



Report on Expanding T21 Mozambique to Cover Environment Issues

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Introduction

The Mozambican Ministry of Planning and Development (MOPD) requested support for improving its comprehensive national planning process with a focus on poverty-environment mainstreaming. This work entails expanding the T21-Mozambique model to cover environmental issues. SIDA and UNDP are providing the financial and administrative support. Other project partners such as the Mozambican Debt Group, the Mozambican Ministry of Coordination of Environmental Affairs, and UNEP are also involved in the process of extending T21-Mozambique.

The proposed modifications to the model were initially based on the discussions Weishuang Qu and John Shilling had with the Ministry of Planning and Development in November 2005, on the “Mozambique Strategic Plan for the Environmental Sector,” and on the Millennium Institute’s experience with environmental factors in the model. We have since received comments on our initial proposed changes from MOPD (Sergio Dista, Peter Mulder, and Jonas Tembe) and refined the approach to take account of the comments, suggestions, and guidance received.

Sectors added to address the environment issues are:

1. Energy demand and supply (including natural gas, coal, oil, and hydro power)
2. Air emissions (including CO₂, N₂O, CH₄, SO_x, and SPM)
3. Water demand and supply
4. Water pollution and access to safe drinking water
5. Land use (including agriculture land, forest land, settlement land, fallow land, and waste land) and land degradation
6. Natural disaster

The revised model and this report will be sent to Maputo for officials in the MOPD and Ministry of Environment to review, provide further input, and consider the model’s integration into the planning process. MI staff will visit Mozambique in June 2006 for extensive consultations, adapting further changes to the model as appropriate, discussions of how best to apply the revised model, and extension of its use by key stakeholders. We will seek additional information on the suggested changes in order to fully understand the relations and obtain the needed data. The changes agreed in the field will be finalized by MI staff at HQ. Additional training will be provided during this visit to government staff and other stakeholders, including on how to use the model in decision-making. Resources for further application of the model and training of Mozambican users will also be sought.

The next section will provide a comprehensive overview of the environmental sector additions to the model for the decision-makers involved. The following section will provide more detail about the structure of the changes to facilitate the technical discussions and potential revisions in the structure of these sectors.

Additions to the Environmental Sector

Energy

Mozambique is endowed with abundant but unexplored energy resources. Biomass (fuelwood) is currently the main source of energy consumption. About 70% of population in Mozambique live in rural areas and depend on this source of energy for cooking as well as for water and indoor house heating and for food stuff drying. This has contributed to about 50,000 hectares forest loss each year.

Currently Mozambique is a net exporter of electricity (30% of total generation), natural gas (99% of total production), and coal (80% of total production). Oil reserves have not been discovered so far, so all domestic oil demand is met by imports, about 500,000 tons in 2005. Gas production began in 2003, and coal expanded sharply in 2001

Measured in heat content, Mozambique is a net energy exporter in 2005, and will stay that way until about 2010, when its oil import could exceed its total export in electricity, natural gas and coal measured in heat content.

The government of Mozambique is planning on using more gas as a fuel for vehicle transportation to reduce its dependence on oil imports. This plan is included in the model. Further substitution of oil imports with abundant domestic gas is possible, but due to data constraints, it is not included in the current model.

Electricity

Mozambique is rich in hydro power potential. The estimated hydro potential is about 12,500 MW. The Cahora Bass Hydro Power Dam (HCB) in the north of Mozambique is the major existing hydro plant and it has a capacity of 2,000 MW. There are plans to build more dams, but progress on implementation is slow. It is assumed in T21 that hydro capacity will slowly but gradually increase to 2,400 MW by 2025.

Due to abundant water supply, hydro power plants operate at a high rate, about 70% of capacity or higher, generating 13 billion KWH in 2005. In 2025, they will generate about 16 billion KWH.

Electricity generated from other sources (diesel and gas) is less than two percent of total electricity production in 2005, and is assumed to stay at that level through 2025. However, it was about 10% of non-mega project consumption as significant parts of the country do not yet have access to the power grid supplied by hydro.

In 2005, total electricity consumption was 9.5 billion KWH. The Mozal mega project is a huge electric power consumer, consuming 7.8 billion KWH, or 82%. Domestic electricity consumption is low, as only about 7% of the households have access to electricity.

Future electricity demand will be influenced substantially by the completion of 2 mega mining projects on so-called heavy sands (Corridor Sands in Chibuto in South

Mozambique, and Moma project in North Mozambique). The expansion of Mozal (adding a third line of production) in the near future could mean a substantial increase in its electricity consumption. It is assumed that additional power consumption from the mega projects will reach 2 billion KWH/year in the future.

Domestic and other non-mega industry demands (including rural electrification) are assumed to grow with real GDP, with an elasticity of 1.1.

With these supply and demand assumptions, Mozambique will stay as a net exporter of electricity in the future. But its electricity supply could be interrupted by drought, as the country depends heavily on hydro generation.

Table 1: Baseline electricity generation and consumption in Million KWH/Year

Time	2005	2010	2015	2020	2025
hydro power generation	13,242	13,956	14,651	15,328	15,987
Hydro Power Capacity in M KW	2.09	2.18	2.27	2.35	2.43
domestic electricity demand	9,343	11,587	12,640	13,434	14,147
mozal electricity demand	7,784	7,838	7,892	7,946	8,000
non mozal electricity demand	1,559	2,218	3,061	3,644	4,147
other mega electricity demand	0	1,531	1,688	1,844	2,000
net electricity export	3,899	2,369	2,011	1,894	1,839

Policy variable: Hydro capacity, other mega projects electricity demand, and rural electrification (elasticity value)

Natural gas

Mozambique has discovered natural gas reserves of 4.445 billion thousand cubic feet (thousand cubic feet, or KCF, is used as the unit for natural gas), or 127 billion cubic meters, most of which is in the Pande and Temane regions. The natural gas mega project from these regions is in operation. Its production reached 74 million KCF in 2005, and is expected to rise to 100 million KCF in the near future.

In the last few years domestic gas consumption grew from almost non-existent to about 0.6 million KCF in 2005, due to the introduction of natural gas in some local industries, and this trend is expected to continue as more manufacturing industry shows interest in using gas.

The huge surplus of gas production over domestic consumption is exported.

Domestic gas consumption can grow faster due to three probable activities: 1) Starting from 2007, gas will be consumed by vehicles; 2) New gas fired electricity plants; and 3) Mozal expansion

Table 2: Baseline gas production and consumption in Million Cubic Feet/Year

Time	2005	2010	2015	2020	2025
gas production	74,017	93,129	97,000	98,500	100,000

domestic gas demand	607	1,282	1,923	2,431	2,904
mozal 3 and vehicle gas use	0	300	400	500	600
other gas demand	607	982	1,523	1,931	2,304
net gas exports	73,410	91,847	95,077	96,069	97,096

Policy variables: Gas production, Mozal 3 and vehicle gas use

Oil

Oil exploration in Rovuma basin (northern Mozambique) has started, but so far no discovery has been made. All domestic oil demand is met by imports.

Oil demand is assumed to be affected by real GDP (with an elasticity of 0.5) and real oil prices (with an elasticity of -0.2).

Table 3: Baseline oil consumption in Ton/Year

Time	2005	2010	2015	2020	2025
domestic oil demand	532,744	606,352	683,380	717,304	740,698

Policy variable: real oil price

Coal

Mozambique has three large deposits of coal in Moatize-Minjova, Senangoe and Mucanhavuzi, all in Tete province. Total reserves of coal are estimated to be about 2 billion tons. But due to low domestic demand and inadequate investment in coal mining and transportation, coal production has been very low, less than 50,000 tons a year. About 80% of coal production is exported, and about 20% is for domestic demand. Measured in heat content, domestic coal demand is less than 1% of total domestic energy demand.

For the future, plans are underway to produce more for export and to build a coal-fired power plant.

Domestic coal demand is assumed to grow with real GDP with an elasticity of 1.2.

Table 4: Baseline coal production and consumption in Ton/Year

Time	2005	2010	2015	2020	2025
coal production	50,000	57,500	65,000	72,500	80,000
domestic coal demand	12,364	18,163	25,804	31,212	35,942
net coal exports	37,636	39,337	39,196	41,288	44,058

Policy variable: planned coal production

Energy policy discussion:

- Rural electrification, to provide access to TV for education in farming, HIV prevention, etc (increase yield and reduce poverty)*
- Coal for cooking, with special stove and processing of coal to save the forest*

- *Promote private industry using gas and coal*

For the future we might expect some substitution effects, but probably not that big

Land

Mozambique has rich land resources. Of the 78 million hectares (MHa) of land area, only 4.5 MHa is used for crop farming in 2005. Forest is estimated to be 16.8 MHa (data from FAO). Settlement area is estimated to be 1.1 MHa, and the rest, about 55.6 MHa, is fallow and waste land. We assume in 2005, less than 4 Mha is waste land (desert and other severely degraded land). Most of the fallow land, about 85% in 2005, is still in good condition to be used for pasture land, planting crops or trees. The rest 15% is assumed badly degraded, and could deteriorate further to become waste land.

Agricultural (crop) land will slowly grow as demand from a growing population grows, from 4.5 MHa now to about 6.2 MHa in 2025. Assuming no effective measure is implemented to slow land degradation, the degraded part of agricultural land will grow from 1 MHa (22%) in 2005 to 2 MHa (32%) in 2025.

Forest land will further shrink, due to fuel wood logging, from 16.8 MHa in 2005 to 15.9 MHa in 2025.

Settlement land will grow with population from 1.1 MHa in 2005 to 1.4 MHa in 2025.

Due to land degradation happening to agricultural land and fallow land, waste land will grow from 3.8 MHa in 2005 to 8.1 MHa in 2025.

Fallow land will shrink from about 52 MHa in 2005 to 47 MHa in 2025.

Table 5: Baseline land use in Hectare

Time	2005	2010	2015	2020	2025
Agricultural Land	4,509,106	4,664,185	5,093,308	5,618,362	6,219,313
[CULTIVABLE]	3,434,321	3,366,721	3,593,166	3,903,707	4,279,222
[DEGRADED]	1,074,784	1,297,464	1,500,142	1,714,656	1,940,091
Fallow Land	52,189,532	50,894,036	49,496,192	48,135,224	46,801,852
[CULTIVABLE]	44,092,700	43,891,908	43,399,124	42,793,868	42,097,416
[DEGRADED]	8,096,831	7,002,129	6,097,069	5,341,356	4,704,437
Forest Land	16,814,664	16,585,397	16,351,182	16,109,618	15,856,019
Settlement Land	1,125,247	1,201,936	1,272,642	1,351,877	1,452,392
Waste Land	3,761,446	5,054,437	6,186,671	7,184,914	8,070,415

Policy variable: Land policy, human planting, less fuel wood logging

Water

Water supply and demand

Mozambique has abundant water resources. The annual average precipitation for the whole country is 1,032 mm and the rainy season lasts from October to April.

Precipitation varies widely from the coast to the inland areas and from north to south. With 86% of precipitation evaporated immediately, internally produced water is 97.3 km³ in surface water and 17 km³ in groundwater annually. In addition, 116.8 km³ of surface water enter the country annually, thus total actual renewable water resources become 217.1 km³/yr, or 217.1 billion m³/yr.

The total capacity of 27 reservoirs with dams of a height of 10 m or more is estimated at 64.5 km³.

Water use estimates in T21 for 2005 is 1,365 million m³, less than 1% of total renewable water resources. The main consumer of water is agriculture, accounting for 920 million m³ (67.5 percent), followed by the domestic sector using 430 million m³ (31.5 percent), and industry consuming 15 million m³ (1 percent).

Agriculture water use is based on the assumption that irrigated land needs 3,000 m³ water per hectare annually, and rain-fed land needs 100 m³. This use will grow due to expansion of agriculture land and irrigated land.

Domestic water use is based on the assumption that rural people consume 40 liters/person/day and urban consume 100 liters/person/day. These consumption rates could change with income and water use efficiency.

Industry water use is related to industry output and water use efficiency.

The baseline projection of water supply and demand is in the following table.

Although measured as a national average, Mozambique does not seem to have any water shortage for the entire simulation period (2005 to 2025). Due to seasonal and regional differences and climatic change, water shortages could still emerge in places during the dry seasons. Mozambique is also subject to occasional severe flooding.

Table 6: Baseline water supply and demand in Million Ton/Year

Time	2005	2010	2015	2020	2025
total water demand	671	762	847	924	999
agriculture water demand	570	642	713	780	846
domestic water demand	86	98	106	113	121
industry water demand	15	22	27	31	33
total water available	132,564	132,569	132,574	132,578	132,581
discharge water available	4,530	4,531	4,531	4,531	4,531
pumping capacity	34	38	42	46	50
reservoir flow capacity	128,000	128,000	128,000	128,000	128,000

Policy variable: irrigated land, precipitation.

Surface water pollution

Biochemical oxygen demand (BOD), the most commonly used index of water pollution, is used in T21 to measure water pollution from agriculture, industry, and domestic sewage in surface water.

Daily BOD from the domestic wastes of one person is 77 grams. Based on this per capita daily rate and population in rural and urban areas, annual domestic BOD in 2005 was 378 million kg from rural areas and 155 million kg from urban areas. Access to adequate sanitation was 13% and 62% respectively for rural and urban. Thus national sewage BOD from unsanitary households was computed at 387 million kg. Assuming 60% of it reaches surface water, the domestic BOD pollutant is 232 million kg.

The BOD pollution of water from agriculture is not significant, because most production is by smallholders, whose level of fertilizer use and other artificial input is low due to lack of funding. Total national fertilizer use in 2005 was 16.6 million kg. A small fraction of this amount, 20%, will reach the surface water and become pollutants. Fertilizer BOD pollution is the so-called secondary pollution (See Appendix) and the value of the parameter is assumed to be 2, i.e., 1 kg of fertilizer that finally reaches surface water will produce 2 kg BOD. Agriculture BOD is thus computed to be 6.65 million kg for 2005.

Surface water BOD pollution from industry is assumed to increase with industry production and decrease with technology progress, and its historical data is available from the World Bank. In 2005, industry BOD release into surface water was estimated to be 4.91 million kg.

Table 7: Baseline surface water BOD pollutants in Ton

Time	2005	2010	2015	2020	2025
Pollutants In Surface Water	328,257	303,848	275,224	256,728	248,022
pollutants to surface water	228,621	208,754	190,268	180,393	176,125
agriculture pollutants	6,345	6,784	7,558	8,435	9,393
industry pollutants	4,924	6,724	8,209	9,249	9,810
sewage pollutants	217,352	195,245	174,502	162,708	156,922

Policy variables: Provision of additional adequate sanitation,

Access to safe drinking water

Access to safe drinking water is assumed to consist of two parts: those who use water from treated water or ground water, and those who use surface water. Water for the first part, either treated or ground, is assumed safe and clean. In 2005, it is estimated by T21 that 23.7% of households in rural areas and 65.6% in urban areas have access to it. The rest of the population, 76.3% in rural and 34.4% in urban, has to buy bottled water or use surface water, including water from rivers, lakes, and reservoirs, which can be easily

polluted. The percentage of the second group of population who has access to safe drinking water is related to the amount of pollutants (measured by BOD level) in surface water and household income. The higher the average pollutant concentration, the lower the percentage of surface water that is still safe to drink. The higher the income, the more likely that the household can afford bottled water or other water purification and disinfection methods. In 2005, it is computed by T21 that nationally, 46.65% of population has access to safe drinking water, about 33.3% for rural and 79.3% for urban.

Table 8: Baseline access to safe drinking water

Time	2005	2010	2015	2020	2025
access to safe drinking water	47.66%	54.78%	61.58%	66.68%	70.51%
[RURAL]	34.45%	41.40%	48.56%	54.20%	58.55%
[URBAN]	79.94%	84.87%	88.58%	90.62%	91.77%

Policy variables: ACCESS TO GROUND OR TREATED WATER TABLE,

Air emissions

Air emissions of CO₂, N₂O, SO_x, CH₄, and SPM, due to fossil fuel use and deforestation, are computed in T21 in the next table.

Toxic emissions of SO_x and SPM are assumed to affect health, especially to families of the poor. They are linked to life expectancy in T21.

Table 9: Baseline air emissions in Ton/Year

Time	2005	2010	2015	2020	2025
co2 emission	20,012,528	20,627,128	21,347,523	22,231,097	23,500,694
n2o emission	275	287	300	313	330
ch4 emission	3,340	3,417	3,511	3,653	3,868
fossil fuel sox emission	2,421	2,886	3,421	3,721	3,960
spm emission	155,052	151,755	150,665	151,075	153,876

Technical Documentation

Energy sector

Electricity demand and supply

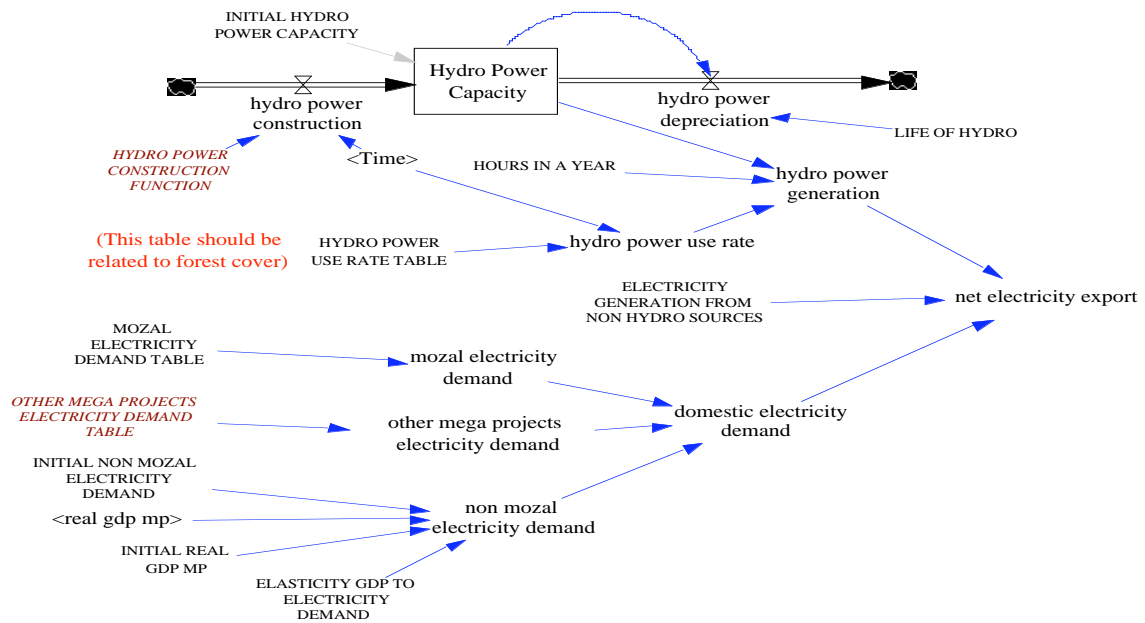


Figure 1: Electricity demand and supply

Mozambique has large existing and potential hydro power capacity. In 2005, domestic electric power demand was about 70% of its hydro generation. Electric power generation from other sources (diesel and gas) is negligible. With more hydro power generation projects in the pipeline, Mozambique will stay as a net exporter of electricity in the future.

Major assumptions

- Mozambique will continue to rely on hydro electric power, with negligible electric generation from other sources, except where there is local demand that cannot be satisfied from the grid.
- Mozal and other mega projects are the primary consumers of electricity
- Non mega electricity demand will grow with GDP

Input Variables

- real GDP
- hydro power construction

- other mega projects electricity demand

Output Variables

- net electricity export
- hydro power generation
- domestic electricity demand

Explanation of Major Components

Hydro power generation will continue to grow, from 13 billion KWH in 2005 to about 16 billion KWH in 2025. Hydro power capacity will increase from 2 million KW in 2005 to about 2.4 million KW in 2025. Hydro power use rate is assumed to stay at over 70%, due to abundant water supply.

Domestic electricity demand is separated into mega project electricity demand and other (non mega) electricity demand. Mega project electricity demand is exogenous, while non mega electricity demand is assumed to grow with GDP, with an elasticity of 1.1.

Coal demand and supply

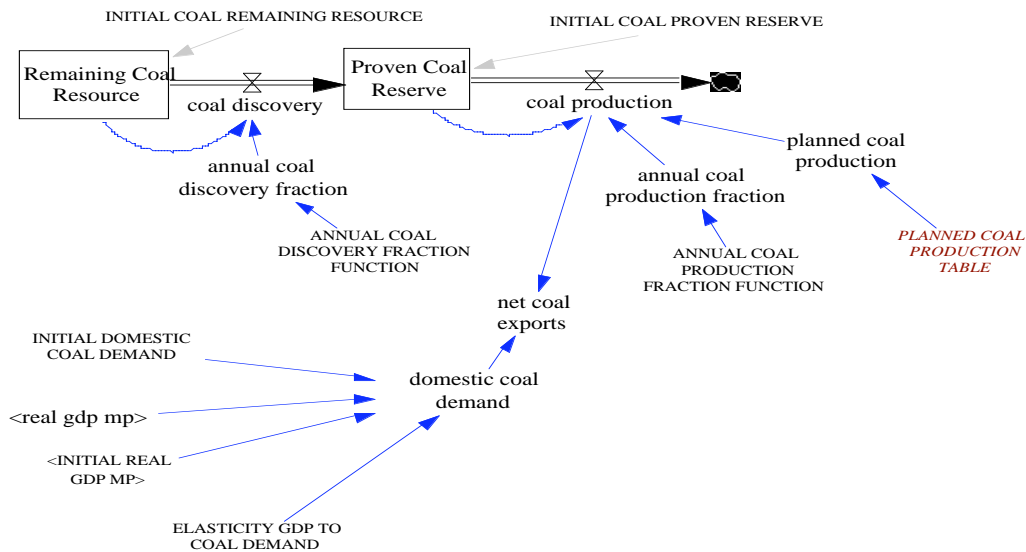


Figure 2: Coal demand and supply

Mozambique has sizable coal reserves (over 2 million metric tons by Peter Mulder) but due to low demand from domestic industries and lack of investment in mining and transportation, coal production has been low, and most of it has been for export, which is expected to continue.

Major assumptions

- Domestic coal demand will grow with GDP

Input Variables

- real GDP
- planned coal production

Output Variables

- domestic coal demand
- coal production
- net coal exports

Explanation of Major Components

Coal production. For many countries, coal production is limited by its proven reserves. Usually the annual production is a few percentage points of its proven reserve. But Mozambique does not seem like that. Its annual production is less than 0.1% of its proven reserve, due to low demand from domestic industries and lack of investment in mining and transportation. In the model, the exogenous variable, *planned coal production*, is used to determine the coal production.

Domestic coal demand is assumed to grow with real GDP with an elasticity of 1.2[Why?].

Natural gas demand and supply

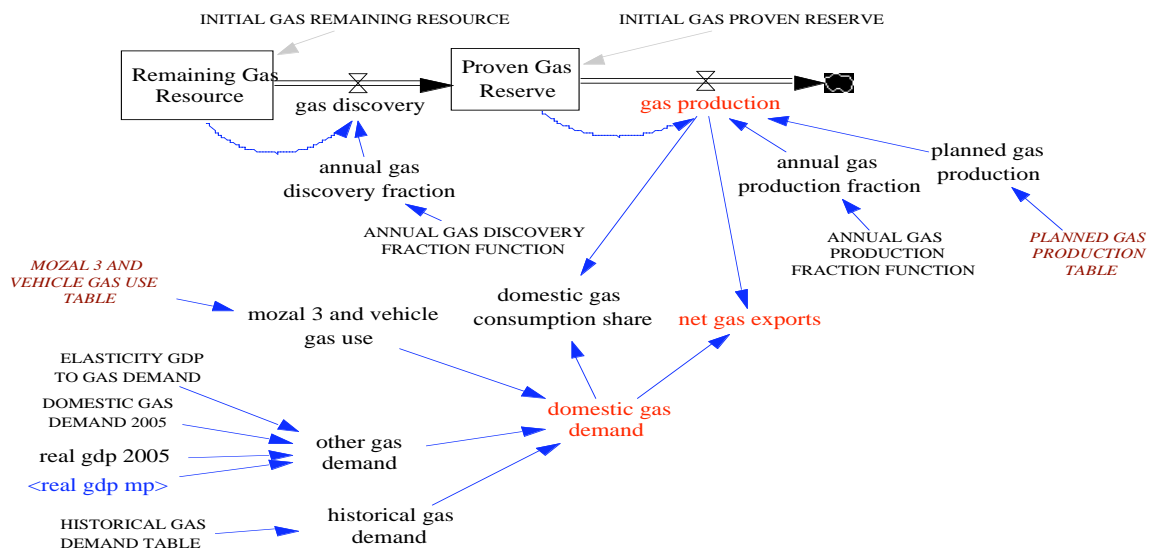


Figure 3: Gas demand and supply

All gas produced in Mozambique is from the natural gas Mega project. Its current production is about 74 M KCF (million thousand cubic feet) per year, and can be raised to 108 M KCF without further investment (Peter Mulder). Most of the gas is exported. Domestic consumption will stay under 5% for the near future.

Major assumptions

- Domestic gas demand will grow fast, due to increased vehicle gas demand, Mozal expansion, and a possible gas fired electricity plant. The variable *Mozal 3 and vehicle gas use* allows the user to input their estimate of this demand.
- Other domestic gas demand will grow with GDP

Input Variables

- real GDP
- planned gas production
- Mozal 3 and vehicle gas use

Output Variables

- gas production
- domestic gas demand
- net gas exports

Explanation of Major Components

Gas production is all from the mega project, and its capacity is predetermined with the variable *planned gas production*.

Domestic gas demand has two parts: *Mozal 3 and vehicle gas use* and *other gas demand*. The former two are exogenous time series inputs from the user, and the latter grows with GDP with an elasticity of 1.5.

Oil demand

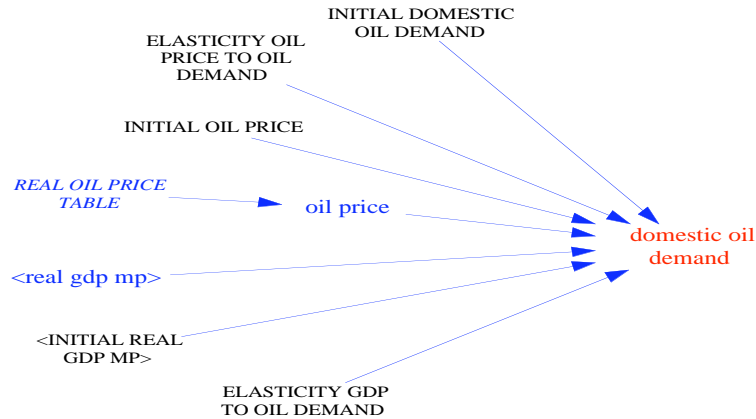


Figure 4: Oil demand

Mozambique has not discovered any oil reserve. All its oil demand is imported. If oil is found in the future, a structure similar to gas and coal production can be added to estimate oil production in the future.

Major assumptions

- Oil demand will change with GDP and world oil prices (in real term)

Input Variables

- real GDP
- oil price

Output Variables

- domestic oil demand

Explanation of Major Components

Oil demand is affected by both GDP and real oil prices with the following elasticity values:

- GDP elasticity 0.5
- Real oil price elasticity -0.2

Land

General land use

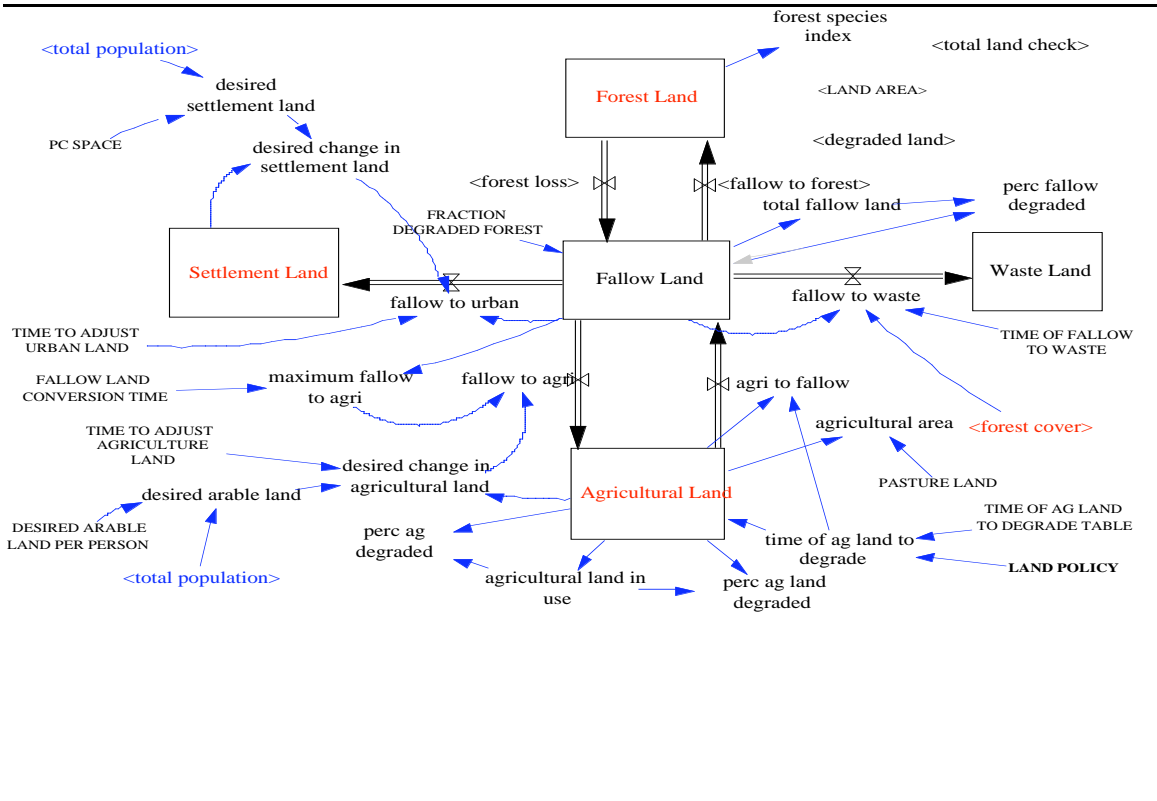


Figure 5: Sketch of the Land Use Sector

In T21, land is divided into five categories: Agriculture, forest, settlement, fallow, and waste. Agriculture land is cropland, including permanent crops. Forest land includes all forests: natural, man-made, protected, and unprotected. Settlement land includes roads, residence areas, offices areas, factories, schools, hospitals, and all other areas that are used exclusively for human settlement activities. Fallow land includes pasture land, non-forest natural reserves, and other land that is still usable for growing trees or grass, or being converted to agriculture (crop) land. Waste land includes desert and other severely degraded land that, without heavy investment, is no longer usable for planting anything.

While the areas in each of the five types of land stock change, the land sector ensures that the total land area remains constant.

Major Assumptions:

- All land conversions from one type to another go through Fallow Land
- Forest land is not degraded. Settlement land and waste land are all classed as degraded.

- Fallow land and agricultural land are partly degraded. The non-degraded part is named “cultivable”, meaning fertile, as both the cultivable and degraded agriculture land are technically arable.
- Cultivable agriculture land can become degraded with different speeds, depending on *LAND POLICY*. Under normal conditions, it is assumed that it would take about 50 years for a fully cultivable land to become fully degraded if it is abandoned and not allowed to return to natural vegetation.
- Degraded agriculture land can further degrade to become uncultivable fallow land with different speeds, depending on *LAND POLICY*.
- Forest land, once deforested, becomes fallow land. It could become degraded very quickly, depending on its topology, soil condition, and rainfall. The variable, *FRACTION DEGRADED FOREST*, represents the part that will degrade quickly (50%).
- Cultivable fallow land can be brought into agriculture production to become cultivable agriculture land and be used to plant trees to become forest land
- Fallow Land is lost to Settlement Land through increases in population and urbanization. Degraded fallow land will be used first for settlement land. If degraded is not available, then cultivable fallow land will be used.

Input Variables

- forest land
- total population

Output Variables

- agricultural land
- fallow land
- settlement land
- waste land

Major Components:

- 1. Forest Land***
- 2. Agricultural Land***
- 3. Fallow Land***
- 4. Settlement Land***
- 5. Waste Land***

Forest

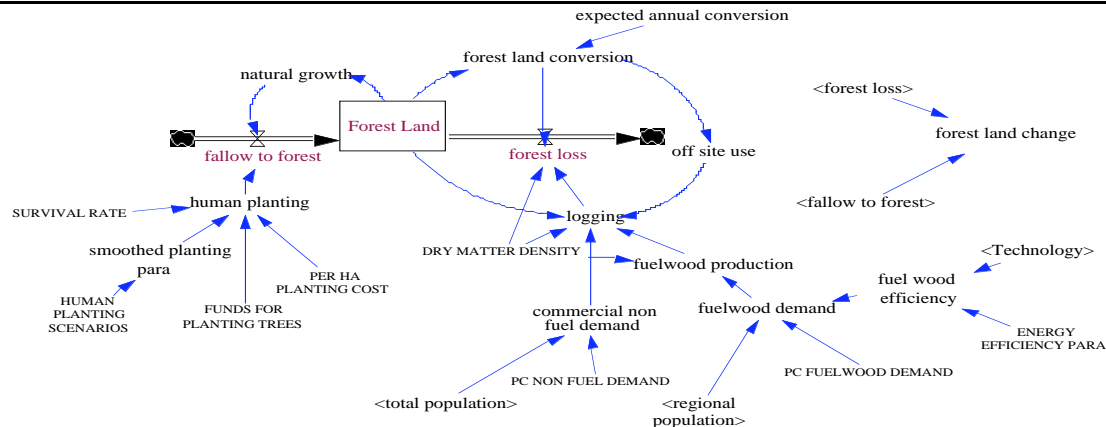


Figure 6: Forest sector

Major Assumptions:

- The natural growth of forests, while affecting the density of forests, has very little effect on the total forested area.
- Logging does not include managed logging, which selectively logs trees in a fashion that may affect forest density but does not affect the total forested area.
- The demand for fuel wood falls with urbanization (fuel wood is more heavily used in rural areas).
- The demand for fuel wood falls with fuel wood efficiency

Input:

- total population
- government effort in reforestation
- rural and urban population

Output:

- forest land
- forest loss

Explanation of Major Components:

The stock of Forest Land is increased by reforesting fallow land and decreased by clearing forest land either for conversion to other use, or by harvesting the resources through logging.

$$\text{Forest Land} = \text{INTEG}(\text{fallow to forest} - \text{forest loss}, \text{INIT FOREST LAND})$$

Threshold 21 assumes that re-forested land comes from fallow land (see Land Sector for more details on the different classifications of land). The increase in the forested area, *reforesting fallow to forest*, is the sum of increases due to human planting and the natural growth of forests:

$$\left| \text{fallow to forest} = \text{natural growth} + \text{human planting} \right.$$

The variable *human planting* is a function of funds (investment) and three exogenous variables - smoothed planting para, PER HA PLANTING COST and SURVIVAL RATE.

$$\left| \text{Human planting} = \frac{\text{FUNDS FOR PLANTING TREES} * \text{smoothed planting para}}{\text{PER HA PLANTING COST} * \text{SURVIVAL RATE}} \right.$$

Smoothed planting para is a policy variable that can vary across different scenarios.

The variable *natural growth* can mean both (1) forest land area growth, and (2) forest dry matter density growth. The IPCC Workbook gives the default value for density growth of 5,000 kg per year per hectare for forests under 100 years of age. Older forests have no annual density growth. The current version of T21 assumes that forest dry matter density is constant, either because the forests in question are in general over 100 years old or because managed logging maintains their density.

Natural forestland growth is assumed to be a very small percentage (less than 1% per year) of the surface area of forestland. The exact percentage is represented by the parameter *NATURAL GROWTH RATIO* in the following equation:

$$\left| \text{natural growth} = \text{Forest Land} * \text{NATURAL GROWTH RATIO} \right.$$

Forest loss is a function of *forest land conversion* and *logging*. *Forest land conversion* measures the amount of forest land lost to agriculture, aquaculture, or homesteads.

$$\left| \text{forest land conversion} = \text{MIN}(\text{Forest Land} / \text{UNIT YEAR}, \text{expected annual conversion}) \right.$$

The MIN function is used because *forest loss* must always be less than the total amount of forestland available. The variable *EXPECTED ANNUAL CONVERSION* is a look-up function measuring forest land conversion. Its past values are based upon historical data, and its future values are exogenous.

The variable *off site use* measures the amount of wood that is obtained through the clearing of forest land and used off site for fuel-wood or non-fuel commercial purposes.

$$\left| \text{off site use} = \frac{\text{clearing forest land} * \text{FRACTION OFF SITE} * \text{DRY MATTER DENSITY}}{\text{DENSITY}} \right.$$

DRY MATTER DENSITY is used to estimate the amount of wood, in kilograms, that can be obtained per hectare of forest land (based on Table 5-3 of the IPCC workbook). *FRACTION OFF SITE* is an estimate of the fraction of wood that is carried off site during the clearing of forest land, as opposed to being burned on site or left to decay. The *FRACTION OFF SITE* is set by default to 50% of all the wood cleared.

The wood that is harvested during the clearing of forest land satisfies some of the demand for wood for fuel and for commercial, non-fuel purposes. *Logging* is conducted to satisfy the rest of the demand.

$$\text{logging} = \text{MIN}(\text{Forest Land} * \text{DRY MATTER DENSITY} / \text{UNIT YEAR}, \text{MAX}(0, \text{fuelwood demand} + \text{commercial non fuel demand} - \text{off site use}))$$

The MIN function is used to prevent logging from exceeding the amount of trees available in the forest. The MAX function ensures that logging cannot be negative. Logging is calculated to include only the logging that affects the amount of total forested area. Managed logging that selectively harvests trees to sustain the forested area is not considered.

Commercial non-fuel demand measures demand for wood based upon commercial, non-fuel uses. *Commercial non-fuel demand* is calculated as the total population times per capita demand. The per capita demand for wood for commercial, non-fuel purposes is calculated from 1990 data (IPCC, p.310). The value of per capita demand in the model is slightly smaller than the value in the data because it subtracts the demand for wood for non-fuel purposes that is met through managed logging (and does not affect the area of forest land.)

Fuelwood demand represents demand for fuelwood that is satisfied by logging and off-site use. Fuelwood demand depends on three factors: *regional population* and *PC FUELWOOD DEMAND*, and *fuel wood efficiency*

$$\text{fuelwood demand} = (\text{regional population}[\text{RURAL}] + \text{regional population}[\text{URBAN}] * 0.6) * \text{PC FUELWOOD DEMAND} / \text{fuel wood efficiency}$$

PC FUELWOOD DEMAND can be either a constant or a function of per capita real GDP. In the latter case, it is assumed that, as a country continues to develop and disposable incomes rise, the demand for fuelwood will fall as people turn to other sources for energy needs.

Logging and conversion, then result in *forest loss*:

$$\text{forest loss} = \text{forest land conversion} + \text{logging} / \text{DRY MATTER DENSITY}$$

References:

Intergovernmental Panel on Climate Change (IPCC), *Greenhouse Gas Inventory Workbook*.

World Bank, *Social Indicators of Development 1990*. Baltimore: Johns Hopkins University Press, 1991.

World Resources Institute, *World Resources 1994-95*. New York: Oxford University Press, 1994.

Water Supply and Demand

Major Assumptions

- A large fraction (80 – 90%) of precipitation is evaporated immediately.
- The remaining water from precipitation feeds into surface water (80 – 90%), or infiltrates into ground water.
- Water supply from surface water will be used first. If that supply alone is not enough, then ground water and reservoir water will be used.
- Domestic water demand depends on population size and per capita water demand, which depends on real per capita GDP.
- Agricultural water demand is primarily for irrigation.

Input Variables

- total population
- real gdp
- land area
- technology
- irrigation

Output Variables

- fraction water available
- water stress index

Major components

1. Water supply

The modeling of water supply requires attention to the seasonal variation of water supply and the various types of infrastructure constructed to regulate the flows and quantities of water available over the course of a year. Specifically, the water supply part of the model must address the dynamics of water flows and water storage. The structure of the water supply model used in T21 is presented in Figure 7.

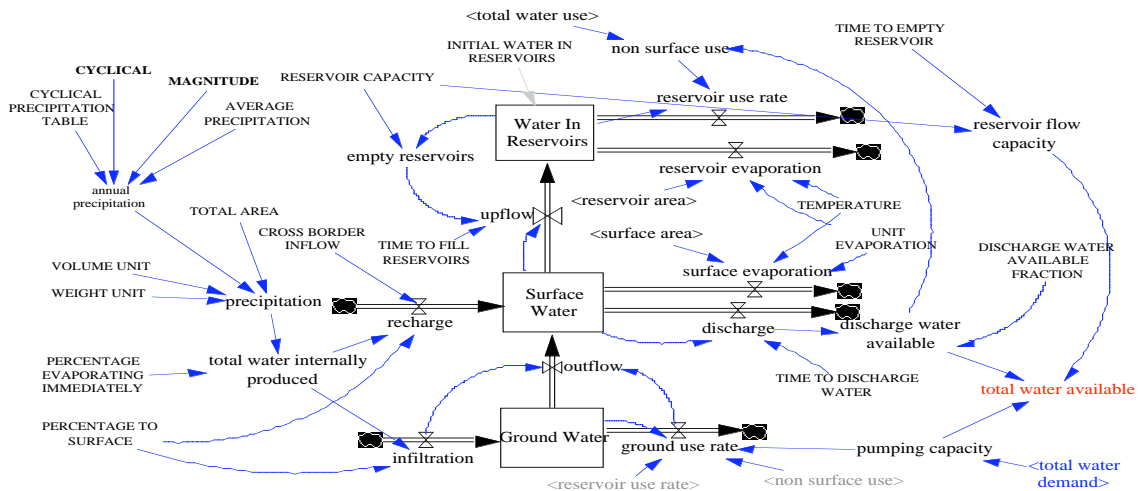


Figure 7: Water Supply graph

As illustrated in Figure 7, water available to the country usually comes only from two sources, cross border inflows and precipitation. In T21 Mozambique, the cross border inflows is huge, about 117 billion cubic meters annually, while precipitation flows in three ways: to surface water, to ground water, and to the atmosphere (evaporated). Then there are flows among the surface, ground, and reservoir water stocks. For most countries, there is a net flow from ground water to surface and about 30% of surface water originates as ground water. Reservoirs are usually charged by surface water, although it could also be partially charged by ground water, or flow back into ground water. In T21-Mozambique, we assume there is no direct flow between ground water and reservoirs.

In addition to the flows of water into the country and the flows between the three water stocks of surface, ground, and reservoir water, there are other flows out of each of the three stocks. Water in reservoirs will either evaporate or be used. Evaporation depends on three factors: temperature, humidity, and surface area. Reservoir use rate depends on water demand and reservoir water availability.

Surface water in rivers is different from water in reservoirs in that it can not be stored, but is constantly flowing out of the country. Usually only a small fraction of surface water is used, by industry, agriculture, and urban areas, but in some cases rivers are pumped dry before they reach the sea.

Ground water can be classified into two categories: rechargeable and non-rechargeable. Rechargeable ground water, if depleted, will be recharged from precipitation at a rate depending on natural conditions of the country. Non-rechargeable ground water, once drawn, will not recover in the time scale of the human life span. Evaporation from ground water stocks is usually negligible.

Water to meet human demands comes from the three stocks: reservoir, surface, and ground water. Some of the flows, especially agricultural water demand and precipitation, are highly seasonal. The traditional challenge in water management has been shifting water supply in time from when there is too much to when there is not enough, although in many countries, water supplies are being exhausted as aquifers are pumped down and rivers are pumped dry before they reach the sea.

Water comes from two sources: surface water (including reservoir) and ground water, which are represented by the three stock variables in the above diagram: *Water in Reservoirs*, *Surface Water*, and *Ground Water*. *Surface water* consists of lakes and rivers, and reservoirs. *Surface water* comes from two flows: *recharge*, which includes precipitation, cross-border flow from other countries, and *outflow* from ground water.

```
Surface water = INTEG(-discharge + outflow + recharge - surface evaporation -
upflow, INITIAL SURFACE WATER)
```

The outflow from ground water to surface water could be up to 31% of total surface water (p. 45 of AQUA, and p.335 of Miller). The current version of T21 assumes that ground water is stable so that outflow is equal to its net inflow. Surface water goes to reservoirs, evaporates, and the rest is discharged into the sea (or to other countries).

The stock of surface water decreases due to *discharge*, *surface evaporation*, and *upflow*:

```
discharge = Surface Water/TIME TO DISCHARGE WATER
surface evaporation = TEMPERATURE * surface area * UNIT EVAPORATION
upflow = IF THEN ELSE(Surface Water>0,empty reservoirs/TIME TO FILL
RESERVOIRS,0)
```

The equation for *surface evaporation* is based on p.43 of AQUA, which states that evaporation is equal to the average temperature in Celsius * 0.025 * 0.3 e7 kg per year per hectare. Similar inflows and outflows change the levels of reservoir and ground water.

```
Water in Reservoirs = INTEG(upflow - use rate reservoir - reservoir evaporation,
INITIAL WATER IN RESERVOIR)
Ground Water = INTEG(infiltration - outflow - use rate ground, INITIAL
GROUND WATER)
```

A few more flow variables appear in these equations. They are defined as:

```
reservoir evaporation = TEMPERATURE * reservoir area * UNIT
EVAPORATION
infiltration = (1 - PERCENTAGE TO SURFACE) * total water internally
produced
```

The infiltration rate is based on p. 42 of AQUA, which defines it to be between 10% and 30% of precipitation, depending on land cover.

The Total Water Supply is *total water available*, and is equal to discharge from surface water times an exogenous use fraction plus the use rate of ground water plus the use rate of reservoirs.

$$\text{total water available} = \text{discharge water available} + \text{pumping capacity} + \text{reservoir flow capacity}$$

2. Water demand

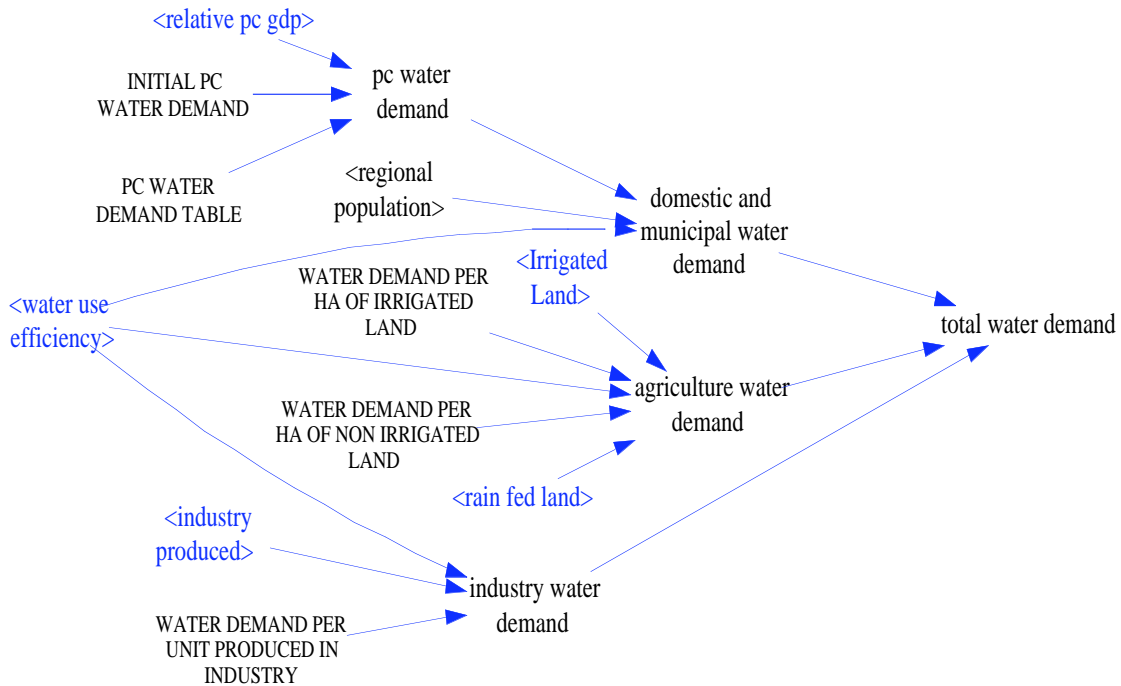


Figure 8: Sketch of Causal Factors Determining Water Demand

As shown in Figure 8, water demand is the sum of sectoral demands from domestic, agriculture, and industry sectors.

$$\text{Total water demand} = \text{agriculture water demand} + \text{domestic and municipal water demand} + \text{industry water demand}$$

Domestic and municipal water demand grows with population as well as per capita GDP, and decreases due to water use efficiency. Threshold 21 assumes that per capita water demand increases with per capita GDP.

$$\text{domestic and municipal water demand} = \text{regional population} * \text{pc water demand} / \text{water use efficiency}$$

Industry water demand depends on an exogenous parameter, WATER DEMAND PER UNIT PRODUCED IN INDUSTRY, industrial production, and water use efficiency

$$\text{Industry water demand} = \text{industry produced} * \text{WATER DEMAND PER UNIT PRODUCED IN INDUSTRY} / \text{water use efficiency}$$

Agriculture water demand comes from two areas: water for irrigated land and water for rain fed land. Per hectare irrigated land needs a large amount of water annually, while per hectare rain fed land usually needs little water other than natural precipitation.

$$\text{agriculture water demand} = (\text{Irrigated Land} * \text{WATER DEMAND PER HA OF IRRIGATED LAND} + \text{rain fed land} * \text{WATER DEMAND PER HA OF NON IRRIGATED LAND}) / \text{water use efficiency}$$

Water demand is also influenced by water use efficiency: the higher the efficiency, the lower the demand. This efficiency is related to investment in environmental technology.

water use efficiency

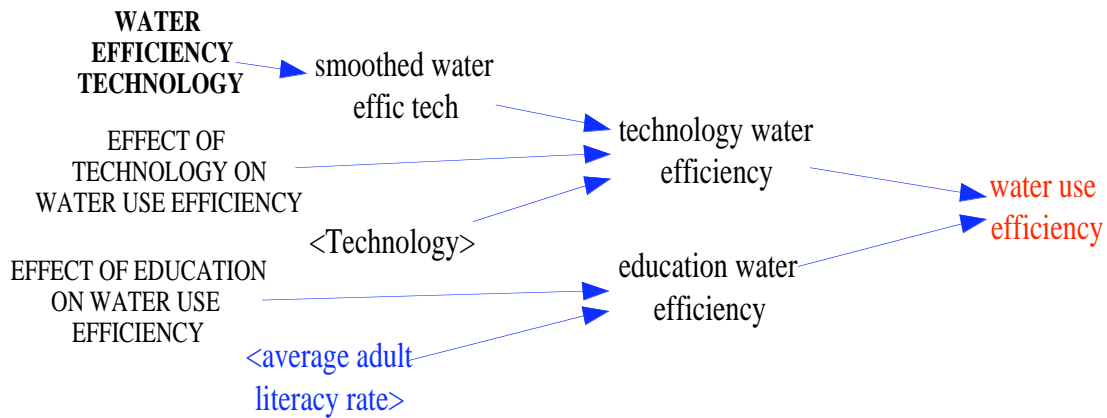


Figure 9: Water use efficiency graph

Water use efficiency depends on two factors: technology and education. *WATER EFFICIENCY TECHNOLOGY* is a policy variable which can change for different scenarios.

References:

Hoekstra, A., *AQUA, a Framework for Integrated Water Policy Analysis*, National Institute of Public Health and Environment (RIVM), July 1995.

Miller, G. T., *Living in the Environment*, seventh edition, Wadsworth, 1992

Water Pollution

The purpose of the water pollution sector is to simulate access to safe drinking water in Mozambique. Water pollutants include virus, toxic materials, and nutrients (measured in BOD, biochemical oxygen demand). In the current version of T21-Mozambique, BOD is used to represent the overall pollution situation. BOD in Mozambique comes from three sources: sewage, agriculture, and industry. And they directly pollute the surface water.

A brief explanation of BOD is quoted from page 556 of Ehrlich, P.R., et el, *Ecoscience, population, resources, environment*:

- The most commonly used index of (water) pollution is the biochemical oxygen demand (BOD), which refers to the quantity of oxygen required by bacteria to oxidize organic waste aerobically to carbon dioxide and water. A standard measure of BOD in practice is the amount of oxygen used in the first five days of decomposition at 20 degrees Celsius.
- A BOD of 0.17 pound, or 77 grams, is sometimes called a population equivalent, being roughly equal to the daily (BOD) requirement for the domestic wastes of one person. When commercial and industrial wastes are added in, there are about 3 population equivalents of BOD produced per person in the United States.

BOD water pollution from sewage

Water pollution from sewage is assumed to come primarily from human waste in Mozambique. With adequate sanitation, this waste will not reach sources of drinking water.

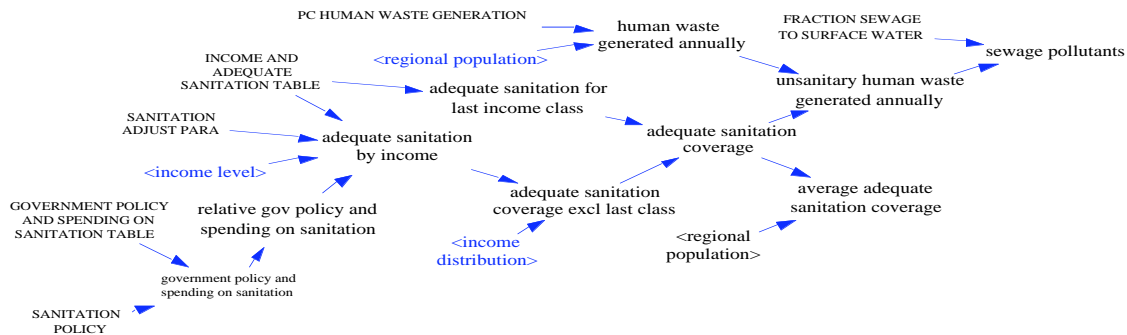


Figure 10: Water pollution from sewage

Looking from left to right and from top to bottom in Figure 10, *human waste generated annually* can be computed using total population and an average amount representing per capita waste generation. Of the total human waste, part of that is unsanitary, or *unsanitary human waste generated annually*, that could become pollutants. This variable is calculated as:

$$\text{unsanitary human waste generated annually} = \text{human waste generated annually} * (1 - \text{adequate sanitation coverage})$$

Not all the *unsanitary human waste generated annually* will become water pollutant. The variable on top right, *FRACTION SEWAGE TO SURFACE WATER*, is the parameter that determines the average fraction that will become *sewage pollutants* to pollute water. For Mozambique this fraction is estimated to be 0.6.

The major challenge in Figure 10 is to model the variable in the middle to the right: *adequate sanitation coverage*. This coverage should be related to income and government policy in raising public awareness, providing tax benefit or subsidy, and building sewage treatment facilities.

As T21 has household income distribution in it, access to adequate sanitation is first related to income as in Figure 11. The horizontal axis is household income in MZM95 (exchange rate in 1995 was 9023 MZM/US\$). It is believed that at the income level of 50 Million MZM95/year (about 5,500 US\$95/year), 100% will have access. The lower the household income, the lower the access rate. This curve is calibrated with data from Internet:

From http://www.wssinfo.org/pdf/country/mozambique_san_02.pdf access to *improved* sanitation has improved:

- 1997 urban and rural, 49% and 14%;
- 2000 urban and rural, 53% and 15%.
- Access to *adequate* sanitation is assumed to be lower than access to *improved* sanitation

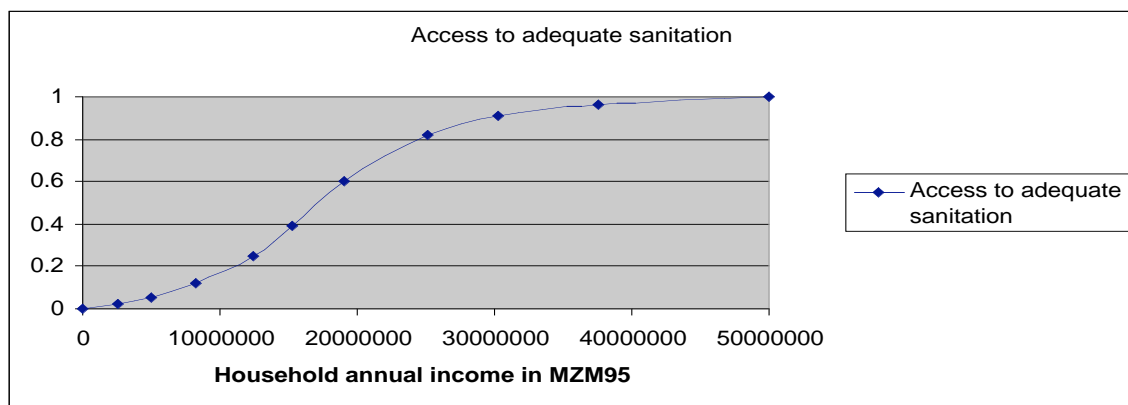


Figure 11: Relationship between access to sanitation and household income

Next, it is assumed that the effectiveness of government policy to increase adequate sanitation is related to government spending on the related programs. The curve in Figure 11 will shift up or down depending on government spending relative to its initial

level of spending. The higher relative government spending in social services and sanitation, the higher the curve.

Refer to the model for the mathematics of curve shifting.

With this algorithm, *adequate sanitation coverage* changes with both income and government policy.

Water pollution from agriculture

Water pollution from agriculture is assumed to come primarily from fertilizer use. It is assumed that fertilizer is applied to both irrigated and rain fed land in Mozambique.

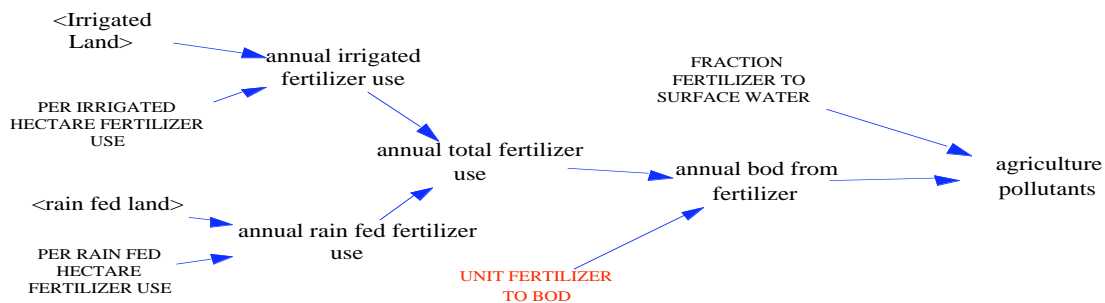


Figure 12: Water pollution from agriculture

The parameter at the center, *UNIT FERTILIZER TO BOD*, represents the quantitative conversion of fertilizer to BOD. Fertilizer BOD pollution is the so-called secondary pollution (See Appendix) and the value of the parameter is assumed to be 2.

Not all the fertilizer will become pollutants. Some are absorbed by plants, and only a small fraction will reach the surface water and become pollutants. The variable at the top right, *FRACTION FERTILIZER TO SURFACE WATER*, is assumed to be 0.2.

Data for national fertilizer use is in WDI: 14,300 tons in 2000 for Mozambique. This is used to calibrate the model. It is assumed that each hectare of irrigated land uses 20 kg of fertilizer and each hectare of rain fed land uses 3 kg.

Water pollution from industry

Water pollution from industry is assumed to increase with industry production and decrease with technology progress.

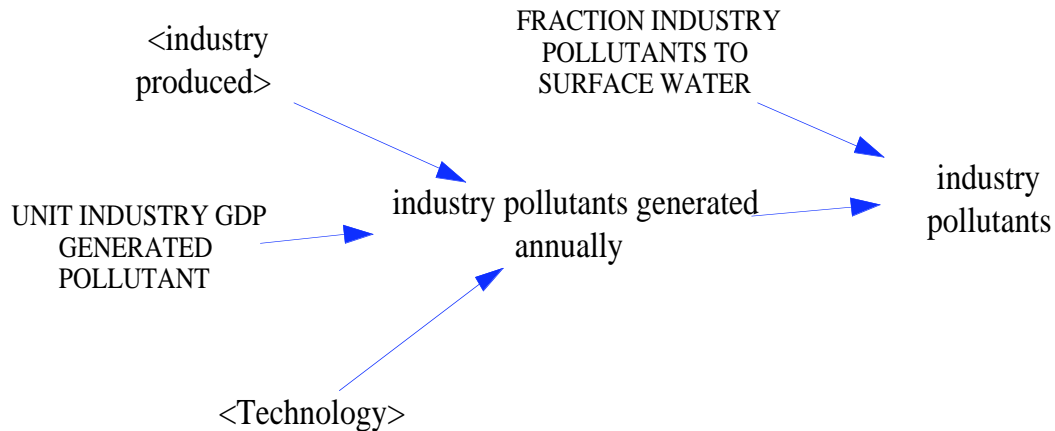


Figure 13: Water pollution from industry

Industry pollutants generated annually is determined by three factors: industry production, *Technology*, and *UNIT INDUSTRY GDP GENERATED POLLUTANT*. Part of the pollutants will pollute the surface water, depending on the parameter value of *FRACTION INDUSTRY POLLUTANTS TO SURFACE WATER*, whose value is assumed to be 0.8.

Data for industry BOD pollutants is in WDI, which is used to calibrate the model.

References:

Hoekstra, A., *AQUA, a Framework for Integrated Water Policy Analysis*, National Institute of Public Health and Environment (RIVM), July 1995.

Miller, G. T., *Living in the Environment*, seventh edition, page 602, Wadsworth, 1992

Ehrlich, P.R., et el, *Ecoscience, population, resources, environment*, page 556, W. H. Freeman and Company, 1977.

Note: Primary and secondary BOD pollution

From <http://www.greywater.com/pollution.htm>:

Short description of how (BOD) pollution is measured -- primary and secondary pollution.

Primary pollution

Historically speaking, it was not so very long ago that lakes, rivers and coastal waters were clean and supported a balanced aquatic plant and animal life. As rivers and lakes started to receive organic pollution from industry, sewers, septic systems, and present-day agricultural and livestock-raising practices, these organics decomposed in the water, consuming the oxygen dissolved in it--oxygen crucial for fish and other aquatic animals. This process is known as primary pollution. The commonly used measurement of primary pollution is BOD5 (five-day Biological Oxygen Demand) and COD (Chemical Oxygen Demand)--the amount of oxygen extracted from water by bacteria when pollutants decompose. The more organic material

there is in sewage, the greater the amount of oxygen needed to decompose these pollutants and, consequently, the greater the primary pollution.

Secondary pollution

Concomitant with the primary pollution, algae and other "out-of-balance" plant species start to grow as the result of being fertilized by the surge of nutrients from the above-mentioned sources. These fertilized plants, in turn, die and decompose, further robbing the water of its naturally dissolved oxygen. This phase is called secondary pollution, or "eutrophication", and is considerably *more damaging to the oxygen level* than primary pollution. The principal nutrients causing secondary pollution are nitrogen, phosphorous and potassium. Secondary pollution is measured by how much fertilizer is added to water. To understand their growth potential in water, it is necessary to know which nutrients in it are in short supply in the water. Some lakes are growth-restricted by the lack of phosphorous, others by lack of nitrogen and others, yet again, by the lack of potassium.

Air pollution

The air pollution emissions sector simulates air pollution for CO₂, NO_x, SO_x, CH₄ and SPM.

Greenhouse Gas (GHG) Emissions

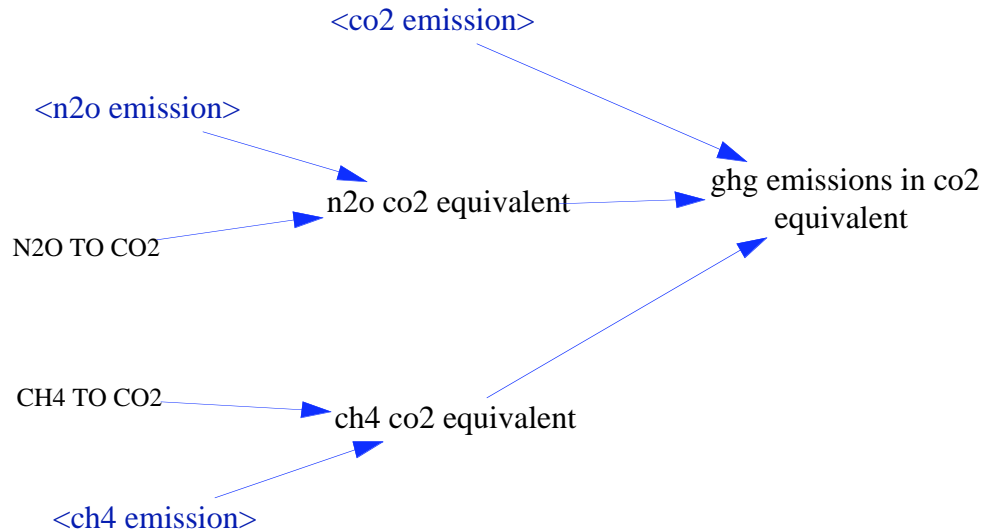


Figure 14: Sketch of the Causal Factors Determining GHG Emissions

The Green House Gas (GHG) emissions sector is based upon the guidelines for national greenhouse gas inventories published by the Intergovernmental Panel on Climate Change (IPCC). The model uses the IPCC guidelines to calculate levels of greenhouse gasses based upon energy use, industrial production, agriculture, livestock, forestry and waste. In the current version of T21, greenhouse gasses includes CO₂ (carbon dioxide), CH₄ (methane) and NO_x (nitrogen oxides). Sulfur oxides (SO_x) are in the model, but they are not considered to be greenhouse gasses, as they cool rather than warm the earth.

Input Variables

- real GDP
- total energy burned
- total population
- urban population
- deforestation rate

Output Variables

- CO₂ emission
- CH₄ emission
- NO_x emission
- GHG emissions in CO₂ equivalent

Explanation of Major Components

1. CO₂ emission

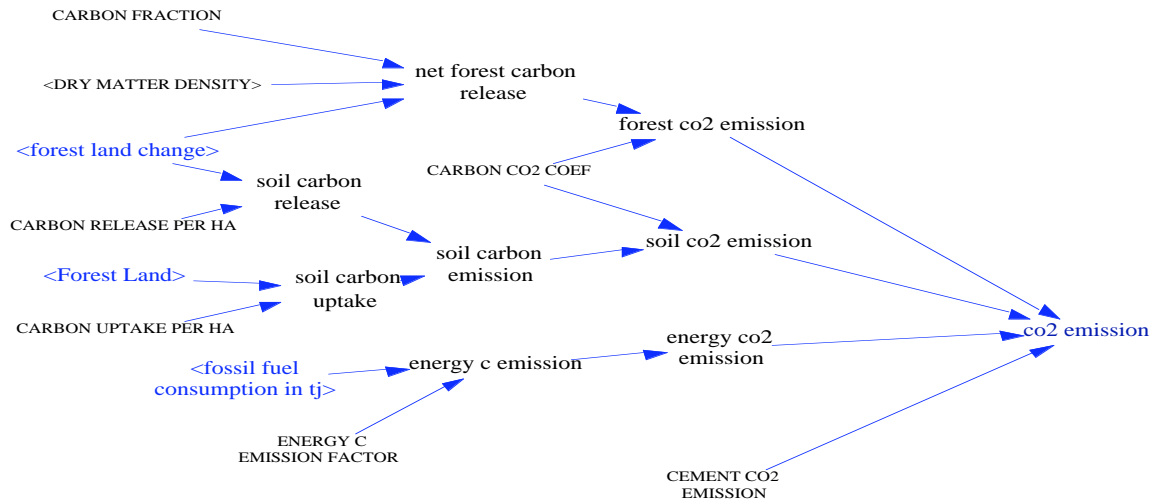


Figure 15: Sketch of the Major Components of CO₂ Emissions

CO₂ emissions have four major inputs: cement CO₂ emission, forest CO₂ emission, soil CO₂ emission, and energy CO₂ emission.

A. Cement CO₂ emission

Cement CO₂ emission is assumed to be negligible for Mozambique.

B. Forest CO₂ emission

Forest CO₂ emission is a function of *net forest carbon release*. Forests act as a reservoir for carbon. They both absorb and release carbon dioxide. For each kilogram of net decrease in the level of carbon in a forest, 44/12 (the ratio of molecular weights) kilograms of CO₂ are released (assuming all carbon changes to CO₂). Note that the net release of carbon dioxide can be negative, representing a net absorption. *Net forest carbon release* is a function of the change in Forest Land and the density of carbon in the forests (measured as dry matter).

C. Soil CO₂ emission

Soil CO₂ emission is a function of the difference between soil carbon release and soil carbon uptake. Soil carbon release is caused by deforestation, that is, a negative forest land change. The IPCC workbook defines CARBON RELEASE PER HA (where ha stands for hectare) to be 65 tons per hectare. To simplify calculations, some carbon releases which actually happen over a multi-year period, (such as commercial logging, biomass decay, and soil carbon release), are attributed to the year in which the activity begins, as is the practice in the IPCC workbook and the COPATH model. Since there are

regular new activities in these areas, this is consistent with a regular flow over time of each activity, unless there is a major change in the rate of activity. Soil carbon uptake is the result of forest tree growth. Uptake is the product of Forest Land and CARBON UPTAKE PER HA. According to p. 5-18 of IPCC Workbook, CARBON UPTAKE PER HA has the following values for different forest age groups:

- CARBON UPTAKE PER HA [under 20] = 1300 kg per hectare per year
- CARBON UPTAKE PER HA [20 to 100] = 650 kg per hectare per year
- CARBON UPTAKE PER HA [over 100] = 0 kg per hectare per year

D. Energy CO2 emission

Energy CO2 emission is calculated based on *energy carbon emission*. *Energy carbon emission* is the product of *energy consumption in Tj* (Tj are tetrajoules, that is, 10^{12} Joules) and the *ENERGY C EMISSION FACTOR* for each of the three fossil fuels: oil, gas, and coal. The amount of *energy burned* using oil, gas and coal is generated in the Energy Sector. The unit used in T21 is BTU, while the IPCC guidelines uses J (Joules). One BTU is equal to 1055.056 J, which allows for the conversion from *energy burned* (in BTU) to *energy consumed in Tj* (Department of Energy, p.356). It is assumed that *energy burned* is in NCV (net calorific values) (see the IPCC workbook, pp.1-4). NCV are 90% to 95% of GCV (gross calorific values). The *ENERGY C EMISSION FACTOR* for oil, gas, and coal are 20, 17.2, and 26, respectively. These factors indicate how many tons of carbon are in the production of one Tj of energy (IPCC workbook, pp.1-6).

2. CH4 emission

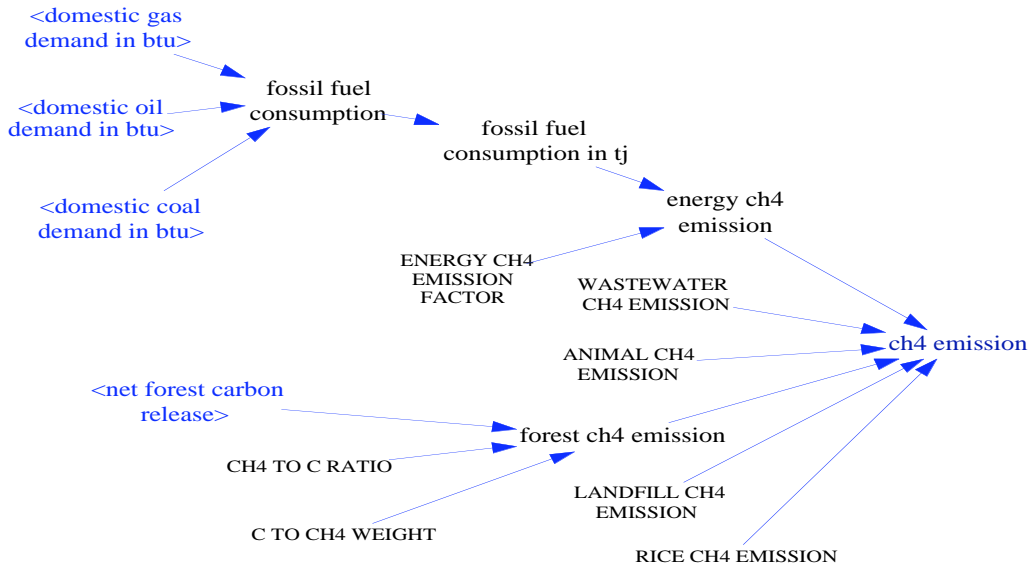


Figure 16: Sketch of the Major Components of CH4 Emissions

CH₄ emissions have six major inputs, as illustrated in Figure 16: energy CH₄ emissions, animal CH₄ emissions, landfill CH₄ emissions, waste water CH₄ emissions, forest CH₄ emissions, and rice CH₄ emissions.

For Mozambique, only energy CH₄ emissions and forest CH₄ emissions are computed.

A. Energy CH₄ emission

Energy CH₄ emission is the product of *ENERGY CH₄ EMISSION FACTOR* and *energy consumption in Tj*. Unit CH₄ emissions from fossil fuels are estimated based on tables 1-8 (pp. 1-21) of the IPCC workbook. The default values in the workbook, however, have wide ranges. The CH₄ emission estimates used in T21 for unit oil and gas consumption in a “developing country” are:

- CH₄ emissions from oil production: 2,000 kg per Pj
- CH₄ emissions from oil transportation, storage and refining: 1,500 kg per Pj
- CH₄ emissions from gas production: 60,000 kg per Pj
- CH₄ emissions from gas transportation, storage and refining: 250,000 kg per Pj

where one Pj is equal to one thousand Tj. The total factor for oil is therefore:

$$2,000 + 1,500 = 3,500 \text{ kg / Pj} = 3.5 \text{ kg / Tj}$$

And the total factor for gas is:

$$60,000 + 250,000 = 310,000 \text{ kg / Pj} = 310 \text{ kg / Tj}$$

Assuming that coal does not contribute to CH₄ emissions, the final equation reads:

$$\text{ENERGY CH}_4 \text{ EMISSION FACTOR}[\text{oil, gas, coal}] = 3.5, 310, 0$$

B. Livestock CH₄ emission

Livestock CH₄ emission includes enteric fermentation and manure management. The data in Table 10 below, obtained from Tables 4-2 to 4-5 of the IPCC workbook, lists values of CH₄ emission for different types of livestock, in terms of kilograms per head per year:

Table 10: Livestock CH₄ Emissions

Livestock	Enteric	Manure	Total
Cattle	32	1	33
Swine	1	2	3
Goat	5	0.22	5.22
Poultry	0	0.02	0.02
Cow	36	1	37

These values are the inputs to the *LIVESTOCK CH₄ EMISSION FACTOR*. *Livestock CH₄ emission* is the product of the emission factor and the stock of livestock, defined in the Food and Nutrition Sector.

C. Landfill CH₄ emission

Landfill CH₄ emission is the product of *LANDFILL CH₄ EMISSION FACTOR* and *urban population*. Urban population is a fraction of the total population. The *LANDFILL CH₄ EMISSION FACTOR* is estimated as follows, using default values provided in Table 6-1 of IPCC workbook (Volume 2):

First estimate levels of municipal solid waste (MSW) generation, in units of kg per person per year, come from the per capita solid waste generation data provided in Table 11 for selected countries:

Table 11: Per Capita Solid Waste Generation, Selected Countries

Municipal Solid Waste	Kg/person year
MSW developing countries	182
MSW former Soviet bloc	210
MSW USA/Australia Canada	700
MSW other developed countries	300

Then the model calculates what fraction of municipal solid waste is deposited in landfills. The fraction of MSW in landfills may vary from country to country.

$$\left| \begin{array}{l} \text{fraction of MSW in landfills} = 0.8 \end{array} \right.$$

It then estimates what fraction of the municipal solid waste is degradable organic carbon (DOC) and what fraction of the DOC is actually degraded.

$$\left| \begin{array}{l} \text{fraction DOC of MSW} = 0.15 \\ \text{fraction actually degraded DOC} = 0.77 \end{array} \right.$$

The annual amount of carbon released per urban person for a developing country is:

$$\left| \begin{array}{l} \text{carbon released per person} = \text{MSW developing countries} * \text{fraction of MSW in} \\ \text{landfills} * \text{fraction DOC of MSW} * \text{fraction actually degraded DOC} \\ = 182 * 0.8 * 0.15 * 0.77 \\ = 16.8 \text{ kg per person per year} \end{array} \right.$$

Only 50% of the carbon emission turns into CH₄. Furthermore, the ratio of the molecular weights of carbon to methane is 16/12, so:

$$\left| \begin{array}{l} \text{Landfill CH}_4 \text{ emission factor} = 16.8 * 0.5 * 16/12 = 11.2 \text{ kg per person per year} \end{array} \right.$$

D. Wastewater CH₄ emission

For the calculation of *wastewater CH₄ emission*, both domestic and commercial wastewater are included. The variable *wastewater CH₄ emission factor* is the CH₄ emission per urban person, and is calculated as follows:

From Table 6-3 of IPCC Workbook, the default value of biochemical oxygen demand (BOD) value from wastewater per urban person per year is:

$$\left| \begin{array}{l} \text{BOD in developing countries} = 14 \text{ kg per person per year} \end{array} \right.$$

| BOD in developed countries = 18 kg per person per year
Only anaerobically treated wastewater generates CH₄. The fraction that is anaerobically treated is assumed to be:

| fraction treated in developing countries = 0.1 (or less)

| fraction treated in developed countries = 0.15

The emission coefficient of BOD to CH₄ is 0.22. Recovery of CH₄ from wastewater is assumed to be zero. Therefore, for developing countries, CH₄ emission per urban person per year is:

| wastewater CH₄ emission factor = 14 * 0.1 * 0.22 = 0.308 kg per person per year

And for developed countries,

| wastewater CH₄ emission factor = 18 * 0.15 * 0.22
= 0.594 kg per person per year

Wastewater CH₄ emission is the product of the WASTEWATER CH₄ EMISSION FACTOR and urban population.

E. Forest CH₄ emission

To calculate *forest CH₄ emission*, it is necessary to first estimate the fraction of carbon that goes into CH₄. According to IPCC Workbook, it is 0.012, which is the value of the variable *CH₄ C ratio*. For each kg of carbon that changes to CH₄, 16/12 kg of CH₄ is generated, which is the value of the variable *C to CH₄ weight*. Hence the equation for forest CH₄ emission is:

| forest CH₄ emission = net forest carbon release * CH₄ C ratio * C to CH₄ weight

F. Rice CH₄ emission

Rice CH₄ emission is calculated based upon the water management practices used to grow rice. The model considers three types of rice land: continuously flooded, intermittently flooded, and dry. The model calculates the total area of land dedicated to rice production, *rice harvested area*, as a percentage (which should vary from country to country) of total agricultural area. The rice-harvested surface area is then distributed into the three types of rice land: continuously flooded, intermittently flooded, and dry by means of *WATER MANAGEMENT DISTRIBUTION [water management]*. The distribution of rice land in a country is estimated to be 14% continuously flooded, 72% intermittently flooded, and 14% dry (IPCC, Tables 4-6). These three areas, *rice harvested area by water*, are then multiplied by the appropriate *EMISSION FACTOR* (IPCC, Tables 4-7) and an estimated growing *SEASON LENGTH* (IPCC, Table 4-6). The sum of the three component factors is then taken to yield total *rice CH₄ emission*.

3. NO_x emission

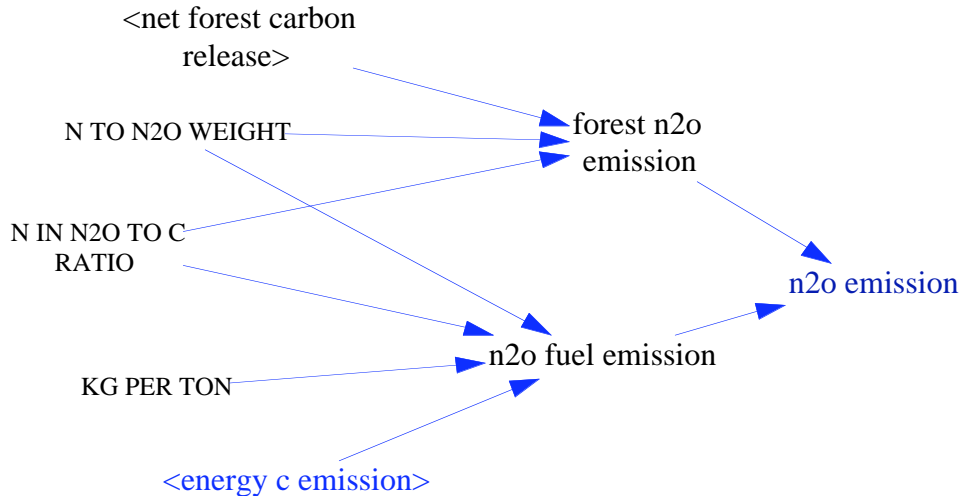


Figure 17: Sketch of the Major Components of NO_x Emissions

NO_x emission has two inputs: *forest NO_x emission* and *fuel NO_x emission*. The equation for *forest NO_x emission* is:

$$\text{forest NO}_x \text{ emission} = \text{net forest carbon release} * \text{N IN NO}_x \text{ C RATIO} * \text{N TO NO}_x \text{ WEIGHT}$$

The calculations of *N IN NO_x C RATIO* and *N TO NO_x WEIGHT* are based on pp. 1-13 of IPCC Workbook (Volume 2). The ratio of the weight of nitrogen to the weight of carbon is 0.01. Approximately 12.8 percent of nitrogen becomes NO_x, so

$$\begin{aligned} \text{N IN NO}_x \text{ C RATIO} &= (\text{N} / \text{C}) * ((\text{N in NO}_x) / (\text{N in N}_2)) = 0.01 * 0.128 \\ &= 0.00128 \end{aligned}$$

N TO NO_x WEIGHT converts N weight to NO_x weight. Assuming the average molecular weight of NO_x is equal to NO, or 30,

$$\text{N TO NO}_x \text{ WEIGHT} = \text{NO} / \text{N} = (14 + 16) / 14 = 30 / 14 = 2.14$$

In other words each kg of nitrogen will generate 2.14 kg of NO_x. NO_x fuel emission is based on Mark Symonds' research: Each BTU from burning oil, gas, and coal generates 3.26e-007, 1.42e-007, and 3.16e-007 kg of NO_x, respectively. These parameters are assumed to decline slightly over time due to technology progress.

SO_x and SPM emissions

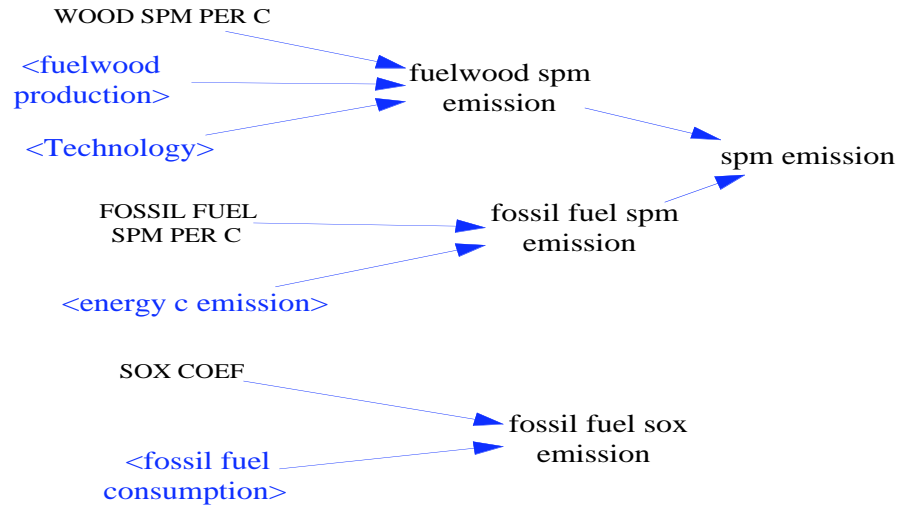


Figure 18: Sketch of the SO_x and SPM Emissions

1. SO_x emission

SO_x emission is based on Mark Symonds' research. For each BTU from burning oil, 9e-008 kg of SO_x will be released. For each BTU from burning gas, 1.7e-008 kg of SO_x will be released. For each BTU from burning and coal, 1.364e-006 kg of SO_x will be released. Technology reduces the emissions.

$$\text{SO}_x \text{ emission} = \frac{\text{SUM}(\text{total energy burned}[\text{fossil fuel!}] * \text{SO}_x \text{ COEF}[\text{fossil fuel!}])}{\text{Technology}[\text{environment}]}$$

2. SPM emission

As illustrated in Figure 18, SPM emission is assumed to come from two sources: wood burning and fossil fuel burning as the above sketch shows.

References

US Department of Energy and AES Corporation, *An Overview of the IDEAS Model*, (updated and extended FOSSIL2 Model), October 1993

Intergovernmental Panel on Climate Change (IPCC), IPCC Guidelines for National Greenhouse Gas Inventories: Greenhouse Gas Inventory Workbook. Greenhouse Gas Emissions.

United States Department of the Interior, Mineral Facts and Problems. Bureau of Mines Bulletin 667.

United States Department of Energy, Annual Energy Review 2003.

Notes on Data

Data needed for energy, land, air, and water are summarized in the Excel file (name to confirm)

This Excel workbook was sent to MOPD, MOE, and UNEP in Maputo to be filled (double check time and receiving parties)

Mr. Peter Mulder and Mr. Jonas Tembe sent back the filled energy sheets in the workbook, in “*Energy_Mozambique.xls*”. They also provided valuable response and insights to many questions raised by Weishuang Qu at MI (in Appendix)

Other data sources include FAO, UNEP, WRI, and the World Bank.

T21 Mozambique version 3.6 was expanded in its energy, land, water, and air sectors. In the following sections, the logic and analysis of the data assumptions used in T21 Mozambique version 3.6 are provided.

Energy

Excellent data files from Peter Mulder and Jonas Tembe

- “Energy_Mozambique.xls”
- Communications in Appendix B

Land

Land is divided into five categories in T21: Agriculture, forest, settlement, fallow, and waste.

Agriculture land is cropland, including permanent crops. Forest land includes all forest, either natural, man-made, protected or unprotected. Settlement land includes roads, residence area, offices area, factories, schools, hospitals, and all other area that is used exclusively for human settlement activities. Fallow land includes pasture land, non-forest natural reserves, and other land that is still usable for growing trees or grass, or being converted to agriculture (crop) land. Waste land includes desert and other severely degraded land that, without heavy investment, is no longer usable for planting anything.

Sources of land data:

- Agriculture land is cropland, including permanent crops. It correspond to “Arab&Perm Cr (1000Ha)” in FAO data
- Forest land is from FAO in “Forest&Wood (1000Ha)” (17 M ha in 1994)
- Forest land is also from UNEP (Chris) data file “Total Forest Extent - National.XLS” (1990, 31.2 M ha; 2000, 30.6 M ha).
- Forest data is also on <http://rainforests.mongabay.com/20mozambique.htm>: total forest area: 19.262 MHa (2005), annual deforestation: 50,000 Ha

- Forest data from WRI: <http://earthtrends.wri.org/text/forests-grasslands-drylands/country-profile-127.html>, total forest area: 30.5 MHa (2000), annual deforestation: 0.2%. It also said 22% (of 79 MHA is 17.16 MHa) of land area is covered by forest
- Forest land data from the above 4 sources are not consistent between forest area (about 30 M ha) and forest cover (about 22%), as land area is about 78 M ha. Decision: Use 22%, which generates similar forest area as FAO: 17.25 M ha in 1995. Annual deforestation: about 50,000 ha.
- Waste land should be smaller than “All Other Land (1000Ha)” from FAO
- Irrigated land is in both FAO and WDI data
- Potential irrigated land for Mozambique, according to aquastat, is 3 Million Ha

Definition of degraded land is not found anywhere, and neither is its data. Thus land degradation is based on assumptions I made after my initial study and research in this topic.

Water

Water supply and demand data for Mozambique come from several sources:

- FAO, in *aquastatMozambique.xls*
- Cross border inflow in Aquastat, (“Water resources: total external”): 116.8 cubic km, or 1.17 e14 kg)
- The AQUA model by Hoekstra, A., *AQUA a Framework for Integrated Water Policy Analysis*, National Institute of Public Health and Environment (RIVM), July 1995.

BOD, or biochemical oxygen demand, is used to represent water pollution. BOD pollution data come from the following sources:

- Sewage, from page 556 of Ehrlich, P.R., et el, *Ecoscience, population, resources, environment*
- Agriculture: fertilizer use data come from World Development Indicators (WDI) of the World Bank, and secondary pollution from <http://www.greywater.com/pollution.htm>
- Industry: BOD pollution from WDI of the World Bank

Data for improved/adequate sanitation come from the following sources:

- Access to improved sanitation (Definition of improved sanitation not clear.) from: http://www.wssinfo.org/pdf/country/mozambique_san_02.pdf, 1997 urban and rural, 49% and 14%; 2000 urban and rural, 53% and 15%.
- Cost of “domed latrine slab”: \$22, from http://www.wsp.org/publications/af_bg_moz.pdf
- Access to improved sanitation, 2000, from: http://earthtrends.wri.org/pdf_library/country_profiles/pop_cou_508.pdf, urban 68%, rural 26%
- Adequate sanitation from http://www.unicef.org/infobycountry/mozambique_statistics.html: urban 2002, 51%, rural 2002, 14%

Data for access to safe drinking water come from the following sources:

- For access to improved drinking water source (its definition not clear), from: http://www.wssinfo.org/pdf/country/mozambique_wat_02.pdf, 1997 urban and rural, 84% and 20%; 2000 urban and rural, 67% and 26%. Urban deteriorated?
- Deterioration explained in: http://www.wsp.org/publications/af_bg_moz.pdf, dying of external funded sanitation project
- Access to an improved water source, 2000, from: http://earthtrends.wri.org/pdf_library/country_profiles/pop_cou_508.pdf, urban 81%, rural 41%
- Access to safe drinking water national average from UNEP: *42% in 2002* (“*Improved Drinking Water Coverage - Total Population - National.XLS*”)
- Access to safe drinking water in urban: *76% in 2002* (“*Improved Drinking Water Coverage - Urban Population - National.XLS*”)
- Access to safe drinking water in rural can be calculated as *30% in 2002*

Air

Air emissions are based on inputs from other sectors, including energy consumption, deforestation, and fuel wood production. Parameter values are from *Intergovernmental Panel on Climate Change (IPCC), IPCC Guidelines for National Greenhouse Gas Inventories: Greenhouse Gas Inventory Workbook*.

Appendix A: Assessment of environment-poverty modeling needs

Weishuang Qu and John Shilling
February 8, 2006

I. Introduction

The Mozambican Ministry of Planning and Development (MOPD) has requested support for improving its comprehensive national planning process in Mozambique with a focus on poverty-environment mainstreaming. This work involves expanding the T21-Mozambique model as described in the attached TOR and work plan to be carried out by the Millennium Institute, the creator of T21. SIDA and UNDP are providing the financial and administrative support. Other project partners such as the Mozambican Debt Group, the Mozambican Ministry of Environment, and UNEP are identified in the TOR.

This brief paper summarizes the proposed modifications and additions to T21 MOZ that will be made to complete the work described in the TOR (Annex C) and work plan. Further suggestions are very welcome and will help improve the project as we move forward. In fact, we hope to get additional input and ideas for improving the model in the course of the project, especially during the field work.

The proposed modifications to the model were based initially on the discussions Weishuang Qu and John Shilling had with the Ministry of Planning and Development in November 2005, on the “Mozambique Strategic Plan for the Environmental Sector,” and on the Millennium Institute’s experience with environmental factors in the model. We have since received comments on our initial proposed changes and refined the approach to take account of the comments, suggestions, and guidance received.

Once the initial work on these modifications is completed by MI¹, the revised model will be sent to Maputo for officials in the MOPD and Ministry of Environment to review, seek input on, and further consider application. MI staff will visit Mozambique in April or June² for extensive consultations, adapting further changes to the model as appropriate, discussions of how best to apply the revised model, and extension of its use by key stakeholders. We will seek additional information on the suggested changes in order to fully understand the relations and obtain the needed data. The changes agreed in the field will be finalized by MI staff at HQ. The priority changes to be investigated in the field are mentioned below. Additional training will be provided during this visit to government staff and other stakeholders, including on how to use the model in decision-making. Resources for further application of the model and training of Mozambican users will also be sought.

¹ With assistance from MOPD representative, Sergio Dista, during his Jan 10-Feb 6, 2006 training in Arlington.

² The timing will depend on the schedule of the officials in Mozambique and whether Mozambican staff will attend the newly instigated course in T21 being offered by the University of Bergen in April and May. We would plan to visit after they return.

II. Proposed Modifications

The Mozambique Strategic Plan for the Environmental Sector identified seven priority issues:

1. Water and Environmental Cleanup
2. Territorial zoning
3. Land degradation
4. Natural Resource Management
5. Legal and Institutional Issues
6. Pollution (air, water)
7. Natural (drought, floods, desertification) and Environmental Disasters

Based on available data, knowledge, and capabilities of T21, four issues of the above list can be modeled in T21: issues 1, 3, 6, and 7. In order to address these issues, four sectors need to be added to T21 MOZ and linked to the rest of the model. *We have proposed the structure of these sectors below, and will confirm or modify as needed based on our discussion in the field.* After the addition of these sectors, users of T21 MOZ will be able to explore the interactions among development, poverty, resource use, and the environment in these areas.

The addition of these sectors to T21 MOZ will also enable users to explore aspects of issue 4 --natural resource management – with respect to management of land and water to a reasonable extent. We expect that this round of modifications will lay the basis for further thinking and work to extend the model to cover additional important issues that impact the environment and sustainable development prospects. Impacts of mining, infrastructure extension, such as roads, and other major projects can be considered, depending on resources and priorities.

The four sectors proposed to be added are:

1. Energy and air emission
2. Water demand, supply, pollution, and access to safe water
3. Land (including five categories of Agriculture, forest, settlement, fallow, and waste) and land degradation
4. Natural disaster

Given the limited resources available under this project, it may not be possible to fully address all these sectors at this stage. We propose to give the first priority to Energy, Water, and Natural disaster. All four proposed additions are described below with simplified flow charts to show the relations that we have identified. *They are designed to show the causal relations that will be included in the model. The arrows represent equations, or groups of equations, that will be used to represent the proposed relations in the model. In some cases, the relations are necessarily simplified due to lack of detailed data or research on the structure of the relations. As we get more information, the*

relations can be refined. We hope this presentation provokes additional thinking about how these sectors actually function in Mozambique, and we would welcome suggested modifications in the relations. The ability to include sectors and variables within sectors depends on the availability of relevant data, so provision of that data is critical to being able to include modifications.

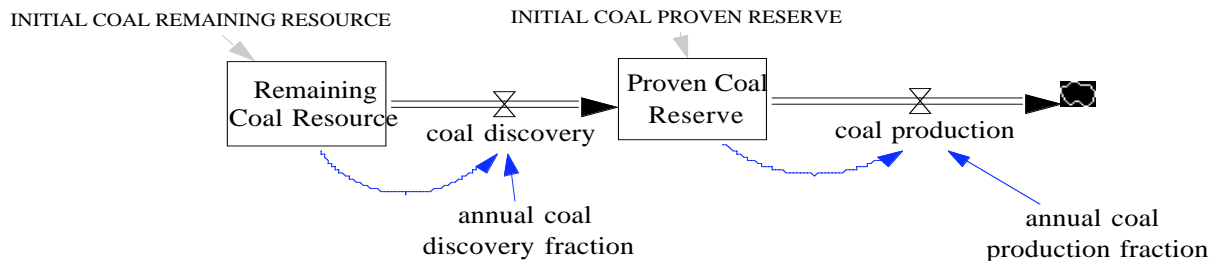
III. Energy and air emission

Energy is critical to the continued development of Mozambique. It also has serious environmental implications, both in the production and use. This sector has several components:

- Energy supply
- Energy demand
- Air emissions

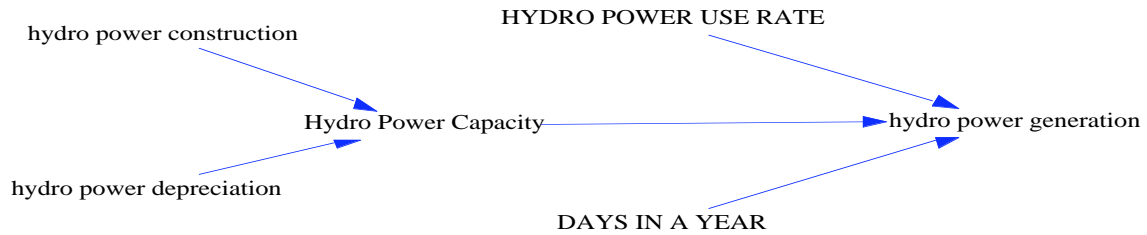
Energy demand includes electricity demand and non-electricity demand. Electricity can be generated from hydro power, coal, gas, oil, or wind. Non-electricity energy demand includes coal, gas, oil, and fuel wood. Primary non-electricity uses include transportation, home heating and cooking, and certain industrial processes. All elements in energy demand will be included in T21 MOZ.

Energy supply is either imported or domestically produced. The domestic production of coal, gas, and oil *as natural resources* is modeled using a similar structure. The flow chart for coal is shown here.

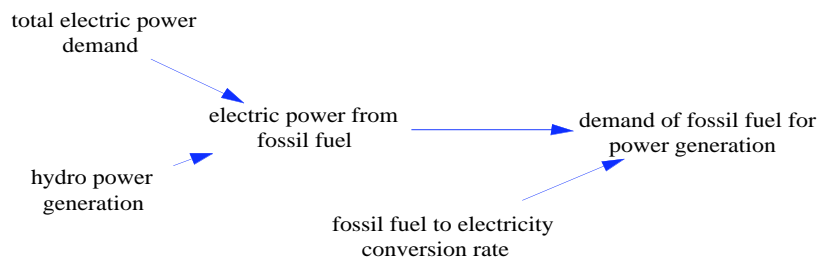


The generation of electricity from *renewable resources*, hydro and wind, is modeled using the following structure (for hydro)³:

³ This approach has been clarified on the basis on comments received.



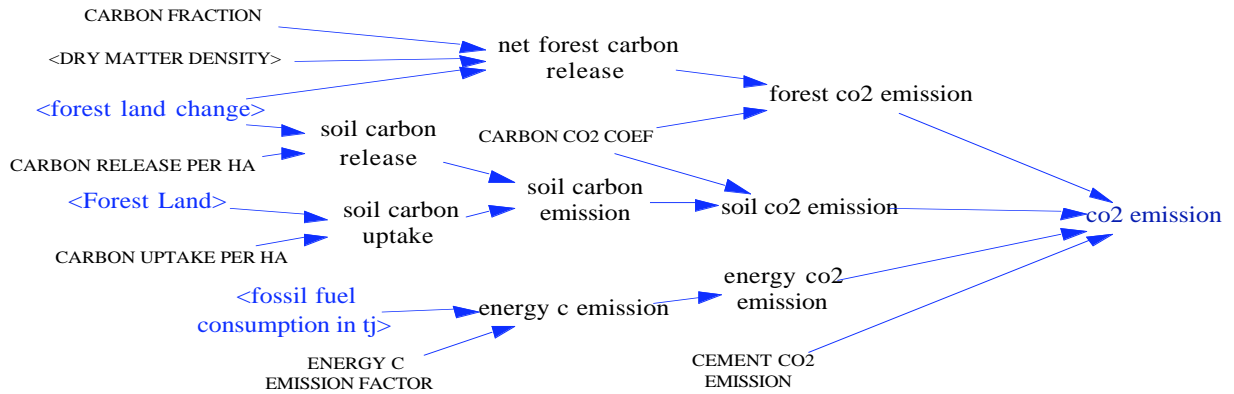
The majority of electric power supply in Mozambique is from hydro power. *However, some is generated from coal, gas, or oil, and the diagram below describes the use of fossil fuel to generate electricity.*



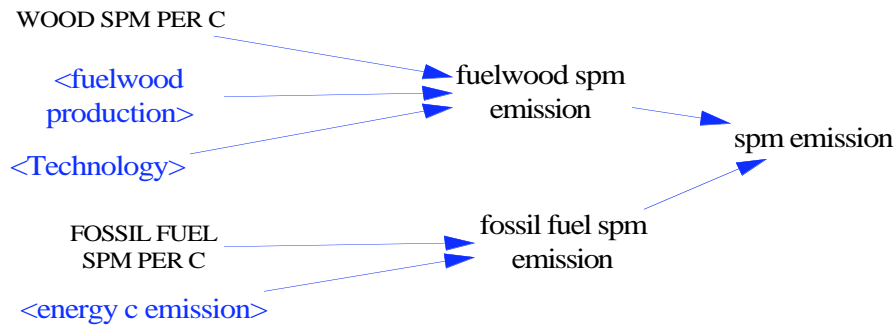
All the fossil fuels used in power generation, transportation, households, or industry will produce various emissions that impact the environment and health. T21 MOZ includes the air emissions for CO₂, SO_x, NO_x, CH₄, and SPM. Some, such as CO₂, have little direct impacts on Mozambique in the short term,⁴ while others, such as SO_x and SPM can have serious local impacts. The algorithm and parameter values used are based on documents from IPCC (Intergovernmental Panel on Climate Change). Also note that the production of each of these pollutants differs for each type of fuel, and the actual T21 MOZ model uses separate functions for each, though a single “fossil fuel” sector is shown in the summary diagrams below.

For example, CO₂ emission is modeled using the following structure:

⁴ CO₂ has a significant impact on global environmental factors, and the resulting global warming may have critical impacts on Mozambique, but Mozambique’s production of CO₂ is insignificant on a global scale.



SPM emission is modeled as:



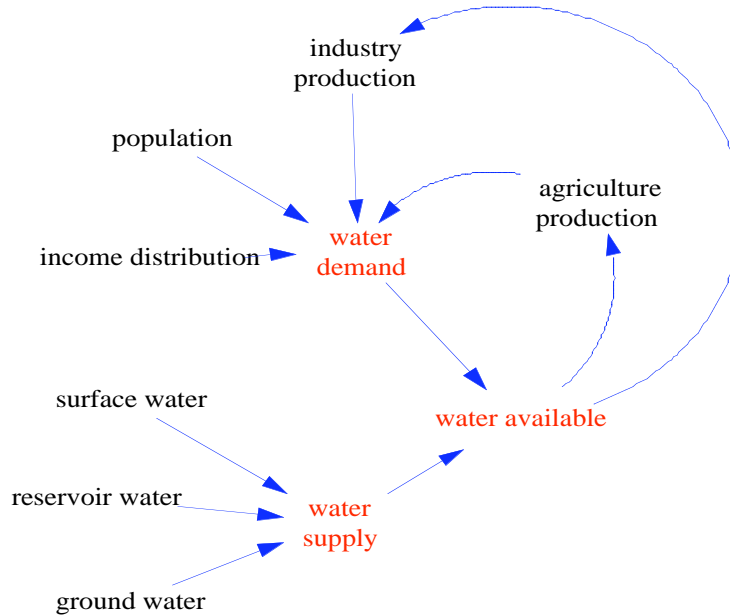
These emissions are linked to economic development and deforestation. They can also be linked to changes in life expectancy and productivity. Some of them, such as SPM from fuelwood, can bring particularly harmful effects to the rural poor. The model includes these and other links. *Comments received have suggested some elaboration in these areas, and more information is needed to refine these links further. We will seek as much additional information and data as possible during our visit.*

IV. Water demand, supply, pollution, and access to safe water

Water is also vital to sustained growth and to human well-being. Mozambique is highly dependent on agriculture, which requires adequate water supplies. The population needs clean water for healthy living, and it needs adequate sanitation. This sector includes the components:

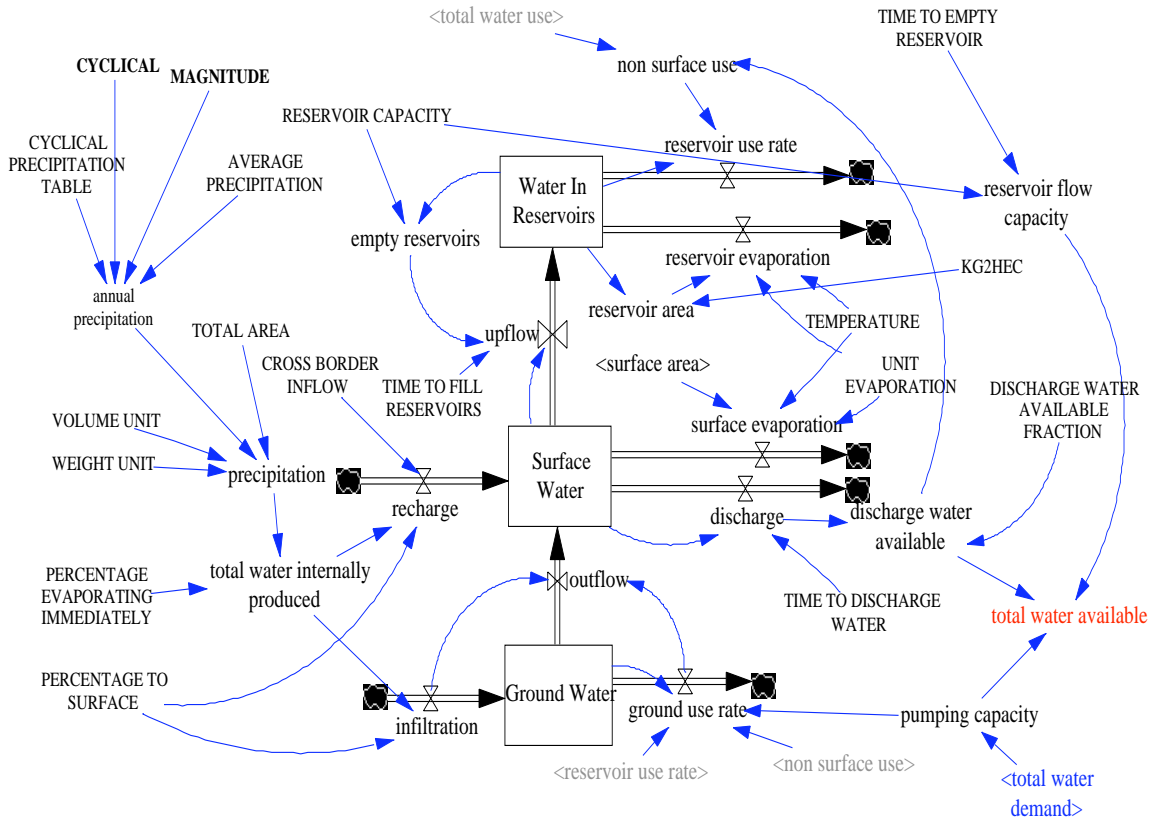
- Water Supply
- Water Demand
- Pollution
- Availability of Safe Water

The following diagram shows the simplified structure of water demand and supply (in red) to be added to T21 MOZ and their linkages to the rest of the model. Water supply is composed of surface water (rivers and lakes), reservoir storage, and ground water, each of which have different characteristics, costs, and interactions.

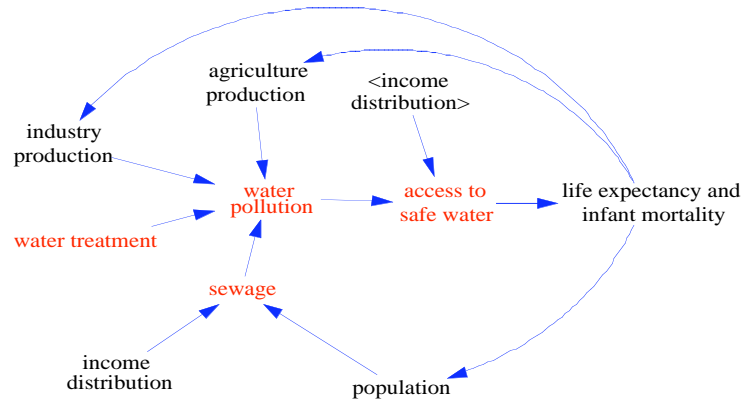


Water demand is determined by four factors: population, income distribution, industry production, and agriculture production. Per capita water demand in urban and rural areas are different in T21, and they both change with income. *Comments have raised concerns about the formulation of this demand. The extent of this difference in demand across income groups needs to be investigated and validated. In urban areas, differences in effective demand may depend on access to piped water supply. In rural areas, it may depend on access to water sources, i.e. location.* Water availability is calculated from water demand and water supply, and it further affects agriculture and industry productions. *We assume that the population will have access to adequate supplies of water unless there are severe shortages. We will seek additional information about accessibility and how it affects demand.*

Water supply in T21 is actually modeled with the following structure:



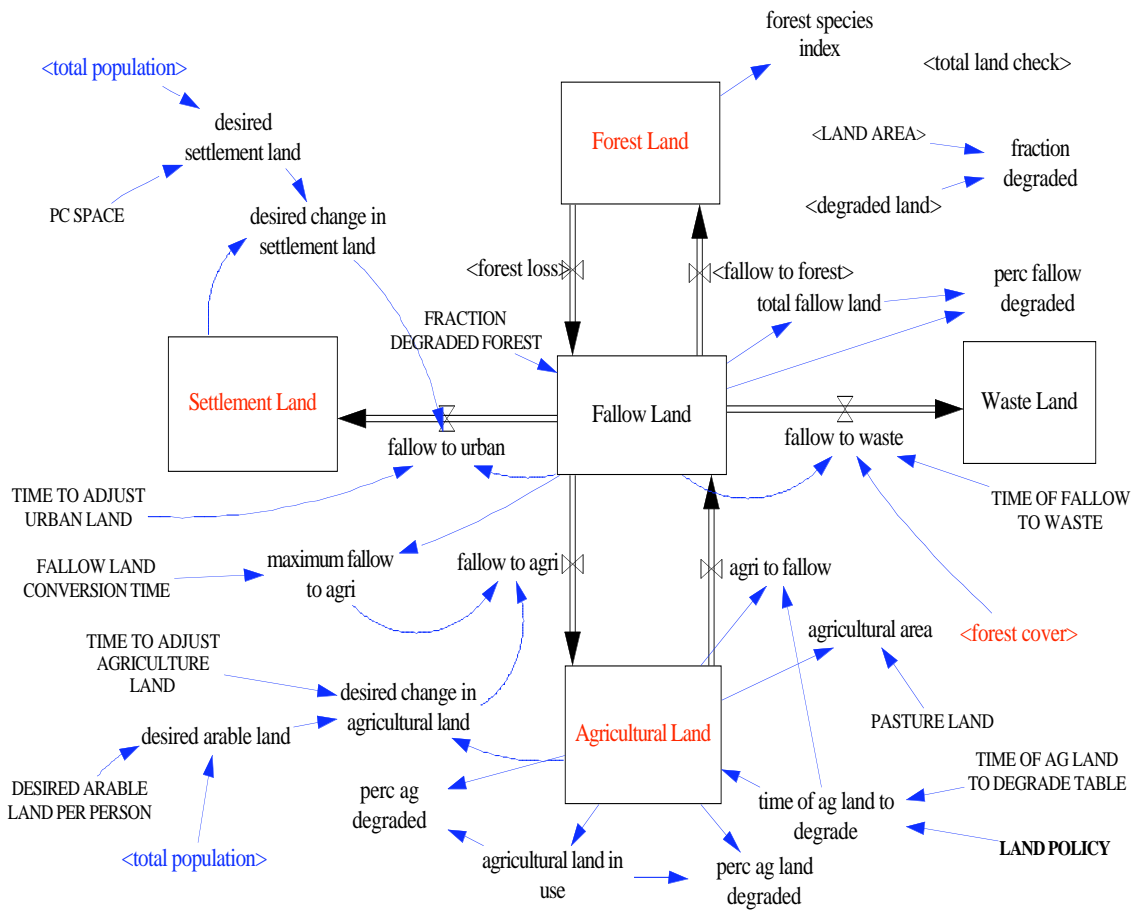
The simplified structure for water pollution and access to safe water (in red) is shown below. It takes account of multiple sources of pollution and the requirement to put water purification in place to assure access to safe water. *Reviewers have noted that there are a large number of different pollutants that can affect water, and by means of the distribution through the water, affect human health and other factors, such as agricultural productivity. These relations can be complicated. For now the model uses only representative pollutants, primarily BOD. As we gain further information, we can put more detail into these relations. However, that will take more time and resources. This would be a useful area for the involved ministries (Agriculture, Environment, Health) to get more involved in the revisions of the model over time. Pollution reduction is not only a high priority of Mozambique, but one of the MDGs that need to be tracked.*



V. Land and land degradation

Land is also vital to development. It provides the basis for agriculture, helps control water flows, and supports biodiversity, among other things. In T21 MOZ, land is divided into five categories: agriculture, forest, settlement, fallow, and waste. Agriculture land is cropland, including permanent crops. Forest land includes all forest, either natural, man-made, protected or unprotected. Settlement land includes roads, residence area, offices area, factories, schools, hospitals, and all other area that is used exclusively for human settlement activities. Fallow land includes pasture land, non-forest natural reserves, and other land that is still usable for growing trees or grass, or being converted to agriculture (crop) land. Waste land includes desert and other severely degraded land that, without heavy investment, is no longer usable for planting anything.

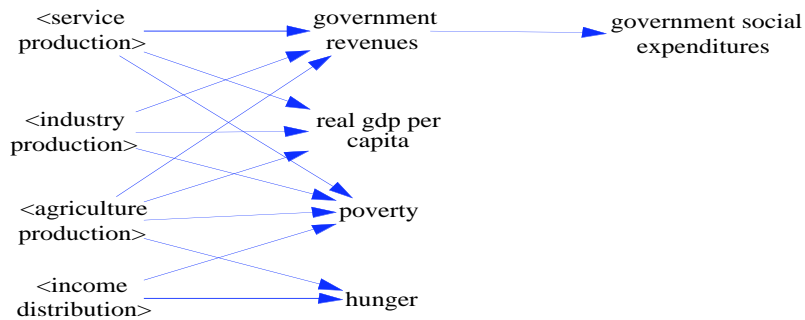
Fallow land and agricultural land can be degraded. The speed of degradation depends on country conditions, farming practices, and policies on the use of land in different situations. The diagram below summarizes the many relations among the different categories of land. Briefly, forest land, once deforested, becomes fallow land. It could become degraded very quickly, depending on its topology, soil condition, and rainfall. Or it could be converted into agriculture production before it degrades. Existent fallow land could be used to plant trees to become forest land, *or shifted back into agriculture*. Agricultural land and its degradation affect agricultural production directly, which further affects rural poverty. And the other relations are as shown.



Forest land is further modeled with the following structure:

VI. Impacts on Poverty

Poverty will be affected by most of these environmental factors, both directly through the impacts on production and productivity in each sector, and indirectly through impacts on health, access to safe water, etc. The diagram below summarizes the direct effects. The indirect effects are incorporated into the structure of the model, where increases in pollution, for example, could affect health, and reduced health lowers productivity and incomes. Both sets of relations can be very important. *Refining these relations will continue to be an important aspect of the model and its evolution. T21 is always a “work-in-progress.”*



Appendix B: Correspondence with Mulder and Tembe

The Energy Sector in MOZAMBIQUE

Peter Mulder & Jonas Tembe
MPD, Maputo
January 2006

Introduction

Mozambique is endowed with abundant but unexplored energetic resources. Biomass is currently the main source of energy consumption. About 80% of population in Mozambique live in rural areas and depend on this source of energy for cooking as well as for water and indoor house heating and for food staff drying. More than 90% of the families use exclusively biomass for cooking, while less than 10% use domestic coal. Only about 7% of the households have access to electricity (see figure 1).

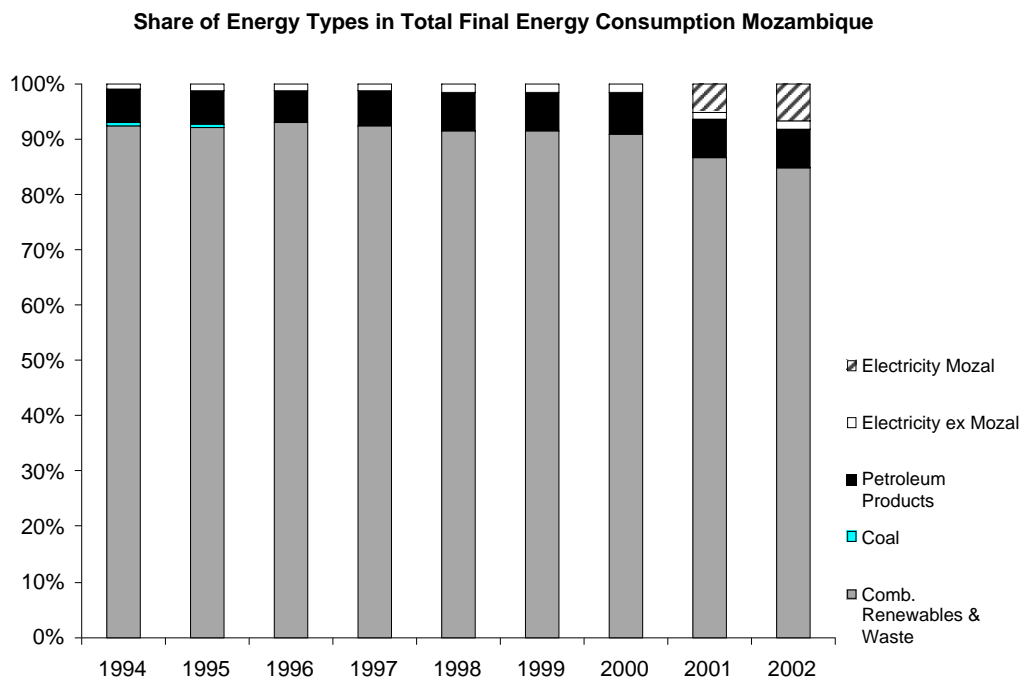


Figure 1.

However, the availability of a substantial amount of hydropower capacity and potential as well as natural gas resources makes that the energy sector plays an important and strategic role in the country's development as well as in the wider southern African region. The likely availability of crude oil resources will increase the sector's importance even further.

This short notes aims to highlight a few peculiarities of the Mozambican energy sectors to enhance understanding of the data and to serve the development of the T21 model for Mozambique.

Data

Over the last month we have collected energy data from various national sources to construct a consistent energy database for Mozambique as of the year 2000 (further back in history turned out to be impossible). We refer to this data as data of the Ministry of Energy (ME). In addition we used the IEA energy balance data and some incidental other sources to fill in the T21 datasheet. This required conversion, (re)construction and some estimation of data. This is reflected in the Excel file as follows:

1. worksheet Energy is are the final data series
2. worksheet Energy ME originaldata includes the original domestic data
3. worksheet Energy IEA originaldata includes the original IEA data
4. worksheet conversion&calculation shows as much as possible the calculations, estimations and conversions undertaken to construct the final data series.

Electricity

The electricity sector in Mozambique has a somewhat peculiar structure that one needs to know in order to understand the energy data as well as the role of the energy sector in the wider economy.

There are 2 key phenomena here:

1. **The Cahora Bass Hydro Power Dam (HCB)** in the north of Mozambique. With its 2075MW it is the 2nd largest dam in Africa. 90% of the generated electricity is exported to South Africa via a direct long distance transmission line. Apart from a relatively new and small transmission line in the north of Mocambique, this is also the only transmission line to transport the generated electricity to the rest of Mocambique, including the Maputo area, the economic most vibrant part of the country. This means that virtually all domestic consumption from HCB is wheeled through South Africa before it reaches the southern part of Mocambique. As a result of this and depending on your definitions of 'import', some international data, including the IEA energy balances, might give a wrong picture of the actual situation. Although technically seen this electricity is imported from South Africa it is essentially domestically produced and only transported through South Africa. The national statistics therefore distinguish between 'import' and 'acquirement' of electricity, with the latter being the production of electricity from HCB that is purchased by EdM (Electricidade de Mocambique, the national electricity company), and wheeled through South Africa. In the data file we have tried to construct the data as much as possible in line with this structure of the energy sector. Furthermore, it is relevant to know that HCB was built in the 1970s at the end of the Portuguese colonial regime, and that during the subsequent 18 years of civil war the transmission line has been subject to sabotage, as a result of which HCB has been producing way below its potential for a long time. Only in the 1990s the

infrastructure has been repaired and production gradually returned to normal capacity. One can see this clearly in the data.

2. **The Mozal aluminum plant just outside Maputo.** The Mozal mega-project is not only dominating the national economic data, but also the energy data. It started operating in 2000 and is a very big energy consumer. It uses about 7 times as much electricity as the rest of the country altogether. Its electricity is directly imported from South Africa by a separate company called MOTRACO. Because of its extraordinary size in terms of energy consumption we have separately identified the consumption of Mozal in the datafile. The T21 modeling team might consider doing the same.

An overview of the electricity sector is given in its Energy Balance in Table 1.

		2000	2001	2002	2003	2004	2005
Produção / Production	MWh	9,693,866	11,872,787	12,707,876	10,903,214	11,713,571	13,289,000
HCB	MWh	9,397,700	11,583,500	12,411,400	10,626,600	11,559,400	13,126,400
Parte adquirida para EdM (através RSA/ESKOM)	MWh	854,035	1,138,819	1,386,643	1,542,600	1,765,501	1,857,232
EDM	MWh	296,166	289,287	296,476	276,614	147,418	155,382
A base de Gas Natural / On the basis of Natural Gas	MWh	0	0	0	0	6,752	7,218
ENMo	MWh					2,879	5,184
Elgas	MWh			3,686	3,328	3,874	2,034
+ Importações / Imports	MWh	1,297,394	3,893,128	3,899,417	6,080,902	7,912,661	8,065,512
EDM	MWh	244,667	33,011	13,048	10,671	13,963	9,365
MOTRACO	MWh	1,052,727	3,860,117	3,886,369	6,070,231	7,898,698	8,056,147
- Exportações / Exports	MWh	7,789,514	9,463,200	10,275,905	8,376,800	9,046,924	10,488,016
HCB	MWh	7,789,200	9,463,200	10,120,200	8,131,200	8,768,400	10,126,200
EDM	MWh	314	0	155,705	245,600	278,524	361,816
= Fornecimento Total Primário / Total Primary Supply	MWh	3,201,746	6,302,716	6,331,388	8,607,315	10,579,308	10,866,496
- Perdas de Transporte / Transport Losses	MWh	114,437	244,131	229,448	312,932	361,068	383,842
EdM	MWh	101,543	137,674	129,689	101,984	76,281	111,317
MOTRACO	MWh	12,894	106,457	99,759	210,948	284,787	272,525
ENMo	MWh				0	0	0
Elgas	MWh				0	0	0
Perdas de Transporte e Auto Consumo HCB / Transport Loss and Auto Consumption HCB	MWh	754,465	981,481	904,557	952,800	1,025,499	1,142,968
= Energia Bruto Disponível / Gross Energy Available	MWh	2,332,844	5,077,104	5,197,384	7,341,583	9,192,740	9,339,687
- Serviços e Consumos Auxiliares de Subestações EdM / Services and Own Consumption EdM	MWh	80,681	97,853	101,235	52,400	15,759	22,051
= Energia Distribuída / Energy Distributed	MWh	2,252,163	4,979,251	5,096,149	7,289,183	9,176,981	9,317,636
Iluminação Pública (EdM) / Public Lighting (EdM)	MWh	23,700	27,562	30,185	27,562	32,057	54,254
Consumos Internos (EdM) / Internal Consumption (EdM)	MWh	10,800	15,871	15,249	15,871	10,172	15,027
- Perdas de Distribuição (EdM) / Distribution Losses (EdM)	MWh	162,688	135,726	210,723	335,144	368,925	348,550
= Consumo Final Total / Final Consumption	MWh	2,054,975	4,800,092	4,839,991	6,910,606	8,765,826	8,899,805
- Perdas Totais (Transp. + distribuição) / Total Losses	MWh	264,231	273,399	340,412	437,129	445,206	459,867
Consumo Final Mozal (MOTRACO)	MWh	1,039,833	3,753,660	3,786,610	5,859,283	7,613,911	7,783,623
Consumo Final com base Gas Natural (ELGAS&ENMo)	MWh	0	0	0	0	6,752	7,218
Consumo Final EdM	MWh	1,015,142	1,046,432	1,053,381	1,051,323	1,145,164	1,108,964

Table 1.

Gas

Mozambique has large sedimentary basins of natural gas. Recently, three reserves of gas in Pande, Temane and Buzi were discovered, which are estimated in about 700x109m³. Until 2004 the gas was only used to fuel 2 gas fired electricity plants, but as of 2004 the South African company Sasol started to explore the gasfields and export the gas to South Africa through a pipeline. As of 2005 part of the gas (max 5%) is tapped to be used domestically. These 2 developments can be clearly seen in the data.

An overview of the gas sector is given in its Energy Balance in Table 2.

		1999	2000	2001	2002	2003	2004	2005
Produção / Production	m3		927,000	1,244,900	2,420,779	2,522,897	1,245,529,145	2,095,916,939
+ Importação / Imports	m3		0	0	0	0	0	0
- Exportação / Exports	m3		0	0	0	0	1,242,600,444	2,027,920,833
- Variação Reservas / Stock Changes	m3							
= Fornecimento Total Primário / Total Primary Supply	m3	669,116	927,000	1,244,900	2,420,779	2,522,897	2,928,701	67,996,106
- Produção de Energia Eléctrica / Electricity Production	m3	655,456	746,965	1,041,462	2,198,169	2,198,169	2,582,129	2,408,653
ENMo	m3						507,381	1,660,071
ELGAS	m3				630,811	1,177,428	1,362,193	748,582
- Perdas e Auto consumo / Losses and Own Consumption	m3	0	159,113	166,979	173,113	74,214	0	47,715,142
- Diferenças Estatísticas / Statistical Differences	m3	0	0	0	0	186,955	0	696,689
- Perdas de Distribuição / Distribution Losses	m3	0	0	0	0	0	0	0
= Consumo Final Total / Total Final Consumption	m3	13,660	20,922	36,459	49,497	63,559	346,572	17,175,622
Total do Sector Industrial / Total Industry Sector	m3	0	0	0	0	0	0	16,949,738
Total do Sector de Transporte / Total Transport Sector	m3	0	0	0	0	0	0	0
Total de Comercio e Serviços / Total Commerce and Services Sector	m3	10,048	14,737	23,866	29,070	35,905	204,791	169,833
Comercio / Commerce	m3	9,148	12,321	20,380	24,946	31,278		
Serviços / Services	m3	900	2,416	3,486	4,124	4,627		
Doméstico / Residential	m3	3,612	6,185	12,593	20,427	27,654	141,781	56,051

Table 2

Coal

Mozambique has three large deposits of coal in Moatize-Minjova, Senangoe and Mucanhavuzi, all in Tete province. Total reserves of coal are estimated to be about 2 billions of tons. Plans for increased exploration exist.

Crude Oil

The government of Mozambique has recently launched an international bid for oil researching at the Rovuma basin in the North of Mozambique. The Rovuma basin is believed to contain considerable amounts of exploitable oil. So far, however, there are no proven oil reserves.

Petroleum Products

100% of domestic fuel consumption is imported. It is to be noted that direct fuel imports are around 11% of total imports while indirect fuel imports (oil-intensive chemical products, plastics and rubber) are around 9% of total imports. Together this makes that 20% of total imports is oil related. This is a lot (in most oil-importing developed countries this figure is about 5%). Hence Mozambique is very vulnerable to oil price shocks.

Biomass and Renewable energy

In spite of the fact that the vast majority of the Mozambican population relies on biomass for its energy consumption, the existence and quality of the data is limited. So far we have to rely on the IEA energy balances and a few loose numbers. We plan to work on improving the situation here.

Questions and answers February 2006

Questions by Weishuang Qu of MI

Answers by Peter Mulder & Jonas Tembe of MOPD

1. Electricity demand and supply: In 2005, electricity production was 13.3 billion KWH (cell U5 of the first sheet), while total electricity demand was 9.5 billion KWH (cell U58), so Mozambique is a net exporter of electricity for 2005 (all imports are really transported and can be viewed as originated from Mozambique). Is this correct?

Yes, Mozambique indeed is a net exporter of electricity (mainly to South Africa (ESKOM)). The principal reason for this is the large Cahora Bassa Hydro (HCB) dam, producing a lot more electricity (about 13,000 GWh) than Mozambique consumes.

Then, almost 2,000 GWh of this is sold to the national electricity company EdM for domestic consumption. Because of the infrastructure this is transported through South Africa, but essentially it is domestic consumption rather than imports (see the accompanying note we sent you). The remaining 11,000 GWh or so from HCB is exported to various countries, mainly South Africa.

In addition to the domestic consumption through EdM, a large domestic consumer of electricity is the Mozal aluminum plant which uses on its own about 7 times as much electricity as the rest of the country altogether. The electricity for the Mozal plant is imported from South Africa, not by EdM but by a different company called MOTRACO. One could argue that this electricity import is also originating from HCB and thus from within Mozambique, although there is no direct link here: HCB sells a main part of its production to ESKOM, and MOTRACO buys the Mozal electricity from ESKOM (in the end, electricity is a homogenous product). On the other hand, there is a relation with HCB in the sense that the fact that ESKOM is able to buy cheap electricity from HCB allows them to sell cheap electricity to MOTRACO/Mozal... In this latter sense, yes all imports can be viewed as originating from Mozambique). See below the detailed numbers.

		2000	2001	2002	2003	2004	2005
Importações / Imports	MWh	1,297,394.2	3,893,128.3	3,899,417.0	6,080,901.8	7,912,660.9	8,065,512.4
EDM, E.P.	MWh	244,667.0	33,011.0	13,048.0	10,670.8	13,962.9	9,365.0
MALAWI (ESCOM)	MWh	3,057.8	3,506.0	2,449.0	2,966.0	2,753.0	
ZIMBABWE (ZESA)	MWh	284.0	795.0	447.0	284.0	58.0	
ÁFRICA DO SUL (ESKOM)	MWh	241,289.4	28,961.0	10,315.0	7,254.0	10,874.0	
Statistical Difference	MWh	35.8	-251.0	-163.0	166.8	277.9	
MOTRACO (to MOZAL)	MWh	1,052,727.2	3,860,117.3	3,886,369.0	6,070,231.0	7,898,698.0	8,056,147.4
Exportações / Exports	MWh	7,789,514.0	9,463,200.0	10,275,905.3	8,376,800.0	9,046,923.6	10,488,016.0
EDM	MWh	314.0	0.0	155,705.3	245,600.0	278,523.6	361,816.0
Namibia (NAMPOWER)	MWh					2,858.0	43,231.0
Botswana (BPC)	MWh					32,056.0	165,113.0
Africa do Sul (ESKOM)	MWh					91,127.0	21,617.0
Zimbabwe (ZESA)	MWh					11,349.0	2,477.0
Suazilândia (SEB)	MWh					141,547.0	129,395.0
Statistical Difference	MWh					-413.4	-17.0
MOTRACO	MWh	0.0	0.0	0.0	0.0	0.0	0.0
ENMo	MWh	0.0	0.0	0.0	0.0	0.0	0.0
Eigas	MWh	0.0	0.0	0.0	0.0	0.0	0.0
HCB	MWh	7,789,200.0	9,463,200.0	10,120,200.0	8,131,200.0	8,768,400.0	10,126,200.0
RAS (ESKOM)	MWh	4,304,300.0	6,264,300.0	6,805,400.0	5,365,400.0	7,020,400.0	7,884,700.0
Zimbabwe (ZESA)	MWh	3,484,900.0	3,198,900.0	3,270,000.0	2,182,800.0	1,433,500.0	2,079,400.0
Botswana (BPC)	MWh	0.0	0.0	30,200.0	252,400.0	77,800.0	20,100.0
STEM	MWh	0.0	0.0	14,600.0	315,100.0	236,700.0	142,000.0
ZESCO	MWh	0.0	0.0	0.0	15,500.0	0.0	0.0
Outros	MWh	0.0	0.0	0.0	0.0	0.0	0.0

2. Unit: What is ktoe? Is it thousand ton of oil equivalent? If so, then 1 ktoe should equal to about 1,000 tons of oil and 2,000 tons of coal. In your last sheet for conversion, 1 ktoe is 41868 short tons. What does it mean?

Yes, 1 ktoe = 1 kilotonne of oil equivalent = 1000 ton of oil equivalent. So, 1ktoe indeed is equal to about 1,000 tons of oil. It also is equal to about 1,500 – 1,600 tons of coal (the inverse of the

value in row 22 of the last sheet for conversion). The exact value of coal equivalent depends on the quality of the coal; for Mozambique I assume the heat content values in row 19 in my last sheet for conversion, resulting in the amount of ktoe per Ton in row 22.

Thanks to your question I noticed that in my last sheet for conversion I made a mistake. 1 ktoe is 41868 GJ (cell G9) and the value in cell F9 is an error: 1 ktoe is NOT also 41868 short ton.

Apologies for the confusion.

3. Coal: You have some good production numbers, but I also need either demand or import numbers. If data is not available, could you do some estimate for me, such as Mozambique is usually a net importer or exporter, and import/export usually accounts for what percentage of its production or demand.

Coal production has picked up as of 2002 and for 2002 and 2003 is about 26 ktoe (IEA data). In addition, for sure Mozambique is a net exporter of Coal. Domestic consumption is very low; IEA gives for 2003 a domestic demand of 5 ktoe (in the category "other sectors"). The remaining 21 ktoe in 2003 then is exported according to IEA, and import is zero. Hence, about 80% of coal production is exported, about 20% is for domestic demand, import is 0. I cannot yet check or refine these numbers with national data, but they make sense.

Moreover, coal production is expected to increase over the next few years due to planned investment in coal exploration. Due to lack of domestic industries and/or coal fired power plants, the vast majority of production is meant to be exported.

4. Natural gas: It seems that Mozambique is a huge gas exporter, as its production was 74 million kcf in 2005 (cell U4), and its consumption was only 0.6 million kcf in 2005 (cell U39). Is it correct? Also from 2004 to 2005, consumption increased from 0.012 to 0.6 million kcf, a 50 time jump. What happened in 2005 in terms of natural gas consumption? Will this trend continue?

Yes indeed, Mozambique is a huge gas exporter, due to the recent large investments in this sector. As of 2004 the South African company SASOL is exploring gas fields in Southern Mozambique, of which more than 95% is exported to South Africa via pipeline. Domestic consumption of gas is still very limited indeed. So, yes the numbers are correct.

The 50 time jump from 2004 to 2005 was due to the introduction of natural gas in some local industries, and this trend is supposed to continue as more manufacturing industry shows interest in using gas. However, the domestic gas consumption is unlikely to exceed 5% of total gas exploration, hence minimal 95% of total gas explored will be exported. The reason is that the contract between the Government of Mozambique and SASOL includes a 5% payment of royalties, either in money or in gas. In 2004 this royalty was mainly paid in tax, in 2005 the share paid in gas increased sharply due to the realization of a tap connection from the pipeline to the local industry close to Maputo. In sum, the high percentage increases in production and consumption in 2004 and 2005 are due to growth from (almost) zero to quite something. The changes from 2005 to 2006 will be less dramatic.

5. Oil imports, including gasoline, diesel, kerosene, and LPG, (but excluding other petrochemical products, plastics and rubber) are in your first sheet, rows 30 – 34. Correct?

Yes, that is correct.

Questions and answers March 2006

Questions by Weishuang Qu of MI

Answers by Peter Mulder & Jonas Tembe of MOPD

Comments by Weishuang Qu in (WQ: Comments)

1. Electricity:

- From the data you provided, Mozambique also has some electric power generation from non-hydro sources. Is it mostly from coal, or gas, or renewable? This could become significant in the future if the hydro power is not enough.

Re: Currently, the non-hydro electric power generation is mainly from diesel and gas (production from renewable is negligible). EdM's own thermal/diesel production is currently about 40.000 MWh (out of about 155.000 MWh total). In addition, electricity production on basis of gas is about 7.000 MWh. Plans exist to build a new coal fired electricity plant of 1500 *MW* (in Moatize) as well another one on basis of gas (600-1500 *MW*).

(WQ: Hydro generation is 13 B KWH in 2005, or 13,000,000 MWH. So electricity from other sources is only a few percentage points.)

- Does Mozambique have untapped hydro power capacity? If yes, is Mozambique planning on building more reservoirs/dams? What are their estimated timing and capacities?

Re: Yes Mozambique has substantial untapped hydro power capacity. The estimated hydro potential is about 12.500*MW*/60.00GWh. Lots of plans to build dams exist, but progress of implementation is slow.

The largest potential is at the river Zambezi: an additional 1200 MW capacity at Cahora Bassa on the north bank of the Zambezi, and several new hydro projects downstream of Cahora Bassa; Mepanda Uncua (1600 *MW*); Baroma (444 MW); and, Lupata (654 MW). Development of these projects may be carried out following power purchase agreements with neighboring countries. Progress of implementation is slow and it is expected that it will take at least another 5-7 years before the first new dam in the Zambezi starts to operate - and probably longer.

In sum, our guess would be that within the next 5 years we can expect at maximum 200MW new hydrocapacity from new relatively small dams and rehabilitation of existing dams.

(WQ: Update "HYDRO POWER CONSTRUCTION FUNCTION")

- As Mozal uses so much electricity, I decided to separate Mozal from all the other electric power demand. I am assuming Mozal is reaching its full capacity in 2005, so its electricity demand will stay within 8 billion KWH/year for the future (its

electricity demand for 2005 was 7.78 billion KWH/year). Is this assumption reasonable?

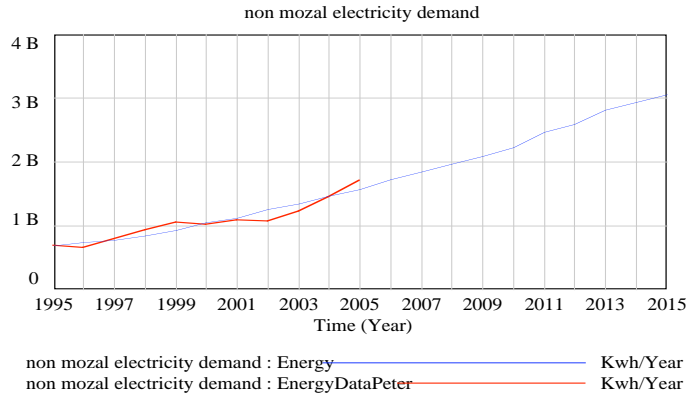
Re: We very much agree with your decision to treat Mozal separately. Currently Mozal is indeed at full capacity. But Mozal is planning to build a third line of production in the near future, which means they will need more electricity. In case they build the third line of production (Mozal III), they will consume the equivalent of about **500 MW**. This is still under negotiations with the government: The plan is that Mozal will benefit from the realization of the Mepanda Uncua dam (see above), but the latter depends in his turn on the price Mozal is willing to pay for electricity supply. Given the support from the government to Mozal and the (economic) power of Mozal, we expect Mozal III to become operational in about 5 years time, one way or another.

In addition, it is to be noted that future electricity demand will be influenced substantially by the realization of **2 mining projects on so-called heavy sands** (Corridor Sands in Chibuto in South Mocambique, and Moma project in North Mocambique). These projects will be among the largest mineral sand (e.g. titanium oxide) exploration sites in the world. Both projects are in the start-up phase; Moma is expected to be operational as of 2006, Corridor Sands as of 2008. The Corridor Sands project is expected to use **155 MW** of power during its first phase (as of 2008), increasing to **350 MW** at full capacity. The Moma project is expected to consume about **20MW**.

Concerning the Corridor Sands project, the original plan was to purchase power from Eskom (RSA), wheeled through to Maputo and then via a 200 km long power line to the project site. However alternative options are currently being evaluated and negotiated, for example with EdM using new hydro power capacity. The Moma project will get its electricity from Cahora Bassa.

(WQ: Add “other mega projects electricity demand” to take care of possible electricity demand from other MEGA projects)

- The non-Mozal (or all other) electricity demand shows a GDP elasticity of about 1.1. Does that make sense? The following figure shows the simulation results (blue) and data (red).



Re: yes, a 1.1 elasticity does make sense. Electricity consumption is growing relatively fast because of economic growth and rural electrification; as a result there is a lot of room for catch-up type of growth in electricity consumption in the near future. Concerning the future, see also note on heavy-sands projects above

2. Coal:

- For many countries, coal production is limited by its proven reserves. Usually the annual production is a few percentage points of its proven reserve. But Mozambique does not seem like that. Its annual production is less than 0.1% of its proven reserve. How do you expect coal production to increase over the next few years?

Re: The production of coal has been limited in recent years because damage to a rail line during the civil war in the 1980s cut off access from the Moatize coalfield to overseas markets. Output was 16,525 t in 2004 compared with 36,742 t in 2003 and 16,115 t in 2000. Production shut down in the first quarter of 2004 because of the installation of a new transportation system at the Chipanga XI Mine. Exports of coal rose to 30,288 t in 2004 compared with 15,138 t in 2003; coal was exported to Malawi. In 2005, coal production was expected to rise by 59% because of the completion of repairs at the Chipanga XI Mine and rising world demand for coal. In November 2004, Companhia Vale do Rio Doce (CVRD) of Brazil won the bid to develop the Moatize coalfield. The company planned to conduct a feasibility study from January 2005 to January 2007. If the feasibility study yielded favorable results, CVRD planned to build a mine that would produce 14 to 15 Mt/yr of coal. Production was expected to start in 2009. CVRD also planned to build a coal-fired power station with a capacity of 1,500 megawatts (MW). The company agreed to market 15% of Moatize's production in Mozambique; most of the remainder would be consumed by steel plants in Brazil. (Source: USGS Minerals Yearbook 2004, Volume III – Mozambique).

- Domestic coal demand is assumed to increase with GDP, with an elasticity of 0.8. Does this sound reasonable?

See above.

(WQ: Domestic coal consumption is to increase to 15 Mt/yr * 15% = 2.25 Mt/yr, so it is to increase very fast. Use a higher elasticity value of 1.2.)

3. Natural gas:

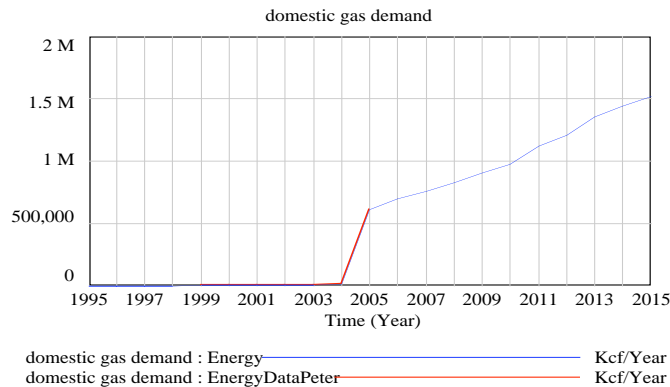
- Is gas primarily from the natural gas Mega project? If yes, then is there a designed production level/target for the project? I am assuming the design capacity is about 90 million KCF (in 2005 gas production was 74 M KCF). Is this level reasonable?

Re: yes, all gas is from the natural gas Mega project.

Concerning targets and capacity: Mozambique had natural gas reserves of 127 billion cubic meters (WQ: or 4445 B CF, or 4.445 B KCF), most of which were in the Pande and Temane gasfields. The new pipeline to transport gas from Pande and Temane to South Africa was completed in 2003; gas would be supplied to South Africa starting in the first quarter of 2004. Sasol Ltd. of South Africa expected to produce nearly 2.1 billion cubic meters (WQ: 73.5 B CF, or 73.5 M KCF) of natural gas per year; the company indicated that it could increase production to more than 3.1 billion cubic meters (WQ: 108 M KCF) without further investment. (Source: USGS Minerals Yearbook 2003/4, Volume III – Mozambique). Current export is about 85 million GJ/year, and is expected to increasing to 120 million GJ/year in the medium-term. However, the pipeline has a capacity for some 240 million GJ/year.

(WQ: Adjust “PLANNED GAS PRODUCTION TABLE”)

- I am using GDP elasticity to forecast future gas demand. This elasticity should be high, as Gas is readily available in Mozambique. I use the value of 1.5, and the domestic gas demand is shown in the figure below. Does this seem reasonable?



Re: yes, we agree that the elasticity should be high. Your graph looks good, but it might be that domestic gas consumption will grow even faster. There are a number of reasons for this:

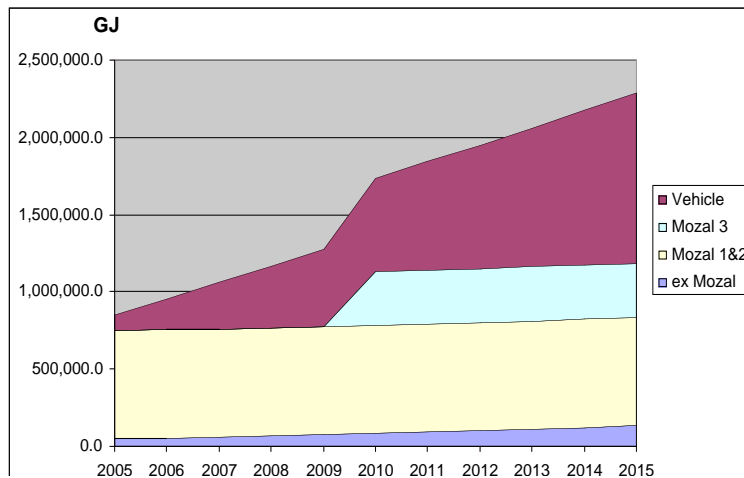
1. As of 2007 gas will also be consumed by vehicles, initially about 100.000GJ/year with expected growth to 1 million GJ/year in 10 years time.
2. If Mozal 3 will be realized, gas consumption might suddenly increase substantial. Right now, Mozal consumes almost 700.000GJ/year (WQ: 588,700 KCF/Year); Mozal 3 will be a 50% increase in production capacity. Thus possibly also leading to a 50% increase in their gas consumption? That would be an increase of 350.000 GJ/year.
3. If a new gas fired electricity plant will be realized, domestic consumption goes up again. I have an initial number of 40 million GJ/year, but we have not yet been able to confirm this right now. Does the number make sense to you?

So again, Mozal is a major driving force of the results, while other big projects are potentially important as well. As a result, the domestic consumption of gas might be more the function of sudden increases than a gradual increase. Maybe you need to separate Mozal here as well?

- If you take 2005 domestic gas consumption excluding Mozal (which is about 50.000 GJ), 7% GDP/year and an elasticity of 1.5, you end up with about 135.000 GJ in 2015.
- If Mozal 3 is NOT realized, we need to add about 700.000 GJ (its current consumption at more or less peak capacity). Result: 835.000GJ in 2015.
- If Mozal 3 is realized, we need to add another 350.000 GJ. Result: 1.185.000GJ in 2015.
- If the vehicle project is successful, we need to add 100.000 GJ/year. Result: 2.185.000 GJ.

The results are summarized in the graph below.

If the gas fired electricity plant gets realized, domestic gas consumption explodes with an additional 40 million GJ (if we are correct on this number).



(WQ: Add “mozal 3 and vehicle gas use”. Total of gas demand in 2015 is 2.3 M GJ, which converts to 1.93 M KCF, based on Peter’s conversion that 1 GJ = 0.841 KCF.)

4. Oil:

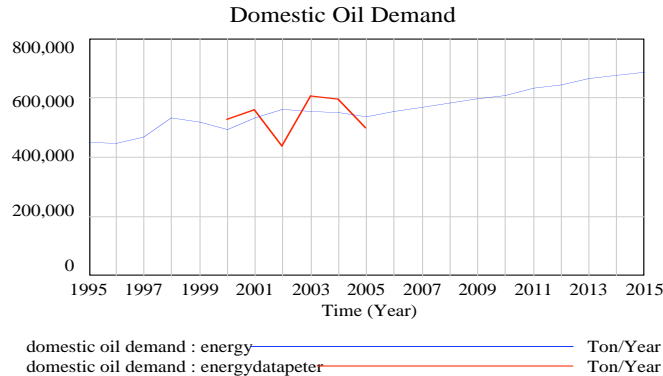
- Mozambique has not discovered any oil so far, so I will assume its oil resource is zero, although it puzzles me that it has large natural gas but zero oil. Please comment.

Re: An international oil bid has recently (2 weeks ago) been evaluated for oil exploration in Rovuma basin (northern Mozambique) following studies made of possible existence of oil in that region. All indicates that there is oil in Rovuma and several international well positioned companies have been selected to investigate oil reserves in the 6 areas of the Rovuma, 1 onshore and 5 offshore. Results are expected within 3 years.

- I am assuming domestic oil demand is affected by both GDP and real oil prices with the following elasticity values. Does it make sense to you?
 GDP elasticity 0.5
 Real oil price elasticity -0.2

Re: Yes, we think that sounds good. It is not too small, given the expected growth in vehicle fleet? On the other hand, the potential use of gas in vehicles, as well biofuels might have an impact in the long run. Please note that we do not yet have strong opinion here.

- The following compares domestic oil demand from model (blue) with data (red). Does it make sense to you?



Re: Yes it does. The 2002 fall in consumption is well known, but yet unexplained. The 2005 fall in consumption can be explained by high prices.

5. Are there substitution effects of different energy sources in domestic demand? Such as in 2005, world oil prices shot up, so oil imports was down, while natural gas demand was up tremendously. Are these two demands (oil and gas) somewhat related?

Re: They seem to be related for Mozal (and to a lesser extent with the other industrial consumers of gas). They apparently substituted some fuel (diesel?) for gas.

Substitution may also take place in the vehicle gas project, but is at the same time limited in terms of volume of fuel substituted.

Gas consumption for electricity has no relation with oil, since it is substitution with hydro. We are not aware of any significant reduction in diesel generator use for electricity production due to high oil prices.

In general, the sharp increase in gas demand so far is first and most motivated by the very availability of it. Until 2004 it was simply not there. For the future we might expect some substitution effects, but probably not that big (?).