UNECA SDG model technical specifications

Republic of the Congo

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1. Introduction to System Dynamics

Finding that most currently available national planning models are either too detailed or narrowly focused (see Bassi, 2014), this project proposes an approach that: a) extends and advances the policy analysis carried out with other tools by accounting for the dynamic complexity embedded in the systems studied; and b) facilitates the investigation and understanding of the relations existing between natural capital, society and the economy. The inclusion of cross-sectoral relations supports a wider analysis of the implications of alternative development policies, and proposes a long-term perspective that allows for the identification of potential side effects and sustainability of different strategies.

The approach proposed uses the System Dynamics (SD) methodology as its foundation, serving primarily as a knowledge integrator. System dynamics modelling is a form of computer simulation modelling designed to facilitate a comprehensive approach to development planning in the medium to long term (Meadows, 1980; Randers, 1980; Richardson & Pugh, 1981; Forrester, 2002). A key characteristic of SD is that it allows to integrate the three spheres of sustainable development in its analytical process. SD operates by simulating differential equations for a period of at least one decade, and are validated by comparing simulation results with the available data. The simulation then continues into the future, after validation of historical performance is completed.

The purpose of such models is not to make precise predictions of the future; rather, they are a tool for exploring alternative policy scenarios in order to identify those policies that could improve conditions in the future and contribute to the achievement of desired goals and objectives (Roberts, Andersen, Deal, Garet, & Shaffer, 1983; Probst & Bassi, 2014).

SD allows to represent stocks and flows of human, built and natural capital explicitly, and to capture linkages among them through the use of feedbacks, delays and non-linearity. SD also allows to simultaneously use other modeling techniques, such as optimization and econometrics. In fact, SD has been successfully coupled, in the context of green economy work, with a CGE model in Mexico (Ibarrarán, Bassi, & Boyd, 2015), with spatially explicit models like InVEST for Borneo (Van Paddenburg et al., 2012) and in Thailand (Bassi et al, 2014) and with energy sector optimization models for several countries and in the global green economy modeling work of UNEP (2012) (UNEP, 2012).

2. Modelling the SDGs and Green Economy interventions

The UNECA SDG model is based on the Green Economy Model (GEM) and was designed explicitly to analyze sustainable development paths. As a result, it includes several sectors across social, economic and environmental dimensions. The effective integration of these sectors is made through the use of stocks and flows, which brings consistency to the mathematical formulations used to create the model. This integration was possible through several interactions with leading international experts, national researchers, policy makers and members of the community in several countries.

Figure 1 presents the generalized underlying structure of the GEM, the model used as a starting point for the creation of the UNECA SDG model. This diagram shows how the four key capitals (physical, human, social and natural) are interconnected, and contribute to shaping future trends across social, economic and environmental indicators. Specifically, feedback loops can be identified that are reinforcing (R) in all areas, pertaining economic growth and social development. These are primarily enabled by the availability of natural capital (especially in the context of countries that rely on the primary sector), which, if not properly managed, can constrain economic growth (hence the balancing loops -(B)- identified in the diagram). Policies can be implemented to promote sustainable consumption and production, decoupling economic growth from resource use (also through education and behavioral change), to mitigate the exploitation of natural capital and generate stronger and more resilient social progress, and economic growth.

As a result, applications of the UNECA SDG model can be used to (1) test the effectiveness of individual policies and investments (by assessing their impact within and across sectors, and for social, economic and environmental indicators); (2) inform budgetary planning (by assessing the effectiveness of annual plans in delivering sustainable and inclusive growth); (3) support the formulation and analysis of development plans that span across sectors and target medium to longer term goals.

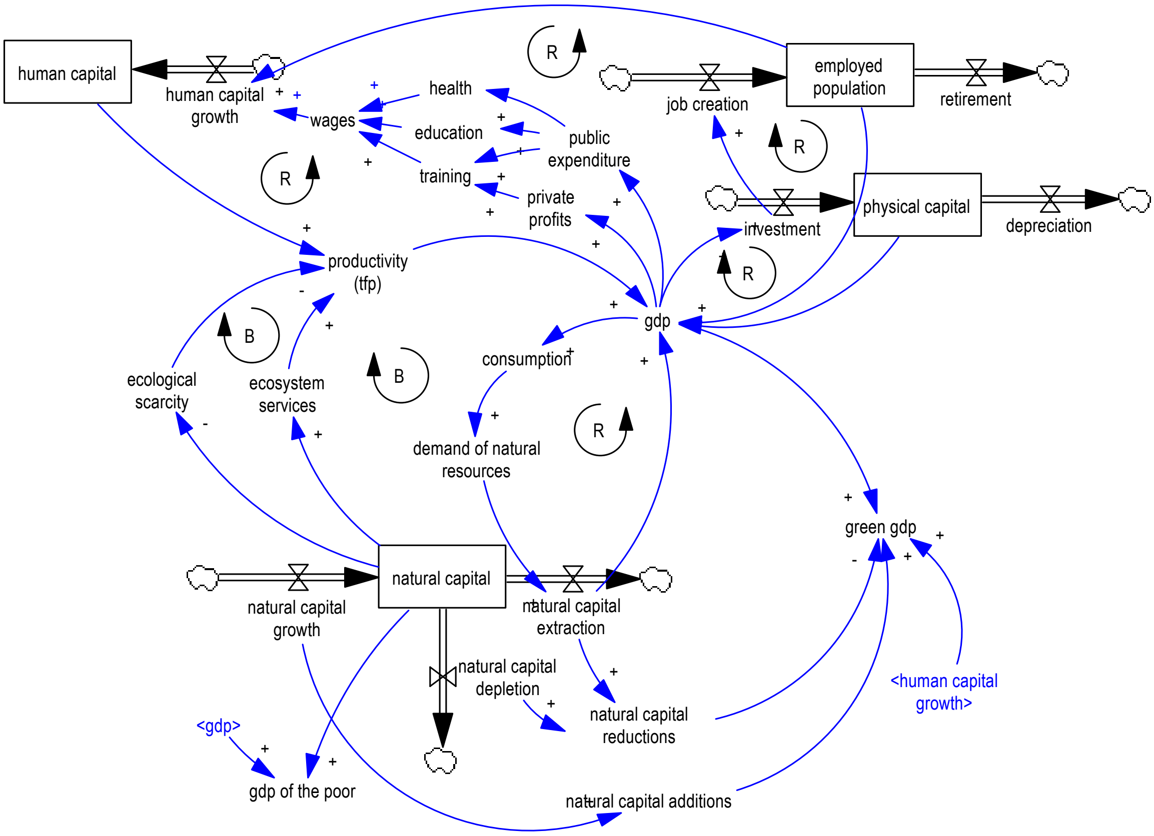
The models are customized at the country level, to properly capture the local context and dynamics. In general, the models include the following groups of sectors, to ensure that policy interventions and their impacts are effectively analyzed:

- *Natural capital-based sectors:* heavily relying on the availability of natural resources (stocks and flows), these sectors can thrive and be sustainable only if resource extraction is managed in ways that maintain the ecosystem balance. Overexploitation of natural resources should be avoided (1) to curb impacts on ecosystem services, which would ultimately undermine productivity and competitiveness, and (2) to avoid volatility in economic performance (e.g. from constrained exports).

- *Industrial sectors:* embedded in the conventional (carbon-intensive) structure that contributes to modern lifestyles and, as proven by various studies, is being challenged by rising energy prices and externalities. Such sectors have to aim for a transition to energy efficient technologies and resource efficiency to prosper while lowering costs and reducing their impact on the environment. Major steps are necessary to retrofit and replace old ‘brown’ economic structures, to develop innovative regulations, and to transition towards new sustainable economic structures.

With the horizontal integration of several sectors having the potential to re-shape consumption and production, the models are able to inform policy formulation and evaluation for *emerging economies* (those that find themselves increasingly locked into the primary sector, conventional energy and carbon intensive economic structures, but can more easily turn to greener and more sustainable paths than developed countries, as their economies are more flexible and adaptable) as well as *developing economies* (being less locked into carbon-intensive capital and thus having the unique opportunity to steer their development path towards the new and ‘greener’ economic development paradigm).

Figure 1
Causal Loop Diagram (CLD) representing the main variables and feedback loops of GEM applications.



3. Scenarios and simulation results

The UNECA SDG model developed for the Republic of Congo uses primarily data from the World Bank (World Development Indicators) (World Bank Data, 2018), complemented by national statistics to fill relevant gaps. The results presented next are originating from an initial version of the model (Version 1.0) created to share information on the potential contribution of SD to development planning. The model is conceived to be of support at a national workshop, highlighting key indicators and feedback loops. The results the simulation show macro trends, and may considerably change if the model is further customized and detail is added (both in terms of adding variables and sectors, as well as adding more interconnections among these variables and sector). It results that the information presented next is preliminary and may be subject to revision if/as the country is interested in exploring this methodology in more detail and the project continues.

The UNECA SDG model is calibrated based on historical data and trends and projects the development of variables across multiple sectors (e.g. government, households, macroeconomy) into the future. This section presents scenarios and model outputs for some of the key variables in the model.

3.1 Scenarios

The analysis currently considers two scenarios, a Business as Usual (BAU) case and a National Development Plan (NDP) scenario. The BAU scenario represents a continuation of historical trends, with no additional measures implemented and hence without increased ambition to achieve the SDGs. The NDP scenario includes instead selected interventions that supports sustainable development. These interventions include (1) an increase in investments, (2) investments in technology, (3) improvements in education, and (4) the shift towards a more extensive use of renewable energy sources, especially for power generation. The following paragraphs provide a more detailed overview of the assumptions used to create the NDP scenario.

Increase in investments

The investment assumptions considers that total investments in the industry sector are 10% higher than in the baseline between 2019 and 2025 to revitalize the sector after the crisis in 2016. The assumption is based on the ambition to increase investment as a share of GDP. An investment multiplier for the industry sector is assumed.

Investments in sustainable agriculture

The Investment scenario assumes the implementation of sustainable agriculture on 15% of cropland in the Republic of Congo. The implementation of the policy is assumed to happen linearly between 2019 and 2025.

Increased energy efficiency

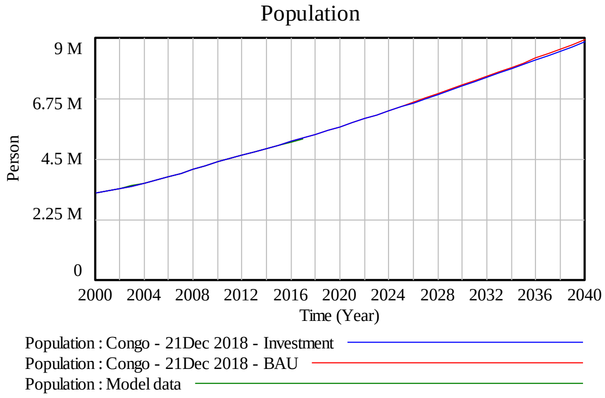
This assumption in the energy sector assumes that the Republic of Congo will increase investments in energy efficiency simultaneously with the investments occurring in the industry sector. Energy efficiency is assumed to increase by 2% per year between 2019 and 2025, which doubles energy efficiency gains compared to the 1% increase in the baseline scenario. This implies that overall energy demand will be curbed compared to the baseline scenario.

3.2 Simulation results

Population and GDP

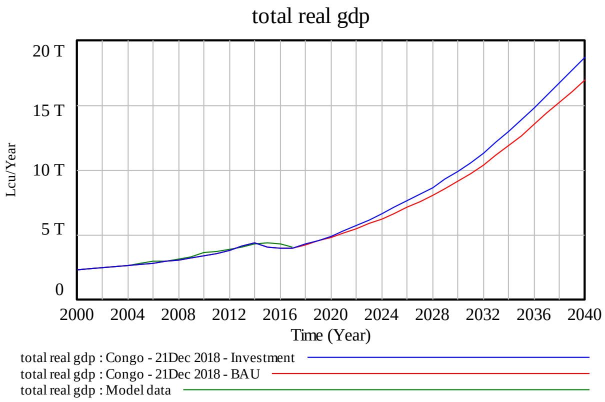
In the BAU scenario, Congo's population is projected to increase to 8.93 million people by 2040. The population growth rate between 2020 and 2040 averages 2.29%. As a consequence of increasing well-being (with higher income and education), the Investment scenario, population by 2040 totals 8.84 million people and is hence 1.01% lower compared to the BAU scenario. In the NDP scenario, population grows on average at 2.1% per year between 2020 and 2040. Figure 2 compares the development of population in the BAU and the NDP scenario to the historical trend.

Figure 2
Total population



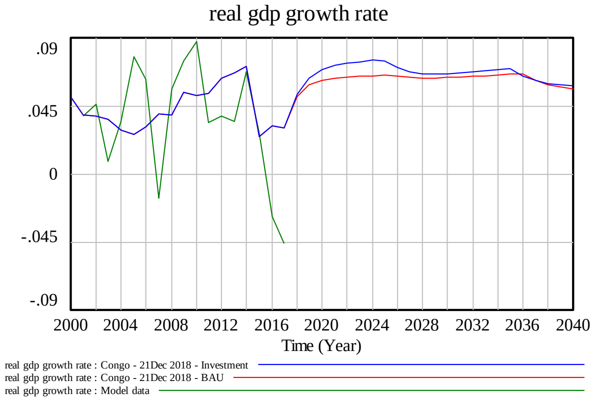
Total real GDP of the Republic of Congo in the BAU scenario is projected to increase from CDF 4.27 trillion in 2016 to CDF 17.0 trillion in 2040, which represents a total increase of CDF 12.73 trillion, or approximately three times higher than in 2016. Increased investments and improvements in total factor productivity in the Investment scenario accelerate GDP growth and increase total real GDP to CDF 18.73 in 2040, which is 10.2% higher compared to the baseline. Specifically, productivity increases thanks to technology improvement, increased access to health care and education. Figure 3 displays the projections of total real GDP and access to basic health care services in the baseline and the Investment scenario compared to historical data.

Figure 3
Real GDP



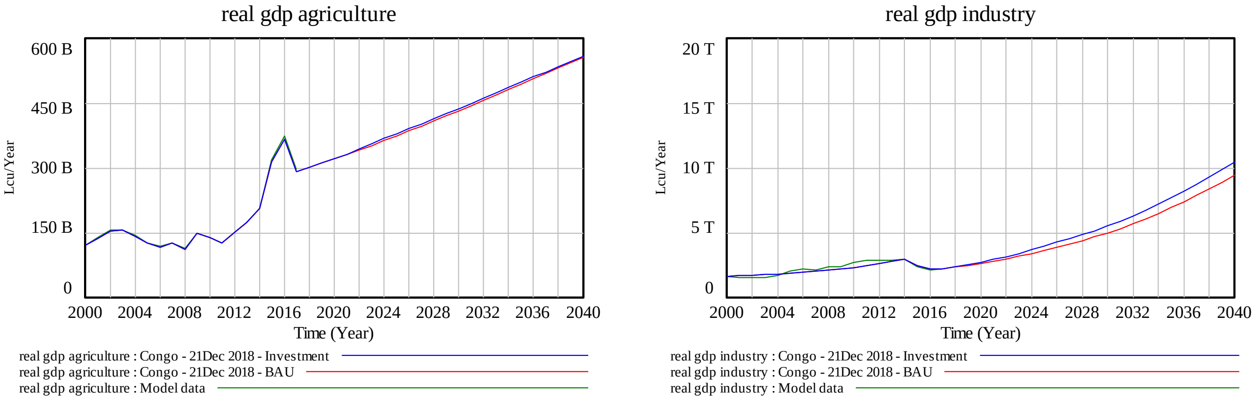
Real GDP growth between 2020 and 2040 averages 6.32% in the BAU scenario, assuming a recovery from the crisis in 2016. In the investment scenario, total real GDP is projected to increase by CDF 1.73 trillion compared to the BAU scenario in 2040, with an average GDP growth of 6.75% between 2020 and 2040. Overall, the additional investments contribute to an additional value creation and increase average real GDP growth by 0.43% compared to the baseline. The real GDP growth rate in the BAU and Investment scenario is displayed in Figure 4. A decline in the growth rate is observed after 2035, due to the reduction in the ambition of the interventions simulated in the Investment scenario.

Figure 4
Real GDP growth rate



In addition to the total real GDP, the UNECA SDG model provides information about sectoral performance, productivity indicators and employment. Figure 5 provides an overview of the real GDP generated by the agriculture and industry sector for the BAU and Investment scenario compared to historical data.

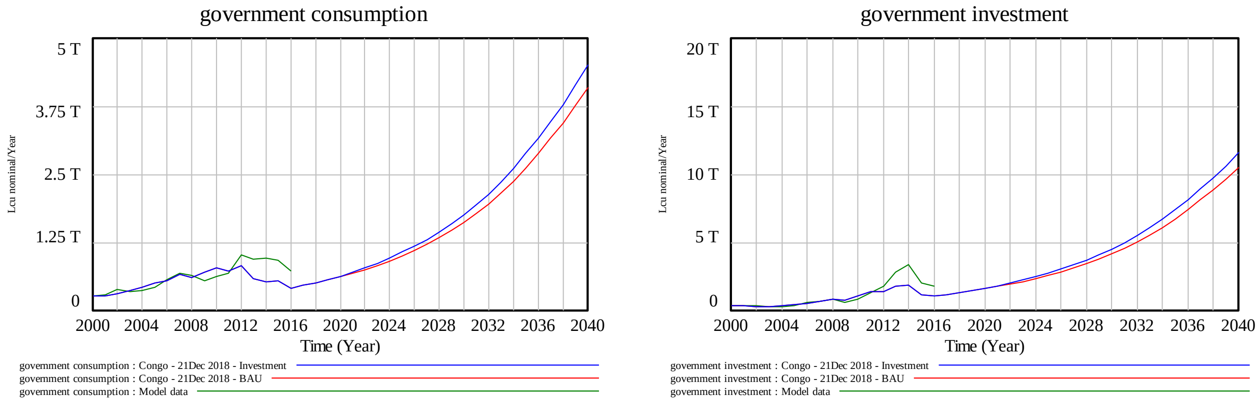
Figure 5
Real GDP Agriculture and Industry



Government accounts

The model generates projections on many of the variables contained in the System of National Accounts (SNA), but at a high level of aggregation. Figure 6 provides an overview of the development of total government consumption and the government investment between 2000 and 2040, presented in monetary terms (i.e. not inflation adjusted), compared to historical data. In the baseline, government consumption is projected to increase to CDF 4.1 trillion in the year 2040, compared to CDF 719.3 billion in 2016, which is equivalent to an average annual increase of approximately 9.94%. In the Investment scenario, government consumption increases to CDF 4.52 trillion, or 10.23% higher by 2040 compared to the baseline. The annual growth rate of government revenues between 2020 and 2040 averages 10.4% and is hence 0.47% higher compared to the baseline. The government investment totals CDF 10.54 trillion in the baseline and CDF 11.61 trillion in the NDP scenario by 2040. The average growth rate of required government investments is 9.94% in the baseline and 10.4% in the Investment scenario. While this investment generates positive returns for the economy, it is important to consider possible repercussions on the initial cost of financing.

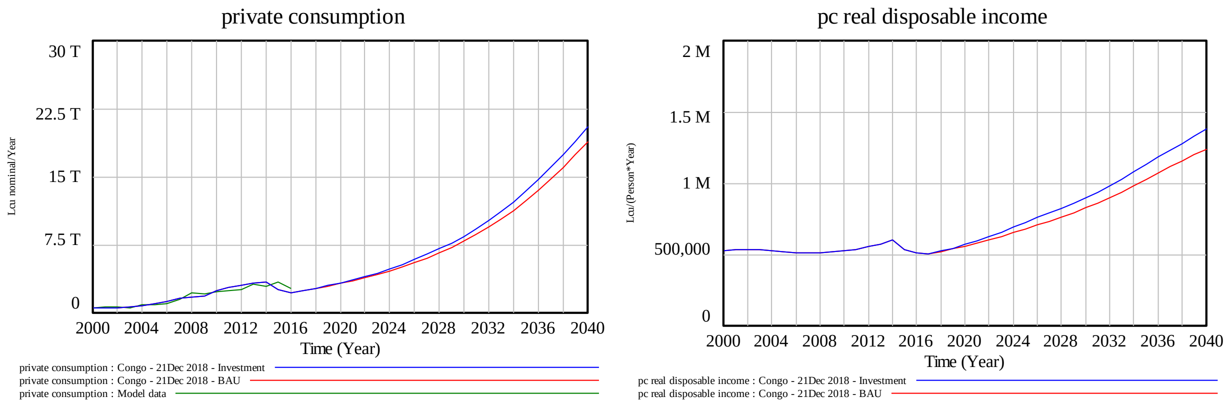
Figure 6
Government consumption and Government investment



Household accounts

The household accounts provide an overview of household performance, for variables such as private consumption and investment, disposable income and real per capital income. The development of private consumption and real per capita disposable income is illustrated in Figure 7. Private consumption is projected to more than triple from CDF 2.62 trillion in 2016 to CDF 18.88 trillion in 2040 in the BAU scenario, representing an increase of CDF 16.26 trillion. In the Investment scenario, private consumption is projected to increase to CDF 20.57 trillion by 2040, which is approximately 9% higher than in the baseline. In the BAU scenario, real disposable income per capita by 2040 is forecasted to range around CDF 1.24 million and hence more than double compared to the 2016 value. Real disposable income per capita in the Investment scenario almost triples compared to 2016, reaching CDF 1.38 million per capita by 2040.

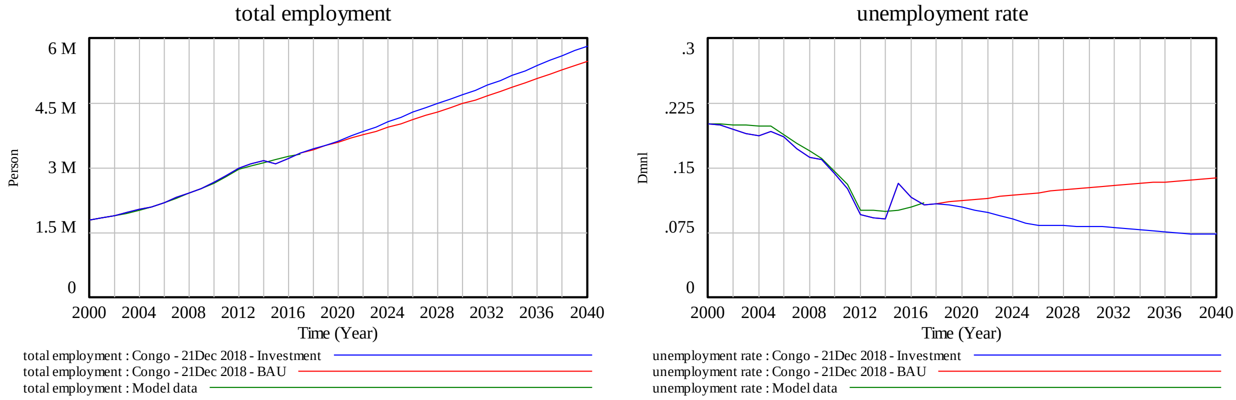
Figure 7
Private consumption and Real per capital disposable income



Employment, education and health

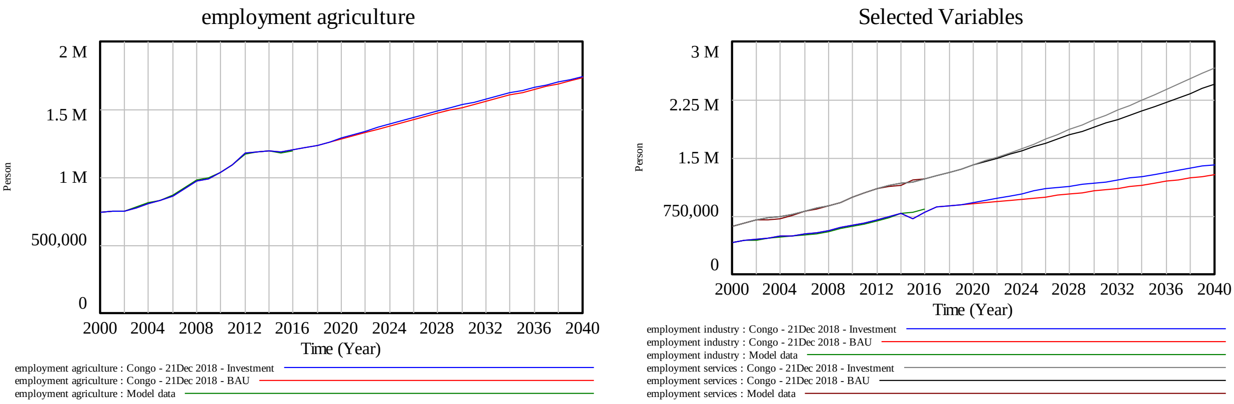
Figure 8 illustrates the development the labor force and total employment in the Republic of Congo (RdC) between 2000 and 2040 compared to historical data. The RdC's economy is projected to provide approximately 5.46 million jobs by 2040, which represents a 67.6% increase compared to 2016. During the same period, the total labor force is expected to increase to roughly 6.33 million people. In the Investment scenario overall employment is 6.5% higher compared to the baseline, which indicates that additional investments in technology, sustainable agriculture and energy efficiency generate approximately 355,200 additional jobs. Population and labor force are lower in the Investment scenario, with the former being 90,200 people lower compared to the baseline in 2040. The unemployment rate by 2040 is projected at 13.82% and 7.28% for the BAU and Investment scenario respectively.

Figure 8
Total employment and Unemployment rate



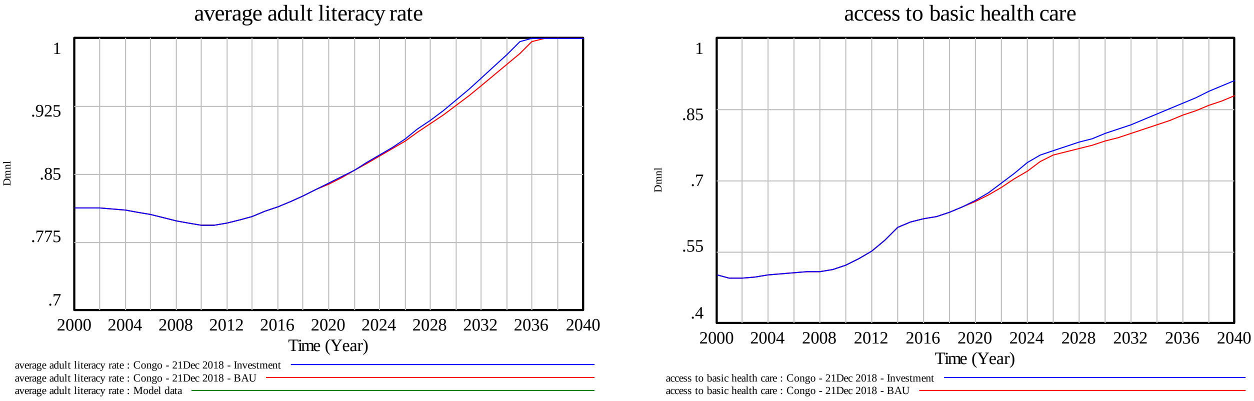
The strongest increase for employment is projected for the industry and services sectors. Figure 9 provides an overview of the development of sectoral employment over time for all three production sectors, by scenario and compared to historical data.

Figure 9
Sectoral employment for agriculture and industry and services



In the BAU scenario, the average literacy rate increases from around 81% in 2016 to 100% in 2037, while the NDP scenario achieves full (primary) literacy by 2036. Access to health care increases in the baseline scenario from 61.9% in 2016 to 87.8% by 2040. Improved economic performance contribute to a higher budget for health care and increase the access to health care to 91.1% by 2040, which is 3.3% higher compared to the baseline

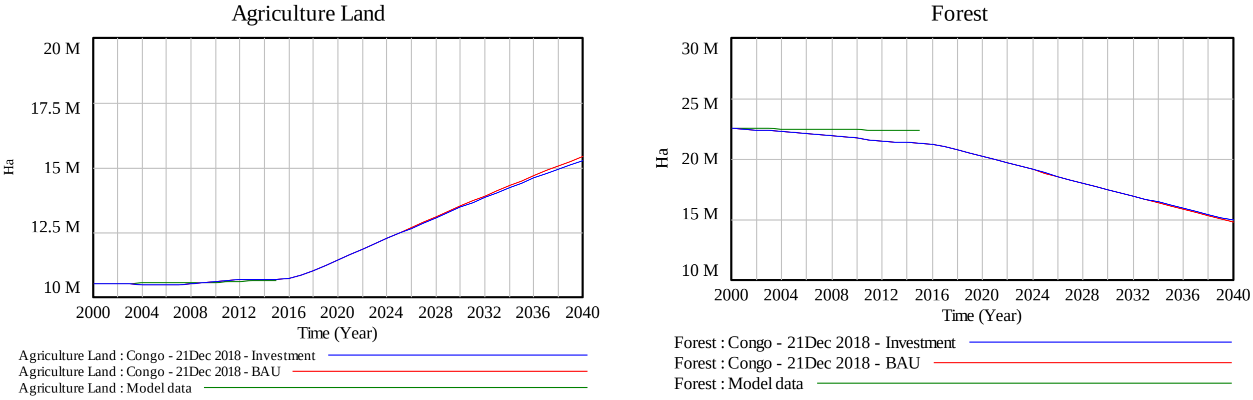
Figure 10
Average adult literacy rate and access to health care



Land use

The UNECA SDG model provides information on land use and land use change (LULC). The development of total agriculture land and forest land are depicted in Figure 11. In the baseline scenario, driven by population growth, total land used for agriculture is projected to reach 15.43 million hectares in 2040. The increase in agriculture land is assumed to cause deforestation and hence reduce forestland. Based on model projections, the amount of forestland would total roughly 14.76 million hectares in the year 2040, which represents a reduction of 34.6% compared to 2015. As a consequence of slightly lower population growth in the Investment scenario, total annual deforestation for agriculture is lower, which leads to the forest stock being 155,800 hectares higher compared to the baseline. On the other hand, it can be expected that the reduced use of biomass (due to electrification) and the economic transition to industrial development, may further reduce land use. The development of total agriculture and forestland is illustrated in Figure 11, compared to historical data.

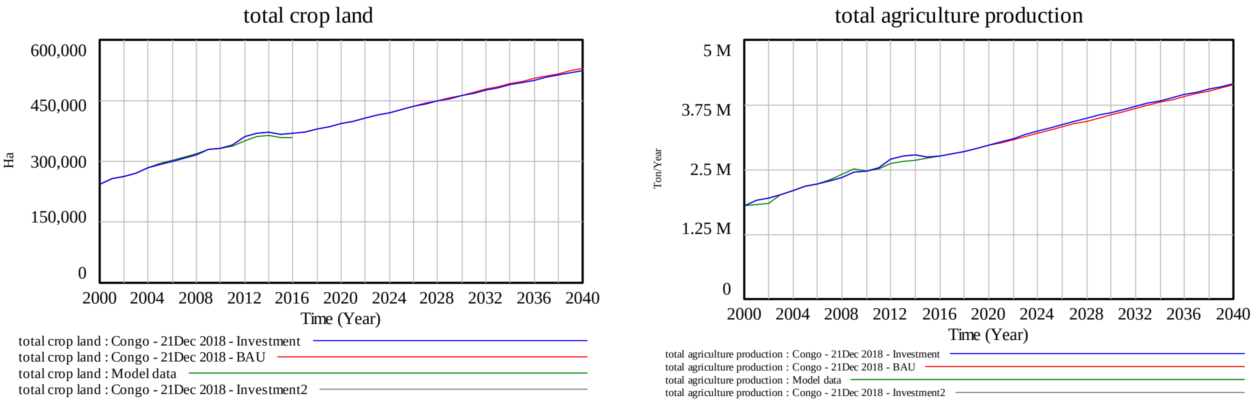
Figure 11
Agriculture and Forest land



Agriculture production in the baseline is projected to increase from 2.76 million tons in 2016 to 4.13 million tons in 2040, with no sustainable agriculture production. In the Investment scenario, total agriculture production increases by 0.6%, or 17,000 tons, to 4.15 million tons in 2040, of which 675,200 tons, or 16.3%, stem from sustainable production. Figure 12 displays the development of crop land and total agriculture production in the BAU and the NDP scenario.

Figure 12

Cropland and total agriculture production

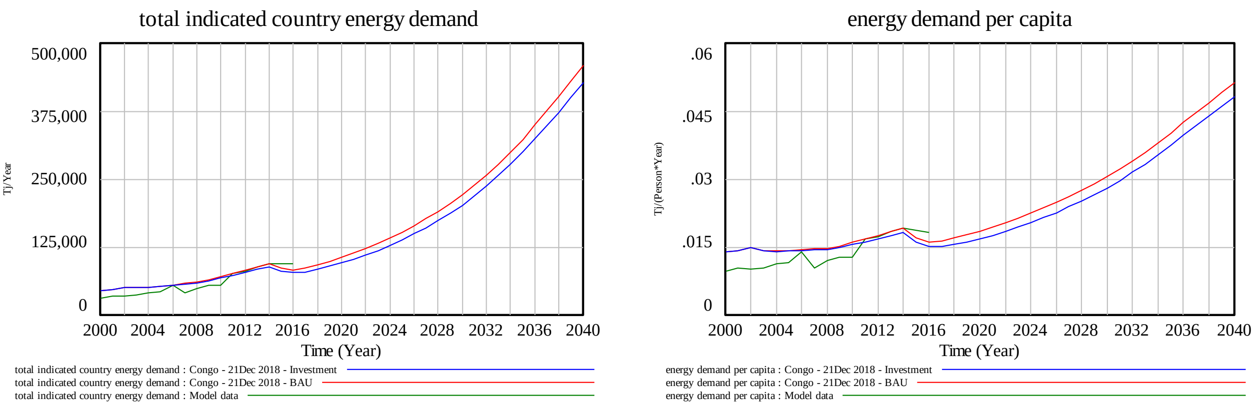


Energy and emissions

The UNECA SDG model estimates total CO2 emissions from economic activity, depending on the energy demand, mix of fuel sources and technological progress. The total energy demand in the baseline and Investment scenario are projected to increase from 93,660 in 2016 to 459,200 TJ per year and 427,300 TJ per year by 2040 respectively. In the baseline, energy demand per capita is projected to increase from 0.0183 TJ per person year in 2016 to 0.0514 TJ per person per year in 2040. Additional investments in energy efficiency between 2019 and 2025 reduce the energy demand per capita by 6% to 0.0483 TJ per person per year in 2040 in the Investment scenario. Figure 13 displays the total indicated country energy demand and energy demand per in the BAU and the Investment scenario.

Figure 13

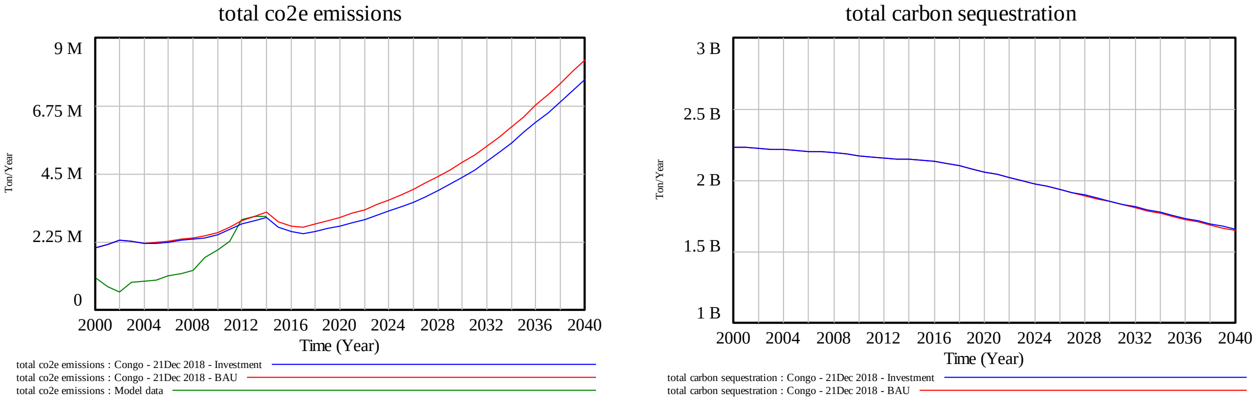
Total indicated country energy demand and Energy demand per capita



In the BAU scenario, the RdC's CO2 emissions are projected to increase from 3.1 million tons per year in 2014 to 8.3 million tons per year in 2040 in the BAU, and 7.6 million tons in the Investment scenario. This indicates that emissions are expected to almost triple during the next two decades. Based on the projections, the RdC's CO2 emission rate increases on average by 5.21% per year in the BAU, and by 5.36% per year in the Investment scenario.

Concerning carbon sequestration, as a consequence of land conversion, the RdC's CO2 absorption capacity is projected to decline from 2.13 billion ton in 2016, to 1.65 billion and 1.66 billion tons in the BAU and Investment scenario respectively in 2040. Lower land conversion from forest to agriculture cause the total carbon stock in the Investment scenario to be higher than in the baseline. The development of total CO2 emissions and carbon absorption capacity is displayed in Figure 14.

Figure 14
CO2 emissions and carbon sequestration



4. Analysis, identification of key feedback loops

The development of a country, as presented in the trends described above, is primarily driven by feedback loops. These are circular relations that can amplify or curb change and, when identified and exploited, can generate multiplier effects in supporting development.

Specifically, there are two types of feedback loops: reinforcing and balancing (Forrester 1961).

- Reinforcing loops are found when an intervention in the system triggers other changes that amplify the effect of that intervention, thus reinforcing it.

- Balancing loops tend towards a goal or equilibrium, balancing the forces in the system.

Several reinforcing and balancing loops can be identified in the UNECA SDG model. The most relevant ones, i.e. those that have the largest impact on the behavior of the model, are presented next. This is to explore in more depth, and better understand how the model works, especially in a first approach to System Dynamics, as the introductory trainings are.

4.1 Reinforcing feedback loops – Investment, economic growth and resource consumption

Investments in physical capital

A higher investment increases in GDP, which in turn leads to higher government revenues and household income. When income increases, private investment increases again, creating a reinforcing loop. At the same time, an increase in government revenues leads to higher budget and investment in public services (described in more detail below), which also leads to higher economic growth, through improved productivity.

Similarly, increasing annual investments leads to a faster growth of the capital stock, which facilitates GDP growth, which in turn generates more money that can be reinvested. In other words, the faster GDP grows, the more resources will be available for reinvesting in fixed capital, which will stimulate economic growth.

Investments in human capital

Investments in physical capital generates more jobs and increases income. Higher employment and human capital, impacted by education and health, affected by GDP, income and public spending lead to increased total factor productivity, which in turn contributes to faster GDP growth.

Investment in public services

Investments in public services such as education and health care contribute to economic growth by increasing the well-being and the skill level of the population. Investments in education and health contribute to an increase in productivity up to the point where the maximum coverage (or universal access) is reached, beyond which the quality of education and health care becomes more relevant.

Consumption of natural capital

Economic production (GDP) is sustained by the consumption of natural resources, which implies that an increase in production stimulates the demand and extraction of natural resources. The higher the extraction of resources, the higher the potential for economic production. In other words, this loop contributes to the depletion of natural resources at an increasing pace (see balancing loop described below), but also leads to growing economic performance if resources are available.

4.2 Balancing feedback loops – Ecological capital and ecosystem services

Erosion of ecosystem services

Economic production (GDP) increases the consumption and hence the demand for natural resources. The increase in demand for natural resources leads to a higher extraction of natural resources and a faster depletion of natural capital (e.g. forests, water bodies, soil, fossil fuels).

Natural capital provides a range of ecosystem services that humanity is directly (e.g. fresh water, non-timber forest products) or indirectly (e.g. pollination, water cycle) dependent on, and these services have an economic value.

A reduction in natural capital hence causes a reduction in ecosystem services, which negatively impacts total factor productivity (by implying that the service received declines and that in some circumstances investments in physical capital are required to counter this decline (e.g. water treatment plants). In other words, the depletion of natural capital beyond sustainable levels has a balancing effect that slows down economic growth, by lowering productivity and requiring extra budget allocation (and thus reducing the effectiveness of budget allocation, or value for money, overall).

Ecological scarcity

Rapid GDP growth and the resulting consumption of natural resources trigger a second balancing loop. The exploitation of natural capital, especially non-renewable resources, increases the degree of ecological scarcity, meaning a reduction in the availability of ecosystem services and resources available for economic production. Reducing the relative amount of resources available increases the cost of extraction or maintenance, and vulnerability to climate impacts (among other possible exogenous shocks). Higher costs, or scarcity, negatively affect the production and the productivity per unit extracted, and has a balancing effect on economic value creation.

The feedback loops described above are important to consider when assessing the potential outcomes of policy interventions. The extent to which we affect a reinforcing or a balancing loop can determine the success (or the effectiveness) of our policy interventions, and hence the performance of the system (across economic actors, sectors, dimensions of development, over time and in space).

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List of variables

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ELASTICITY OF AGRICULTURE YIELD TO AGRICULTURE TFP

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INITIAL YIELD PER HECTARE

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POLICY SWITCH SUSTAINABLE AGRICULTURE

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Share of cropland sustainable

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Sustainable agriculture production

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INITIAL EMPLOYMENT INDUSTRY

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INITIAL REAL GDP

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Capital Services

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EFFECT OF HEALT CARE ON LABOR PRODUCTIVITY TABLE SERVICES

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6. Employment and technology

Actual Relative Labor Cost

Annual technology growth rate

ELASTICITY OF LABOR COST TO DEMAND SUPPLY BALANCE

INITIAL LABOR DEMAND SUPPLY BALANCE

Labor cost adjustment

LABOR COST ADJUSTMENT TIME

Labor demand supply balance

Labor force

Labor force participation rate

Policy annual technology growth rate

POLICY SWITCH TECHNOLOGY

Relative indicated labor cost

Tech

Tech advancement

Total employment

Unemployment rate

7. Households

Disposable income

ELASTICITY OF PROPENSITY TO CONSUME TO INCOME

IMPORT DEMAND AS A FRACTION OF INCOME

INITIAL PC REAL DISPOSABLE INCOME

INITIAL PROPENSITY TO CONSUME

Nominal consumption

Nominal export

Nominal import

Nominal investment

Nominal production

Pc real disposable income

Private consumption

Private savings

Private savings for private investment

Propensity to consume

Relative pc real disposable income

SHARE OF SAVINGS FOR PRIVATE INVESTMENTS TABLE

8. Government

ADMINISTRATIVE EXPENDITURE AS SHARE OF BUDGET

Debt share of gdp

Desired government deficit

DESIRED GOVERNMENT DEFICIT TABLE

Desired share of development expenditure for education

DESIRED SHARE OF DEVELOMENT EXPENDITURE FOR EDUCATION TABLE

Desired share of development expenditure for health

DESIRED SHARE OF DEVELOMENT EXPENDITURE FOR HEALTH TABLE

Desired share of development expenditure for resource efficiency

DESIRED SHARE OF DEVELOMENT EXPENDITURE FOR RESOURCES EFFICIENCY TABLE

Development expenditure

Education expenditure

Effective tax rate

Expenditure for resources efficiency

FRACTIONAL INTEREST RATE

Government budget

Government budget after interest

Government consumption

Government domestic financing

Government domestic revenue

Government investment

Health expenditure

Interests on public debt

Net debt change

Nominal import

Non development expenditure

Non development expenditure per capita

Public Debt

Relative investment

Share of government consumption over total expenditure

SHARE OF GOVERNMENT CONSUMPTION OVER TOTAL EXPENDITURE TABLE

TAX RATE TABLE

Total government revenue

Total investment

9. Health care

Access to basic health care

Average Health Expenditure

EFFECT OF PER CAPITA HEALTH EXPENDITURE ON ACCESS TO BASIC HEALTH CARE TABLE

INITIAL ACCESS TO BASIC HEALTH CARE

INITIAL HEALTH CARE EXPENDITURE

INITIAL PER CAPITA HEALTH EXPENDITURE

Net change in perceived health expenditure

Per capita health expenditure

Real health expenditure

Relative per capita health expenditure

TIME TO CHANGE HEALTH CARE SERVICES

10. Education

Adult crude death rate

Adult crude migration rate

Adults literacy rate

Age 6 population

AGE 6 SHARE OF TOTAL POPULATION

Average adult literacy rate

Average Education Expenditure

Dropout fraction

Dropout rate

Dropout rate education policy

Effect of education expenditure on dropout

EFFECT OF EDUCATION EXPENDITURE ON DROPOUT TABLE

Effect of expenditure on school entrance

EFFECT OF EXPENDITURE ON SCHOOL ENTRANCE TABLE

Entrance rate

Government expenditure on education over gdp

Graduation rate

INITIAL DROPOUT FRACTION

INITIAL FRACTIONAL ENTRANCE RATE

INITIAL LITERATE ADULTS

INITIAL PER PUPIL EDUCATION EXPENDITURE

INITIAL PER STUDENT EDUCATION EXPENDITURE

INITIAL STUDENTS -

Literate Adults

Literate adults loss rate

Net change in average education expenditure

Pc real education expenditure

Per pupil education expenditure

Per student education expenditure

POLICY SWITCH EDUCATION

Real education expenditure

Relative per pupil education expenditure

Relative per student education expenditure

Students

TIME FOR SECONDARY SCHOOL GRADUATION -

TIME TO CHANGE EDUCATION SERVICES

11. Environment and resources

Annual discovery fraction

Discovered Resources

Discovery rate

Effect of technology on discovery rate

EFFECT OF TECHNOLOGY ON DISCOVERY RATE TABLE

INITIAL DISCOVERED RESOURCES

INITIAL DISCOVERY FRACTION

INITIAL UNDISCOVERED RESOURCES

MAXIMUM FRACTION EXTRACTED PER YEAR

Maximum theoretic yearly production

Number of barrels produced reference mode

OIL EXTRACTION RATE TABLE

Resources demand supply balance

Resources production rate

Undiscovered Resources

12. Land

Agriculture Land

Agriculture to waste

AVERAGE FOREST REGENRATION TIME

AVERAGE LIFE OF AGRICULTURE LAND

CARBON FACTOR AGRICULTURE

CARBON FACTOR FALLOW

CARBON FACTOR FOREST

CARBON FACTOR SETTLEMENT

Carbon sequestration agriculture

Carbon sequestration fallow

Carbon sequestration forest

Carbon sequestration settlement

Desired agriculture land

Desired agriculture land per capita

Desired change in agriculture land

Desired change in settlement land

Desired settlement land

Desired settlement land per capita

Forest

Forest to agriculture

Forest to settlement

Settlement Land

TIME TO CONVERT FOREST LAND

TIME TO CONVERT WASTE LAND

Total carbon sequestration

Total land

Waste Land

Waste to forest

Waste to settlement

13. Energy

Actual coal subsidy per kt

Actual electricity subsidy per kwh

Actual natural gas subsidy per tcf

Actual petroleum subsidy per liter

Average emissions per tj of electricity generation

BASELINE COAL SUBSIDY PER KT

BASELINE ELECTRICITY SUBSIDY PER KWH

BASELINE NATURAL GAS SUBSIDY PER TCF

BASELINE PETROLEUM SUBSIDY PER LITER

Biofuels and Waste Demand

Biofuels and waste emissions

Biofuels and Waste Price Substitutability

Carbon intensity (energy)

Change in energy efficiency

Co2 emissions per capita

CO2E EMISSIONS PER TJ OF BIOFUELS AND WASTE

CO2E EMISSIONS PER TJ OF COAL

CO2E EMISSIONS PER TJ OF NATURAL GAS

CO2E EMISSIONS PER TJ OF PETROLEUM

Coal Demand

Coal emissions

Coal price

Coal Price Substitutability

COAL PRICE TABLE

Coal subsidy removed per kt

ELASTICITY OF BIOFUELS AND WASTE DEMAND TO BIOFUELS AND WASTE PRICE

ELASTICITY OF BIOFUELS AND WASTE DEMAND TO GDP

ELASTICITY OF BIOFUELS AND WASTE DEMAND TO POPULATION

ELASTICITY OF COAL DEMAND TO COAL PRICE

ELASTICITY OF COAL DEMAND TO GDP

ELASTICITY OF COAL DEMAND TO POPULATION

ELASTICITY OF ELECTRICITY DEMAND TO ELECTRICITY PRICE

ELASTICITY OF ELECTRICITY DEMAND TO GDP

ELASTICITY OF ELECTRICITY DEMAND TO POPULATION

ELASTICITY OF NATURAL GAS DEMAND TO GDP

ELASTICITY OF NATURAL GAS DEMAND TO NATURAL GAS PRICE

ELASTICITY OF NATURAL GAS DEMAND TO POPULATION

ELASTICITY OF PETROLEUM DEMAND TO GDP

ELASTICITY OF PETROLEUM DEMAND TO PETROLEUM PRICE

ELASTICITY OF PETROLEUM DEMAND TO POPULATION

Electricity Demand

Electricity emissions

Electricity price

Electricity Price Substitutability

Electricity subsidy removed per kwh

Emissions intensity

EMISSIONS PER GWH OF COAL POWER GENERATION

EMISSIONS PER GWH OF GAS POWER GENERATION

Energy demand per capita

Energy demand per unit of gdp

Energy efficiency change

ENERGY EFFICIENCY RATE

Indicated biofuels and waste demand

Indicated biofuels and waste demand 1

Indicated coal demand

Indicated coal demand 1

Indicated electricity demand

Indicated electricity demand 1

Indicated natural gas demand

Indicated natural gas demand 1

Indicated petroleum demand

Indicated petroleum demand 1

Indicated share of biofuel and waste

Indicated share of coal

Indicated share of electricity

Indicated share of natural gas

Indicated share of petroleum

INITIAL BIOFUELS AND WASTE DEMAND

INITIAL COAL DEMAND

INITIAL COAL PRICE

INITIAL ELECTRICITY DEMAND

INITIAL ELECTRICITY PRICE

INITIAL ELECTRICITY PRICE USD PER KWH

INITIAL NATURAL GAS DEMAND

INITIAL NATURAL GAS PRICE

INITIAL PETROLEUM DEMAND

INITIAL PETROLEUM PRICE

INITIAL TOTAL CO2E EMISSIONS

INITIAL TOTAL INDICATED COUNTRY ENERGY DEMAND

INITIAL TOTAL REAL GDP

Natural Gas Demand

Natural gas emissions

Natural gas price

Natural Gas Price Substitutability

NATURAL GAS PRICE TABLE

Natural gas subsidy removed per tcf

Normalized biofuels and waste demand

Normalized biofuels and waste share of energy demand

Normalized coal demand

Normalized coal share of energy demand

Normalized electricity demand

Normalized electricity share of energy demand

Normalized natural gas demand

Normalized natural gas share of energy demand

Normalized petroleum demand

Normalized petroleum share of energy demand

Oil Price Substitutability

Petroleum Demand

Petroleum emissions

Petroleum price

Petroleum Price Growth

Petroleum price growth rate

PETROLEUM PRICE PERCENT INCREASE

Petroleum price time series

Petroleum subsidy removed per liter

Real gdp per capita

RELATIVE BIOFUELS AND WASTE PRICE

Relative coal price

Relative electricity price

Relative Energy Efficiency

Relative gdp

Relative natural gas price

Relative petroleum price

Relative population

Relative total co2e emissions

Relative total indicated country energy demand

Relative weighted average energy price

SHARE OF GAS

Share of oil and coal

Smooth petroleum price growth

SUBSIDY REMOVAL TABLE

TIME TO ADAPT DEMAND TO PRICE CHANGES

Total co2e emissions

Total coal primary demand for domestic use in tj

Total country energy demand

Total country normalized biofuels and waste demand

Total country normalized coal demand

Total country normalized electricity demand

Total country normalized natural gas demand

Total country normalized petroleum demand

Total gas demand for domestic use in tj

Total indicated country energy demand

Total petroleum demand for domestic use in tj

14. Power generation capacity

AVERAGE CAPITAL COSTS PER MW OF CONVENTIONAL CAPACITY

Average capital costs per mw of other renewable capacity

AVERAGE LIFETIME CONVETIONAL

AVERAGE LIFETIME OTHER RENEWABLE

AVERAGE O&M COSTS PER MW OF CONVENTIONAL CAPACITY

Average o&m costs per mw of other renewable capacity

Change in cumulative cost of power generation

Change in cumulative total electricity generation rate

Change in discounted cumulative cost of power generation

Change in discounted cumulative total electricity generation rate

Construction employment conventional capacity

Construction employment other renewable capacity

Construction employment per mw of conventional capacity

Construction employment per mw of other renewable capacity

Construction rate conventional

Construction rate other renewable

Conventional damage to capacity

Conventional Power Generation Capacity

Cumulative Cost Of Power Generation

Cumulative Total Electricity Generation Rate

Depreciation Rate Conventional

Depreciation Rate Other Renewable

Desired power generation capacity

DISCOUNT RATE

Discounted Cumulative Cost of Power Generation

Discounted Cumulative Total Electricity Generation Rate

Effect of precipitation on load factor conventional

Effect of temperature on load factor conventional

Effect of water scarcity on load factor renewable

ELASTICITY OF LOAD FACTOR CONVENTIONAL TO PRECIPITATION

ELASTICITY OF POWER GENERATION CAPACITY TO CLIMATE IMPACTS

ELASTICITY OF RENEWABLE LOAD FACTOR TO WATER SCARCITY

Electricity demand in mwh

Electricity generation rate conventional

Electricity generation rate other renewable

Fraction of power generation capacity renewable

Fraction of power generation capacity renewable baseline

Fraction of power generation capacity renewable policy

HOURS PER YEAR

INITIAL CONVENTIONAL POWER GENERATION CAPACITY

INITIAL ELECTRICITY GENERATION RATE

INITIAL OTHER RENEWABLE POWER GENERATION CAPACITY

Investment in conventional power generation capacity

Investment in renewable power generation capacity

Labor income from conventional capacity

Labor income from renewable capacity

LABOR INCOME PER EMPLOYEE IN ENERGY

Lcoe – levelized cost of electricity

Load factor conventional

Load factor other renewable

MWH PER TJ

O&m costs conventional power generation capacity

O&m costs renewable power generation capacity

O&m employment conventional

O&m employment other renewables

O&m employment per mw of conventional capacity

O&m employment per mw of other renewable capacity

POLICY SWITCH ENERGY

Potential gdp (including impact of electricity supply)

Relative electricity generation rate

Renewable Power Generation Capacity

Renewables damage to capacity

Replacement rate conventional

Replacement rate other renewable

Share of electricity generated by conventional capacity

Share of electricity generated by other renewables

START TIME OF DISCOUNTING

Time step for discounting

TIME TO CONSTRUCT POWER GENERATION CAPACITY

Total annual costs conventional power generation capacity

Total annual costs of power generation capacity

Total annual costs renewable power generation capacity

Total construction employment energy sector

Total electricity generation rate

Total employment energy sector

Total labor income energy sector

Total o&m employment energy sector

Weighted average load factor

15. Climate assumptions

Alignment shift

Annual temperature

Baseline Precipitation

Baseline Temperature

Change in annual temperature

Change in baseline precipitation

Change in growth rate

CLIMATE SWITCH

Cycle time

Effect on season shift

Flood indicator

FRACTIONAL CHANGE IN ANNUAL TEMPERATURE

Growth Rate Variability

Indicated seasonal precipitation

INITIAL PRECIPITATION

INITIAL SIMULATION TIME

INITIAL TEMPERATURE

MAXIMUM PRECIPITATION THRESHOLD

MINIMUM PRECIPITATION THRESHOLD

Month counter modulo

MONTH PER YEAR

Normal seasonal precipitation

PERCENT CHANGE IN BASELINE PRECIPITATION

Percent change in variability

PI

Precipitation

Relative annual temperature

Relative precipitation

Relative seasonal precipitation

SEASON SHIFT SWITCH

Seasonal distribution of precipitation

Seasonality factor

Seasonality shift

SEASONALITY SWITCH

Sin seasonality factor

Variability above normal

Variability below normal

Variability in temperature

Variability in precipitation

Water scarcity indicator