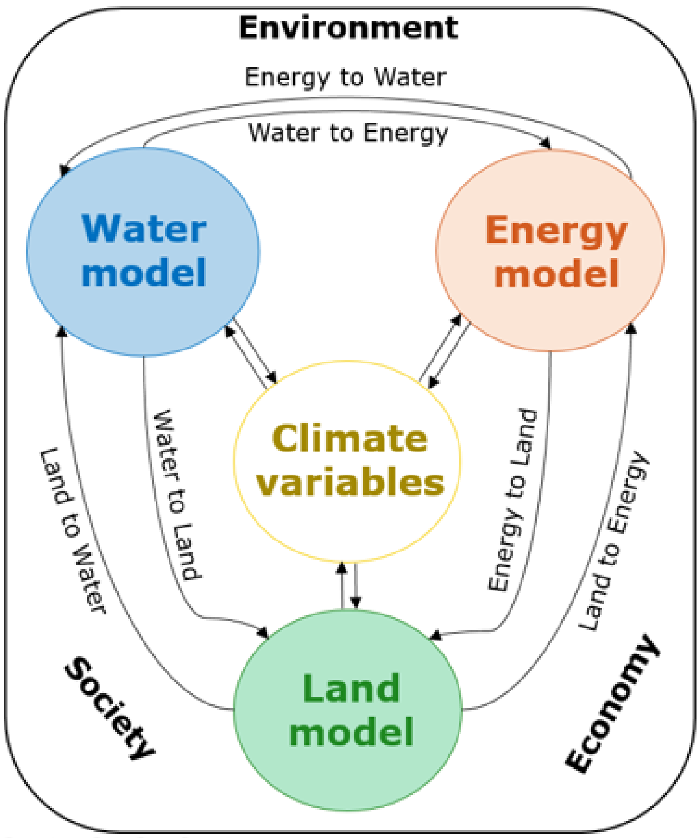

Fig. 1: *Figure: CLEWCR model and the nexus concept*

2.3 1.3 The Open Source energy Modelling System (OSeMOSYS) and CLEWCR

OSeMOSYS is an optimization software for long-term energy planning. It is an open source model structured in blocks of functionality that allows easy modifications to the code, providing a great flexibility for the creative process of the solution. The models built on OSeMOSYS are based upon two general components: technologies (or processes) and fuels (or products/goods). In the case of CLEWCR, the processes include, but are not limited to, the purification and distribution of water, the generation of electricity, and the production of pineapple and coffee. On the other hand, examples of fuels are superficial water, electricity, electric vehicles and produced sugar. Every process is associated to input and output fuels.

In addition, processes are described by a wide variety of parameters that allow a realistic modelling. These parameters are related to aspects such as costs, capacity, lifetime, implementation limits or targets, emissions factors in the case of processes and demands, and availability in the case of fuels. Parameters such as demands can vary over the different time slides considered in the modelling, and emission targets can be included. For CLEWCR, these parameters were included with the best available information, which is most of the time national data. The purpose of this documentation is to present the data values and sources used to parametrized the CLEWCR model.

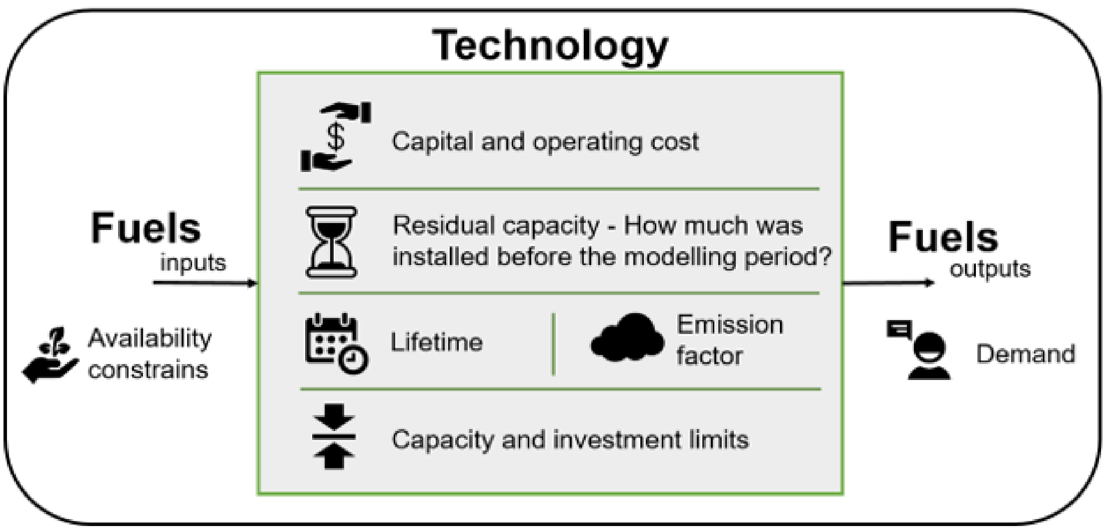

Fig. 2: *Figure: OSeMOSYS parametrization*

The models that are built in OSeMOSYS minimize the total cost of the system for a certain period of time, defining the configuration of the supply system, considering the restrictions on activity, capacity, and emissions of technologies set by the parameters [**?**]. This is shown in the following equation:

$$Minimize \sum_{y,t,r} Total\ discounted\ cost_{y,t,r},$$

where: *y* corresponds to the year, *t* to the technology and *r* to the region.

The discounted cost can be expressed as follows:

$$\forall_{y,t,r}\ Total\ discounted\ cost_{y,t,r}\ = DOC_{y,t,r} + DCI_{y,t,r} + DTEP_{y,t,r} - DSV_{y,t,r},$$

where:

- *DOC (Discounted Operational Cost):* Corresponds to the cost related to maintenance (fixed, usually associate to capacity) and operation of technologies (variable, linked to fuel uses and level of activity).

- *DCI (Discounted Capital Investment):* It is the cost of investment of all technologies selected to supply energy on the whole period.
- *DTEP (Discounted Technology Emission Penalty):* It is associated to the use of pollutants. The calculation is based on the emission factor and the activity of technologies and the specific cost by pollutant.
- *DSV (Discounted Salvage Value):* As the capital cost is discounted in the first year a technology is acquired, if in the last year of study the technologies have remaining years of operational life, the corresponding value is counted.

The general documentation of OSeMOSYS is also available.

CHAPTER

THREE

2. LAND MODEL: FRAMEWORK

In this section, we give an insight to the general structure of the land-use module of CLEWCR. The land-use sector is a cross-cutting topic in the decarbonization plan. However, it is explicitly considered in the last three lines of actions:

- Line of action 8 - The promotion of efficient agricultural food systems that generate low-carbon local export goods and consumption.
- Line of action 9 - Consolidation of an eco-competitive livestock model based on productive efficiency and reduction of greenhouse gases.
- Line of action 10 -Management of rural, urban and coastal territories that considers nature-based solutions (Conservation of forests and ecosystems).

The land-use module aims at representing and quantifying cover changes, livestock and crops yields, changes in emissions as a result of different production practices, ecosystem services, production costs, local production, exports, imports and demands, among other factors.

3.1 2.1 General model structure

The modeling framework structure is divided into six different land covers:

- **Crops:**
  - Rice.
  - Banana.
  - Coffee.
  - Sugar cane.
  - Palm oil.
  - Pineapple.
  - Other agricultural products.
- **Grassland:**
  - Meat.
  - Milk.
- **Forests:**
  - Mangroves primary and secondary forest.
  - Moist primary and secondary forest.
  - Palm primary and secondary forest.

- Moist primary and secondary forest.
- Dry primary and secondary forest.
- Wet primary and secondary forest.
- Forest plantations (timber production).

- **Urban areas.**
- **Other covers.**

Overall, the land-use modeling framework represents supply chains of goods and services produced by the different land cover/use system types. In this context, land supply, demand, and land use change are conditioned by, for the most part, on national and international market forces, policies, institutional factors and production schemes yield.

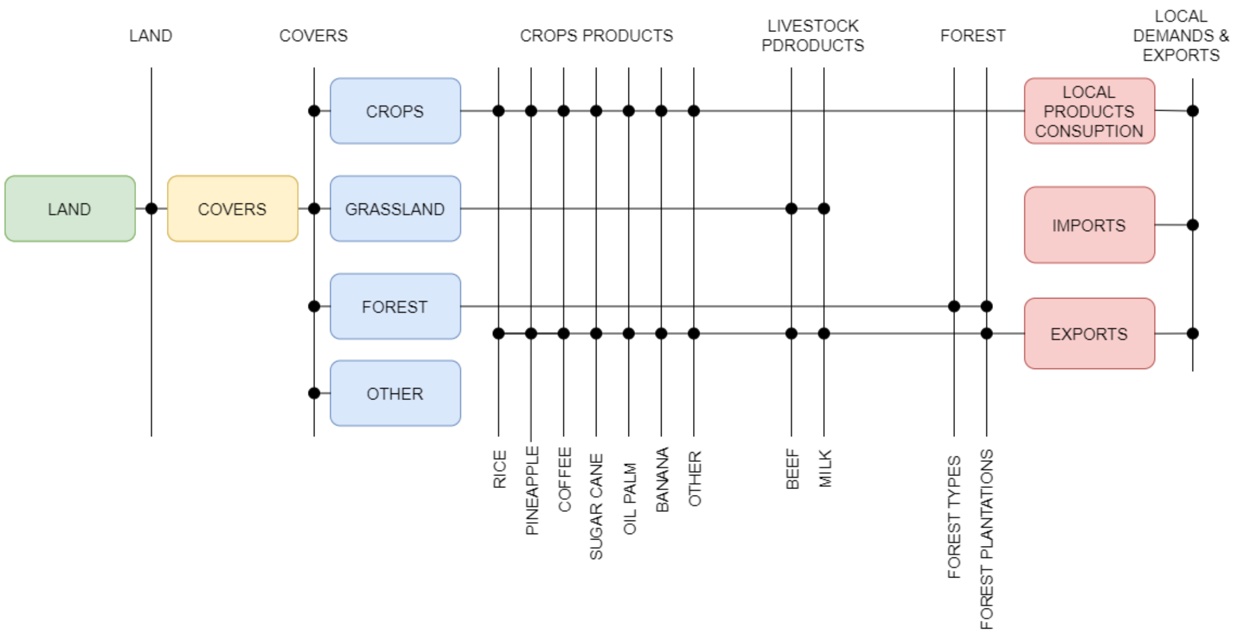

Fig. 1: *Figure: General structure of the land-use module of CLEWCR*

3.2 2.2 Sets

The sets are responsible for defining the structure of the model (i.e. temporal space, geographic space, elements of the system, etc.). In OSeMOSYS, the group of sets include: years, fuels, technologies, emissions and modes of operation. As it going to be further explained, the sets are characterized through parameters. These subsections present the sets that compose the current version of CLEWCR.

3.2.1 2.2.1 Year

This corresponds to the period of analysis. For CLEWCR it is from 2015 to 2050. However, the data from 2015 to 2018 is set acccording to historical information.

3.2.2 2.2.2 Fuels and technologies

A complete list of the fuels and technologies of the land-use module can be found in the *Model codification* section.

3.2.3 2.2.3 Emissions

Table: Summary of emissions included in the land module of CLEWCR.

Emission	Description
CR02_LULUCF_ABS	L_Forest removals
CR02_LULUCF_EMI	L_Land use change emissions
CRCO2_EQ_ESTIERCOL	L_Eq carbon dioxide manure management
CRCO2_EQ_FERMEN	L_Eq carbon dioxide from enteric fermentation
CRCO2_ABS_P_FOR	L_Removals from forest plantations
CRCO2_CULTIVOS	L_Emissions from crops
SE_DRY_Forest	L_Ecosystem services from dry forest
SE_MANGRO_Forest	L_Ecosystem servoces from Mangroves
SE_PALM_Fosrest	L_Ecosystem services from Palm Forest
SE_WET_MOIST_Forest	L_Ecosystem services from Moist Forest

3.2.4 2.2.4 Mode of operation

The model has one mode of operation, Mode 1, for representing the normal operation of the system.

3.2.5 2.2.5 Region

The model has a nationwide scope, therefore it only has one region: Costa Rica (CR).

3. ENERGY MODEL: FRAMEWORK

This section presents the general structure of the energy module, also known as OSeMOSYS-CR, of CLEW-CR.

4.1 3.1 General model structure

The Costa Rican energy sector is enterly modeled in OSeMOSYS. However, while the transport and electricity sectors are subject to linear optimization, other smaller demands, such as the firewood used in the residential sector or the coke consumption by industries, are only represented with trends to account for their possible greenhouse gases (GHG) contributions. The overall structure of the model can be represented by the reference energy system shown in Figure 2.1. The primary energy supply consists of four main sources: renewable, imports of fossil fuels, biomass and electricity imports. These sources are transformed in order to satisfy different demands including industrial, residential and commercial requirements, and the transport demands of passengers (public and private) and cargo (light and heavy).

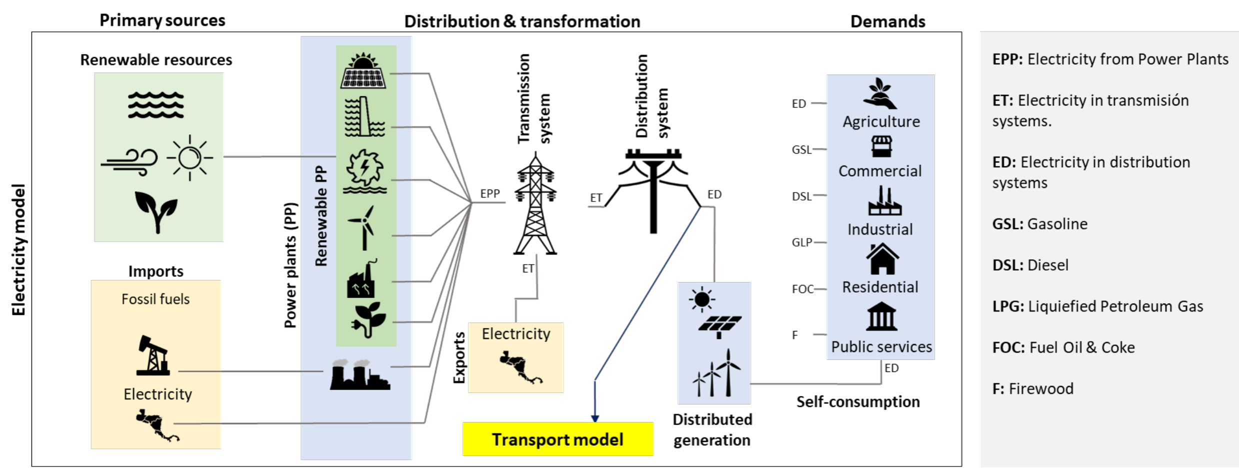

Fig. 1: *(a)*

In OSeMOSYS-CR, the connection between the electricity and transport sectors is crucial for understanding the technological transition of fossil-powered vehicles to other options with lower or zero carbon emissions. The next section describes the group of sets considered in OSeMOSYS-CR for representing the elements commented above.

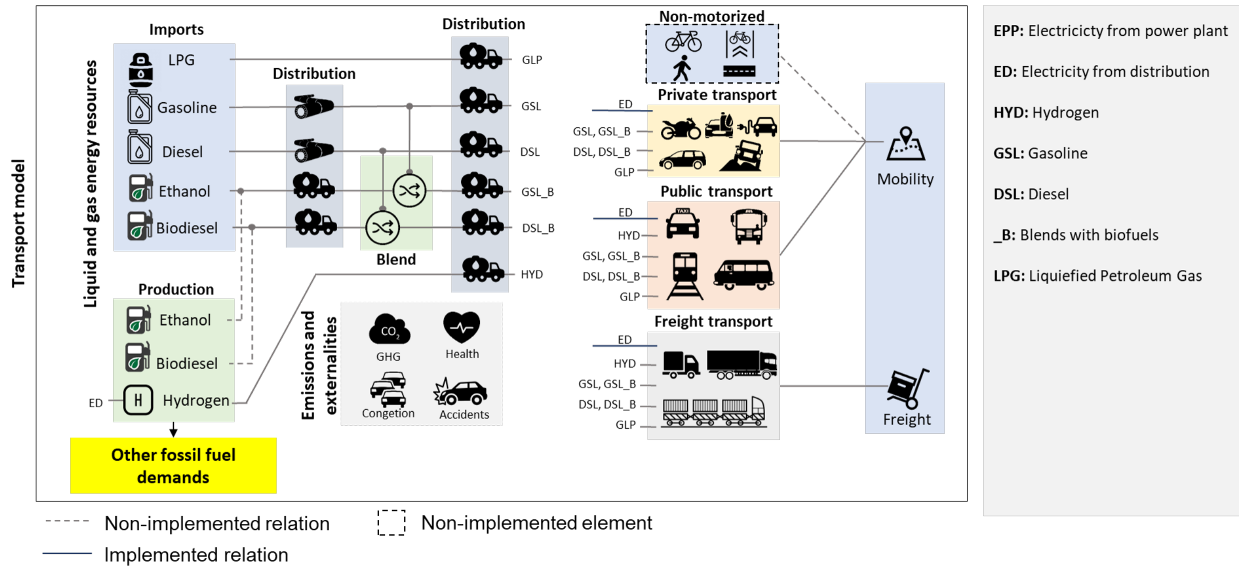

Fig. 2: *(b)*

Figure: Simplified Reference Energy System of the Costa Rica model for the (a) Electricity and (b) Transport sectors

4.2 3.2 Sets

The sets are responsible for defining the structure of the model (i.e. temporal space, geographic space, elements of the system, etc.). In OSeMOSYS, the group of sets include: years, fuels, technologies, emissions and modes of operation. As it going to be further explained, the sets are characterized through parameters. These subsections present the sets that compose the current version of OSeMOSYS-CR.

4.2.1 3.2.1 Year

This corresponds to the period of analysis. For OSeMOSYS-CR it is from 2015 to 2050. However, the data from 2015 to 2018 is set acccording to historical information.

4.2.2 3.2.2 Fuels and technologies

A complete list of the fuels and technologies of the land-use module can be found in the Model codification section.

4.2.3 3.2.3 Emissions

Table 2.3 shows a description of the emissions included in the model. In general, to quantify GHG contributions, the values are in terms of equivalent carbon dioxide (CO2e).

Table: Summary of emissions included in the energy module of CLEWCR.

Code	Name
CO2_sources	Carbon Dioxide from primary sources
CO2_transport	Carbon Dioxide from transport
CO2_AGR	Carbon Dioxide from agriculture
CO2_COM	Carbon Dioxide from the commercial sector
CO2_IND	Carbon Dioxide from the industrial sector
CO2_RES	Carbon Dioxide from the residential sector
CO2_Freigt	Carbon Dioxide from freigt transport
CO2_HeavyCargo	Carbon Dioxide from heavy cargo
CO2_LightCargo	Carbon Dioxide from light cargo

In addition, with this set the model incorporates benefits resulting from the implementation of mitigation policies in the energy sector. These are:

- Health improvements of the population as a result of a reduction in GHG emissions.
- Reduction of congestion, which leads to an increase in the country's productivity.
- Reduction of accidents on the national roads.

4.2.4 3.2.4 Mode of operation

The model has one mode of operation, Mode 1, for representing the normal operation of the system.

4.2.5 3.2.4 Region

The model has a nationwide scope, therefore it only has one region: Costa Rica (CR).

A more detailed documentation of this energy module, OSeMOSYS-CR, can be found in a separate Documentation .

CHAPTER

FIVE

4. WATER MODEL: FRAMEWORK

In this section, we give an insight to the general framework of the water module of CLEWCR. The water sector is a cross-cutting topic in the decarbonization plan, and it is explicitly considered in the 7th line of action: Development of an integrated waste management system based in the separation, reuse, revaluation, and high efficiency and low-GHG final disposal.

5.1 4.1 General model structure

The modeling framework is structued as follow:

- **Water availability:**
  - **Precipitation.**
    - Evapotranspiraton.
    - Surface runoff.
    - Groundwater recharge.
- **Extraction:**
  - Superficial extraction.
  - Underground extraction.
- Potabilization.
- Irrigation.
- **Concessions:**
  -Industrial. - For agriculture.
- Water distribution.
- **Water demands.**
  - For human consumption.
  - Industrial.
  - For agriculture.
- **Water disposal.**
  - Sewage.
  - Septic tank.
  - **Water treatment.**

  * From human consumption.
  * Industrial.
- Water without treatment.

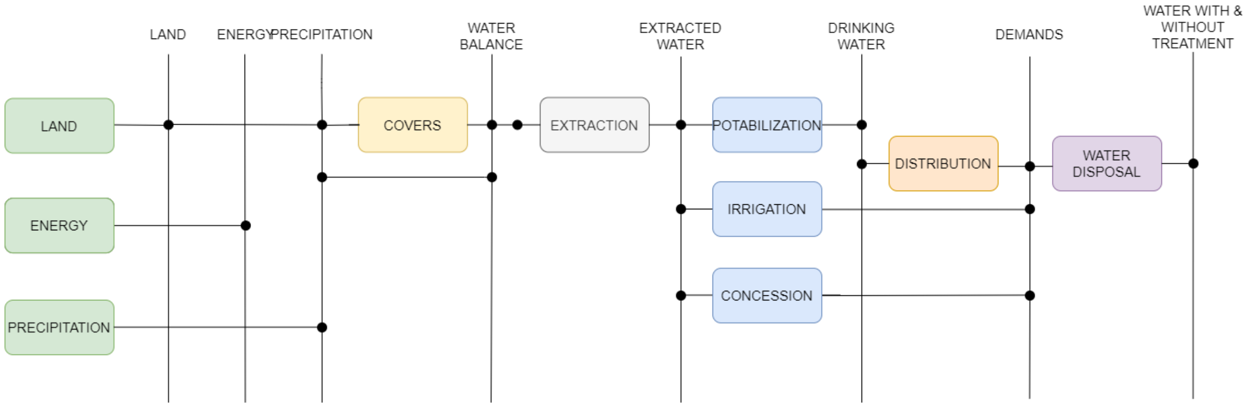

Fig. 1: *Figure: General structure of the water module of CLEWCR*

5.2 4.2 Sets

The sets are responsible for defining the structure of the model (i.e. temporal space, geographic space, elements of the system, etc.). In OSeMOSYS, the group of sets include: years, fuels, technologies, emissions and modes of operation. As it going to be further explained, the sets are characterized through parameters. These subsections present the sets that compose the current version of CLEWCR.

5.2.1 4.2.1 Year

This corresponds to the period of analysis. For CLEWCR it is from 2015 to 2050. However, the data from 2015 to 2018 is set acccording to historical information.

5.2.2 4.2.2 Fuels and technologies

A complete list of the fuels and technologies of the land-use module can be found in the *Model codification* section.

5.2.3 4.2.3 Emissions

Table: Summary of emissions included in the water module of CLEWCR.

Emissions	Description
CO2	W_Emissions from waste water
CR_A_ANC_entrada	Economic benefits of reducing water losses
CR_A_ANC_salida	Benefits in health of water treatment

5.2.4 4.2.4 Mode of operation

The model has one mode of operation, Mode 1, for representing the normal operation of the system.

5.2.5 4.2.5 Region

The model has a nationwide scope, therefore it only has one region: Costa Rica (CR).

CHAPTER

SIX

4. SCENARIO BUILDING

CLEW-CR started by estimating a base case, and subsequently, including the effect of a set of policies defined by stakeholders in two levels of decarbonization. This exercise allowed the creation of three different scenarios:

(i) A Business-as-usual (BAU) scenario, that represents the behavior of the emissions without considering public policy interventions (i.e. following the historic trends).

(ii) A 1.5°C that is compatible with a goal of net zero emissions by 2050.

The BAU scenario considers that the energy consumption, economic activity and population grow according to the historical trends. This scenario incorporates the electricity generation expansion plan from the Costa Rican Electricity Institute to represent the development of the electricity sector [**?**]. It also includes a moderate penetration of solar and wind generation, distributed generation for self-consumption, prived electric vehicles and electric public transport (buses). In terms of emissions, this scenario does not have a significant change in relation to the trend trajectory.

The 1.5°C scenario considers that the social and economic situation described in the BAU scenario remains the same. However, they incorporate the political objectives generated through stakeholder engagement and the participatory process.

6.1 4.1 Land Scenarios

6.2 4.Energy Scenaripos

6.3 4.3 Water Scenarios

CHAPTER SEVEN

MODEL CODIFICATION

7.1 A1. Energy model

7.1.1 A1.1. Fuels

The following table shows the fuels included in OSeMOSYS-CR.

Name	Description	Group
E0BIODSL	Biodisel imported or produced	Pre-sources
E0DSL	Diesel imported	Pre-sources
E0DSLBLEND	Diesel and biodiseal blend	Pre-sources
E0ETHAN	Ethanol imported or produced	Pre-sources
E0GSL	Gasoline imported	Pre-sources
E0GSLBLEND	Gasoline and ethanol blend	Pre-sources
E0LPG	LPG imported	Pre-sources
E0NATGAS	Natural Gas imported	Pre-sources
Name	Description	Group
E1BIO	Biomass energy	Sources
E1DSL	Diesel	Sources
E1FOI	Fuel Oil	Sources
E1FWO	Firewood	Sources
E1GAS	Gasoline	Sources
E1GEO	Geothermal energy	Sources
E1GSL	Gasoline	Sources
E1JEFU	Jet Fuel	Sources
E1LPG	Liquid Petroleum Gas	Sources
E1METH	Methene	Sources
E1PCO	Petroleum coke	Sources
E1SOL	Solar energy	Sources
E1WAT	Hydraulic energy	Sources
E1WIN	Eolic Energy	Sources
E2ELC01	Electricity Supply by Plants	Electricity
E2HYD	Hydrogen produced	Hydrogen
E3ELC02	Electricity for Transmission	Electricity
E3ELC03	Electricity for Distribution	Electricity
E3ELC04	Electricity Exports	Electricity
E4ELC03AGR	Agriculture Electricity Demand	Electricity Demand
E4ELC03COM	Commercial Electricity Demand	Electricity Demand

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Table 1 – continued from previous page

Name	Description	Group
E4ELC03IND	Industrial Electricity Demand	Electricity Demand
E4ELC03PUB	Public Electricity Demand	Electricity Demand
E4ELC03RES	Residential Electricity Demand	Electricity Demand
E5BIOIND	Biomass for Industry	Final Demand
E5DSLAGR	Diesel End Use Agriculture	Final Demand
E5DSLIND	Diesel End Use Industry	Final Demand
E5FWCOM	Firewood End Use Commercial	Final Demand
E5FWIND	Firewood End Use Industry	Final Demand
E5FWRES	Firewood End Use Residential	Final Demand
E5LGPCOM	LGP End Use Commercial	Final Demand
E5LPGIND	LPG End Use Industry	Final Demand
E5LPGRES	LPG End Use Residential	Final Demand
E5OFIND	Fuel Oil End Use Industry	Final Demand
E5PCIND	Petroleum Coke End Use Industry	Final Demand
E6TDAIR	Transport Demand Air	Final Demand
E6TDFREHEA	Transport Demand Freigth Heavy	Final Demand
E6TDFRELIG	Transport Demand Freigth Light	Final Demand
E6TDPASPRIV	Transport Demand Passenger Private	Final Demand
E6TDPASSPUB	Transport Demand Passenger Public	Final Demand
E6TDSPE	Transport Demand Special Equipment & Se	Final Demand
E6TRNOMOT	Transport Demand Passenger No Motorize	Final Demand
E6TRRIDSHA	Transport Demand Passenger Ride Sharing	Final Demand
ETFREIGHT	Cargo demand	Final Demand
ETPASSENGER	Passanger demand	Final Demand
E7DSL_Ag	Diesel for agriculture	Monitor_Agriculture
E7ELE_Ag	Electricity for Agriculture	Monitor_Agriculture
E7ELE_Co	Electricity for Commerce	Monitor_Commerce
E7ELE_Pb	Electricity for public service	Monitor_Commerce
E7FWO_Co	Wood for commerce	Monitor_Commerce
E7LPG_Co	LPG for commerce	Monitor_Commerce
E7DSL_HF	Diesel for light heavy transport	Monitor_FrieghtTransport
E7DSL_LF	Diesel for light freight transport	Monitor_FrieghtTransport
E7ELE_HF	Electricity for heavy freight transport	Monitor_FrieghtTransport
E7ELE_LF	Electricity for light freight transport	Monitor_FrieghtTransport
E7GSL_LF	Gasoline for light freight transport	Monitor_FrieghtTransport
E7HYD_HF	Hydrogen for heavy freight transport	Monitor_FrieghtTransport
E7LPG_HF	LPG for heavy freight transport	Monitor_FrieghtTransport
E7LPG_LF	LPG for light freight transport	Monitor_FrieghtTransport
E7BAG_In	Baggase for Industry	Monitor_Industry
E7BIO_In	Biomass for Industry	Monitor_Industry
E7COK_In	Coke for Industry	Monitor_Industry
E7DSL_In	Diesel for industry	Monitor_Industry
E7ELE_Ind	Electricity for Industry	Monitor_Industry
E7FOI_In	Fuel Oil for Industry	Monitor_Industry
E7FWO_In	Wood for industry	Monitor_Industry
E7LPG_In	LPG for industry	Monitor_Industry
E7BIO_El	Biomass for electricity	Monitor_Other
E7DSL_El	Diesel for electricity	Monitor_Other
E7DSL_Eq	Diesel for special equipment	Monitor_Other

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Table 1 – continued from previous page

Name	Description	Group
E7FOI_El	Fuel oil for electricity	Monitor_Other
E7JFU_Ai	Jet fuel for aircraft	Monitor_Other
E7DSL_Pr	Diesel for private transport	Monitor_PrivateTransport
E7ELE_Pr	Electricity for private transport	Monitor_PrivateTransport
E7GSL_Pr	Gasoline for private transport	Monitor_PrivateTransport
E7LPG_Pr	LPG for private transport	Monitor_PrivateTransport
E7DSL_Pu	Diesel for public transport	Monitor_PublicTransport
E7ELE_Pu	Electricity for public transport	Monitor_PublicTransport
E7GSL_Pu	Gasoline for public transport	Monitor_PublicTransport
E7HYD_Pu	Hydrogen for public transport	Monitor_PublicTransport
E7LPG_Pu	LPG for public transport	Monitor_PublicTransport
E7ELE_Re	Electricity for Commerce	Monitor_Residencial
E7FWO_Re	Wood for residential	Monitor_Residencial
E7LPG_Re	LPG for residential	Monitor_Residencial
E8Fossil_HF	Demand Fossil Fuel Heavy Freight	Transport_Demands
E8Fossil_LF	Demand Fossil Fuel Light Freight	Transport_Demands
E8Fossil_pri	Demand Fossil Fuel Private	Transport_Demands
E8Fossil_pu	Demand Fossil Fuel Public	Transport_Demands
E8Fossil_RS	Demand Fossil Fuel RideSharing	Transport_Demands
E8LowCO2_HF	Demand Low Carbon Heavy Freight	Transport_Demands
E8LowCO2_LF	Demand Low Carbon Light Freight	Transport_Demands
E8LowCO2_pr	Demand Low Carbon Private	Transport_Demands
E8LowCO2_pu	Demand Low Carbon Public	Transport_Demands
E8LowCO2_RS	Demand Low Carbon RideSharing	Transport_Demands
E8NoMotor_B	Demand No motorize Bikes	Transport_Demands
E8NoMotor_W	Demand No motorize walk	Transport_Demands
E9ELESTOR_HF	Electricity storage for heavy freight	Storage
E9ELESTOR_LF	Electricity storage for light freight	Storage
E9ELESTOR_Pr	Electricity storage for private vehicle	Storage
E9ELESTOR_Pu	Electricity storage for public transpor	Storage
E9ELESTORAGE	Electricity storage	Storage
HYDROGEN	Hydrogen	Storage
E7BIKEWAYS	Bikeways infrastructure	Transport_Infraestructre
TIBIKEWAYS	Bikeways infrastructure	Transport_Infraestructre
TIRAILS	Rails infrastructerestrucre	Transport_Infraestructre
TIROADS	Roads infrastructure	Transport_Infraestructre
TISIDEWALKS	Sidewalks infrastructure	Transport_Infraestructre
E7BIKEWAYS	Bikeways infrastructure	Transport_Infraestructre
TIBIKEWAYS	Bikeways infrastructure	Transport_Infraestructre
TIRAILS	Rails infrastructerestrucre	Transport_Infraestructre
TIROADS	Roads infrastructure	Transport_Infraestructre
TISIDEWALKS	Sidewalks infrastructure	Transport_Infraestructre

7.1.2 A1.2. Technologies

The following table shows the technologies included in OSeMOSYS-CR.

Name	Description	Group
BACKSTOP_PS	Backup Power Systems	Backup
BACKSTOP_TS	Backup Transport Sector	Backup
BLENDDSL	Blend Diesel	Primary Sources
BLENDGAS	Blend Gasoline	Primary Sources
DIST_DSL	Distribution Diesel	Primary Sources
DIST_GSL	Distribution Gasoline	Primary Sources
DIST_LPG	Distribution LPG	Primary Sources
DIST_NG	Distribution Natural Gas	Primary Sources
ESIMPBIODSL	Importing biodiesel	Primary Sources
ESIMPDSL	Importing Diesel	Primary Sources
ESIMPETHAN	Importing ethanol	Primary Sources
ESIMPGAS	Importing Gasoline	Primary Sources
ESIMPJEFU	Importing Jet Fuel	Primary Sources
ESIMPLPG	Importing LPG	Primary Sources
ESIMPNG	Importing Natural Gas	Primary Sources
ESIMPOIFU	Importing Oil Fuel	Primary Sources
ESIMPPCO	Importing Petroleum Coke	Primary Sources
ESPROBIODSL	Production biodiesel	Primary Sources
ESPROBIOGAS	Production biogas	Primary Sources
ESPROETHAN	Production ethanol	Primary Sources
ESRNBIO	Biomass Resources	Primary Sources
ESRNFW	Fire wood Resources	Primary Sources
ESRNGEO	Renewable Resource Geothermal	Primary Sources
ESRNSUN	Renewable Resource Solar	Primary Sources
ESRNWAT	Renewable Resource Water	Primary Sources
ESRNWND	Renewable Resource Wind	Primary Sources
ESROMBIO	Organic Material Resources	Primary Sources
PPBIO001	Biomass Power Plant (existing)	Power Plants
PPBIO002	Biomass Power Plant (new)	Power Plants
PPDSL001	Diesel Power Plant (existing)	Power Plants
PPDSL002	Diesel Power Plant (new)	Power Plants
PPFOB001	Oil Power Plant (existing)	Power Plants
PPFOB002	Oil Power Plant (new)	Power Plants
PPGEO001	Geothermal Power Plant (existing)	Power Plants
PPGEO002	Geothermal Power Plant (new)	Power Plants
PPHDAM001	Hydro Dam Power Plant (existing)	Power Plants
PPHDAM002	Hydro Dam Power Plant (new)	Power Plants
PPHROR001	Hydro Run of River Power Plant (existing)	Power Plants
PPHROR002	Hydro Run of River Power Plant (new)	Power Plants
PPPVD001	Photovoltaic Power Plant Distribution (existing)	Power Plants
PPPVD002	Photovoltaic Power Plant Distribution (new)	Power Plants
PPPVT001	Photovoltaic Power Plant Transmission (existing)	Power Plants
PPPVT002	Photovoltaic Power Plant Transmission (new)	Power Plants
PPWND001	Wind Power Plant Distribution (existing)	Power Plants
PPWND002	Wind Power Plant Distribution (new)	Power Plants
PPWNT001	Wind Power Plant Transmission (existing)	Power Plants

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Table 2 – continued from previous page

Name	Description	Group
PPWNT002	Wind Power Plant Transmission (new)	Power Plants
EDDISTAGR	Electric Power Distribution for Agriculture	Electricity Distribution
EDDISTCOM	Electric Power Distribution for Commercial	Electricity Distribution
EDDISTIND	Electric Power Distribution for Industry	Electricity Distribution
EDDISTPUB	Electric Power Distribution for Public	Electricity Distribution
EDDISTRES	Electric Power Distribution for Residential	Electricity Distribution
EDEBIOIND	Biomass Distribution Industry	Energy Distribution
EDEDSLAGR	Diesel Distribution Agriculture	Energy Distribution
EDEDSLIND	Diesel Distribution Industry	Energy Distribution
EDEFOIND	Fuel Oil Distribution Industry	Energy Distribution
EDEFWCOM	Firewood Distribution Commercial	Energy Distribution
EDEFWIND	Firewood Distribution Industry	Energy Distribution
EDEFWRES	Firewood Distribution Residential	Energy Distribution
EDEJFUAIR	Jet fuel oil Distribution air	Energy Distribution
EDELGPCOM	LGP Distribution Commercial	Energy Distribution
EDELPGIND	LPG Distribution Industry	Energy Distribution
EDELPGRES	LPG Distribution Residential	Energy Distribution
EDEPCIND	Petroleum Coke Distribution Industry	Energy Distribution
DDSL_Ag	Diesel for agriculture	Monitor_Agriculture
DELE_Ag	Electricity for agriculture	Monitor_Agriculture
DELE_Co	Electricity for commerce	Monitor_Commerce
DELE_Pb	Electricity for public service	Monitor_Commerce
DFWO_Co	Wood for commerce	Monitor_Commerce
DLPG_Co	LPG for commerce	Monitor_Commerce
DDSL_HF	Diesel for heavy freight transport	Monitor_FreightTransport
DDSL_LF	Diesel for light freigth transport	Monitor_FreightTransport
DELE_HF	Electricity for heavy freight transport	Monitor_FreightTransport
DELE_LF	Electricity for light freigth transport	Monitor_FreightTransport
DGSL_LF	Gasoline for light freigth transport	Monitor_FreightTransport
DHYD_HF	Hydrogen for heavy freight transport	Monitor_FreightTransport
DLPG_HF	LPG for heavy freight transport	Monitor_FreightTransport
DLPG_LF	LPG for light freight transport	Monitor_FreightTransport
DBIO_In	Biomass for industry	Monitor_Industry
DCOK_In	Coke for industry	Monitor_Industry
DDSL_In	Diesel for industry	Monitor_Industry
DELE_In	Electricity for industry	Monitor_Industry
DFOI_in	Fuel Oil for Industry	Monitor_Industry
DFWO_In	Wood for industry	Monitor_Industry
DLPG_In	LPG for industry	Monitor_Industry
DBIO_El	Biomass for electricity	Monitor_Others
DDSL_El	Diesel for electricity	Monitor_Others
DDSL_Eq	Diesel for equipment	Monitor_Others
DFOI_El	Fuel Oil for Electricity	Monitor_Others
DJEFU_Ai	Jet fuel air craft	Monitor_Others
DDSL_Pr	Diesel for private transport	Monitor_PrivateTransport
DELE_Pr	Electricity for Private Transport	Monitor_PrivateTransport
DGSL_Pr	Gasoline for private transport	Monitor_PrivateTransport
DLPG_Pr	LPG for private transport	Monitor_PrivateTransport
DDSL_Pu	Diesel for public transport	Monitor_PublicTransport

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Table 2 – continued from previous page

Name	Description	Group
DELE_Pu	Electricity for Public Transport	Monitor_PublicTransport
DGSL_Pu	Gasoline for public transport	Monitor_PublicTransport
DHYD_Pu	Hydrogen for heavy public transport	Monitor_PublicTransport
DLPG_Pu	LPG for public transport	Monitor_PublicTransport
DELE_Re	Electricity for residencial	Monitor_Residential
DFWO_Re	Wood for residential	Monitor_Residential
DLPG_Re	LPG for residential	Monitor_Residential
TRFWDDSL01	Four-Wheel-Drive (existing)	Private Transport
TRFWDDSL02	Four-Wheel-Drive Diesel (new)	Private Transport
TRFWDELE02	Four-Wheel-Drive Electric (new)	Private Transport
TRFWDGAS01	Four-Wheel-Drive Gasoline (existing)	Private Transport
TRFWDGAS02	Four-Wheel-Drive Gasoline (new)	Private Transport
TRFWDHYBD02	Four-Wheel-Drive Hybrid Electric-Diesel (new)	Private Transport
TRFWDLPG01	Four-Wheel-Drive LPG (existing)	Private Transport
TRFWDLPG02	Four-Wheel-Drive LPG (new)	Private Transport
TRFWDPHYBD02	Four-Wheel-Drive Plug-in Hybrid Electric-Diesel(new)	Private Transport
TRLDDSL01	Light Duty Diesel (existing)	Private Transport
TRLDDSL02	Light Duty Diesel (new)	Private Transport
TRLDELE02	Light Duty Electric (new)	Private Transport
TRLDGAS01	Light Duty Gasoline (existing)	Private Transport
TRLDGAS02	Light Duty Gasoline (new)	Private Transport
TRLDHYBG02	Light Hybrid Electric-Gasoline (new)	Private Transport
TRLDPHYBG02	Light Plug-in Hybrid Electric-Gasoline (new)	Private Transport
TRMIVDSL01	Minivan Diesel (existing)	Private Transport
TRMIVDSL02	Minivan Diesel (new)	Private Transport
TRMIVELE02	Minivan Electric (new)	Private Transport
TRMIVGAS01	Minivan Gasoline (existing)	Private Transport
TRMIVGAS02	Minivan Gasoline (new)	Private Transport
TRMIVHYBD02	Minivan Hybrid Electric-Diesel (new)	Private Transport
TRMIVHYBG02	Minivan Hybrid Electric-Gasoline (new)	Private Transport
TRMIVLPG01	Minivan LPG (existing)	Private Transport
TRMIVLPG02	Minivan LPG (new)	Private Transport
TRMOTELC02	Motorcycle electric (new)	Private Transport
TRMOTGAS01	Motorcycle Gasoline (existing)	Private Transport
TRMOTGAS02	Motorcycle Gasoline (new)	Private Transport
TRBUSDSL01	Bus Diesel (existing)	Public Transport
TRBUSDSL02	Bus Diesel (new)	Public Transport
TRBUSELC02	Bus Electric (new)	Public Transport
TRBUSHYBD02	Bus Hybrid Electric-Diesel (new)	Public Transport
TRBUSHYD02	Bus Hydrogen (new)	Public Transport
TRBUSLPG02	Bus LPG (new)	Public Transport
TRMBUSDSL01	Microbus Diesel (existing)	Public Transport
TRMBUSDSL02	Microbus Diesel (new)	Public Transport
TRMBUSELE02	Microbus Electric (new)	Public Transport
TRMBUSHYBD02	Microbus Hybrid Electric-Diesel (new)	Public Transport
TRMBUSHYD02	Microbus Hydrogen (new)	Public Transport
TRMBUSLPG02	Microbus LPG (new)	Public Transport
TRTAXDSL01	Taxi Diesel (existing)	Public Transport
TRTAXDSL02	Taxi Diesel (new)	Public Transport

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Table 2 – continued from previous page

Name	Description	Group
TRTAXELC02	Taxi Electric (new)	Public Transport
TRTAXGAS01	Taxi Gasoline (existing)	Public Transport
TRTAXGAS02	Taxi Gasoline (new)	Public Transport
TRTAXHYBD02	Taxi Hybrid Electric-Diesel (new)	Public Transport
TRTAXHYBG02	Taxi Hybrid Electric-Gasoline (new)	Public Transport
TRTAXLPG01	Taxi LPG (existing)	Public Transport
TRTAXLPG02	Taxi LPG (new)	Public Transport
TRYLFDSL01	Mini Trucks (existing)	Freight Transport
TRYLFDSL02	Mini Trucks Diesel (new)	Freight Transport
TRYLFELE02	Mini Trucks Electric (new)	Freight Transport
TRYLFGAS01	Mini Trucks Gasoline (existing)	Freight Transport
TRYLFGAS02	Mini Trucks Gasoline (new)	Freight Transport
TRYLFHYBD02	Mini Trucks Hybrid Electric-Diesel (new)	Freight Transport
TRYLFHYBG02	Mini Trucks Electric-Gasoline (new)	Freight Transport
TRYLFLPG01	Mini Trucks LPG (existing)	Freight Transport
TRYLFLPG02	Mini Trucks LPG (new)	Freight Transport
TRYTKDSL01	Trucks Diesel (existing)	Freight Transport
TRYTKDSL02	Trucks Diesel (new)	Freight Transport
TRYTKELC02	Trucks Electric (new)	Freight Transport
TRYTKHYBD02	Trucks Hybrid Electric-Diesel (new)	Freight Transport
TRYTKHYD02	Trucks Hydrogen (new)	Freight Transport
TRYTKLPG02	Trucks LPG (new)	Freight Transport
DIST_HYD	Distribution Hydrogen	Hydrogen
PROD_HYD_CH4	Production hydrogen CH4	Hydrogen
PROD_HYD_H20	Production hydrogen H2O	Hydrogen
TRANOMOTBike	No motorized transport bikes	No Motorized Transport
TRANOMOTWalk	No motorized transport bikes	No Motorized Transport
TRXTRAINDSL01	Train Diesel (existing)	Railroad
TRXTRAINDSL02	Train Diesel (new)	Railroad
TRXTRAINELC02	Train Electric (new)	Railroad
TRZAIR001	Air (existing)	Special Transport
TRZSEQ001	Special Equipment & Sea (existing)	Special Transport
TDDIST01	Electricity Distribution (existing)	T&D Systems
TDDIST02	Electricity Distribution (new)	T&D Systems
TDMEREL01	Imports of electricity	T&D Systems
TDMEREL02	Exports of electricity	T&D Systems
TDTRANS01	Electricity Transmission (existing)	T&D Systems
TDTRANS02	Electricity Transmission (new)	T&D Systems
DTRFF_hf	Transport distribution demand fossil fuel heavy cargo	Transport_Distribution
DTRFF_lf	Transport distribution demand fossil fuel light cargo	Transport_Distribution
DTRFF_pr	Transport distribution demand fossil fuel private	Transport_Distribution
DTRFF_pu	Transport distribution demand fossil fuel public	Transport_Distribution
DTRFF_rs	Transport distribution demand fossil fuel ride sharing	Transport_Distribution
DTRLC_hf	Transport distribution demand Low carbon heavy cargo	Transport_Distribution
DTRLC_lf	Transport distribution demand Low carbon light cargo	Transport_Distribution
DTRLC_pr	Transport distribution demand Low carbon private	Transport_Distribution
DTRLC_pu	Transport distribution demand Low carbon public	Transport_Distribution
DTRLC_rs	Transport distribution demand Low carbon ride sharing	Transport_Distribution
DTRNM_Bk	Transport distribution demand Bikes	Transport_Distribution

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Table 2 – continued from previous page

Name	Description	Group
DTRNM_Wk	Transport distribution demand Walks	Transport_Distribution
TI_BW_01	Bikeway (existing)	Transport_Infraestructure
TI_BW_02	Bikeway (new)	Transport_Infraestructure
TI_RaRo_01	Railroad (existing)	Transport_Infraestructure
TI_RaRo_02	Railroad (new)	Transport_Infraestructure
TI_RoNet_01	Road network (existing)	Transport_Infraestructure
TI_RoNet_02	Road network (new)	Transport_Infraestructure
TI_SW_01	Sidewalk (existing)	Transport_Infraestructure
TI_SW_02	Sidewalk (new)	Transport_Infraestructure

7.2 B1. Land model

7.2.1 B1.1. Fuels

Name	Description
CR_XF_SE_DRY	L_Ecosystem services dry forest
CR_XF_SE_MAN	L_Ecosystem services mangroves forest
CR_XF_SE_MOI	L_Ecosystem services moist forest
CR_XF_SE_PAL	L_Ecosystem services palm forest
CR01SUELO	L_Land
CR02BOSQUE	L_Forest
CR02CULTIVOS	L_Crops
CR02HUMEDALES	L_Wetlands
CR02OTR_TIERRAS	L_Other land covers
CR02PASTOS	L_Grassland
CR02SIN_INFO	L_Covers without information
CR02URBANO	L_Urban areas
CR03ARROZ	L_Rice crops
CR03BANANO	L_Banana crops
CR03CAFE	L_Coffee crops
CR03CANA	L_Sugarcane crops
CR03CARNE_Vacu	L_Land for beef production
CR03LECHE	L_Land for milk production
CR03OTROS	L_Land for other agricultural products prooduction
CR03PALMA	L_Land for oil palm production
CR03PINA	L_Land for pineapple production
CR05DRY_PRI_FOREST	L_Dry Primary Forest
CR05DRY_SEC_FOREST	L_Dry Secondary Forest
CR05MADERA	L_Wood demand
CR05MANGR_PRI_FOREST	L_Mangroves Primary Forest
CR05MANGR_SEC_FOREST	L_Mangroves Secondary Forest
CR05MOIST_PRI_FOREST	L_Moist Primary Forest
CR05MOIST_SEC_FOREST	L_Moist Secondary Forest
CR05PALM_PRI_FOREST	L_Palm Primary Forest
CR05PALM_SEC_FOREST	L_Palm Secondary Forest
CR05WET_PRI_FOREST	L_Wet Primary Forest
CR05WET_SEC_FOREST	L_Wet Secondary Forest

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Table 3 – continued from previous page

Name	Description
CR06ACEITE	L_Palm oil production
CR06AZUCAR	L_Sugar production
CR06BAGAZO	L_Bagasse production
CR06MELAZA	L_Molasses production
CR07DEMAACEITE	L_Palm oil demand
CR07DEMAARROZ	L_Rice demand
CR07DEMAAZUCAR	L_Sugar demand
CR07DEMABAGAZO	L_Bagasse demand
CR07DEMABANANO	L_Banana demand
CR07DEMACAFORO	L_Coffe demand
CR07DEMAMELA	L_Molasses demand
CR07DEMAPINA	L_Pineapple demand
CR07EXPOACEITE	L_Palm oil exports
CR07EXPOARROZ	L_Rice exports
CR07EXPOAZUCAR	L_Sugar exports
CR07EXPOBANANO	L_Banana exports
CR07EXPOCAFORO	L_Coffee exports
CR07EXPOMELA	L_Molasses exports
CR07EXPOPINA	L_Pineapple exportes
CR08DEMACAR_VACU	L_Beef demand
CR08DEMALECHE	L_Milk demand
CR08EXPOCAR_VACU	L_Beef exports
CR08EXPOLECHE	L_Milk exports
CR09DEM_MADERA	L_Wood demand|
CR09EXPO_MADERA	L_Wood exports
CR09USOSUELO	L_Land-use change emissions

7.2.2 B1.2. Technologies

Name	Description
BACKSTOP	L_Backup for land system
CR_DRY_PRI_FOREST	L_Dry Primary Forest
CR_DRY_SEC_FOREST	L_Dry Secondary Forest
CR_MANGR_PRI_FOREST	L_Mangroves Primary Forest
CR_MANGR_SEC_FOREST	L_Mangroves Secondary Forest
CR_MOIST_PRI_FOREST	L_Moist Primary Forest
CR_MOIST_SEC_FOREST	L_Moist Secondary Forest
CR_PALM_PRI_FOREST	L_Palm Primary Forest
CR_PALM_SEC_FOREST	L_Palm Secondary Forest
CR_WET_PRI_FOREST	L_Wet Primary Forest
CR_WET_SEC_FOREST	L_Wet Secondary Forest
CR_XT_SE_DRY	L_Ecosystem services dry forest
CR_XT_SE_MAN	L_Ecosystem services mangroves forest
CR_XT_SE_MOI	L_Ecosystem services moist forest
CR_XT_SE_PAL	L_Ecosystem services palm forest
CRCOB_OTR_TIERRAS	L_Other land covers
CRCOB_SIN_INFO	L_Land covers without information
CRCOBCULT	L_Crops

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Table 4 – continued from previous page

Name	Description
CRCOBERBOS	L_Forest
CRCOBHUMEDA	L_Wetlands
CRCOBPAST	L_Grassland
CRCOBURB	L_Urban areas
CRCONSU_MADERA	L_Wood demand
CRCONSUACEITE	L_Palm oil demand
CRCONSUARROZGR	L_Rice demand
CRCONSUAZUCAR	L_Sugar demand
CRCONSUBAGAZO	L_Bagasse demand
CRCONSUBANA	L_Banana demand
CRCONSUCAFEORO	L_Coffee demand
CRCONSUCAR_VACU	L_Beef demand
CRCONSULECHE	L_Milk demand
CRCONSUMELA	L_Molasses demand
CRCONSUPINA	L_Pineapple demand
CREXPORT_MADERA	L_Wood exports
CREXPORTACEITE	L_Palm oil exports
CREXPORTARROZGR	L_Rice exports
CREXPORTAZUCAR	L_Sugar exports
CREXPORTBANA	L_Banana exports
CREXPORTCAFEORO	L_Coffee exports
CREXPORTCAR_VACU	L_Beef exports
CREXPORTLECHE	L_Milk exports
CREXPORTMELA	L_Molasses imports
CREXPORTPINA	L_Pineapple imports
CRIMPORT_MADERA	L_Wood imports
CRIMPORTACEITE	L_Palm oil imports
CRIMPORTARROZGR	L_Rice imports
CRIMPORTAZUCAR	L_Sugar imports
CRIMPORTBANA	L_Banana imports
CRIMPORTCAFEORO	L_Coffee imports
CRIMPORTCAR_VACU	L_Beef imports
CRIMPORTLECHE	L_Milk imports
CRIMPORTMELA	L_Molasses imports
CRIMPORTPINA	L_Pineapple imports
CRPLANTA_FORESTAL	L_Forest plantations
CRPROCEAZUCAR	L_Sugar production
CRPROCEPALMA	L_Oil palm production
CRPRODARROZ	L_Rice production
CRPRODBANA	L_Banana production
CRPRODCAF	L_Coffee production
CRPRODCANA	L_Sugarcane production
CRPRODCARN_Vacu	L_Beef production
CRPRODLECH	L_Milk production
CRPRODOTRO	L_Other agricultural products production
CRPRODPALM	L_Oil palm production
CRPRODPIN	L_Pineapple production
CRSUELO	L_Land
CRUSOSUELO	L_Land use change

7.3 C1. Water model

7.3.1 C1.1. Fuels

Name	Description
CR00ENERGIA	W_Energy
CR00PRECIP	W_Precipitation
CR00SUELO	W_Land
CR01AGUASUB	W_Underground water
CR01AGUASUP	W_Superficial water
CR01EVAPOT	W_Evapotranspiration
CR02EXTHIDROELEC	W_Water extraction for hydroelectricity
CR02EXTSUB	W_Underground extraction
CR02EXTSUP	W_Superficial extraction
CR03AGUAPOT	W_Drinking water
CR03AGUARIEGO	W_Water for irrigation
CR04AGUADIST	W_Water for distribution
CR05DEMAGROP	W_Demand for agriculture
CR05DEMINDYSERV	W_Industrial demand
CR05DEMCOHUMANO	W_Residential commercial and turism water demand
CR05DEMINDYSERV	W_Water industrial and services demand
CR06VERTCOHUMANO	W_Waste water from human consumtion
CR06VERTINDYSERV	W_Waste water from industries and services
CR06RESTR	W_Collected wastewater
CR05DEMHIDROELECTRICIDAD	W_Water demand for hydroelectricity
CR03CONSUB	W_Underground concessions for industry and services
CR03CONSUBAGROP	W_Underground concessions for agriculture
CR03CONSUPAGROP	W_Superficial concessions for agriculture
CR03CONSUP	W_Superficial concessions for industry and services

7.3.2 C1.2. Technologies

Name	Description
BACKSTOPAGUA	W_Backup water
CRADEMAGROP	W_Agricultural water demand
CRADEMCOHUMANO	W_Residential commercial and turism water demand
CRADEMINDYSERV	W_Industrial water demand
CRCOBBOSQUE	W_Forest
CRCOBOTROS	W_Other land coverages
CRENENERGIA	W_Energy
CRENPRECIP	W_Precipitation
CRENSUELO	W_Land
CREPOT	W_Water purification
CRERIEGO	W_Irrigation
CREXTSUB	W_Underground water extraction
CREXTSUP	W_Superficial water extraction
CRREDACUED	W_Water distribution
CRRETSUB	W_Underground water return

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Table 5 – continued from previous page

Name	Description
CRRETSUP	W_Superficial water return
CRADEMCOHUMANO	W_Water demand for human consumption
CRADEMINDYSERV	W_Water industrial and services demand
CRRIEGOFUT	W_Irrigation (new)
CRVSINTRATCOHUMANO	W_Water without treatment from human consumption
CRVSINTRATINDYSERV	W_Water without treatment from industries and services
CRVTRATCOHUMANO	W_Water treatment from human consumption
CRVTRATINDYSERV	W_Water treatment from industries and services
CRECONSUB	W_Underground concessions
CRECONSUP	W_Superficial concessions
CRVTRATFUTCOHUMANO	W_Water treatment from human consumption (new)
CRVTRATFUTINDYSERV	W_Water treatment from industries and services (new)
CRALCURB	W_Urban Severage
CRALCURBFUT	W_Urban Severage (new)
CRPOZOSRUR	W_Septic tank rural
CRPOZOSRURFUT	W_Septic tank rural (new)
CRALCSINTRAT	W_Urban Sewerage without treatment
CR03CONSUPAGROP	W_Concession for agriculture
CR03CONSUP	W_Concession for industries
CRCOBCARROZ	W_Rice crops
CRCOBCBANANO	W_Banana crops
CRCOBCCAFE	W_Coffee crops
CRCOBCCANA	W_Sugarcane crops
CRCOBCOTROS	W_Other crops
CRCOBCPALMA	W_Oil palm crops
CRCOBCPINA	W_Pineapple crops
CRCONSUBAGROP	W_Underground concessions for agriculture
CRCONSUPAGROP	W_Superficial concessions for agriculture
CRADEMHIDROELECTRICIDAD	W_Water demand for hydroelectricity

CHAPTER

EIGHT

LAND: CROPS

The specific crops considered in the model were selected based on the area they occupy and their overall economic relevance to the country. Therefore, based on these criteria, pineapple, coffee, banana, sugarcane, oil palm, and rice were considered. A category of “others” was also included which groups crops that do not have a large area of cultivation, but are important for the country’s food security (e.g., beans, corn).

8.1 Rice crops

Set codification:	CRPRODARROZ
Description:	Rice crops
Set:	Technology

8.1.1 CapitalCost[r,t,y]

The capital cost is given in MUS$ per Mha. This information is based on reports of the National Rice Corporation (CONARROZ). It includes aspects such as soil preparation, seeds, cleaning, and drainage preparation, among others.

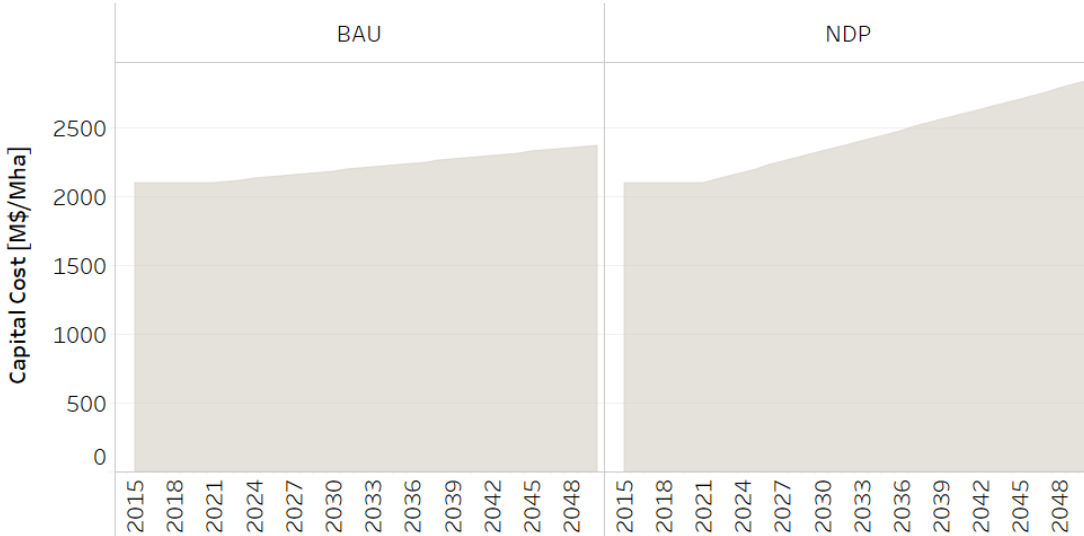

Fig. 1: *Figure: Capital Cost of Rice Production* .

8.1.2 EmissionActivityRatio[r,t,e,m,y]

The data on emissions is based on the National Inventory of Greenhouse Gases. To calculate the emission factor per hectare, the total emissions (CH4) of rice crops were divided by the total number of occupied hectares this type of crop, and then converted into tons of CO2 equivalent.

In the BAU scenario, emission factors remain constant until 2050, considering that there are not changes in the way rice is produced. In the NDP scenario, emissions factors decrease by 39% from 2022 onwards. This modification is based on the Food and Agriculture Organization's GHG emission projections for agriculture, and it contemplates more sustainable rice production schemes.

8.1.3 FixedCost[r,t,y]

This data is based on information from the Central Bank of Costa Rica.

8.1.4 OutputActivityRatio[r,t,y]

This parameter represents the crop yield. This parameter is based on historical data from reports of the Executive Secretariat for Agricultural Sector Planning. In the BAU scenario, the crop yield increase according to the historical data. In the NDP scenario, the increase is greater since better production practices are put into place.

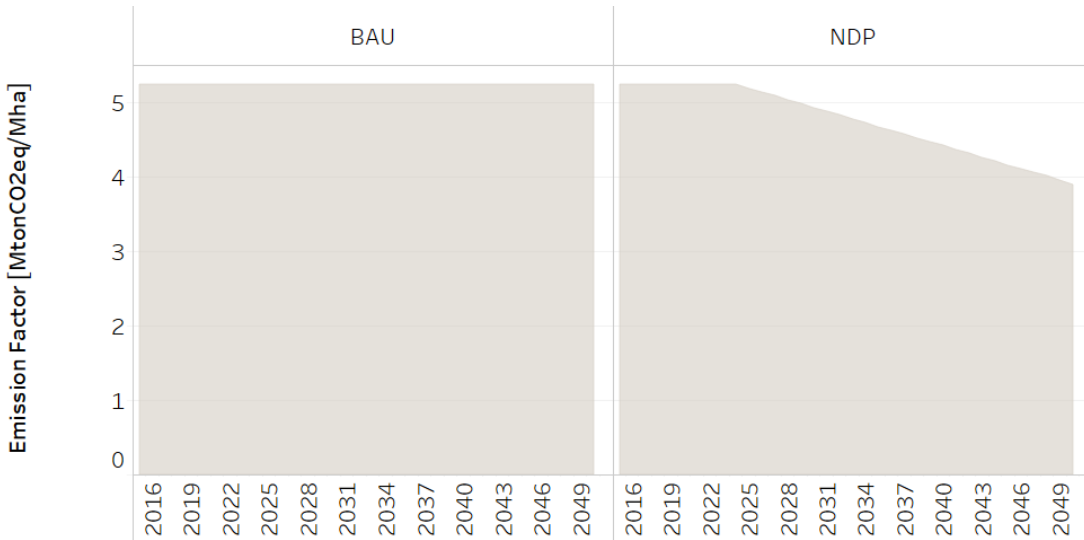

Fig. 2: *Figure: Emission Activity Ratio of Rice Production* .

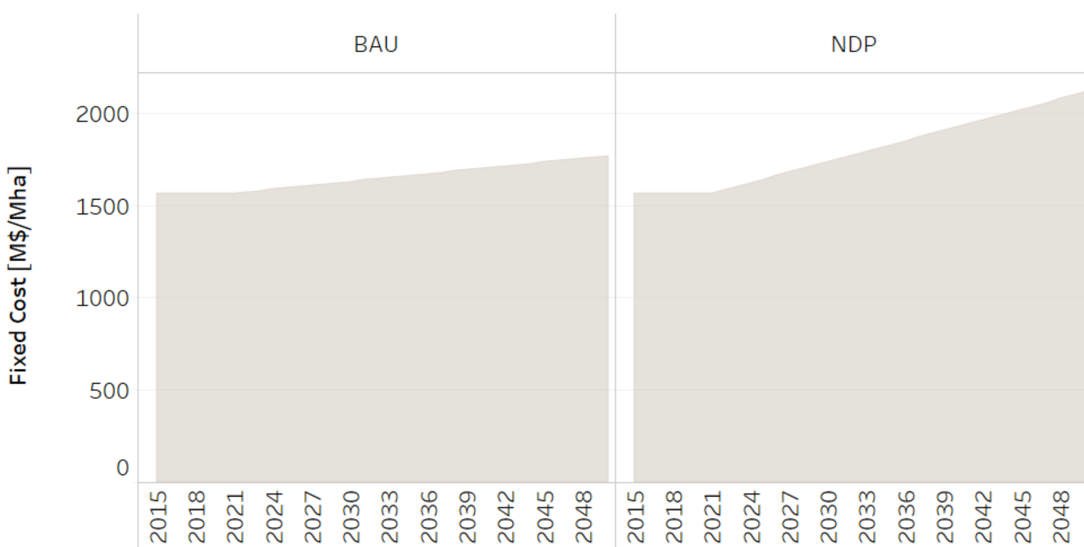

Fig. 3: *Figure: Fixed Cost of Rice Production* .

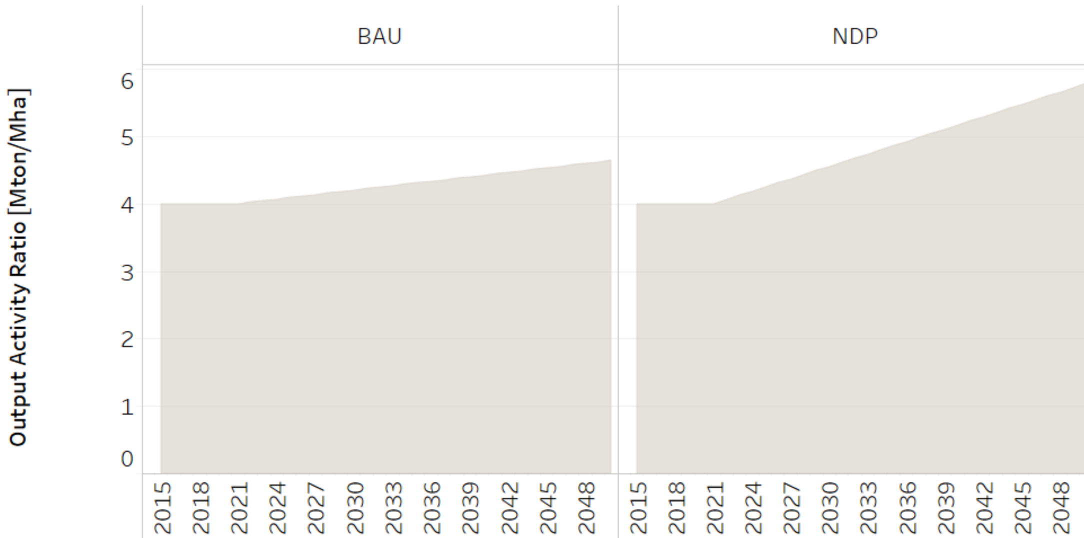

Fig. 4: *Figure: Output Activity Ratio of Rice Production* .

8.1.5 ResidualCapacity[r,t,y]

Here, the residual capacity is understood as the area remaining from a period prior to modeling and is obtained by subtracting each year a proportion of the available area (Mha) based on an average of the operational life of rice crops. It is a function and tends to zero. This parameter is based on the following equation:

$$\frac{Area(year-1) - Area(year)}{Operational\ life}.$$

In the case of rice crops, their operational life is 1 year. The data is based on the National Territorial Information System, from the Executive Secretariat of Agricultural Sector Planning (SEPSA) and from the Ministry of Agriculture and Livestock (MAG).

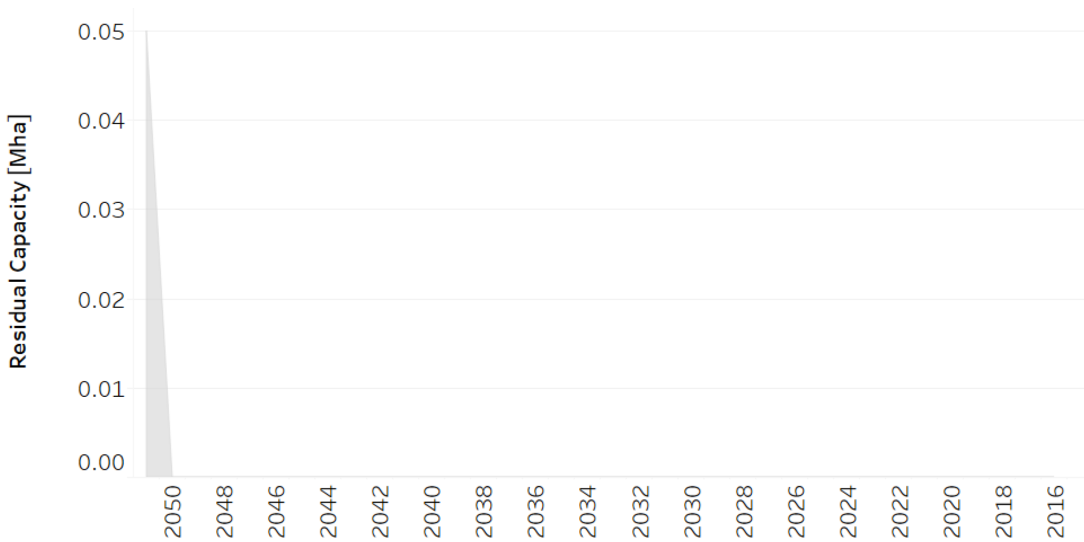

Fig. 5: *Figure: Residual Capacity of Rice Production* .

8.2 Banana crops

Set codification:	CRPRODBANA
Description:	Banana crops
Set:	Technology

8.2.1 CapitalCost[r,t,y]

The capital cost is given in MUS$ per Mha. This information is based on reports of the Executive Secretariat of Agricultural Sector Planning (SEPSA). It includes aspects such as soil preparation, seeds, cleaning, and drainage preparation, among others.

8.2.2 EmissionActivityRatio[r,t,e,m,y]

The data on emissions is based on the National Inventory of Greenhouse Gases. To calculate the emission factor per hectare, the total emissions (CH4) of banana crops were divided by the total number of occupied hectares this type of crop, and then converted into tons of CO2 equivalent.

In the BAU scenario, emission factors remain constant until 2050, considering that there are not changes in the way bananas are produced. In the NDP scenario, emissions factors decrease by 39% from 2022 onwards. This modification is based on the Food and Agriculture Organization's GHG emission projections for agriculture, and it contemplates more sustainable rice production schemes.

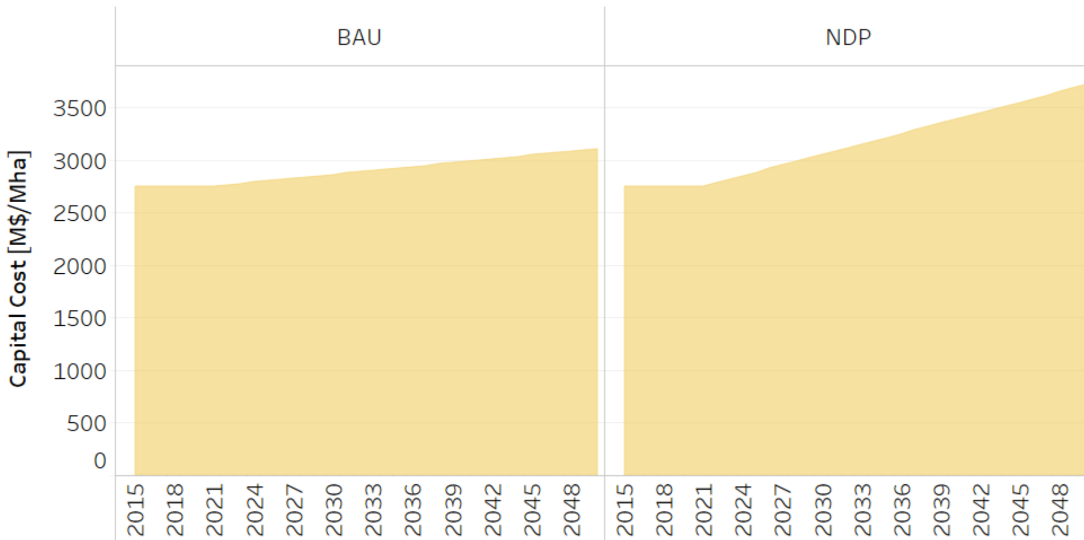

Fig. 6: *Figure: Capital Cost of Banana Production* .

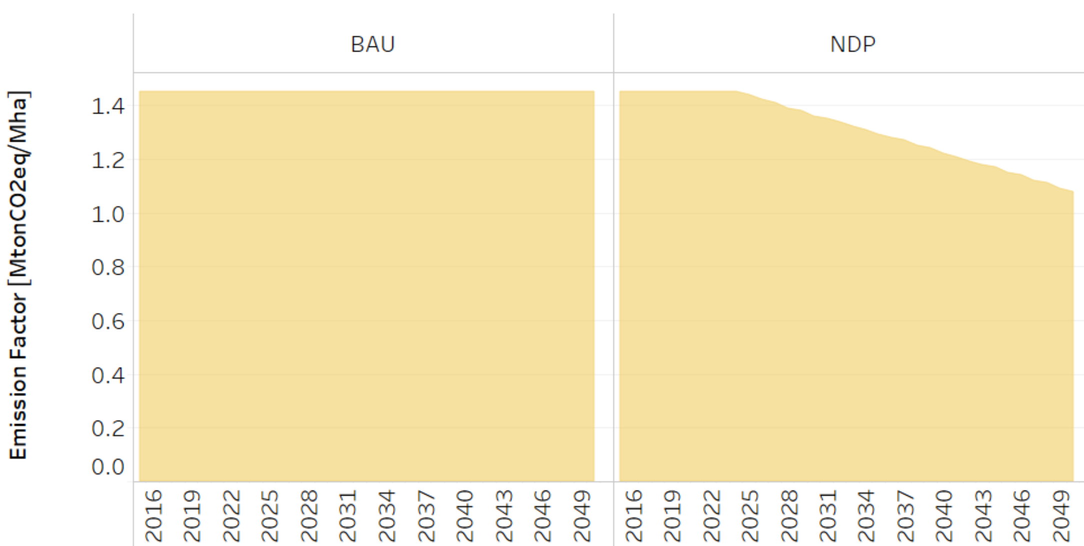

Fig. 7: *Figure: Emission Activity Ratio of Banana Production* .

8.2.3 FixedCost[r,t,y]

This data is based on information from the Central Bank of Costa Rica.

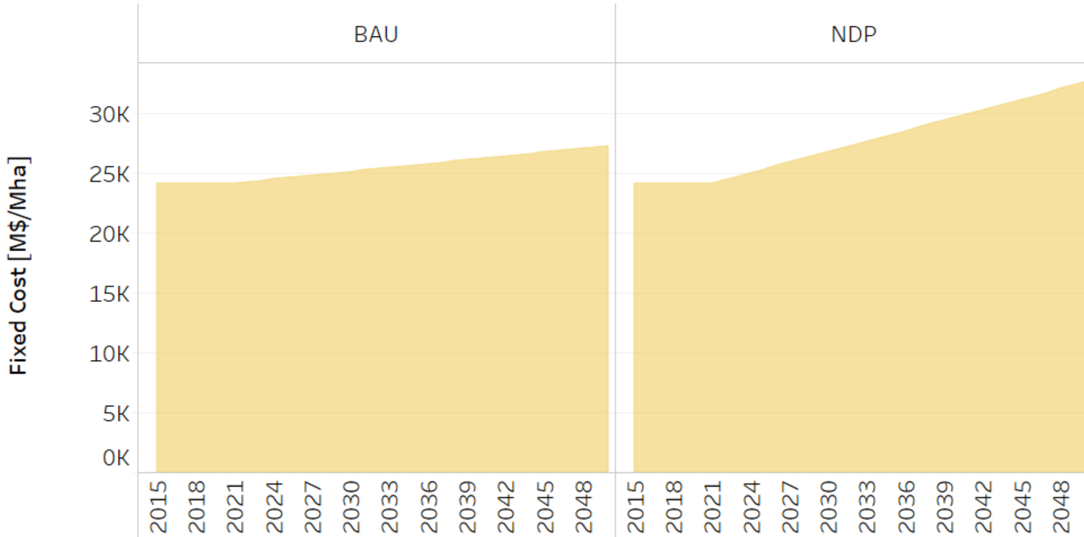

Fig. 8: *Figure: Fixed Cost of Banana Production* .

8.2.4 OutputActivityRatio[r,t,y]

This parameter represents the crop yield. This parameter is based on historical data from reports of the Executive Secretariat for Agricultural Sector Planning. In the BAU scenario, the crop yield increase according to the historical data. In the NDP scenario, the increase is greater since better production practices are put into place.

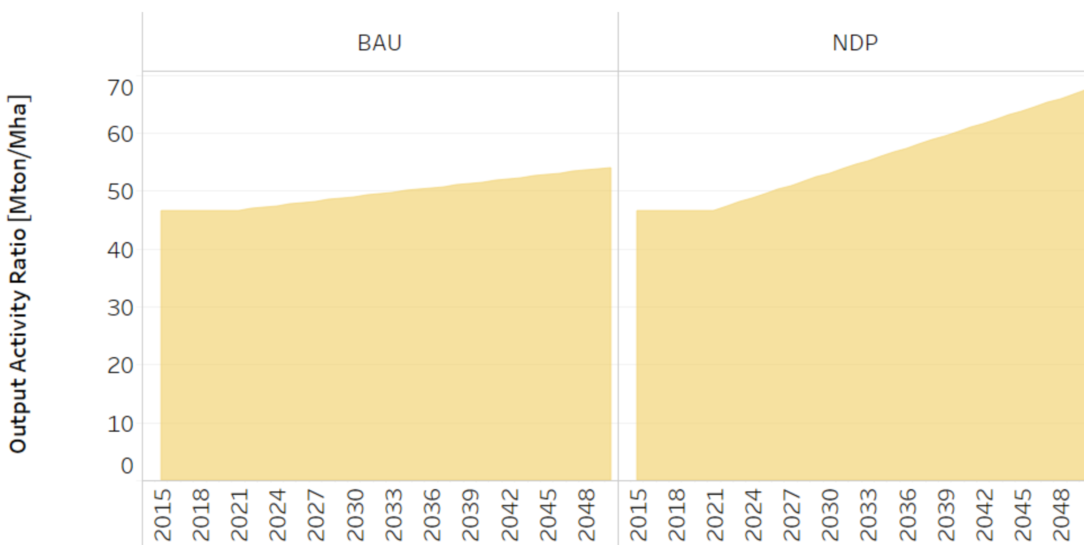

Fig. 9: *Figure: Output Activity Ratio of Banana Production* .

8.2.5 ResidualCapacity[r,t,y]

Here, the residual capacity is understood as the area remaining from a period prior to modeling and is obtained by subtracting each year a proportion of the available area (Mha) based on an average of the operational life of banana crops. It is a function and tends to zero. This parameter is based on the following equation:

$$\frac{Area(year-1) - Area(year)}{Operational\,life}.$$

In the case of banana crops, their operational life is 15 years. The data is based on the National Territorial Information System, from the Executive Secretariat of Agricultural Sector Planning (SEPSA) and from the Ministry of Agriculture and Livestock (MAG).

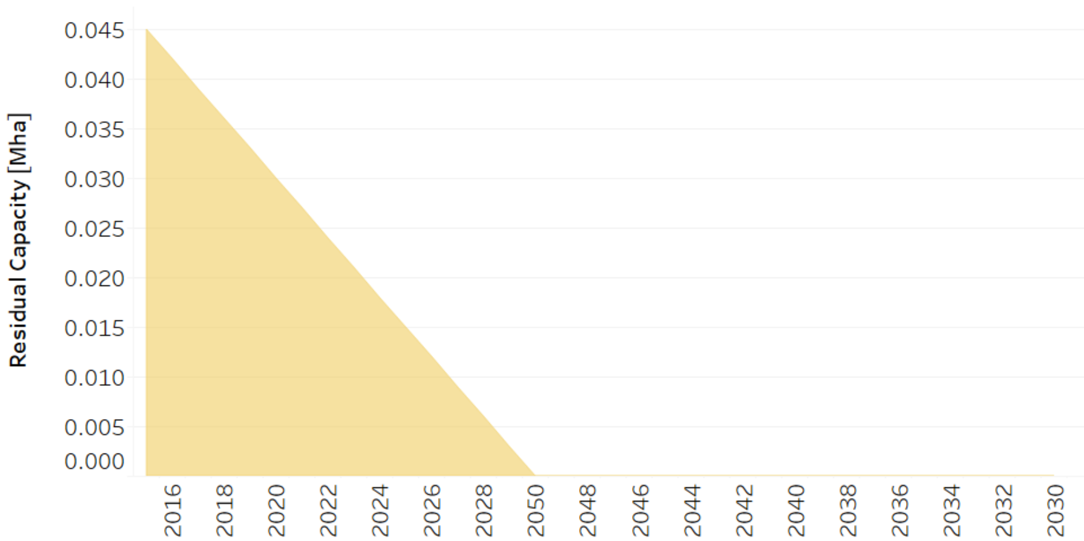

Fig. 10: *Figure: Residual Capacity of Banana Production* .

8.3 Coffee crops

Set codification:	CRPRODCAF
Description:	Coffee crops
Set:	Technology

8.3.1 CapitalCost[r,t,y]

The capital cost is given in MUS$ per Mha. This information is based on reports of the Costa Rican Coffee Institude (ICAFE). It includes aspects such as soil preparation, seeds, cleaning, and drainage preparation, among others.

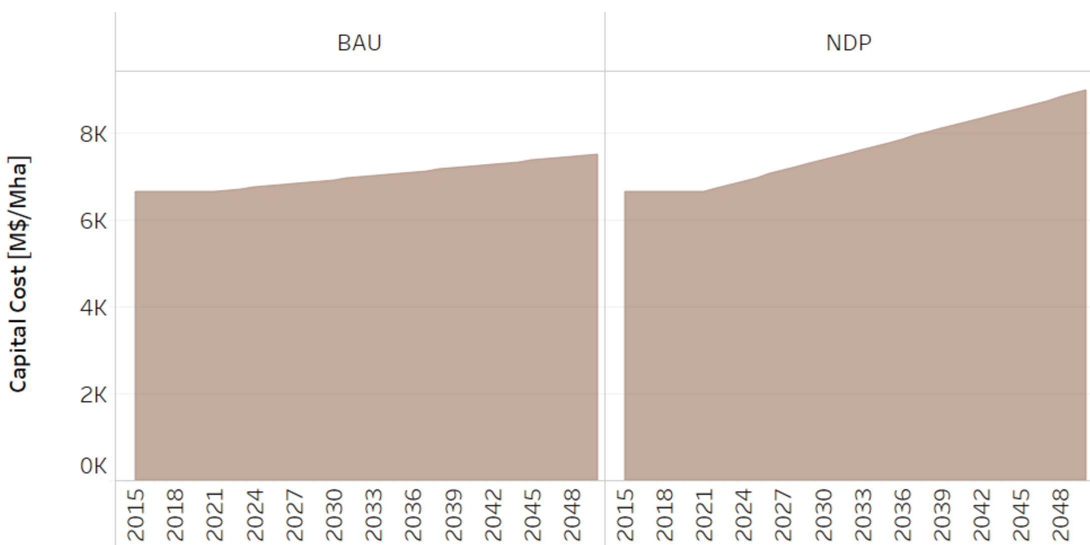

Fig. 11: *Figure: Capital Cost of Coffee Production* .

8.3.2 EmissionActivityRatio[r,t,e,m,y]

The data on emissions is based on the National Inventory of Greenhouse Gases. To calculate the emission factor per hectare, the total emissions (CH4) of coffee crops were divided by the total number of occupied hectares this type of crop, and then converted into tons of CO2 equivalent.

In the BAU scenario, emission factors remain constant until 2050, considering that there are not changes in the way coffee is produced. In the NDP scenario, emissions factors decrease by 39% from 2022 onwards. This modification is based on the Food and Agriculture Organization's GHG emission projections for agriculture, and it contemplates more sustainable coffee production schemes.

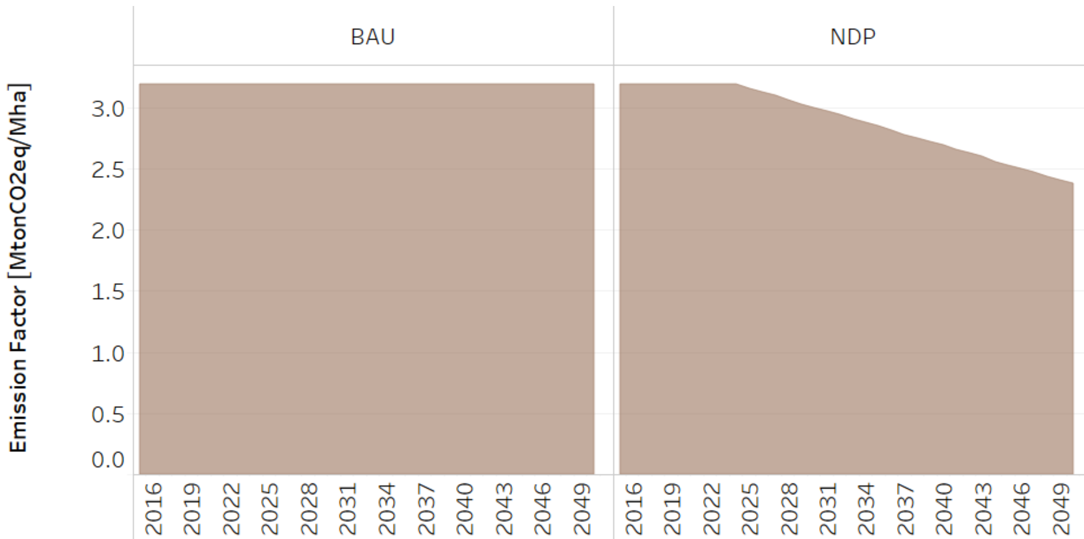

Fig. 12: *Figure: Emission Activity Ratio of Coffee Production* **.**

8.3.3 FixedCost[r,t,y]

This data is based on information from the Central Bank of Costa Rica.

8.3.4 OutputActivityRatio[r,t,y]

8.3.5 ResidualCapacity[r,t,y]

Here, the residual capacity is understood as the area remaining from a period prior to modeling and is obtained by subtracting each year a proportion of the available area (Mha) based on an average of the operational life of coffee crops. It is a function and tends to zero. This parameter is based on the following equation:

$$\frac{Area(year-1) - Area(year)}{Operational\ life}.$$

In the case of coffee crops, their operational life is 20 years. The data is based on the National Territorial Information System, from the Executive Secretariat of Agricultural Sector Planning (SEPSA) and from the Ministry of Agriculture and Livestock (MAG).

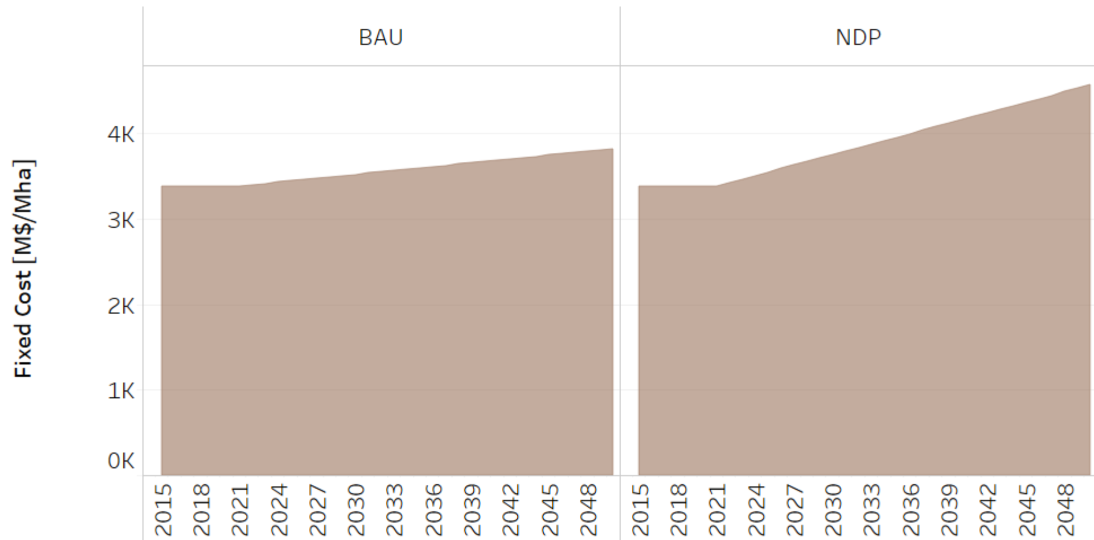

Fig. 13: *Figure: Fixed Cost of Coffee Production* .

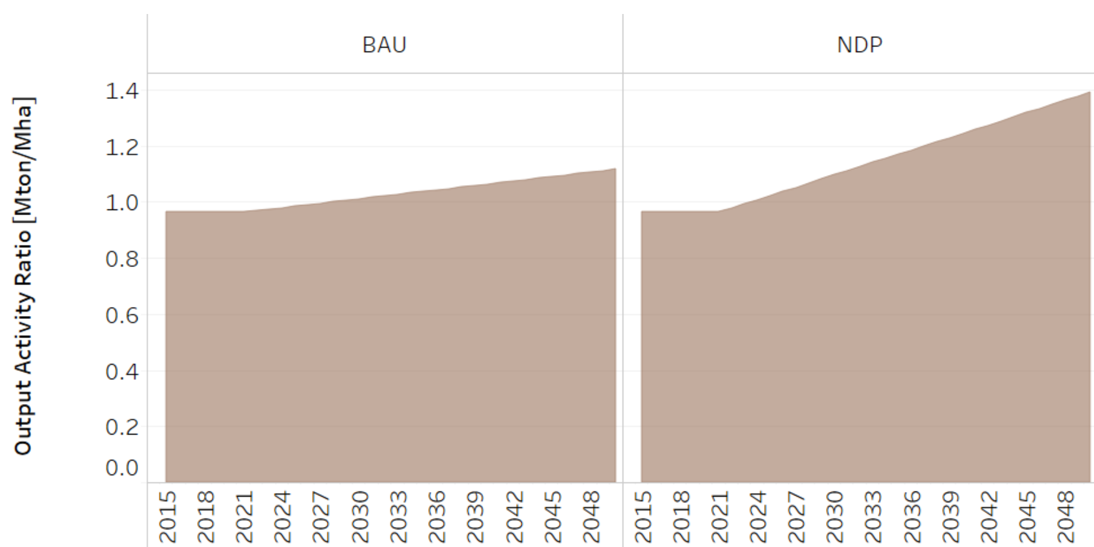

Fig. 14: *Figure: Output Activity Ratio of Coffee Production* .

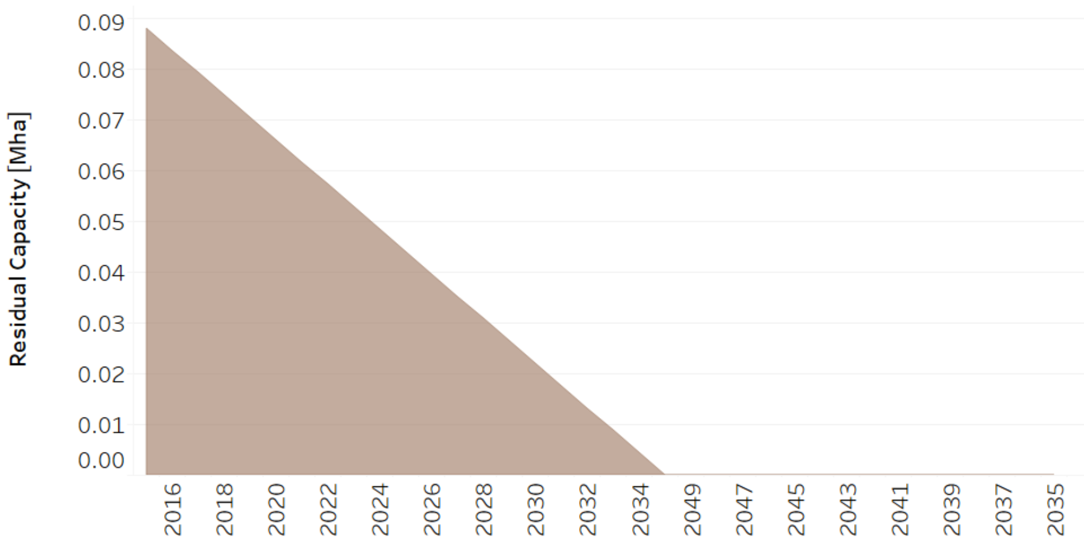

Fig. 15: *Figure: Residual Capacity of Coffee Production* .

8.4 Sugar Cane crops

Set codification:	CRPRODCANA
Description:	Sugar Cane crops
Set:	Technology

8.4.1 CapitalCost[r,t,y]

The capital cost is given in MUS$ per Mha. This information is based on reports of the National Federation of Oil Palm Growers (FEDEPALMA). It includes aspects such as soil preparation, seeds, cleaning, and drainage preparation, among others.

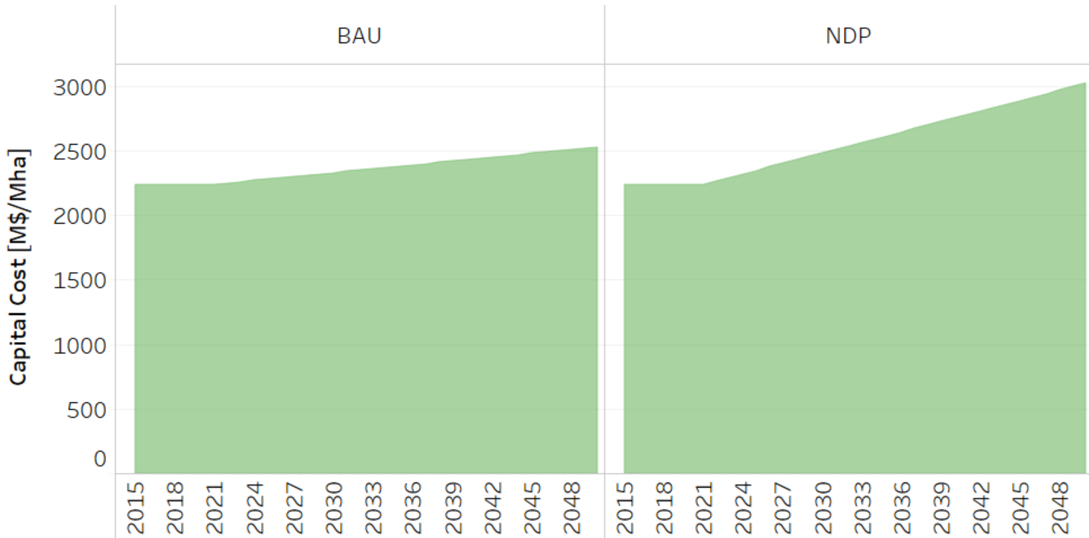

Fig. 16: *Figure: Capital Cost of Sugar Cane Production* .

8.4.2 EmissionActivityRatio[r,t,e,m,y]

The data on emissions is based on the National Inventory of Greenhouse Gases. To calculate the emission factor per hectare, the total emissions (CH4) of sugar cane crops were divided by the total number of occupied hectares this type of crop, and then converted into tons of CO2 equivalent.

In the BAU scenario, emission factors remain constant until 2050, considering that there are not changes in the way sugar cane is produced. In the NDP scenario, emissions factors decrease by 39% from 2022 onwards. This modification is based on the Food and Agriculture Organization's GHG emission projections for agriculture, and it contemplates more sustainable sugar cane production schemes.

8.4.3 FixedCost[r,t,y]

This data is based on information from the Central Bank of Costa Rica.

8.4.4 OutputActivityRatio[r,t,y]

This parameter represents the crop yield. This parameter is based on historical data from reports of the Executive Secretariat for Agricultural Sector Planning. In the BAU scenario, the crop yield increase according to the historical data. In the NDP scenario, the increase is greater since better production practices are put into place.

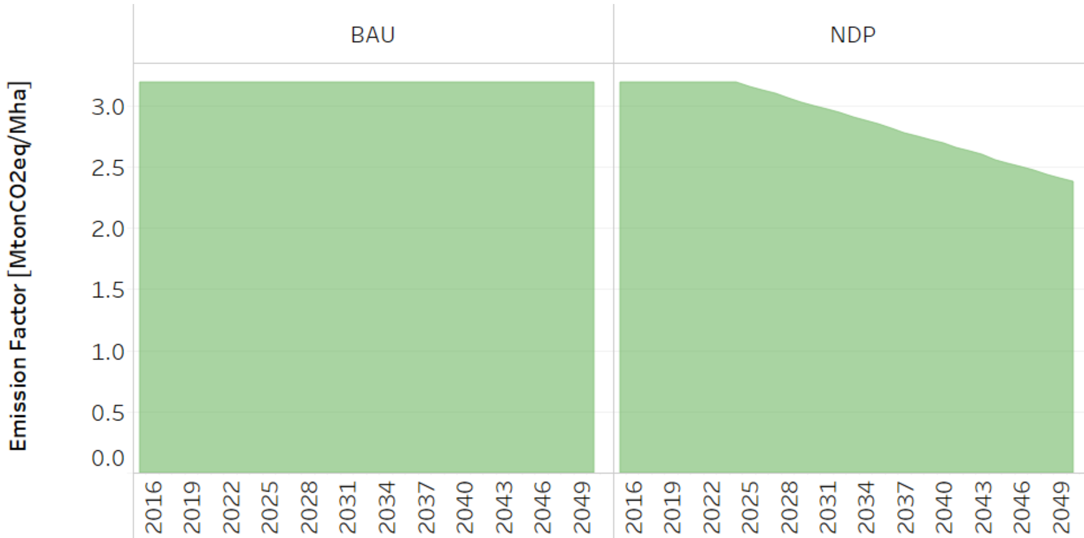

Fig. 17: *Figure: Emission Activity Ratio of Sugar Cane Production* .

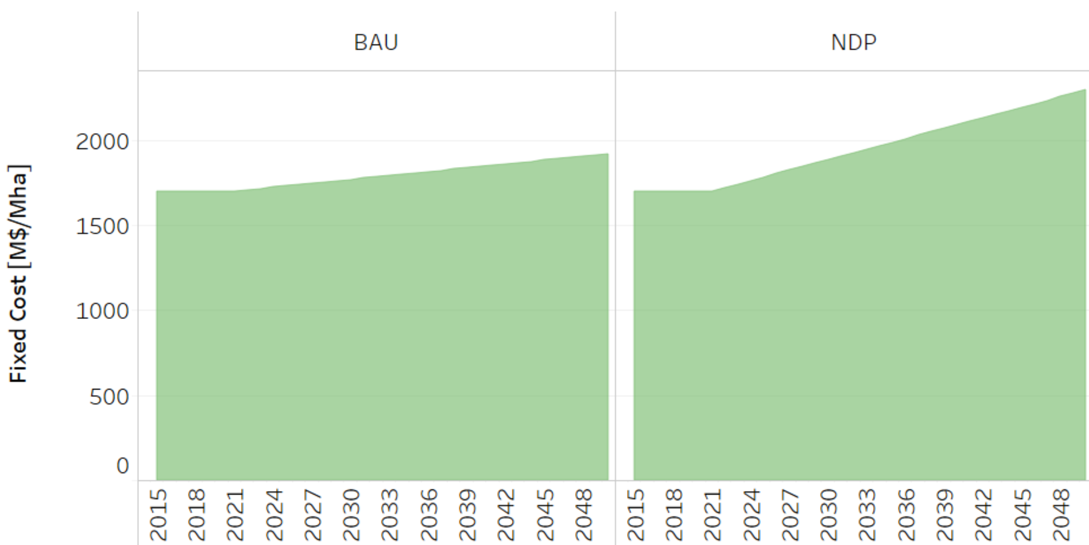

Fig. 18: *Figure: Fixed Cost of Sugar Cane Production* .

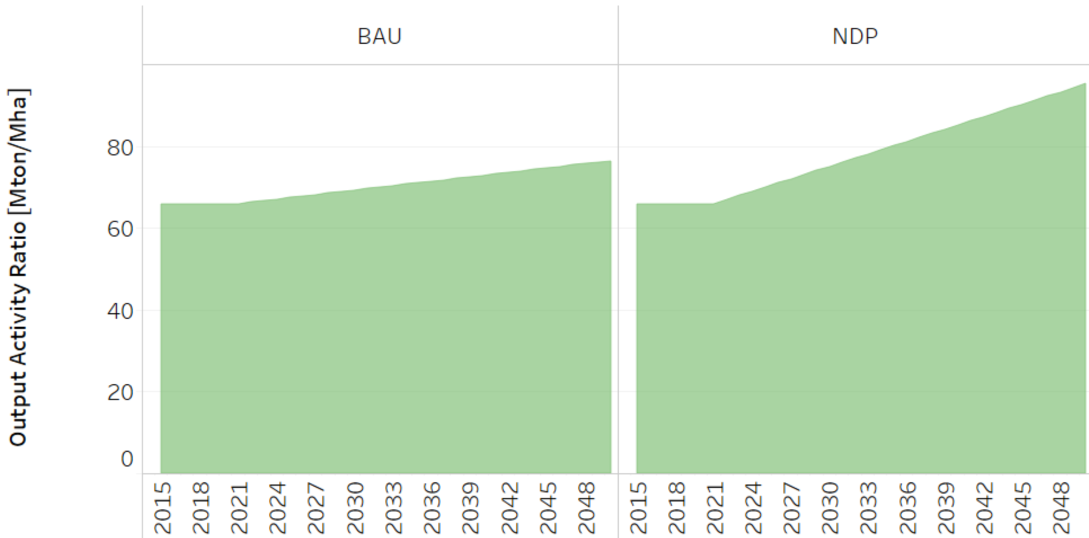

Fig. 19: *Figure: Output Activity Ratio of Sugar Cane Production* .

8.4.5 ResidualCapacity[r,t,y]

Here, the residual capacity is understood as the area remaining from a period prior to modeling and is obtained by subtracting each year a proportion of the available area (Mha) based on an average of the operational life of sugar cane crops. It is a function and tends to zero. This parameter is based on the following equation:

$$\frac{Area(year-1) - Area(year)}{Operational\ life}.$$

In the case of sugar cane crops, their operational life is 5 years. The data is based on the National Territorial Information System, from the Executive Secretariat of Agricultural Sector Planning (SEPSA) and from the Ministry of Agriculture and Livestock (MAG).

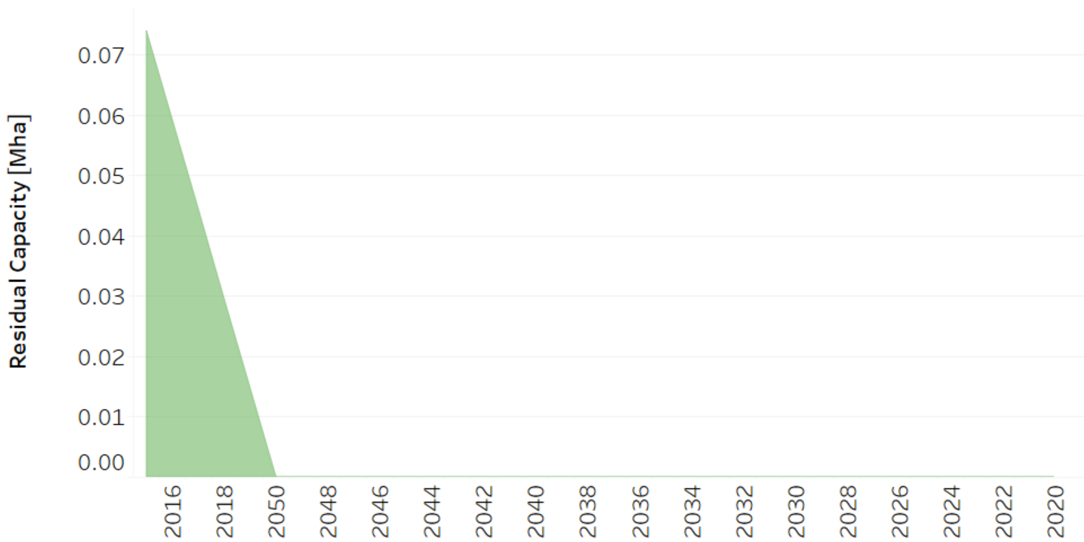

Fig. 20: *Figure: Residual Capacity of Sugar Cane Production* .

8.5 Palm Oil crops

Set codification:	CRPRODPALM
Description:	Palm Oil crops
Set:	Technology

8.5.1 CapitalCost[r,t,y]

The capital cost is given in MUS$ per Mha. This information is based on reports of the National Federation of Oil Palm Growers (FEDEPALMA). It includes aspects such as soil preparation, seeds, cleaning, and drainage preparation, among others.

8.5.2 EmissionActivityRatio[r,t,e,m,y]

The data on emissions is based on the National Inventory of Greenhouse Gases. To calculate the emission factor per hectare, the total emissions (CH4) of palm oil crops were divided by the total number of occupied hectares this type of crop, and then converted into tons of CO2 equivalent.

In the BAU scenario, emission factors remain constant until 2050, considering that there are not changes in the way palm oil is obtained. In the NDP scenario, emissions factors decrease by 39% from 2022 onwards. This modification is based on the Food and Agriculture Organization's GHG emission projections for agriculture, and it contemplates more sustainable rice production schemes.

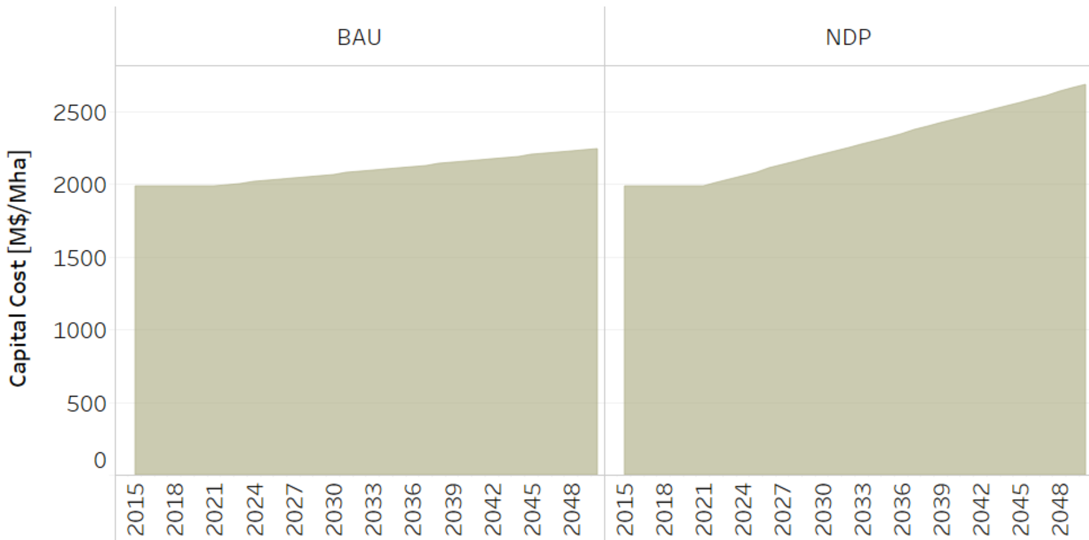

Fig. 21: *Figure: Capital Cost of Palm Oil Production* .

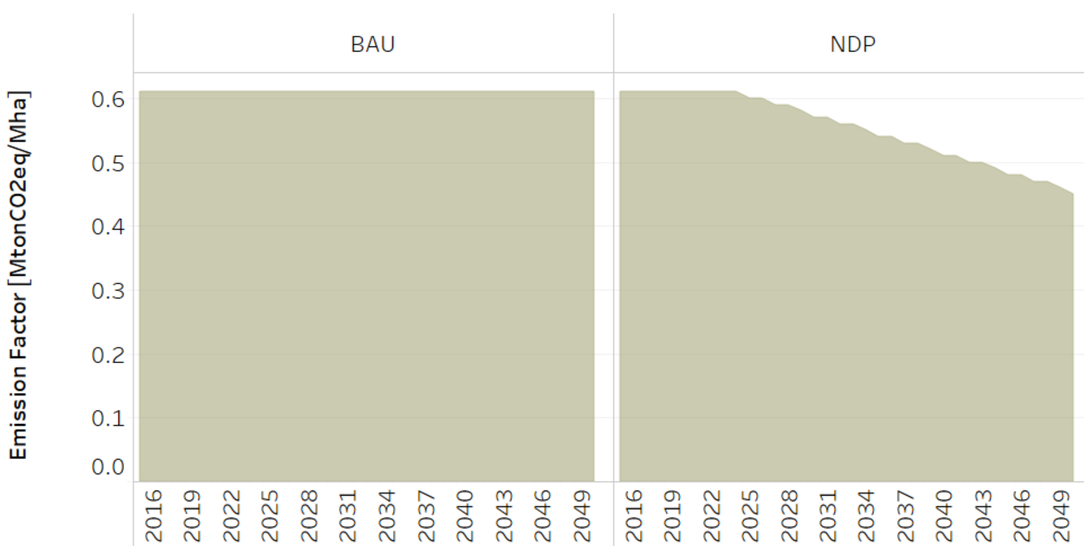

Fig. 22: *Figure: Emission Activity ratio of Palm Oil Production* .

8.5.3 FixedCost[r,t,y]

This data is based on information from the Central Bank of Costa Rica.

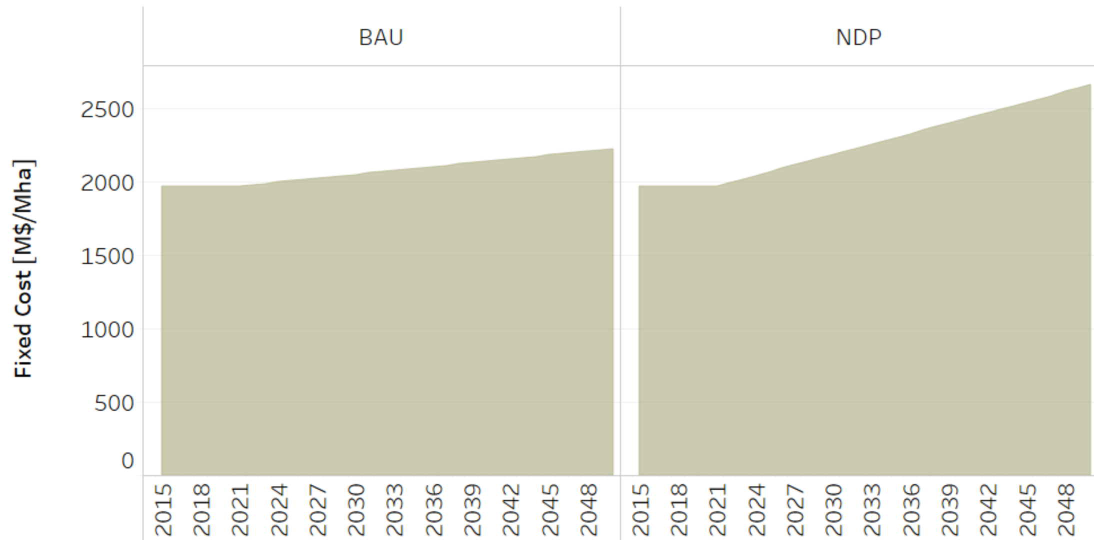

Fig. 23: *Figure: Fixed Cost of Palm Oil Production* .

8.5.4 OutputActivityRatio[r,t,y]

This parameter represents the crop yield. This parameter is based on historical data from reports of the Executive Secretariat for Agricultural Sector Planning. In the BAU scenario, the crop yield increase according to the historical data. In the NDP scenario, the increase is greater since better production practices are put into place.

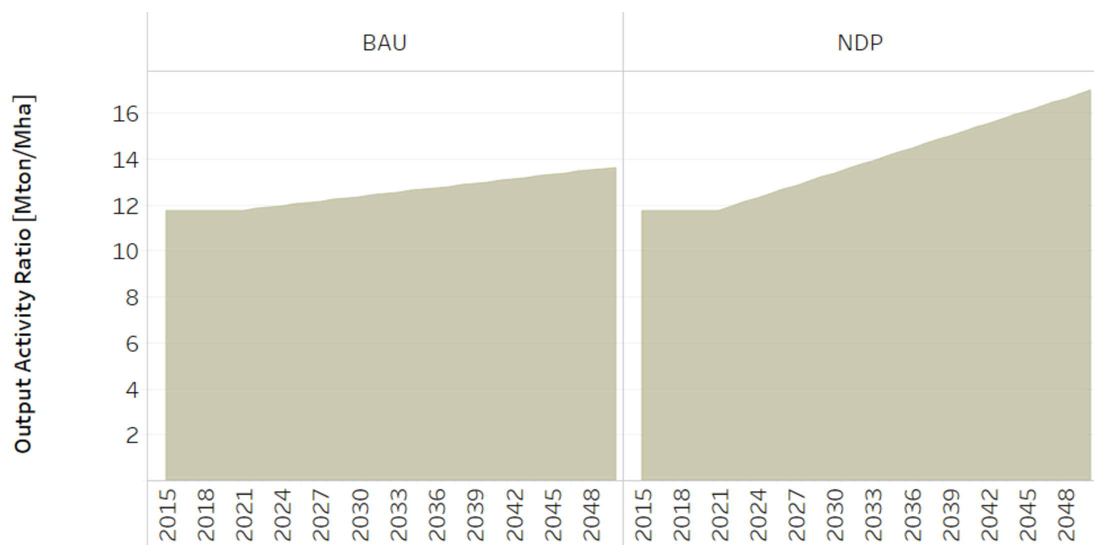

Fig. 24: *Figure: Output Activity of Palm Oil Production* .

8.5.5 ResidualCapacity[r,t,y]

Here, the residual capacity is understood as the area remaining from a period prior to modeling and is obtained by subtracting each year a proportion of the available area (Mha) based on an average of the operational life of palm oil crops. It is a function and tends to zero. This parameter is based on the following equation:

$$\frac{Area(year-1) - Area(year)}{Operational\ life}.$$

In the case of palm oil crops, their operational life is 25 years. The data is based on the National Territorial Information System, from the Executive Secretariat of Agricultural Sector Planning (SEPSA) and from the Ministry of Agriculture and Livestock (MAG).

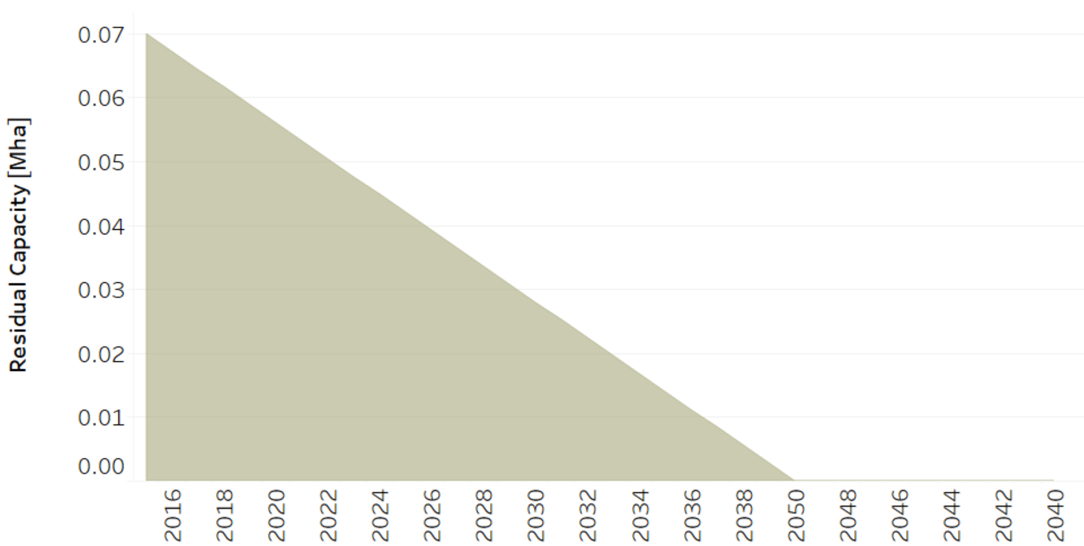

Fig. 25: *Figure: Residual Capacity of Palm Oil Production* .

8.6 Pineapple crops

Set codification:	CRPRODPIN
Description:	Pineapple crops
Set:	Technology

8.6.1 CapitalCost[r,t,y]

The capital cost is given in MUS$ per Mha. This information is based on reports of the Executive Secretariat of Agricultural Sector Planning (SEPSA). It includes aspects such as soil preparation, seeds, cleaning, and drainage preparation, among others.

8.6.2 FixedCost[r,t,y]

This data is based on information from the Central Bank of Costa Rica.

8.6.3 OutputActivityRatio[r,t,y]

This parameter represents the crop yield. This parameter is based on historical data from reports of the Executive Secretariat for Agricultural Sector Planning. In the BAU scenario, the crop yield increase according to the historical data. In the NDP scenario, the increase is greater since better production practices are put into place.

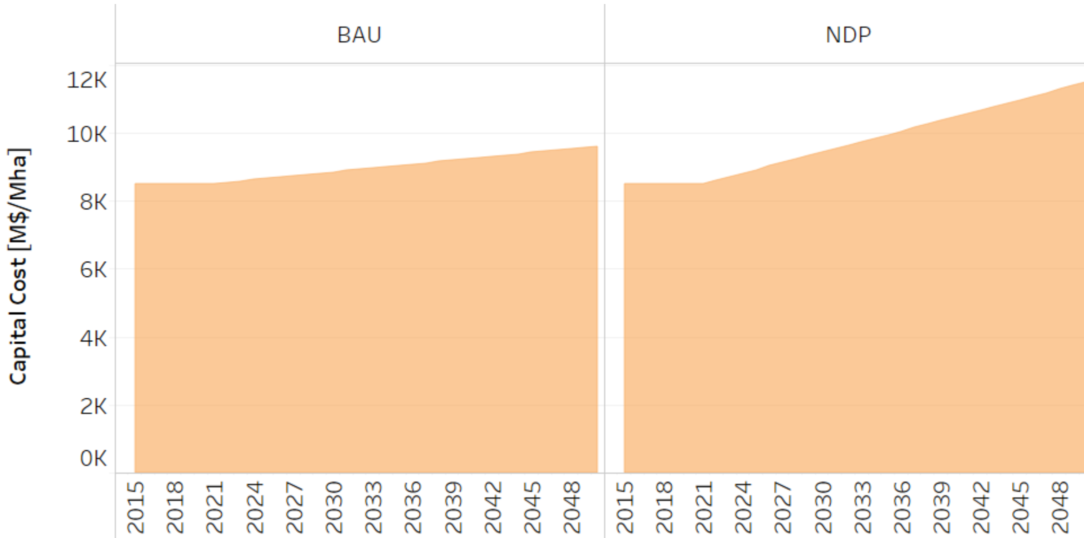

Fig. 26: *Figure: Capital Cost of Pineapple Production* .

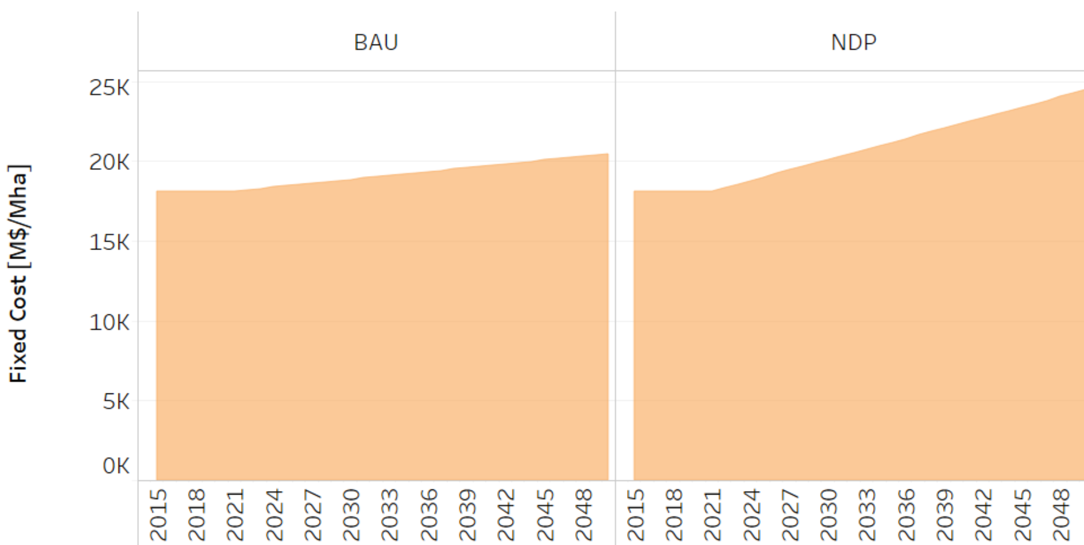

Fig. 27: *Figure: Fixed Cost of Pineapple Production* .

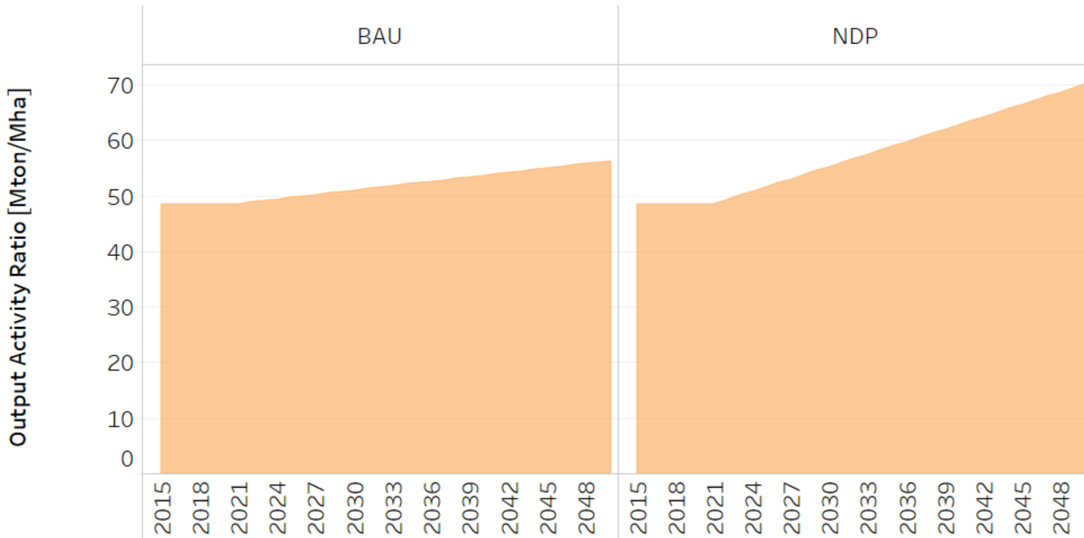

Fig. 28: *Figure: Output Activity Ratio of Pineapple Production* .

8.6.4 ResidualCapacity[r,t,y]

Here, the residual capacity is understood as the area remaining from a period prior to modeling and is obtained by subtracting each year a proportion of the available area (Mha) based on an average of the operational life of pineapple crops. It is a function and tends to zero. This parameter is based on the following equation:

$$\frac{Area(year-1) - Area(year)}{Operational\ life}.$$

In the case of pineapple crops, their operational life is 1 year. The data is based on the National Territorial Information System, from the Executive Secretariat of Agricultural Sector Planning (SEPSA) and from the Ministry of Agriculture and Livestock (MAG).

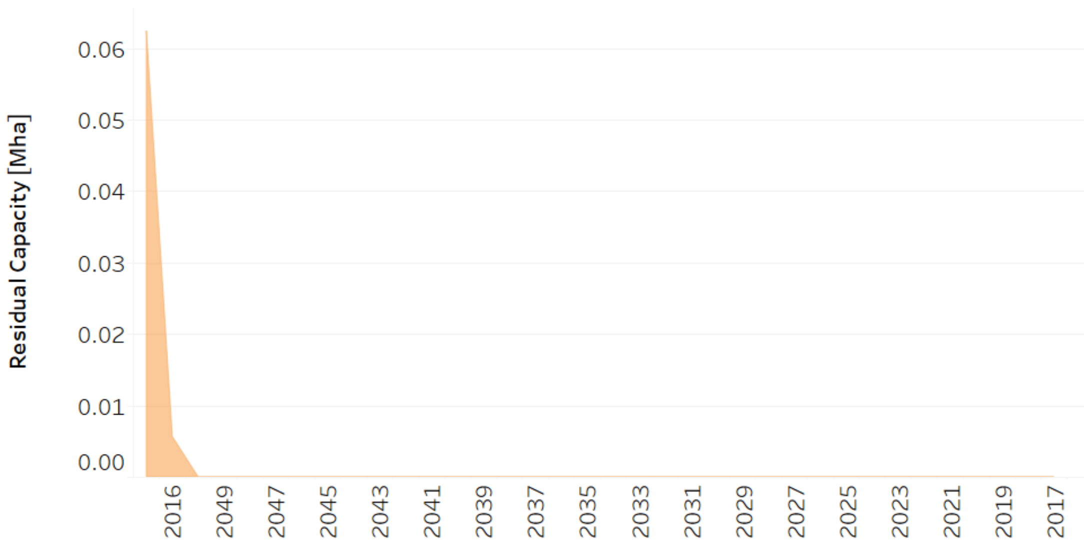

Fig. 29: *Figure: Residual Capacity of Pineapple Production* .

CHAPTER

NINE

LAND: GRASSLAND

9.1 Beef

Set codification:	CRPRODCARN_Vacu
Description:	Beef
Set:	Technology

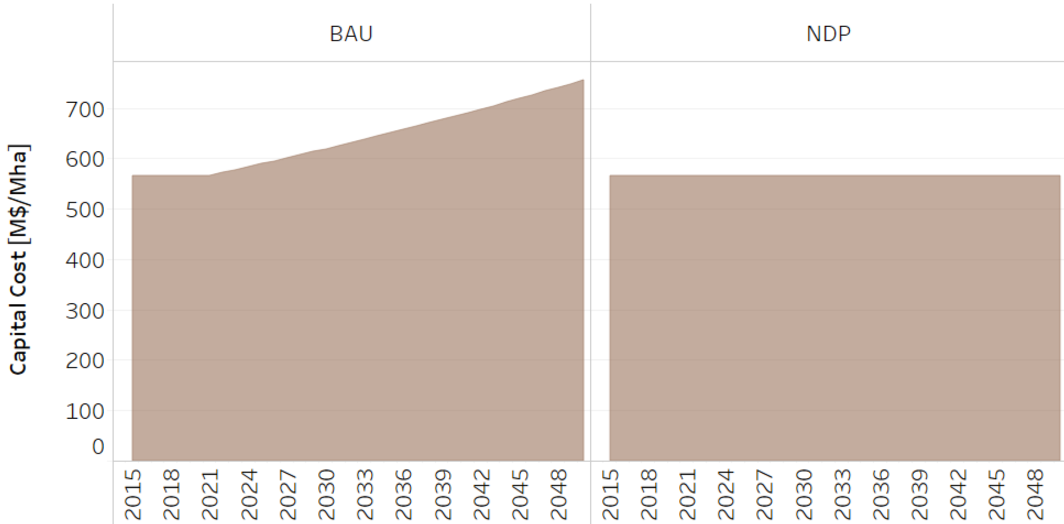

Fig. 1: *Figure: Capital Cost of Beef Production* .

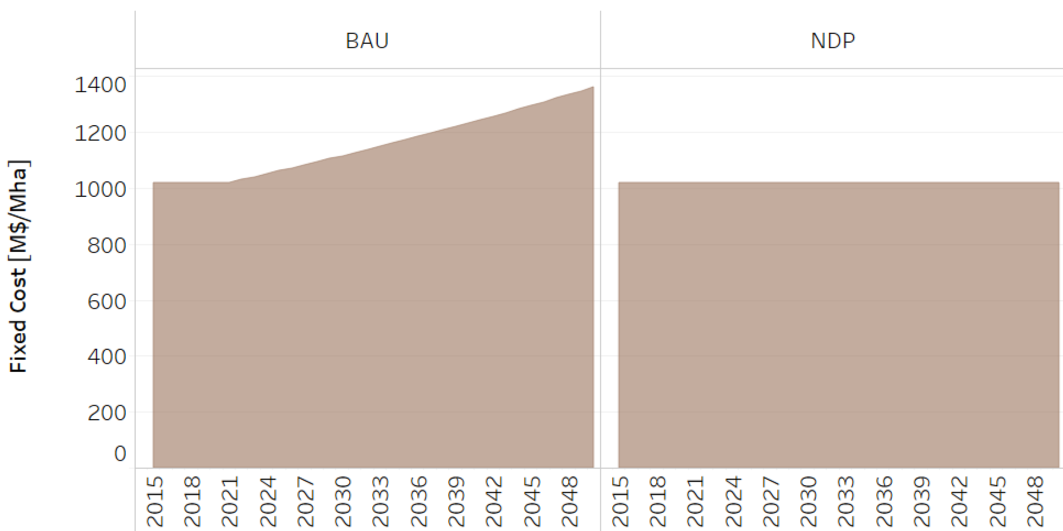

Fig. 2: *Figure: Fixed Cost of Beef Production* .

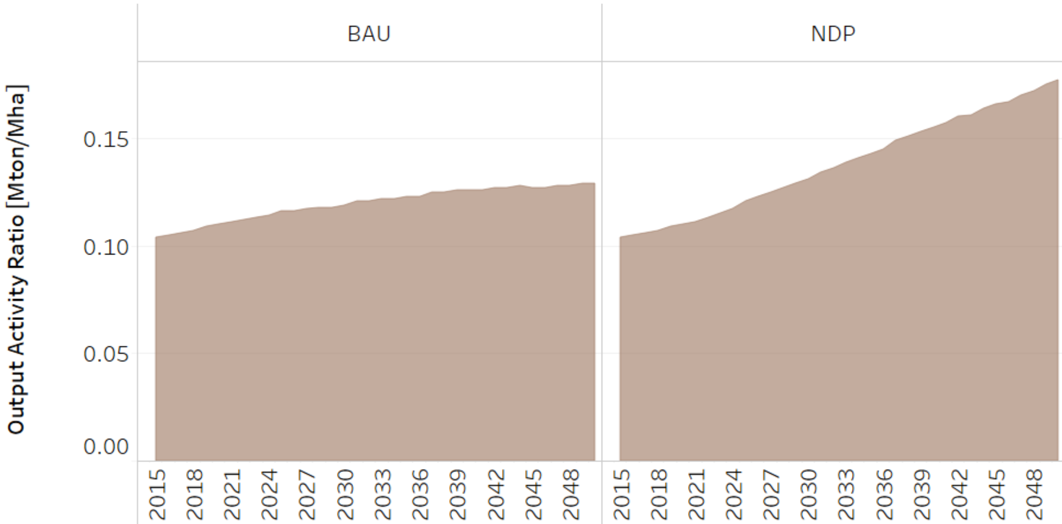

Fig. 3: *Figure: Output Activity Ratio of Beef Production* .

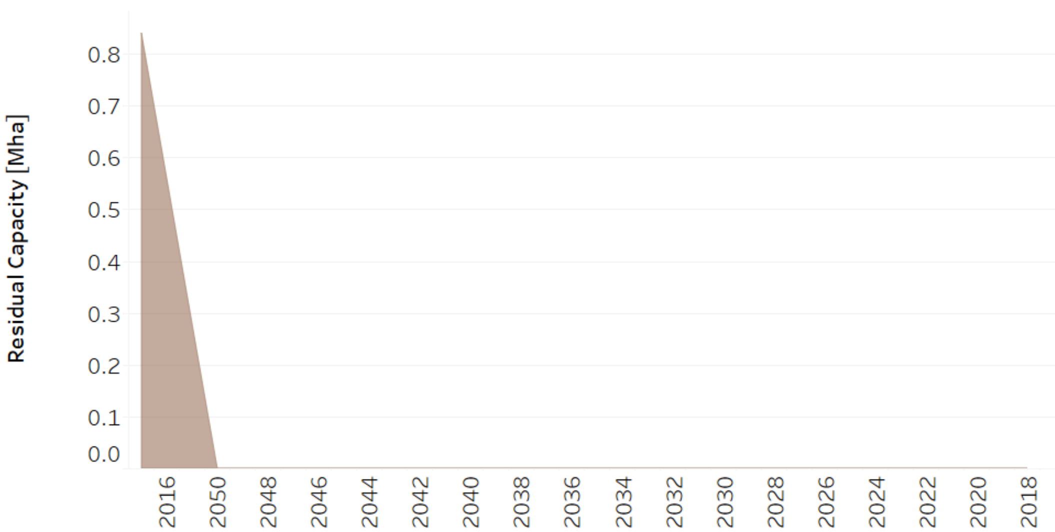

Fig. 4: *Figure: Residual Capacity of Beef Production* .

9.1.1 CapitalCost[r,t,y]

9.1.2 FixedCost[r,t,y]

9.1.3 OutputActivityRatio[r,t,y]

9.1.4 ResidualCapacity[r,t,y]

9.2 Milk

Set codification:	CRPRODLECH
Description:	Milk
Set:	Technology

9.2.1 CapitalCost[r,t,y]

9.2.2 FixedCost[r,t,y]

9.2.3 OutputActivityRatio[r,t,y]

9.2.4 ResidualCapacity[r,t,y]

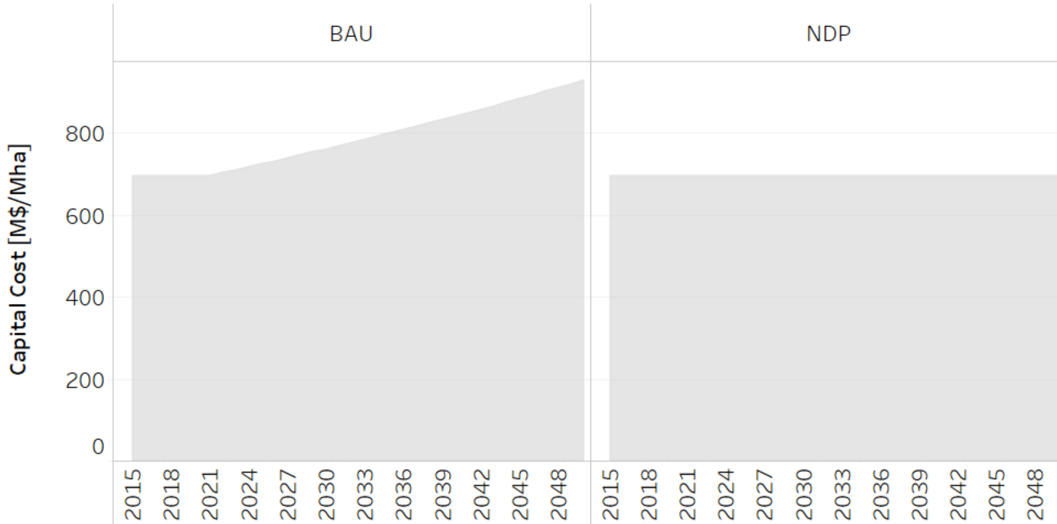

Fig. 5: *Figure: Capital Cost of Milk Production* .

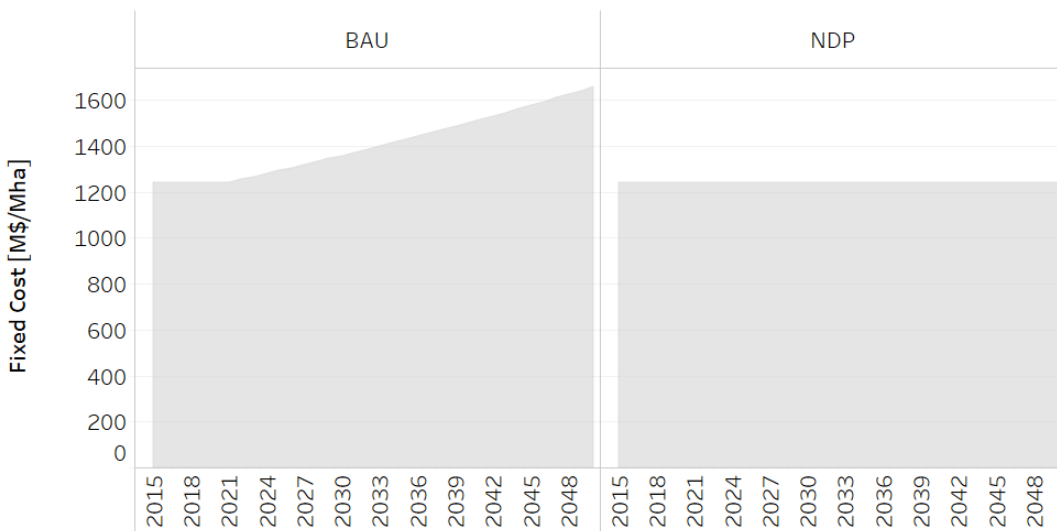

Fig. 6: *Figure: Fixed Cost of Milk Production* .

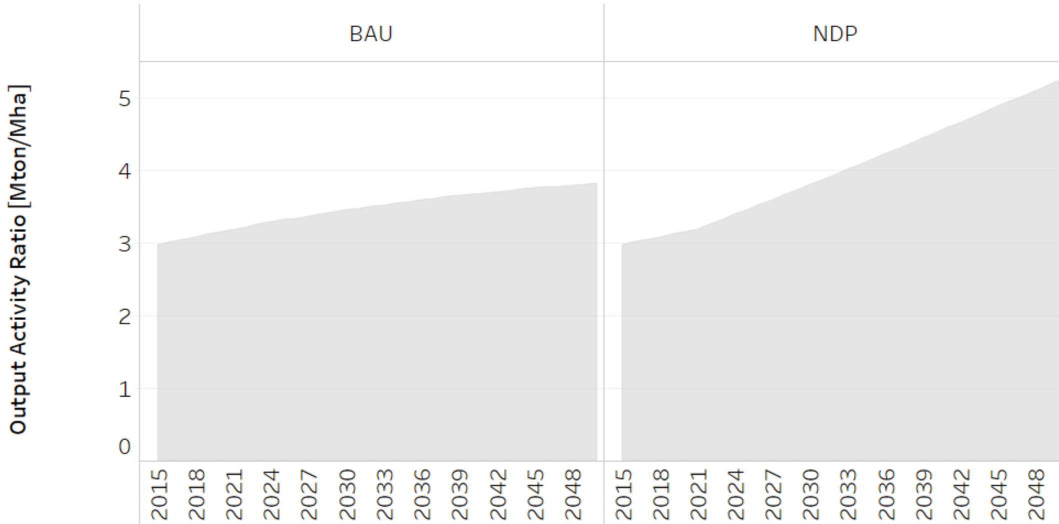

Fig. 7: *Figure: Output Activity Ratio of Milk Production* .

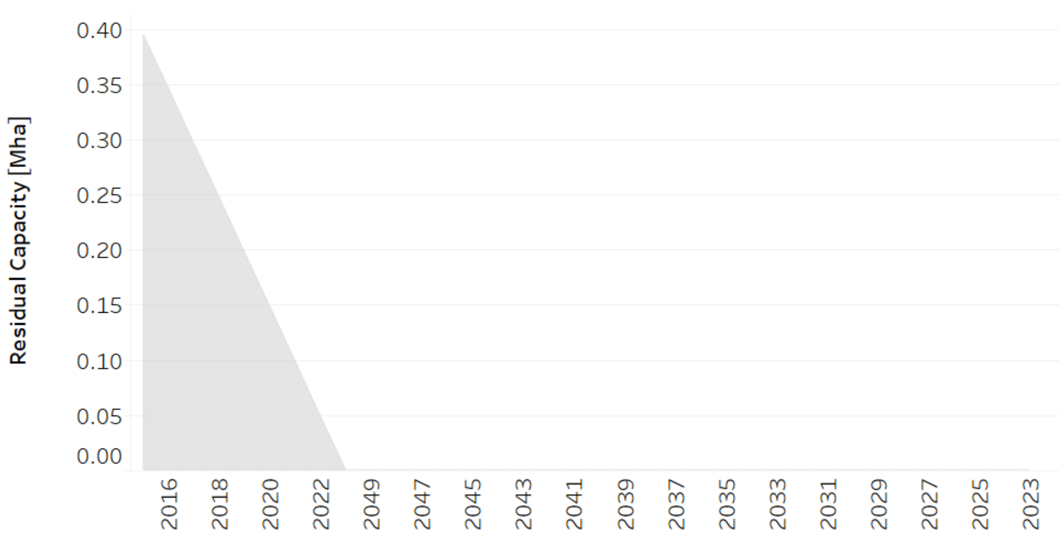

Fig. 8: *Figure: Residual Capacity of Milk Production* .

CHAPTER

TEN

LAND: FORESTS

10.1 Forests

Set codification:	
Description:	Forests
Set:	Technology

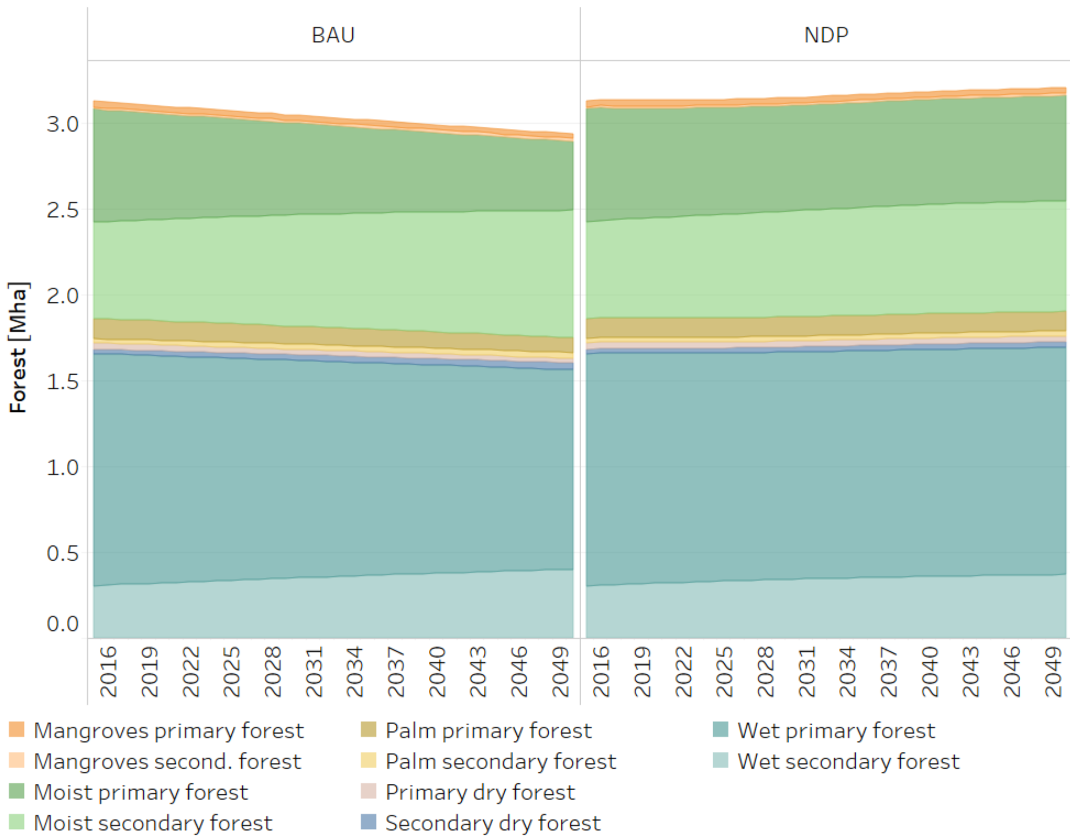

Fig. 1: *Figure: Forest* .

10.1.1 SpecifiedAnnualDemand[r,f,y]

10.2 Forests Plantations

Set codification:	
Description:	Forests Plantations
Set:	Technology

CHAPTER

ELEVEN

LAND: DEMANDS

In this section, the demand are separated in three categories: crops demands, livestock demands and wood demand.

11.1 Crops Demands

Set codification:	CR07DEMAPINA, CR07DEMAAZUCAR, CR07DEMAMELA, CR07DEMAARROZ, CR07DEMABAGAZO, CR07DEMAACEITE, CR07DEMABANANO, CR07DEMACAFORO
Description:	Crops Demands
Set:	Technology

11.1.1 SpecifiedAnnualDemand[r,f,y]

The pineapple, sugar, molasses, rice, bagasse, palm oil, banana and coffee future demands are calculated by using average per capita consumption data (kg/inhab/yr) and population projections (millions of people) from the National Institute of Statistics and Census of Costa Rica. In the model, the per capita consumption values are kept constant through out all of the modeling period. The demands are calculated as indicated by the following equation:

$$Demand_{crop_i}[\frac{Mton}{year}] = \frac{per\ capita\ consumption_i\ x\ population}{1x10^9}.$$

These demands are the same in both scenarios. The information regarding the local production, the exports and imports is crucial in order to calculate the per capita consumption values. The latter data was obtained from the National Rice Corporation and Costa Rica's Foreign Trade Promoter. In the case of the local production, the data is from reports of the National Rice Corporation, National Federation of Oil Palm Growers, and the Executive Secretariat for Agricultural Sector Planning.

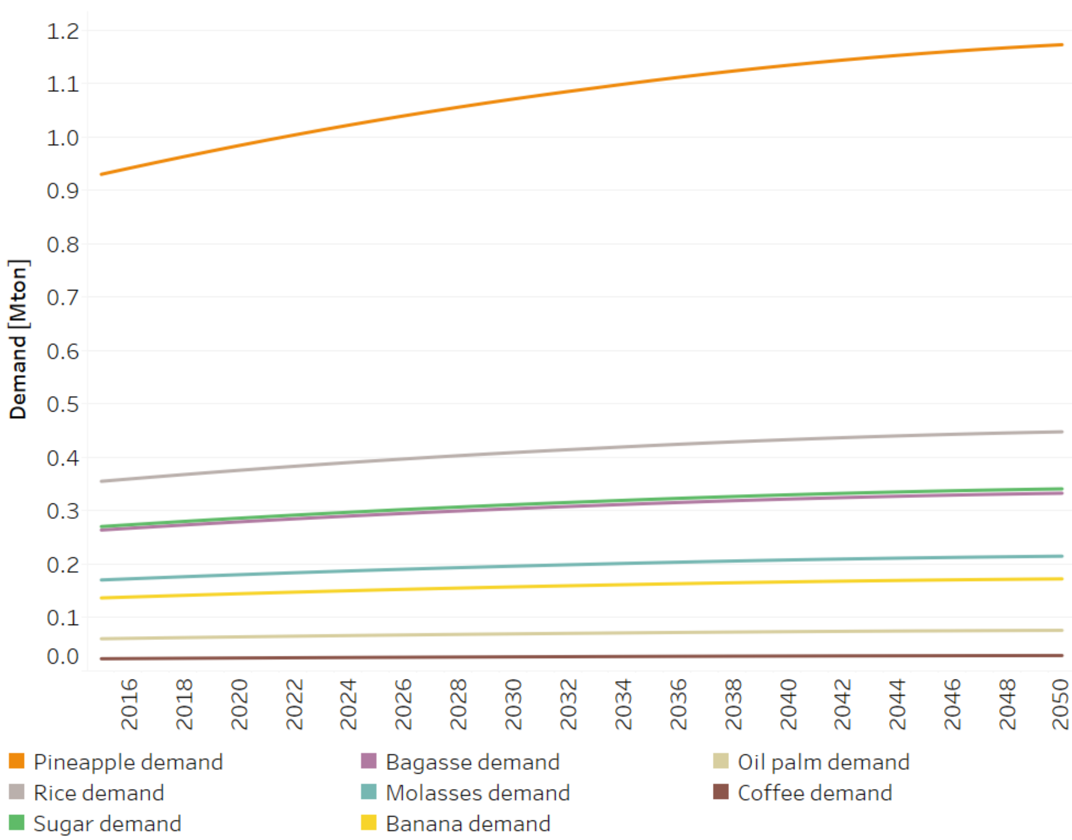

Fig. 1: *Figure: Crops Demands* .

11.2 Livestock Demands

Set codification:	CR08DEMACAR_VACU, CR08DEMALECHE
Description:	Livestock Demands
Set:	Technology

11.2.1 SpecifiedAnnualDemand[r,f,y]

The beef and milk local future demands are calculated by using the same principle used for the crops demands. Here, the per capita consumption values are also kept constant through out all of the modeling period, and the demand is the same in both scenarios.

11.3 Wood Demands

The wood demand in the BAU scenario is based on the same method used for agricultural products. The NDP scenario contemplates a higher demand of wood, since the National Decarbonization Plan aims at promoting the use of wood in construction. In the model, the increase in this demand results in a higher area of forest plantations. This aspect has implications in the CO2 removals in the country, which are higher in the NDP scenario.

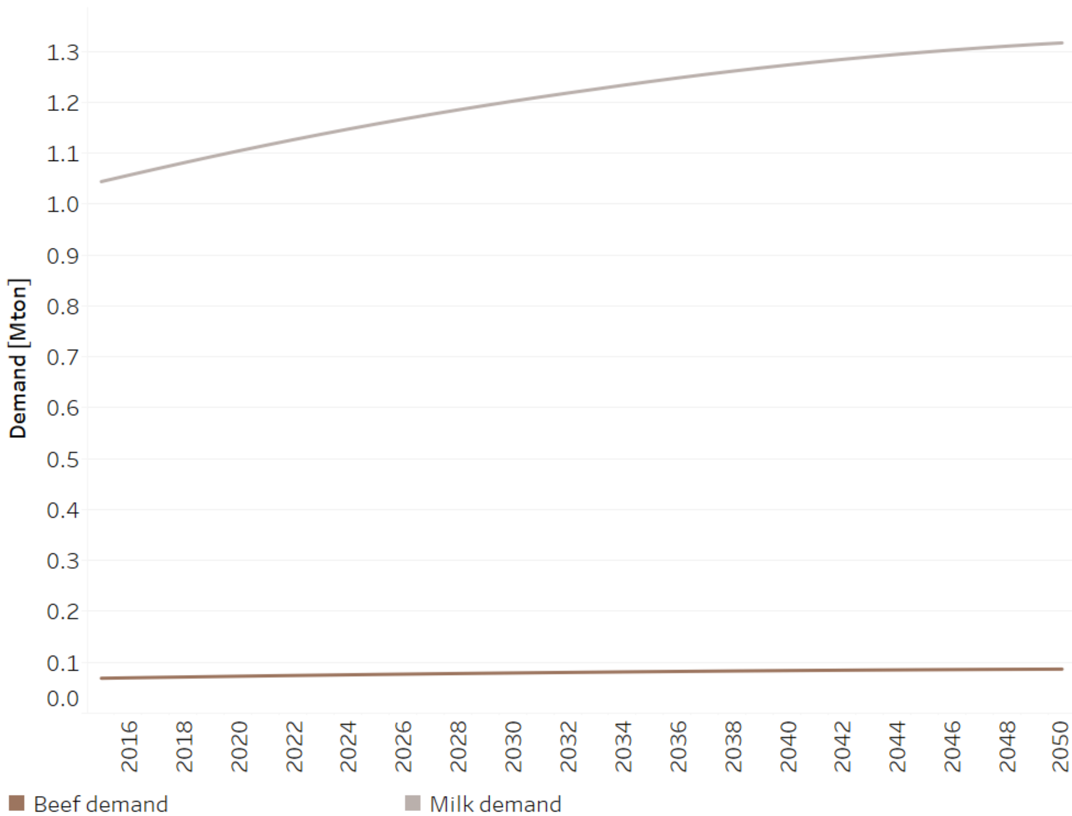

Fig. 2: *Figure: Livestock Demands* .

	
Set codification:	CR09DEM_MADERA
Description:	Wood Demands
Set:	Technology

11.3.1 SpecifiedAnnualDemand[r,f,y]

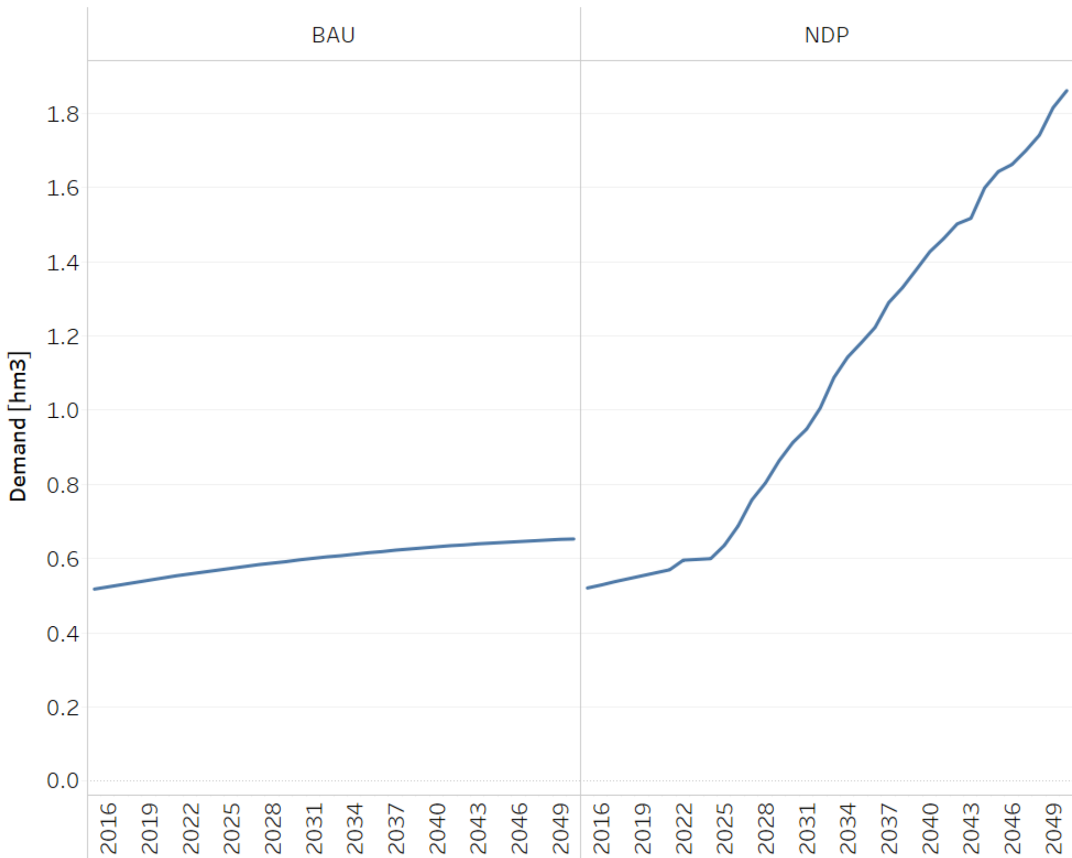

Fig. 3: *Figure: Wood Demands* .

CHAPTER TWELVE

LAND: IMPORTS

12.1 Crops Imports

Set codification:	CRIMPORTARROZGR, CRIMPORTPINA, CRIMPORTMELA CRIMPORTACEITE, CRIMPORTCAFEORO, CRIMPORTAZUCAR CRIMPORTBANA
Description:	Crops Imports
Set:	Technology

12.1.1 TotalTechnologyAnnualActivityLower and Upper Limit[r,t,y]

These parameters present a lower and upper limit to the level of imports, both are expressed in Mton. The imports remain constant through out all of the modeling period, except for rice and coffee which both grow by 1% per year. The base values this parameter were calculated based on information from Costa Rica's Foreign Trade Promoter.

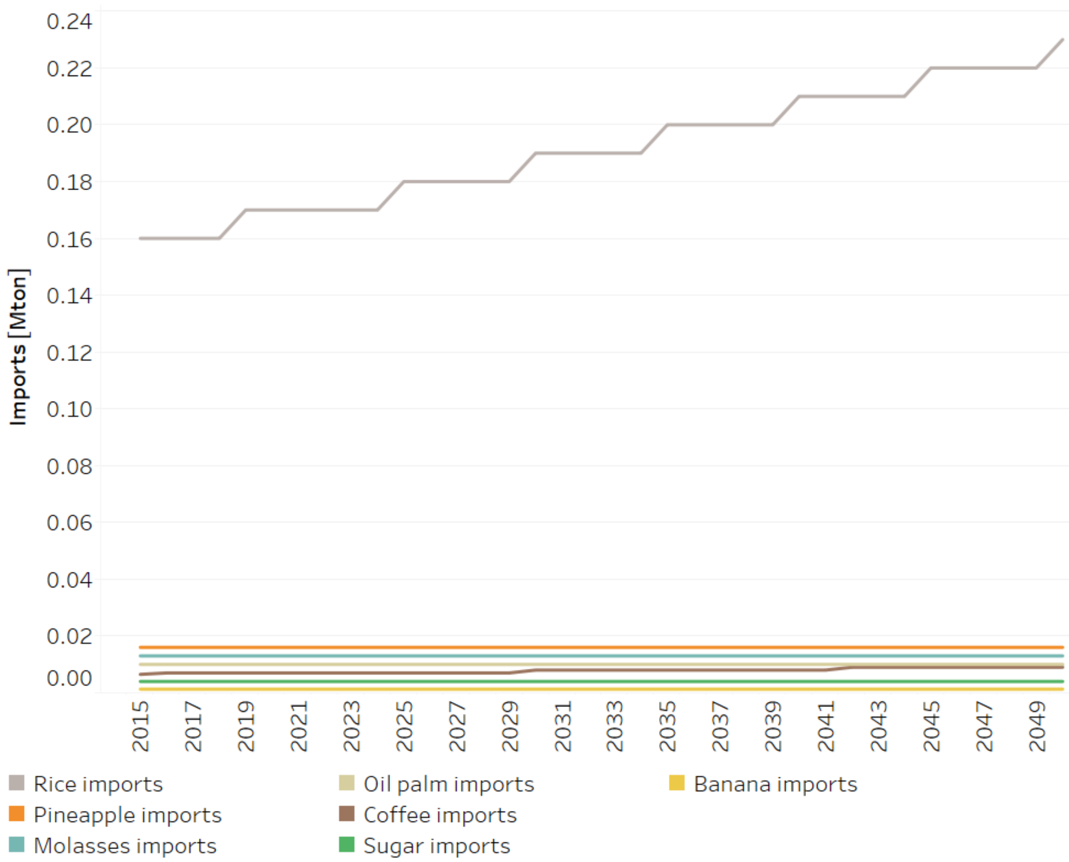

Fig. 1: *Figure: Crops Imports* .

12.1.2 Variable Cost [r,t,y]

This parameter refers to the international prices of the agricultural products, which in this case are from a report of the World Bank Group.

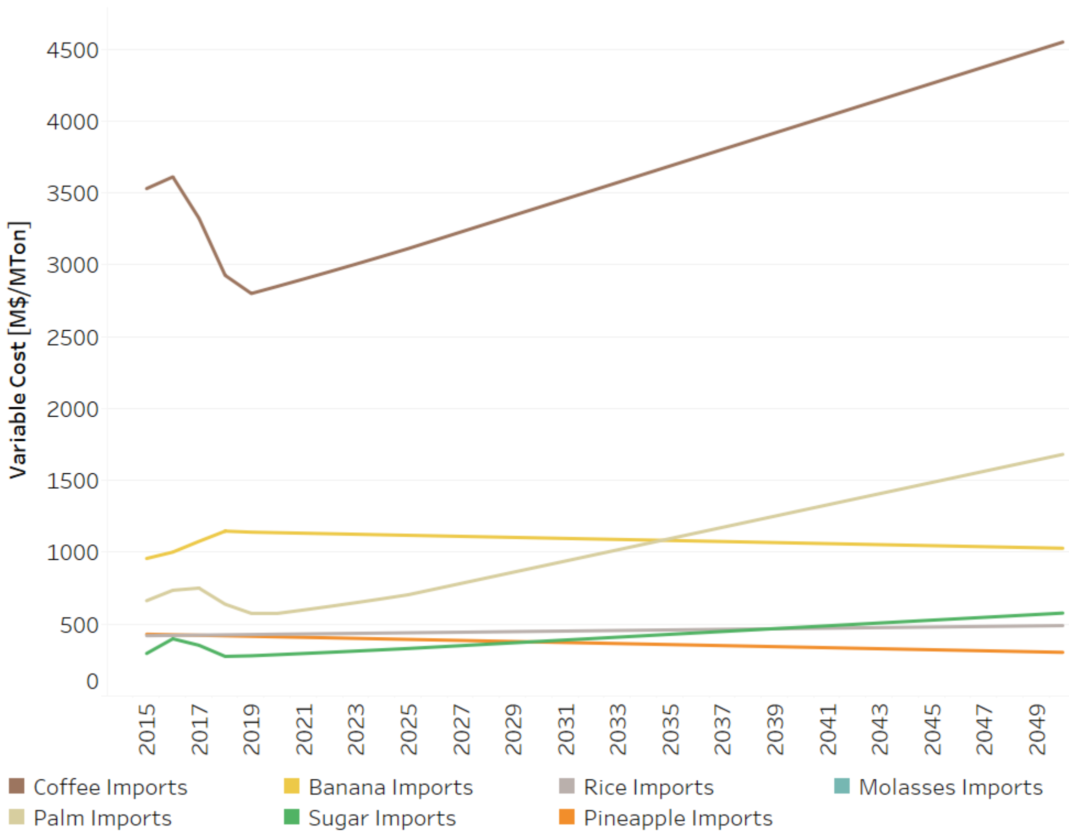

Fig. 2: *Figure: Variable Cost of Imports* .

12.2 Livestock Imports

Set codification:	CRIMPORTLECHE, CRIMPORTCAR_VACU
Description:	Livestock Imports
Set:	Technology

12.2.1 TotalTechnologyAnnualActivityLower and Upper Limit[r,t,y]

The imports of livestock products remain constant through out all of the modeling period. The base values this parameter were calculated based on information from Costa Rica's Foreign Trade Promoter.

12.2.2 Variable Cost [r,t,y]

This information refers to the international prices of the agricultural products, which are from a report of the World Bank Group in the case of beef and the National Chamber of Milk Producers in the case of milk.

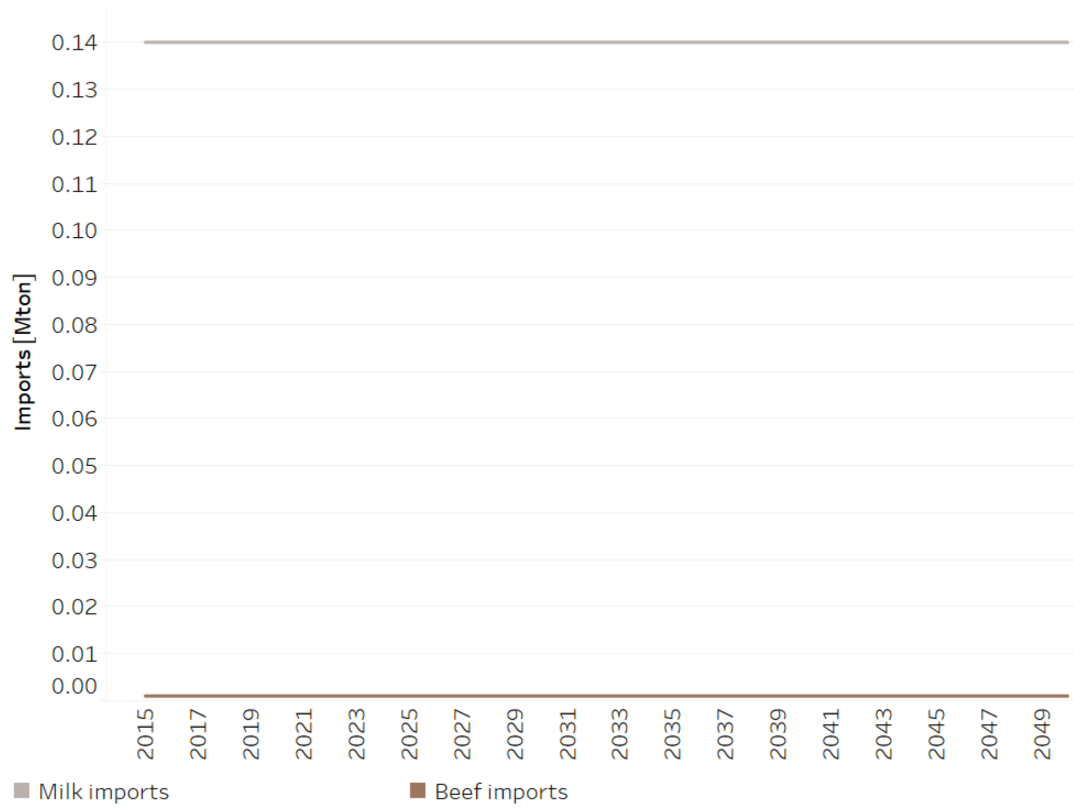

Fig. 3: *Figure: Livestock Imports* .

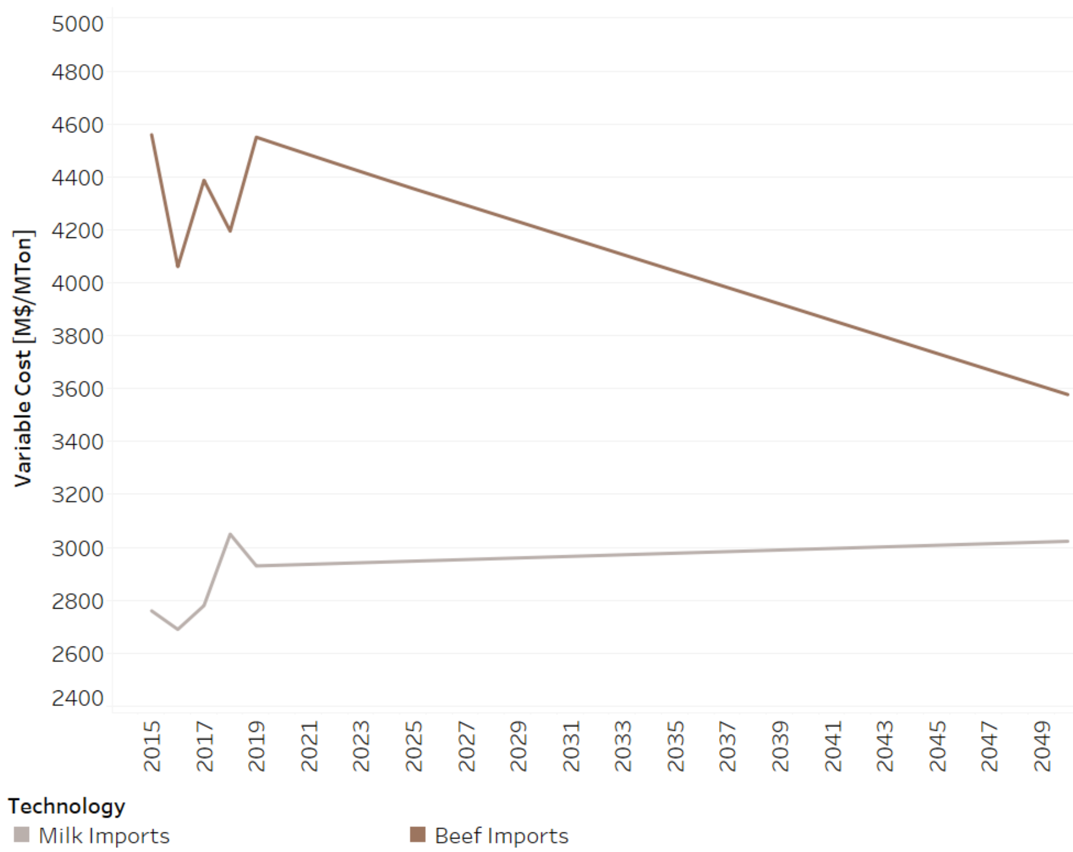

Fig. 4: *Figure: Variable Cost of Imports* .

CHAPTER

THIRTEEN

LAND: EXPORTS

13.1 Crops Exports

Set codification:	CREXPORTARROZGR, CREXPORTPINA, CREXPORTMELA CREXPORTACEITE, CREXPORTCAFEORO, CREXPORTAZUCAR CREXPORTBANA
Description:	Crops Exports
Set:	Technology

13.1.1 SpecifiedAnnualDemand[r,f,y]

This parameter stablishes the level of exported agricultural products, and it is presented in Mton. The following equation expresses the amount of exported tons for the i agricultural product:

$$Exports_i\ [Mton] = Local\ production_i\ [Mton]\ -\ Local\ demand_i\ [Mton]\ +\ imports_i\ [Mton]$$

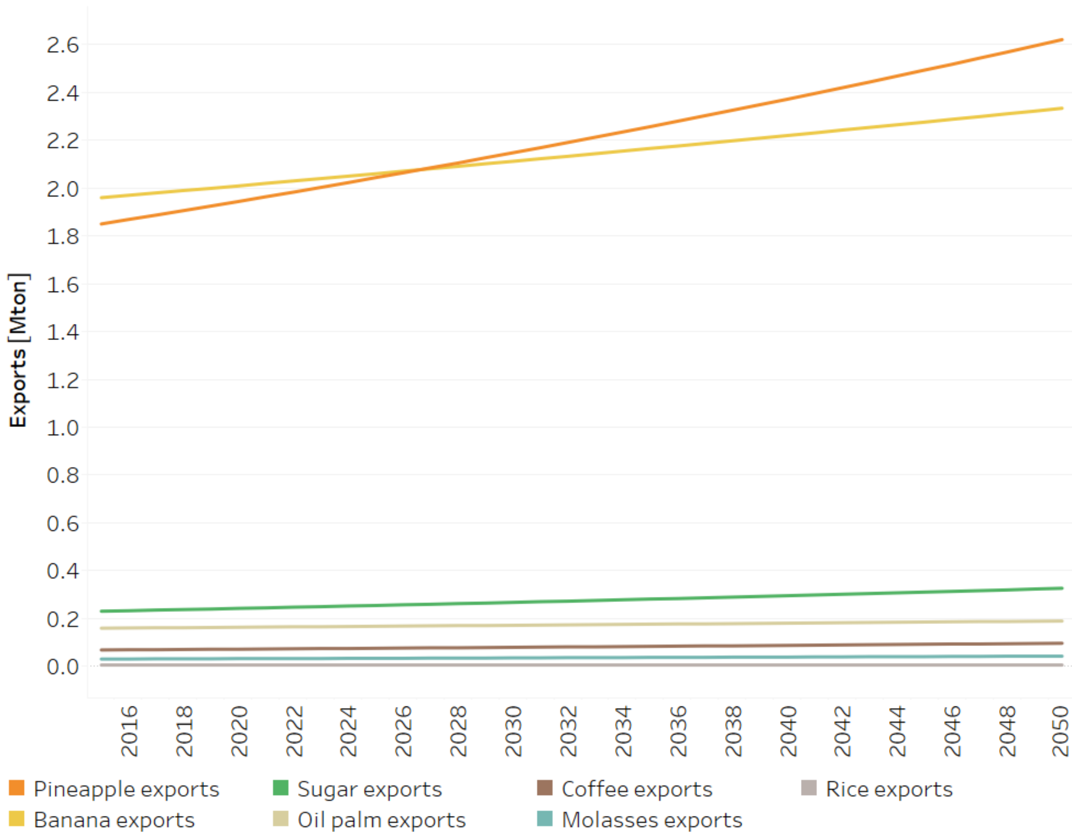

Fig. 1: *Figure: Crops Exports* .

13.1.2 Variable Cost [r,t,y]

This parameter presents the economic gains of exporting products, which are based on information from Costa Rica's Foreign Trade Promoter.

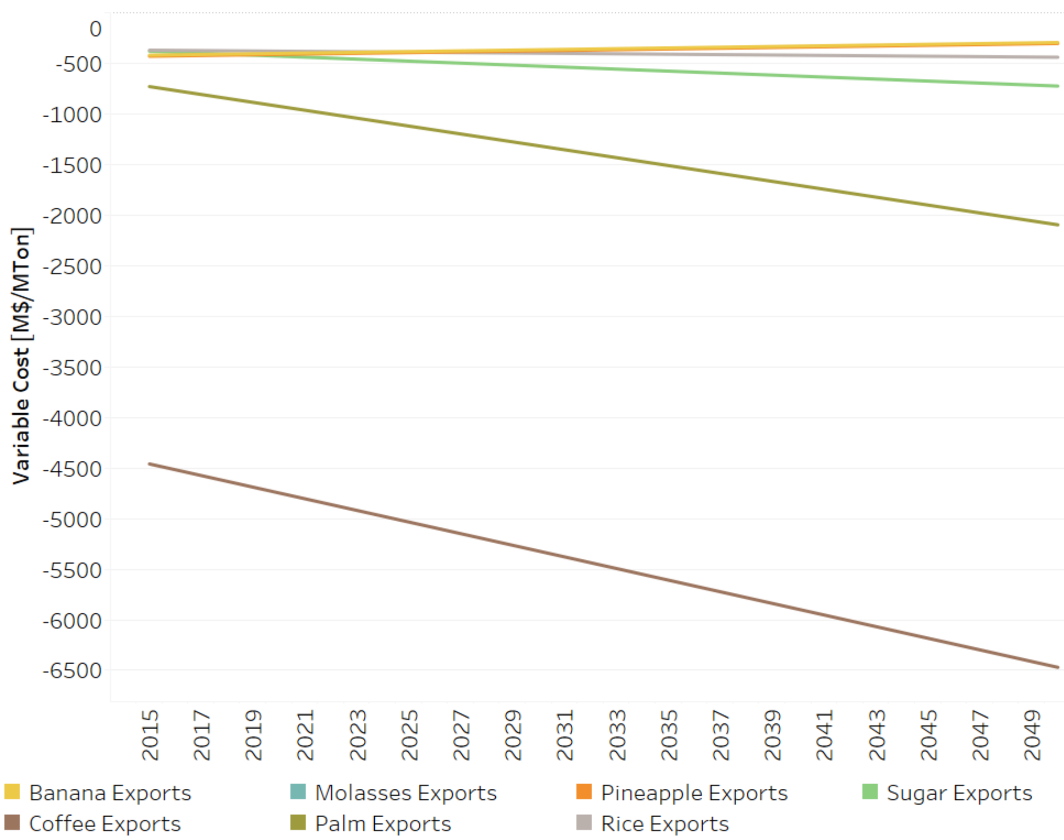

Fig. 2: *Figure: Variable Cost of Exports* .

13.2 Livestock Exports

This parameter stablishes the level of exported agricultural products, and it is presented in Mton. It follows the same principle as the crops exports.

Set codification:	CREXPORTLECHE, CR EXPORTCAR_VACU
Description:	Livestock Exports
Set:	Technology

13.2.1 SpecifiedAnnualDemand[r,f,y]

13.2.2 Variable Cost [r,t,y]

This parameter presents the economic gains of exporting products, which are based on information from Costa Rica's Foreign Trade Promoter and the National Chamber of Milk Producers.

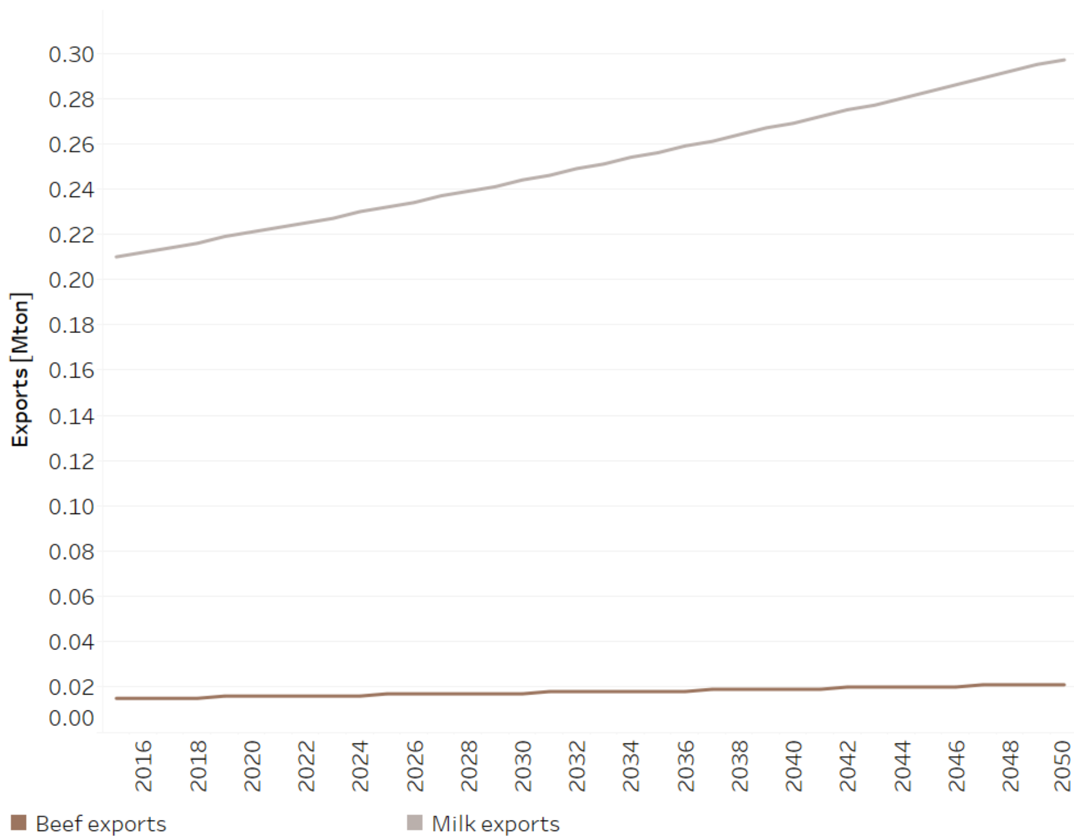

Fig. 3: *Figure: Crops Exports* .

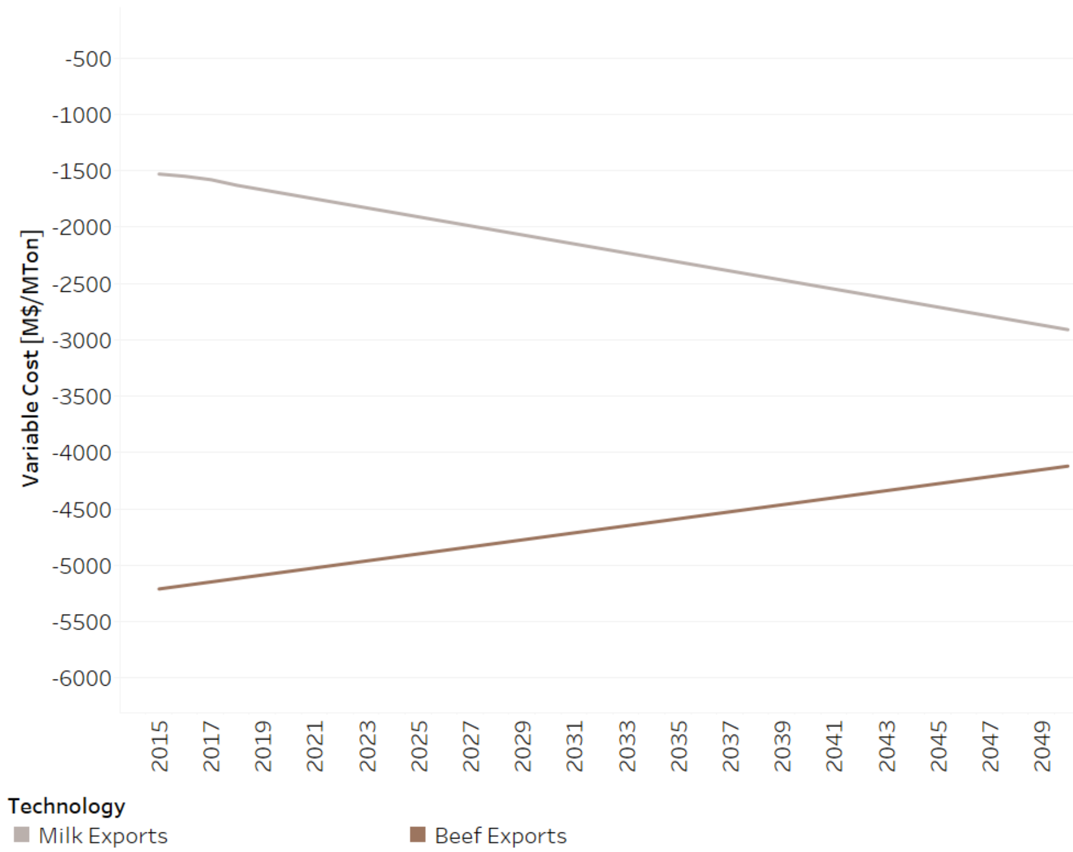

Fig. 4: *Figure: Variable Cost of Exports* .

CHAPTER

FOURTEEN

WATER: PRECIPITATION

14.1 Precipitation

Set codification:	CRENPRECIP
Description:	Precipitation
Set:	Technology

14.1.1 TotalTechnologyAnnual Activity[r,t,y]

Homogeneous precipitation per season is assumed at national level, in units of cubic kilometers per mega hectare (km3/Mha). The data is based on the Regional Climate Model of the Center for Geophysical Research (CIGEFI).

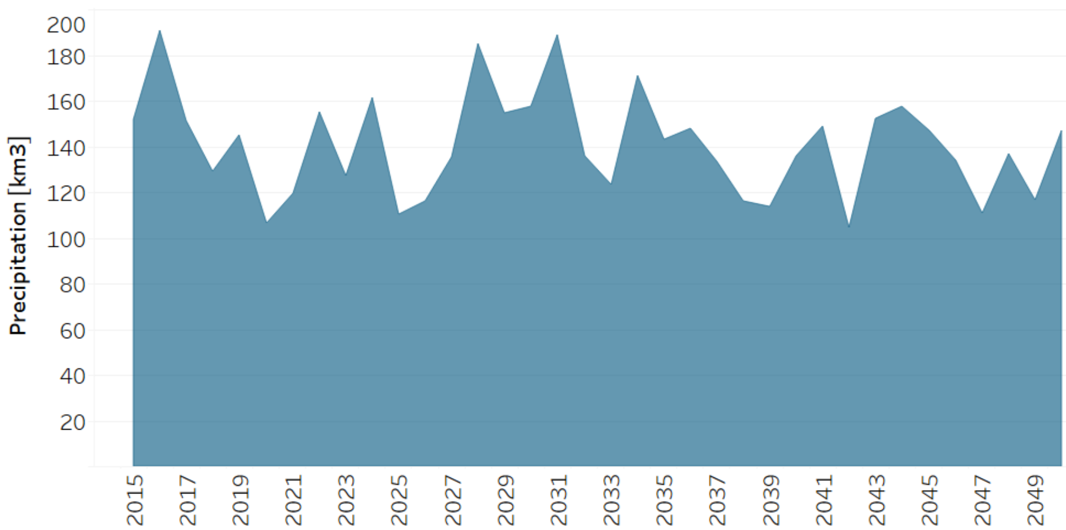

Fig. 1: *Figure: Total Technology Annual Activity Capacity Factor* .

14.1.2 CapacityFactor[r,t,y]

The Capacity Factor is the relationship given between the accumulated precipitation of each season (dry or wet) and the annual amount. This parameter is based on the following equation:

$$Capacity factor = \frac{Accumulated Annual precipitation}{Accumulated precipitation per season}$$

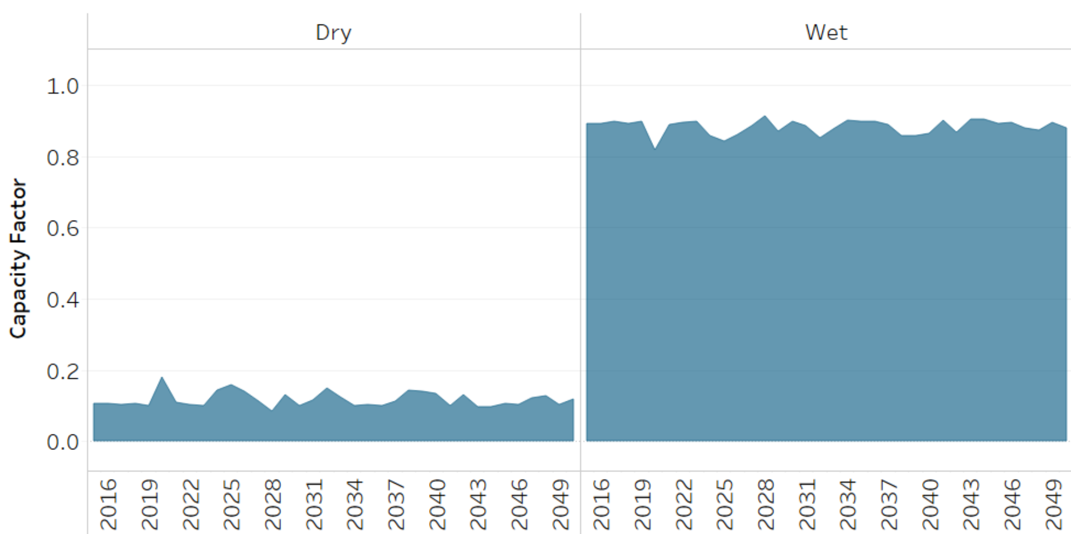

Fig. 2: *Figure: Precipitation Capacity Factor* .

CHAPTER

FIFTEEN

WATER: WATER BALANCE

15.1 Water Balance

Set codification:	CRRETSUP, CRRETSUB
Description:	Water Balance
Set:	Technology

15.2 Superficial water return

The general percentage of water supply by superficial water return is based on information from the 2015 Central Bank of Costa Rica Water Account. The specific percentage by type of coverage is adjusted to match the percentage of environmental accounts.

15.2.1 TotalTechnologyAnnualActivityLo[r,t,y]

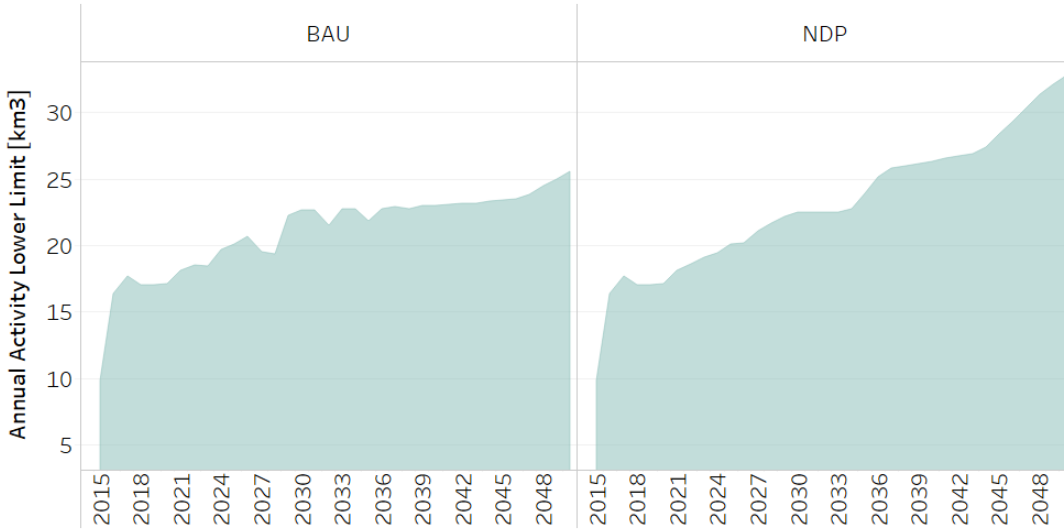

Fig. 1: *Figure: Total Technology Annual Activity for Superficial water return* .

15.2.2 ResidualCapacity[r,t,y]

It is assumed that the residual capacity is equal to the activity of each technology.

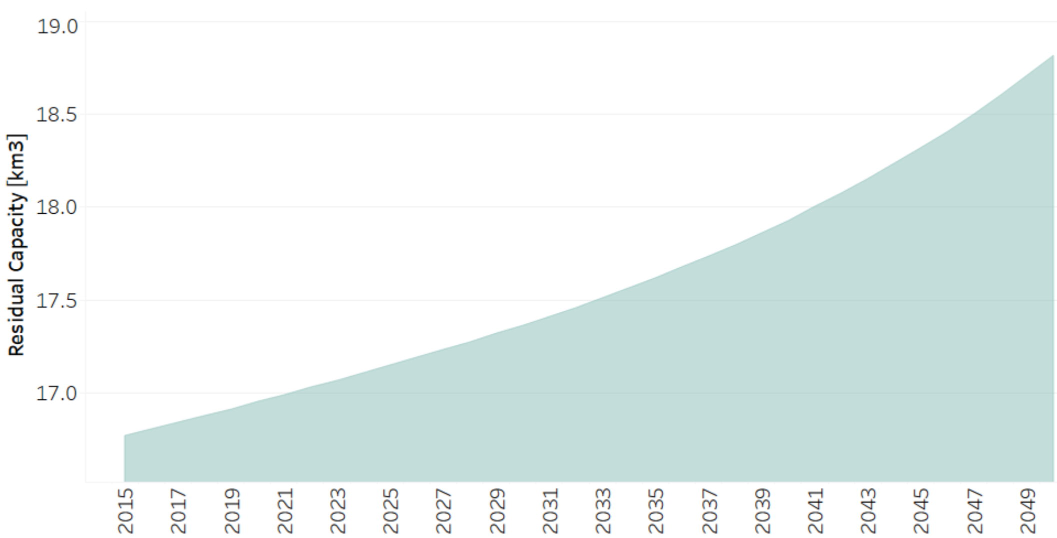

Fig. 2: *Figure: Residual Capacity of Superficial water return* .

15.3 Underground water return

The general percentage of water supply by underground water return is based on information from the 2015 Central Bank of Costa Rica Water Account. The specific percentage by type of coverage is adjusted to match the percentage of environmental accounts.

15.3.1 TotalTechnologyAnnualActivityLo[r,t,y]

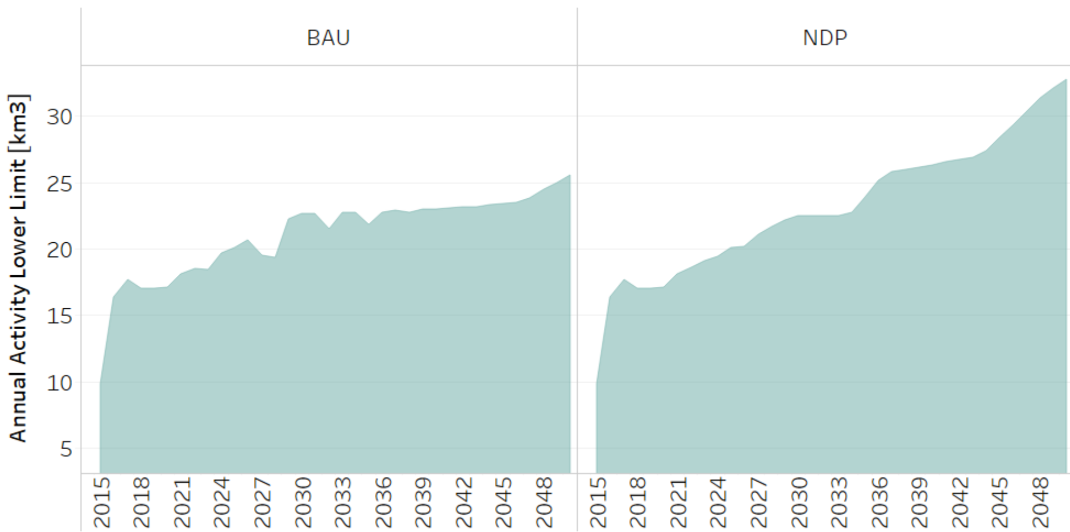

Fig. 3: *Figure: Total Technology Annual Activity for Underground water return* .

15.3.2 ResidualCapacity[r,t,y]

It is assumed that the residual capacity is equal to the activity of each technology.

15.4 Evapotranspiration

The general percentage of water supply by evapotranspiration is based on information from the 2015 Central Bank of Costa Rica Water Account. The specific percentage by type of coverage is adjusted to match the percentage of environmental accounts.

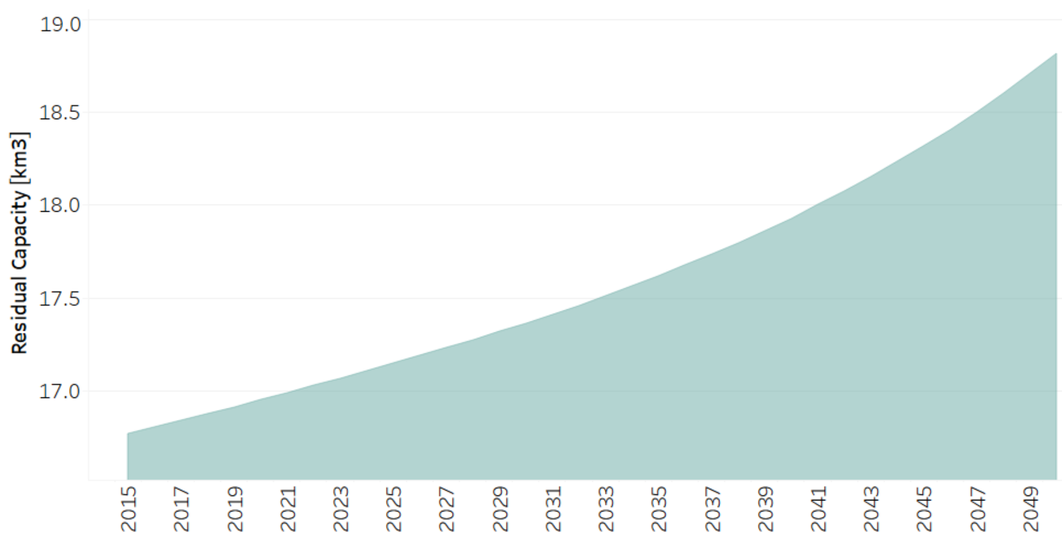

Fig. 4: *Figure: Residual Capacity for Underground water return* .

CHAPTER

SIXTEEN

WATER: EXTRACTION

16.1 Superficial extraction

Set codification:	CREXTSUP
Description:	Superficial extraction
Set:	Technology

16.1.1 CapitalCost[r,t,y]

The capital cost is given in MUS$ per km3. This information is based on international sources and projects of the Costa Rican Institute of Aqueducts and Sewers (AYA).

Constant Value	1.26 [MUS$/km3]

16.1.2 FixCost[r,t,y]

The fix cost is given in MUS$ per km3. This information is based on international sources and projects of the Costa Rican Institute of Aqueducts and Sewers (AYA).

Constant Value	0.07 [MUS$/km3]

16.1.3 ResidualCapacity[r,t,y]

It is assumed that the residual capacity is equal to the activity of each technology.

Constant Value	2.924 [km3]

16.1.4 TotalAnnualMaxCapacity[r,t,y]

The data is based on international sources and projects of the Costa Rican Institute of Aqueducts and Sewers (AYA).

Constant Value	2.924 [km3]

16.1.5 OperationalLife[r,t,y]

A 50-year lifespan was assigned to the new technologies.

16.2 Underground extraction

Set codification:	CREXTSUB
Description:	Underground extraction
Set:	Technology

16.2.1 CapitalCost[r,t,y]

The capital cost is given in MUS$ per km3. This information is based on international sources and projects of the Costa Rican Institute of Aqueducts and Sewers (AYA).

Constant Value	127.6 [MUS$/km3]

16.2.2 FixCost[r,t,y]

The fix cost is given in MUS$ per km3. In this case, the model assumes a 43% of the capital cost as the fixed cost.

Constant Value	6.86 [MUS$/km3]

16.2.3 ResidualCapacity[r,t,y]

Constant Value	0.45 [km3]

16.2.4 TotalAnnualMaxCapacity[r,t,y]

The data is based on international sources and projects of the Costa Rican Institute of Aqueducts and Sewers (AYA).

Constant Value	0.45 [km3]

CHAPTER

SEVENTEEN

WATER: POTIBILIZATION

The water treatment inputs correspond to the proportion of superficial and underground extraction that is carried out for this activity. Similarly, the activity requires an energy component, which is entered in units of petajoules per cubic kilometer (PJ/km3). These data is assigned to current and future technologies and remained constant throughout the time series.

17.1 Potabilization

Set codification:	CREPOT
Description:	Potabilization
Set:	Technology

17.1.1 CapitalCost[r,t,y]

The capital cost is given in MUS$ per km3. This information is based on international sources and projects of the Costa Rican Institute of Aqueducts and Sewers (AYA).

Constant Value	49.62 [km3]

17.1.2 FixedCost[r,t,y]

The FixedCost is based on data from the Costa Rican Institute of Aqueducts and Sewers (AYA), for current and future technologies.

Constant Value	188.2 US$/km3

17.1.3 ResidualCapacity[r,t,y]

It is assumed that the residual capacity is equal to the activity of each technology.

Constant Value	0.7 [km3]

17.1.4 EmissionActivityRatio[r,t,e,m,y]

The data of emissions is based on the National Inventory of Greenhouse Gases and Carbon Absorption from the National Meteorological Institute (IMN).

Constant Value	1 [MtonCO2eq/km3]

CHAPTER

EIGHTEEN

WATER: IRRIGATION

18.1 Common Irrigation

Set codification:	CRERIEGO ???
Description:	Common Irrigation
Set:	Technology

18.1.1 FixedCost[r,t,y]

The FixedCost is based on data from the Costa Rican Institute of Aqueducts and Sewers (AYA), for current and future technologies.

Constant Value	2.51 US$/km3

18.1.2 ResidualCapacity[r,t,y]

It is assumed that the residual capacity is equal to the activity of each technology.

Constant Value	1.34 [km3]

18.2 Water: DRAT

Set codification:	CRRIEGOFUT ???
Description:	DRAT
Set:	Technology

18.2.1 CapitalCost[r,t,y]

The capital cost is given in MUS$ per km3, the data is based on the Arenal-Tempisque Irrigation Project and from the project of Water Supply for the Middle basin of the Tempisque River and Coastal Communities (PAACUME project).

Constant Value	52 MUS$/km3

18.2.2 OutputActivityRatiot[r,t,y]

The output of this technology is 40% over the entire time series, for both current and future technologies.

Constant Value	40%

18.2.3 FixedCost[r,t,y]

The FixedCost is based on data from the Costa Rican Institute of Aqueducts and Sewers (AYA), for current and future technologies.

Constant Value	10.3 US$/km3

CHAPTER

NINETEEN

WATER: WATER DISTRIBUTION

19.1 Water Distribution

Set codification:	CRREDACUED
Description:	Water Distribution
Set:	Technology

19.1.1 ResidualCapacity[r,t,y]

It is assumed that the capacity is equal to the activity of the technologies.

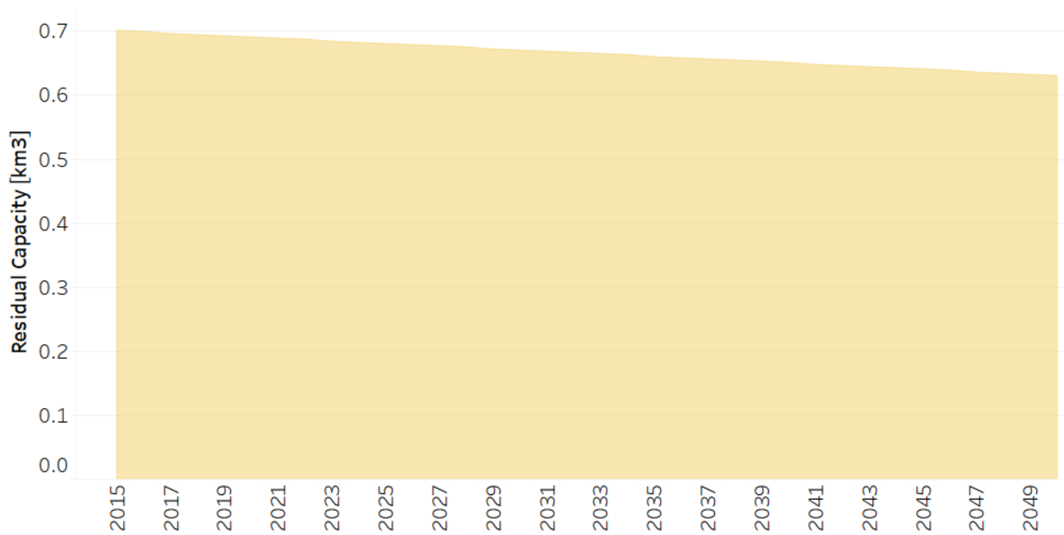

Fig. 1: *Figure: Residual Capacity of Water Distribution* .

19.1.2 CapitalCost[r,t,y]

The capital cost is given in MUS$ per km3. This information is based on the National Sanitation Investment Plan, on international sources and on projects of the Institute of Aqueducts and Sewers (AYA).

Constant Value	198.5 MUS$/km3

19.1.3 FixedCost[r,t,y]

The fix cost is given in MUS$ per km3. This information is based on projects of the Costa Rican Institute of Aqueducts and Sewers (AYA), for current and future technologies.

Constant Value	752.7 MUS$/km3

19.1.4 EmissionActivityRatio[r,t,e,m,y]

The data of emissions is based on the National Inventory of Greenhouse Gases and Carbon Absorption from the National Meteorological Institute (IMN).

Constant Value	1 [MtonCO2eq/km3]

19.1.5 OutputActivityRatiot[r,t,y]

The aqueduct network also includes losses due to leaks and illegal intakes, which correspond to 50%, so the output of this technology is 0.5, for current and future technologies.

Constant Value	50%

CHAPTER TWENTY

WATER: DEMANDS

20.1 Water Demands

The water demand corresponds to the current and future demand of water resources for each user sector and it is given in cubic kilometers [km3]. In the total demand of water resources, one part is effectively consumed and the other becomes wastewater. To establish this distribution the percentages of actual consumption assumed in the Central Bank of Costa Rica's water account is used. The projections are made based on data from the National Plan for Integrated Water Resources Management and from the model projections of Land Use and Energy Sectors, corresponding to the extension of crops and the growth of hydroelectric generation plants, specifically.

Set codification:	CR05DEMAGROP, CR05DEMINDYSERV, CR05DEMHIDROELECTRICIDAD, CR05DEMCOHUMANO CR06VERTCOHUMANO, CR06VERTINDYSERV
Description:	Water Demands
Set:	Technology

20.1.1 SpecifiedAnnualDemand[r,t,y]

For residential, commercial and turism Water Specified Annual Demand, an average per capita consumption was established from the Central Bank of Costa Rica's water account data between 2012-2015 and multiplied by the population projections of the National Institute of Statistics and Censuses of Costa Rica, as shown in the following equation:

$$Humanconsumptiondemand = Consumptionpercapita * population$$

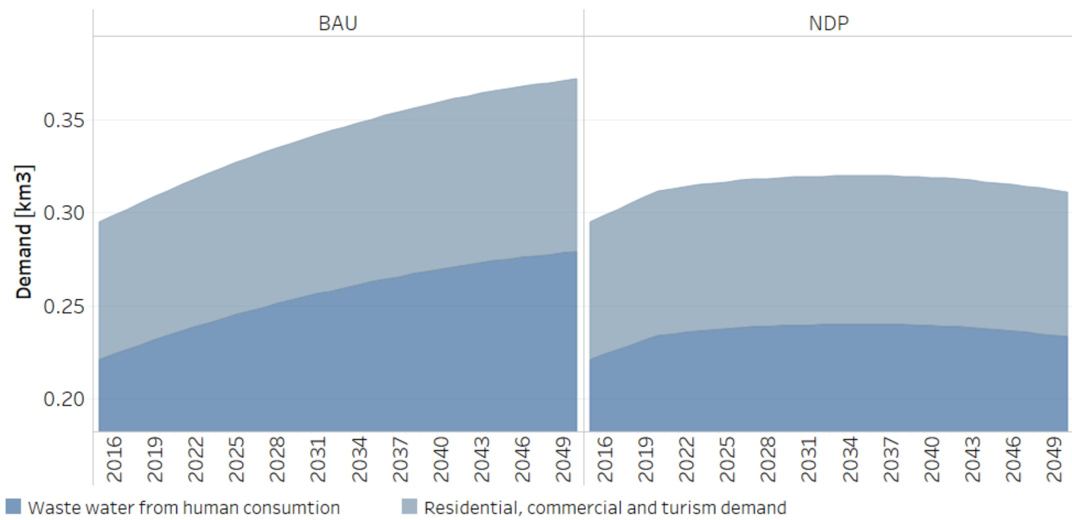

Fig. 1: *Figure: Human Consumtion Specified Annual Demand* .

The projections of the Industrial Water Specified Annual Demand is estimated from the annual growth established by the National Plan for Integrated Water Resources Management.

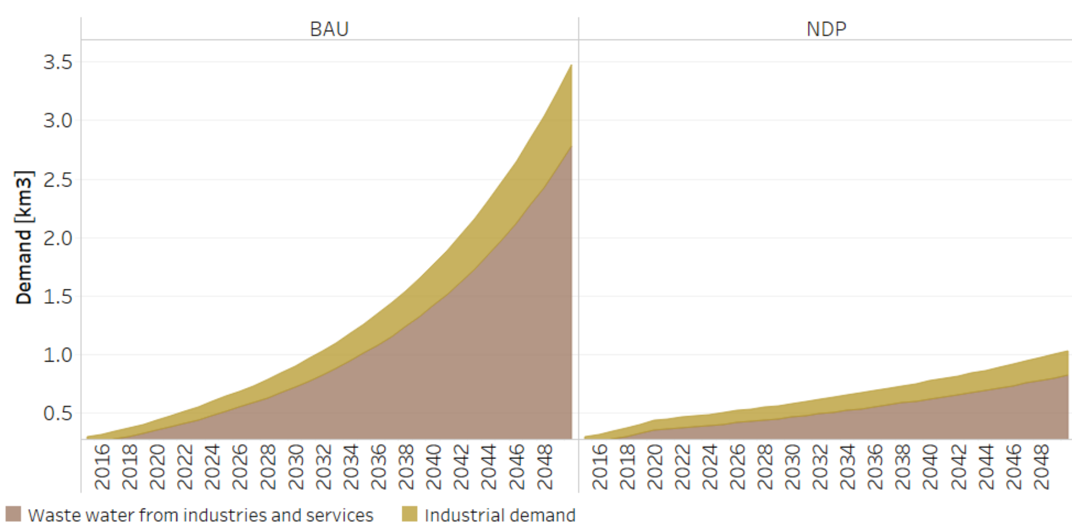

Fig. 2: *Figure: Industrial Water Specified Annual Demand* .

The Water Specified Annual Demand for hydroelectricity is Based on the National Energy Control Center (CENCE) reports and energy model projections.

$$Hydroelectricgenerationdemand = WaterReq * kWh$$

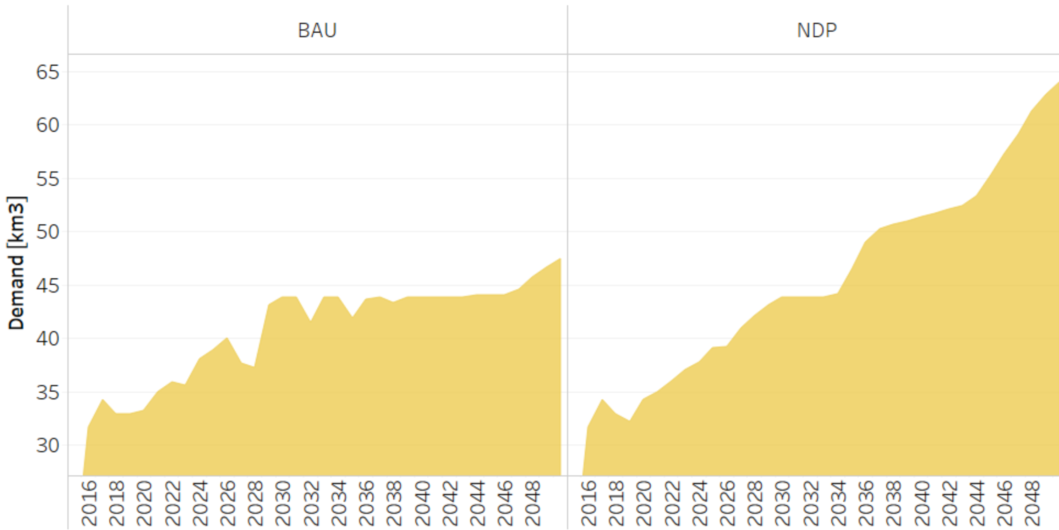

Fig. 3: *Figure: Water Specified Annual Demand for hydroelectricity* .

The calculation of the water demand for the agricultural sector is based on the water footprint of crops, the data is obtenied from the National University and from internation reports. The coverage projections of the land use model are calculated as shown below:

$$AgriculturalDemand = ReqAgua\frac{km2}{Mha}Activitycoverage$$

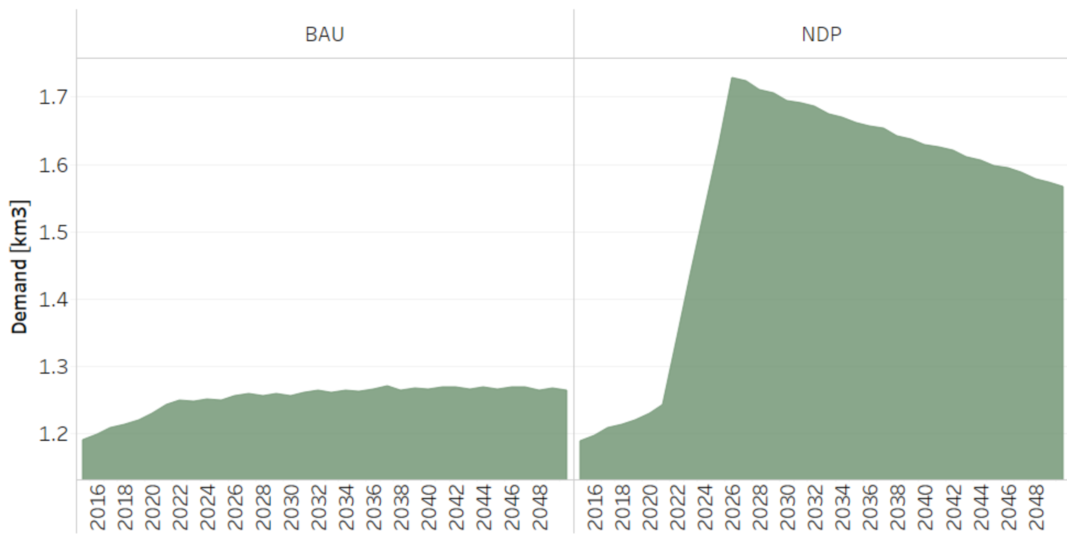

Fig. 4: *Figure: Water Specified Annual Demand for Agriculture* .

CHAPTER

TWENTYONE

WATER: WASTEWATER DISPOSAL

21.1 Wastewater disposal

The structure of discharges and wastewater treatment is based on the National Policy on Wastewater Sanitation Sewage.

Set codification:	CRALCURB, CRALCURBFUT
Description:	Sewage
Set:	Technology

21.1.1 CapitalCost[r,t,y]

The capital cost of wastewater disposal is given in MUS$ per km3. This information is based on the National Sanitation Investment Plan, which applies for both current and future technologies.

Constant Value	723.9 MUS$/km3

21.1.2 FixedCost[r,t,y]

The FixedCost is based on data from the Costa Rican Institute of Aqueducts and Sewers (AYA), for current and future technologies.

Constant Value	306.9 US$/km3

21.2 Water treatment of industrial wastewater

Set codification:	CRVTRATINDYSERV, CRVTRATFUTINDYSERV
Description:	Water treatment of industrial wastewater
Set:	Technology

21.2.1 CapitalCost[r,t,y]

The capital cost of wastewater disposal is given in MUS$ per km3. This information is based on the National Sanitation Investment Plan, which applies for both current and future technologies.

Constant Value	605.2 MUS$/km3

21.2.2 FixedCost[r,t,y]

The FixedCost is based on data from the Costa Rican Institute of Aqueducts and Sewers (AYA), for current and future technologies.

Constant Value	371.6 US$/km3

21.2.3 EmissionActivityRatio[r,t,e,m,y]

The data of emissions is based on the National Inventory of Greenhouse Gases and Carbon Absorption from the National Meteorological Institute.

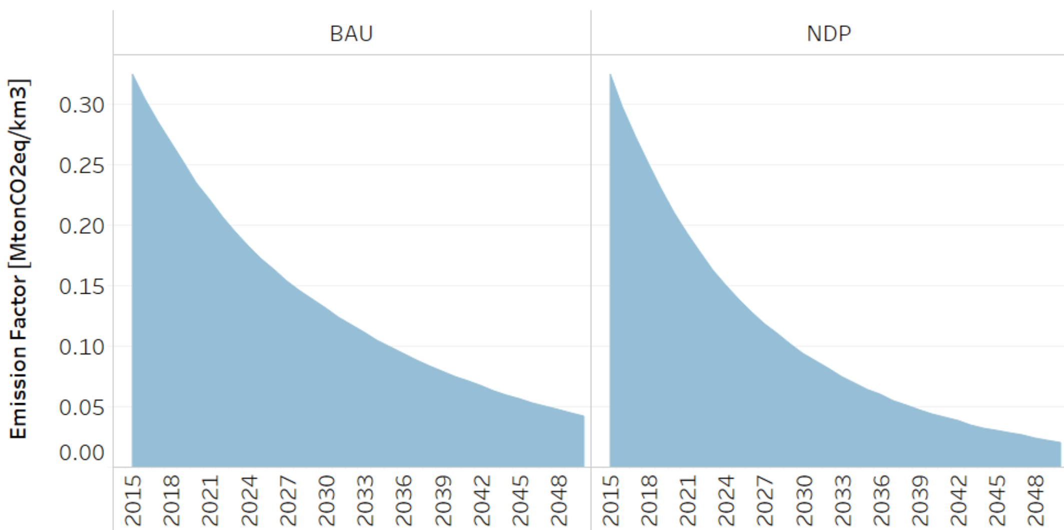

Fig. 1: *Figure: Emission Activity Ratio of Water treatment of industrial wastewater* .

21.2.4 ResidualCapacity[r,t,y]

Constant Value	0.035 [km3]

21.3 Septic tank

Set codification:	CRPOZOSRUR, CRPOZOSRURFUT
Description:	Septic Tank
Set:	Technology

21.3.1 CapitalCost[r,t,y]

The capital cost of wastewater disposal is given in MUS$ per km3. This information is based on the National Sanitation Investment Plan, which applies for both current and future technologies.

Constant Value	49.78 MUS$/km3

21.3.2 FixedCost[r,t,y]

The FixedCost is based on data from the Costa Rican Institute of Aqueducts and Sewers (AYA), for current and future technologies.

Constant Value	306.9 US$/km3

21.3.3 EmissionActivityRatio[r,t,e,m,y]

The data of emissions is based on the National Inventory of Greenhouse Gases and Carbon Absorption from the National Meteorological Institute.

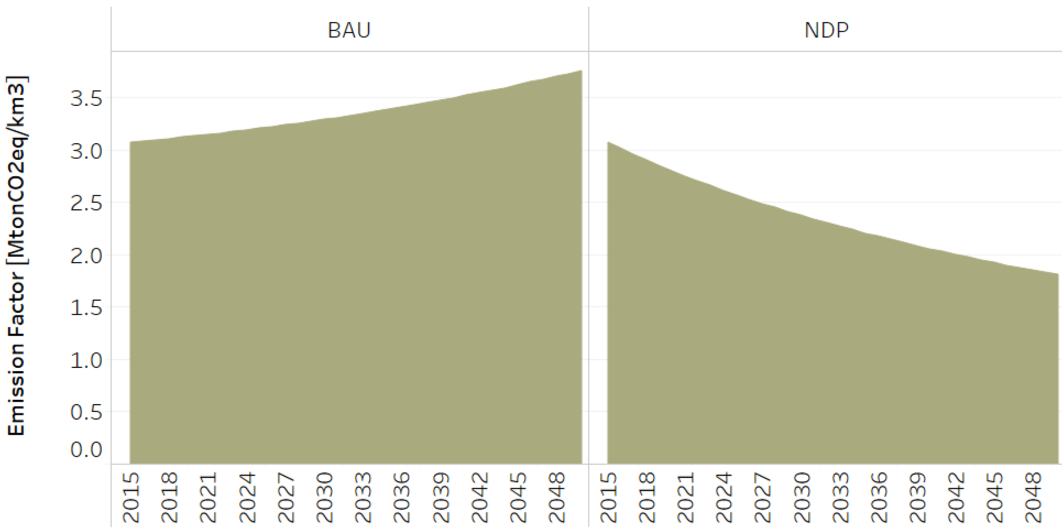

Fig. 2: *Figure: Emission Activity Ratio of Septic tanks* .

21.3.4 AnnualActivityLowerLimit[r,t,e,m,y]

The Annual Activity is based on information from the National Policy on Wastewater Sanitation, as well as information from the BCCR Water Account 2015.

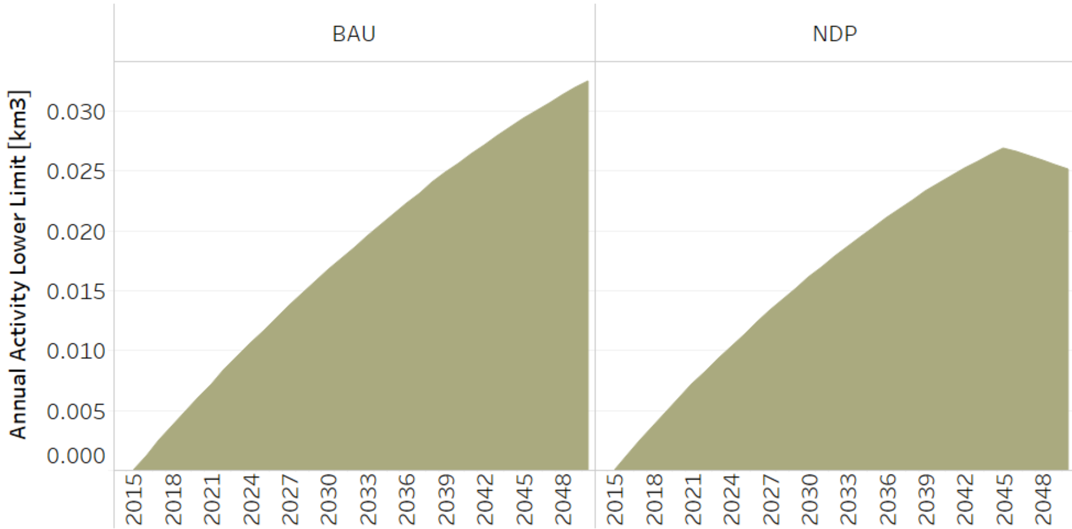

Fig. 3: *Figure: Annual Activity Lower Limit of Septic tanks* .

21.4 Water treatment of wastewater from human consumption

Set codification:	CRVTRATCOHUMANO, CRVTRATFUTCOHUMANO
Description:	Water treatment of wastewater from human consumption
Set:	Technology

21.4.1 CapitalCost[r,t,y]

The capital cost of wastewater disposal is given in MUS$ per km3. This information is based on the National Sanitation Investment Plan, which applies for both current and future technologies.

Constant Value	605.2 MUS$/km3

21.4.2 FixedCost[r,t,y]

The FixedCost is based on data from the Costa Rican Institute of Aqueducts and Sewers (AYA), for current and future technologies.

Constant Value	371.6 US$/km3

21.4.3 EmissionActivityRatio[r,t,e,m,y]

The data of emissions is based on the National Inventory of Greenhouse Gases and Carbon Absorption from the National Meteorological Institute.

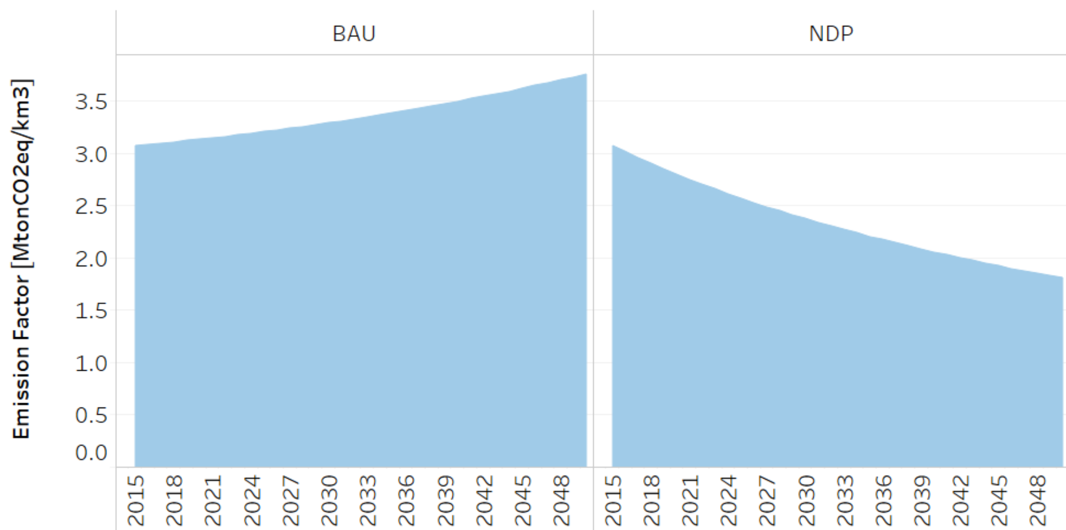

Fig. 4: *Figure: Emission Activity Ratio of Water treatment of wastewater from human consumption* .

21.4.4 ResidualCapacity[r,t,y]

Constant Value	0.033 [km3]

21.4.5 AnnualActivityLowerLimit[r,t,e,m,y]

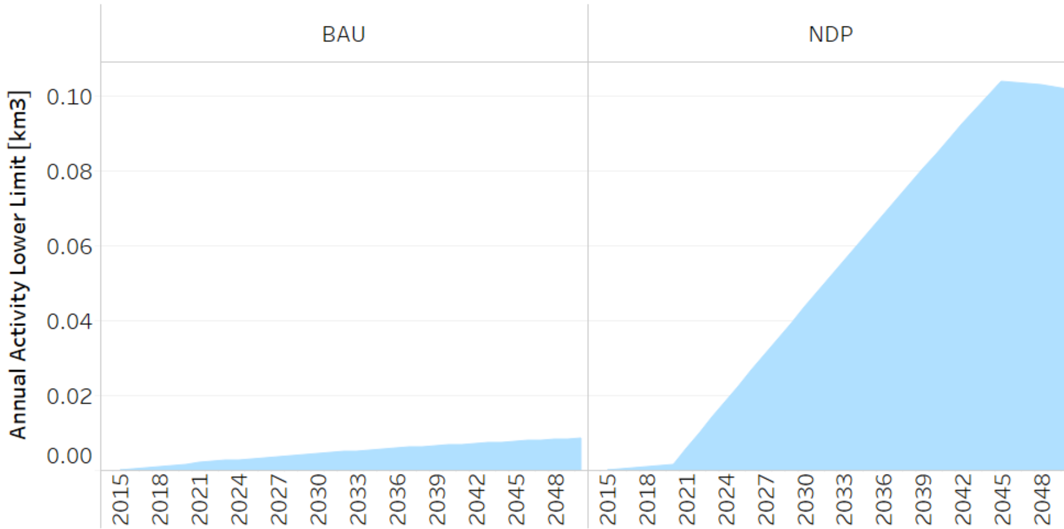

Fig. 5: *Figure: Annual Activity Lower Limit of Water treatment of wastewater from human consumption* .

21.5 Water without treatment

Set codification:	CRVSINTRATCOHUMANO, CRVSINTRATINDYSERV
Description:	Water without treatment
Set:	Technology

21.5.1 EmissionActivityRatio[r,t,e,m,y]

The data of emissions is based on the National Inventory of Greenhouse Gases and Carbon Absorption from the National Meteorological Institute, for both current and future technologies.

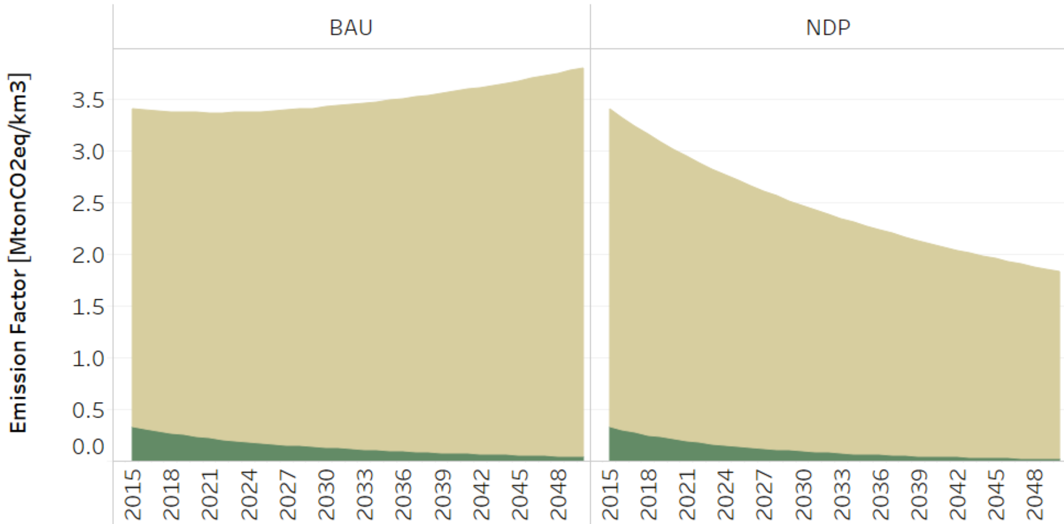

Fig. 6: *Figure: Emission Activity Ratio of Water without treatment* .