RWANDA

National Integrated Clean Cooking Plan

IN PARTNERSHIP WITH:

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REPORT

Concept note

This report describes a collaboration with the Government of Rwanda (GoR) towards achieving the goals of the country related to increasing the adoption of clean-cooking technologies, aligning with and complementary to official strategic documents available to date.

The plans introduced in the report are aimed at providing valuable insights on potential paths to achieve certain objectives by applying innovative methods, cause-and-effect relations, sensitivity analyses and decision criteria. As the sector evolves and targets progress, the underlying tools used to produce the introduced plans are dynamic instruments that can be used to produce further updates as required.

This collaboration proves the commitment of the GoR to the use of advanced planning tools to contribute to the achievement of its energy access goals.

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Acronyms and Abbreviations

BEST	Biomass Energy Strategy
BRD	Rwanda Development Bank
CAPEX	Capital Expenditure
CCDI	Clean Cooking Data for All initiative
CO2	Carbon Dioxide
CO2e	Carbon Dioxide Equivalent
DALYs	Disability-adjusted life years
EAQIP	Rwanda Energy Access and Quality Improvement Project
EBITDA	Earnings Before Interest, Taxes, Depreciation, and Amortisation
EDCL	Energy Development Corporation Ltd
EEP	Energy and Environment Partnership Trust Fund
ENABEL	Belgian Development Agency
ESMAP	Energy Sector Management Assistance Program
EU	European Union
EUCL	Energy Utility Corporation Limited
GCF	Green Climate Fund
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIZ	German Agency for International Cooperation
GLPGP	Global LPG Partnership
GoR	Government of Rwanda
HH	Household(s)
ICS	Improved Cook Stove
IIT	Institute for Research in Technology, ICAI School of Engineering, Comillas University
IPCC	Intergovernmental Panel for Climate Change
IUCN	International Union for Conservation of Nature
kg	Kilogram
kgCO2Eq	Kilograms of equivalent CO2, unit for emissions
kW	Kilowatt
kWh	Kilowatt hour
LPG	Liquefied Petroleum Gas
M	Millions
MECS	Modern Energy Cooking Services
MININFRA	Ministry of Infrastructure
MIT	Massachusetts Institute of Technology
MT	Million metric tons
MTF	Multi-Tier Framework
NEP	National Electrification Plan (of Rwanda)
NICCP	National Integrated Clean-Cooking Planning

NISR	National Institute of Statistics of Rwanda
OPEX	Operational Expenditure
PV	Photovoltaic
RBS	Rwanda Standards Board
ReCIC	Reducing Climate Impact of Cooking in Rwanda through improved cooking systems
REG	Rwanda Energy Group
REMA	Rwanda Environment Management Authority
RFA	Rwanda Forestry Authority
RLMA	Rwanda Land Administration and Use Authority
ROE	Return on Equity
RPHC5	Fifth Rwanda Population and Housing Census
RSB	Rwanda Standards Board
RURA	Rwanda Utilities Regulatory Authority
RWF	Rwandan franc
SDG	Sustainable Development Goals
SEforALL	Sustainable Energy for All
SNV	Netherlands Development Organisation
Ton	Metric ton = 1000 kg
TREPA	Transforming Eastern Province Through Adaptation
TWG	Technical Working Group
UNDP	United Nations Development Programme
USD	United States Dollar ($)
UTM	Universal Transverse Mercator (projection, or coordinate system)
VAR	Used to refer to variable costs
VOM	Variable Operation and Maintenance (costs)
WHO	World Health Organisation

Key Terms

Access	Refers to the access to **Fuels**, **Appliances**, and **Technologies**. It is the percentage of consumers in an area that could use (have access to) a particular fuel, appliance, or technology. Example: for electric cooking, it would be the percentage of consumers with electric supply compatible with the peak power and daily energy required for cooking.
Adoption	Refers to the adoption of technologies. It is the percentage of the cooking demand (or **C-Demand**) satisfied by a given **Technology**. It could be applied to a single household, an aggregated group of consumers, or a whole country.
Appliances (set)	Category of the set of cookstoves and kitchenware used for a given cooking **Fuel**. The category is defined by its average parameters, like price, lifetime, efficiency, or emissions rate. A combination of **Fuel** and **Appliances** defines a **Technology**. In this work, a maximum of 3 appliance sets have been defined for each fuel.
Appliances (market size estimation)	The estimation is made by dividing the total annual usage of each type of appliance (country level) by the lifetime of the type of appliance, both in cooking demand units (cooks). Therefore, it represents the number of appliances "consumed" annually, which in a steady state would coincide with the number of appliances of each type to be deployed annually (sold or repaired).
Attribute	A relevant **Effect** used to evaluate plans (by the planner) or technologies (by the consumers). Here, the attributes are **Economic costs**, **Social costs**, **Health**, **Time&Gender**, **Emissions**, and **Deforestation**.
Availability	Refers to **Fuels**, **Appliances**, and **Technologies**. It is defined as a combination of two percentual parameters: **Access**, and **Capacity**.
Blended Finance	The use of both public and private funds to finance a project.
C-Demand	Cooking demand, measured in **Cooks**.
Capacity	Refers to **Fuels**, **Appliances**, and **Technologies**. It is the percentage of the total cooking demand of a given area that could be satisfied using a particular fuel, appliance, or technology. The capacity of a technology is the minimum of the capacity of the fuel and the capacity of the appliances since a technology is the combination of both. In the case of fuels, it depends on the total quantity that could be supplied per year (or other time unit). In the case of appliances, it depends on both the quantity supplied per time and the lifetime of the appliance. In this work, the capacities for electricity and LPG are adjusted to the actual local **Adoption** of the technologies, plus some capacity margins defined by the user.
Capital Structure	The mix of debt, equity, and other forms of financing used by an organisation or project.
Carbon Credits	Tradable certificates that represent the right to emit a certain amount of carbon dioxide or other greenhouse gases.
Concessional loans	Loans offered on more generous (lower interest) terms than market loans to support development projects, often with lower interest rates and longer repayment periods.
Cook (unit)	The cooking-demand unit defined here, so that the unit itself and the demand profile **C-Demand** are independent of the **Technology** used. The Cook is defined as the cooking demand satisfied with 1 kWh of electricity when cooking with a hotplate, heated by Joule effect (resistor), and using non-efficient kitchenware.
Deforestation	This is a specific **Effect** selected as an **Attribute**. It is evaluated as the amount of kg of wood used, either as a raw material or as a cooking fuel.
Demand area	A territory partition defined as the set of buildings (consumers) belonging to the same **Planning area**, and to the same **Supply area** for each and every **Fuel**.

Consequently, all the external conditions (like prices and **Availabilities** of cooking technologies) are homogeneous for the consumers of the demand area. In this work, the demand area has been aggregated to the district level (i.e., a total of 30 demand areas).

E-Demand	Electric demand excluding electric cooking, measured in kWh.
Economic costs	This is a specific **Effect** selected as an **Attribute**. From the planner's perspective, it is the cost for the State, as it is ultimately responsible for public services and welfare. From the consumer perspective, it is used as the cost of each **Technology** (a combination of price and efficiency), and the average costs of cooking.
Effect	A result of the evaluation of a **Plan** subject to a given **Scenario** and using **Off-line inputs**. Some relevant effects are selected as **Attributes**, either to evaluate plans (by the planner) or technologies (by the consumers). Other effects provide additional information to analyse a plan, like the penetration of clean-cooking technologies, or the average cost of cooking for the population. The results include other types of information, like the **Adoption** of different technologies over time (by groups of consumers or by Planning Area) or sectorial cash-flows estimated from the **Economic costs** effect.
Emissions	This is a specific **Effect** selected as an **Attribute**. It is evaluated as the amount of kg of CO_2 equivalent. Emissions include the whole supply chain, from raw materials to the kitchen.
Equity	Investments made directly by stakeholders, demonstrating confidence in the long-term viability.
Fuel	A specific fuel used for cooking, defined at the kitchen point or end of the supply chain (a different concept is the raw material at the beginning of the supply chain). In this work, 8 different fuels have been considered: Electricity (at the connection point), LPG, Biogas (only individual systems), Charcoal, Commercial Firewood, Free Biomass (collected, crops waste, forest waste, and similar fuels), Pellets (which includes other similar fuels, like briquettes or sawdust), and Free Firewood (collected). Note the use of capitalisation to identify the keyword. For instance, Electricity means the specific electric-cooking fuel, while electricity would be the generic and common term for the kind of energy or the economic sector.
Health	This is a specific **Effect** selected as an **Attribute**. It is evaluated as damage to the population, especially women and children. These damages are usually calculated through the adverted Disability Adjusted Life Years (DALYs) and deaths. The values for different **Technologies** have been normalised with respect to the use of three-stone systems with firewood or biomass.
Measure (of a Plan)	A specific physical action or decision, either about investments (like infrastructures to be deployed), or about pricing and regulations (like subsidies, incentives, regulated tariffs, and taxes), in specific time stages and locations, and for any cooking technology. A set of measures defines a **Plan**. The types of measures are called **Policies**.
Off-line inputs	Inputs to the **Interactive tool** that are not interactive. They are computed off-line, either because they are constant data, or configuration parameters established in advance, or because they require complex processes and **Off-line tools** that take a considerable computing time.
Off-line tools	Computer tools in charge of data preparation, parameter estimation, or pre-design of infrastructures (for Electricity and LPG). They generate or assist in the generation of the **Off-line inputs** required by the **Interactive tool**.
Operating Margins	Measure of profitability considering operating income as a percentage of revenue.
Plan	A clean cooking plan is defined as a set of **Measures** – physical actions and decisions – in multiple time stages and locations, and for all cooking technologies. The types of measures are called **Policies**.

Planning area	An administrative territory partition (here the District, the Province of the Country), which is relevant to analyse results and to apply planning decisions.
Policy	A type of **Measure**. For instance, a policy could be to apply a tax to charcoal. A measure of this type could be to apply a 20% tax to charcoal during a certain period of the **Plan**.
Scenario	Set of uncertain socio-economic parameters defined by the user of the **Interactive tool** to describe the context in which a **Plan** will be applied, thus affecting the **Effects** or results of the plan.
Social costs	This is a specific **Effect** selected as an **Attribute**. It is a weighted average of other effects (and also attributes): **Health**, **Time&Gender**, **Emissions**, and **Deforestation**.
Social cluster	A type of consumer, or a consumer profile, characterised by a set of behavioural parameters. Two social clusters have been used in this work: the average rural household, and the average urban household.
Supply area	A territory partition related to the supply chain of a specific fuel, defined as the set of buildings (consumers) belonging to the same supply subsystem. In the case of electricity, these are the buildings that would be connected to the same HV/MV substation. In the case of LPG, the buildings supplied from the same local warehouse. In this work, the supply areas have been aggregated to the district level (30 supply areas)
Tariff income	The direct revenue generated from users.
Technology	A cooking technology, defined by a combination of **Fuel** and **Appliances**. In this work, 19 technologies have been defined, as combinations of 9 fuels and 12 appliances sets.
Time&Gender	This is a specific **Effect** selected as an **Attribute**. It is evaluated as time spent and inconvenience in general (mostly suffered by women), in the preparation-cooking-cleaning process in the kitchen, and in the fuel-gathering process. The values for different **Technologies** have been normalised with respect to the use of three-stone systems with firewood or biomass.
Viability gap funds	Financial support needed to cover the shortfall between project operating costs and the revenues generated, often used in infrastructure projects.

EXECUTIVE SUMMARY

The National Survey on Cooking Fuel Energy and Technologies in Households, Commercial and Public Institutions in Rwanda (MININFRA, 2021), and the Analysis of Energy Access in Rwanda (ESMAP, 2023) reveal that most Rwandan households predominantly use wood and charcoal for cooking. This results in multiple negative effects, such as an increase in respiratory diseases, deforestation, and GHG emissions. To change this trend, the Government of Rwanda (GoR) has endorsed the Biomass Energy Strategy 2019-2030, in addition to numerous initiatives that have been undertaken by the private sector, many supported by international development agencies and NGOs. Still, the targets established are far from being met.

National integrated and coordinated planning efforts are urgently needed to overcome this challenge, strategically guiding implementation efforts. This report presents a National Integrated Clean Cooking Planning (NICCP) approach, built on innovative interactive tools that estimate the effects of planning decisions in terms of techno-economic and financial results.

The NICCP serves as an instrument to guide efforts towards the expansion of clean cooking solutions in the country and can be adjusted to different contexts and needs, as the sector continues to develop. The NICCP and its underlying tools are intended to become a living instrument to support the GoR and its collaborators in making and adapting decisions in a dynamic and informed way. This approach provides insights to decision-makers on potential outcomes of planning decisions, allowing them to search efficiently for the combination of measures that is likely to lead to the most desirable outcome.

This report presents two plans, whose effects are analysed over time, emphasising the results obtained for the years 2029 and 2034, respectively, compared to a baseline. The first plan (*Aligned*) aims to achieve a particular technology mix aligning with the country's current ambitions. The second plan (*CleanStep*) seeks a higher penetration of clean cooking by 2029, while focusing on the economic recovery in the second period (2030-34), ensuring that the social costs are kept stable.

The adoption of cooking technologies in the context of each plan varies over time and space. The spatial dimension of adoption depends on the local deployment of electric and LPG infrastructures, the types of consumers, and the land-use mix in the area (for example, the proportions of buildings, forest, rangeland, and agriculture).

The main takeaways and recommendations from the NICCP are listed below.

- The full deployment of electricity and LPG infrastructure, as well as ensuring universal access to clean cooking technologies by 2029, does not guarantee adoption and sustained use due to affordability gaps, especially in rural areas.
- Plans with combined pricing measures (subsidies on a wide range of clean cooking appliances and fuels) not only help achieve more adoption of clean cooking technologies but also reduce investment costs for implementation of the plans in the long term.
- In the Aligned plan, 74% of the national cooking demand (85% in urban areas and 65% in rural areas) is covered by clean cooking technologies (Tier 3+), equivalent to 3,005,538 households; reducing the use of inefficient biomass technologies (Tier <3) by 64% compared to the Baseline by 2029. In

the same period, the CleanStep plan results in 3,446,097 households adopting clean cooking technologies, covering 85% of the national cooking demand (91% in urban areas and 81% in rural areas), reducing the use of inefficient biomass technologies by 75% compared to the Baseline.

- By 2029, the CleanStep plan responds better to environmental factors than the Aligned plan, such as emissions (saving 2.2 MTon CO_2eq/y more) and Deforestation (saving 2 MTon wood/y more), and social factors, such as Time and Gender (saving 1.57 days/person/y more). However, the Aligned plan is slightly better in terms of Health costs (saving 25,365 DALYs/y more). These effects are produced by the different measures applied to this period and the resulting technology mix.
- By 2034, the Aligned plan has 86% of the national cooking demand (93% in urban areas and 80% in rural areas) covered by clean cooking technologies, equivalent to 4,241,913 households; reducing the use of inefficient biomass technologies by 74% compared to the Baseline. The CleanStep plan results in 4,077,667 households adopting clean cooking technologies, covering 83% of the national cooking demand (93% in urban areas and 74% in rural areas), reducing the use of inefficient biomass technologies by 71% compared to the Baseline.
- For the same year, the CleanStep plan performs better in Emissions (saving 0.1 MTon CO_2eq/y more) and Deforestation (saving 0.9 MTon wood/y more), while the Aligned plan shows improvements in Health (saving 30,985 DALYs/y more) and Time and Gender (saving 3.92 full days/person/y more).
- The cost of cooking for an average household in both plans and both years are generally higher than or the same as in the baseline, especially for urban households. The slight increase in costs for rural households can be manageable considering the expected economic growth.
- Providing support to the private sector is critical to rapidly increasing the production and distribution capacity of appliances and fuels, which is a prerequisite for both the analysed plans. For example, by 2029, the Aligned plan requires an increase in deployment of clean cooking appliances by 1 M units/year compared to the baseline (mainly charcoal Tier3+, LPG and ethanol). For the same period, this value is 1,15 M units/year for the CleanStep plan (mainly allocated to firewood Tier3+, LPG, ethanol, pellets and e-cooking).
- The CleanStep plan anticipates a required funding of USD 611M by 2029 (with a total CAPEX of USD 523.5M), and of USD 874M by 2034 to fully implement its strategy. The Aligned plan increases the total funding from USD 519 M by 2029 (with a total CAPEX of USD 323M) to USD 967M by 2034, indicating a more significant financial commitment over time. Most of the funding is projected to come from the viability gap, concessional loans and grants, and equity and taxes/subsidies.
- As Rwanda plans the implementation of clean cooking strategies, reducing CO_2 emissions presents a significant opportunity for engagement in the carbon market. Both plans are designed to capitalise on this potential by certifying and selling the avoided CO_2 emissions as carbon credits. The total projected avoided CO_2 emissions for the CleanStep plan are 60.5 MT, compared to 38.5 MT for the Aligned plan.

Taking the necessary measures to reach an enabling environment is critical for the successful implementation of the analysed plans. Among the recommended measures are to deploy campaigns aimed at raising awareness about the benefits of transitioning to cleaner fuel, to ensure a harmonised coordination among relevant players in the sector, to identify the respective roles of each sub-sector and authority to achieve the common objectives, to support programmes dedicated to building local capacity not only on the usage; but also on the production, sales, operation and maintenance of clean cooking technologies to ensure a sustainable value chain and reduce the dependence on international markets.

INTRODUCTION

Rwanda has one of the fastest-growing electrification rates in Sub-Saharan Africa. According to the 2024 Tracking SDG7 Report (IEA, IRENA, UNSD, World Bank, WHO, 2024) the country has transitioned from 4.72% electricity access in 2001 (35.88% in urban areas and 0% in rural areas) to 50.58% in 2022 (98% in urban areas and 38.20% in rural areas). Additionally, the latest data from the 2022 Rwanda National Census shows an even higher electricity access rate of 61% (75,2% and 51,1% in urban and rural areas, respectively) (National Institute of Statistics of Rwanda, 2022). However, progress in clean cooking has been limited, with only 8% of the population having had access to clean cooking in 2022.

The current situation is generally characterised by insufficient population awareness about the problem of non-clean cooking, low penetration of the existing clean and efficient technologies, insufficient industrial investment in equipment and appliances, inadequate and/or insufficient financing, and the need for more effective coordination of the multiple ongoing initiatives. There is a need to invest in improving the supply chains of cleaner fuels and to deploy energy-efficient modern stoves. According to (MININFRA, 2021) most households rely on firewood and charcoal and use inefficient appliances (70% used only firewood, 10% used only charcoal, and 5% used only a combination of firewood and charcoal).

The Government of Rwanda (GoR) is firmly committed to improving access to clean cooking in the country. However, the planned targets are far from being met. Considering this, Sustainable Energy for All (SEforALL) and the GoR have established a collaboration to develop a National Integrated Clean Cooking Planning (NICCP) approach in collaboration with the Institute for Research in Technology (IIT) of the ICAI School of Engineering at the Pontifical University of Comillas and the Energy Initiative of the Massachusetts Institute of Technology (MIT).

Overview

The NICCP includes two complementary analyses. The first and most complex analysis evaluates the techno-economic aspects of a plan, such as the optimal design of infrastructures (electricity and LPG), the behaviour of the consumers (technology adoption model), the economic costs (CAPEX, OPEX, taxes, subsidies), and the social costs (health damages, emissions, deforestation, time and gender aspects, and cost of cooking). It is developed through an Integrated Clean Cooking Planning Tool (ICCPT), made of data-preparation, off-line and interactive modules, and using data such as cooking-technologies features, the geospatial distribution of buildings (residential, commercial and public), roads, biomass and land-use characteristics, and population censuses.

The second analysis comprises a financial model to rigorously evaluate key aspects of the analysed plans, drawing on detailed techno-economic analyses. This model incorporates a variety of financing mechanisms, including blended finance options, and develops sustainable tariff strategies while assessing potential risks to project feasibility. It involves multiple financial institutions, from development finance entities and private companies to international organisations, supplemented by philanthropic contributions.

The financial strategy aims to attract a broad spectrum of investors by highlighting the project's potential for financial returns and socio-economic impacts. It demonstrates the NICCP's capability for financial sustainability with minimal reliance on external subsidies, adherence to crucial financial ratios for private investments, and compliance with national macroeconomic policies. The model outlines two potential outcomes: one where the NICCP achieves financial sustainability and another providing insights for enhancing viability if initial financial independence is unattainable. This approach ensures the clean cooking initiative is not only aligned with Rwanda's existing energy frameworks but is also adaptable, promoting a comprehensive strategy for national clean cooking solutions.

A clean cooking plan is defined as a set of measures – physical actions and decisions – consisting of (i) investments (infrastructures to be deployed, supply chains to be established, and support to the business models necessary to implement the investments) and (ii) policy and regulatory decisions (subsidies and incentives to be applied, and regulated tariffs and taxes to be set up), in multiple time steps and locations, and for a wide range of cooking technologies. Examples of investments are the electrification of some villages by extending the grid, or the creation of necessary infrastructure to transport and store LPG canisters in selected regions. An example of a policy decision is the additional taxation of certain fuels, such as charcoal.

In addition to the measures adopted, the outcome of a plan is affected by the context, i.e., those inputs that impact the outcome of the plan but that are beyond the control of the planning team. For example, the price of imported LPG, the national economic growth, or the population growth in urban and rural contexts.

The ICCPT estimates the diverse consequences (effects) of the set of measures that define a plan. For instance, the number of people who decide to switch their current cooking technology, either totally or partially, according to their preferences and the characteristics and cost of the different options, the economic costs of implementing the measures, the associated level of deforestation, and the estimated number of casualties associated with traditional cooking practices. It is impossible to achieve all the desired objectives at the same time. For instance, the plan with the minimum economic cost might have undesirable consequences in other environmental or social aspects. The choice of plan should come from the decision maker, considering the best combination of outcomes. Note that the concept of best is subjective since there are multiple criteria, and economic costs usually conflict with social costs.

Purpose of this report

The NICCP and its underlying tools intend to inform policy design and formulate a comprehensive strategic roadmap towards achieving clean cooking access objectives and to support the wider clean cooking sector to identify opportunities for implementation, investment and service delivery. This report is focused on introducing the NICCP by presenting two plans that align with the current country's vision, while also providing a brief description of the overall methodology and underlying tools (ICCPT and Financial Model) and the data that are necessary to better understand it. For more information about the tools and data, it is recommended to consult the Methodology Report and the Data Preparation Report, documents complementary to this report.

The first section provides an overview of the methodology and information required to understand the NICCP and the generated results, including the main inputs and outputs of the underlying tools, and the assumptions made. The second part describes the plans evaluated under the NICCP, including the measures and techno-economic and financial results. Finally, the third section presents the conclusions and recommendations derived from the NICCP analysis.

Clean cooking access challenge in Rwanda

The National Survey on Cooking Fuel Energy and Technologies in Households, Commercial and Public Institutions in Rwanda (MININFRA, 2021), hereon National Survey, and the Analysis of Energy Access in Rwanda (ESMAP, 2023), hereon Analysis of Energy Access, reveal that most Rwandan households predominantly use wood and charcoal for cooking.

The National Survey indicates that as of 2020, a substantial 80.37% of households in Rwanda relied on firewood for cooking, predominantly using traditional three-stone stoves. Charcoal and agricultural waste also constitute significant portions of the cooking fuel mix. Among cleaner fuel options, Liquefied Petroleum Gas (LPG) is the most prevalent, as detailed in Table 1.

Table 1. Distribution of household cooking fuel types based on energy source (MININFRA, 2021). Totals in columns exceed 100% because one household may use multiple types of fuels.

	Fuel	Urban	Rural	Nationwide
Biomass	Firewood	39.42%	91.14%	80.37%
	Charcoal	59.34%	7.17%	18.03%
	Pellets	0.10%	0.12%	0.11%
	Biogas	0.25%	0.20%	0.21%
	Cow dung	0.10%	0.10%	0.10%
	Crop residues	5.05%	10.71%	9.54%
	Papyrus	0.00%	0.07%	0.06%
	Sawdust	0.16%	0.39%	0.34%
Fossil fuels	Kerosene	0.00%	0.03%	0.02%
	LPG	25.62%	0.40%	5.65%
Electricity	Electricity	0.92%	0.03%	0.21%

The Analysis of Energy Access aligns with the primary findings of the National Survey, revealing that as of mid-2022, only 4% of households utilised clean stoves. There was a rise in the adoption of LPG stoves in urban areas, increasing from 1.7% in 2016 to 19% in 2022. Traditional three-stone stoves remain predominant, with 69.4% usage for firewood and 78.8% for crop residues. For charcoal burning, different stove types are prevalent: the Canamake stove, Metal-clay stove, and Rondereza-plus stove account for 30.2%, 25.6%, and 21.2% of usage, respectively (MININFRA, 2021), However, it is important to note that all of these charcoal stoves have a thermal efficiency below 30%. Furthermore, the Analysis of Energy Access highlights the prevalent use of cooking systems that fall into the lower tiers of the Multi-Tier Framework for measuring energy access (Bhatia & Angelou, 2015), as illustrated in Table 2.

Table 2. Distribution of households by cooking Tier (ESMAP, 2023).

	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Nationwide	57.6%	34.4%	3.8%	0.3%	0.0%	3.9%
Rural	62.2%	34.8%	2.2%	0.2%	0.0%	0.6%
Urban	36.5%	32.55	11.2%	0.8%	0.0%	19.0%

Stove stacking, the practice of using multiple cookstoves within a household, reflects not only the diversity of culinary needs and food types but also signifies the households' aspirations for higher-performing cooking solutions or the necessity of backup options. Often, these additional stoves are used alongside, rather than as replacements for, existing cooking methods. In this context, the standardisation of improved cooking stoves becomes crucial, guiding households towards more efficient and environmentally friendly options.

The Analysis of Energy Access indicates a higher prevalence of quality biomass stoves compared to the findings of the National Survey. Regarding primary stove usage, 28.9% of households use a three-stone or open-fire stove (33.9% in rural areas and 5.9% in urban). Traditional or locally built stoves are used by 38.3% of households (42.9% rural and 17.5% urban), while 28.9% utilise manufactured stoves (22.6% rural and 57.2% urban).

Firewood collection is a common practice, with 68.6% of households engaging in it. The largest share travels 500 meters to 1 kilometre (41.2%), followed by those covering less than 500 meters (26.2%), 1 to 2 kilometres (20.8%), and more than 2 kilometres (11.8%). According to the Rwanda MTF survey (ESMAP, 2018), each household spent an average of more than 8 hours per week for fuel acquisition and preparation, and to prepare the cook stoves. Women and children predominantly undertake this task, with only 17.9% of men involved in firewood collection, and just 11.8% of households distribute this responsibility equally among all family members (Table 3). Charcoal remains a convenient fuel option for both rural and urban users, with 56.3% purchasing it from nearby retailers. Additionally, 60.6% of these households report that the distance to the purchase point is less than 500 meters.

Table 3. Individuals responsible for firewood supply (MININFRA, 2021).

Categories	Percentage
Women (>18 years)	42.8%
Boys (<18 years)	5.9%
Girls (<18 years)	5.3%
Women and children	16.3%
Men (>18 years)	11.8%
Everyone equally	17.9%

The National Survey reveals the average monthly household expenditures on different cooking fuels. Households spend an average of 18,575 RWF on firewood, 14,315 RWF on LPG, and 13,084

RWF on charcoal. The expenditure on LPG is 22.93% less than that for firewood and only 9.41% more than for charcoal. This pricing dynamic indicates potential opportunities for increased LPG usage, particularly among higher-income households.

Furthermore, the survey estimates annual consumption at about 6 million tons/year for firewood and 318,856 tons/year for charcoal. In rural areas, commercial firewood covers 55% of the demand, while free firewood covers 31%; while in urban areas, commercial firewood covers 25% of the demand, and free firewood 10%. When accounting for the consumption by industries and institutions, the inefficient 13% conversion rate of charcoal kilns, the low efficiency of boilers in tea factories, and the current state of forest cover, it becomes evident that wood consumption is unsustainably high. This level of consumption poses a significant risk of deforestation. Additionally, the burning of firewood and charcoal contributes to black carbon production and, through unsustainable firewood collection, greenhouse gas emissions. These factors exacerbate global warming and climate change.

Another critical concern is the health impact. The 2024 Global Burden of Diseases study (GBD 2021 Causes of Death Collaborators, 2024) estimates that in 2021, household air pollution caused around 9,300 deaths and 382,000 Disability Adjusted Life Years (DALYs) in Rwanda. Cooking with firewood and charcoal increases household air pollution, increasing the risk of respiratory and cardiovascular diseases. This is especially true for women, who typically spend more time in kitchens, and for vulnerable groups such as children, the elderly, and the sick.

The Biomass Energy Strategy 2019-2030 (MININFRA, 2019) identifies several key challenges hindering the transition to cleaner fuels and the sustainable use of biomass resources:

- **Low awareness**. There is a general lack of awareness about the availability of efficient cooking appliances and alternative fuels.
- **Inefficient production technologies**. Technologies used for producing charcoal and briquettes are inefficient. While pellet fuels are efficient and clean, particularly with specific cookstoves, their production levels remain low.
- **Limited production and market development**. The production of equipment and components is limited, and markets for such equipment and services are underdeveloped. This is largely due to high initial investment costs and the financial difficulties of many to cover these initial expenses.
- **Inadequate financing and monitoring**. There are insufficient financing and monitoring mechanisms, leading to a low adoption rate of efficient technologies and inadequate scale-up of production capacities and biomass market development.
- **Poor coordination among stakeholders**. There is a lack of coordinated effort among institutions involved in the biomass sub-sector.

Despite recent years seeing an increase in LPG penetration, the deployment of other non-biomass technologies, such as e-cooking, biogas, and bioethanol, is still nascent. Most activities in these areas are limited to pilot or small-scale projects.

Relevant strategic documents, programmes and initiatives

In a move towards cleaner and more modern cooking solutions, the GoR has endorsed the Biomass Energy Strategy (BEST) 2019–2030. The core objective is to facilitate fuel-switching from traditional biomass towards modern biomass energy technologies and cleaner alternative fuels to achieve a more sustainable wood fuel balance and to deliver related socio-economic, health and environmental benefits.

The strategy hinges on promoting the shift to non-biomass modern energy sources, particularly LPG, and highly efficient biomass technologies. In scenarios where immediate adoption of these alternatives is impractical, it suggests adopting sustainable fuel production methods and certifying both fuels and high-efficiency technologies, such as Improved Cook Stoves (ICS) and enhanced kilns.

Cross-cutting initiatives focused on enhancing stakeholder capacity building, promoting new products, technologies, and fuels, and placing a strong emphasis on educational and awareness campaigns. The key targets and milestones of this clean cooking strategy are summarised in Table 4, and the investment requirements are summarised in Table 5.

Table 4. Key targets of the BEST (MININFRA, 2019).

Indicators	Baseline and target values
Population using inefficient cooking technologies	Baseline value 2017: 72.5% Target value 2024: 36 % Target value 2030: 20 %
Rural population shifting from inefficient use of woody biomass to modern improved cooking solutions (improved biomass fuels and ICS)	Baseline value 2017: 0.5 % Target value 2024: 30 % Target value 2030: 65 %
Urban average monthly household charcoal consumption (kg)	Baseline value 2017: 38.8 kg Target value 2024: 20 kg Target value 2030: 5 kg
Public institutions with high biomass consumption (schools, prisons, or police and military camps) shift from woody biomass to clean cooking solutions*	Baseline value 2017: NA Target value 2024: 100 % Target value 2030: 100 %
Commercial institutions (hotels, restaurants, tea factories, brick factories) shift from inefficient wood and charcoal to clean cooking solutions*	Baseline value 2017: NA Target value 2024: 100 % Target value 2030: 100 %

**Note: Defined as LPG, electricity, biogas, pellets, briquettes, high efficiency cookstoves.*

Table 5. Proposed investments in the BEST **(MININFRA, 2019)**.

Description	2018-2024 (million USD)	2024-2030 (million USD)
LPG equipment and infrastructure	70	93
Strategic and commercial LPG stocks	31	41
High-efficiency Clean Cookstoves Programme	81	135
Sustainable forest management	58	96
Total	240	365

Regrettably, the progress toward the 2024 targets outlined in the BEST is lagging. For instance, 68.8% of the population still relied on firewood for cooking in 2022, and contrary to the goal of reducing charcoal usage, its consumption in urban households rose to 73.5% (ESMAP, 2023). This discrepancy indicates that the initial targets may not have fully accounted for critical factors such as fuel and appliance costs, a realistic model of adoption rates, and the financial capacity needed to implement various policies. The NICCP aims to address these issues by conducting a comprehensive techno-economic and financial analysis of potential solutions.

The clean cooking sector in Rwanda has seen significant growth, with numerous private sector companies offering a diverse array of fuels and stoves. This expansion has been further propelled by the entry of multiple new companies, supported by investments from international agencies keen on stimulating the market. In addition, the Ministry of Infrastructure introduced the Ministerial Guidelines for Clean Cooking Technologies (MININFRA, 2022) to clarify the clean cooking institutional framework and provide direction for both new and existing market aggregators. These aggregators are companies specialising in clean cooking solutions, tasked with the mobilisation of beneficiaries and the procurement and distribution of eligible stoves to qualified households. The key programmes and initiatives, and the Ministerial Guidelines are summarised in Annex 2.

The present state of the clean-cooking sector highlights the necessity for balanced investments in enhancing the supply chains of cleaner fuels and deploying energy-efficient modern stoves. Upon examining the current landscape and future projections for clean cooking in Rwanda, several key observations emerge:

- While current clean-cooking initiatives in Rwanda, particularly those aimed at disseminating cookstoves, are effectively reducing costs through subsidies, questions about long-term sustainability remain. The primary concern stems from the fact that cookstoves generally have a lifespan ranging from one to five years, necessitating regular maintenance and potentially increased subsidies over time. Therefore, it is crucial to balance short-term efforts with long-term strategies to ensure the sustainable adoption of clean cooking technologies.
- There is significant potential for e-cooking, providing high-tier access levels (Tier 4 and 5), especially for households connected to the grid (Bisaga & Menyeh, 2022). This includes those that will benefit from ongoing and planned grid extension projects. Two pilot initiatives have been successfully developed in Kigali, catering to both urban and peri-urban areas. Its implementation in mini-grid areas is less feasible due to the high costs of electricity production in such systems.
- The adoption of e-cooking presents not only advantages for consumers but also potential revenue growth for the utility company Rwanda Energy Group/Energy Utility Corporation Limited (REG/EUCL), due to increased electricity demand. Electric cooking serves as a modern alternative to LPG, which is a fossil fuel entirely reliant on imports and subject to global price fluctuations. However, the successful integration of e-cooking requires further technical studies to assess local grid distribution infrastructure, the safety of household electrical installations, and strategies for making electricity tariffs more affordable.
- Efforts have been made to enhance the charcoal and wood supply value chains. Such initiatives are crucial for increasing forest cover and improving efficiency within these value chains. They play a vital role in ensuring cooking energy security and in combating deforestation, especially in rural areas.
- The biomass energy sub-sector for cooking sees participation from various stakeholders, involved in aspects like enhancing policy and regulatory frameworks, developing cooking technologies, and establishing efficient fuel supply value chains. There is a need for more cohesive efforts, especially

among government institutions like Rwanda Energy Group (REG), Rwanda Environment Management Authority (REMA), Rwanda Forestry Authority (RFA), and Rwanda Land Administration and Use Authority (RLMA). A major goal of such coordinated efforts should be establishing a centralised and consistent platform for information sharing within the biomass sub-sector. The Biomass Technical Working Group (TWG) could potentially serve as this crucial coordination platform.

- The Rwanda MTF survey (ESMAP, 2023) has significantly contributed to the understanding of clean cooking access. Although it establishes a baseline for clean cooking access, the survey insights into stove costs, efficiencies, and emissions are derived from proxy indicators or observations that need further validation. Consequently, critical attributes such as affordability, cooking efficiency, and exposure to cooking emissions are not yet precisely quantifiable from the survey data. The recent establishment of a testing laboratory for cookstoves and fuels presents an opportunity to obtain more accurate data on efficiency and emissions, thereby filling this information gap.
- Self-reported surveys on household cooking energy expenditure in Rwanda have historically been unreliable. A more effective approach would be to combine cookstove usage studies with survey methods, as this blended strategy is likely to yield more accurate data than either method alone. Initiatives like the Clean Cooking Data for All (CCDI) under the SEforALL framework and the Fifth Rwandan Population and Housing Census (RPHC5), conducted in August 2022 and published in February 2023, aim to bridge this information gap.
- Although there have been significant efforts to promote the adoption of clean cooking solutions in Rwanda, these awareness campaigns need to be more extensively executed using mass media channels. Broadening the reach of these campaigns, especially through platforms with national coverage, will complement and amplify the impact of existing initiatives.

METHODOLOGY

This section provides an overview of the NICCP methodology and the underlying tools that were used to analyse the plans presented in this report. For more information about the tools and data, it is recommended to consult the Methodology Report and the Data Preparation Report, documents complementary to this report. It is important to note that the NICCP is agnostic to geography and can be applied regardless of country, but has been used here for the case of Rwanda.

Overview

Traditional cooking stoves typically employ biomass as fuel and burn fuel inefficiently. They contribute to environmental problems such as deforestation and GHG (greenhouse gases) emissions, cause health problems, and negatively impact the quality of life of people, particularly women, because of the time spent gathering fuel and cooking. These negative effects will be addressed as social costs in this document.

To mitigate these effects, the Government may apply a techno-economic analysis that identifies how to enhance the use of either modern cooking technologies (electricity and LPG), transitional technologies (improved cookstoves, ICS), or the use of biomass waste from crops or livestock (biogas, ethanol, or burning biomass waste in efficient appliances). This analysis may support the formulation of a plan that is defined as a set of decisions:

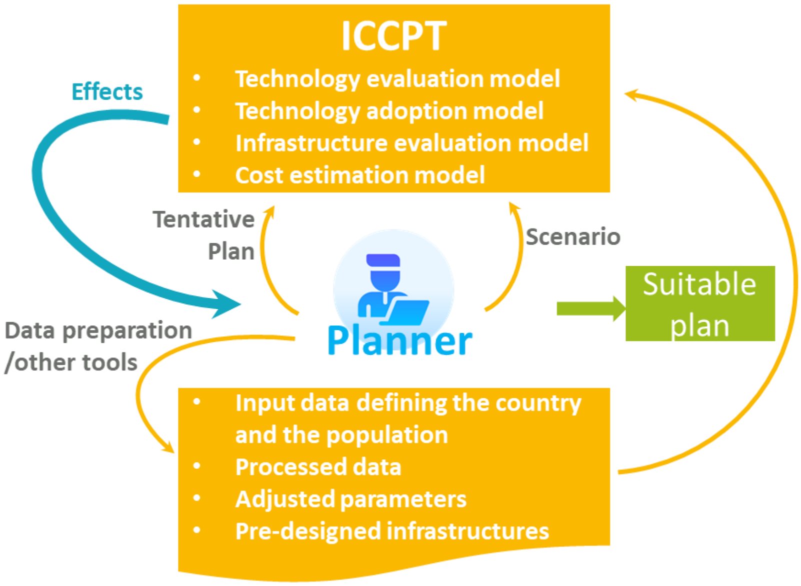
- Related to investments in the deployment and capacity of infrastructures, supply chains, and businesses that will implement targeted interventions.
- Concerning pricing and regulatory policies, such as regulations (including bans on fuels or appliances), subsidies, incentives, regulated tariffs, and taxes.
- In general, the decisions may be assigned to different locations and at different time stages.

To provide a comprehensive analysis of the effects of a plan, the NICCP is comprised of both a techno-economic and a financial analysis. The techno-economic analysis is produced by applying the Integrated Clean Cooking Planning Tool (ICCPT); then, the economic outputs are used as input for a financial model to develop the financial analysis.

Integrated Clean Cooking Planning Tool (ICCPT)

The techno-economic analysis of the NICCP has been generated using the ICCPT. The ICCPT estimates the *effects* of a *plan* subject to a given *scenario*, and the user or planner may test and formulate different plans until some targets (or combinations of desired effects) are met. Other inputs are not interactive; they are computed off-line, either because they are constant data or configuration parameters established in advance, or because they require processes and tools that take a considerable computing time.

Figure 1. The interactive ICCPT.



Overview

An overview of the ICCPT is presented in Figure 1. In the terminology used in this report, a ***plan*** is defined as a set of political and strategic ***measures***, and the different types of measures are called ***policies***. For instance:

- Two *policies* could be (a) Apply taxes to charcoal, and (b) Subsidise high-efficiency charcoal cookstoves.
- A simple plan could consist of two specific *measures*, like (a1) Apply 20% of taxes to charcoal, and (b1) Subsidise 50% of the price of high-efficiency charcoal cookstoves.
- Some expected *effects* of this plan could be (i) Revenue for the State due to taxes, (ii) Moderate expenditure for the State due to subsidies, (iii) Reduction of the overall consumption of charcoal for cooking by the population, because of taxes and higher efficiency, (iv) Decrease of negative effects of cooking with charcoal, like deforestation, emissions, or health problems, and (v) Less cooking expenditure of the population, since the savings in the fuel quantities purchased overcompensate the increment of price.

This qualitative-effects analysis is simple, but there are caveats. First, it is insufficient to handle statements like “high” or “moderate”; all expected increments must be quantified. Second, other combinations of measures (including other policies) could provide better results. Third, there are side effects to consider, like people partially replacing charcoal with firewood, that could alter the expected results. This is why the ICCPT is required to evaluate every possible effect in quantitative terms.

Inside the ICCPT, there are internal modules in charge of the accurate estimation of effects (Figure 1):

- The **Technology evaluation model** calculates the standard effects of the different cooking technologies, considering the whole supply chain of each fuel and the particularities of each type of appliance.

- The **Technology adoption model** estimates the population's response to prices, habits (response is incremental), and availability of the different technologies.
- The **Infrastructure evaluation models** apply to Electricity and LPG supply chains. The aim of these modules is the processing of pre-designed infrastructures (part of the off-line inputs in Figure 1) to adapt them to specific plans. The adaptation includes the partial deployment of access and the sizing of components according to the required capacity (which depends on the level of adoption, plus some capacity margins defined as design parameters).
- The **Costs estimation models** evaluate the economic and social costs (the effects) using the results of the other modules.

During the planning process, different plans may be tested against the same scenario to select good plans according to the desired effects and, eventually, to select the best plan (the definition of best is subjective since the effects comprise diverse factors related to economic, environmental and social costs). The planning process may also include testing the same plan subject to different scenarios to assess its robustness against uncertainty.

Main inputs and outputs

The main inputs of the interactive planning tool are the ***plan*** and the ***scenario***, and the main outputs are the ***effects***. To understand their contents, particular modelling aspects must be clarified in advance.

Electricity and LPG are modelled as regulated fuels. This means that the Government plans their supply chains (infrastructures) centrally and fixes their prices (or tariffs). The prices for the rest of the fuels and the appliances are assumed to be fixed by local markets, as well as their supply chains.

The scenarios define the (uncertain) evolution of different socio-economic parameters, including the base prices for fuels and appliances. Additionally, the plans may impose price variations as specific measures, modelled as price multipliers:

- In the case of regulated fuels, the price multiplier may increase or decrease the tariff.
- For the rest of the fuels and for the appliances, a price multiplier means a tax (price multiplier > 1) or a subsidy (price multiplier < 1).

Since the effects include components of quite diverse nature measured in different units, such as economic or social costs (deforestation, health, emissions, etc.), comparing them using absolute figures is not practical. Instead, the effects of a plan subject to a given scenario are evaluated in per-unit (or percentual) reductions with respect to the initial state. For instance, when comparing two alternative plans A and B, we may state that Plan A reduces 10% of the cost, 15% of deforestation and 20% of health damages, while Plan B reduces 5% of the cost, 20% of deforestation and 25% of health damages. It is up to the planner to decide which plan is better.

The differences between regulated and non-regulated fuels, and the use of price multipliers, allow the description of the possible policies included in plans as follows (all of them applicable in different stages or planning periods):

- Deployment targets (infrastructures) for regulated fuels.

- Tariff variations for regulated fuels.
- Subsidies/taxes for non-regulated fuels and for appliances.
- Bans for certain fuels or appliances, especially in urban environments.
- Education/awareness campaigns that could bias the habits and preferences of the population towards cleaner technologies.

To better understand the deployment targets for Electricity and LPG, it is important to note that the availability of these fuels, as perceived by the consumers, has two different features: access and capacity. Access is the percentage of consumers of a given area that could use a fuel, while capacity is the percentage of total demand that could be supplied with the fuel. For electricity, access is limited by the maximum peak power of each consumer, while capacity is limited by the simultaneous peak power at upstream transformers, substations, and lines (or maybe by the maximum energy at the generation level). In the case of LPG, access is limited by the proximity to retail shops or delivery services, while capacity is limited by the total quantity of LPG that could be delivered per week or per month to the area.

In the present NICCP, deployment targets mean ***access***, i.e., the percentage of the population that could adopt electricity or LPG as cooking technology. Capacity is adjusted to the actual local adoption of the technologies, plus some capacity margin defined by the planner (for example, around 3% for electricity and LPG).

The scenarios are defined to model uncertain macroeconomic and behavioural factors in terms of annual percentage variations. The economic factors are deflated, i.e., expressed in constant currency. The scenario factors selected in the elaboration of the NICCP are the following:

- Base prices of fuels/appliances/imports, and costs of the components of infrastructures (Electricity and LPG).
- Consumer behaviour/awareness, related to the education and social development of the population.
- Economic growth of the country. It affects energy demand and average income levels.
- Population growth, including the unbalances due to rural-to-urban migrations.

The main output, the effects of applying a plan subject to a given scenario, is related to the different types of damages related to cooking with traditional (dirty) technologies, the so-called social costs. However, this reduction should be achieved with a minimum burden of economic costs, and therefore, economic parameters are included in the effects to be evaluated. The effects that a plan should try to minimise include:

- <u>Economic cost</u> for the State, as the ultimate responsible party for public services and welfare. In the techno-economic analysis, the costs are evaluated in a simplified way, using annual cash flows and equivalent annuities. The financial analysis evaluates in detail the financial health of the State, the sectors, and even the main companies involved in the NICCP.
- <u>Health cost</u>. Damages to the population, especially women and children. These damages are usually calculated through the averted Disability Adjusted Life Years (DALYs) and deaths. However, the use of percentual reductions with respect to the initial state allows any kind of unit, and the values for different technologies have been normalised with respect to the use of three-stone systems with firewood or biomass.

- Time&Gender cost. Time spent and inconvenience in general (mostly suffered by women), both in the kitchen (preparation-cooking-cleaning process) and in the fuel-gathering process. The values for different technologies have been normalised with respect to the use of three-stone systems with firewood or biomass.
- Emissions**.** Measured in kg of CO_2 equivalent. They include the emissions of the whole supply chain, from raw materials to the kitchen.
- Deforestation**.** Measured in total kg of wood used, either as a raw material or as a cooking fuel.

Other components of the effects are used as additional evaluation criteria (or KPIs) to compare alternative plans:

- The fraction of cooking demand that is covered by clean technologies (to be maximised)**.** This is the addition of the percentual adoptions of Electricity, LPG, Biogas, Ethanol, Pellets (including similar fuels, like briquettes or sawdust), and top-level improved cookstoves for Charcoal, Firewood, and Biomass.
- Cooking costs for consumers (to be minimised, if possible)**.** Average per-unit ($/unit) cost, and annual average expenditure in fuels and appliances. This evaluation criterion is also relevant in relative terms, comparing the increments in cooking costs with respect to the initial state and with the country's economic growth.

Offline inputs

These inputs are computed off-line, either because they are constant data or configuration parameters established in advance, or because they require processes and tools that take a considerable computing time.

Some examples of configuration and objective data adjustable for the country of application are the characteristics of the generation mix of the electricity system. Examples of subjective configuration data are the capacity margins used for the design of supply chains, or the relative balance between the different social costs when they are accumulated into a single figure.

Other inputs require the use of external sources plus a significant effort in pre-processing. Some examples are:

- Identification and labelling of buildings. The goal is to locate each individual building by coordinates (longitude, latitude) and label it in terms of type, size, land-use context, rural or urban, administrative area, and social category.
- Land-use and biomass characteristics. The goal is to identify areas dominated by different land-use types. In this application, it is relevant to locate areas dominated by buildings, trees, crops, or rangeland, so that the availability of free biomass fuels and local price multipliers for commercial biomass can be assessed.
- Cooking demand profiles and initial adoption of cooking technologies. These inputs require the processing of existing surveys and the application of systematic corrections.
- Behavioural parameters of the consumers. Using successive adoption patterns and their contexts, consumers' responses to prices and features of the technologies can be adjusted. Behavioural parameters include willingness to pay and affordability, as well as willingness to change, and the relative balance between the perceived cost and convenience (social versus economic costs from the consumer perspective).

Some offline inputs are technical and objective in principle, but they require certain modelling and validation efforts. This is the case of the parameters related to cooking technologies. The different combinations of fuels and appliances must be parameterised regarding price, efficiency, emissions, health, etc. In addition, the different supply chains, from raw materials to fuels, must also be defined in terms of costs and emissions.

Finally, there are critical offline inputs that come from external tools that design infrastructures (Electricity and LPG in this case) with optimality criteria. They also present the results for interpolation, extrapolation, and cost-reduction estimation. It is beyond the scope of this report to describe these tools in detail, but they share some features that can be noted here:

- The supply chains are designed in full detail, from generation (or import) to the last-mile distribution (the individual building), seeking minimum cost.
- Existing infrastructures are partially considered, especially upstream high-capacity elements. The rest are designed from scratch, since the goal is to estimate costs accurately with minimum inputs, not to resemble the existing layouts in detail.
- Detailed cost breakdown is included in the solution.
- To deploy components, geographic and logistic details are considered, such as roads, streets, or difficult (or even forbidden) areas.
- Upstream system costs can be adjusted using the participation factors of the different subsystems. This allows the estimation of upstream cost savings due to subsystem demand reductions.
- Local subsystem costs can be interpolated or extrapolated because several solutions are provided for each subsystem, each one with a different demand for rural or urban consumers.

Modelling Concepts

This section contains a brief description of the elements required to understand the nomenclature used in the plans and results. Detailed descriptions of the modelling approach can be found in the specific document devoted to the methodology.

Plans over time

Plans are defined over three reference years: the baseline year, the intermediate year (2029), and the final year (2034). This allows the specification of two stages, baseline-2029 and 2030-34, in which the measures applied can be different. Scenarios are defined as annual increments of some parameters, valid for the whole scope of the planning period (baseline-2034).

For each reference year, two states are computed, corresponding to its first and second semesters. This is because of possible changes in pricing measures in the middle of the year; note that, in contrast, infrastructure changes take time, and they are distributed uniformly along each planning stage.

Technologies and the Cook unit

A total of 19 cooking technologies have been defined by combining 9 fuels with 13 sets of appliances (in increasing order of average efficiency and average price):

- The Electricity fuel allows 3 alternative sets of appliances, thus 3 technologies.

- The LPG fuel is assumed to be used only with one level of appliances, a single technology.
- The Biogas fuel has a unique level of appliances and, thus, a single technology.
- The Charcoal fuel with 3 sets of appliances, thus 3 technologies.
- The Commercial Firewood fuel with 3 sets of appliances, and therefore 3 technologies.
- The Free Biomass fuel with 3 sets of appliances, so 3 technologies.
- The Pellets fuel (which includes other similar fuels, like briquettes or sawdust) with a unique level of appliances, and thus a single technology.
- The Free Firewood fuel with 3 sets of appliances, so 3 technologies.
- The Ethanol fuel with a unique level of appliances, and thus a single technology.

The cooking-technologies model, and the whole ICCPT to some extent, rely on the definition of an absolute, standard, and objective unit for the cooking demand: the Cook. Any parameter related to a particular technology will be expressed in units/Cook (Costs, Emissions, Deforestation, Health, etc.). This allows for fair comparisons among technologies, and scaling the relative adoption share to absolute values by multiplying it by the total demand.

Geospatial features and territory partitions

Geo-referenced data are critical elements in the analysis. They include natural characteristics, like mountains, rivers, lakes, and natural resources (such as solar irradiance), and administrative areas, such as province, district, or municipality borders, represented as polygons. Land-use information and biomass patterns also describe territory partitions or types of areas, and supply subsystems break the territory partitions into smaller areas. Finally, the intersection of all those partitions plus the aggregation of types of consumers defines the demand areas, which, once split into rural and urban sub-types, are the basic subjects of the adoption models.

The technology adoption model

The Technology Adoption Model simulates or predicts the behaviour of diverse types of consumers when choosing combinations of alternative cooking technologies, according to perceived (subjective) economic and social costs. It also simulates the effects of limitations of availability, reluctance to change, willingness to pay and affordability limits, and subjective balances between social and economic costs (including education and awareness factors). The behavioural parameters can be adjusted based on historical evolution (recent surveys).

Main assumptions and limitations

Most of the simplifications and limitations are related to the lack of granularity of the current prototype version of the ICCPT, implemented in Excel. Other limitations are due to the lack of flexibility of the Excel version itself, meaning the rigid number and fixed meaning of rows and columns of the sheets:

- The granularity of the present NICCP is limited on the demand side. Supply areas have been aggregated into districts to match the demand areas (also districts), with the partition into Rural and Urban consumers. The only types of buildings considered are domestic (households), although the non-residential demand has been emulated by a demand multiplier or factor to design the electric network more accurately.

- The plans must be applied at a country level, not allowing different planning targets for provinces or districts. This limitation has been mitigated by algorithms that optimise the territorial deployment of centralised fuels (Electricity and LPG) using cost/benefit ratios. Some inputs are expressed in terms of patterns instead of local features.
- Finally, there are improvements or extensions required for data and inputs in general, including a full set of buildings, or more inputs required to better adjust parameters. In particular, the data used for adjusting quite relevant parameters, such as the initial adoption of technologies and the behaviour of consumers, would be significantly improved by having access to an updated version of the National Survey (MININFRA, 2021); not just to have updated information, but mainly to characterise the changes and estimate better the future response.

Assumptions related to the scenario applied to the plans should be validated by Rwandan experts, checking predicted versus actual figures. For instance, the growth of electric demand during the last year, the growth of urban and rural populations, the economic growth, or the evolution of costs and prices.

Despite the simplification applied in the prototype of using only domestic cooking (urban and rural households), the results and conclusions of the planning exercise are reasonably valid. This is because (1) including institutional and commercial cooking is not critical on the overall figures, because of their estimated percentage/participation, and the similarity of economic-social trade-offs, and (2) the results are slightly conservative because institutional and commercial consumers will follow more closely the government criteria.

Financial Model

This section describes a post-processing model and tool used for the financial analysis of the techno-economic plans. The financial modelling framework for the NICCP is designed to evaluate the financial viability of clean cooking plans thoroughly. Each technology, be it tied to electricity, LPG, or other fuels, has its potential economic impact analysed to understand the specific financial implications for each plan.

Overview

The methodology encompasses a detailed assessment where each sector's financial health is examined individually and then integrated into a broader financial strategy. This integration allows for a nuanced understanding of how each clean cooking solution contributes to the overall economic objectives of the NICCP. The financial model leverages data from techno-economic evaluations, projecting the costs and benefits over time, ensuring that strategic decisions are grounded in solid economic analysis.

e-Cooking approach

The strategy for e-cooking begins with an evaluation of how e-cooking will integrate into and impact Rwanda's broader electrification efforts. This involves a detailed assessment led by the Energy Development Corporation Limited (EDCL) and the Rwanda Energy Group (REG), which focuses on adapting the existing electrification strategies to incorporate e-cooking seamlessly. A critical element of this strategic integration involves estimating the additional capital expenditure

(CAPEX) and operational expenditure (OPEX) required to support the enhanced infrastructure and service demands introduced by e-cooking.

Financial considerations are central to this strategy. Initial financial assessments start with tariff projections based on the adoption models, which are iteratively refined to strike a balance between the financial sustainability of the initiative and affordability for consumers. Achieving this balance necessitates exploring various financing mechanisms, including grants for CAPEX investments and incentives to encourage the widespread adoption of e-cooking technologies.

LPG approach

The financial strategy for LPG involves setting up a comprehensive infrastructure capable of managing the entire LPG supply chain, from import to bottling, storage, transportation, and fee collection. This infrastructure plan, likely overseen by a public entity, is designed to guarantee efficient and reliable LPG distribution throughout Rwanda. The model considers the potential for private sector participation in certain supply chain segments, impacting the overall financial dynamics through variations in capital costs.

A critical component of the LPG financial model is its sustainability. It recognises the potential for financial shortfalls within the LPG supply chain, requiring necessary subsidies from the GoR when committing to rural expansion. The market for LPG, shaped by major providers under the regulatory oversight of the Rwanda Utilities Regulatory Authority (RURA), operates within a competitive, free-market framework. This structure promotes competitive pricing and adherence to safety standards but also faces challenges in reaching less profitable, remote, or economically disadvantaged areas due to higher operational costs. To mitigate this, the financial model includes strategies such as government subsidies to ensure that LPG benefits are equitably distributed across all regions of Rwanda.

Regulatory, market, and technological considerations

Both the e-cooking and LPG financial models are intricately tied to the regulatory landscape, market dynamics, consumer behaviour, and technological advancements. These models are designed to be flexible and adaptive, capable of responding to global energy trends, local economic shifts, and changing consumer preferences. The overarching aim is to foster a sustainable, inclusive clean cooking ecosystem in Rwanda that not only meets immediate energy and environmental needs but also contributes to the country’s long-term socio-economic development.

Deployment and financing of Clean Cooking technologies

The deployment strategy for clean cooking technologies includes promoting appliances through a business model focused on Results-Based Financing (RBF) to manufacturers/retailers per appliance delivered, or direct consumer subsidies per appliance purchased. This approach is anticipated to be effective given the expected durability of cooking appliances and the significant technological shift they represent. For improved cookstoves (ICS), the financial plan also accommodates the need for more frequent appliance replacements to maintain sustainability.

In addition, carbon credits could provide financial support if pricing and implementation costs are favourable, with revenue from these credits potentially funding long-term appliance subsidies. A proposal for the potential revenue from these measures is presented.

A comprehensive feasibility study will set the parameters for RBF grants and establish eligibility criteria for vendors, technologies, and users, including strategies to ensure effective deployment in rural areas and robust recycling policies. The techno-economic analysis will forecast additional adoption and emissions reductions at various levels of subsidy support and incorporate these projections into a 20-year financial plan for the RBF grants.

Main inputs and outputs

The financial analysis will simulate the flow of economic resources in an Excel-based model under different regulatory conditions during the period agreed in the concession for the implementation and execution of the clean cooking plan.

This model facilitates decision-making through structured modules, each addressing key aspects necessary for the successful deployment and sustainability of clean cooking infrastructures.

Integration of diverse data inputs

The financial model is built from a comprehensive integration of multiple inputs essential for a nuanced understanding of the economic and financial landscapes. These include:

- **Techno-economic analysis**. This foundational analysis calculates capital and operating expenditures based on expected adoption rates and specific requirements of clean cooking technologies. It carefully considers every aspect of the initial investment and ongoing costs that are critical to the long-term viability of the project.
- **Macroeconomic context**. Economic indicators such as GDP growth, demand growth, and infrastructure costs provide a macroeconomic context. These data ensure that the project is aligned with national economic conditions and ambitions.
- **Regulatory framework**. Tariffs and cross-subsidy policies are critical inputs that define the operational landscape for clean cooking solutions. Understanding these regulatory elements enables modelling of the economic environment in which these technologies will operate.
- **Financing options**. Exploring different financing mechanisms, including commercial and concessional debt, equity, and grants, is critical. This aspect of the model addresses capital requirements and outlines potential financing options to support both the deployment and ongoing operations of the initiative.

Strategic modules that drive the financial plan

The financial model is divided into several strategic modules, each designed to address specific challenges and objectives:

- **CAPEX roll-out plan**. The model emphasises the strategic deployment of infrastructure, planned in phases to match the projected uptake of clean cooking technologies in different regions of Rwanda. This ensures efficient and equitable distribution, with a comprehensive capital expenditure payback schedule that reflects the expected lifespan of the infrastructure.

- **Revenue streams and operating income**. To financially sustain the infrastructure, the model includes a well-structured tariff system that balances affordability for users with the financial needs of the supply chain. It also considers additional revenue streams, such as fees for new connections and non-energy services, which are essential to offset initial set-up costs and contribute to the financial health of the initiative.
- **Cost management**. Operating costs are carefully analysed and include the purchase of energy resources, maintenance of infrastructure, and administrative overhead. This ensures the long-term reliability and efficiency of the supply chain, with administrative costs factored in to increase customer satisfaction and operational success.
- **Working capital and financial management**. Effective working capital management is critical to the smooth operation of the supply chain and includes efficient inventory management and financial transactions. The model also incorporates a strategic tax approach, considering incentives such as tax rebates or holidays to encourage investment.
- **Comprehensive financing structure**. The financial model employs a multi-faceted financing strategy that includes securing loans on favourable terms, leveraging government subsidies, and attracting equity investments from key stakeholders. This strategy is critical to cover the significant upfront capital costs and ensure ongoing financial sustainability.
- **Use of carbon credits**. Finally, the model integrates the innovative use of carbon credits, which can provide an alternative revenue stream by capitalising on the environmental benefits of clean cooking solutions. This strategy includes detailed plans for certification, market engagement, and maximising the value of carbon credits.

Output Generation and Strategic Implementation

The outputs from this financial model include developed financial statements and ratios, detailed assessments of funding uses and sources, and visual plans for implementation and investment. Continuous refinement of these outputs ensures that the financial model remains adaptable and robust, effectively supporting Rwanda's goals for a sustainable and inclusive clean cooking ecosystem. The outputs of this comprehensive model include:

- **Financial statements and metrics**. Provides insight into the program's financial health over time.
- **Uses and sources of funds**. Details of financial flows, showing how funds are allocated and used throughout the project's life.
- **Implementation and investment plans**. Visualises the timing and scope of investments and regulatory strategies, ensuring stakeholders have a clear view of the project's progress.

Main assumptions and limitations

The financial model for Rwanda's clean cooking strategy is based on several key assumptions that underpin the projected financial dynamics and outcomes. This model operates exclusively in U.S. dollars, ensuring uniform financial transactions and streamlined international transactions.

A key element of the financing strategy is concessionary debt, which carries an interest rate of 8% with a substantial grace period of five years and an initial term of ten years. This term can be extended as necessary, providing flexibility in managing long-term financial commitments. Grants are integrated with equity deployments under a stringent 2:1 ratio, meaning for every two parts of the grant, one part of equity is used. This integration is reflected in the profit and loss statement in proportion to the percentage of annual capital expenditures deployed relative to the total capital expenditures, with no repayment obligations assumed.

The financial model is designed with a conservative approach to dividend policies. While a 0% payout policy is assumed, meaning no regular dividends are distributed, there is a provision for dividends to be paid if Free Cash Flow to Equity remains positive. This highlights a flexible approach to profit distribution based on actual financial performance.

It is important to consider operational expenses, particularly in sectors like LPG, where tariff income may not fully cover operational costs. In such cases, a percentage of annual subsidies is incorporated into the financial plan to bridge the funding gap. However, this reliance on subsidies can be reduced through strategic adjustments to tariffs to support the rural expansion needs of the LPG sector.

The model anticipates non-technical losses, accounting for approximately 5% of the tariff income, which reflects realistic expectations of system inefficiencies. Additionally, a corporate tax rate of 28% is applied, following current tax laws and regulations.

The operational logistics within the network, including roll-out and investment costs, are based on a mid-year convention. The values are extrapolated between the various states of the solution as defined in the techno-economic analysis. This assumption is based on the premise that all activities related to capital expenditure and new customer connections are evenly distributed throughout the year. This approach simplifies the financial calculations by allowing for a straightforward linear projection of costs and activities. The same mid-year assumption is applied to other recurring costs, including upstream energy costs, operations and maintenance expenses, and administrative expenses. This provides a consistent basis for financial planning.

Lastly, working capital assumptions are carefully defined, with trade receivables and payables both set at 30 days. This approach to cash flow management ensures that the company maintains liquidity while effectively managing its credit terms and payment obligations to suppliers.

However, the financial model for Rwanda's clean-cooking strategy, while comprehensive, has inherent limitations that could impact its effectiveness and accuracy. These limitations originate from the model's dependence on specific assumptions and external variables:

- **Data accuracy and timeliness**. The model depends on accurate and timely input data, including macroeconomic indicators, consumer behaviour forecasts, and regulatory changes. Any discrepancies or delays in updating these data points could result in inaccurate financial projections, potentially influencing strategic decisions.
- **Market and technology volatility**. The rapid pace of technological advancement and market evolution can render the assumptions embedded within the model obsolete. Frequent updates are, therefore, essential to ensure the model's continued relevance. Furthermore, the model may not fully account for the complex interplay between local and global trends influencing technology adoption. This could result in discrepancies between projected and actual outcomes.
- **Fluctuations in regulatory and socioeconomic factors**. Changes in regulatory frameworks or government policies, as well as broader socioeconomic shifts such as changes in GDP growth or consumer purchasing power, can significantly impact the economic landscape and the financial viability of a project.
- **Financing assumptions and ROE**. It is essential to consider the availability of financing, including grants and concessionary loans, when making assumptions. Fluctuations in financial markets or changes in lending policies can impact these assumptions, influencing the project's capital

structure. Furthermore, if the actual Return On Equity (ROE) is lower than projected, it could deter investment and affect the initiative's sustainability.

- **Environmental and social impact**. The model's incorporation of environmental benefits, like carbon credits, may not fully account for the broader impacts of clean cooking solutions. Furthermore, the model may not adequately address the distribution of benefits and costs across different communities, which could raise concerns about equity in deploying technologies.

Acknowledging these assumptions and limitations is essential for the ongoing refinement of the financial model. It is crucial for stakeholders to remain flexible, updating assumptions and recalibrating strategies as conditions evolve to ensure the model provides valuable guidance for Rwanda's clean cooking strategy.

NATIONAL INTEGRATED CLEAN COOKING PLANNING

Techno-economic Analysis

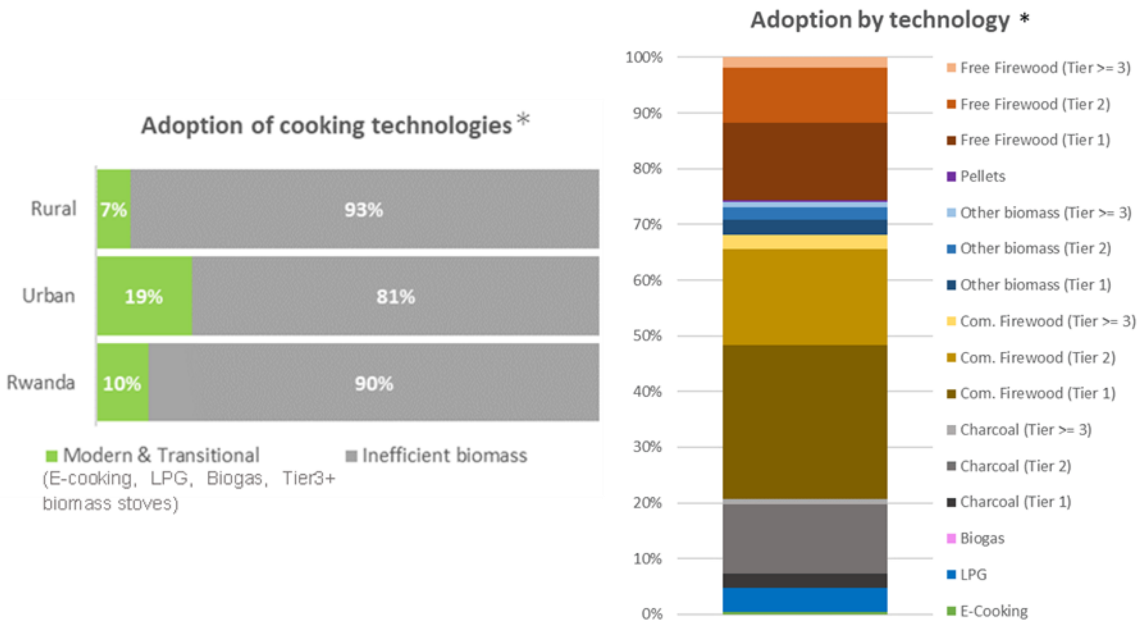
This section presents the two plans analysed in the NICCP. The first plan (*Aligned*) focuses on achieving a particular technology mix by the target years. The second plan (*CleanStep*) seeks a higher clean cooking adoption in the first planning stage, and focuses on economic recovery in the second stage, while keeping the respective social costs stable.

As stated in the Methodology section, plans are defined over three reference years: the baseline year (2024), the intermediate year (2029), and the final year (2034). This allows the specification of two stages, 2024-29 and 2030-34, in which the measures applied can differ.

Baseline

The baseline is relevant to the analysis of a plan in two ways. First, it states a reference point for future improvements regarding social and economic costs. Second, it supports identifying the initial adoption of technologies, which is critical to simulate the future behaviour of the consumers, considering current habits towards technology use and expenses.

Figure 2. Baseline considered for adoption of cooking technologies at a national level (left), and this adoption disaggregated by technology (right).



**Adoption is defined as the share of cooking demand, allowing for technology stacking.*

The adoption of technologies in the Baseline was formulated using the National Survey on Cooking Fuel Energy and Technologies in Households, Commercial and Public Institutions in Rwanda as a reference (MININFRA, 2021). In the Baseline, electric cooking is considered to be available to 60% of the population (high-tier electrification rate), mainly in urban areas (RURA, 2022), (REG, 2022), and LPG is available to 25% of the population, almost exclusively in urban areas (The Global LPG Partnership, 2021).

Figure 2 shows the initial landscape of the adoption of cooking technologies in the country. The share of clean cooking technologies is low in the overall adoption, with inefficient Firewood (rural) and Charcoal (urban) as the dominant options. The effects estimated for the Baseline, and their specific sources, are the following:

- Emissions related to cooking are approximately 21.9 M Ton/year of CO_2 eq. The CO_2 eq is calculated from the initial status of technologies adoption, based on the emissions factors and the Global Warming Potential using data from the Fifth Assessment Report (AR5) (IPCC, 2014).
- Deforestation related to cooking is approximately 9.5 M Ton/year. This is calculated from the initial status of technologies adoption, assuming the biomass stoves of the National Survey (MININFRA, 2021) and a 13% conversion efficiency of charcoal kilns. The total amount of wood consumed is the proxy used to evaluate deforestation.
- Health costs are estimated at 5,400 M Units/year of damages. Normalised units are good for relative improvements, and they can also be interpreted in terms of physical effects using the results of (GBD 2021 Causes of Death Collaborators, 2024). These 5,400 M Units/year are equivalent to 600,000 Disability Adjusted Life Years (DALYs)/y, including the years of life lost by 15,000 premature deaths per year.
- Time and gender costs are estimated at 10,306 M Units/year, and this can also be interpreted in terms of wasted time using the results from (MININFRA, 2019). This is equivalent to 50 full days/person/year.
- Economic costs are estimated to be USD 154 M /year, comprising the annuity cost for the electricity and LPG sectors, and the initial balance between taxes and subsidies. The costs have been calculated by the electricity and LPG off-line design models. In the case of initial taxes or subsidies for technologies (that are not considered in the Baseline), the extra costs or incomes would be taken from the market prices of each appliance and fuel (see Annex 3).
- The cost of cooking for the average household is estimated at USD 105 /year for rural consumers and USD 180 /year for urban consumers. The cost of cooking has been calculated considering the cost of the appliances and fuels at market price.

Rationale behind presented plans

The plans presented in this report were formulated through stakeholder consultations, aligning with the GoR's vision for the years 2029 and 2034. The plans aim to provide the GoR and the broader clean cooking sector in Rwanda with a comprehensive overview of the effects of implementing a set of measures to increase the clean cooking adoption share at a national level. A brief description of the plans is presented below.

Aligned. This plan tries to achieve a particular technology mix suggested by the Technical Working Group (TWG), including representatives from REG and MININFRA. This technology mix[1] is described in Table 6.

Table 6. Technology-mix targets in the Aligned plan. Note that the national values displayed integrate rural and urban targets. The values represent the share of overall households adopting each technology for each specific year.

Fuel	2029	2034
Electricity	4.43%	10.18%
LPG	24.78%	22.47%
Biogas	0.34%	0.30%
Charcoal	25.64%	20.40%
Firewood (total)	29.59%	15.70%
Free Biomass	0.02%	0.02%
Pellets + similar fuels	3.43%	3.15%
Ethanol	11.76%	27.77%
Total	**100.00%**	**100.00%**

CleanStep. This plan seeks a higher clean cooking adoption rate in the first phase, implying high investment costs, and focuses on economic recovery in the second stage, while keeping the respective social costs stable. Therefore, in the first stage, clean technologies are promoted by implementing pricing policies (subsidies), while all considered non-clean are penalised with taxes. In the second stage, these taxes are increased, and subsidies are applied in a more moderate way (only for those with the higher benefit/cost ratios).

The main assumptions about the presented plans are:

- Both outline a 100% deployment of electricity access by 2029, with 75% geared towards high-tier electrification suitable for electric cooking, as proposed by the National Electrification Plan (NEP), in its current version (REG, 2019)[2]. However, it diverges from the NEP in terms of capacity, as it incorporates the necessary investments to satisfy the specific percentage of electric cooking demand, which the NEP does not address.
- Both consider a 100% deployment of LPG infrastructure by 2029, adapting the required capacity to the actual demand.

[1] information provided by the technical working group (TWG) integrated by representatives from REG and MININFRA, the 2029 values are included in the draft of upcoming strategic documents and valid at the time this report was written. The values presented for 2034 are preliminary projections provided by the TWG.

[2] It is important to note that the NEP is a dynamic plan subject to adjustments and improvements as new data becomes available and targets are revised, at the time this report was written, an updated version of the NEP was being developed.

- Both assume no limitations of availability in the other fuels, and no limitations in the availability of appliances. This means that the demand for those fuels and appliances is assumed to be satisfied, with the observation that vast efforts are required to produce and import clean cooking appliances and fuels. Industrial sectors must be promoted to attract private capital, and a stable legal and economic framework is the best tool to achieve it (long-term subsidy programmes).
- In the application of any plan, there is a need for efficient procedures to monitor that clean cooking technologies are not only accessible but also adopted and used.

Description of measures

The measures applied to each plan respond to its different purposes or targets. Table 7 shows a summary of these measures.

The *CleanStep* plan applies more pricing policies (subsidies and taxes), focusing on increasing the share of overall clean cooking technologies in the mix, irrespective of each individual technology. The measures applied in the *Aligned* plan adjust to achieve the expected targets for each individual technology.

Table 7. Summary of measures applied to the Aligned and the CleanStep plans.

Plan	Description of measures	
	2024 - 2029	2030 - 2034
Aligned	• 100% deployment of electricity and LPG infrastructures. • Subsidising upfront cost of most efficient e-cooking appliances by 40%. Same 40% subsidy to pellets appliances. • Subsidizing upfront cost of LPG stoves by 80%, biogas stoves by 30%, ethanol stoves by 70%, and Tier3+ charcoal stoves by 99%. • Increased taxation on commercial firewood by 5%.	Extension of the same measures except for: • Less subsidies for stoves: LPG (55%), Biogas (10%), Pellets (30%) • More subsidies for Ethanol stoves (80%)
CleanStep	• 100% deployment of electricity and LPG infrastructures. • Subsidising upfront cost of the least efficient e-cooking appliances by 60% and most efficient e-cooking appliances by 80%. • Subsidising LPG, biogas, ethanol, pellets and Tier3+ charcoal and firewood stoves by 80% • Increased taxation on charcoal and commercial firewood by 20%	• Subsidising most efficient e-cooking appliances by 40% • Subsidizing stoves: LPG by 35%, biogas by 50%, ethanol by 30%, pellets by 40% • Increased taxation on charcoal and commercial firewood by 35%

Results

The measures applied over time are analysed with the ICCPT, focusing on estimating the relative improvements achieved with respect to the Baseline. The results obtained from this analysis are listed below and further described for each target year in the following subsections.

- Technology adoption achieved.
- Social costs, including Health, Time and Gender, Emissions and Deforestation.
- Economic costs for the State include balances of electricity (only the fraction assigned to e-cooking), LPG, taxes, and subsidies. The techno-economic model provides the annual and accumulated cash-flows by stage.
- The cost of cooking for the average household.
- Some complementary but critical information concerns the industrial deployment requirements. This is represented by the annual needs of appliances of each type that should be imported or locally produced. The ICCPT also provides the annual needs for raw materials, like electricity generation, LPG, Ethanol, etc.

Note that the measures of the plans produce the adoption results, and the latter have subsequent social and economic effects. Despite the challenges to relate plans to effects (both qualitatively and quantitatively), tools like the ICCPT represent a step forward to provide approximate and reasonable estimations.

Regarding the economic costs resulting from this section, the techno-economic analysis estimates the economic states in the reference years of the plans. In each state, OPEX and incremental investment (accumulated CAPEX) are computed. The intermediate cash flows are estimated by interpolating OPEX values between successive states and distributing investments (incremental CAPEX) uniformly between successive states. These values do not consider the specific parameters of each type of funding source, to be applied further in the financial analysis.

Impacts by 2029

The adoptions of technologies in both plans are compared in Figure 3 for the year 2029 (end of the first phase). The main differences can be found in two separate blocks. At the lower half of the technology stacks, part of the share of LPG of the Aligned plan is replaced by Electricity and Biogas in the CleanStep plan. At the upper part of the stack, most of the Charcoal share of the Aligned plan is replaced by Pellets and other biomass fuels in the CleanStep plan.

By this year, the Aligned plan results in 3,006,700 households[3] adopting clean cooking technologies (66% allocated to Tier4-5), reducing the use of inefficient biomass technologies (Tier <3) by 64% compared to the Baseline. The CleanStep plan results in 3,446,097 households adopting clean cooking technologies (67% allocated to Tier4-5), reducing the use of inefficient biomass technologies by 75% compared to the Baseline.

[3] Note: these are 'equivalent households' to ensure that aggregated values are accurate independently on technology stacking (e.g., two households that use 50% clean cooking technologies are equivalent to one household that uses 100% of such technologies).

Figure 3. Overall adoption of cooking technologies, for the years 2024 and 2029. *Note: the annual values are presented in Annex 4.*

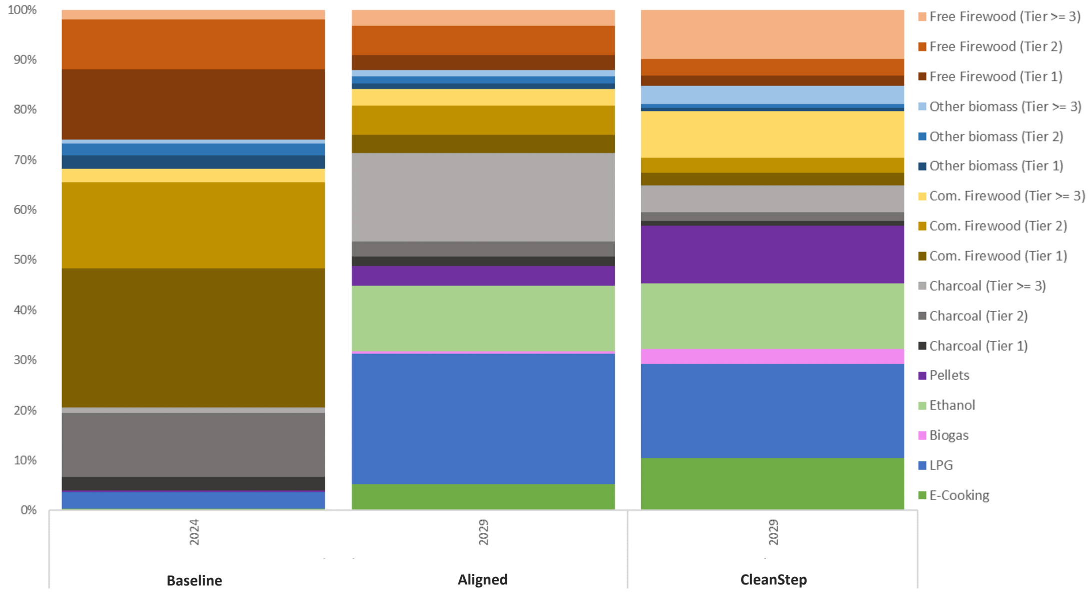
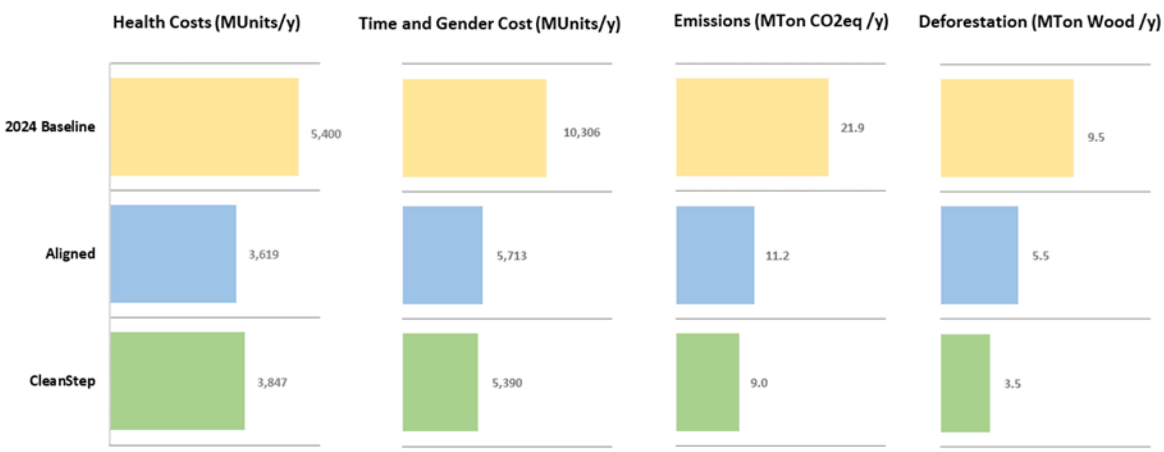


Figure 4. Social and environmental impacts by the year 2029.



Concerning social costs, both plans reduce to about half the absolute level of damages in comparison to the baseline, despite the increase in population (see Figure 4). When comparing both plans, the CleanStep plan responds better to environmental factors, such as Emissions (saving 2.2 MTon CO2eq/y more) and Deforestation (saving 2 MTon wood/y more), and social factors, such as Time and Gender (saving 1.57 full days/household/year more). However, the Aligned plan is slightly better in terms of Health costs (saving 25,365 DALYs/y more). These effects are caused by the measures applied in this period, the CleanStep plan considers a diverse mix of subsidies distributed among different efficient technologies (including those using biomass), which results in a slightly higher share of firewood technologies in the mix when compared to the Aligned plan - which measures are highly impacting the shares of LPG, ethanol and Tier 3+ charcoal in the final mix.

Figure 5 and Figure 6 present the comparison of the resulting economic costs. Figure 5 (left) shows the net investment required by the State to implement each analysed plan for the period 2024-29 (costs and revenues of other types of electric demand have been subtracted, accounting only for those corresponding to the e-cooking demand). Figure 6 presents the breakdown of costs and revenues used to estimate the net investment required. The annual values are found in Annex 4. The net investment requirements (subtracting revenue from tariffs, sales and taxes) for the period by 2029 are USD 329.4 M for the Aligned plan and USD 419.3 M for the CleanStep plan. These figures are close to the USD 364 M of investment planned for the period 2024-2030 in the BEST (MININFRA, 2019) and shown in Table 5.

Figure 5. Net investment requirements (subtracting revenue from tariff, sales and taxes) for the period by 2029 (left), and comparison of cost of cooking for households between 2024 and 2029 in USD/year (right).

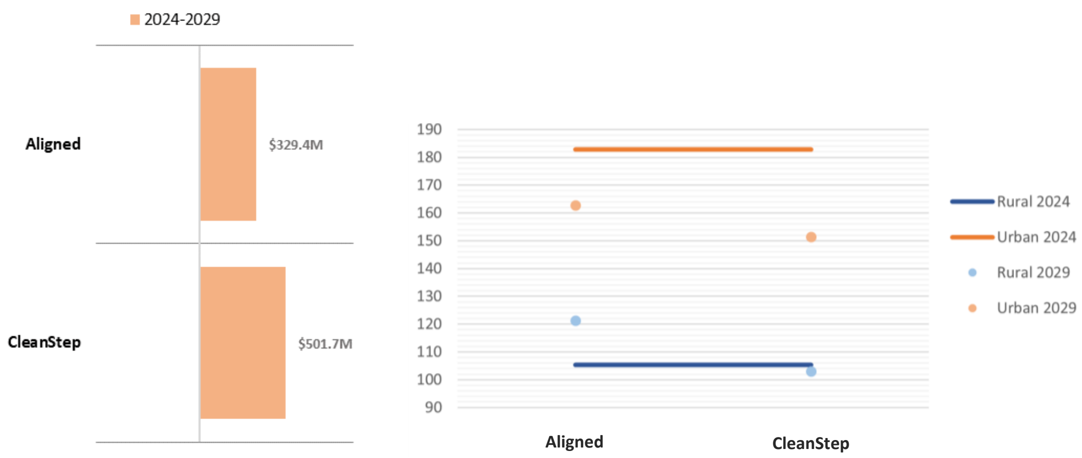


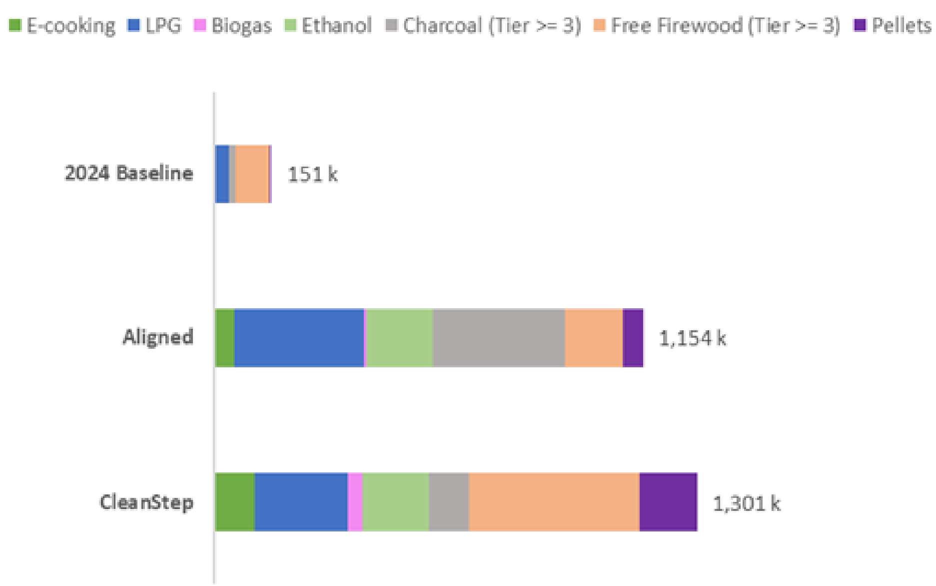
Figure 6. Estimation of net investment required for each analysed plan for the period 2024-2029. *Note: the annual values are presented in Annex 4.*

The CleanStep plan is more costly (requiring USD 171.3 M more net investments than the Aligned plan) due to the high subsidisation of clean cooking technologies and the increased e-cooking demand. However, the revenues from the additional e-cooking demand, taxation of polluting fuels and LPG sales compensate for part of those investments. Figure 5 (right) shows the impacts on the domestic economy of the average household, for both rural and urban. Generally, the expected effects are positive for both plans, especially for urban households (paying 11% less in the Aligned plan and 17% less in the CleanStep plan, when compared to the Baseline). The increase in costs for rural households in the Aligned plan (15%) can be manageable, considering the expected economic growth of the country from 2024 to 2029 (costs and prices are deflated).

Figure 7 displays the annual needs for appliances (either imported or locally produced) of different types until 2029 for both plans and in reference to the Baseline. The estimation is made by dividing the total annual usage of each type of appliance (country level) by the lifetime of the type of appliance, both in cooking demand units (cooks). Therefore, it represents the number of appliances "consumed" annually, which in a steady state would coincide with the annual needs for appliances.

The Aligned plan requires the yearly deployment of mostly Tier 3+ biomass (512 k, mainly charcoal), LPG (351 k), ethanol (178 k), e-cooking (53 k), pellets (53 k) and biogas (6 k) stoves. While the CleanStep plan requires the yearly deployment of mostly Tier 3+ biomass (570 k, mainly firewood), LPG (253 k), ethanol (176 k), e-cooking (107 k), pellets (155 k) and biogas (41 k) stoves. As the results are consistent with the adoption mix of technologies in each plan, the lifetime of the diverse types of stoves differs, and it is considered in the analysis.

Figure 7. Deployment capacity required for the year 2029 (units of appliances per year). *Note: the annual values are presented in Annex 4.*



Impacts by 2034

The adoptions of technologies in both plans are compared in Figure 8 for the years 2029 and 2034, as the cumulative effects of the measures taken during the first period are reflected in the results for the second period, although the measures taken for the latter are different. The main difference in the results for 2034, compared to 2029, lies in the role of charcoal (decrease of 7.5%), LPG (decrease of 3.1%), ethanol (increase of 17%) and e-cooking (increase of 5.8%) in the adoption mix of the Aligned plan. Compared to the Aligned plan, the CleanStep plan uses 10% less charcoal, 6.3% less ethanol, and 5.5% less LPG, compensating these reductions with 7.8% more e-cooking and 6.1% more pellets. The Aligned plan results in 4,241,913 households adopting clean cooking technologies, and the CleanStep plan in 4,077,667 households. This is because CleanStep focuses on improving the financial results in the second period, and, as a side effect, the population is prone to pay less for cooking, accepting extra inconveniences related to their fuel choices.

Concerning social costs, both plans reduce the absolute values of damages when compared to the Baseline, despite the increase of the population (which is close to 40% by 2034), presenting only slight differences in the overall results (see Figure 9). At the end of the second period (2034), the CleanStep plan performs better in Emissions (saving 0.1 MTon CO2eq/y more) and Deforestation (saving 0.9 MTon wood/y more), while the Aligned plan shows improvements in Health (saving 30,985 DALYs/y more) and Time and Gender (saving 3.92 full days/person/y more).

Figure 8. Overall adoption of cooking technologies, for the years 2024, 2029 and 2034. *Note: the annual values are presented in Annex 4.*

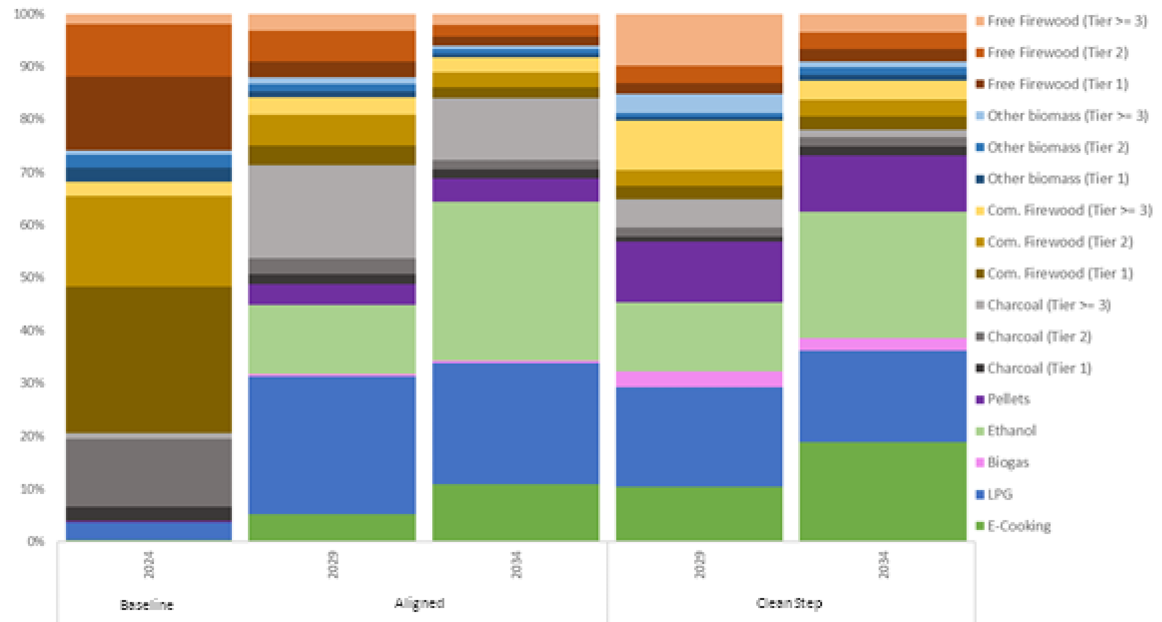


Figure 9. Social and environmental impacts for the year 2034.

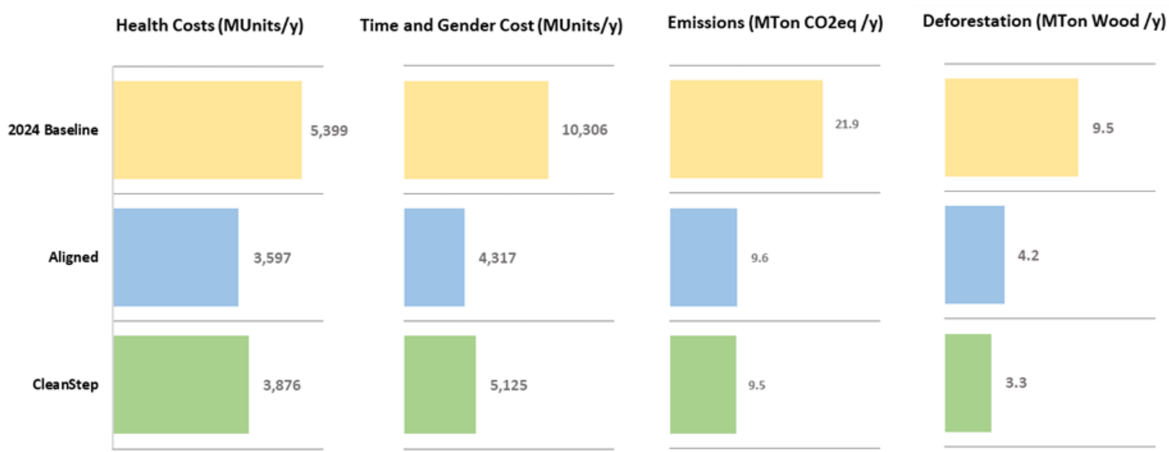


Figure 10 and Figure 11 present the comparison of the economic results. Figure 10 (left) shows the net investment required (subtracting the revenues from tariffs, sales and taxes) for the period 2030-34 and for the whole 2024-34 period (costs and incomes of other types of electric demand have been subtracted). The CleanStep plan is USD 116.8 M less expensive (in terms of net investment requirements) than the Aligned plan for the whole period (2024-34) due to the economic recovery measures applied during the second period (2030-34). Figure 11 shows the breakdown of costs and revenues used to estimate the total investment required, and the annual values are found in Annex 4.

Figure 10. Net investment requirements (subtracting revenues from tariffs, sales and taxes) for the period 2030-2034 and overall, 2024-2034 (left), and comparison of cost of cooking for households between baseline and 2034 (in USD per year).

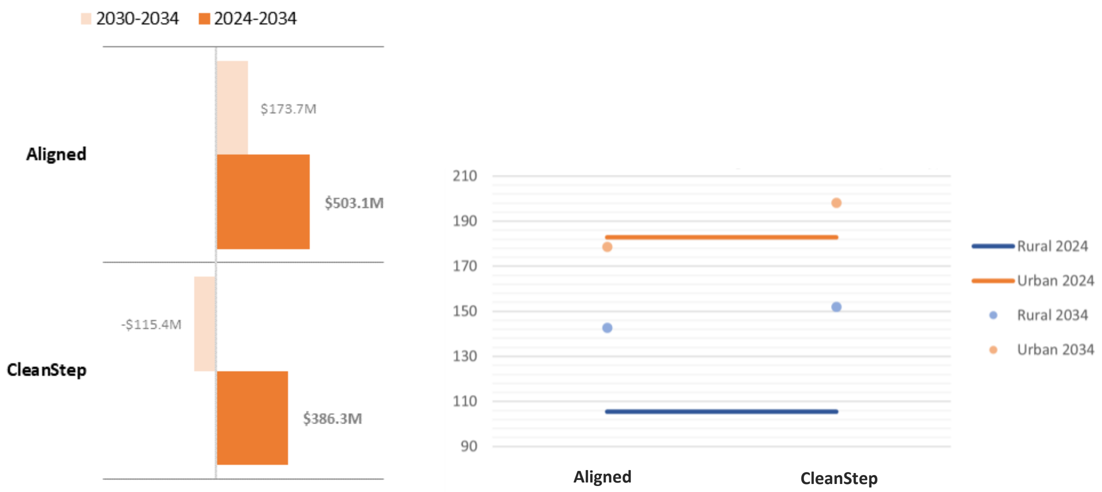


Figure 11. Estimation of net investment required for each analysed plan for the period 2030-2034. *Note: the annual values are presented in Annex 4.*

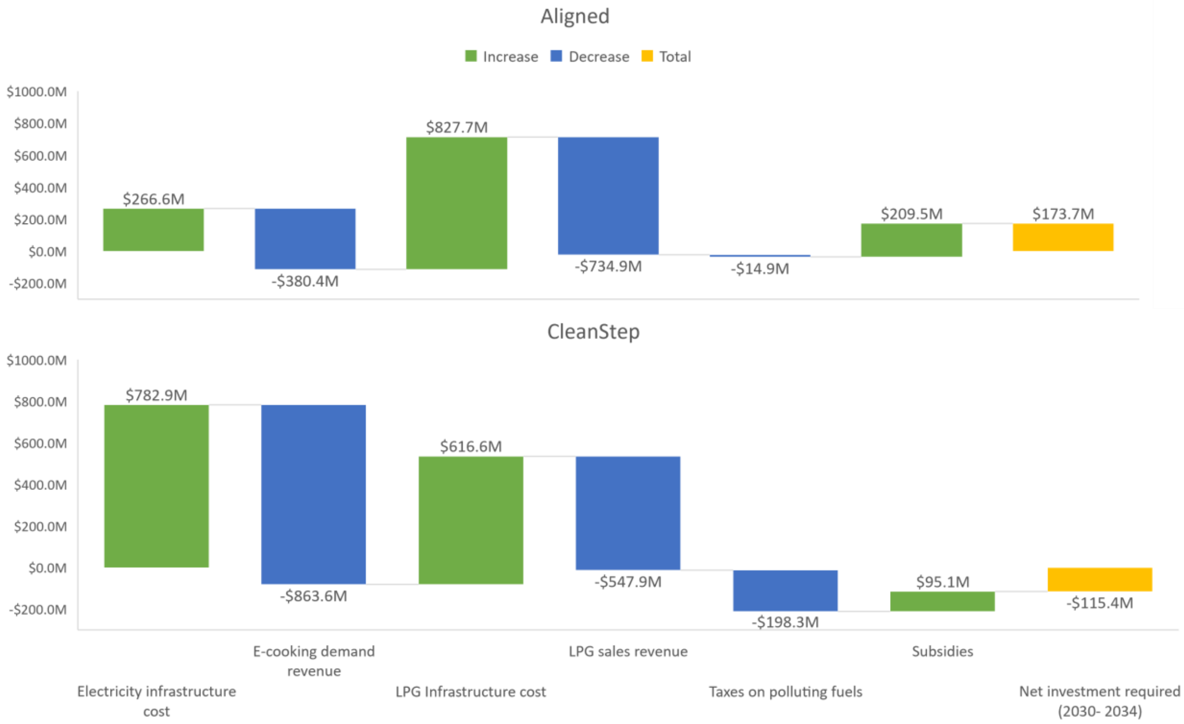
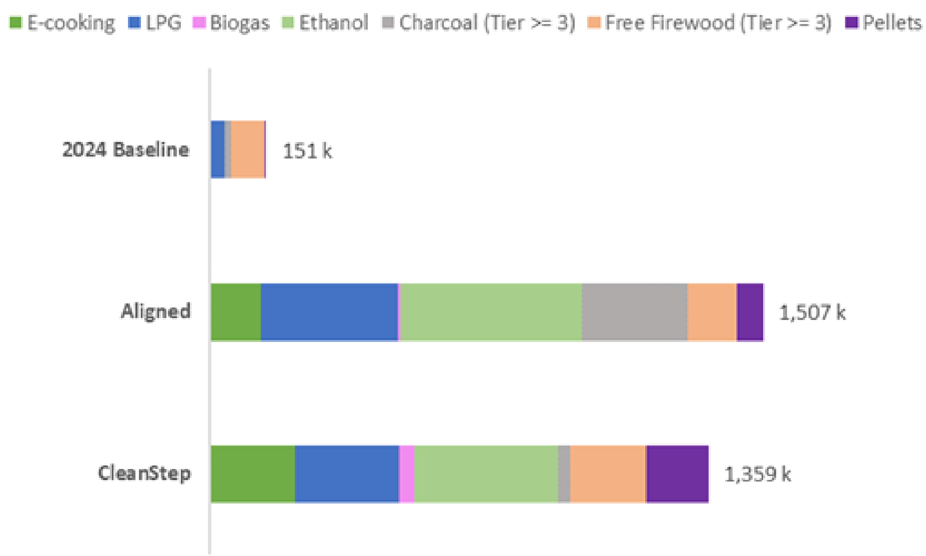


Figure 10 (right) shows the impacts on the domestic economy of the average urban and rural household. In general, the costs of cooking increase for both urban and rural households when compared to the results from the year 2029 in both plans, even though results are more neutral for urban households in relation to what these pay today (Baseline). In both plans, the main reason for the increment in cost for rural households is the set of measures applied that, as a result, reduce the consumption of fuels that can be obtained for free (firewood and biomass). Also, the CleanStep plan is more expensive for households because it also aims to reach the economic sustainability of the plan, while ensuring the stability of the clean cooking share in the technology mix, despite the population growth.

Figure 12 displays the annual needs for appliances of different types in 2034 for both plans and the reference of the Baseline. The Aligned plan requires more LPG, Ethanol, and Charcoal stoves, while the CleanStep plan requires more electric appliances, pellet stoves, and biomass stoves (used for Firewood and Free Biomass).

For this period, the Aligned plan requires the yearly deployment of mostly Tier 3+ biomass (421 k, mainly charcoal), LPG (375 k), ethanol (496 k), e-cooking (135 k), pellets (72 k) and biogas (7 k) stoves. While the CleanStep plan requires the yearly deployment of mostly Tier 3+ biomass (238 k, mainly firewood), LPG (285 k), ethanol (393 k), e-cooking (231 k), pellets (172 k) and biogas (40 k) stoves. The effect of the lifetime of the diverse types of stoves is clear in this period. For example, e-cooking appliances have longer lifetimes, so the CleanStep plan requires fewer appliances per year in total.

Figure 12. Deployment capacity required for 2034 (units of appliances per year). *Note: the annual values are presented in Annex 4.*



Geospatial and temporal representation

With the objective of providing insights that can inform decision-makers and the clean cooking sector in Rwanda regarding the deployment of the technologies considered, the adoption of technologies as modelled is presented and projected geographically here.

Comparisons of technologies adoption between plans

The figures below present the comparative evolution over space[4] and time of adoptions between the Aligned and the CleanStep plans. The technologies displayed are Electricity, LPG, Ethanol, Firewood (including freely gathered and commercial), Charcoal, and other biomass fuels (Pellets and similar fuels, Biogas, and free Biomass). It is important to emphasise that the geospatial representation shows where the fuels are consumed, not necessarily where they are extracted. However, this can be a good proxy for fuels that are gathered locally (e.g., free firewood).

[4] Space is represented by a map of districts and buildings. Each fuel is identified by a colour, and each building is represented as a small polygon displayed with a colour intensity scaled from 0 (0%) to 1 (100%), which indicates the levels of adoption of each fuel by each building, representing the usage of multiple fuels to meet the building's cooking needs (fuel stacking).

Figure 13. Geospatial and temporal representations of the adoption of e-cooking technologies.

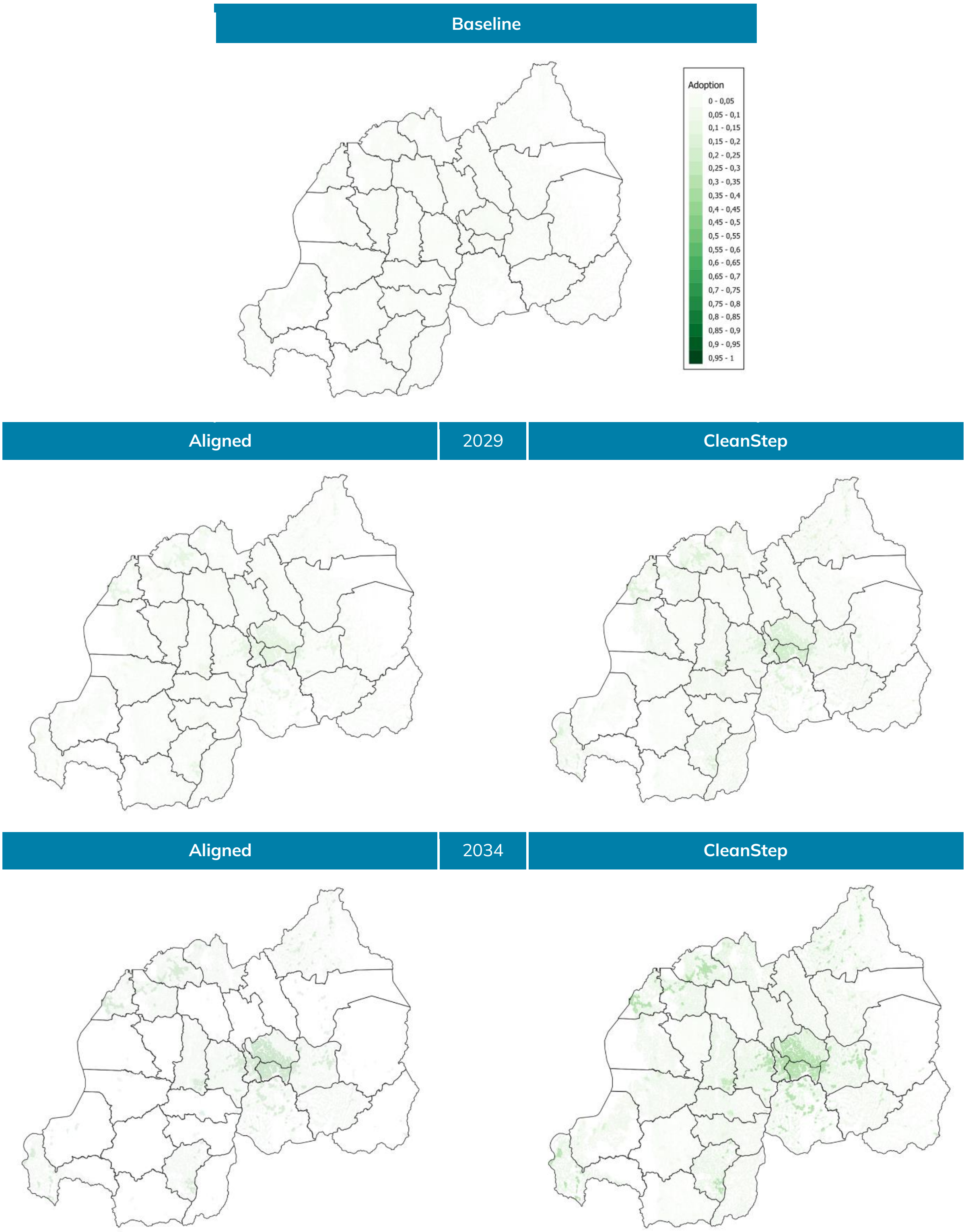


Figure 14. Geospatial and temporal representations of LPG adoption.

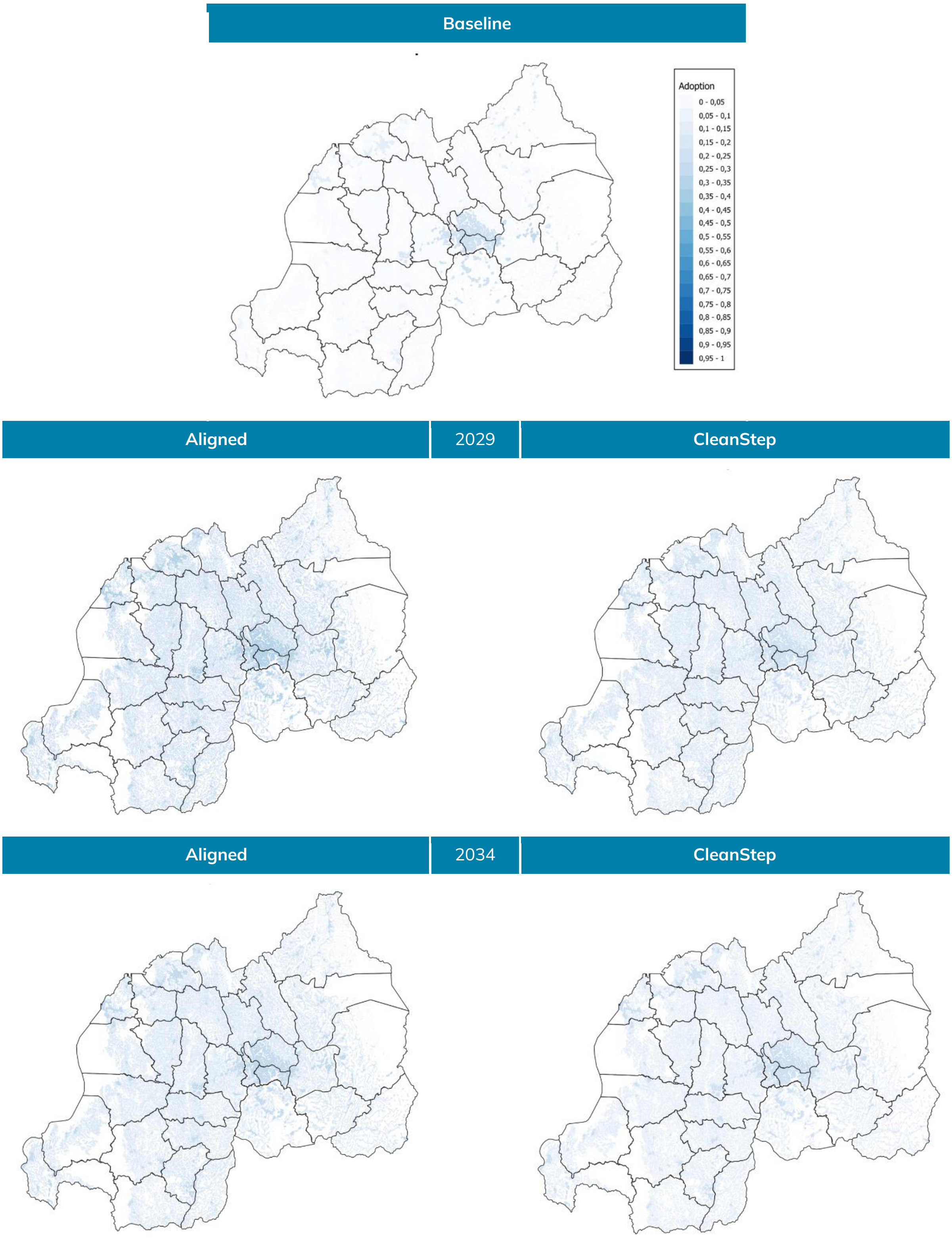


Figure 15. Geospatial and temporal representations of the adoption of ethanol technologies.

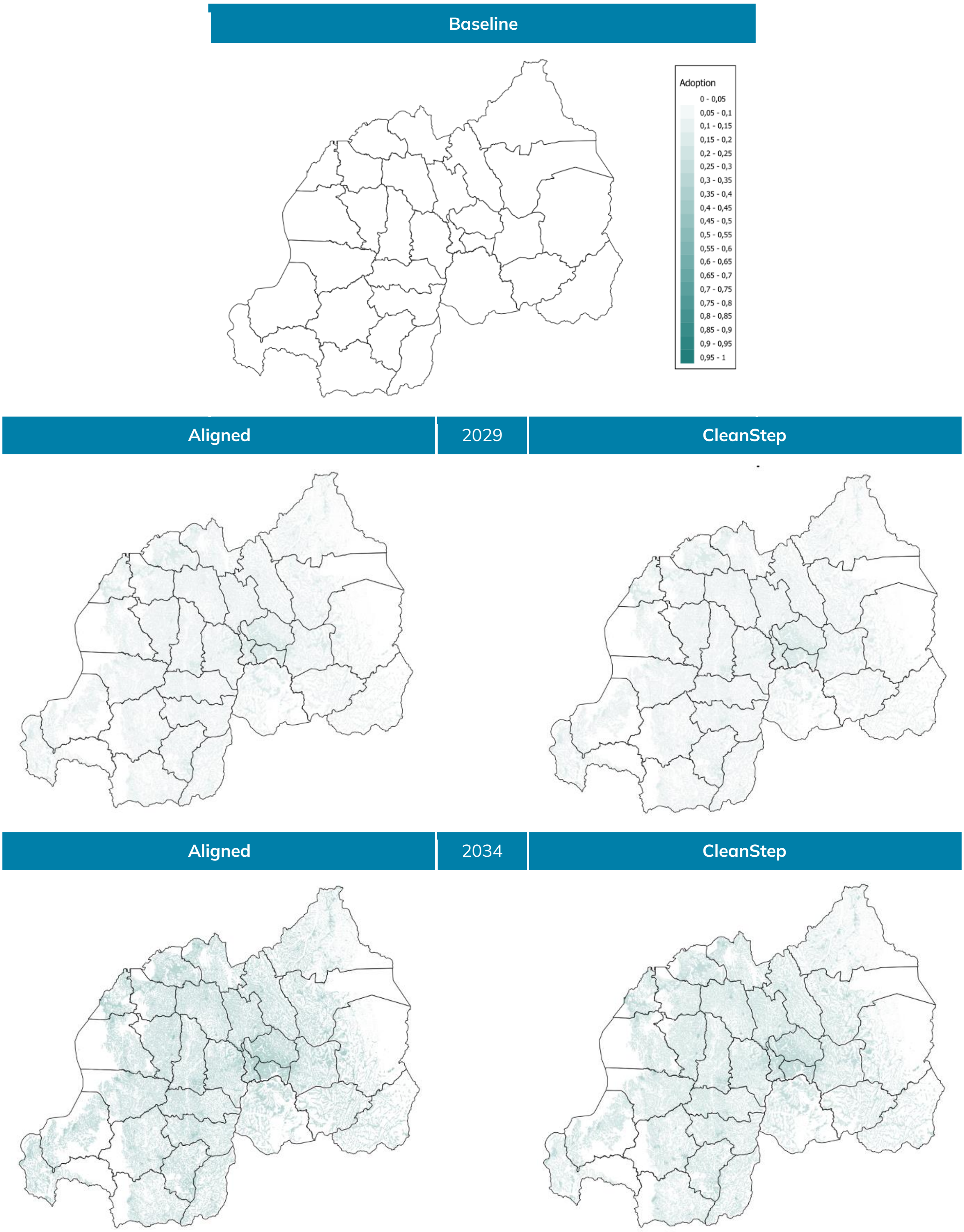


Figure 16. Geospatial and temporal representations of the adoption of firewood (commercial and free-gathering).

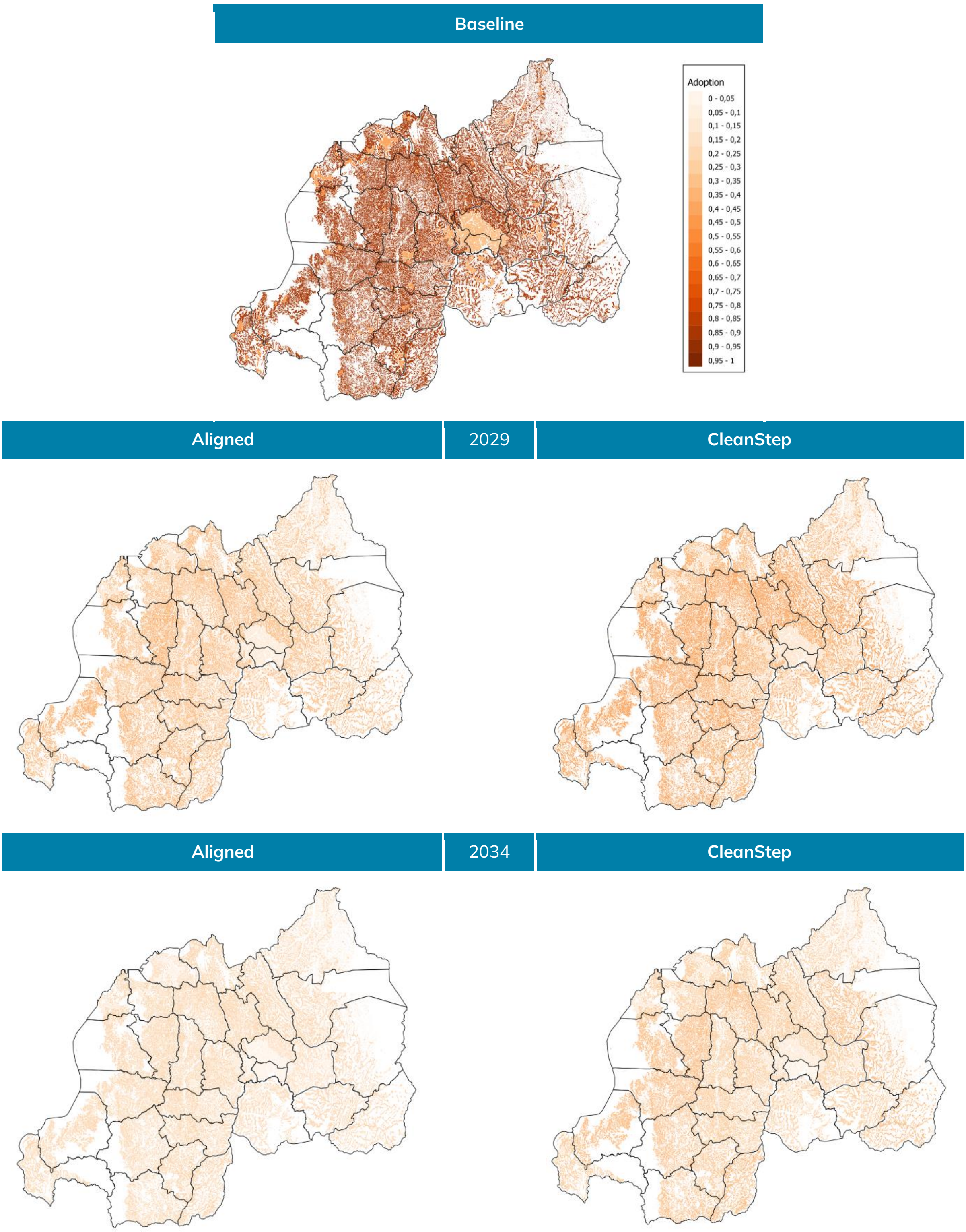


Figure 17. Geospatial and temporal representations of the adoption of charcoal technologies.

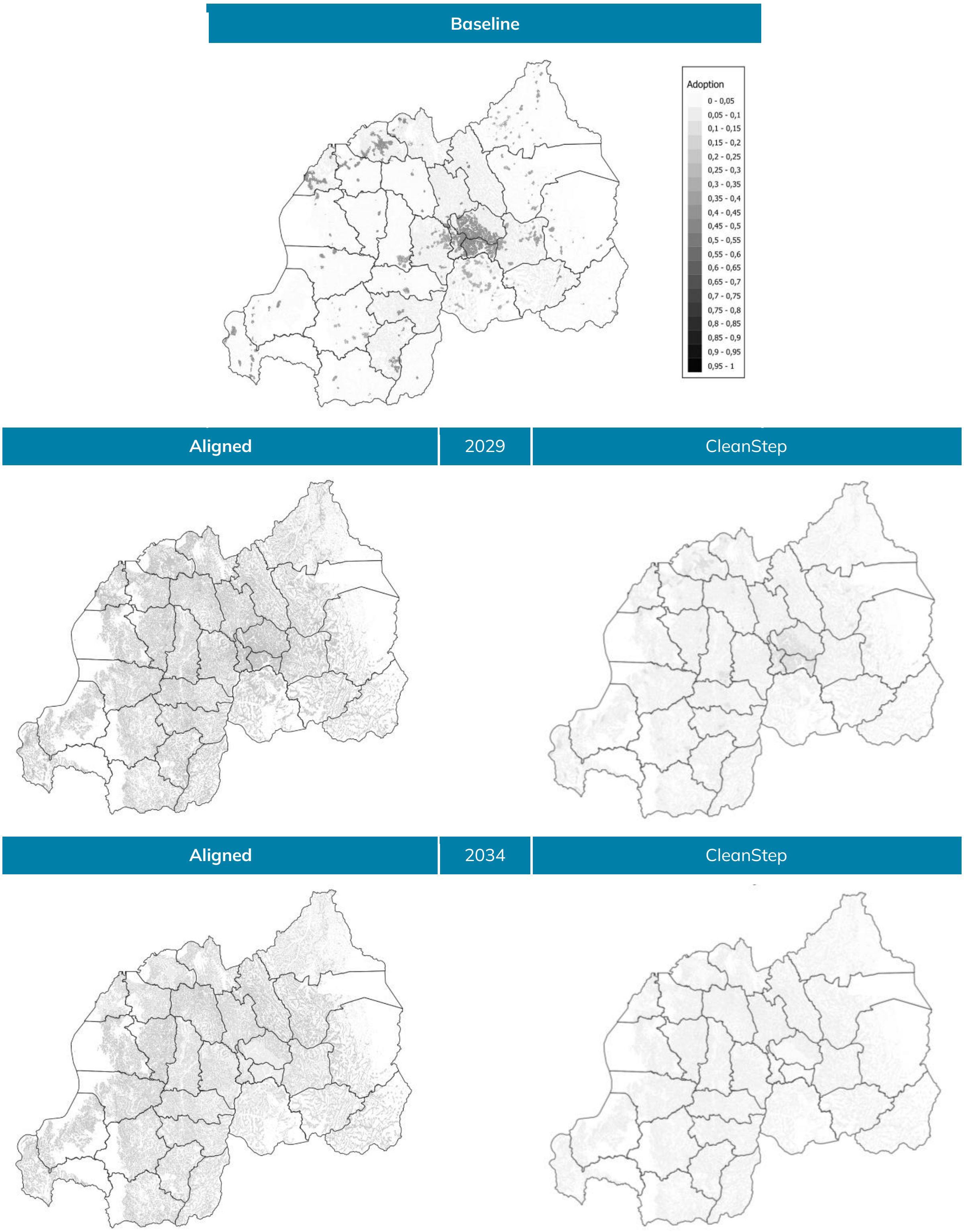
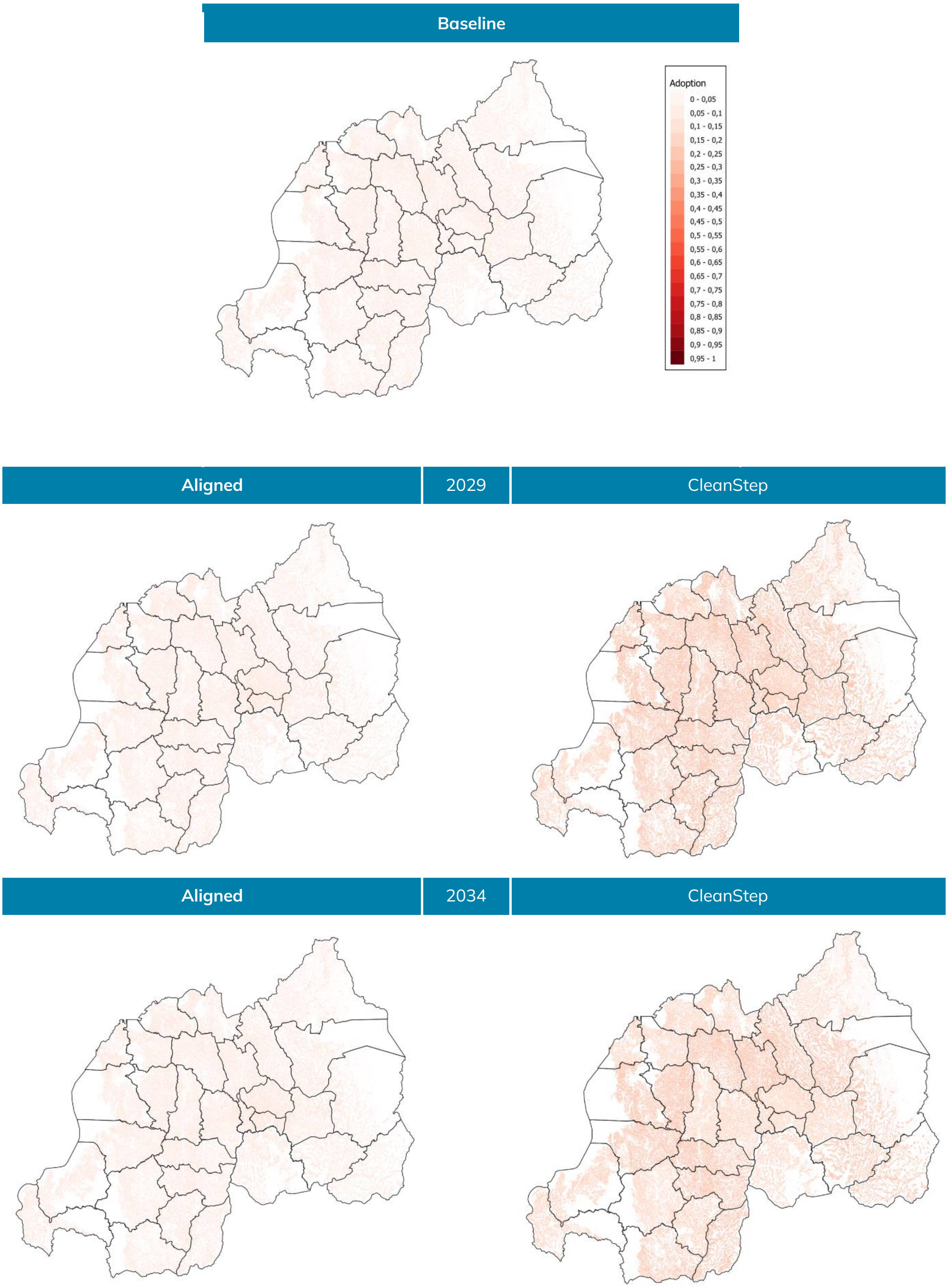


Figure 18. Geospatial and temporal representation of other biomass technologies (including pellets and briquettes, biogas, and free biomass).



Difference in technologies adoption between rural and urban areas

Figure 19 presents an example of how different types of consumers can be analysed separately in terms of adoption and geography, namely, identifying the differences between rural and urban populations. Figure 20 shows the average results at a national level for these types of consumers.

Figure 19. Some adoptions of urban and rural consumers by location (from Aligned plan at 2029).

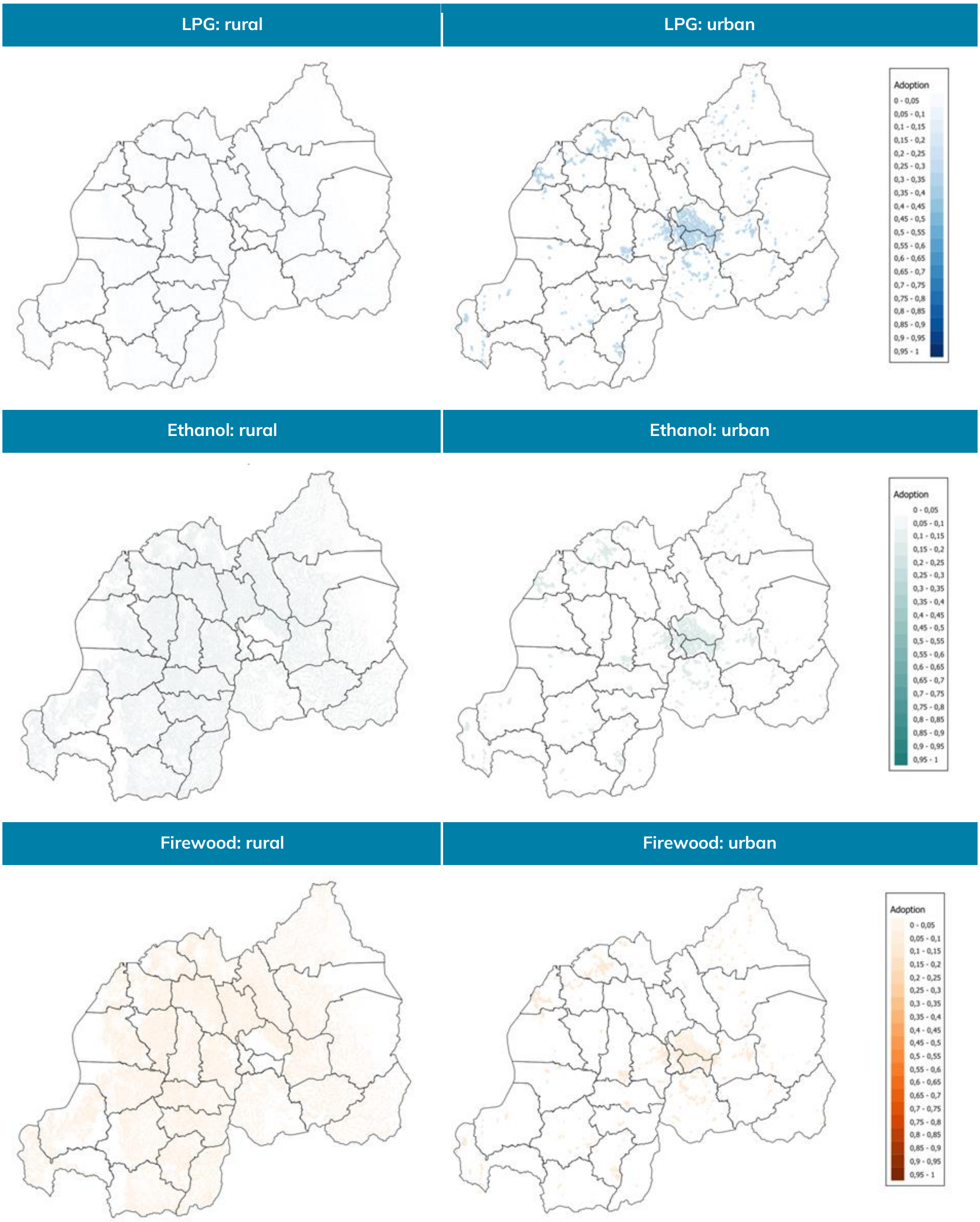
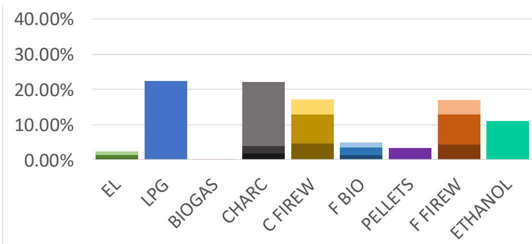
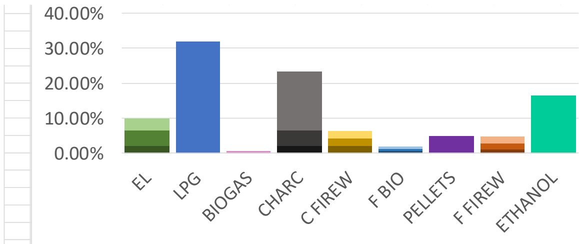


Figure 20. Adoptions at national level of rural (left) and urban (right) consumers (Aligned plan at 2029).





LPG priority areas for deployment

Figure 21 presents the list of areas and the approximate number of buildings without current e-cooking capacity (most of them are in rural areas). These areas could, therefore, be prioritised for the deployment of LPG infrastructure to compensate for the insufficient e-cooking capacity.

Figure 21. LPG priority areas for deployment.

Province	District	Area	#Buildings without e-cooking
Southern	Nyanza	Rural	51370
	Nyaruguru	Rural	50681
	Nyamagabe	Rural	65937
		Urban	11275
Western	Karongi	Rural	49765
	Rutsiro	Rural	41731
	Ngororero	Rural	71052
	Nyamasheke	Rural	50445
Northern	Rulindo	Rural	50605
	Gakenke	Rural	63369
	Gicumbi	Rural	62364
Eastern	Gatsibo	Rural	101261
		Urban	16701
	Kayonza	Rural	75286
	Kirehe	Rural	66396

Financial Analysis

This section provides a comprehensive analysis of the financial modelling results, focusing on the electricity (only accounting for the share corresponding to the e-cooking demand) and LPG sectors under the two plans. It also presents the potential for a carbon credit structure with an associated income, and the trajectory of taxes and subsidies to understand their impact on adopting different cooking technologies.

Overview of financial dynamics

The following are the sources of financing considered in this analysis (see the “Key Terms” section for definitions of viability-gap funding, grants, concessional loans, and equity):

- **Tariff income** represents the direct revenue generated from users of the clean cooking technologies, reflecting the market's contribution to the financing of the company's expansion.
- **Viability gap funding** is provided to bridge the gap between the revenue generated by users of the clean cooking technologies and the costs of expanding the market. Essential subsidies are provided to ensure the financial viability of the projects, covering gaps where user tariffs alone would not fully fund operational and capital expenditures.
- **Concessional loans and grants**. Soft loans and grants from various development partners provide essential low-cost financing to support infrastructure development and initial operational costs.
- **Equity**: These are investments made directly by stakeholders, which demonstrate confidence in the long-term viability of clean cooking solutions.

The following are examples of how financing can be used:

- **CAPEX** refers to the outlay of funds to purchase tangible assets. Significant investment in physical infrastructure is required to deploy some clean cooking technologies.
- **OPEX** (Operational Expenditure). Costs associated with the maintenance and operation of systems.
- **Debt repayment and financial expenses**. Repayment of borrowed funds and financial obligations.
- **Dividends.** Potential returns paid to investors, related to profitability and financial health.

The balance between the sources and uses of funds demonstrates the importance of careful financial planning and management. All financial needs must be met without deficits, which is crucial for the long-term viability of the initiatives. This equilibrium also demonstrates the strategic allocation of funds, with a significant proportion of capital directed towards the construction and maintenance of the necessary infrastructure to support Rwanda's energy transition goals.

Results (Electricity and LPG)

The analysis encompasses various financial aspects, including capital expenditures, revenue generation, EBITDA margins, capital structures, and the uses and sources of funds. This shows the financial implications and operational dynamics associated with each analysed plan.

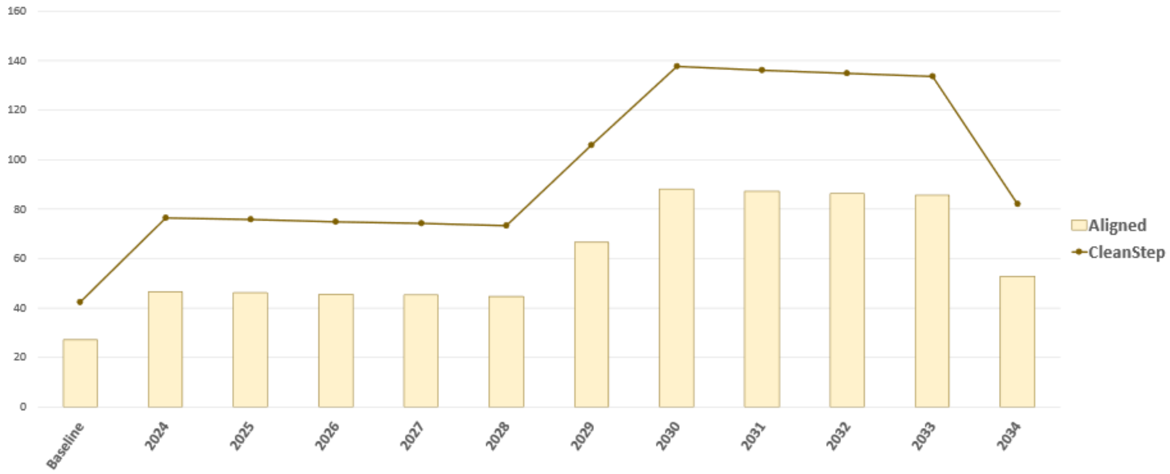
Capital Expenditure

This section provides a comprehensive examination of the capital expenditures (CAPEX) associated with implementing each analysed plan, highlighting the investments required for the e-cooking and LPG components, to assess their viability and sustainability.

Electricity Sector (e-cooking share)

The financial analysis includes all CAPEX investments from the baseline to the projected year of 2034 (sourced from the techno-economic modelling tool). Figure 22 and Figure 23 illustrate the varying scales of implementation, as well as the timing and financial commitment required to achieve each plan's goals between the baseline year and 2034.

Figure 22. Annual CAPEX investments (M USD) for the e-cooking share in both plans.



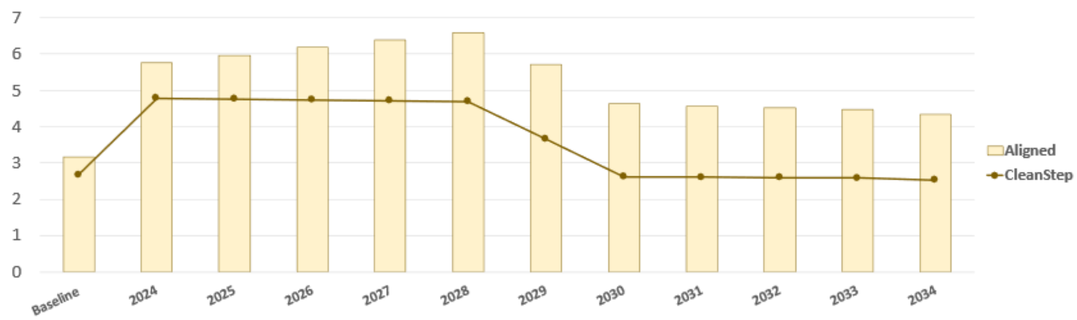
In the Aligned plan, from the baseline year to 2029, the total CAPEX investment is estimated at **USD 323 M.** This investment continues to grow, reaching a cumulative total of **USD 724 M** by the end of 2034. The CleanStep plan, due to its promotion of e-cooking, requires higher CAPEX investments with **USD 523 M** by 2029, and a cumulative total investment of **USD 1.148 B** by 2034. The latter plan prioritises rapid scale-up and early adoption, to achieve widespread e-cooking implementation ahead of the gradual timelines set by the Aligned Plan.

Figure 23. Accumulated CAPEX investments (USD M) only for the e-cooking share in both plans and different timelines.

LPG Sector

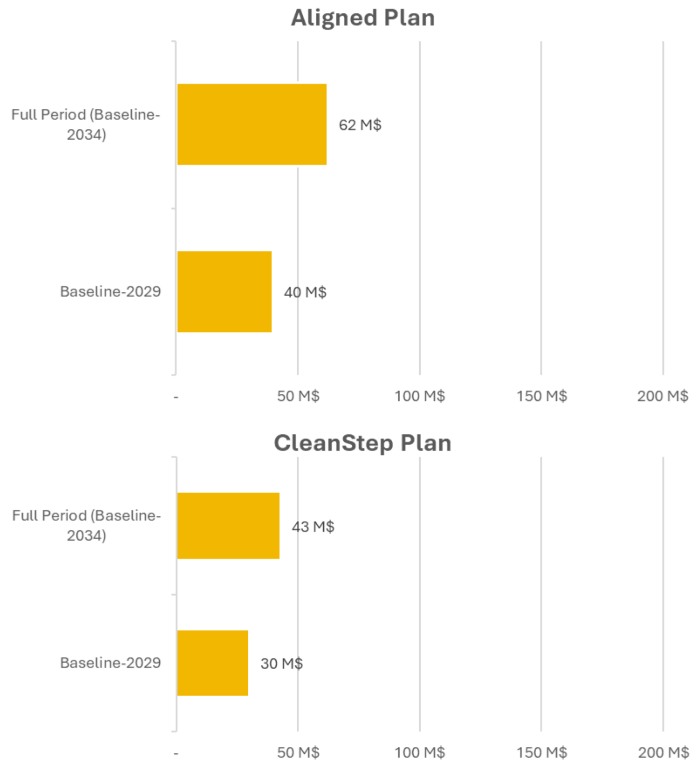
The Aligned and CleanStep plans for the LPG sector in Rwanda demonstrate a distinct CAPEX trajectory from the baseline year to 2034 (see Figure 24 and Figure 25). This is consistent with the higher adoption of LPG in the Aligned plan, instead of e-cooking.

Figure 24. Annual CAPEX investments (USD M) for LPG in both plans.



The Aligned plan begins with substantial investments from the baseline year, with a commitment of USD 40 M by 2029, increasing to a total of USD 62 M by 2034. By contrast, the CleanStep plan presents a more moderate investment strategy, with an initial commitment of USD 30 M by 2029, rising to USD 43 M by 2034. While both plans aim to deploy LPG infrastructure by 100% for 2029, the Aligned plan sets measures that favour LPG demand and reduce the e-cooking share, thus the supply capacity is adapted to meet the higher demand for LPG.

Figure 25. Accumulated CAPEX investments (USD M) for LPG in both plans.



Revenue model and operating margins

To evaluate the financial viability of both analysed plans, the revenue generation and operating margins need to be estimated.

Electricity Sector (e-cooking share)

The financial performance of the electricity sector, including the e-cooking share, shows substantial growth over the projected period. In the first full year of operations both plans generate revenues to the electricity sector of over USD 276 M.

As e-cooking technologies gather pace, driven by growing consumer interest and improved infrastructure, revenues continue to grow. By 2034, the CleanStep plan presents a notable increase in revenue, reaching over USD 846 M, compared to USD 753 M under the Aligned plan. The disparity in revenue growth is consistent with the higher e-cooking adoption rates in the CleanStep plan, which require higher capacity investments.

Figure 26. Revenues / EBITDA (USD M) for the total electricity sector in both plans.

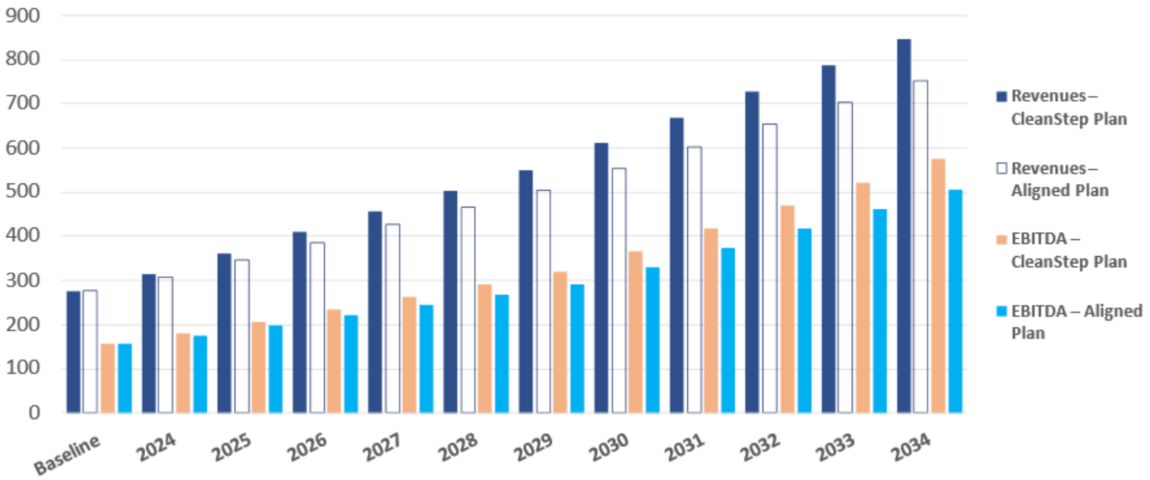
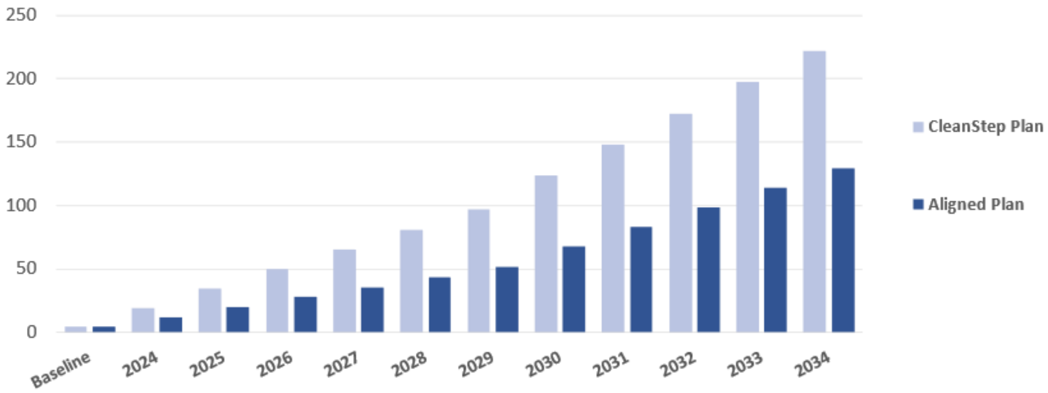


Figure 27. Revenues / EBITDA (USD M) only for the e-cooking share in both plans.



For reference, Figure 26 illustrates the revenues generated by the entire electricity sector, including the e-cooking share. It shows a consistent upward trajectory across both plans, with the CleanStep plan outperforming the Aligned Plan each year because of the broader integration of e-cooking technologies in the mix. Figure 27 presents the revenues generated exclusively from the e-cooking share. This is where the contrast between the two plans becomes more evident, reflecting the strategic focus on rapid scale-up within the CleanStep plan, to capture a larger market share at an earlier stage of the deployment phase.

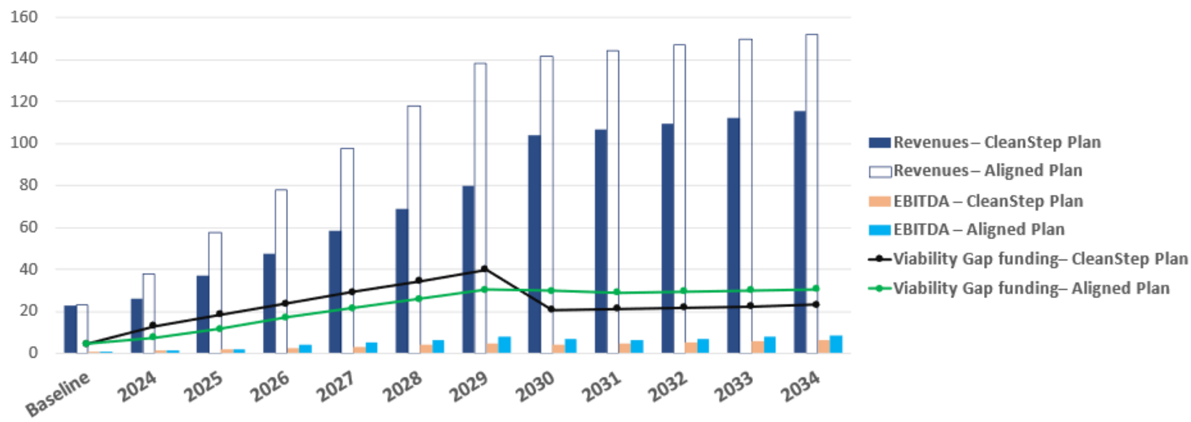
This analysis highlights the importance of aligning investment strategies with consumer adoption rates and market potential in Rwanda's clean cooking sector. By effectively managing the balance between costs and revenue growth, both plans can achieve sustainable operating margins that support the long-term viability of the e-cooking sector.

LPG

The revenue trajectories for the LPG sector show both plans starting with an initial figure of USD 23 M (see Figure 28). Over the projection period (by 2034), the Aligned plan demonstrates a substantial revenue increase, reaching up to USD 152 M. In contrast, the CleanStep plan shows a more moderate growth, with revenues growing to USD 115 M.

It is notable that both plans rely on viability gap funding, which is defined as the subsidy required to cover operational costs above tariff income. This funding guarantees competitive pricing and operational continuity, particularly in rural or underserved markets. Without such subsidies, maintaining competitive pricing or even operational viability would be challenging, potentially limiting the expansion and adoption of LPG services.

Figure 28. Revenues / EBITDA / Viability gap (USD M) funding for the LPG sector in both plans.



In the initial period (until 2029), the CleanStep plan requires a higher proportion of its tariff income to be subsidised, with an average of 35%; this is because the regulated price of LPG is reduced, as part of its strategy to favour all clean technologies. By 2029, the CleanStep plan will have accumulated USD 163 M in subsidies, compared to USD 119 M for the Aligned plan, with a lower average subsidy rate of 21%.

By the end of the projection period (2034), the total amount of subsidies will reach USD 273 M under the CleanStep plan, compared to USD 267 M under the Aligned plan. The differences are reduced because the second stage of the CleanStep plan is conservative in economic terms, and it can also be seen in the reduction of the viability gap for the CleanStep plan.

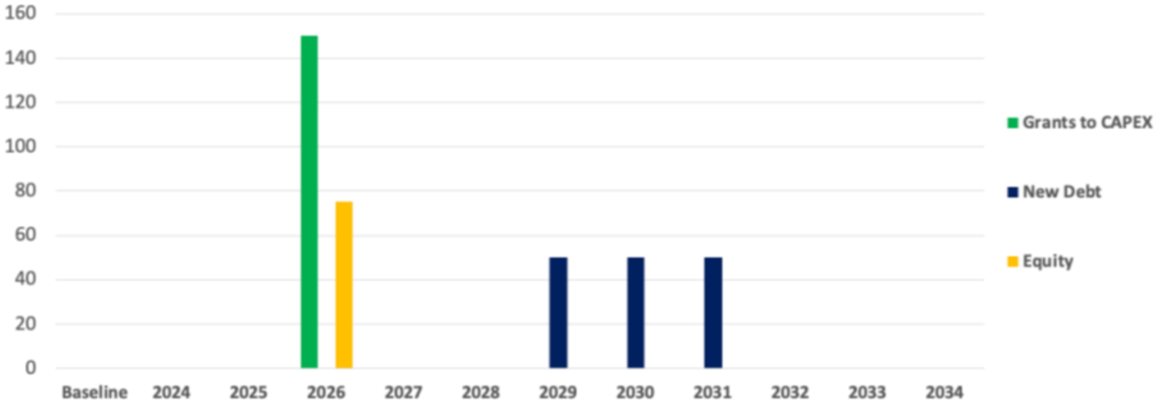
Capital structure

To facilitate the implementation and expansion of clean cooking, various potential financial structures are analysed. This analysis informs the strategic financing decisions that should be made to accommodate the required investments for both plans.

Electricity Sector (e-cooking share)

The changes in the capital structure resulting from the e-cooking share under the Aligned plan highlight the need for new grants to support CAPEX investments, particularly during the initial phase, with a peak in 2026, where grants reach approximately USD 140 M (see Figure 29). This is complemented by incremental equity (USD 75 M) and new debt (USD 150 M), which are introduced in a more gradual manner throughout the projection period. From 2029 onwards, the plan will maintain a consistent annual injection of new debt, indicating a planned approach to financing ongoing expansions and operational costs through borrowed funds.

Figure 29. Changes in the capital structure (USD M) due to the e-cooking share in the Aligned plan.

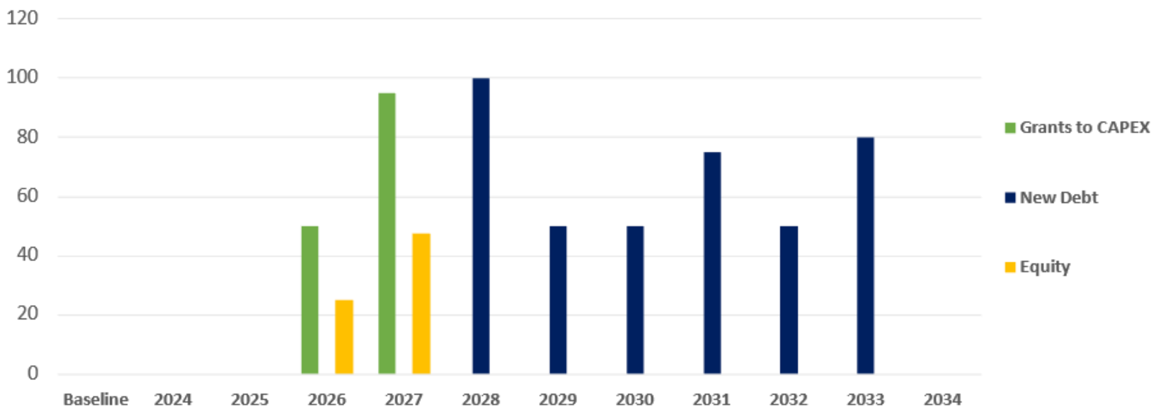


The graph showing the changes in the capital structure for the e-cooking share in the Aligned Plan in 2026 is an example of a methodological approach to understanding the impact of annual variations in financing the full electricity sector with and without the inclusion of e-cooking investments. This representation is essential for understanding how the integration of e-cooking affects the financial requirements of the plan.

The spike in 2026 represents a significant change in the financing strategy, marking a period where additional capital is specifically allocated towards e-cooking technologies within the overall electrification efforts. This increase indicates a deliberate strategy to strengthen the infrastructure and capabilities necessary to support the anticipated expansion of e-cooking solutions, in line with broader national energy objectives.

Similarly, the CleanStep plan begins with a new requirement for grants, which are distributed more evenly over the early years, reaching a peak of almost USD 100 M in 2027, amounting to a total of USD 145 M (see Figure 30). It is essential to make equity contributions at the earlier stages (totalling USD 73 M) to support the initial infrastructural developments and grants acquisition. From 2028 onwards, the plan transitions to a greater reliance on new debt (totalling USD 405 M), indicating a strategy of rapidly scaling operations and covering increasing costs through borrowing.

Figure 30. Changes in the capital structure (USD M) due to the e-cooking share in the CleanStep plan.

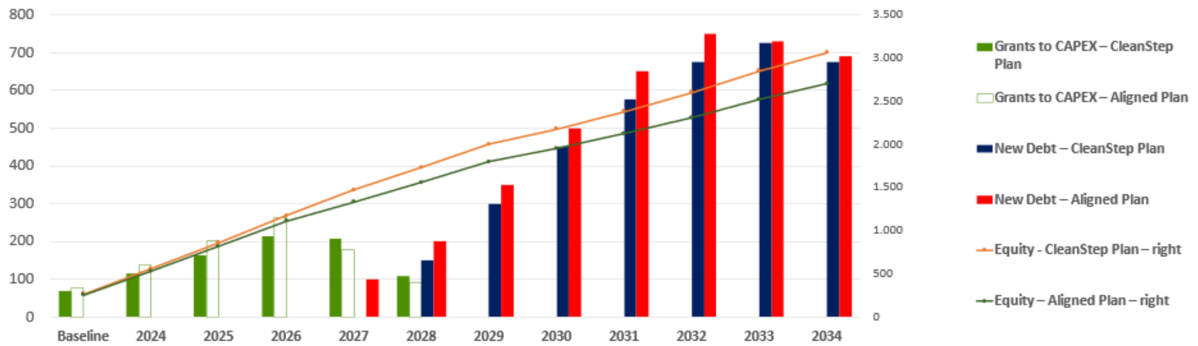


To gain insight into how these two blocks contribute to a unified view of the entire electricity sector, including e-cooking, Figure 31 illustrates how both plans effectively manage the significant investments required across the entire sector, as evidenced by the accumulated capital structure up to 2034. The graph highlights that both plans gradually increase their reliance on new debt over time, indicating a transition towards more sustainable funding sources as the sector matures.

By 2029, the CleanStep plan uses a combination of funding sources to finance the USD 2.5 B in CAPEX. This includes USD 695 M in grants, USD 300 M in concessional loans, and USD 347.5 M in equity. By comparison, the Aligned Plan's USD 2.3 B CAPEX requirement until 2029 is to be financed with USD 600 M in grants, USD 350 M in loans and USD 300 M in equity.

To fund the USD 4.5 B CAPEX from the baseline to 2034, the CleanStep plan deploys a combination of funding sources, including USD 695 M in grants, USD 775 M in concessional loans, and USD 347.5 M in equity. By comparison, the Aligned plan's CAPEX requirement of USD 4.1 B is to be financed through grants to the value of USD 600 M, loans to the value of USD 750 M and equity to the value of USD 300 M.

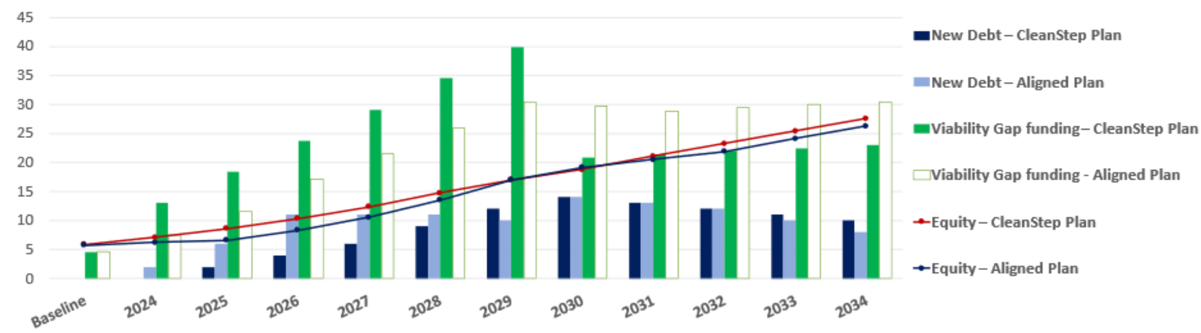
Figure 31. Accumulated capital structure (USD M) for the full electricity sector in both plans.



LPG Sector

The capital structure for the LPG sector is characterised by a blend of equity, debt financing and, notably, viability gap funding. This combination of funding is vital for ensuring the continued affordability and operational continuity of LPG services, particularly in rural or economically challenging regions.

Figure 32. Accumulated capital structure (USD M) for the full LPG sector in both plans.



The CleanStep plan evidences a distinct and progressive escalation in both equity and debt over the course of the project (see Figure 32). The plan initially incorporates a relatively modest equity contribution, with an increase in debt financing as the plan progresses. This reflects a strategy to leverage borrowed funds to accelerate infrastructure development and market penetration. The total CAPEX planned is USD 43 M, including USD 14 M in debt and USD 5 M in equity. It is worth noting, however, that the plan allocates a significant sum of USD 273 M to viability gap funding. This is due to the high promotion of clean technologies in the first stage of the plan; however, the second stage is conservative in economic terms, as can be seen in the reduction of the viability gap.

The Aligned plan demonstrates a different approach to financial management. The plan shows greater restraint in debt utilisation, which totals USD 10 M, while maintaining equity investment at USD 5 M, with a higher total capital expenditure of USD 62.3 M. This conservative debt strategy demonstrates a cautious approach to financial risk, emphasising sustainability over rapid expansion. However, the plan relies significantly on subsidies, with viability gap funding reaching USD 267 M, almost on par with the CleanStep plan. This stresses the necessity for significant support to guarantee the provision of services in less economically viable regions.

Note that figures 22-25 quantify the year-specific investment; figures 29-32 assign that investment—year by year—to public and private instruments, while figures 36-43 confirm that the aggregate of those instruments meets each annual adoption target.

Carbon economy

As Rwanda plans the implementation of clean cooking strategies, reducing CO_2 emissions presents a significant opportunity for engagement in the carbon market. The CleanStep and Aligned plans are designed to capitalise on this potential by certifying and selling the avoided CO_2 emissions as carbon credits. Based on the assumption that 80% of the avoided emissions can be certified and sold in the voluntary carbon market and considering a fully liquid market with a price of USD 10 per ton of CO_2, the models forecast substantial revenue streams from these credits.

Figure 33. Avoided CO_2 emissions (CO_2Eq MT/y) and potential income (USD M) from carbon credits in both plans.

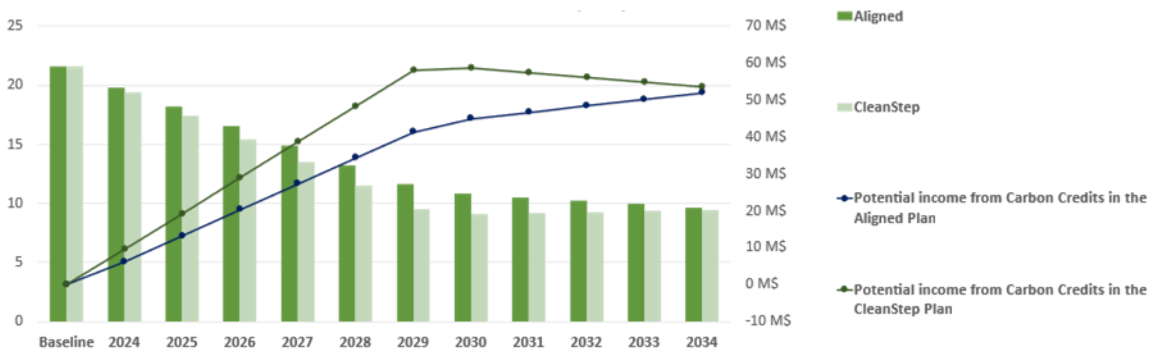


Figure 33 indicates a reduction in CO_2 emissions for both plans over the projection period, because of the successful adoption of clean cooking technologies. The CleanStep plan demonstrates a more pronounced decrease in emissions, reflecting its more ambitious approach to promoting clean-cooking solutions. The total projected CO_2 emissions avoided for this plan are 60.5 MT, compared to 38.5 MT for the Aligned plan.

The potential income from carbon credits reaches its highest point in different years for each plan. The CleanStep plan is expected to generate a peak income of USD 58 M in 2029, demonstrating the rapid realisation of economic benefits from emission reductions. In comparison, the Aligned plan's peak income is reached at a later stage, in 2034, with potential earnings of USD 52 M. The difference in timing reflects the varying pace and scale of adoptions of clean cooking solutions between the two plans.

The revenue generated from carbon credits offers two key benefits. Firstly, it provides an additional financial incentive to reduce GHG emissions. Secondly, it generates a significant income stream that can support the ongoing funding of clean cooking initiatives. For Rwanda, participating in the carbon market not only provides the means to finance its environmental goals but also contributes to global efforts in combating climate change.

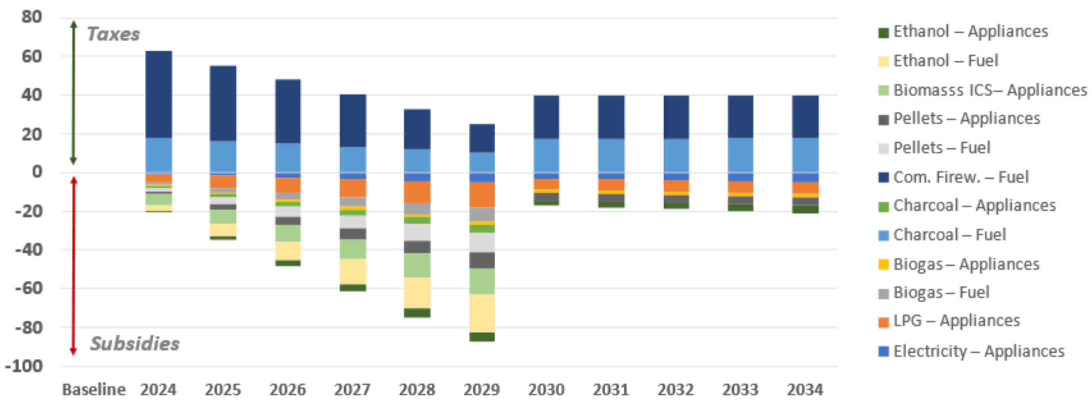
The projection of these revenues demonstrates the importance of strategic planning in emissions reduction initiatives. By aligning clean cooking technologies with carbon credit market opportunities, Rwanda can enhance the sustainability and impact of its energy policies. The strategic differences in the speed at which these revenues are generated between the CleanStep and Aligned plans demonstrate the broader economic and environmental trade-offs involved in the pace of implementing clean energy solutions.

Other technologies

This section analyses the fiscal dynamics associated with the various cooking technologies analysed under the NICCP, in this case, the impacts of the CleanStep and Aligned plans. The analysis focuses on the balance of taxes (revenue for the state) and subsidies (costs to the state), which are crucial for the correct deployment and adoption of specific technologies.

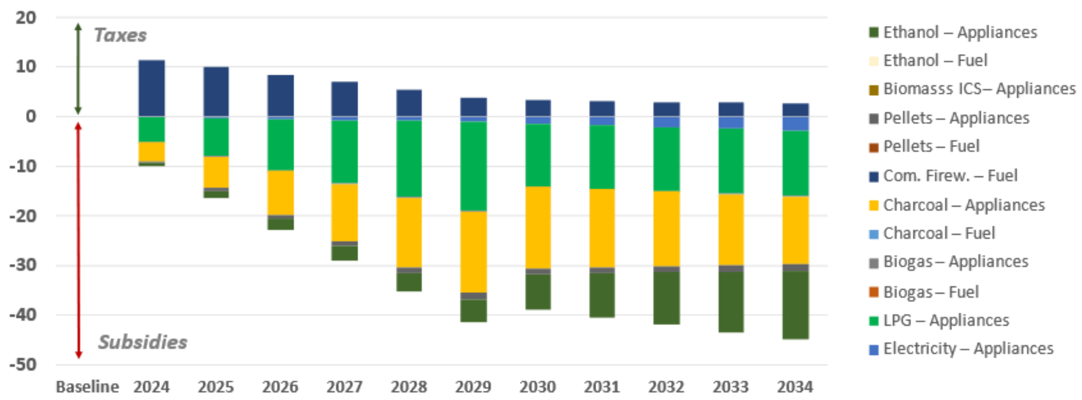
The CleanStep plan significantly applies subsidies across all clean technologies (fuels and appliances), particularly in the first stage, to rapidly scale up adoption. It also applies significant taxes to fuels like charcoal and commercial firewood (see Figure 34). This reflects a strategic emphasis on using fiscal measures to support environmental objectives.

Figure 34. Taxes and subsidies (USD M) to diverse cooking technologies in the CleanStep plan.



The Aligned plan is generally more conservative in subsidy allocation but consistent with its technology targets (see Figure 35). For instance, the measure of almost completely subsidising charcoal Tier3+ appliances may imply preserving the charcoal market. Tax revenues in the Aligned plan are also less substantial, reaching USD 11 M in the first year compared to USD 63 M in the CleanStep plan. Contributions from commercial firewood remain consistent over time, but charcoal is not subject to taxes crucial to achieving the adoption targets.

Figure 35. Taxes and subsidies (USD M) to diverse cooking technologies in the Aligned plan.



Impacts by 2029

This section provides a comprehensive visual representation of the applications and sources of financing up to 2029 for both the e-cooking and LPG segments for both analysed plans under the NICCP. This provides an overview of how each segment's expansion is funded and how financial resources are allocated across different needs.

Each figure in this section presents a balanced view of financing sources and their respective uses, ensuring that total sources match the total uses for the initial stage, which extends up to 2029. This serves two purposes: firstly, to track the flow of funds and secondly, to highlight the proportions of financing that each component – ranging from tariff income to external grants and concessional loans – contributes to the overall financial structure.

Electricity Sector (e-cooking share)

Figure 36. Uses/sources of financing for the e-cooking share in the CleanStep plan until 2029.

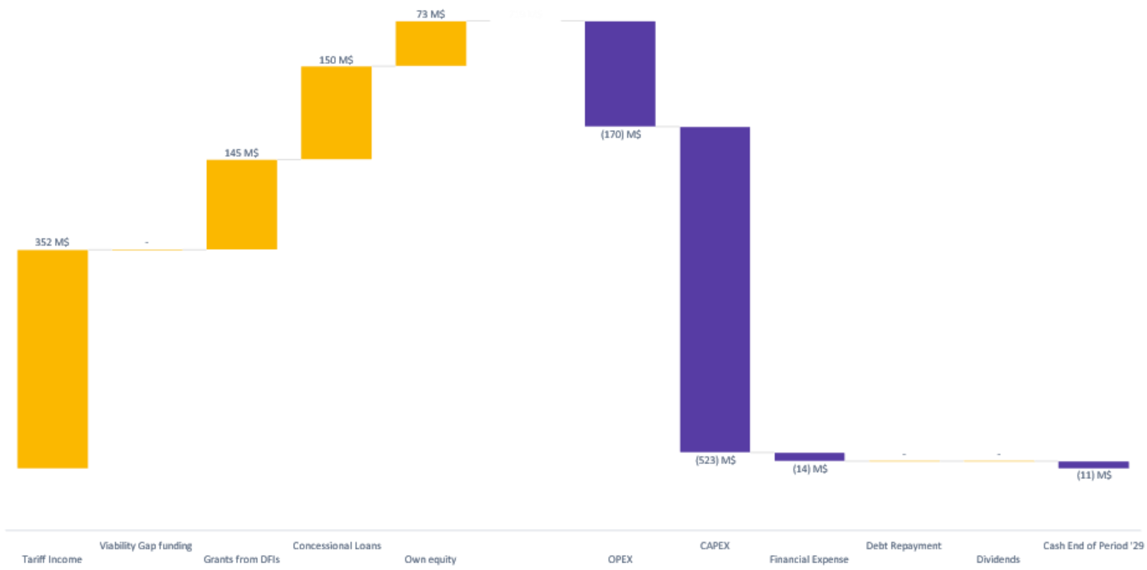


Figure 37. Uses / Sources of financing for the e-cooking share in the Aligned plan until 2029.

LPG Sector

Figure 38. Uses/sources of financing for the LPG sector in the CleanStep plan until 2029.

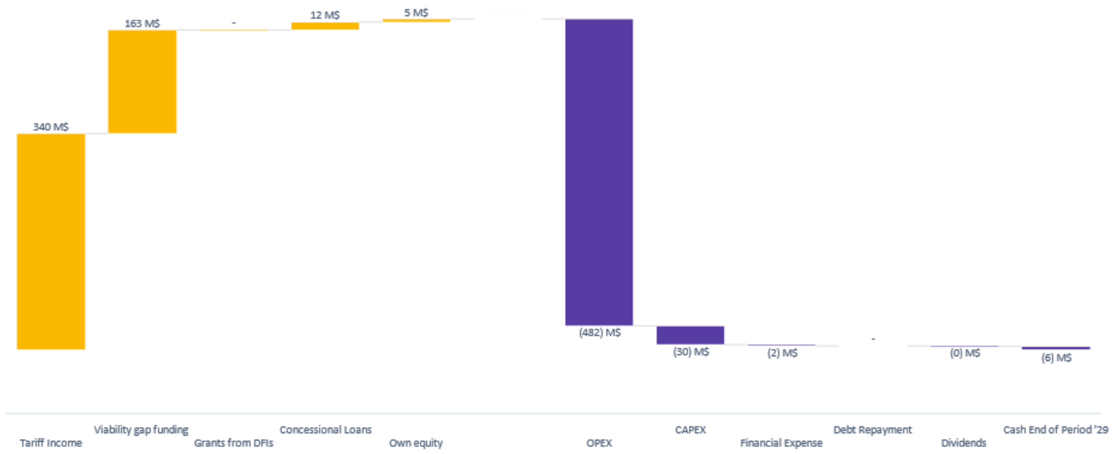
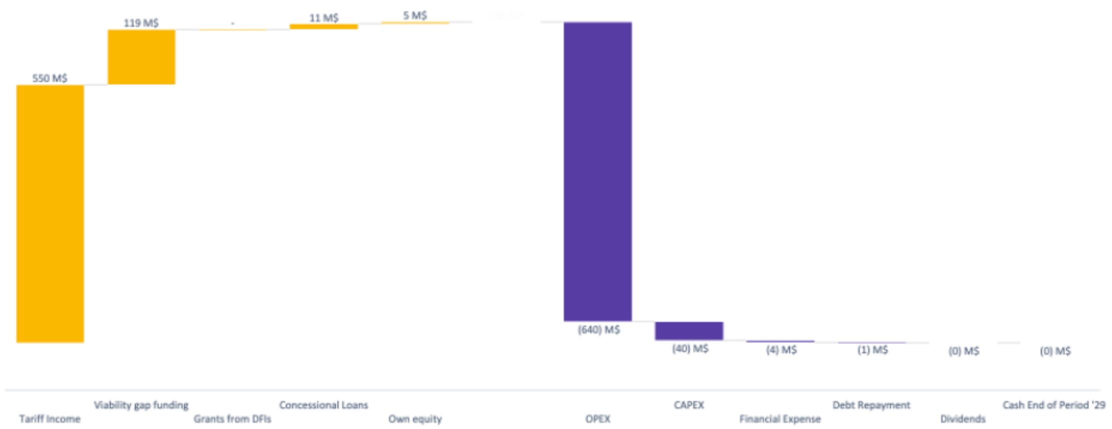


Figure 39. Uses/sources of financing for the LPG sector in the Aligned plan until 2029.



Impacts by 2034

This section shows the financial dynamics of Rwanda's clean cooking strategies, focusing on the e-cooking share and the LPG sector up to 2034.

Electricity Sector (e-cooking share)

Figure 40. Uses/sources of financing for the e-cooking share in the CleanStep plan until 2034.

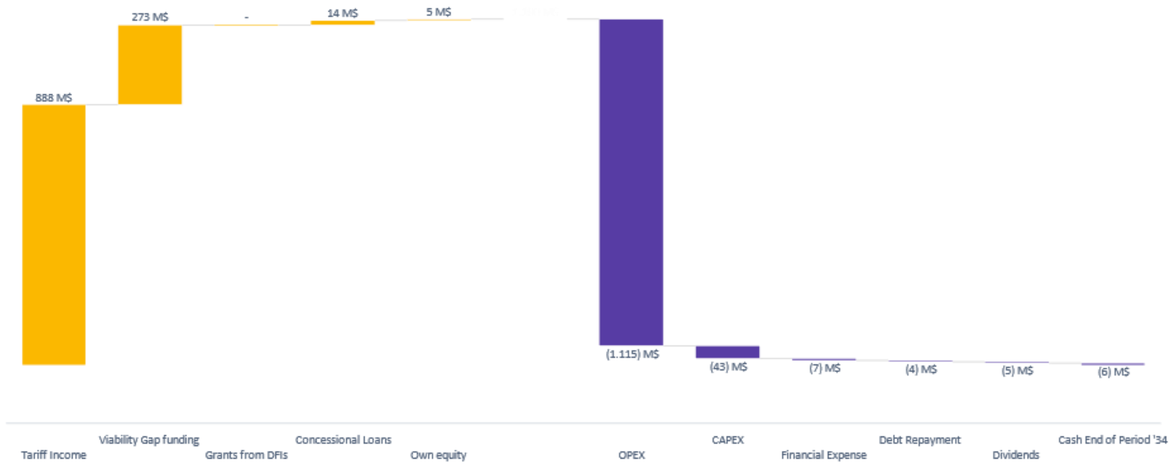
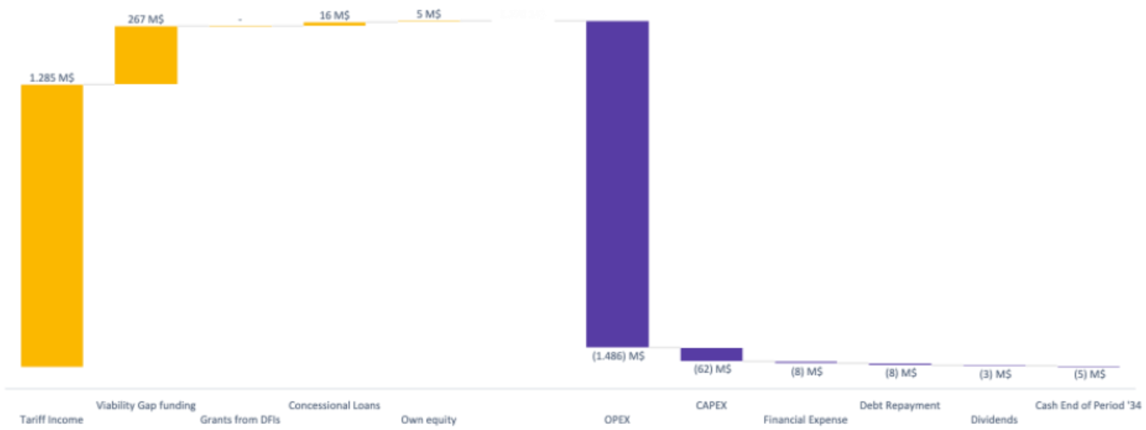


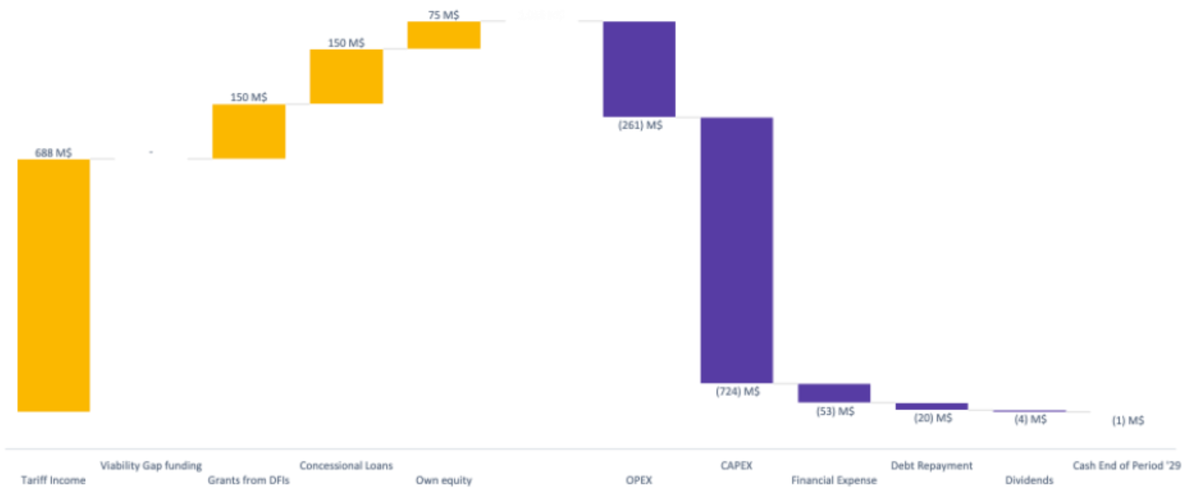
Figure 41. Uses/sources of financing for the e-cooking share in the Aligned plan until 2034.



LPG Sector

Figure 42. Uses/sources of financing for the LPG sector in the CleanStep plan until 2034.

Figure 43. Uses/sources of financing for the LPG sector in the Aligned plan until 2034.



Funding needed to implement the plans

The total sources of funding presented for both plans reflect not only the monetary scale of Rwanda's clean cooking ambitions but also the diverse financial mechanisms utilised to meet these goals. The funding approach of each plan demonstrates its strategic priorities and the financial risks it is willing to assume. By outlining these financial requirements, this section helps stakeholders to better understand the scale of investment needed and the potential financial consequences of Rwanda's transition to cleaner cooking solutions. This financial overview is a critical complement to the strategic planning documents, providing a clear pathway for funding and implementing the strategies.

This final section provides an overview of the financial requirements needed to implement both the CleanStep and Aligned plans, aiming to provide stakeholders with a clear and concise overview of the capital required to achieve the objectives of each plan effectively.

The figures below show various funding mechanisms considered in the analysis for both plans and their strategic approaches, showcasing the scale and the timeline of financial engagements needed for their implementation.

Funding instruments are shown separately to reflect their distinct financial characteristics. While public sources (grants, concessional loans, subsidies) cover most of the requirements, private contributions (equity and commercial debt) are also essential. Grouping by instrument rather than by public/private avoids conflating funding that is disbursed versus repaid, or risk-bearing versus fixed-return.

Figure 44 shows how the CleanStep plan anticipates a total funding of USD 874 M by 2034 to fully implement its strategy, representing a moderate increase from the USD 611 M estimated to be required by 2029. The following sources are expected to provide most of the funding:

- **Viability gap funding.** A substantial increase is observed in viability gap funding, going from USD 163 M to USD 273 M, underscoring the heavy reliance on subsidies to drive technology adoption.

- **Concessional loans and grants.** Funding from concessional loans rises to USD 419 M in 2034, with stable support from grants at USD 145 M, reflecting a robust external financial support structure.
- **Equity and taxes/subsidies.** There has been a modest increase in equity contributions and the balance from taxes versus subsidies ("net of Taxes/Subsidies to technologies" in the figure, meaning tax receipts minus subsidies paid), which indicates a balanced approach to leveraging private investment and fiscal policies.

Figure 44. Summary of the total sources of funding needed to implement the CleanStep plan.

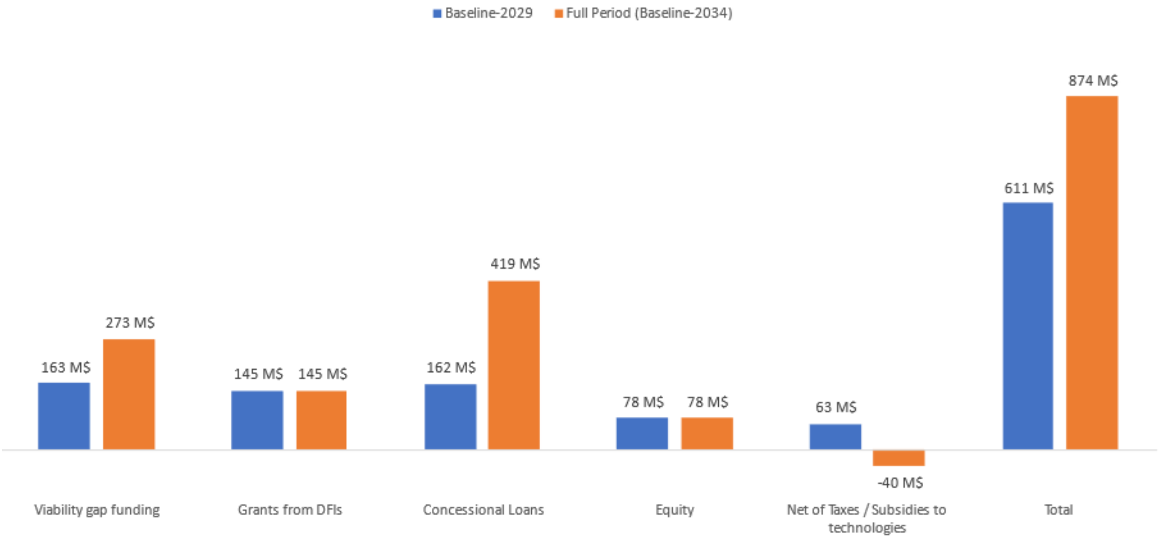


Figure 45. Summary of the total sources of funding needed to implement the Aligned plan.

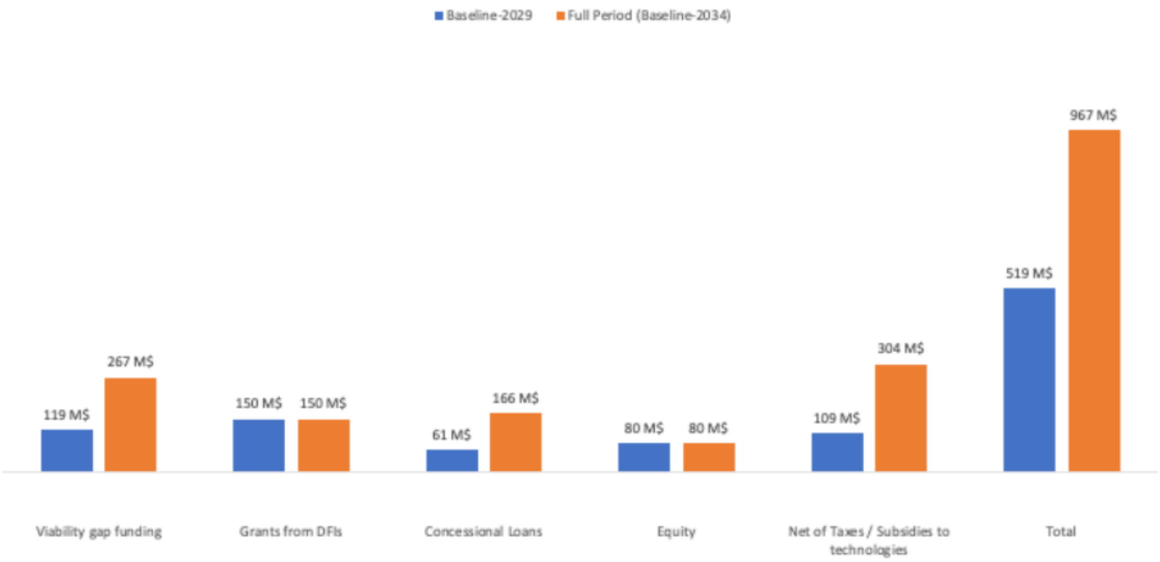


Figure 45 shows how the Aligned plan increases the total funding from USD 519 M by 2029 to USD 967 M by 2034, indicating a more significant financial commitment over time. The following sources are expected to provide most of the funding:

- **Viability gap funding.** Increases from USD 119 M to USD 267 M, slightly less than the CleanStep plan, yet still a major component of the funding strategy.

- **Concessional loans and grants.** The latest figures show a more conservative growth in concessional loans to USD 166 M, with grants remaining at USD 150 M. As a result, the uptake of external funding is expected to be more gradual.
- **Equity and taxes/subsidies**. The equity investments are comparable at USD 80 M, with a net fiscal contribution through taxes/subsidies increasing from USD 109 M to USD 304 M, which is above the level set out in the CleanStep plan.

Publicly sourced mechanisms are expected to contribute most of the financing—principally through viability-gap subsidies, concessional credit lines and donor grants—while private capital (equity plus commercial borrowing) fills the balance. The precise proportion will be finalised during implementation once tariff levels, subsidy caps and investor commitments are confirmed.

The Government should mobilise public funds, deploy them through targeted subsidies and RBF schemes, and maintain cost-reflective tariffs and risk-management tools so private capital can scale manufacturing and distribution while rural service remains affordable.

RECOMMENDATIONS

This section draws not only from the quantitative outcomes generated by the NICCP but also incorporates broader considerations, including insights, informed judgments, and a consensus on what is deemed practical and beneficial for all stakeholders involved. The responsibility rests with local policymakers to identify the most effective approach for implementing social initiatives and overarching strategies. While the quantitative results offer a data-driven basis, it is critical to recognise that these outcomes are directly influenced by the initial hypotheses, as represented by the input data. Therefore, the interpretation and application of these results require a balanced approach, acknowledging the contextual nuances that shape policy decisions.

It is important to consider the following recommendations to optimally formulate the plans aimed at increasing the adoption share of clean cooking technologies in Rwanda.

- The sole deployment of electricity and LPG infrastructure and ensuring access to all clean cooking technologies for the entire population does not guarantee adoption and usage due to the high affordability gap, especially affecting the rural population. This suggests a need to reconsider the way policies are defined and the metrics to be monitored. Pricing measures are needed to bridge the affordability gap and promote the adoption of - already accessible - clean cooking technologies.
- Due to the fuel stacking principle, focusing on highly subsidising only one clean cooking technology at a time does not ensure that the population will adopt it and use it to meet their overall cooking needs, as it is most likely that they will still use other technologies - including inefficient biomass stoves, either as back-up or for cooking specific meals.
- Subsidising the up-front costs of clean cooking appliances may increase their likelihood of adoption; however, it does not necessarily mean that the cost of cooking for the population will be cheaper. While it does present improvements during the first period, people still need to consume the fuels they need for their respective appliances in the long term.
- If cleaner fuels are subsidised (e.g., LPG, pellets and biogas), the adoption of appliances that depend on these fuels may increase, displacing further traditional fuels (such as charcoal, firewood and biomass), reaching overall positive impacts on health, time and gender, emissions and deforestation, while reducing the cost of cooking for the population. Therefore, combining pricing measures for appliances and fuels is needed to achieve better adoption results.
- Applying a taxation scheme for charcoal and commercial firewood may decrease the use of these fuels in the overall mix and increase revenues from taxes. However, it is important to note the side effects, as the population might be shifting to more affordable fuels (while using their current stoves), such as freely collected firewood and other biomass. The cost of cooking becomes expensive for those households (mainly urban) that rely on the fuels being taxed, even if these households acquire efficient stoves.
- For the Aligned plan, the share of charcoal Tier3+ technologies in the overall mix achieved by 2029 and 2034 could be significantly reduced if a lower target is set. This may improve the social costs and imply the application of more practical measures on this technology. Setting a lower target for LPG would also be advisable, as it may incur financial deficit and risk (depending on international markets).
- It is highly advisable that clean cooking targets are defined at a national level, not accounting for geographic delimitations (e.g., for rural and urban households separately). This avoids the formulation of local measures that are practically difficult to implement and monitor (artificial border effects) for both the private sector and consumers. However, measures directed to

different types of consumers depending on their socioeconomic conditions (e.g., previous Ubudehe categories) would contribute to achieving the targets while ensuring that no one is left behind.

To ensure the financial viability during the implementation phase of the plans, it is Important to consider that:

- The successful implementation of the plans depends on a substantial financial investment, as outlined in the funding proposals for both the CleanStep and Aligned plans. The scale of the financial requirements, which include viability gap funding, concessionary loans and equity contributions, is ambitious – yet crucial. The strategy requires over USD 600 M and USD 500 M for the CleanStep and Aligned plans, respectively, in the form of grants, debt, and equity to establish and scale clean cooking technologies up to 2029.
- The credibility of these financial targets is contingent upon the robustness of the tariff structures and risk management strategies. By aligning tariffs with the actual cost of providing services, the plans can significantly reduce the reliance on external subsidies, moving towards a more sustainable model where operational revenues can sustain ongoing expenses. This cost-reflective tariffing approach, coupled with dynamic adjustments, ensures that financial models remain adaptable to changing economic conditions and technology costs, enhancing their feasibility.
- It is also essential to manage financial risk effectively by implementing robust risk mitigation mechanisms to address potential financial instabilities, including fluctuations in international financial support and local economic conditions. Effective foreign exchange risk management strategies, such as using financial derivatives, are essential for managing the volatility associated with foreign-denominated loans and grants. Furthermore, the creation of economic resilience plans, including the establishment of reserves or contingency funds, will provide a financial buffer that can help maintain the initiative during periods of economic downturn or reduced external funding.
- To attract and secure the necessary capital from these diverse sources, it is essential to have robust governance structures and policy support in place. Advocating for supportive policies and enhancing the institutional capacities of agencies overseeing clean cooking initiatives will strengthen investor confidence and facilitate efficient funds management. Furthermore, transparent and effective governance will guarantee that financial strategies are adhered to and that projects remain compliant with both local and international financial standards.
- Capitalising on carbon credits represents a significant opportunity to generate substantial income, which can be used to support the financing needs of the clean cooking sector. This requires the implementation of a comprehensive and integrated carbon finance strategy that not only prioritises the maximisation of immediate financial returns from carbon credits but also reinvests a portion of these revenues to facilitate the scalability and sustainability of clean cooking technologies. It is essential to view the potential revenue from carbon credits as a critical component of the funding structure, complementing other sources such as concessionary loans, grants, and equity financing.
- By integrating these strategies, Rwanda can establish a robust and adaptable financial framework that facilitates the achievement of its clean cooking objectives. This framework will guarantee the availability of necessary funds through strategic tariff management and the leveraging of carbon finance. It will also enhance the credibility and feasibility of the financial plans, thereby attracting the required investments and grants to achieve the ambitious targets set out in the clean cooking strategy.

In addition, it is advisable to support measures to establish an enabling environment, such as:

- Enhancing the promotion of e-cooking appliances and incentivising e-cooking demand (e.g., considering the implementation of an e-cooking tariff) to ensure its expected adoption and contribution to the technology mix. The planned expansion of electricity access in Rwanda must be able to meet the e-cooking demand in optimal conditions.
- Working closely with the LPG industry to enable the conditions for ensuring full deployment of LPG infrastructure by 2029 to make it accessible to the entire population, reviewing the National LPG Master Plan to align the implementation objectives.
- Disseminating the targets to be achieved for each technology to the main players in the pellet, ethanol, biogas and efficient appliances industries. It is critical to support the industrial development in Rwanda to be able to supply the fuels and equipment that are needed to be deployed each year, with a focus on enhancing their local production.
- Working closely with the biomass energy sub-sector, especially among government institutions such as the Rwanda Energy Group (REG), Rwanda Environment Management Authority (REMA), Rwanda Forestry Authority (RFA), and Rwanda Land Administration and Use Authority (RLMA), to coordinate the efforts needed to implement the plans and strategies. The Biomass Technical Working Group could potentially serve as a crucial coordination platform.
- Reformulating how clean cooking access is defined and proposing innovative monitoring mechanisms. Critical aspects such as actual usage, availability, affordability, technology efficiency, and exposure to household air pollution should also be considered. This can be done by improving of existing survey mechanisms, integrating monitoring devices in clean cooking appliances that monitor their actual usage (especially when planning the promotion of e-cooking technologies, which is highly relevant to planning electricity access expansion), working with testing laboratories for appliances and fuels, and promoting initiatives such as the Clean Cooking Data for All (CCDI).
- Implementing educational and awareness-raising campaigns. These campaigns may include using mass media channels, especially through platforms with national coverage, with a marketing focus on time savings, health, financing, costs, environment, and safety. Also, by placing demonstration labs in districts (acting as information centres) or community-based (using existing Village Kitchens). It is critical to recognise the role that local clean cooking ambassadors can play in the adoption of these technologies; for this, it is vital to support programmes dedicated to building local capacity not only on the usage, but also on the production, sales, operation and maintenance of these technologies to ensure a sustainable value chain.

ANNEX 1: References

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ANNEX 2: Key programmes and initiatives in the Rwandan clean cooking sector

This is a list of the main programmes and initiatives in the clean-cooking sector of Rwanda:

- **Clean Cooking Result-Based Financing.** This initiative, funded by the World Bank and operated under the ESMAP, is a part of the Rwanda Energy Access and Quality Improvement Project (EAQIP). With a total investment of USD 150 million (comprising a USD 75 million grant and a USD 75 million loan), it dedicates USD 20 million to clean cooking. This includes USD 10 million as a grant and another USD 10 million as a loan, expected to attract an additional USD 30 million in investments from both the public and private sectors. This project is the World Bank's largest clean cooking operation in Africa. The initiative is implemented by the Energy Development Corporation Ltd (EDCL), the Development Bank of Rwanda (BRD), and the Rwanda Standards Board (RSB). It focuses on making clean cooking technologies more affordable through subsidies, particularly for the lower-income categories 1, 2, and 3. The goal is to reach at least 500,000 households, including a target of 25% female-headed households, thereby benefiting about 2.15 million people with clean cooking technologies.
- **Reducing Climate Impact of Cooking in Rwanda through improved cooking systems (ReCIC)**, funded by the EU and executed by GIZ and SNV. this project adopts a market-based approach to address supply and demand barriers in the ICS market. ReCIC targets the sustainable production and dissemination of 500,000 improved cookstoves by 2025.
- **Transforming Eastern Province through Adaptation (TREPA) - Dissemination of Improved Cooking Stoves (ICS) in farmers' households of Eastern Province of Rwanda** (MININFRA, 2023)**.** TREPA has a budget of USD 39 million and spans from 2022 to 2027. The ICS segment of the TREPA project, outlined in MININFRA's 2023 report, is financed by the Green Climate Fund (GCF) with IUCN as the Accredited Entity. Managed by ENABEL, the focus is on disseminating clean and efficient cooking energy technologies among farmers' households. The TREPA project aims to diminish biomass fuel consumption. It encompasses a widespread awareness campaign throughout the Eastern Province, educating on ICS and alternative cooking fuel solutions. The initiative also facilitates access to ICS for over 100,000 rural households in the region, establishes cooking fuel and technology hubs in local markets, and contributes to creating an environment conducive to transitioning from traditional to clean cooking methods. Additionally, as part of TREPA, UNDP has equipped 500 households in the Rwamagana and Ngoma districts with movable aerobic digesters and cooking stoves.
- **Development of Smart Innovation through Research in Agriculture (DeSIRA).** This project, funded by the EU, has a budget of €4 million for the 2020-2024 period. It is executed by ENABEL and IUCN in collaboration with the Rwanda Forestry Authority (RFA), the University of Rwanda, and the Universities of Leuven and Gent. Focused on the Eastern province of Rwanda, the project emphasises applied research with two main objectives: developing (1) adaptable agroforestry techniques and (2) biomass energy fuels alongside clean cooking solutions. Central to this initiative are detailed surveys to assess the demand for biomass for cooking and to inventory supply capacities. These surveys are crucial for modelling sustainable scenarios for biomass supply and demand in cooking. Additionally, the project undertakes tests to gauge the efficiency and adoption rates of biomass ICS. An essential component involves assisting local suppliers in enhancing the design of their ICS products to achieve Tier-3 level efficiency and effectiveness.

- **EEP Africa - The Energy and Environment Partnership Trust Fund.** In Rwanda, the fund supports a range of subsector projects, including hydropower, solar photovoltaics (PV), and clean cooking initiatives. A key project under this umbrella focuses on the local production of electric cookstoves. These stoves are designed to provide an affordable and efficient alternative to charcoal and biomass cooking for rural on-grid customers. The project has set a target to sell 5,000 Tier 5 electric cookstoves, with the dual objectives of creating employment opportunities for 200 women and reducing environmental impact. By substituting biomass and charcoal cookstoves with these electric alternatives, it is projected to cut down CO_2 emissions by 21,200 tonnes. Additionally, this switch is expected to benefit the health of approximately 22,500 people.
- **Renewable Energy for Refugees II (RE4R II).** The Swedish International Development Cooperation Agency (SIDA) collaborates with Practical Action to enhance access to renewable energy solutions for both households and businesses. A key aspect of this collaboration is the promotion of clean cooking methods. This initiative extends to all Rwandan camps for displaced persons.

In the regulatory field, **the Ministerial Guidelines for Clean Cooking Technologies** (MININFRA, 2022) have set minimum performance benchmarks based on the Multitier Framework (Bhatia & Angelou, 2015), which are as follows:

- Cookstoves using woody and non-woody biomass, such as sticks, pellets, briquettes, and torrefied materials: minimum Tier 3.
- Cookstoves using lump charcoal and charcoal briquettes: minimum Tier 3.
- Stoves burning liquid or gel fuels: minimum Tier 4.
- Stoves using bottled or piped gas: minimum Tier 4.
- Electric cooking appliances: at least 70% efficiency.

The Clean Cooking Result-Based Financing (RBF) program (REG, 2023) lists examples of stoves meeting these minimum performance standards. While these guidelines officially took effect upon their publication in 2023, cookstoves burning unprocessed biomass fuels that meet the Tier-2 Voluntary Performance Requirements were still considered acceptable during the transition period, which extended until December 31st, 2023.

ANNEX 3: Prices of technologies

The tables below present the market prices that were used in the NICCP for all fuels () and their combinations of appliances ().

Table 8. Market prices of fuels.

FUEL	PRICE	Units
Electricity (tariff)	0.20	USD/kWh
LPG	1.02	USD/kg
Biogas	1.10	USD/kg
Charcoal	0.26	USD/kg
Pellets	0.28	USD/kg
Ethanol	0.82	USD/kg
Commercial Firewood	0.09	USD/kg

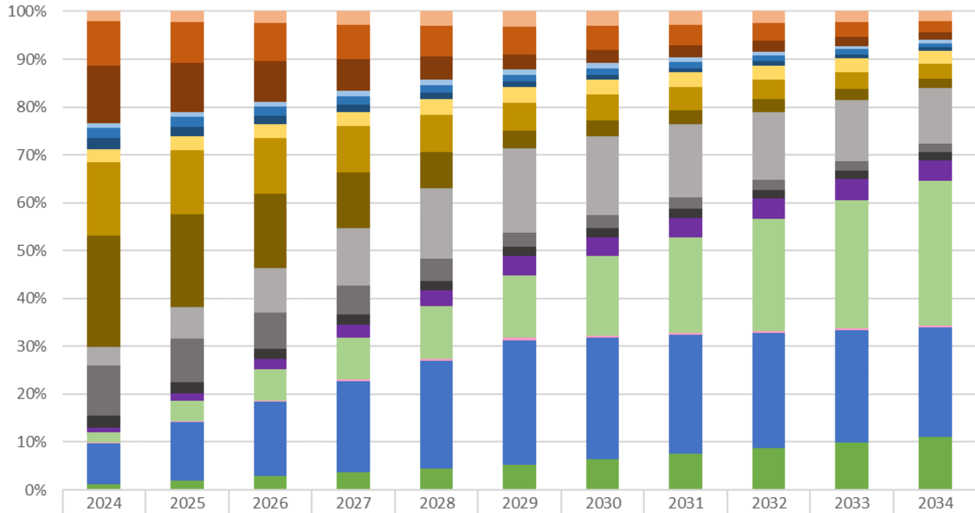
Table 9. Market prices of the sets of appliances defined for the respective fuels.

	APPLIANCES				
FUEL(s)	Tier 2	Tier 3	Tier 4	Tier 5	Tier 5+
Electricity (tariff)			30.00	57.25	87.00
LPG			68.00		
Biogas			68.00		
Charcoal	25.00	50.00			
Pellets			72.00		
Ethanol			40.00		
Commercial Firewood	20.00	40.00			

ANNEX 4: NICCP Annual results

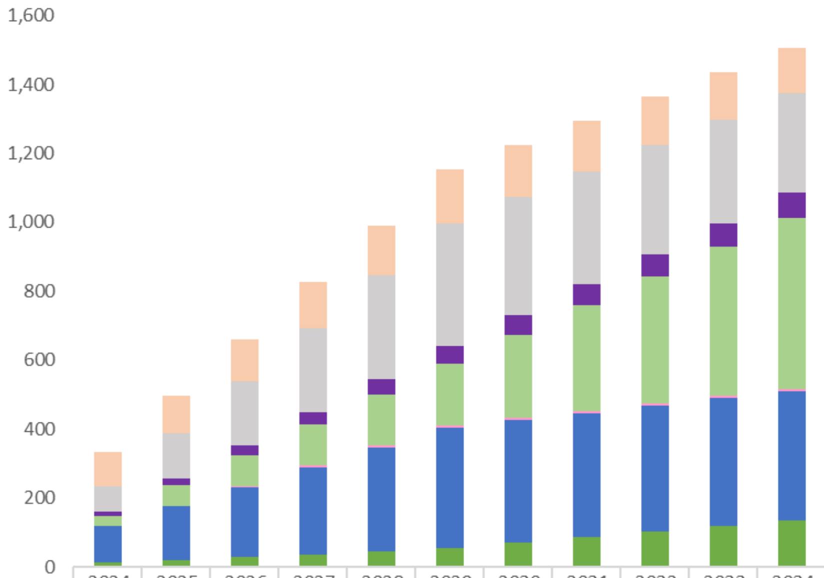
Plan Aligned

Figure 46. Annual adoption of clean cooking technologies, from the baseline year to 2034.



	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Free Firewood (Tier >= 3)	2.04%	2.27%	2.50%	2.73%	2.96%	3.19%	2.96%	2.74%	2.51%	2.28%	2.05%
Free Firewood (Tier 2)	9.26%	8.57%	7.88%	7.19%	6.50%	5.81%	5.11%	4.41%	3.71%	3.01%	2.31%
Free Firewood (Tier 1)	12.04%	10.25%	8.46%	6.66%	4.87%	3.08%	2.78%	2.49%	2.20%	1.90%	1.61%
Other biomass (Tier >= 3)	0.95%	1.00%	1.04%	1.09%	1.14%	1.19%	1.08%	0.98%	0.87%	0.77%	0.66%
Other biomass (Tier 2)	2.16%	2.02%	1.88%	1.75%	1.61%	1.47%	1.37%	1.26%	1.15%	1.05%	0.94%
Other biomass (Tier 1)	2.36%	2.09%	1.82%	1.56%	1.29%	1.03%	0.97%	0.92%	0.86%	0.81%	0.75%
Com. Firewood (Tier >= 3)	2.74%	2.85%	2.97%	3.08%	3.19%	3.31%	3.19%	3.06%	2.94%	2.82%	2.70%
Com. Firewood (Tier 2)	15.28%	13.41%	11.54%	9.67%	7.80%	5.94%	5.34%	4.75%	4.15%	3.56%	2.97%
Com. Firewood (Tier 1)	23.39%	19.43%	15.47%	11.51%	7.55%	3.59%	3.27%	2.96%	2.65%	2.34%	2.02%
Charcoal (Tier >= 3)	3.76%	6.53%	9.30%	12.08%	14.85%	17.63%	16.44%	15.26%	14.08%	12.90%	11.72%
Charcoal (Tier 2)	10.60%	9.09%	7.58%	6.07%	4.56%	3.05%	2.77%	2.48%	2.20%	1.92%	1.64%
Charcoal (Tier 1)	2.42%	2.32%	2.21%	2.11%	2.01%	1.91%	1.87%	1.83%	1.78%	1.74%	1.70%
Pellets	0.91%	1.51%	2.12%	2.72%	3.32%	3.92%	4.02%	4.12%	4.22%	4.32%	4.41%
Ethanol	2.20%	4.39%	6.59%	8.79%	10.98%	13.18%	16.59%	20.00%	23.41%	26.81%	30.22%
Biogas	0.13%	0.19%	0.25%	0.32%	0.38%	0.44%	0.44%	0.43%	0.42%	0.41%	0.40%
LPG	8.57%	12.06%	15.55%	19.04%	22.53%	26.03%	25.40%	24.77%	24.15%	23.52%	22.89%
E-Cooking	1.22%	2.02%	2.83%	3.63%	4.44%	5.25%	6.40%	7.55%	8.70%	9.85%	11.00%

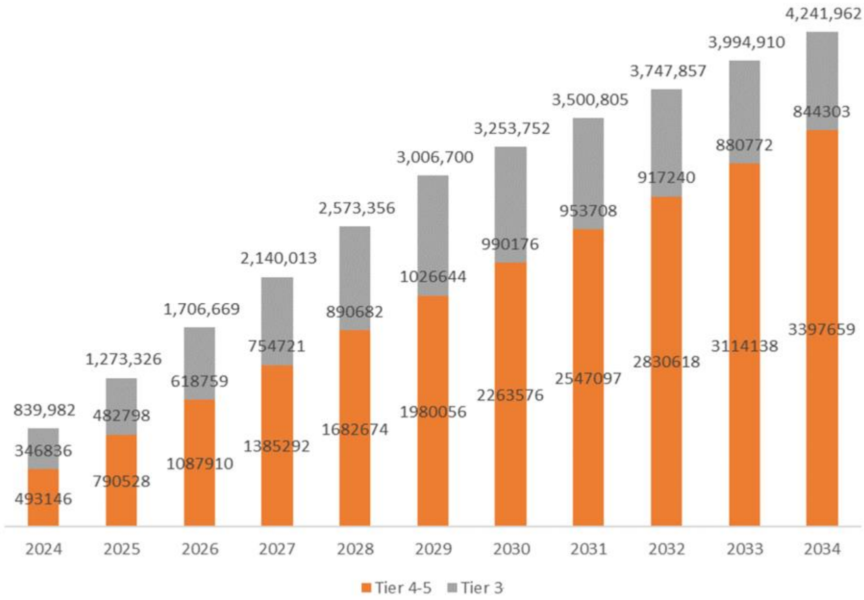
Figure 47. Deployment capacity of clean cooking appliances required for the analysed period (thousands of appliances per year).



	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Firewood (Tier >= 3)	100.0	111.1	122.2	133.4	144.5	155.6	151.1	146.6	142.1	137.6	133.1
Charcoal (Tier >= 3)	73.1	129.8	186.6	243.3	300.1	356.8	343.1	329.4	315.7	302.0	288.3
Pellets	11.7	19.9	28.2	36.5	44.7	53.0	56.8	60.7	64.6	68.5	72.4
Ethanol	29.6	59.3	88.9	118.6	148.2	177.9	241.4	305.0	368.5	432.1	495.7
Biogas	1.6	2.5	3.3	4.2	5.1	6.0	6.1	6.2	6.4	6.5	6.6
LPG	105.6	154.7	203.8	253.0	302.1	351.2	356.1	360.9	365.8	370.6	375.5
E-Cooking	11.7	20.0	28.3	36.5	44.8	53.1	69.5	86.0	102.4	118.8	135.3

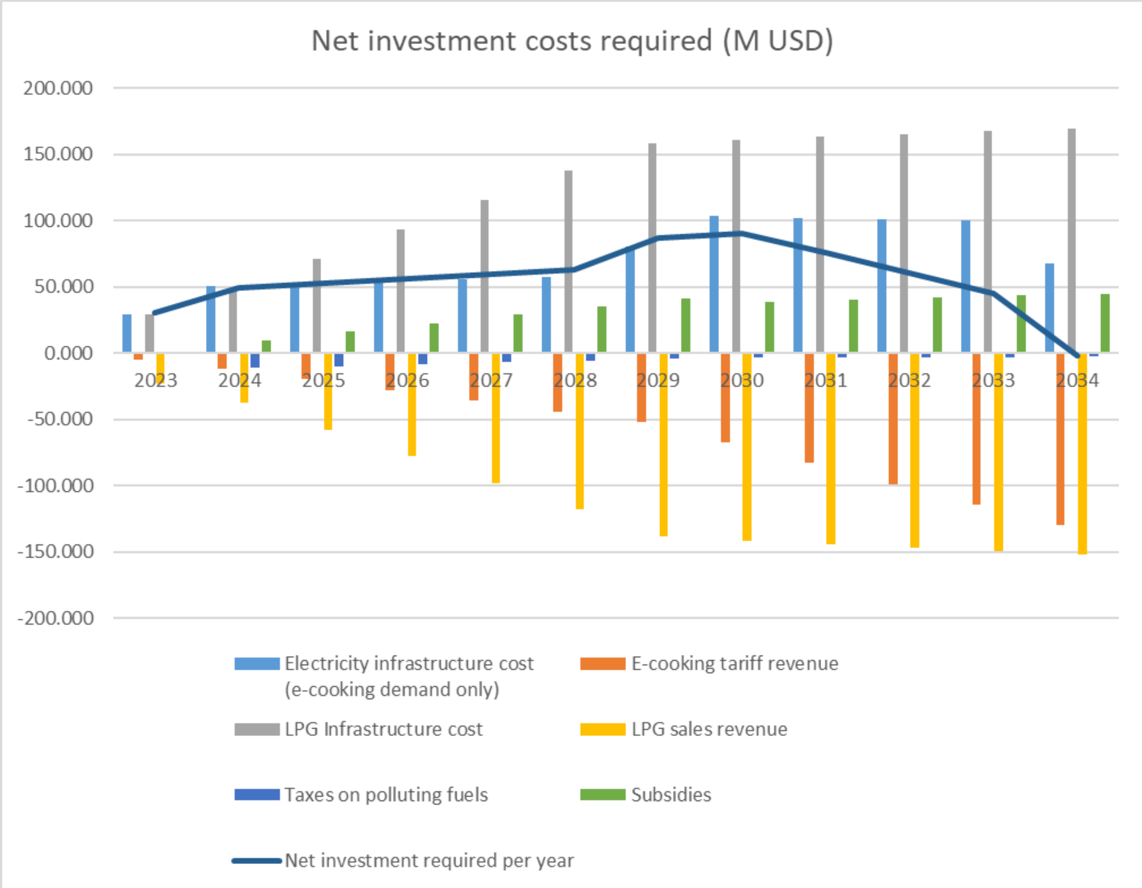
Note: the estimation of the annual deployment capacity is made by dividing the total annual usage of each type of appliance (country level) by the lifetime of the type of appliance, both in cooking demand units (cooks). Therefore, it represents the number of appliances "consumed" annually, which in a steady state would coincide with the number of appliances of each type to be deployed annually (sold or repaired).

Figure 48. Number of households adopting clean cooking technologies from baseline year to 2034.



Note: these are 'equivalent households' to ensure that aggregated values are accurate, regardless of technology stacking (e.g., two households that use 50% clean cooking technologies are equivalent to one household that uses 100% of such technologies).

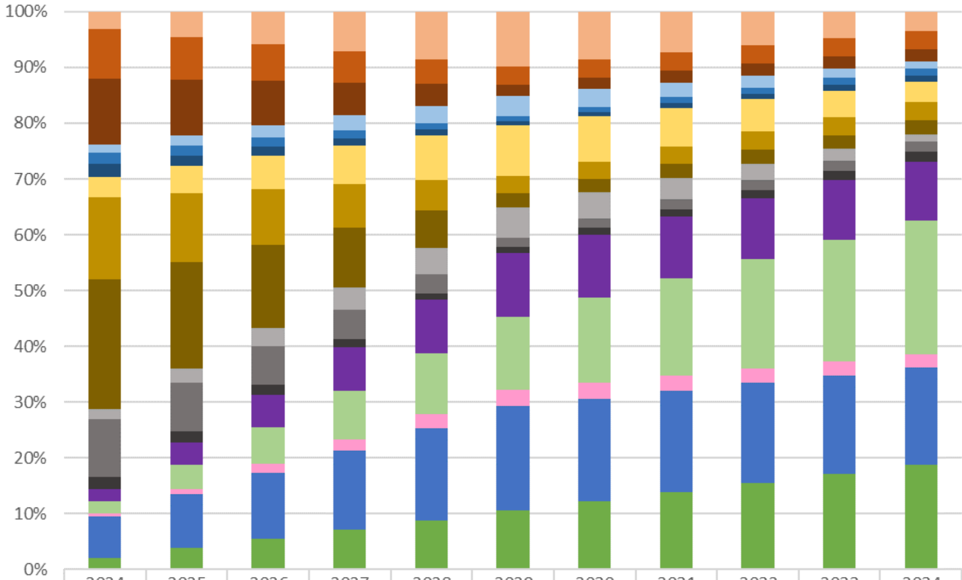
Figure 49. Estimation of yearly cash flows for Aligned plan (in USD M).



ar	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Electricity infrastructure cost(e-cooking demand only	29.414	50.762	52.413	54.026	55.602	57.141	80.945	103.370	102.365	101.370	100.384	67.476
E-cooking tariff revenue	-4.647	-11.672	-19.730	-27.788	-35.846	-43.903	-51.961	-67.627	-83.098	-98.570	-114.041	-129.513
LPG Infrastructure cost	29.153	48.929	71.370	93.720	115.983	138.158	158.736	161.097	163.333	165.565	167.791	169.933
LPG sales revenue	-22.978	-37.731	-57.781	-77.830	-97.879	-117.929	-137.978	-141.730	-144.351	-146.972	-149.592	-152.213
Taxes on polluting fuels	0.000	-11.308	-9.886	-8.435	-6.954	-5.442	-3.899	-3.298	-3.138	-2.974	-2.807	-2.636
Subsidies	0.000	10.001	16.434	22.790	29.070	35.275	41.406	38.858	40.420	41.944	43.430	44.878
Net investment required per year	**30.941**	**48.980**	**52.819**	**56.483**	**59.976**	**63.300**	**87.249**	**90.670**	**75.531**	**60.362**	**45.164**	**-2.075**

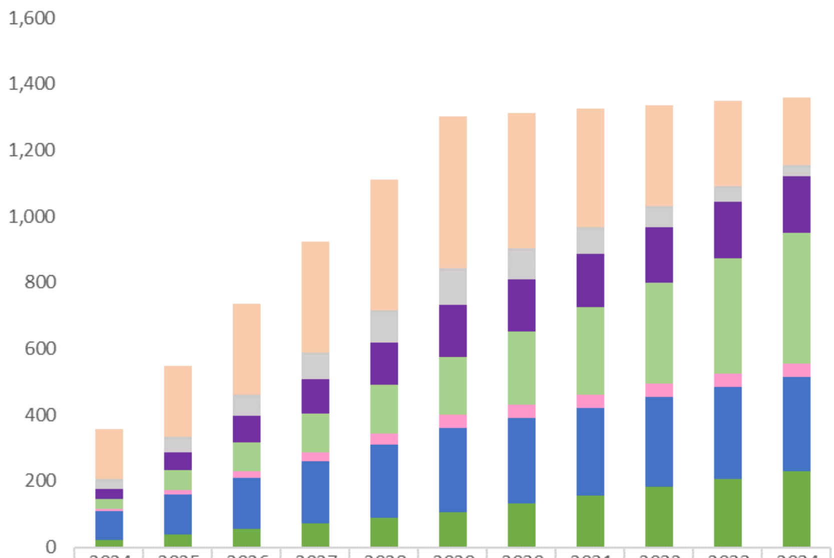
Plan CleanStep

Figure 50. Annual adoption of clean cooking technologies, from the baseline year to 2034.



	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Free Firewood (Tier >= 3)	3.15%	4.50%	5.84%	7.19%	8.53%	9.88%	8.60%	7.32%	6.04%	4.77%	3.49%
Free Firewood (Tier 2)	8.84%	7.73%	6.62%	5.50%	4.39%	3.28%	3.26%	3.23%	3.21%	3.19%	3.17%
Free Firewood (Tier 1)	11.86%	9.88%	7.90%	5.93%	3.95%	1.97%	2.04%	2.11%	2.17%	2.24%	2.31%
Other biomass (Tier >= 3)	1.36%	1.81%	2.27%	2.73%	3.18%	3.64%	3.15%	2.66%	2.18%	1.69%	1.20%
Other biomass (Tier 2)	2.06%	1.82%	1.59%	1.35%	1.12%	0.88%	0.98%	1.07%	1.17%	1.26%	1.36%
Other biomass (Tier 1)	2.29%	1.97%	1.64%	1.31%	0.98%	0.66%	0.75%	0.84%	0.93%	1.01%	1.10%
Com. Firewood (Tier >= 3)	3.72%	4.81%	5.90%	6.99%	8.09%	9.18%	8.07%	6.96%	5.85%	4.73%	3.62%
Com. Firewood (Tier 2)	14.81%	12.47%	10.13%	7.79%	5.46%	3.12%	3.15%	3.18%	3.21%	3.24%	3.27%
Com. Firewood (Tier 1)	23.20%	19.05%	14.90%	10.74%	6.59%	2.44%	2.44%	2.45%	2.46%	2.47%	2.48%
Charcoal (Tier >= 3)	1.73%	2.47%	3.22%	3.96%	4.71%	5.45%	4.63%	3.81%	2.99%	2.17%	1.35%
Charcoal (Tier 2)	10.38%	8.66%	6.93%	5.20%	3.47%	1.74%	1.74%	1.73%	1.73%	1.73%	1.72%
Charcoal (Tier 1)	2.26%	1.99%	1.73%	1.47%	1.21%	0.94%	1.13%	1.32%	1.50%	1.69%	1.87%
Pellets	2.17%	4.04%	5.90%	7.77%	9.63%	11.49%	11.30%	11.10%	10.91%	10.71%	10.51%
Ethanol	2.18%	4.36%	6.53%	8.71%	10.89%	13.07%	15.24%	17.42%	19.59%	21.77%	23.94%
Biogas	0.55%	1.04%	1.53%	2.02%	2.51%	3.00%	2.89%	2.78%	2.67%	2.56%	2.45%
LPG	7.35%	9.63%	11.90%	14.18%	16.45%	18.73%	18.45%	18.18%	17.91%	17.64%	17.37%
E-Cooking	2.10%	3.78%	5.47%	7.16%	8.84%	10.53%	12.18%	13.83%	15.49%	17.14%	18.79%

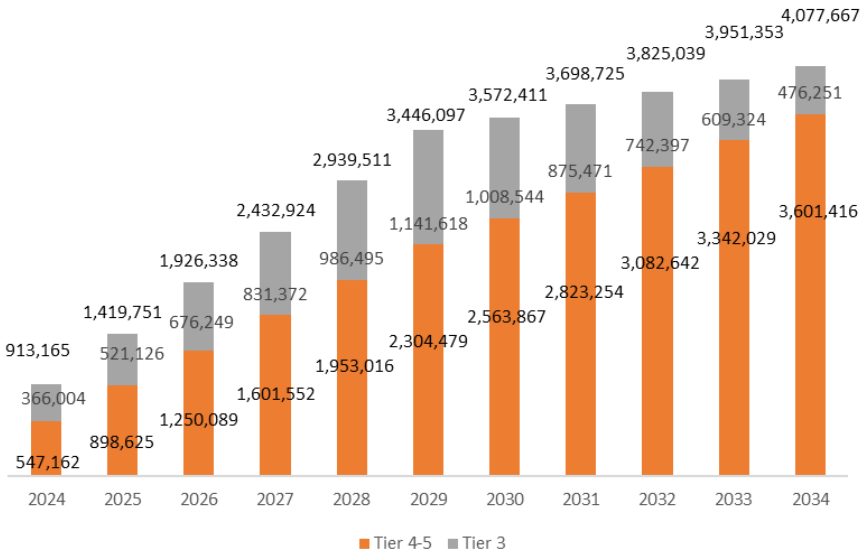
Figure 51. Deployment capacity of clean cooking appliances required for the analysed period (thousands of appliances per year).



	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Firewood (Tier >= 3)	150.6	212.4	274.1	335.9	397.6	459.4	408.4	357.4	306.5	255.5	204.6
Charcoal (Tier >= 3)	32.0	47.7	63.4	79.1	94.7	110.4	95.0	79.5	64.0	48.6	33.1
Pellets	28.7	54.0	79.3	104.5	129.8	155.1	158.6	162.0	165.5	169.0	172.5
Ethanol	29.4	58.8	88.2	117.6	146.9	176.3	219.6	262.9	306.2	349.4	392.7
Biogas	7.3	14.0	20.6	27.3	33.9	40.5	40.5	40.4	40.3	40.2	40.1
LPG	89.1	121.9	154.6	187.3	220.0	252.7	259.1	265.5	272.0	278.4	284.8
E-Cooking	20.6	37.8	55.0	72.2	89.4	106.6	131.5	156.4	181.3	206.2	231.1

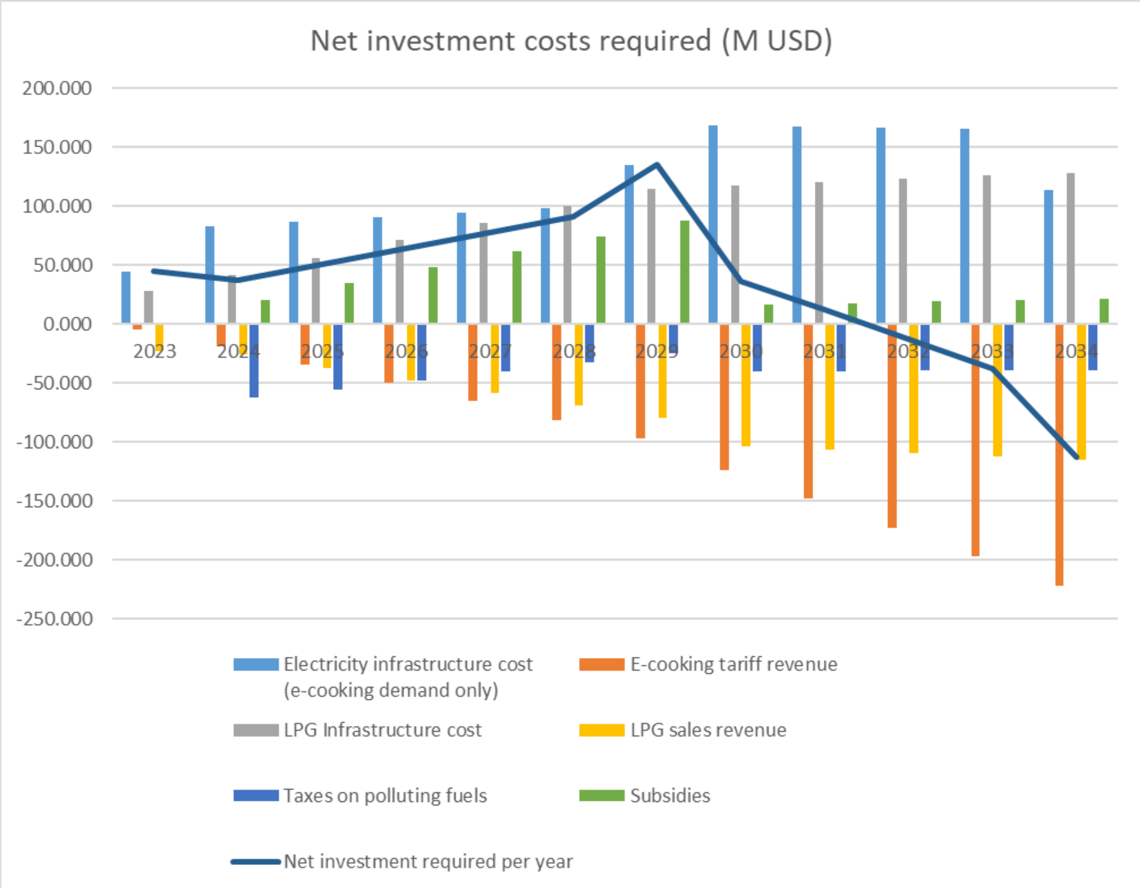
Note: the estimation of the annual deployment capacity is made by dividing the total annual usage of each type of appliance (country level) by the lifetime of the type of appliance, both in cooking demand units (cooks). Therefore, it represents the number of appliances "consumed" annually, which in a steady state would coincide with the number of appliances of each type to be deployed annually (sold or repaired).

Figure 52. Number of households adopting clean cooking technologies for the analysed period.



Note: these are 'equivalent households' to ensure that aggregated values are accurate, regardless of technology stacking (e.g., two households that use 50% clean cooking technologies are equivalent to one household that uses 100% of such technologies).

Figure 53. Estimation of yearly cash flows for the CleanStep plan (in USD M).



	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Electricity infrastructure cost(e-cooking demand only	44.445	83.228	87.091	90.869	94.562	98.173	134.771	168.877	167.728	166.584	165.446	114.219
E-cooking tariff revenue	-4.647	-18.970	-34.523	-50.077	-65.631	-81.184	-96.738	-123.451	-148.087	-172.724	-197.361	-221.997
LPG Infrastructure cost	28.129	41.147	56.132	71.057	85.923	100.732	114.460	118.063	120.703	123.334	125.959	128.527
LPG sales revenue	-22.978	-26.099	-36.804	-47.510	-58.215	-68.920	-79.626	-103.923	-106.754	-109.585	-112.416	-115.247
Taxes on polluting fuels	0.000	-62.662	-55.423	-48.032	-40.489	-32.789	-24.932	-39.686	-39.681	-39.672	-39.659	-39.641
Subsidies	0.000	20.750	34.553	48.138	61.507	74.664	87.611	16.911	17.986	19.039	20.071	21.082
Net investment required per year	**44.948**	**37.394**	**51.025**	**64.444**	**77.658**	**90.674**	**135.545**	**36.792**	**11.894**	**-13.023**	**-37.959**	**-113.057**

ANNEX 5: Technologies adoption by district over time

The following figures present the adoption of clean, transitional, and polluting technologies in the different districts over time.

Clean technologies include Electricity, LPG, Biogas, Pellets (and similar fuels, such as briquettes), and Ethanol, here assumed to use Tier-4 cookstoves. The transitional technologies are levels 1 and 2 of Charcoal and level 2 of Free Biomass and Firewood. This classification follows the Tier thresholds from (Bhatia & Angelou, 2015) and (ESMAP, 2023).

The names of the districts have been coloured in the final state of the planning period according to the addition of clean technologies and half of the penetration of transitional technologies. The thresholds are:

Districts' names, by clean addition: 0% < RED < 50% < YELLOW < 75% < GREEN < 100%.

The criteria for colours in the cells of the tables are the following:

Clean technologies:	0% <	RED	< 25% < YELLOW < 50% <	GREEN	< 100%.
Transitional technologies:	0% <	WHITE	< 25% < YELLOW < 75% <	RED	< 100%.
Polluting technologies:	0% <	GREEN	< 25% < YELLOW < 50% <	RED	< 100%.

Plan Aligned

Figure 54. Penetration of technologies by district over time: plan Aligned

ALIGNED	2024			2029			2034			2034
Name	CLEAN	TRANS	POLLUT	CLEAN	TRANS	POLLUT	CLEAN	TRANS	POLLUT	FINAL STATE
Rwanda	5.86%	18.42%	75.72%	48.81%	28.37%	22.82%	68.93%	18.77%	12.30%	Rwanda
Kigali	19.80%	36.36%	43.84%	63.60%	25.90%	10.50%	84.05%	10.51%	5.43%	Kigali
Nyarugenge	20.72%	34.62%	44.66%	63.06%	25.98%	10.96%	83.60%	10.77%	5.63%	Nyarugenge
Gasabo	18.14%	34.89%	46.97%	62.79%	25.82%	11.39%	83.40%	10.76%	5.84%	Gasabo
Kicukiro	22.11%	40.45%	37.44%	65.40%	25.97%	8.62%	85.49%	9.92%	4.59%	Kicukiro
Southern	2.84%	13.83%	83.34%	43.84%	29.16%	27.01%	62.24%	22.41%	15.35%	Southern
Nyanza	1.06%	11.68%	87.26%	41.11%	29.64%	29.25%	58.20%	24.45%	17.35%	Nyanza
Gisagara	0.86%	10.83%	88.31%	40.74%	29.37%	29.89%	56.42%	25.36%	18.23%	Gisagara
Nyaruguru	0.61%	10.70%	88.69%	37.93%	30.79%	31.28%	53.33%	27.84%	18.83%	Nyaruguru
Huye	3.56%	15.93%	80.51%	47.31%	28.13%	24.56%	66.85%	19.71%	13.44%	Huye
Nyamagabe	1.46%	13.05%	85.48%	39.66%	31.10%	29.24%	56.88%	26.14%	16.98%	Nyamagabe
Ruhango	1.21%	12.77%	86.03%	42.63%	29.08%	28.29%	60.51%	23.12%	16.37%	Ruhango
Muhanga	5.09%	15.69%	79.22%	46.22%	28.79%	24.99%	65.86%	20.47%	13.67%	Muhanga
Kamonyi	7.38%	18.31%	74.31%	50.57%	27.53%	21.89%	71.18%	17.28%	11.54%	Kamonyi
Western	2.52%	16.50%	80.98%	45.51%	29.14%	25.34%	64.81%	21.23%	13.96%	Western
Karongi	1.27%	12.36%	86.37%	41.13%	29.86%	29.01%	58.42%	24.58%	17.01%	Karongi
Rutsiro	0.73%	11.21%	88.06%	39.76%	29.95%	30.28%	55.97%	25.98%	18.05%	Rutsiro
Rubavu	6.84%	27.09%	66.08%	56.38%	26.26%	17.36%	77.55%	13.59%	8.87%	Rubavu
Nyabihu	2.95%	17.43%	79.63%	46.78%	28.75%	24.48%	67.20%	19.61%	13.19%	Nyabihu
Ngororero	0.75%	10.89%	88.36%	38.50%	30.43%	31.07%	54.37%	26.77%	18.86%	Ngororero
Rusizi	2.79%	19.48%	77.73%	47.74%	29.56%	22.71%	67.83%	20.37%	11.79%	Rusizi
Nyamasheke	0.81%	12.81%	86.38%	40.11%	31.02%	28.87%	56.98%	26.42%	16.60%	Nyamasheke
Northern	2.50%	15.50%	82.00%	45.47%	29.04%	25.49%	64.42%	21.30%	14.27%	Northern
Rulindo	2.03%	13.39%	84.58%	43.03%	29.64%	27.33%	61.22%	23.02%	15.75%	Rulindo
Gakenke	0.62%	10.97%	88.41%	39.19%	30.42%	30.39%	55.17%	26.58%	18.25%	Gakenke
Musanze	6.85%	26.21%	66.94%	55.36%	27.17%	17.47%	76.43%	14.70%	8.87%	Musanze
Burera	1.25%	13.41%	85.34%	44.08%	28.97%	26.95%	62.03%	22.47%	15.50%	Burera
Gicumbi	0.64%	10.73%	88.63%	40.12%	30.03%	29.85%	56.25%	25.80%	17.95%	Gicumbi
Eastern	5.10%	15.46%	79.43%	46.42%	28.57%	25.01%	66.05%	20.14%	13.81%	Eastern
Rwamagana	10.12%	19.31%	70.57%	52.62%	27.11%	20.27%	73.50%	15.93%	10.57%	Rwamagana
Nyagatare	4.25%	16.10%	79.65%	47.31%	27.93%	24.77%	67.92%	18.70%	13.38%	Nyagatare
Gatsibo	2.17%	13.07%	84.76%	41.22%	30.26%	28.51%	59.87%	23.81%	16.32%	Gatsibo
Kayonza	3.34%	13.54%	83.13%	42.57%	29.73%	27.70%	60.71%	23.24%	16.05%	Kayonza
Kirehe	1.73%	12.30%	85.97%	41.52%	29.60%	28.89%	58.18%	24.62%	17.20%	Kirehe
Ngoma	1.70%	12.37%	85.93%	43.42%	28.74%	27.84%	60.66%	23.06%	16.28%	Ngoma
Bugesera	11.09%	19.99%	68.92%	52.52%	27.43%	20.05%	73.45%	16.21%	10.34%	Bugesera

Plan CleanStep

Figure 55. Penetration of technologies by district over time: plan CleanStep.

CLEANSTEP	2024			2029			2034			2034
Name	CLEAN	TRANS	POLLUT	CLEAN	TRANS	POLLUT	CLEAN	TRANS	POLLUT	FINAL STATE
Rwanda	5.86%	18.42%	75.72%	56.82%	29.89%	13.29%	73.06%	11.38%	15.55%	Rwanda
Kigali	19.80%	36.36%	43.84%	74.23%	19.22%	6.55%	88.60%	5.36%	6.05%	Kigali
Nyarugenge	20.72%	34.62%	44.66%	73.55%	19.64%	6.81%	88.18%	5.51%	6.31%	Nyarugenge
Gasabo	18.14%	34.89%	46.97%	73.01%	19.96%	7.03%	87.77%	5.65%	6.58%	Gasabo
Kicukiro	22.11%	40.45%	37.44%	76.85%	17.61%	5.54%	90.30%	4.74%	4.96%	Kicukiro
Southern	2.84%	13.83%	83.34%	51.00%	33.45%	15.55%	66.10%	14.11%	19.80%	Southern
Nyanza	1.06%	11.68%	87.26%	47.36%	35.72%	16.91%	61.28%	15.89%	22.82%	Nyanza
Gisagara	0.86%	10.83%	88.31%	47.18%	35.77%	17.05%	59.06%	16.78%	24.15%	Gisagara
Nyaruguru	0.61%	10.70%	88.69%	44.22%	37.54%	18.23%	56.86%	17.93%	25.21%	Nyaruguru
Huye	3.56%	15.93%	80.51%	55.57%	30.54%	13.89%	71.21%	11.99%	16.80%	Huye
Nyamagabe	1.46%	13.05%	85.48%	45.94%	36.69%	17.37%	60.84%	16.48%	22.68%	Nyamagabe
Ruhango	1.21%	12.77%	86.03%	49.56%	34.33%	16.10%	64.09%	14.84%	21.07%	Ruhango
Muhanga	5.09%	15.69%	79.22%	53.83%	31.78%	14.39%	70.31%	12.50%	17.18%	Muhanga
Kamonyi	7.38%	18.31%	74.31%	58.96%	28.53%	12.51%	75.73%	10.24%	14.03%	Kamonyi
Western	2.52%	16.50%	80.98%	53.09%	32.18%	14.73%	69.19%	12.96%	17.85%	Western
Karongi	1.27%	12.36%	86.37%	47.59%	35.59%	16.81%	61.80%	15.83%	22.37%	Karongi
Rutsiro	0.73%	11.21%	88.06%	46.44%	36.21%	17.35%	59.47%	16.79%	23.74%	Rutsiro
Rubavu	6.84%	27.09%	66.08%	64.80%	25.04%	10.15%	81.49%	8.02%	10.49%	Rubavu
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Ngororero	0.75%	10.89%	88.36%	43.77%	38.03%	18.21%	56.72%	17.90%	25.39%	Ngororero
Rusizi	2.79%	19.48%	77.73%	57.43%	29.43%	13.14%	74.49%	11.00%	14.51%	Rusizi
Nyamasheke	0.81%	12.81%	86.38%	47.82%	35.21%	16.97%	62.47%	15.72%	21.81%	Nyamasheke
Northern	2.50%	15.50%	82.00%	52.98%	32.18%	14.83%	68.44%	13.10%	18.45%	Northern
Rulindo	2.03%	13.39%	84.58%	49.75%	34.25%	16.00%	64.78%	14.52%	20.70%	Rulindo
Gakenke	0.62%	10.97%	88.41%	45.37%	36.87%	17.77%	58.46%	17.12%	24.43%	Gakenke
Musanze	6.85%	26.21%	66.94%	64.73%	25.01%	10.26%	81.33%	8.11%	10.56%	Musanze
Burera	1.25%	13.41%	85.34%	51.83%	32.80%	15.37%	66.19%	13.89%	19.92%	Burera
Gicumbi	0.64%	10.73%	88.63%	46.59%	36.06%	17.35%	59.60%	16.49%	23.92%	Gicumbi
Eastern	5.10%	15.46%	79.43%	53.77%	31.81%	14.42%	69.91%	12.57%	17.52%	Eastern
Rwamagana	10.12%	19.31%	70.57%	61.24%	27.10%	11.66%	77.90%	9.34%	12.76%	Rwamagana
Nyagatare	4.25%	16.10%	79.65%	54.96%	31.11%	13.93%	71.88%	11.74%	16.38%	Nyagatare
Gatsibo	2.17%	13.07%	84.76%	47.18%	36.00%	16.82%	63.75%	15.06%	21.18%	Gatsibo
Kayonza	3.34%	13.54%	83.13%	48.63%	35.11%	16.26%	63.63%	15.16%	21.21%	Kayonza
Kirehe	1.73%	12.30%	85.97%	47.57%	35.60%	16.83%	60.69%	16.25%	23.06%	Kirehe
Ngoma	1.70%	12.37%	85.93%	51.15%	33.21%	15.63%	64.43%	14.63%	20.93%	Ngoma
Bugesera	11.09%	19.99%	68.92%	61.15%	27.26%	11.59%	78.17%	9.36%	12.46%	Bugesera