Republic of Rwanda

MINIRENA
RNRA - DFNC

PROJECTION SCENARIO

OF SUPPLY/DEMAND OF WOODY BIOMASS

IN RWANDA

FROM 2015 TO 2026

SUMMARY REPORT

June 2016

1. Introduction

Due to the serious increases of demand of woody biomass link to the growth of the population, due to the poor management of forest/woodlots and due to the limitation of the area dedicated for primary economic activities such as agriculture and forestry, the Rwanda is moving to a critical situation in term of balance between supply and demand of woody biomass. The gap between the supply and demand is leading to a serious over-exploitation of the remaining forests. The forest cover area has already started to diminish sensibly, but the most alarming issue is the quick decrease of the stock in these remaining forest areas, where tree resources became poor and very degraded/over-exploited. The increasing forest resources degradation process will lead to a very dramatic environmental and socio-economic situation if no drastic measures are taken both on supply and demand sides.

In order to measure the “health of the forest” and the level of risks of degradation, the ratio “sustainable supply / demand” of woody biomass has been raised as a main indicator of the forestry and sustainable biomass energy sectors. This ratio expresses the percentage (%) of the demand (in oven dry tons/year) that can be satisfied by the sustainable supply (in oven dry tons/year).

The sustainable supply corresponds to the annual productivity or annual yield of the forests, expressing the quantity of wood produced by the natural grow of forests every year. This is equivalent to the quantity of wood that you can harvest every year without diminishing the total remaining stock/area of your forest.

In order to get a 2015 baseline and 2016-2026 projections on supply and demand of woody biomass, an analysis tool has been developed to measure this supply/demand ratio and related parameters in function of main factors influencing both the demand part and the supply part.

A 1 day meeting has been organized the 22th June 2016 with experts and concerned officers of MININFRA/Energy Division in order to present the tool and to design and agree together on best realistic figures of main factors influencing the demand part of the 3 presented scenarios (BAU, MAX and realistic Scenario 1).

A similar 1 day meeting has been held the 24th June 2016 with RNRA/DFNC technical team in order to work on main factors influencing the demand part.

This synthetic report is presenting an overview of the tool and main findings relating the 3 analyzed scenarios (BAU, MAX and realistic Scenario 1).

2. Main setting of the analysis tool

The tool has been developed and customized under Excel software in order to allow an easy share and use by stakeholder. All the cells containing formula and or data not to be changed have been locked and cannot be change without entering the password. All the cells containing data of factors/parameter influencing supply and demand are active (unlocked) and are highlighted in green, and can be completed by the user with different figures to test different scenario. One sheet called "scenario result overview" is containing all main overview results table and graphics, automatically calculated and updated in function of parameters entered by the user.

Analysis is done year per year from 2015 to 2026 and result are presented accordingly. Tool provide comparison of:

- self-designed Realistic scenario 1 with:
- Business as Usual scenario (BAU): this is the more dramatic scenario, if no effort are done to improved current situation;
- Maximum optimistic scenario (MAX): this is the scenario where all the main parameters are set at the maximal technical best situation (unrealistic considering financial/social constraints)

Calculations of supply and demand of woody biomass are done District per District, with aggregation at National level.

3. Calculation method overview

3.1. On supply side

Main principle of calculation is:

Sustainable Supply (odt-oven dry tons of wood/year) = Production Area (non-protected ha) x Productivity (odt/ha/year)

The calculation is done District per District independently for each of the 6 following stratum:

- For TIF (Tree Inside Forest = not protected plantation and forest) :
  - **Old TIF**: areas managed as BAU, not yet (re)converted, not under management;
  - **new TIF** : new plantation established as (re)conversion of old TIF, as conversion of very degraded shrubland/savanna and/or as areas newly afforested.
- For TOFs (Tree Outside Forest in non-protected Shrubland/Savanna):
  - **old TOFs**: non-protected shrubland/savanna areas managed as BAU, without specific measure of plantation/regeneration;
  - **Rehabilited TOFs**: shrubland/savanna where measures to support natural regeneration and progressive return to the initial good shrubland /savanna are taken.
- For TOFO (Tree Outside Forest Other = tree/shrubs scattered in crops and agroforestry areas)
  - **old TOFO**: agroforestry area managed as BAU

- **new TOFO**: agroforestry area where specific planting have been realized and where community are trained and supported to ensure proper management.

National Import/export from District to Districts

The import/export of woody biomass from one District to others Districts is automatically calculated by the model assuming that one District with deficit of woody biomass will do importation and one District with positive sustainable supply/demand balance will do exportation. Sum of export/import for overall District should be null.

Impact of the gap

The total deficit or positive balance at national level (positive or negative gap) is distributed to every District according to their remaining wood stock.

In case of a deficit supply/demand for a specific year, the gap is covered by over-exploitation in old TIF, in old TOFs and in old TOFO, according to the available stock (until reaching the minimum stock). The model assume that this over-exploitation lead both to a decrease of area (for 15% of the gap) and to a decrease of stock in the remaining old area (for 85% of the gap).

The model consider that New TIF/TOFs/TOFO are not affected by the over-exploitation considering that these new areas are sustainably managed (harvesting is done according to the management plan, not more, not less).

In case of positive gap supply/demand, this gap is added to the remaining stock (at maximum up to the productivity) of old TIF/TOFS/TOFO.

Effort of afforestation/reforestation/conversion

The model allows the user to provide expected figures year per year (from 2016 to 2026) on:

- new TIF area (ha) (plantation - afforestation) to be established and to be managed under sustainable plan (additional new TIF);
- old poor TIF area (ha) (old plantation reconversion) to be harvested and reconverted into new good and productive plantations managed under sustainable plan (old TIF => new TIF). In the model, the first areas of old TIF to be reconverted every year are the one affected by the decrease of area (deforested) due to over-exploitation (see point on impact above). The user has to fix the part of this deforested area that must be reconverted every year. In the provided scenario 1, this part is fixes at 100% in order to avoided decraese of total TIF area;
- very degraded TOFs area (ha) (schrubland conversion into plantation) to be converted into new good and productive plantations (potentially with native species) managed under sustainable plan (old TOFS => new TIF);
- degraded TOFs area (ha) (schrubland rehabilitation) to be rehabilitated into good schrubland/savanna according to a specific management plan and protection measures (old TOFS => new TOFS);
- equivalent forest area (ha) of new tree plantation to be established and properly managed in agroforestry/crops areas (additional new TOFO).

In order to allow comparison and summation with plantation (TIF) and/or with shrubland areas (TOFs), woody resources scattered in crops/agroforestry zones (TOFO) are expressed in equivalent ha of forest area (1 equivalent ha of TOFO = 1 theoretical ha gathering 800 trees/ha = 1 ha with around 246.27 m3/ha).

Productivity issue

Productivity of old TIF (plantation) for each District are calculated based on the remaining stock/ha by application of a conversion factors (estimated based on the National Forest Inventory results, RNRA-NFI -2015 – see sheet "conversion factor" in the excel file). Resulting average productivity estimated for 2015 is presented in table below:

Average Forest plantation Productivity (m3/ha/year)	Rwanda	8,66
	Northern Prov & kigali	5,18
	Aestern Prov	5,47
	Western Prov	16,02
	Southern Prov	6,35

In new TIF (plantation considered as well managed), the model allow the user to select the best expected productivity per Province and consider this last one as a constant over the years.

Productivity of Shrubland/Savanna (TOFS) is calculated according to SYLLA formula, based on estimated vegetation cover and pluviometry.

Productivity of 1 ha forest equivalent of old or new TOFO (agroforestry) is considers as constant and equal to 18.54 m3/ha/year.

Silviculture regime

The model allow operator to choose per Province the proportion of new plantation that will be managed according to the 2 main regimes: coppicing or high forest. Assumption provided for scenario 1 is that 77% of new plantation to be established will be under coppicing regime in order to allow the earliest provision of the biomass.

The model allows also the operator to choose rotation period for cutting and thinning and related % of stock harvested by thinning. The figures set for the provided scenarios are following:

	Rotation period of cut for Coppicing (m3/ha/an)	Rotation of Thinning for High Forest	% of stock cut by thinning in TIF - High Forest	
			1st cut	2d cut
Eastern	7	8	25%	25%
Southern	4	8		
Northern & Kigali	5	8		
Western	4	8		

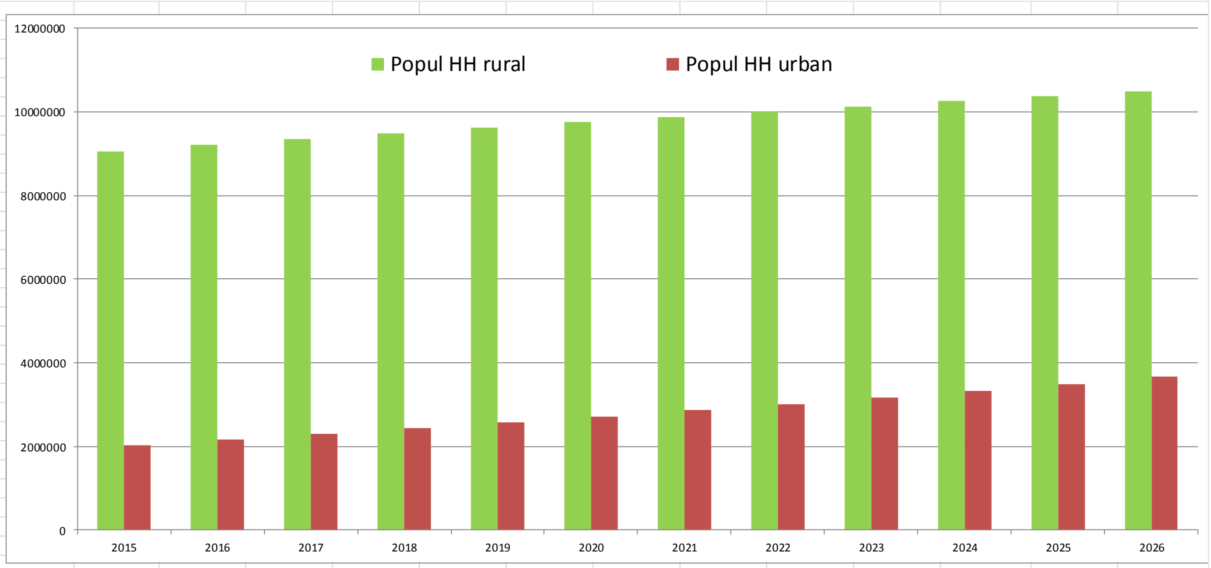
3.2. On demand side

<u>Type of products:</u> 5 types of products are considered in the model: Charcoal, FireWood, Woody Pellet, Poles & Sticks, and Timber.

<u>Population</u>

The main parameter influencing the demand is the population. In the analysis module, the medium projection scenario of the population from last census of 2012 has been applied, with following grow and urbanization rates progression:

Population Grow rate (%)	2012	2032
Average Rwanda	2,55%	1,75%
Population Urbanization rate (%)	**2012**	**2032**
Average Rwanda	16,52%	30,00%



	2009	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Popul HH rural	0	9 064 220	9 206 505	9 346 686	9 484 586	9 620 028	9 752 835	9 882 831	10 009 841	10 133 689	10 254 202	10 371 208	10 484 538
Popul HH urban	0	2 036 555	2 164 279	2 296 113	2 432 061	2 572 125	2 716 299	2 864 573	3 016 926	3 173 334	3 333 765	3 498 180	3 666 534

<u>Poles and timber Household (HH) consumption</u>

For poles and timber, the total Household (HH) Consumption is calculated as follow:

> **Total HH consumption (odt - oven dry tons/year) = Population (nbr capita) X consumption of the product (odt) per capita/year**.

The calculation is desegregated per type of product, per District, and per rural area/urban area. For timber and poles consumption 2015 baseline and 2016-2026 projection, an average has been estimated based on previous study and rough estimation of HH need. The model allows the user to choose and change figures (2015-2026) for the consumption per capita per year (oven dry ton- odt).

<u>Woody pellet HH Consumption</u>: it is calculated as follow:

> **Total HH consumption (odt - oven dry tons/year) = Population (nbr capita) X Part (%) of population using pellet (cooking energy sharing) X consumption of the product (odt)/capita/year**.

The calculation is desegregated per District and per rural area/urban area. For the 2015 baseline, the energy sharing for woody pellet is considered equal to 0%. The model allows the user to choose and change figures of 2016 -2026 for the cooking Energy sharing (%) between main source of energy (firewood, charcoal, woody pellet, LPG, Biogas, electric/solar, other).

The consumption per capita per year of HH using woody pellets is considered as a constant with a value of 95 kg/capita/year in rural area and 190 kg/capita/year in urban area (assuming the use of the same ICS gasifier for pellets by every HH).

<u>FireWood and Charcoal HH consumption</u>

The consumption calculation is desegregated per type of product (charcoal/firewood), per District, per rural area/urban area and additionally per category of HH using ICS. Six following categories of HH are differentiated in the model:

- HH using charcoal basic stove
- HH using charcoal improved stove (canamake, Tear 1)
- HH using firewood and basic 3-stones
- HH using improved firewood stove (canarumwe - improved mud stove, Tear 1)
- HH using local made gasifier cooking stove (for firewood), Tear 2
- HH using imported high efficient gasifier for firewood, Tear 3

So the total Household (HH) Consumption of charcoal or firewood (odt/capita/year) per category of HH is calculated as follow:

> **Total HH consumption (odt/year/category) = Population (nbr capita) X Part (%) of population using charcoal/firewood X baseline consumption (odt/capita/year) of a HH using basic charcoal stove/3 stones X Part (%) of HH charcoal/firewood consumers using ICS X (100 – energy saving factor of the ICS expressed in %)**

The table below presents the energy saving factors (quantity of saved wood, express in % of the total quantity needed for equivalent cooking with 3 stones or basic charcoal stove) considered in the model for each category of ICS:

	Firewood ICS				**Charcoal ICS**	
	3 stones	Tear 1 (canarumwe)	Tear 2 Local Gazifier	Tear 3 – Imported High efficient Gazifier	Basic stove	Tear 1 (canamake)
Wood saving factor	**0%**	**23%**	**40%**	**57%**	**0%**	**23%**
Energetic Efficiency		15-25%	25-35%	35-45%		

The model allows the user to choose and change figures of 2015 -2026 for the following parameters:

- the cooking Energy sharing (% of population using it) between main source of energy (firewood, charcoal, woody pellet, LPG, Biogas, electric/solar, other);
- the penetration per type/category of ICS (= % of firewood/charcoal consumers population using the concerned ICS)
- the baseline consumption/capita/year of a HH using basic charcoal stove/3 stones.

Commercial Consumption (Resto & Hotel)

For the commercial consumption, the same method used in WISDOM 2012 has been applied as follow:

Commercial consumption (odt/year) = Ratio (%) X Urban Consumption

For 2015, the ratio of 10% of the Wisdom study has been applied. For 2016-2026, the user can choose the ration he wants apply.

The provided figures are rough estimation and more accurate data should be got by the organization of specific surveys on Hotel &Resto consumption (to be planned in 2016-20017)

Prisons, Schools and Military/Refugee camps consumption

The same method as for HH consumption is used. The population to be considered in the calculation is the one being resident for the major part of the year in these institutions. For the 2015 baseline, population has been estimated based on Wisdom 2012 study, providing only a rough estimation. For 2016-2026 projection, the module user can apply and expansion factor to made projection of this residential population.

The consumption/capita/year in each institution is based on average baseline of HH consumption in rural area, multiplied by a correction factor chosen by the module user. Additionally the user has to choose for each institution the sharing cooking energy ratio (%) and the penetration of each type of ICS (%) (per year, from 2015 to 2026).

More accurate data can be made available by the organization of data collection (survey) in concerned institution (activity planned and to be done by DFNC in the context of Forestry Monitoring and Evaluation System – FMES data collection).

Tea and brick factories consumption

For tea and brick factories, baseline consumption of 2015 is based on Wisdom 2012 study, providing rough estimation. More accurate data will be made available by the organization of data collection (survey) in concerned institution (activity to be done by DFNC in the context of Forestry Monitoring and Evaluation System –FMES data collection). For 2016-2026 the module user can apply an increase/decrease factor.

3.3. 2015 Baseline of forest cover

One of the main parameter of the supply side is the production (non-protected) forest area of the 3 main stratums: (1) TIF plantation, (2) TOFs schrubland and (3) TOFO agroforestry.

The last detailed and reliable forest cover map has been produced based on high resolution Orto-photo of 2008-2009.

During the National Forest Inventory (NFI -2015) process, more than 1.700 sample units (SU) have been established in TIF and TOFs in order to measure main forest parameters. The initial sampling design that was used to locate randomly these SUs was based on the 2009 forest cover map. By doing the first assessment in the field, it has been found that a significant part of the SUs that was initially (in 2009) a forest area (TIF or TOFS) is now shifted to other non-forest land-use (mainly agriculture and settlement). This shift corresponds to the decrease of area from 2009 to 2015 of plantation (TIF) and shrubland (TOFs) initially mapped, as showed in following table.

	% of SUs initially in forest cover area of 2009, shifted to other land use in 2015	% of SUs initially in forest cover area of 2009, shifted to crops/agroforestry area in 2015	Total no—protected area Rwanda (ha)	
			2009	**2015**
TIF - Plantation	**9.7%**	**3.85%**	**285 242**	**=>257 624**
TOFs- Schrublands	**25.8%**	**18.36%**	**192 365**	**=>142 730**

But this decrease is not capturing new afforestation that have been potentially made in public and private areas that was not included in 2009 forest cover. In order to get a very accurate 2015/2016 baseline, it was mandatory to conduct a new forest cover mapping exercise using similar high resolution images. This new mapping is costly and has not been realized until now, but still remain a priority as well for the updating of the main national indicators than for the adequate design of forest management plans.

Considering the above point, in order to get the most accurate estimation of 2015 baseline forest cover for plantations (TIF) and shrublands (TOFS), following method has been used:

- (1) The forest cover of 2008-2009 has been taken as the initial starting point;
- (2) The 2009-2015 decrease of TIF and TOFs area has been estimated District per District, based on average results of NFI sample unit assessment (as described above), and have been subtract from the 2009 initial forest cover;
- (3) The afforestation realized (from 2009 to 2015) in new area that was not in 2009 forest cover have been estimated à 8.100 ha and have been added.
- So the 2015 baseline = (1) – (2) + (3).

For crops and agroforestry 2015 baseline area (TOFO), the method used is the following:

- TOFO area = Total Land area – Total forest area 2009 – protected area 2015 – river and marshlands area 2015 – urban area 2015 + shift 2009-2015.
- Shift 2009-2015 = The part of the 2009-2015 decrease of TIF and TOFs area that has been shifted to agriculture/agroforestry. This shift has been estimated District per District, based on average results of NFI sample unit assessment.

Considering these methods, the 2015 baseline forest cover is set as follow:

Production areas (no protected) in 2015 (ha)	
TIF – Plantation (ha)	**257 624**
TOFs- Schrublands & Savana (ha)	**142 730**
TOFO - lands available for Crops and agroforestry in ha (average tree density of 25 tr/ha, according to NFI 2015)	**1 503 377**
TOFO – wood resources of TOFO expressed in forest equivalent ha (theoretical tree density of 800 tr/ha)	**46 379**
TOFO – wood resources of TOFO expressed in equivalent standard agroforestry ha (standard tree density of 250 tr/ha)	**150 338**

4. Main factors of changes of 3 presented scenarios

The following tables of chapt 4.1 and 4.2 are presenting main factors of change having a significant impact on supply and demand of woody biomass. Different figures have been set with MININFRA and RNRA for the 3 proposed scenarios.

One of the parameter having a very huge impact on the total demand in charcoal and firewood is the 2015 baseline consumption of HH using basic charcoal stove/ 3-stones. According to different sources of literature from Rwanda and neighboring countries, data differ significantly. For instance, figures on average firewood consumption in kg per capita and per year vary from 330 kg/capita/year to 600 kg/capita/year. Until now there is no specific survey and measurement campaign that have been organized at national level with a solid statistical approach. After discussions with MININFRA technical team, following assumptions have been set for each of the 3 scenario , considering that the resources is becoming rare:

BAU	Scen1 (Realistic)	MAX
From different study on cooking efficiency + wisdom survey Charcoal: 170 kg/capita/year Firewood: 400 kg/capita/year	Total average from Wisdom 2012 report Charcoal: 150 kg/capita/year Firewood: 350 kg/capita/year	Total average from Wisdom 2012 report Charcoal: 150 kg/capita/year Firewood: 350 kg/capita/year

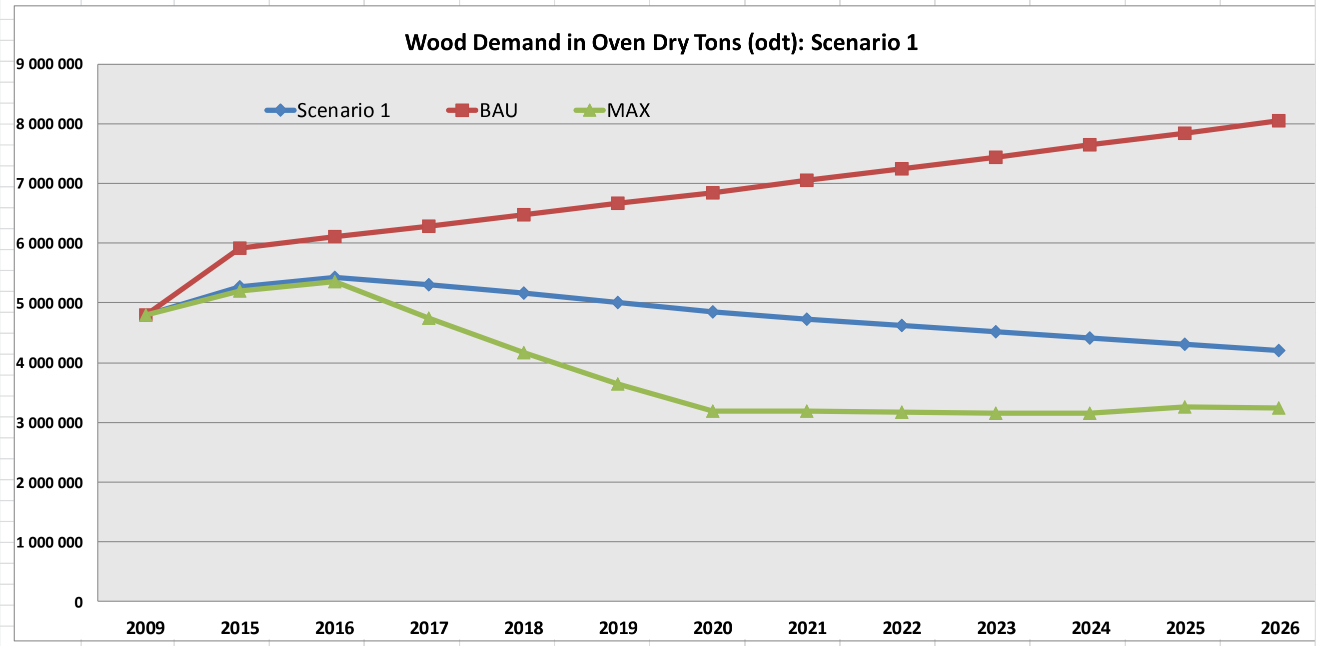
4.1. Main factors of change of Demand side

Demand parameters	BAU scenario	Scenario I (Realistic)	MAX scenario
% of **<u>improved « green » charcoal</u>** (compare to total consumption)	<u>2020:</u> 1% <u>2026:</u> 1%	<u>2020:</u> 80% <u>2026:</u> 100%	<u>2020:</u> 80% <u>2026:</u> 100%
<u>Penetration of ICS in HH</u>	2020 Charcoal: 53 % Firewood: 52% 2026 Charcoal: 53 % Firewood: 52%	2020 Charcoal:85 % Firewood:70% 2026 Charcoal:100 % Firewood:100%	2020 Charcoal:92 % Firewood:100% 2026 Charcoal:100 % Firewood:100%
<u>Share of energy used by HH</u>	**<u>From 2016- to 2026:</u>** FireWood: 82,5% Charcoal: 16% Pellets: 0% LPG: 0.2% Biogas: 0.3% other: 1%	<u>**2020**</u> <u>**2026**</u> FireWood: 76% 68% Charcoal: 15% 11% Pellets: 3,4% 10.6% LPG: 3.4% 6.7% Biogas: 1% 2% other: 2% 2%	<u>**2020**</u> <u>**2026**</u> FireWood: 61% 53% Charcoal: 7% 4% Pellets: 18% 23,3% LPG: 7% 10% Biogas: 2,8% 4% other: 1% 1%
<u>Commercial consumption</u> in % of HH urban consumption	**<u>From 2016- to 2026:</u>** FireWood: 7% Charcoal: 10% Pellets: 0%	<u>**2020**</u> <u>**2026**</u> FireWood: 3% 1% Charcoal: 7% 3% Pellets: 0% 0%	<u>**2020**</u> <u>**2026**</u> FireWood: 2% 0% Charcoal: 5% 2% Pellets: 2% 3%

4.2. Main factors of change of Supply side

Main <u>Supply</u> parameters	BAU	Scen 1 (Realistic)	MAX
TIF (plantation) **<u>area reforested /converted and managed under Sustainable Management Plan</u>** until 2026 (total from 2016 to 2026)	41.000 ha (Coppicing: 76,8%)	206.740 ha (Coppicing: 76,6%)	267.000 ha (Coppicing: 87,8%)
Productivity of newly planted/converted areas	13.3 m3/ha/year	16,7 m3/ha/year	17.3 m3/ha/year
<u>Tree plantation in TOFO area</u> (agroforestry) until 2026 (in equivalent forest ha) (total from 2016 to 2026)	9.266 ha	46.332 ha	92.665 ha

5. Main findings of demand projection

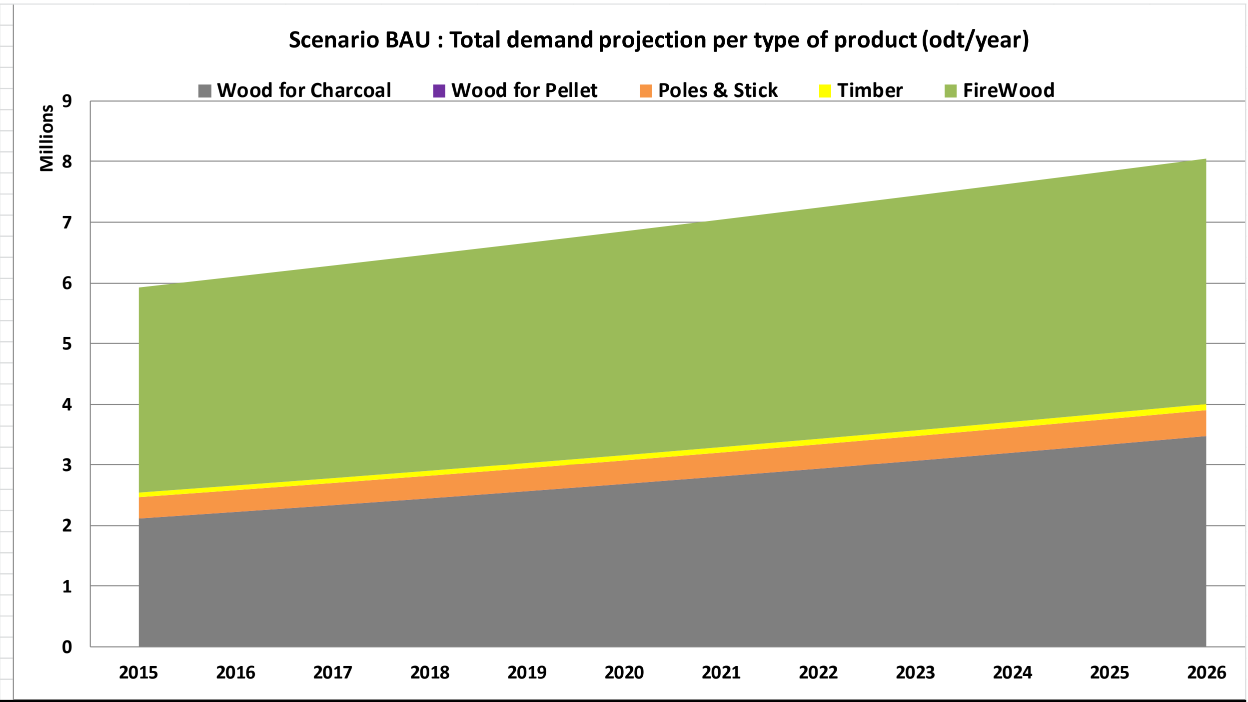


	2009	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Scenario 1	4 801 000	5 266 330	5 419 753	5 295 382	5 157 688	5 008 682	4 850 469	4 733 386	4 620 519	4 511 275	4 405 208	4 301 991	4 201 390
BAU	4 801 000	5 922 900	6 103 513	6 286 064	6 471 356	6 659 310	6 849 840	7 043 922	7 240 498	7 439 468	7 640 728	7 844 168	8 049 672
MAX	4 801 000	5 207 384	5 356 669	4 744 575	4 171 940	3 651 027	3 188 924	3 182 039	3 172 646	3 160 829	3 146 682	3 250 021	3 239 869

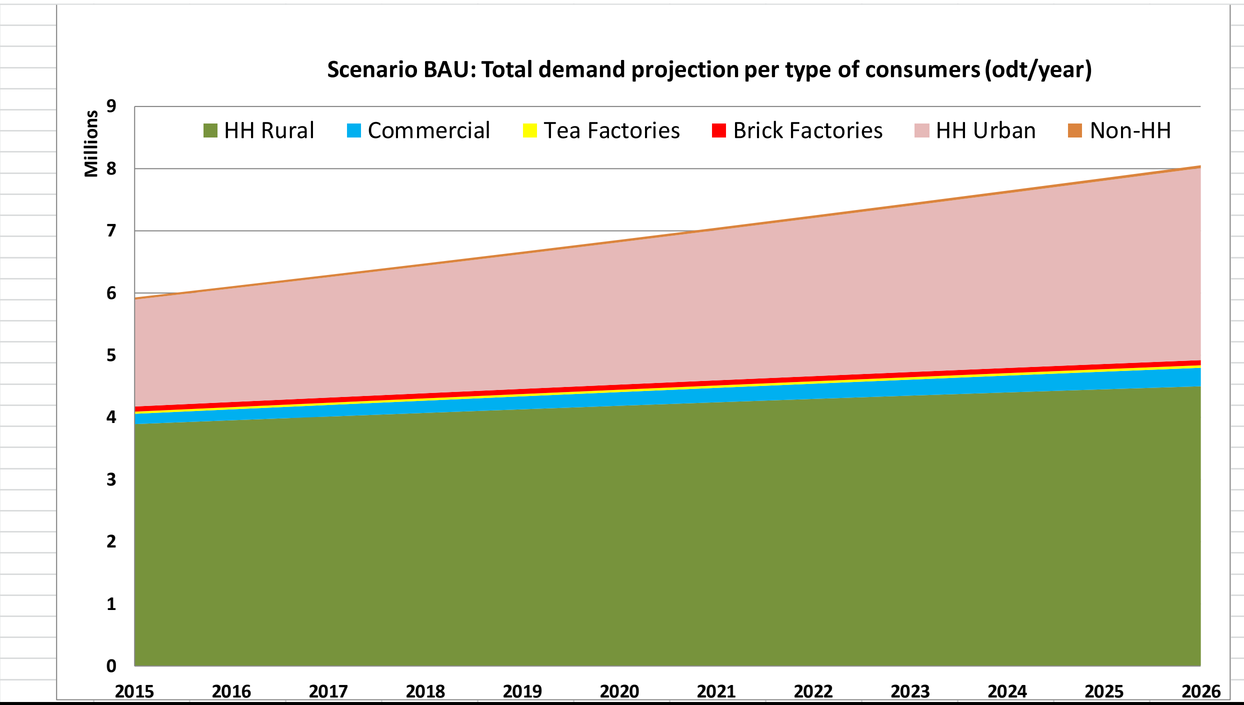
According to the more pessimistic BAU scenario, the demand of 2015 around 6 M odt (million oven dry tons of wood) per year, while this total around 5.2 M odt for the realistic and maximum scenario.

The increasing curve of BAU scenario is reflecting the increase of the population. By applying urgently an ambitious but realistic action plan according to the target set in the Scenario 1, the demand curve can be improved in order to reach a total demand of 4.2 M in 2026.

As presented in the 2 graphics and 2tables below, the main part of the 2015 demand consist in firewood for rural HH and in wood for charcoal for urban HH.



Code	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Wood for Cha	36%	36%	37%	38%	38%	39%	40%	41%	41%	42%	42%	43%
FireWood	57%	56%	56%	55%	55%	54%	53%	53%	52%	51%	51%	50%
Wood for Pell	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Poles & Stick	6%	6%	6%	6%	6%	6%	6%	6%	5%	5%	5%	5%
Timber	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
HH Rural	66%	65%	64%	63%	62%	61%	60%	59%	58%	58%	57%	56%
HH Urban	29%	30%	31%	32%	33%	33%	34%	35%	36%	37%	38%	38%
Commercial	2,8%	2,9%	3,0%	3,1%	3,1%	3,2%	3,3%	3,4%	3,5%	3,5%	3,6%	3,7%
Tea Factories	0,6%	0,6%	0,6%	0,6%	0,6%	0,6%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%
Brick Factori	1,4%	1,4%	1,3%	1,3%	1,2%	1,2%	1,2%	1,1%	1,1%	1,1%	1,1%	1,0%
Non-HH	0,6%	0,6%	0,6%	0,6%	0,6%	0,6%	0,6%	0,6%	0,6%	0,6%	0,6%	0,6%

So the 4 first prior factors of change to be implemented are:

- Replacing a part of the charcoal demand of urban area by LPG. This solution is very costly (especially for tax exemption, see chapter table of cost below) for the government and remain on the dependence of international market. This solution is not providing significant additional value/contribution to GDP and is not providing a huge impact on employment. This measure cannot be applied to replace all the charcoal demand.

- Replacing a part of the charcoal demand of urban and rural areas by woody pellets (combined with the use of high efficient gasifier cooking stove). This solution is technically the best solution but will request a time of adaptation and investment to shift to this value chain. This value chain is highly efficient, allows the best valorization of residue of wood industry and is providing additional value and employment based on a renewable energy under the control of Rwanda.

- Radical and quick shifting from traditional charcoal to "improved green charcoal"[1]. For this issue traditional charcoal must be taxed (30% VAT will provide income for government which will compensate partially the investment cost) for coming years before being totally forbidden in 3-4 years. This period will serve for the transition to green charcoal (in anyway a part of charcoal demand will remain), requesting the establishment and support/training of well recognized charcoal making cooperatives, and the setting-up of a traceability system.

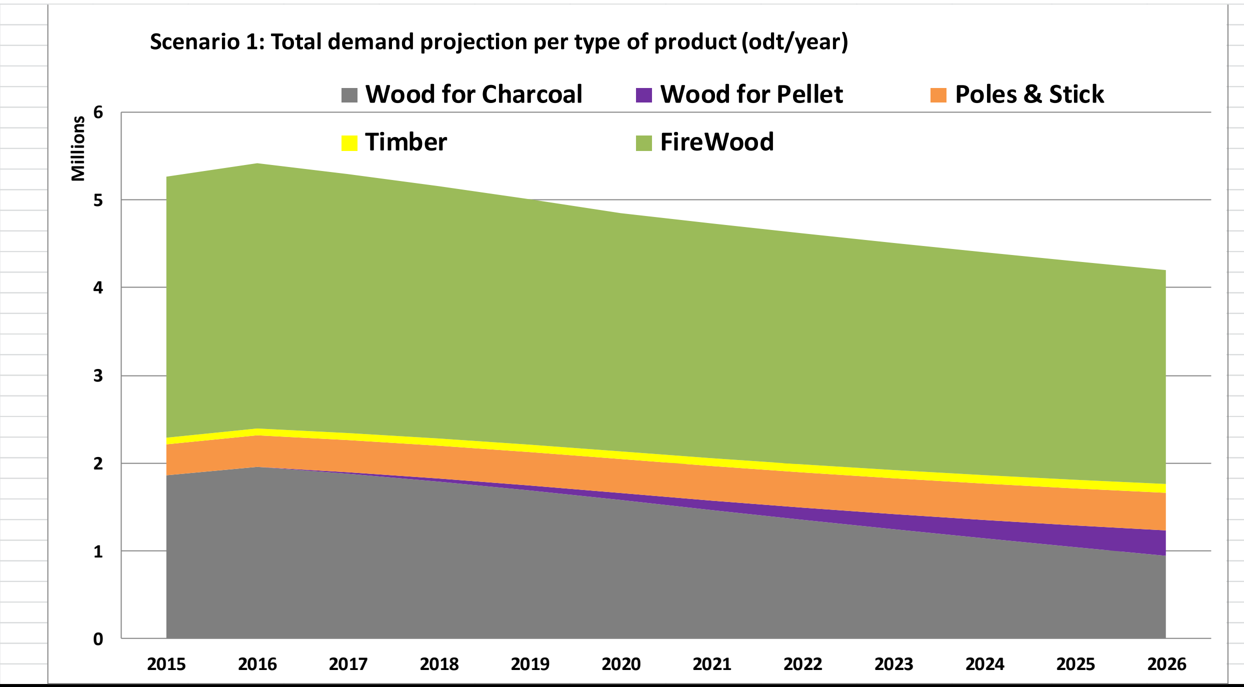
- Ensuring the full penetration of high efficient ICS in rural area (locally made firewood gasifier).

The secondary measures to be taken are:

- Biogas dissemination in rural area;
- Control of brick factories to reduce wood consumption;
- Improved full penetration of ICS, woody pellet and LPG in hotels, restaurants, school, prisons, military/refugee camp, etc…

By applying these measures according to target set in the scenario1 (see chapt 4.1 above), the following projection can be expected:

[1] Improved green charcoal is a charcoal produced with improved high efficient kilns (at laest 16-18%) and using wood coming from forest harvested according to a sustainable management plan.



Code	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Wood for Cha	35%	36%	36%	35%	34%	33%	31%	29%	28%	26%	24%	22%
FireWood	56%	56%	56%	56%	56%	56%	57%	57%	57%	58%	58%	58%
Wood for Pell	0,0%	0,0%	0,3%	0,7%	1,1%	1,6%	2,3%	3,0%	3,8%	4,7%	5,8%	6,9%
Poles & Stick	6,7%	6,6%	6,9%	7,2%	7,6%	8,0%	8,3%	8,7%	9,1%	9,4%	9,8%	10,2%
Timber	1,4%	1,4%	1,5%	1,6%	1,7%	1,8%	1,9%	2,0%	2,1%	2,2%	2,3%	2,4%

The table below is presenting the synthesis of the estimation of the cost for the implementation of the 3 scenario from 2016 to 2026.

	Total Cost (Euros) 2016-2026			Scenario 1 Cost	
Items	**Scenario 1**	**BAU**	**Max**	**Gouvnmnt/ Donors**	**Private (investors & farmers)**
Investement	**168 745 579**	**5 367 881**	**343 219 881**	**65 512 354**	**103 233 224**
Green charcoal value chain support	6 732 968	153 793	4 781 328	4 087 471	2 645 497
ICS penetration	37 542 603	4 348 629	56 093 305	27 196 259	10 346 344
Woody pellets penetration	79 081 842	0	197 225 157	187 500	78 894 342
LPG penetration	17 802 056	225 140	26 770 782	13 351 542	4 450 514
Biogas penetration	27 586 111	640 319	58 349 310	20 689 583	6 896 528
TAX schift cost	**240 888 302**	**147 776 048**	**500 134 263**	**240 888 302**	**0**
Tax to be applied on Charcoal:	Tax 30% => income: -33 423 267	Tax exemption=> cost 136 719 912	Tax 30%=> income -16 901 656	-33 423 267	0
Tax exemption on pellets (cost of exemption)	56 803 926	0	141 867 113	56 803 926	0
Tax exemption on LPG (cost of exemption)	217 507 643	11 056 136	375 168 806	217 507 643	0

According to the following table, the green charcoal value chain improvement, the ICS penetration and the woody pellet production are the factors of change having the best cost efficiency, while LPG penetration is very costly. The biogas dissemination is also costly and has a limited impact for technical reasons.

Main factors of change	Total Cost Euros 2016-2026 (investement + tax shift cost)			Impact on total demand of 2026 if not implemented	Cost by % of impact
	Total	Gouvernement/donors	Private/investors		
Green charcoal value chain	-26 690 299	**-29 335 796**	2 645 497	**+10,0%**	-2 945 927
ICS penetration	37 542 603	**27 196 259**	10 346 344	**+17,7%**	1 538 365
Charcoal replacement by woody pellets	135 885 768	**56 991 426**	78 894 342	**+14,9%**	3 834 601
Charcoal replacement by LPG	235 309 698	**230 859 184**	4 450 514	**+13,6%**	16 959 122
Biogas dissemination	27 586 111	**20 689 583**	6 896 528	**+4,0%**	5 142 244

6. Status of forests resources and efforts to be made on supply side

TIF – Production plantation

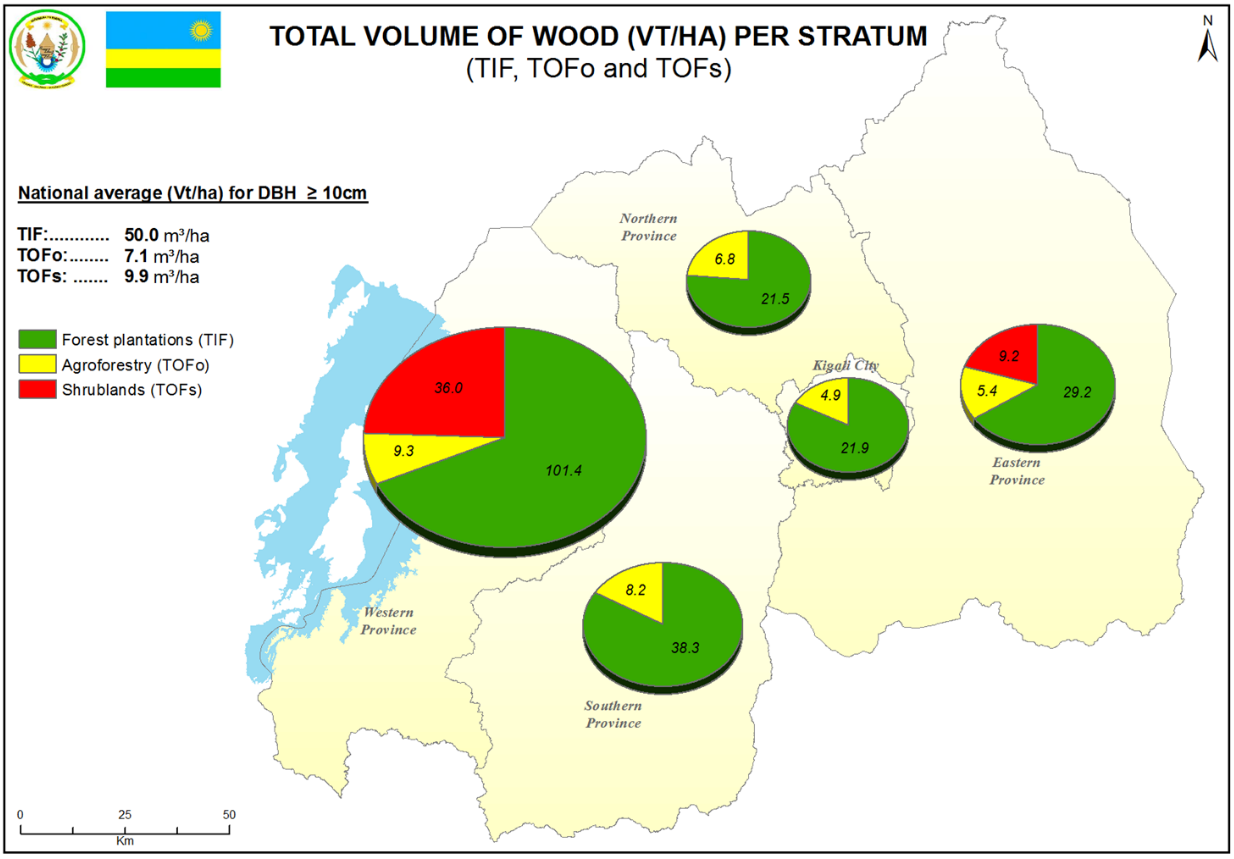
In 2015, the 257 624 ha of TIF were contributing to 70% of the total woody biomass sustainable supply. However, according to NFI report findings, the remaining stock of wood per ha in TIF plantation is dramatically low, with an average of 50 m3/ha (ideal standard should be between 100 and 300 m3/ha).

The private individual area, representing around 67% of the total TIF plantation are particularly affected with an average of only 17 m3/ha. These private areas are totally over-exploited (harvested in average every 2-3 years) and are not managed according to adequate silviculture prescriptions of a management plan. In same time these forest are very old (83% have been established more than 20 years ago). The consequence is the very low stock and the very low productivity of the major part of production plantation.

State forests (28% of TIF plantation) and private institutional forests (3% of TIF plantation) such as tea factories forests are the only one where the stock reach 100 m3/ha. But still an important part of these state forests that have been preserved (mainly in Western and a part of the Southern Provinces) are becoming old and are underproductive.

So it is urgent and important to invest in the conversion of this old and no productive area into high productive forest to be sustainably managed trough well design management plans.

To guaranty the good productivity of forest to be newly established, a specific attention must be done on the provision of good genetic quality tree seeds. This measure can improved the average productivity of newly established forest from 13.3 to 17.3 m3/ha/an.



TOFs - Shrublands and savanna

With an average stock of only 9.8m3/ha (main part being already very degraded and over-exploited) and an very low productivity estimated to 0.77 m3/ha/year, the 142 730 ha of no-protected schrubland & Savanna are contributing only to 3% of the total sustainable supply of woody biomass of Rwanda.

In addition, these degraded TOFs are in many cases seen by local authority as potential area to be converted into agriculture and or settlement. The only way to ensure a more significant participation of these TOFs area to the supply of woody biomass is to convert a part of the degraded TOFs into production plantation well managed with high productive species (native and/or exotic).

If these TOFs area are not converted into production plantation, they must be put under protection and rehabilitated into good schrubland/savanna for biodiversity purpose. In this case these TOFs will not contribute anymore to the woody biomass supply. If these TOFs are not convert into TIF or not protected, these area will be quickly degraded and shifted to another land use such as agriculture or settlement.

TOFO – Tree resources in crops/agroforestry areas

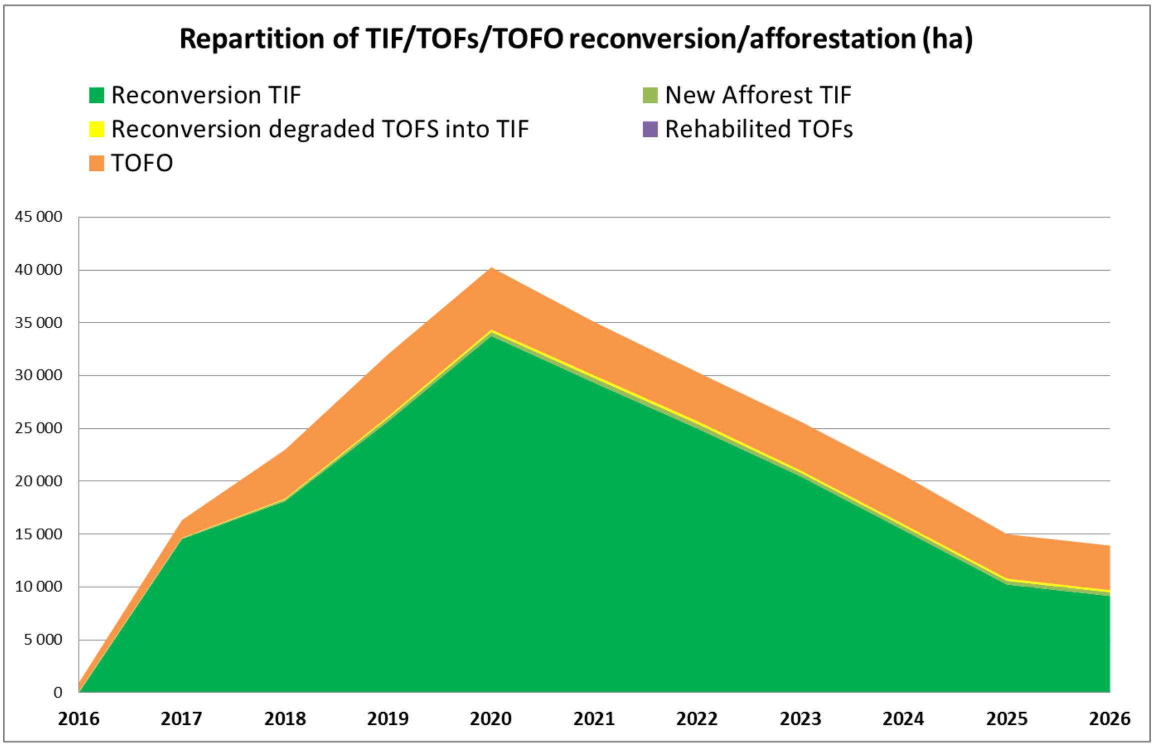
With an average wood stock of 7 m3/ha, the 1 503 377 ha of land for crops and agroforestry are contributing to 27 % of the total sustainable supply of woody biomass of Rwanda. These TOFO areas present an average tree density of 25 tr/ha, while standard for pure agroforestry are considered between 150 and 250 tr/ha. So there is a big room to ensure the development of agroforestry in TOFO areas and to increase the average of tree density to 50-100 tree/ha. This agroforestry development must use the Farmer Field School (FFS) approach and must be coordinated with RAB/Minagri.

Overall efforts

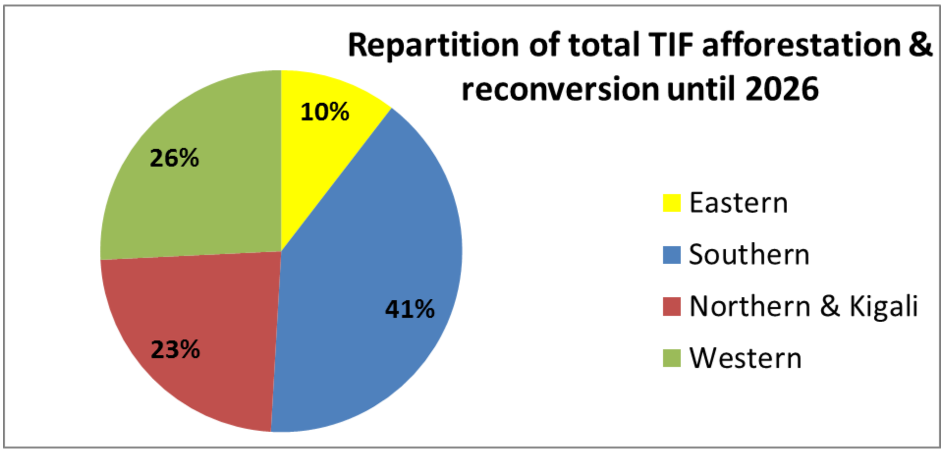
According to the parameter set for the scenario 1, the main strategic efforts to be done to improve the supply of woody biomass are:

- The reconversion of old TIF plantation into high productive TIF plantation managed under sustainable management plan
- The increase of tree in TOFO area
- The provision of high genetic tree seeds/clones in order to ensure the high productivity of newly planted forest.

The total effort to be made in term of new afforestation/reconversion/conversion in TIF, TOFs and TOFO are the following:



	Scenario 1	BAU	MAX
Total TIF	206 740	41 489	265 367
Reconversion TIF (ha)	201 667	38 226	227 850
New Afforest TIF (ha)	3 263	3 263	14 892
Reconversion degraded TOFS into TIF (ha)	1 810	0	22 626
Rehabilited TOFs (ha)	0	0	10 438
TOFO (equivalent ha)	46 332	9 266	92 665
TOTAL	253 072	50 756	368 470



Cost of efforts on supply side

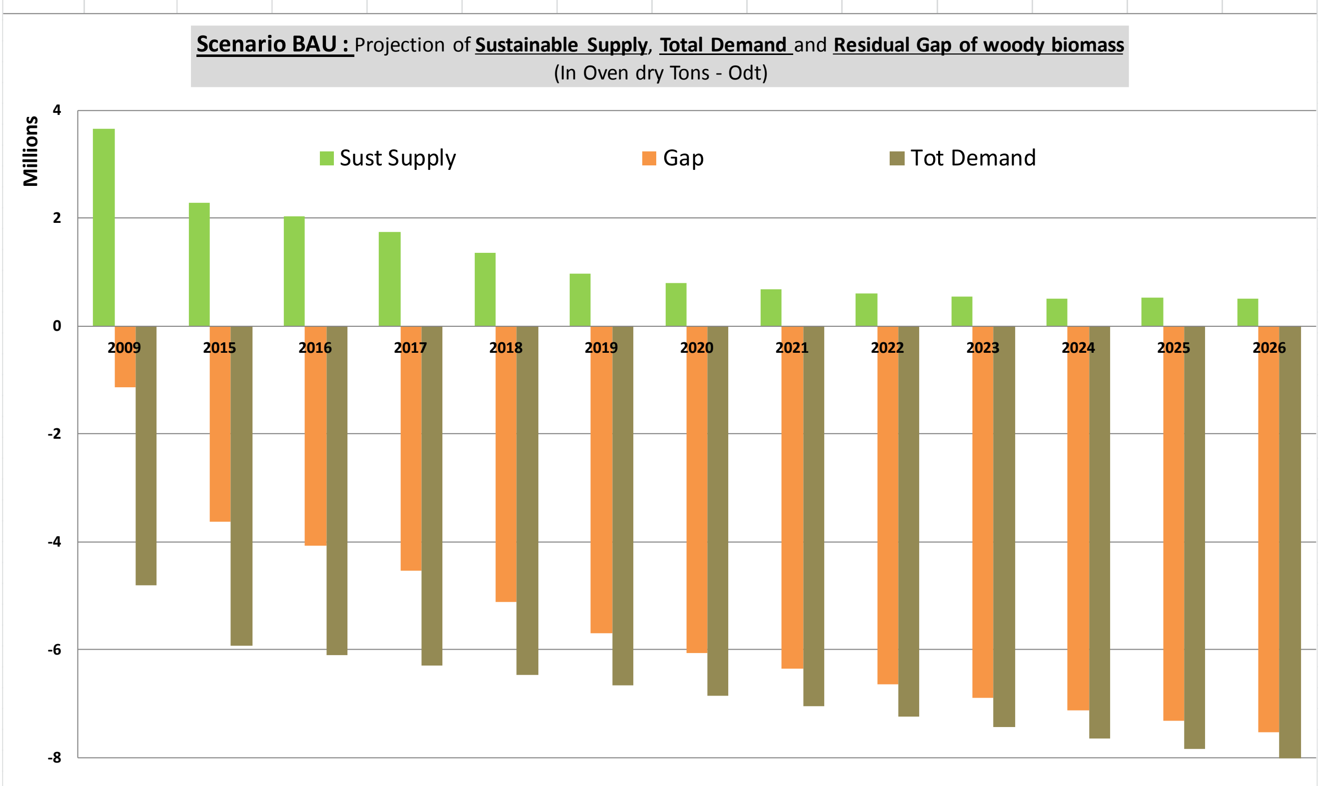
The synthesis of the estimation of the total cost from 2016 to 2026 is as follow:

	Total Cost (Euros) 2016-2026			Scenario 1 Cost	
Items	Scenario 1	BAU	Max	Gouvnmnt/ Donors	Private (investors & farmers)
Supply investement cost	**215 118 540**	**40 833 624**	**286 067 373**	**81 923 131**	**133 195 408**
Design and M&E of DFMP/SFMP of private and public plantation	39 549 148	8 456 865	50 412 839	28 099 005	11 450 143
Afforestation/conversion in private/public plantation	153 723 163	30 260 240	189 177 133	40 366 490	113 356 674
Provision of High quality seed	11 263 636	0	15 199 949	5 631 818	5 631 818
Shrubland/Savana Rehabilitation	0	0	10 112 267	0	0
Developement of agroforestry through FFS	8 590 302	1 718 060	17 180 604	5 833 529	2 756 773
Tree plantation & management on road/river/lake side	1 992 290	398 458	3 984 580	1 992 290	0

According to the following table, the provision of high genetic quality tree seed and the incraese of tree resources in agroforestry areas are the factors of change having the best cost efficiency.

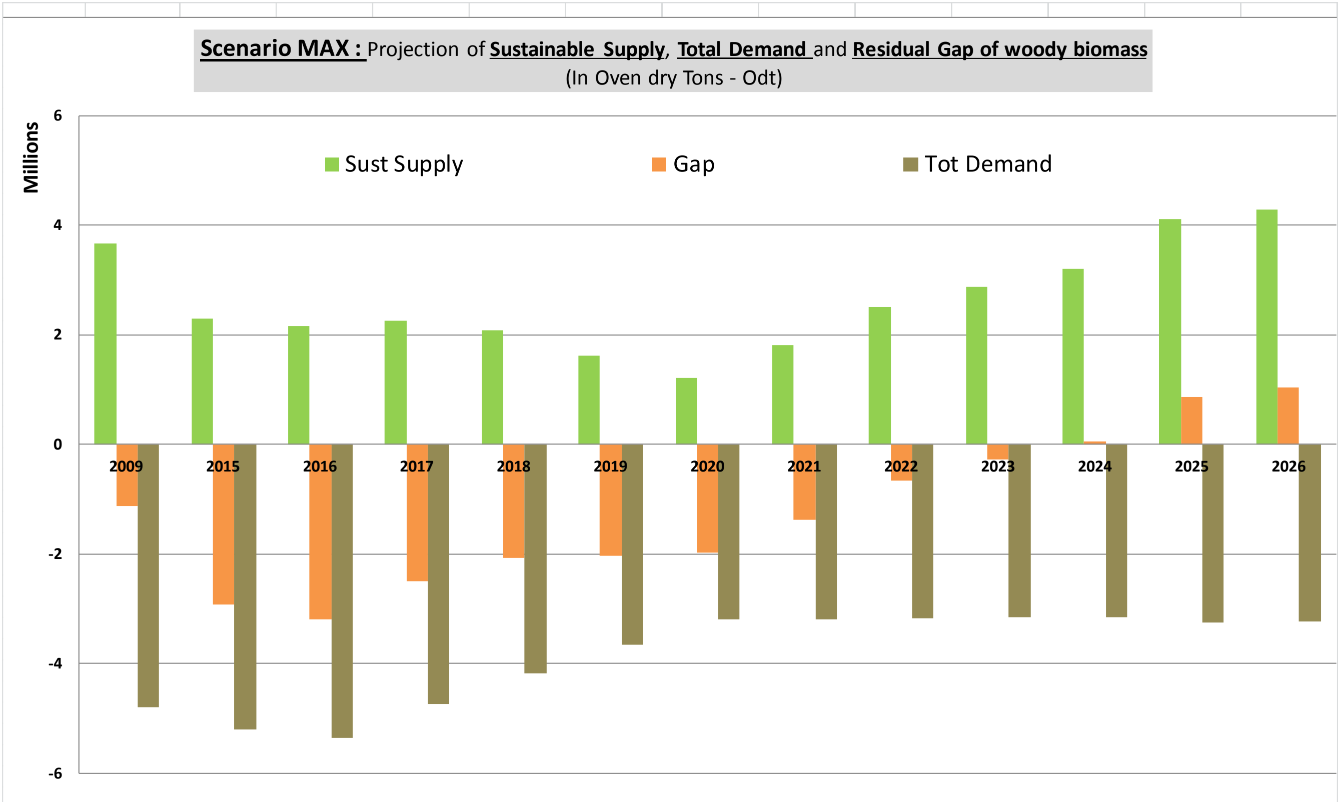
Main factors of change	Total Cost Euros 2016-2026			Impact on total supply of 2026 if not implemented	Cost by % of impact
	Total	Gouvrenemnt/ donors	Private/inves tors		
Afforestation/conversion in TIF and Design & implementation of forest management	193 272 311	68 465 494	124 806 817	-64,9%	1 055 166
Tree resources increase in TOFO areas	10 582 592	7 825 819	2 756 773	-9,1%	859 075
Provision of high genetic quality tree seeds/clones	11 263 636	5 631 818	5 631 818	-12,2%	460 581

7. Main findings on Supply/demand balance of woody biomass



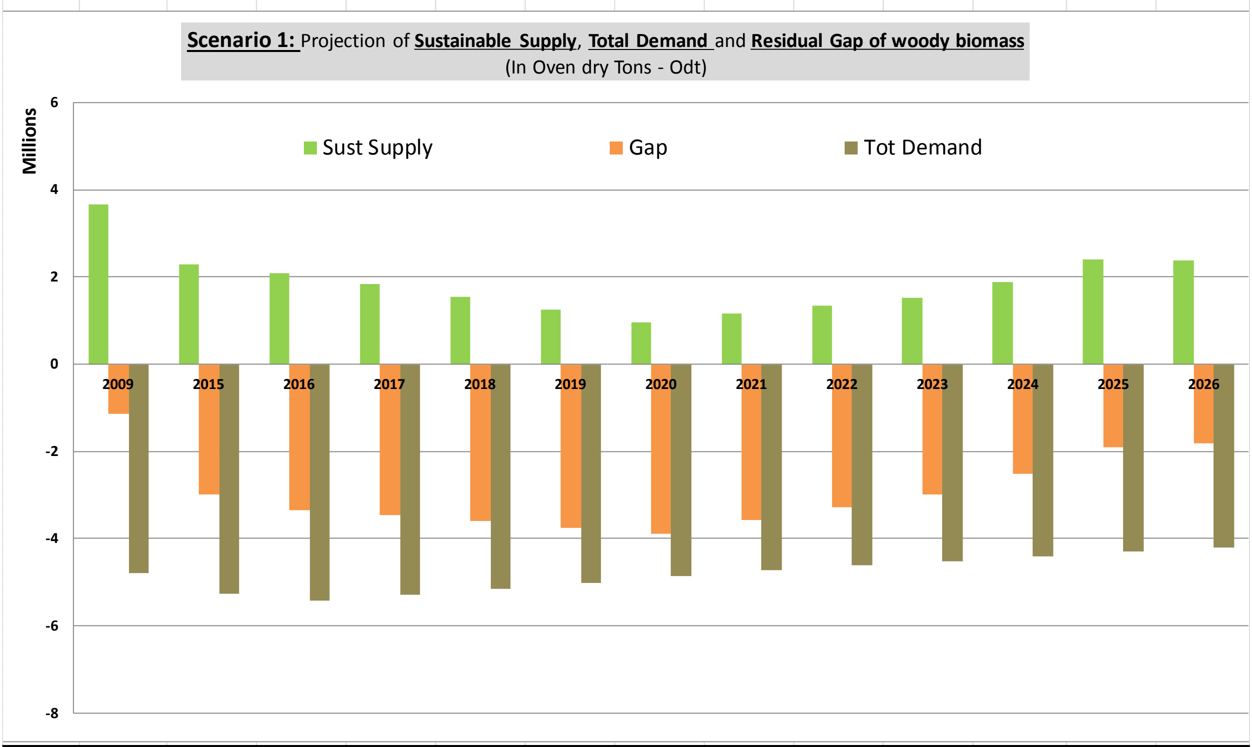
Code	2009	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Sust Supply	3 671 063	2 289 600	2 039 807	1 752 988	1 360 116	973 945	796 900	691 076	598 229	541 844	511 504	526 786	517 705
Tot Demand	-4 801 000	-5 922 900	-6 103 513	-6 286 064	-6 471 356	-6 659 310	-6 849 840	-7 043 922	-7 240 498	-7 439 468	-7 640 728	-7 844 168	-8 049 672
Gap	-1 129 937	-3 633 300	-4 063 706	-4 533 076	-5 111 240	-5 685 365	-6 052 940	-6 352 846	-6 642 268	-6 897 624	-7 129 224	-7 317 382	-7 531 967

According to BAU scenario with a high demand pressure, the important and dramatically increasing gap between supply and demand will lead to over-exploitation of the remaining stock already very low. This over-exploitation will cause both a decraese of TIF/TOFS area and a decraese of stock and productivity in remaining TIF/TOFS/TOFO areas. This is why the sustainable supply will decraese quickly until 2020 by reaching the minimum around 0.5 M odt.



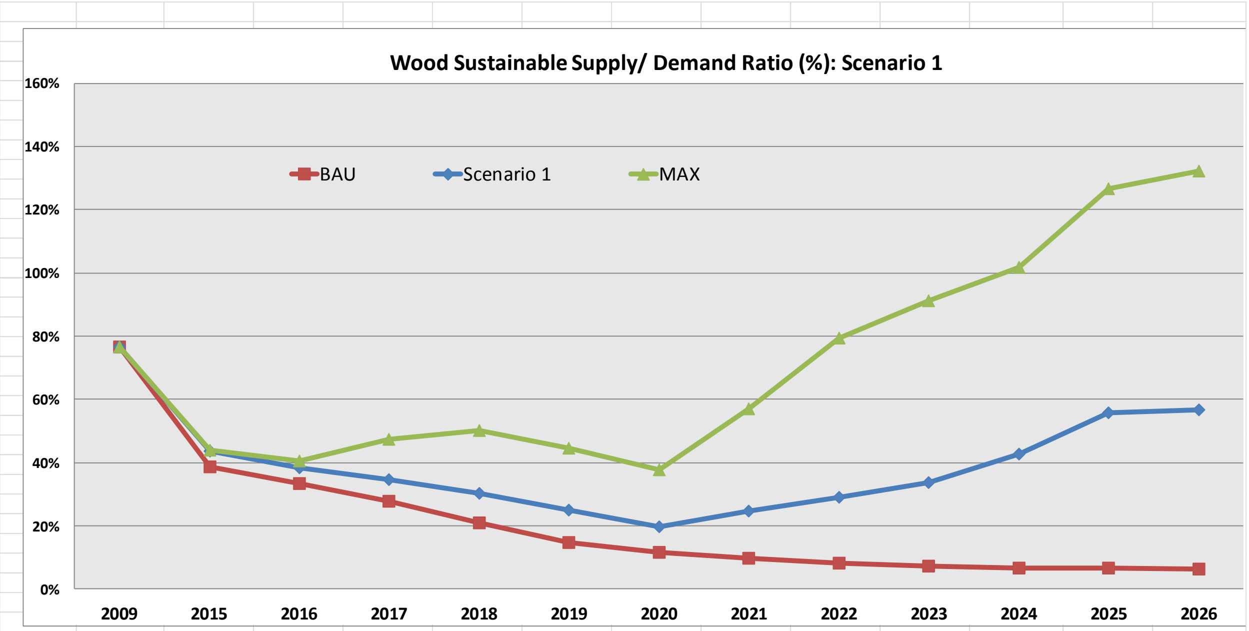
Code	2009	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Sust Supply	3 671 063	2 289 600	2 171 157	2 253 511	2 094 260	1 624 567	1 206 584	1 810 486	2 515 362	2 883 378	3 198 518	4 116 381	4 282 773
Tot Demand	-4 801 000	-5 207 384	-5 356 669	-4 744 575	-4 171 940	-3 651 027	-3 188 924	-3 182 039	-3 172 646	-3 160 829	-3 146 682	-3 250 021	-3 239 869
Gap	-1 129 937	-2 917 785	-3 185 511	-2 491 064	-2 077 680	-2 026 460	-1 982 340	-1 371 553	-657 283	-277 451	51 836	866 360	1 042 904
Gap of MAX Scen	-1 129 937	-2 917 785	-3 185 511	-2 491 064	-2 077 680	-2 026 460	-1 982 340	-1 371 553	-657 283	-277 451	51 836	866 360	1 042 904

According to the Max scenario, the important effort to decrease drastically the demand and to ensure a full supply of woody biomass from TIF/TOFS/TOFO areas could theoretically lead to a positive gap from only 2025. As all new afforestation/reconversion will impact the supply side only after a minimum of 4-7 years (a forest planted in 2016 in coppicing regime will provide the first harvesting only in 2020-2023), the gap will remain significant until 2020.



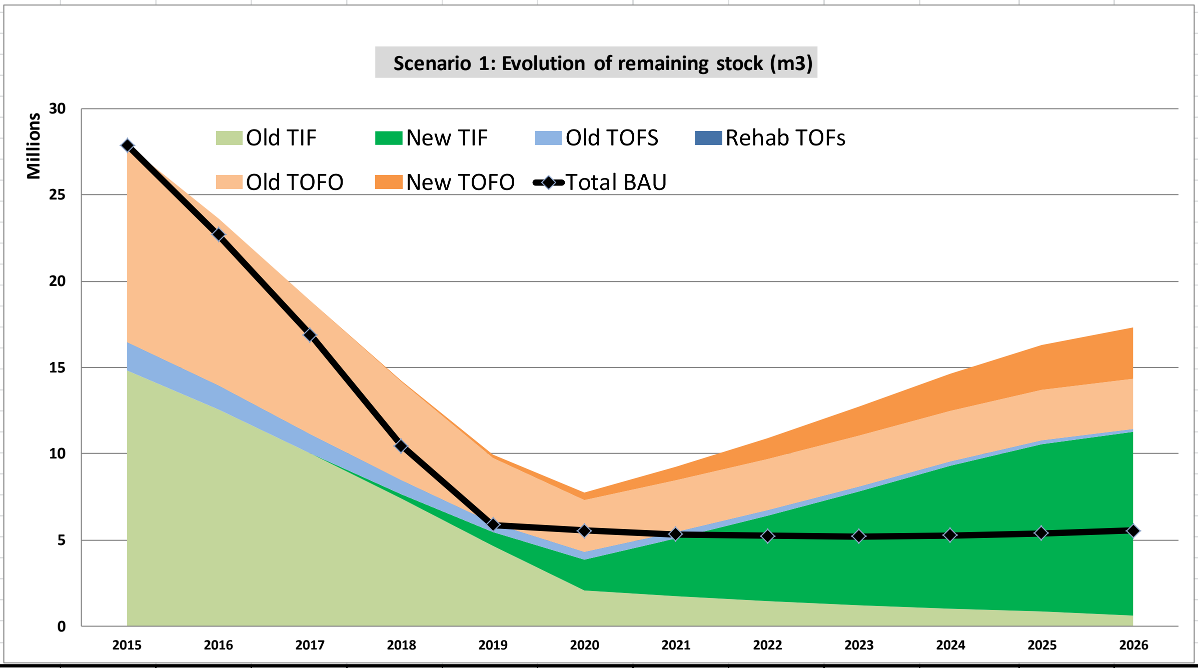
Code	2009	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Sust Supply	3 670 239	2 289 600	2 079 820	1 831 989	1 555 649	1 244 151	954 688	1 160 308	1 341 265	1 524 116	1 886 574	2 395 844	2 384 190
Tot Demand	-4 801 000	-5 266 330	-5 419 753	-5 295 382	-5 157 688	-5 008 682	-4 850 469	-4 733 386	-4 620 519	-4 511 275	-4 405 208	-4 301 991	-4 201 390
Gap	-1 130 761	-2 976 730	-3 339 933	-3 463 393	-3 602 039	-3 764 531	-3 895 780	-3 573 078	-3 279 254	-2 987 159	-2 518 635	-1 906 146	-1 817 199

According to more realistic figures set for each main factors of change for the Scenerio 1, the gap will still increase until 2020 (3.7 M odt, 75%) before being progressively reduced to 1.8 M (43%) odt in 2026 due to the supply contribution of afforested/converted areas. A zero balance could be expected only by 2030 if efforts can be continued.



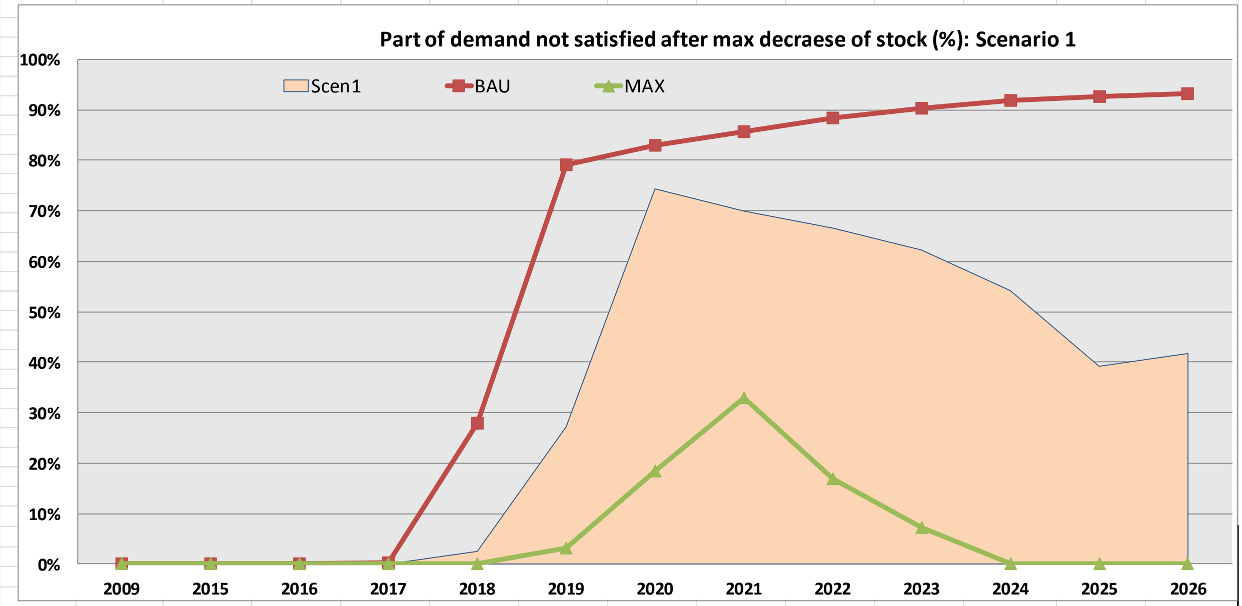
	2009	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Scenario 1	76,4%	43,5%	38,4%	34,6%	30,2%	24,8%	19,7%	24,5%	29,0%	33,8%	42,8%	55,7%	56,7%
BAU	76,5%	38,7%	33,4%	27,9%	21,0%	14,6%	11,6%	9,8%	8,3%	7,3%	6,7%	6,7%	6,4%
MAX	76,5%	44,0%	40,5%	47,5%	50,2%	44,5%	37,8%	56,9%	79,3%	91,2%	101,6%	126,7%	132,2%

This not so good scenario is due to the fact that the gap of 2015 (3 M odt) is representing already more than 10% of the remaining stock, laeding to an equivalent reduction (by over-exploitation) of 10 % of this stock. For 2016 and 2017 the increasing gap will represent respectively 14% and 18% of the remaining stock. This stock decraese will laed to a drastic reduction of the sustainable supply of remaining areas. Area newly afforested /reconverted will contribute to the supply only from 2020 -2021 (harvesting only 4-7 years after planting). This is why the stock will decrease dramatically from 2016 to 2020-2021, reaching the ultimate minimum in 2020. The progressive increase of stock will start only in 2021, based on newly afforested area put under forest management plan and based on TOFO tree resources sustainably managed.

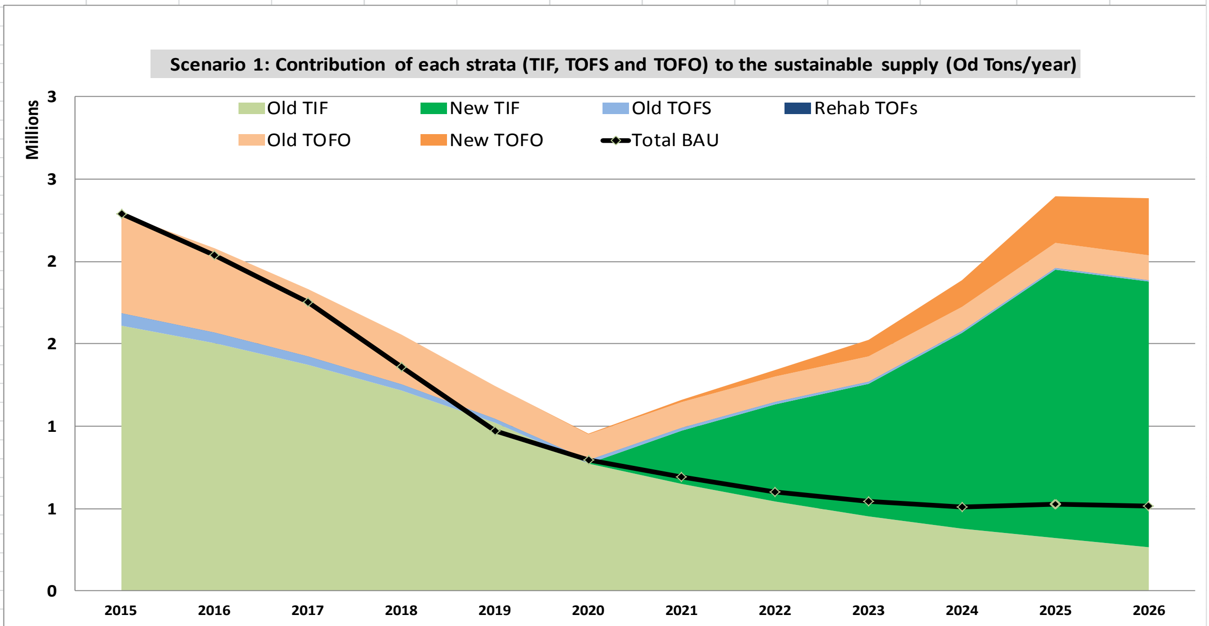


	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Old TIF	14 823 095	12 562 832	10 026 784	7 397 293	4 659 084	2 071 723	1 740 843	1 455 210	1 213 174	1 013 977	855 886	616 047
New TIF	0	0	1 134	246 933	799 023	1 786 923	3 347 931	4 947 391	6 595 042	8 286 186	9 694 284	10 651 667
Tot TIF	14 823 095	12 562 832	10 027 918	7 644 226	5 458 107	3 858 646	5 088 774	6 402 600	7 808 216	9 300 163	10 550 171	11 267 714
Old TOFS	1 643 472	1 392 871	1 111 373	819 587	519 150	448 272	374 029	320 502	279 655	247 769	222 452	161 738
Rehab TOF	0	0	0	0	0	0	0	0	0	0	0	0
Tot TOFs	1 643 472	1 392 871	1 111 373	819 587	519 150	448 272	374 029	320 502	279 655	247 769	222 452	161 738
Old TOFO	11 421 683	9 680 075	7 725 967	5 699 273	3 777 100	3 005 134	2 997 749	2 963 485	2 957 449	2 932 435	2 928 522	2 914 139
New TOFO	0	0	15 613	62 450	195 157	437 152	782 191	1 207 478	1 681 569	2 155 084	2 600 464	2 976 801
Tot TOFO	11 421 683	9 680 075	7 741 580	5 761 723	3 972 257	3 442 287	3 779 939	4 170 962	4 639 019	5 087 519	5 528 986	5 890 940
TOTAL	27 888 250	23 635 778	18 880 871	14 225 536	9 949 514	7 749 205	9 242 742	10 894 065	12 726 889	14 635 450	16 301 608	17 320 392

From 2016 to 2019, the part of the demand not covered by the sustainable supplied (gap) will be satisfied by making over-exploitation in TIF/TOFs/TOFO area managed as usual (so 100% of the demand will be satisfied, meaning that the part not satisfied after over-exploitation will be 0%). From 2020, as the stock will reach its minimum (all the stock harvestable being harvested), over-exploitation will not be any more possible. Then the part of the demand that cannot be satisfied will increase dramatically until around 80%. That means that an important part of the population will not find their basic need in wood for energy.

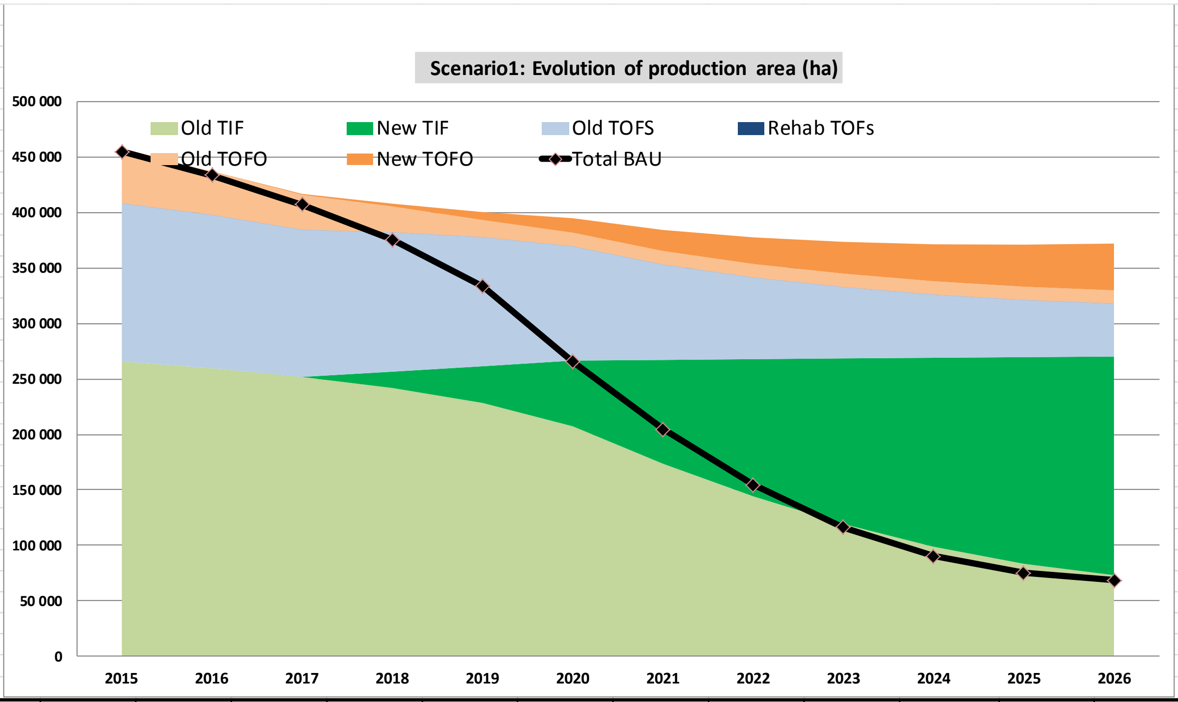


	2009	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Scen1		0%	0%	0%	3%	27%	74%	70%	67%	62%	54%	39%	42%
BAU	0%	0%	0%	0%	28%	79%	83%	86%	88%	90%	92%	93%	93%
MAX	0%	0%	0%	0%	0%	3%	18%	33%	17%	7%	0%	0%	0%



Code	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Old TIF	1 610 234	1 503 836	1 372 286	1 216 336	1 021 162	772 885	649 344	542 632	452 335	377 904	320 832	265 094
New TIF	0	0	0	0	0	130	323 628	589 762	804 744	1 188 492	1 629 463	1 613 512
Old TOFS	76 492	65 038	51 901	38 485	24 627	21 467	18 104	15 613	13 573	12 089	10 907	7 964
Rehab TOFs	0	0	0	0	0	0	0	0	0	0	0	0
Old TOFO	602 874	510 947	407 802	300 829	198 362	155 835	155 461	153 542	153 236	145 749	151 639	150 834
New TOFO	0	0	0	0	0	4 372	13 770	39 715	100 228	162 340	283 005	346 786
Total	2 289 600	2 079 820	1 831 989	1 555 649	1 244 151	954 688	1 160 308	1 341 265	1 524 116	1 886 574	2 395 844	2 384 190

According to scenario 1, the area of TIF plantation and TOFO will remain constant, while area of TOFS will decrease dramatically from 2016 to 2026.



Code	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Old TIF	265 673	259 597	251 736	241 832	228 350	207 312	173 550	144 223	119 226	98 760	83 389	73 156
New TIF	0	0	92	14 735	33 093	59 238	93 600	123 618	149 306	170 326	186 250	197 037
Tot TIF	265 673	259 597	251 828	256 566	261 443	266 550	267 149	267 841	268 533	269 086	269 640	270 193
Old TOFS	142 696	138 344	132 726	125 730	116 448	103 038	86 004	73 735	64 373	57 066	51 595	47 855
Rehab TOFs	0	0	0	0	0	0	0	0	0	0	0	0
Tot TOFs	142 696	138 344	132 726	125 730	116 448	103 038	86 004	73 735	64 373	57 066	51 595	47 855
Old TOFO	46 379	39 307	31 372	23 142	15 337	12 203	12 173	12 033	12 009	11 907	11 892	11 833
New TOFO	0	0	842	2 527	7 160	13 057	18 954	24 009	28 642	33 275	37 908	42 120
Tot TOFO	46 379	39 307	32 214	25 670	22 498	25 260	31 127	36 042	40 651	45 182	49 800	53 953
TOTAL	454 748	437 248	416 768	407 966	400 388	394 847	384 280	377 618	373 557	371 335	371 034	372 001

Forest cover: current situation and projection according factors applied			
	2009	2015	Projection 2026
Total forest cover %	29,37%	26,13%	22,19%
Protected TIF %	5,83%	5,83%	5,83%
Protected TOFS%	2,49%	2,49%	2,49%
Production TIF %	12,14%	11,59%	11,78%
Production TOFS %	8,92%	6,22%	2,09%
TOFO % (equiv area)	2,02%	2,09%	2,35%