Leveraging agroforestry for bioenergy security in Sub-Saharan Africa and Southeast Asia

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Agroforestry Network

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Biomass is often viewed as a primitive source of energy that needs to be modernized. However, it is unlikely that preferred modern energy sources will displace traditional biomass-based energy in the near term, especially in rural Africa and southeast Asia (FAO 2017). Demand for sustainably sourced biomass is likely to increase as the world moves away from fossil fuel dependence and transitions to sustainable energy sources. Agroforestry presents such opportunities for bioenergy security (García-López et. al, 2024). Sustainable biomass sourcing and use require scaling up innovative mechanisms that reduce health and climate risks, efficient energy conversion and land tenure systems that are adaptable to long term tree/shrub cultivation. Bringing biomass production closer to homes and on farms reduces drudgery and environmental risks associated with sourcing from natural forests/woodlands and is vital for food security.

This policy brief highlights the value of agroforestry as an important source of bioenergy for households and small-scale industries; identifies market, production and labour constraints; and showcases the significance of improved cookstoves, briquettes and biogas infrastructure in enabling concurrent food and fuel production.

1 INTRODUCTION

Approximately 2.4 billion people worldwide depend on biomass for meeting their energy needs (World Bank 2022) and most of these people are poor smallholder farmers in rural communities in sub-Saharan Africa (SSA) and Southeast Asia (SEA) (Sharma et al. 2016). Fuelwood, charcoal, dung and crop residues contribute up to 79% of energy consumed in developing countries (Sharma et al. 2016). SDG 7 (Target 7.1) emphasizes "universal access" and transitions to "affordable, reliable and modern energy services" such as solar and wind energy. Meanwhile, full-scale transitions in SSA and SEA are rare with households "stacking up" energy by supplementing new and modern sources with traditional biomass (Ochieng et al. 2020; ESMAP 2021). Despite its widespread use, the contribution of sustainable biomass products to household energy security remains underexplored while the dominant view encourages transitions to other energy sources as incomes increase (Maconachie et al. 2009). **Thus, the potential of smallholder farmers to be both producers and consumers of sustainable bioenergy through agroforestry is missed.**

Bioenergy production has surged globally from 42 exajoules in 2000 to 58 in 2022 (WBA 2022; Kalak 2023) with accompanying implications of acute respiratory diseases and environmental challenges. These effects are tied to "the fuelwood crises" which denotes a mismatch between dwindling fuelwood stocks and increasing household energy needs. With nearly half (46%) of global agriculture land characterized by agroforestry*, the practice holds high latent value for improving bioenergy security (Zomer et al. 2014). Still, utilizing biomass for energy production is viewed as "greenwashing" by critics who advocate for the attainment of net zero greenhouse gas (GHG) emissions rather than carbon neutrality (Seymour 2020). The resulting low emphasis on biomass contributions to energy security requires developing countries to leapfrog from traditional biomass dependence to modern energy solutions; a transition that is extremely difficult (IEA 2017).

* Includes farms with at least 10% tree cover

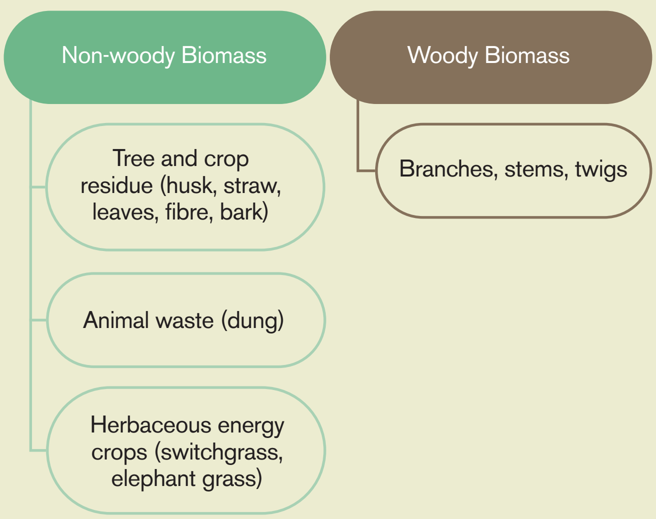
2 BIOENERGY NEEDS IN SSA AND SEA

In SSA and SEA, cheap or freely sourced fuelwood is mainly used in rural communities while charcoal, due to its high energy density and ease of handling, is common in urban areas (Iiyama et al. 2014). Rural Africa (91%) and Southeast Asia (83%) retain high consumption levels of biomass while the urban areas have lower (25–50%) dependence (WHO 2016). Both regions have several fuelwood depletion hotspots leading to over 50% of biomass sourcing remaining unsustainable (Bailis et al. 2015). Notably, demands for charcoal have steadily increased in the past decades and its contribution to economic development is expected to exceed USD 12 billion by 2030, generating employment for 12 million people (World Bank 2011). Besides household use, small businesses including restaurants, brick manufacturers and bakeries depend primarily on biomass for meeting their energy needs.

Photo cred: Selorm Kugbega

Fuelwood and agriculture waste for traditional processing of palm oil.

BIOMASS MATERIALS PRODUCED IN AGROFORESTRY SYSTEMS



TRADITIONAL BIOMASS UTILIZATION AND VALUE IN ETHIOPIA

Approximately 93 million people in Ethiopia, comprising over 90% of the population depend on traditional biomass for household energy needs (World Bank 2018). The sector employs 1.3 million people including farmers, harvesters, charcoal burners, retailers, and transporters (Williamson et al. 2019). With annual volume of harvested fuelwood reaching 60.2 billion kg in 2015, the sector contributes up to 4.5% to GDP (Hundessa and Gemechu 2020). Charcoal is gaining prominence as a vital fuel source for urban areas with consumption increasing from 48,000 tons in 2000 to 4,132,873 tons by 2013 while majority of the revenue (75%) is retained by poor rural producers (Hundessa and Gemechu 2020).

2.1 SDG Linkages

Sustainable biomass production through agroforestry contributes to several SDG's including SDG 7 (Affordable and clean energy), SDG 2 (Zero hunger), SDG 15 (Life on land), SDG 13 (Climate Action), SDG 3 (Good health and well-being), SDG 1 (No poverty) and SDG 5 (Gender equality).

3 AGROFORESTRY CONTRIBUTIONS TO BIOENERGY SECURITY AND LIVELIHOOD IMPROVEMENT

Here are some essential contributions of agroforestry to filling critical energy gaps and related improvements in livelihoods;

Provides a cheap and convenient source of energy: Agroforestry can provide a sustainable supply of woody and non-woody biomass to fulfill household and industrial needs (García-López et. al, 2024). Average annual biomass production ranges from 3.5 t/ha to 16 t/ha with or without coppicing (IRENA 2019). With average farm size of 2 hectares (Lowder et al. 2016) and household biomass consumption of approximately 220 kg per month (Biswas et al. 2023), **many agroforestry systems can provide up to 12 times annual household bioenergy needs in SSA and SEA**. Besides periodic harvesting, tree management practices such as pruning and pollarding can improve energy sufficiency by providing carefully selected and high-quality biomass at predictable volumes. This reduces ad hoc open sourcing and dependence on deadwood which is of lower quality. By sourcing biomass from agroforestry, deforestation pressure on adjacent natural forests is reduced. For urban dwellers, agroforestry systems can fill the biomass supply gaps that develop due to increased demands for fuelwood during energy crises and inflationary periods. This prevents desperate households from relying on low quality biomass or plastic waste which have low combustion efficiency and produce toxic air pollutants (Gathui and Wairimu 2010; Egeru et al. 2014).

Improves food and nutrition security: A continuous supply of biomass allows households to prepare well cooked meals multiple times a day, such as nutritious legumes that require long cooking times (Waswa et al. 2020). Well cooked food contributes to easy digestion, nutrient absorption and food safety by removing toxic organisms and substances such as arsenic which occur naturally in some food crops. It further reduces risks of salmonella and e-coli infection that result from eating raw or partially cooked food. With improved bioenergy access, households can preserve seasonal foods and extend their shelf life.


Photo credit: Michael Mallya, Pixabay

Supports small-scale processing and increases household incomes: Biofuel-fired processing equipment can support small-scale agro-processing for millions of smallholder coffee, shea, cashew, tobacco and tea producers who require energy for drying, parboiling and extraction processes. Among more resourceful farmers and small-scale industries, biomass can be processed into biogas for cooking and powering small farm machines. Thus biomass-based energy can be a catalyst for engagements in higher value chains and rural structural transformation. Revenue from sale of excess biomass can contribute up to 8% of household income, serving as a reliable safety net for households (Angelsen et al. 2014).

Saves labour and reduces health risks: Women and children contribute a large share of the labour and time spent on solid biomass collection (Njenga et al. 2021). With general reductions in woodlands and forests, they walk between 6 to 20 kilometers in search of fuelwood, carry 50 kilos or more and spend up to 6 hours per trip (Thorlakson and Neufeldt 2012). Carrying biomass on the head or back leads to serious injuries while early morning sourcing in woodlands and forests increases risks of rape and attacks by wild animals (Njenga et al. 2021). **With sustainably sourced biomass from agroforestry, women and children avoid personal risks and spend less labour and time on collecting biomass materials, allowing them to engage in other productive activities while increasing children's possibility for school attendance (García-López et. al, 2024).**

Women spend 36 hours per annum when they use biomass from their farms compared with 130 hours when they source from woodlands and natural forests (Mugo 1999).

4 COMMON AGROFORESTRY MODELS AND BIOMASS PRODUCTION POTENTIALS

Various agroforestry models can provide the biomass needed for energy security. Here, we highlight four of these:

Alley Cropping is characterized by alternating rows of crops and trees/shrubs. It is well adapted for cultivating a mix of multiple tree and shrub species with varying biomass yields including early and late maturity tree/shrub strands. For high energy dependent households, alley cropping provides the opportunity for cultivating energy crops in alleys while trees/shrubs are maintained in rows for woody biomass production.

Agrosilvopastoral systems combine tree/shrub, crop and livestock production. They may comprise cultivated pasture and land rotations which allow animals to feed on crop residue or graze in the understory of the farm. Dung from livestock can be combined with other biomass materials for biogas production. However, herds must be large enough and combined with overnight kraals to ensure a steady supply of animal waste.

Home gardens combine cultivation of multiple trees/shrubs, herbaceous plants and crop species on small land parcels close to homes. They are often dense multistoried vegetations with high plant diversity and may include production of small ruminants or poultry. With proximity to homesteads, they drastically reduce time spent on biomass sourcing and are cheaper to establish than other agroforestry systems (Sharma et al. 2022).

Rotational woodlots increase biomass supply by purposely planting high density woodlots. It includes initial intercropping followed by a fallowing phase where trees are left to mature over a 2–5-year period. The fallowing phase includes continuous pruning and tree management while the final stage involves harvesting and intercropping for 2–3 years with coppiced tree stumps. Biomass yields after the fifth year for fast growing rotational woodlots range from 20–50 t/ha (Iiyama et al. 2014) and can meet household energy needs for 7–16 years (Kimaro et al. 2007; Jama et al. 2008). Nonetheless, rotational woodlots are not widely practiced because many small farmers cannot bear the risk of avoiding cropping for a few years in favour of tree development.

Photo Credit: Inga Spence, Alamy

Alley Cropping of Nectarine and Zucchini.

Case: Alley Cropping in Kenya

Mr. Aggrey Lumbasi is a farmer in Western Kenya who has established alley cropping on his farm totaling 4 acres for over 10 years. He plants maize and vegetables together with a mix of long term-trees like Grevillea robusta and fodder shrubs (Calliandra calothyrsus and Leucaena trichandra) in rows. His motivation for starting alley cropping was to get enough fodder from the shrubs to feed his dairy animals, control soil erosion, get enough fuelwood for year-round use and improve soil fertility.

Mr. Lumbasi undertakes periodic thinning, coppicing and harvests fuelwood from pruned branches to reduce shading effects on crops. These management practices provide him with sufficient fuelwood for use in an improved cookstove. Given the increase in his animal herds and experience in handling and selling compost manure, he plans to build a biogas digester in future.

Mr. Lumbasi feels energy secure and rarely purchases fuelwood. His wife and children do not have to spend several hours sourcing fuelwood since it is readily available and harvested from the farm (Interview by Vi Agroforestry, 2024).

BIOMASS MATERIALS FROM COMMON AGROFORESTRY SYSTEMS AND ENERGY CONVERSION PROCESSES

Alley Cropping	Agro-silvopastoral	Home Garden	Rotational Woodlot
Biomass Woody biomass, non-woody tree, crop residue	**Biomass** Woody biomass, non-woody tree, crop residue, animal waste	**Biomass** Woody biomass, non-woody tree, crop residue, anmial waste	**Biomass** Woody biomass, non-woody tree, crop residue (short period)
Energy conversion: Household combustion (firewood) pyrolysis (charcoal), gasification (fuel gas)	**Energy conversion:** Household combustion (firewood) pyrolysis (charcoal), gasification (fuel gas), fermentation (biofuels)	**Energy conversion:** Household combustion (firewood) pyrolysis (charcoal), gasification (fuel gas), fermentation (biogas)	**Energy conversion:** Household and industrial combustion (firewood) pyrolysis (charcoal), gasification (fuel gas)

5 CHALLENGES OF AGROFORESTRY APPLICATIONS FOR BIOENERGY SECURITY

Agroforestry systems may face distinct challenges that limit their uptake as a viable source of biomass. The following constraints are particularly relevant and should be aptly mitigated;

Labour constraints: Some agroforestry systems might require specialized labour for harvesting, pruning and log resizing activities especially in households where these tasks are difficult to complete due to the absence of skilled young men (Zulu and Richardson 2013). In Kenya, labour constrained households may sell a few tree trunks to pay for labour costs (Njenga et al. 2021). In other instances, commercial biomass production and sale has diverted male labour away from crop production, increasing women and children's tasks on the farm (Zulu and Richardson 2013).

Distinctions between potential and effective biomass availability: Many rural communities are presented with a puzzle where tree availability does not necessarily mean bioenergy security. Trees that are highly valued for timber are rarely harvested during fuelwood shortages, while species that do not cope well with intensive pruning don't provide a continuous supply of biomass. Thus, there can be potentially high tree densities, in parallel with energy insecurity, due to unsuitable tree species selection and a desire to satisfy more favored financial needs (Iiyama et al. 2014).

Market risks: Sustainable sourcing and increased biomass dependence can lead to the development of functional markets which may pull in and further degrade natural forests and woodlands. During periods of high demand, there is a risk of excessive pruning, shortened rotation periods and harvesting of immature trees to meet immediate energy needs (Njenga et al. 2019). The effect would be lower biomass yields in subsequent years. Conversely, unless markets are well developed, some agroforestry models- including rotational woodlots- which are oriented towards biomass production for economic gain, may not be attractive for small farmers.

Land tenure/size: Land tenure constraints may affect the capacity to cultivate trees /shrubs that constitute long-term land investments. This is tied to notions of reducing adverse claims to land on the basis of long occupation and managing risks of losing investments in tree/shrub cultivation (Besley 1995). Thus, farmers with poor tenure security including land renters, youth, women and migrant groups that face recurrent risks of eviction are not motivated to engage in agroforestry practices. In some instances, population growth has led to subdivision of existing lands, which disincentivizes farmers from tree or shrub cultivation since they compete for space and present risks to crop production.

6 ENABLING BIOMASS UTILIZATION FOR ENERGY SECURITY

Sustainably sourced biomass requires efficient energy conversion to address health and environmental challenges. Traditional open stoves, commonly used for heating and cooking, are inefficient and contribute to air pollution which leads to multiple respiratory diseases and kills over 3.2 million people yearly (WHO 2022). **Improved cookstoves with insulated combustion chambers enhance energy security by retaining heat and saving 22–31% of household fuel needs compared to open stoves (Gebreegziabher et al. 2018).** With increased adoption, improved cookstoves can reduce health risks of indoor air pollution particularly for women and children who regularly perform household cooking and heating tasks.

Recently, gasifier stoves have emerged as a more efficient alternative that can reduce the volume of biomass needed by 40% compared to open stoves and 27% compared to improved stoves (Njenga et al. 2019). They produce charcoal as a reusable by-product with average yields of 21% depending on the biomass material (Njenga et al. 2019).

Often discarded crop residues or charcoal dust can also be compressed into briquettes which have high calorific value and burn cleaner in improved stoves than fuelwood. Due to their higher energy density, briquettes are useful for meeting urban energy needs and can support small-scale processing.

Besides direct combustion, biomass serves as feedstock for biogas production. This is applicable in zero grazing and agrosilvopastoral systems where woody biomass can be combined with dung, herbaceous plants, tree/crop residues and converted to gaseous fuel through a process of anaerobic fermentation. Biogas combustion is often clean with little effect on indoor air pollution. However, production requires high initial investment in biodigesters, while installation services are rare and concentrated in urban areas. Adoption is often limited to households that have the capital to invest in biogas infrastructure and land for producing consistent volumes of biofuel feedstocks.

Cooking with briquettes saves small industries in the tea sector about 50% of costs and urban households save 88–93% of energy costs for a typical meal in comparison to cooking with charcoal (Njenga et al. 2019).

RECOMMENDATIONS FOR POLICY AND PRACTICE

- Re-evaluate the negative narratives around biomass utilization for energy and embrace the contributions of sustainably sourced biomass to livelihoods, forest protection and rural transformation. This requires policies that recognize the value of biomass in sustainable energy transitions.
- Scale-up access to improved cookstoves that ensure fuel efficient combustion, lower indoor air pollution and reduced environmental effects.
- Target and incentivize multipurpose agroforestry models and high yielding tree/shrub species, while simultaneously managing risks of market expansion and further degradation of natural forests and woodlands. This requires effective regulation of biomass markets through for instance sustainability certifications with traceability functions.
- Improve land tenure security to encourage long term investments in agroforestry. This may be done through establishing communal woodlots, improving individualized land tenure and encouraging benefit sharing through tree tenure agreements.
- Improve knowledge of biomass conversion to cleaner biofuels such as biogas, which are better suited for agricultural mechanization and powering small businesses. Enable decentralized services which allows for easy and low-cost installation of small-scale biogas facilities.
- Polarized debates around net zero GHG emissions and carbon neutrality lead to policy divergence between countries on the value of sustainably sourced biomass for bioenergy security. Decision makers are encouraged to develop harmonized frameworks on biomass applications that are guided by robust scientific research.

Note: The brief has been developed for policy makers and advisors and aims to stimulate private and public investments, as well as engagement towards accelerating agroforestry applications for bioenergy security.

References

Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N. J., Bauch, S., Börner, J., Smith-Hall, C. and Wunder, S. (2014) Environmental Income and Rural Livelihoods: A Global-Comparative Analysis. *World Development* 64, S12-S28.

Bailis, R., Drigo, R., Ghilardi, A. and Masera, O. (2015) The Carbon Footprint of Traditional Woodfuels. *Nature Climate Change* 5 (3), 266–272.

Besley, T. (1995) Property Rights and Investment Incentives: Theory and Evidence from Ghana. *Journal of Political Economy* 103 (5), 903.

Biswas, R., Sharmin, A., Ashaduzzaman, M. and Islam, M. A. (2023) Assessing Rural Households' Biomass Consumption Patterns in Three Upazilas in Khulna District of Bangladesh. *SN Applied Sciences* 5 (7), 188.

Egeru, A., Kateregga, E. and Mwanjalolo Majaliwa, G. J. (2014) Coping with Firewood Scarcity in Soroti District of Eastern Uganda. *Open Journal of Forestry, Vol.4, No.1, 70–74.*

ESMAP (2021) What Drives the Transition to Modern Energy Cooking Services? A Systematic Review of the Evidence. *Energy Sector Management Assistance Program (ESMAP) Technical Report; 015/21 Washington, D.C: World Bank Group.*

Gathui, T. and Wairimu, N. (2010) Bioenergy and Poverty in Kenya: Attitudes, Actors and Activities. *Working Paper, Prepared for Pisces by Practical Action Consulting in Eastern Africa.*

García-López, N., Bargués-Tobella, A., Goodman R.C., Uwingabire S., Sundberg, C., Boman, C. and Nyberg, G. (2024) An integrated agroforestry-bioenergy system for enhanced energy and food security in rural sub-Saharan Africa, Ambio, Springer. DOI: 10.1007/s13280-024-02037.

Gebreegziabher, Z., Beyene, A., Bluffstone, R., Martinsson, P., Mekonnen, A. and Toman, M. (2018) Fuel Savings, Cooking Time and User Satisfaction with Improved Biomass Cookstoves: Evidence from Controlled Cooking Tests in Ethiopia. *Resource and Energy Economics* 52.

Hundessa, A. and Gemechu, K. (2020) Gross Value Added of Wood Fuel Production in Ethiopia. *Journal of Energy Technologies and Policy.*

IEA (2017) *Technology Roadmap. Delivering Sustainable Bioenergy.* Paris, France: International Energy Agency.

Iiyama, M., Neufeldt, H., Dobie, P., Njenga, M., Ndegwa, G. and Jamnadass, R. (2014) The Potential of Agroforestry in the Provision of Sustainable Woodfuel in Sub-Saharan Africa. *Current Opinion in Environmental Sustainability* 6, 138–147.

IRENA (2019) *Sustainable Harvest: Bioenergy Potential from Agroforestry and Nitrogen-Fixing Wood Crops in Africa.* International Renewable Energy Agency, Abu Dhabi.

Jama, B., Mutegi, J. and Njui, A. (2008) Potential of Improved Fallows to Increase Household and Regional Fuelwood Supply: Evidence from Western Kenya. *Agroforestry Systems* 73, 155–166.

Kalak, T. (2023) Potential Use of Industrial Biomass Waste as a Sustainable Energy Source in the Future. *Energies* 16 (4), 1783.

Kimaro, A. A., Timmer, V. R., Mugasha, A. G., Chamshama, S. A. O. and Kimaro, D. A. (2007) Nutrient Use Efficiency and Biomass Production of Tree Species for Rotational Woodlot Systems in Semi-Arid Morogoro, Tanzania. *Agroforestry Systems* 71 (3), 175–184.

Lowder, S. K., Skoet, J. and Raney, T. (2016) The Number, Size, and Distribution of Farms, Smallholder Farms, and Family Farms Worldwide. *World development* 87, 16–29.

Maconachie, R., Tanko, A. and Zakariya, M. (2009) Descending the Energy Ladder? Oil Price Shocks and Domestic Fuel Choices in Kano, Nigeria. *Land use policy* 26 (4), 1090–1099.

Mugo, F. W. (1999) *The Effects of Fuelwood Demand and Supply Characteristics, Land Factors, and Gender Roles on Tree Planting and Fuelwood Availability in Highly Populated Rural Areas of Kenya.* Cornell University.

Njenga, M., Gitau, J. K., Iiyama, M., Jamnadassa, R., Mahmoud, Y. and Karanja, N. (2019) Innovative Biomass Cooking Approaches for Sub-Saharan Africa. *African Journal of Food, Agriculture, Nutrition and Development* 19 (1), 14066-14087.

Njenga, M., Gitau, J. K. and Mendum, R. (2021) Women's Work Is Never Done: Lifting the Gendered Burden of Firewood Collection and Household Energy Use in Kenya. Energy Research & Social Science 77, 102071.

Ochieng, C. A., Zhang, Y., Nyabwa, J. K., Otieno, D. I. and Spillane, C. (2020) Household Perspectives on Cookstove and Fuel Stacking: A Qualitative Study in Urban and Rural Kenya. *Energy for Sustainable Development* 59, 151–159.

Seymour, F. (2020) Seeing the Forests as Well as the (Trillion) Trees in Corporate Climate Strategies. *One Earth* 2 (5), 390–393.

Sharma, N., Bohra, B., Pragya, N., Ciannella, R., Dobie, P. and Lehmann, S. (2016) Bioenergy from Agroforestry Can Lead to Improved Food Security, Climate Change, Soil Quality, and Rural Development. *Food and Energy Security* 5 (3), 165–183.

Sharma, R., Mina, U. and Kumar, B. M. (2022) Homegarden Agroforestry Systems in Achievement of Sustainable Development Goals. A Review. *Agronomy for Sustainable Development* 42 (3), 44.

Thorlakson, T. and Neufeldt, H. (2012) Reducing Subsistence Farmers' Vulnerability to Climate Change: Evaluating the Potential Contributions of Agroforestry in Western Kenya. *Agriculture & Food Security* 1, 1–13.

Waswa, F., Mcharo, M. and Mworia, M. (2020) Declining Wood Fuel and Implications for Household Cooking and Diets in Tigania Sub-County Kenya. *Scientific African* 8, e00417.

WBA (2022) Global Bioenergy Statistics 2022, *World Bioenergy Association.*

WHO (2022) *Factsheet: Household Air Pollution.* World Health Organisation. *https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health*

Williamson, L., N'Goran, K. and Labriet, M. (2019) Sustainability of Biogas and Solid Biomass Value Chains in Ethiopia: Results and Recommendations from Implementation of the Global Bioenergy Partnership Indicators. *United Nations Environment Programme, Addis Ababa, Ethiopia.*

World Bank (2011) *Wood-Based Biomass Energy Development for Sub-Saharan Africa: Issues and Approaches.* World Bank.

World Bank (2018) *Ethiopia–Beyond Connections: Energy Access Diagnostic Report Based on the Multi-Tier Framework.* World Bank, Washington DC.

World Bank (2022) *Tracking Sdg7—the Energy Progress Report.* Washington DC.: International Bank for Reconstruction and Development.

Zomer, R. J., Trabucco, A., Coe, R., Place, F., Van Noordwijk, M. and Xu, J. (2014) *Trees on Farms: An Update and Reanalysis of Agroforestry's Global Extent and Socio-Ecological Characteristics.* Working Paper 179.(ed WACISARPD WP14064. PDF). Bogor, Indonesia.

Zulu, L. and Richardson, R. (2013) Charcoal, Livelihoods, and Poverty Reduction: Evidence from Sub-Saharan Africa. *Energy for Sustainable Development* 17, 127–137.

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