Chapter 7 SDG 7: Affordable and Clean Energy – How Access to Affordable and Clean Energy Affects Forests and Forest-Based Livelihoods

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Key Points

- The role of traditional woodfuels in energy service provision will decline, though energy stacking that includes traditional woodfuels is likely to persist low- and middle-income countries.
- The role of processed woodfuels, forest-derived liquid biofuels, and biopower in achieving SDG 7 will depend on relative costs and innovation in storage capacity of renewables including solar, wind and micro-hydro.
- Transitions to modern fuels (including electricity generated with large-scale hydropower and heavy reliance on agriculture-derived liquid biofuels) threatens forests and forest-based livelihoods.
- Energy transitions involving decreased reliance on traditional woodfuels and increased use of forest-derived modern fuels (e.g. pellets, biofuel) are generally synergistic with achieving other SDGs.

7.1 Introduction

Throughout the world, forests play a significant role in the supply of energy services. The role of forests in ensuring access to affordable, reliable and sustainable energy for all – the overarching objective for SDG 7 – varies widely. In the developing world, an estimated 3–4 billion people rely on solid fuels, primarily traditional woodfuels (e.g. firewood and charcoal) harvested from natural forests and woodlots, for cooking and heating (WHO 2016). For people in low- and middle-income countries where traditional woodfuels dominate the energy portfolio, reliance on biomass for household energy will decline overall in the coming decades, though the absolute number of traditional woodfuel users in sub-Saharan Africa and South and Southeast Asia will grow (Bonjour et al. 2013). To date, evidence suggests that traditional woodfuel harvesting affects deforestation and forest degradation in only a few hotspot

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locations (Bailis et al. 2015). However, rapid urbanisation in Africa and South and Southeast Asia, signalling a potential shift from firewood to charcoal for cooking and heating, raises concerns about the associated impacts on forests in the absence of introduction of clean fuels.

Many middle- and high-income countries are diversifying their domestic energy portfolios. Processed woodfuels and liquid biofuels are an increasingly important component alongside wind, solar, hydro and geothermal energy sources to increase the share of renewable energy in the global energy mix (Ellabban et al. 2014). The majority of liquid biofuels are produced from agricultural crops and residues that have negative impacts on forests when they are cleared to establish plantations. Sustainable uses of bioenergy are important pathways to ensure diversified renewable energy service provision and can broaden livelihood strategies in a wide range of settings. However, in the USA and Europe, renewable energy portfolios for electricity and heat increasingly demand industrially produced pellets, raising concerns about sustainability and high costs of transportation when pellets are not locally produced (Hanssen et al. 2017, Searchinger et al. 2018). New and more efficient technologies for producing electricity from biopower have increased attention and interest in South-eastern Europe, Japan and elsewhere (UNESCAP 2017). Notably, strategies to meet SDG 7 indicators that involve large-scale hydro projects, which frequently inundate forests, lead to deforestation and loss of livelihoods.

This chapter provides an analysis of the implications of achieving SDG 7 (Table 7.1) for forests and for people whose livelihoods depend on forests.

Table 7.1 SDG 7 targets for 2030

7.1	Ensure universal access to affordable, reliable and modern energy services
7.2	Increase substantially the share of renewable energy in the global energy mix
7.3	Double the global rate of improvement in energy efficiency
7.4	Enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology
7.5	Expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, particularly least developed countries, small island developing states and land-locked developing countries, in accordance with their respective programmes of support

Source: Adapted from United Nations 2015

To frame our analysis, we identify four forest energy pathways: (1) sustainable use of traditional woodfuels, (2) processed woodfuels, (3) liquid biofuels and (4) biopower and cogeneration.[1] We discuss their potential to address SDG 7 as well as their hypothesised effects on forest and forest-based livelihoods in the near to medium term.[2] We highlight that in the context of energy service provision at the household level, the major role of forest-based energy is for cooking (developing countries) and heating (globally), and that liquid biofuels primarily support transitions in the transportation and industrial sectors. Cogeneration of electricity or biomass gasification using forest products are the main pathways towards addressing electricity access using wood-based fuels. This study fills an important gap, given that most recent peer-reviewed articles about SDG 7 explicitly focus on energy for lighting and do not address energy for heating and cooking despite the fact that these are the main uses of forest-based energy (Baptista and Plananska 2017, Mentis et al. 2017, Yang and Yang 2017).

We first review theories related to energy transitions and consider the role that forest-based energy plays in both the energy ladder and energy stacking transitions. We then describe the four forest energy pathways we have identified and their implications for supporting both sustainable forest management and forest-based livelihoods. We connect each pathway to its potential contribution to the energy ladder and stacking transitions and the realisation of SDG 7. We also discuss energy transitions that have a large potential impact on forests and forest-reliant peoples, such as large-scale hydro development, but that do not include forest-derived fuels. We provide several case studies that highlight different ways in which forest products influence SDG 7 and how, in turn, progress towards SDG 7 targets impacts forests and people. The cases examined include a small-scale woodfuel (e.g. pellets) and improved cookstove enterprise in Rwanda, global experience with *Jatropha curcas*, and heating and electricity biopower from forest products in South-eastern Europe. We discuss palm-derived liquid biofuels as an example of how an energy transition to modern fuels contributes to deforestation and loss of forest-based livelihoods. The cases intentionally highlight the diverse range of impacts forests have on energy provision and the potential ways that meeting SDG 7 could affect forests – for better and for worse. Finally, we consider

[1] For this analysis, we consider biomass from forests and woodlands, and their contributions to energy production. Forests are land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 per cent, or trees able to reach these thresholds in situ. Woodlands include trees able to meet the forest definition and land with a combined cover of shrubs, bushes and trees above 10 per cent. It does not include land that is predominantly under agricultural or urban land use (FRA 2015).

[2] We do not discuss in any depth non-forest-based energy pathways, which include fossil fuels and renewables other than bioenergy (i.e. solar, wind, geothermal, nuclear).

how the realisation of SDG 7 through forest-based energy pathways will influence other SDGs.

7.2 Energy Ladder and Energy Stacking Theories and SDG 7

Two competing theories posit a relationship between increases in income and energy consumption. The energy ladder theory (Leach and Mearns 1988) differentiates energy use into traditional (animal dung, crop residues and woodfuels), transitional (kerosene and coal) and modern (liquefied petroleum gas [LPG], electricity and other renewables). Under the energy ladder theory, household energy choice moves from traditional to transitional to modern fuels as incomes increase. Traditional fuels are more polluting and less efficient but cheaper, while modern fuels are more energy efficient and cleaner, but more expensive. Energy ladder transitions are linear and assume that as transitional and modern fuels are adopted traditional fuels are no longer used. A competing theory suggests that households will instead stack fuels and technologies as incomes increase. Energy stacking involves the use of multiple fuels by the same household, taking advantage of the benefits each fuel provides (Gupta and Köhlin 2006, Masera et al. 2000, Masera and Navia 1997, Nansaior et al. 2011). Under the energy stacking theory, modern fuel users continue to use traditional and/or transitional fuels irrespective of income level, and assume a gradually partial or full transition to modern fuels, including stacking of multiple fuels and technologies in diverse ways.

An important caveat of both the energy ladder and energy stacking hypotheses is that they place emphasis on household income as the major driver of energy transitions. Indeed, in several studies income is the most important factor in determining fuel choices (Arnold et al. 2006, Cooke et al. 2008, Foster et al. 2000, Heltberg 2005, Hiemstra-van der Horst and Hovorka 2008). We note that few studies have explored supply-side factors affecting fuel choice (Jagger and Shively 2014, Lewis and Pattanayak 2012, Rehfuess et al. 2010). Global estimates (GEA 2012, UN DESA 2015) predict the absolute number of people dependent on biomass fuels will increase through 2030, suggesting that policymakers should be attentive to factors that influence the supply, demand, spatial distribution and governance dimensions of biomass fuels, including traditional woodfuels. Several studies have noted the lack of information available about fuelwood harvesting practices, geography and dynamics, specifically with respect to woody biomass availability within different land uses (Foley 2005, Hiemstra-van der Horst and Havorka 2009, Smeets and Faaij 2007). Insights into the combined spatial and behavioural dynamics of woodfuel supply and demand support a broader understanding of the role of forest products in sustainable energy transitions (Masera et al. 2006, Rehfuess et al. 2010).

7.3 Forest-Based Energy Pathways

Forest products play a range of different roles in energy service provision and sustainable energy transitions depending on a variety of contextual factors. We identify four energy service pathways for forest products: (1) traditional woodfuels, (2) processed woodfuels, (3) liquid biofuels and (4) biopower and cogeneration (Table 7.2). For each pathway we discuss: (1) sustainability or extent to which they contribute to renewable energy targets, (2) socio-economic dimensions of the pathway and (3) how the pathway connects to theories of energy ladders/stacking. We also briefly touch on the regional setting where the pathway is most common, actors engaged in the pathway, the scale of operation and governance. We acknowledge the challenge of differentiating forest-based energy from the broader category of bioenergy. The term 'bioenergy' refers to energy derived from any organic matter available on a renewable basis, including forest and mill residues, agricultural crops (including field and processing residues), wood and wood waste, animal dung, fast-growing trees and herbaceous crops, etc. In practice, it is quite difficult to disaggregate the relative contribution of forests to bioenergy in most contexts due to how data are reported and depending on the definition of forest. In energy terms, the most common use of biomass after traditional cooking/heating is for industrial heat and space heating (REN21 2018). The biomass feedstocks for electricity cogeneration are predominantly forest residues (including black liquor), bagasse and other agricultural residues.

7.4 Traditional Woodfuels

7.4.1 Context

Traditional woodfuels, which include both firewood and charcoal, represent more than half of the global wood harvest and nearly 8 per cent of the primary global energy supply (FAOSTAT 2015, REN21 2018). Roughly 2.8 billion people worldwide (Bonjour et al. 2013), including the world's poorest and most marginalised, burn traditional woodfuels to satisfy their basic energy needs, with cooking and heating being the major services provided. Globally, the absolute number of traditional woodfuel users will increase at least through to 2030 (Riahi et al. 2012). The traditional woodfuel sector is typically comprised of large numbers of small to medium-scale actors. Many traditional woodfuel consumers collect or produce their own woodfuels for subsistence consumption, though there is a rapidly growing trade in charcoal, particularly in sub-Saharan Africa and the Middle East. Traditional woodfuel markets often lack regulatory frameworks or operate in environments where rules related to the production, transport and sale of woodfuels are not enforced.

Table 7.2 Forest-based energy pathways

	Traditional woodfuels	Processed woodfuels	Liquid biofuels	Biopower and cogeneration
Products	Fuelwood and charcoal	Pellets, torrefied biomass; Other compressed wood products	Transportation biofuels; biodiesel	Pellets and other biomass converted to electricity; Co-firing with coal or fossil fuels
Regional focus	Low- and middle-income countries in the Global South	North America and Europe; China; Small-scale examples throughout the Global South	Central America; tropical areas of Africa and Asia; Europe	Europe; Japan; South Korea
Actors	Large number of small-scale producers and consumers	Small number of producers at various scales; Small- and medium-scale consumers	Medium- and large-scale producers; Small- and medium-scale consumers	Industrial and government sectors
Scale	Local with some regional trade	Local, regional or global	Regional or global	Regional or global
Governance	Unregulated; Informal sector	Regulated; Formal sector	Regulated; Formal sector	Regulated; Formal sector
Sustainability	Conditionally renewable but sometimes associated with forest degradation	Pressure to manage forest resources sustainably; Feedstock a supply issue in some settings	Pressure to manage forest resources sustainably; GHG, energy, water, land intensive	Pressure to manage forest resources sustainably; GHG, energy, water, land intensive
Livelihoods/ services/final energy use	Cooking and heating	Cooking and heating	Transportation sector; Electricity; Industrial development	Electricity; Heating, Cooking, Industrial development
Energy ladder or energy stacking	Stacking	Stacking	Ladder and stacking	Stacking

7.4.2 Sustainability

Woodfuel demand is frequently associated with deforestation and forest degradation (de Montalembert and Clement 1983, Eckholm 1975, Eckholm et al. 1984). Concerns about the impacts of firewood and charcoal consumption on forests have motivated interventions to reduce woodfuel consumption several decades. Often implemented by development agencies or other outside actors, interventions have tried to enhance fuel supply through tree nurseries and community woodlots, production of briquettes and promoting fuel-saving cook stoves. Despite decades of attempts, few interventions have achieved widespread success.

Researchers have quantified traditional woodfuel sustainability in different locations (Drigo et al. 2015, Ghilardi et al. 2016). One pantropical assessment estimated that roughly 30 per cent of the global wood harvest is unsustainable, leading to localised degradation, with hotspots concentrated in South Asia and East Africa (Bailis et al. 2015). The loss of terrestrial carbon resulting from woodfuel-consumption-driven land-cover change is equivalent to 1–2 per cent of global CO_2 emissions, and roughly 20 per cent of global land-use change emissions. There is now consensus that, in the absence of other drivers of land-cover change, woodfuel demand rarely results in long-term deforestation. However, under many circumstances it can cause forest degradation.[3] We understand that geographically specific biophysical and socio-economic factors play a critical role in woodfuel sustainability (Hosonuma et al. 2012 Hansfort and Mertz 2011, Mayaux et al. 2013, Singh et al. 2010, Smith et al. 2014b). Biophysical factors include land cover, species distribution, climatic conditions and topography, among others. Socio-economic factors include population distribution, growth and urbanisation rates, wood energy demand and other drivers of land-cover change. Policies affecting land use, forest management and energy preferences are also important to protecting forests and people in areas with populations dependent on traditional woodfuels.

A noteworthy exception of the impact of traditional woodfuel consumption on forest sustainability is the impact of woodfuel demand in humanitarian settings. Sudden influxes of people, and their need for cooking energy in particular, can place pressure on forest resources, as observed in large refugee camps in Kenya, Sudan, Somalia, Nigeria, Myanmar, Bangladesh and

[3] For this discussion, it is important to distinguish between deforestation, defined as direct human-induced conversion of forested land to non-forested land, and forest degradation, defined as long-term reduction of the overall potential supply of benefits from the forest, which includes carbon, wood, biodiversity and other goods and services.

elsewhere (Caniato et al. 2017, Thulstrup et al. 2018). Many of these camps are located in already fragile ecological settings.

7.4.3 Livelihoods

Woodfuels play an important role in the livelihoods of billions of people in the Global South. In a study of forest reliance among rural populations in 25 countries throughout the Global South, Angelsen et al. (2014) estimate that traditional woodfuels account for 35 per cent of forest income (subsistence plus cash). Despite the important role that woodfuels play in income generation and diversification, woodfuel reliance has negative consequences for human health (Bruce et al. 2000, Smith et al. 2014a). Household air pollution (HAP) related to burning solid fuels (including firewood and charcoal) was responsible for 2.6 million deaths in 2016 (Health Effects Institute 2018). Exposure to HAP related to burning biomass as fuel is the thirteenth-largest risk factor overall, and the second-largest environmental risk factor (in low and middle-income countries) for global burden of disease after ambient air pollution (Forouzanfar et al. 2015). Other health effects associated with firewood collection include risk of physical assault (O'Brien 2006), musculoskeletal injuries from carrying fuelwood bundles and insect and snake bites (Haile 1991). In addition to health burdens, reliance on traditional woodfuels has implications for allocation of productive time, particularly for women and children. Where forest resources are scarce, people dedicate more time to wood collection and frequently involve children in the activity. When young girls spend more time collecting wood, they spend less time in school and do not progress to higher levels of education (Oluwafemi et al. 2012).

7.4.4 Link to Energy Transition Theories and SDG 7

Traditional woodfuels have a limited role to play in the way that SDG 7 is articulated. Firewood and charcoal are at the lowest rung on the energy ladder. Munro et al. (2017), in a study in Sierra Leone, express concern for both the lack of attention to energy poverty in SDG 7 discussions and for the flawed dismissal of the role of sustainably sourced traditional woodfuels in supporting the realisation of SDG 7. They cite an overemphasis on 'modern energy', much of which is out of reach for lower-income groups, advocating for an approach that allows for the promotion of multiple energy sources, including traditional woodfuels. This view supports energy stacking as the theory of change required to move towards achieving SDG 7. However, ensuring modern and affordable access to clean energy will likely involve significant reductions in traditional woodfuels.

7.5 Processed Woodfuels and Liquid Biofuels

7.5.1 Context

We distinguish between two main types of forest-based bioenergy: processed woodfuels (densified or torrefied solid fuels), and production of liquid biofuels from forest and woodland products (e.g. *Jatropha curcas*). Processed woodfuels are widely used for home heating in Northern Europe and China; in a small but growing number of countries in the Global South they are used in tandem with micro-gasification cook stoves (Case Study 7.1). Liquid biofuels help society respond to the increased demand for renewable energy sources to meet EU climate policy and renewable energy targets and comply with international agreements on climate change. The transition to renewable fuels in countries addressing the SDG 7 framework may create demand for new forest-based fuel products (Case Study 7.2).

Case Study 7.1 Densified Pellets (Processed Wood Fuel) in Rwanda

Founded in 2012, *Inyenyeri*, a for-profit social benefit company in Rwanda, is a private sector firm marketing processed woodfuels (e.g. pellets, briquettes) and micro-gasification stoves. Other than *Supamoto*, a firm in Zambia, no other pellet/cook-stove promoter in sub-Saharan Africa operates at the same scale. The experience of *Inyenyeri* provides insights into the challenges related to pellet production, improved cook-stove selection and the structure of the marketing model for businesses providing household energy services (Jagger and Das 2018). Here we focus on their experience with producing pellets. The firm's business model requires supplying enough biomass pellets to support the current customer base. Obtaining sustainably sourced feedstock of adequate type and quantity and maintaining a functional production facility are the major issues *Inyenyeri* has dealt with during its pilot phase from 2012 to 2018. The firm has experimented with a range of feedstock supply options, including a trade-in mechanism whereby rural biomass collectors exchange feedstock for pellets, and sourcing sawdust and other feedstocks from larger-scale operations in relatively close proximity to the pelletising plant in north-western Rwanda. The logistics of storing, transporting and drying feedstock have provided additional complexity to the operation. *Inyenyeri* is currently in negotiations with the Government of Rwanda to source feedstock from pine plantations in order to maintain a consistent supply of high-quality material for pelletising. The capital investment required for building large pelletising factories and the challenges of maintenance and repair in central Africa have been obstacles to scaling-up pellet production. Relying on a single pelletiser

Case Study 7.1 (cont.)

is a problem in an environment where capacity for equipment maintenance is low. The efficacy of a decentralised versus centralised system of pellet production (i.e. a few large-scale factories versus several small- to medium-scale enterprises) should be considered.

Inyenyeri's experience over the past five years illustrates the complexity of building a market for a clean cooking solution involving processed woodfuels. The potential of pellet and fan micro-gasification cooking should continue to be explored, particularly in settings where widespread distribution of affordable LPG and electric cooking systems will be realised in the distant future. *Inyenyeri* represents an important test case for understanding how to achieve a clean cooking system using a renewable biomass source in sub-Saharan Africa.

Case Study 7.2 Jatropha Biofuel

Jatropha curcas is a shrub promoted in several low- and middle-income countries as a source of biofuel, with co-benefits of improving rural employment opportunities, diversifying income, securing biodiversity and regenerating degraded lands (Brittaine and Lutaladio 2010, Reubens et al. 2011, Valdés-Rodríguez et al. 2014, von Maltitz and Setzkorn 2012). It survives well in harsh climatic and soil conditions, making it attractive in areas where agricultural production is marginal. Several governments have provided financial incentives to promote *J. curcas* cultivation by smallholders and larger-scale plantations with the aim of fostering a market for biofuels (Jull et al. 2007, Pradhan and Ruysenaar 2014, Soto et al. 2015). Several *J. curcas* cultivation projects were initiated in Central America, where the plant is indigenous, and throughout tropical Africa and Asia in the early 2000s. Evidence of the impact of *J. curcas* cultivation for livelihoods and sustainability is mixed.

In a comparison of smallholder and plantation-based *J. curcas* production, van Eijck et al. (2013) found that smallholder production is associated with more secure land rights, GHG balance, improved biodiversity and effectiveness in the number of people reached. Smallholder projects tend to be more resilient, likely because of lower start-up and production costs (Kgathi et al. 2017). However, because government subsidies for *J. curcas* cultivation tend to go to households with more resources and better risk-coping strategies (Soto et al. 2015), the poorest households are often excluded from government programmes. Low-income households are most vulnerable to negative social effects of *J. curcas* cultivation and are most likely to abandon the

Case Study 7.2 (cont.)

crop (Soto et al. 2018). Plantations, on the other hand, are associated with decreased food security, loss of land rights and decreased biodiversity (van Eijck et al. 2013). Plantation-based production creates more initial employment opportunities and higher incomes, but for a smaller number of people. The economic viability of plantations is limited in many settings because of high upfront costs, slow crop maturation and low yields, causing many projects to collapse before their yields can stabilise (Romijn et al. 2014, Gasparatos et al. 2015).

When cultivation involves clearing natural forest, impacts include deforestation, decreased biodiversity and threatened water sources (Creutzig et al. 2012, Fargione et al. 2008, Laurance et al. 2014, Wu et al. 2014). However, when *J. curcas* is planted on degraded lands, plantations have resulted in reduced soil erosion and renewed stimulation of biological activity, and thus improved soil quality, without competing with food production or depleting natural resources (Wani et al. 2012). Overall, small-scale *J. curcas* production on already degraded land not currently used for crop production has the best social and environmental impacts on forests and forest peoples (Skutsch et al. 2011).

A challenge for this study is the disaggregation of forest versus non-forest-based liquid biofuels. For example, while ethanol and biodiesel produced from agricultural residues are important in China, Brazil and Sweden, they are outside the scope of this study because they are not forest-based. Other liquid biofuels – for example, those derived from palm in Indonesia – play a major role in meeting liquid biofuel targets, but are considered a contributor to deforestation when primary forest is cleared to establish plantations (Case Study 7.3).

Renewable portfolio standards across countries and sectors influence the role of forest products in meeting renewable energy targets, with standards taking different shape depending on the sector, country and policy environment. To date, the EU Renewable Energy Directive (RED) may be the most impactful policy on forest-based bioenergy (Searchinger et al. 2018). RED is a binding target, though member states set their own (frequently non-binding or flexibly binding) domestic goals. Biofuels frequently play different roles in electricity and transportation sectors, ranging from wood pellets burned for electricity generation and household heating to liquid biofuels replacing fossil-fuel reserves in the transportation sector. For cooking, renewable energy

Case Study 7.3 Palm Biodiesel in Indonesia

The development of the biodiesel sector in Indonesia is driven by multiple factors, including (1) a national agenda to support energy security in response to heavy dependence on imported crude oil (Dermawan et al. 2012, Kharina 2016, Naylor and Higgins 2017), (2) expectations that developing the biodiesel sector contributes to efforts to mitigate climate change (da Silva Araujo 2014, McBride et. al. 2011, Sedjo 2011), (3) Indonesia's position as the world's largest producer of palm oil, and (4) a mechanism for mitigating risk associated with fluctuations in the global price of palm oil (Danny 2018, Nurfatriani et al. 2018). The National Energy Policy issued in 2014 mandates that new and renewable energy, including biodiesel, make up 24.5 per cent of the national energy mix by 2025 and 31 per cent by 2050. The main policy to develop the biodiesel sector has been the blending target of 30 per cent of biodiesel use by 2020. The blending target is applicable to the transportation, industrial and electricity sectors, with its main emphasis on the transport sector.

Estimating the impacts of palm oil production for biodiesel on deforestation in Indonesia is empirically challenging for several reasons (Obidzinski et al. 2012). First, the proportion of Indonesian palm oil that goes into biodiesel production is small. In 2017, 2.7 million tonnes – less than 10 per cent of total production – went into biodiesel (Wright and Rahmanulloh 2017). Second, palm oil is a product with multiple uses; biodiesel is only one of them. Large producers of palm oil derivatives can shift the palm oil from one purpose (e.g. food) to another (e.g. biodiesel) depending on economic conditions (Eynck et al. 2013).

Socio-economic analysis of the role of the palm oil sector with specific reference to biofuels is hindered by a lack of traceability of palm oil value chains. Biodiesel producers may receive palm oil from the company mills, from third-party corporate suppliers and from independent smallholders. Changes in biodiesel demand affects producers' allocation of palm oil; however, impacts on forests and smallholders depend more broadly on palm oil demand, which may or may not relate to demand for palm oil-derived biodiesel.

portfolios distinguish between sustainably produced pellet fuels that replace unsustainably produced charcoal and continued use of traditional biomass energy sources.

7.5.2 Sustainability

Bioenergy is controversial for its potential competition with crop production and because of potential links to deforestation (e.g. palm biodiesel, Case Study 7.3). A range of sustainability standards and monitoring frameworks have been developed since the USA and the EU each implemented bioenergy trade rules and regulations in 2007/2008 (Scarlat and Dallemand 2011). Bioenergy plays a particularly challenging role in renewable energy portfolios when sourced from forest products. Policies in place to prioritise waste, residues and specific crops help guide the monitoring and verification of liquid biofuel products, yet significant challenges remain to avoid unintended land-use changes resulting from renewable energy portfolio policies that incentivise bioenergy. Sustainability concerns include biodiversity impacts, landscape impacts, soil nutrients and protective functions, water impacts and GHG emissions. Renewable energy portfolio standards could increase forest product demand for bioenergy initiatives that produce electricity, transportation, heat and chemicals. Improved monitoring and verification of sources of processed woodfuels and liquid biofuels would provide a way to track the use of unsustainable forest products contributing to energy demand.

7.5.3 Livelihoods

Production of processed woodfuels and liquid biofuels is employment intensive, providing jobs at all stages in the value chain. REN21 (2010) estimates there were approximately 1.5 million direct jobs in 2010 for biomass production, operation, harvesting and transportation; biomass facility processing and upgrading; conversion plan construction, operation and maintenance; and distribution of final energy products. Due to the growing demand for bioenergy, the European Renewable Energy Council (EREC) and Greenpeace estimate the creation of 2.1 million new jobs in the sector by 2030 (EREC 2008). In many developed countries, regional policies support development of the bioenergy sector to enhance employment opportunities in rural economies (Halder et al. 2014). Similar potential for growth in the sector exists in low and middle-income countries; however, given the reliance of local populations on forests for a wide range of goods and services, energy and rural development policies should ensure that local populations are not harmed by development of the sector. Cultivation of some biofuel feedstocks is similar to other large-scale monoculture cropping schemes, having large impacts on the supply of goods and services provided by natural forests.

Buongiorno et al. (2011) modelled the aggregate effects of bioenergy on the forestry sector on both local and regional economies. The global forest products model (GFPM) projects the consequences of the global forest sector doubling the rate of growth of bioenergy demand relative to a base scenario, all else being equal. Doubling bioenergy demand leads to the convergence of the price of firewood and industrial roundwood, raising the projected price of industrial roundwood by nearly 30 per cent by 2030. The price of sawn wood and panels would be 15 per cent higher. The price of paper would be 3 per cent higher. Concurrently, the demand for all manufactured wood products would be lower in all countries, but production would rise in countries with competitive advantage. Global value added in wood-processing industries would be 1 per cent lower in 2030; forest stock would be 2 per cent lower for the world and 4 per cent lower for Asia. Estimated effects vary substantially by country. Overall, the analysis implies that development of the bioenergy sector will negatively affect forest product prices and forest sustainability in a number of countries.

7.5.4 Link to Energy Transition Theories and SDG 7

Processed woodfuels and liquid biofuels may play a major role in the realisation of SDG 7; however, pricing and market development for other renewables, along with the regulatory framework surrounding mandated portfolios and certification, will influence how their role evolves. In most low-income countries, there are few examples of processed woodfuels or forest-derived liquid biofuels utilised at a significant scale for cooking and heating, though the use of agriculture and forest-derived liquid biofuels in the transportation sector is common. Most likely, for residential and small-scale industrial use, processed woodfuels and liquid biofuels will be part of an energy stacking transition that also includes traditional woodfuels in low- and middle-income countries, and more diversified portfolios, including other renewables in higher-income countries. For the realisation of SDG 7, several challenges emerge. Modern woodfuels need companion heating and cooking technologies (e.g. improved stoves) to ensure that the energy is clean (i.e. achieving efficiency gains, emission reductions and associated health benefits). In many countries, the development of both processed woodfuels and forest-derived biofuels involves establishing entirely new supply chains or importing high volumes of biomass. The overall sustainability and economic feasibility of developing supply chains is complex.

7.6 Biopower Cogeneration for Electricity

7.6.1 Context

Biopower and combined heat and power systems (cogeneration) use biomass in the form of pellets or other wood products to generate electricity. In the USA, overall biomass electricity generation is increasing in total production but decreasing in share of the electricity mix, possibly due to the rapidly declining cost of natural gas and alternative renewable energy sources. Bioenergy is promoted for electricity generation as a way to decarbonise the electricity sector, reduce emissions and meet Intergovernmental Panel on Climate Change (IPCC) climate targets (Davis et al. 2018). In this context, many countries are exploring retrofitting coal plants to combust bioenergy for heat and power applications. In Brazil, biomass-derived charcoal could substitute for coal in the steel sector. To meet industry demands and phase out coal, millions of hectares of forest are necessary (Sonter et al. 2015). Despite infrastructure and pressure on forest resources, demand for biomass electricity continues to grow in Europe and Japan. Canada and the USA export a significant amount of wood pellets to supply UK and European markets. Dwivedi et al. (2014) estimate a 50–68 per cent decrease in GHG intensity for electricity from wood pellets used for electricity in the UK.

7.6.2 Sustainability

A major challenge for sustainable forest management and biopower production is to ensure the use of waste and residue biomass products before using virgin materials for electricity generation or district heating. Certification of sustainably sourced biomass for electricity generation is a challenge. The UK and the EU have introduced new requirements to sustainably source biomass for electricity, focusing on waste and residues rather than pure wood (European Commission 2016). Future targets that adhere to these priority measures can reduce pressure on forests. RED established non-binding criteria, including banning the use of biomass from land converted from high biodiversity forest areas and favouring national biofuel support schemes. Despite these reporting efforts, monitoring of the origin of biomass consumed in the EU remains a challenge to sustainably managing megawatt-scale biomass heat and power initiatives.

The IPCC Working Group Report includes biomass as a critical electricity generation technology along with carbon capture and storage (bioenergy carbon capture and storage or BECCS) in its models as one of the few ways to maintain two degrees of global warming without incurring significant costs to the electricity system. Future models of decarbonised electricity systems place the levelised cost of biomass electricity in a range similar to renewable electricity systems today – though it may require further integration for cost-effective, low-carbon biomass systems (Sanchez et al. 2015). The affordability and viability of such emissions reductions remain a point of debate and uncertainty, primarily due to the lack of alternative electricity supply options and the assumption that carbon sequestration remains cheaper than alternative generating sources, including solar and wind which do not have the same ‘negative’ emissions potential. Realising emission reduction strategies through BECCS technologies would require significant technological innovation and could impose higher costs than the IPCC estimates. This could significantly affect demand for bioenergy forest products and place pressure on forests in Africa and the Amazon region. Not all BECCS is produced and stored at the same location, which poses challenges to monitor and verify the emission reductions and avoid double counting.

Finally, an important consideration for the future of biopower in realising SDG 7 is the rapidly declining cost of solar, wind, geothermal and battery storage (Kittner et al. 2017). Renewable energy alternatives may affect demand for biopower in the future, but near-term generation indicates continued consumption of electricity from (mainly agriculture-sourced) biomass feedstocks in USA, China, Germany and Brazil. If expanded beyond agricultural capacity, there could be indirect effects on forests, such as the conversion of forestland to produce biopower crops or fast-growing wood pellet farms.

7.6.3 Livelihoods

Evidence of the livelihood impacts of the growth of biopower within the energy sector is limited. Government subsidies that support BECCS could induce conversion from natural forests to plantations to produce bioenergy, which may threaten forests or people with forest-based livelihoods. However, market stimulation of increased biopower energy demand may not have localised effects. For example, if bioenergy products for power generation in the EU are imported in pellet form from exporting nations such as the USA and Canada, employment generation may occur, but not in places where demand for biopower is realised.

7.6.4 Link to Energy Transition Theories and SDG 7

To the extent that biopower will replace other energy sources, particularly for district heating, it supports the stacking hypothesis. The RED set up legally binding mandates to target a certain percentage of energy consumption from renewable sources, and similar policies are in place in the UK. While electricity production using wood pellets will increase, it is unlikely to fully displace current modes of energy production.

Most notably, the RED has generated a large demand for wood pellets used in electricity generation and district heating for urban areas. The RED sets a binding target of 20 per cent final energy consumption from renewable sources by 2020, which includes biomass energy. All EU member states have created action plans, and a number of individual states with large heating demands and forest resources have turned to wood pellets as an energy technology to meet this target. Cogeneration of electricity and

Case Study 7.4 Biopower and Cogeneration in Southeast Europe

Most existing coal power plant infrastructure could transition at a relatively low cost to burning biomass pellets. Switching from coal to biomass pellets using existing infrastructure alleviates the financial burden of financing new infrastructure projects and has gained significant attention in the USA, Europe and China. Eastern European countries maintain large production and consumption shares of forest bioenergy for district heating and cogeneration. In particular, wood chips overtook natural gas in Lithuania as primary district heating fuels in 2017 (REN21 2017). Other countries in Southeast Europe – including Kosovo, Bosnia and Herzegovina, Serbia and Croatia – may continue this trend as they address rising air pollution and associated health burden concerns from burning lignite coal, and can switch fuels without significantly altering boiler technologies (Kittner et al. 2016). For emerging economies, biomass presents a dual challenge. The large area of forest cover in Kosovo provides a cost-effective alternative to lignite coal for household heating and electricity generation if managed domestically. However, sustainability issues remain, and a significant expansion of biomass reliance could increase demand for imported biomass, placing pressure on nations seeking extra revenue from wood product exports.

In Kosovo and the western Balkans, household heating remains a critical challenge to achieving SDG 7. It is expensive and difficult to provide affordable and reliable energy during the winter months, when temperatures can drop below freezing, and there is a high dependence on lignite coal for heating. The region has large areas of forest, allowing for the production and use of higher-quality woodfuels containing fewer toxic pollutants than lignite coal. However, lack of access to quality woodfuels has hindered availability for residents across the country. Switching from lignite towards cleaner bioenergy options could also reduce exposure to toxic trace metals, including chromium and arsenic (Kittner et al. 2018). Efforts to achieve the health benefits of burning cleaner heating fuels should pay special attention to the management and governance of land dedicated to growing fuel wood. Alternatively, if electric heat pumps are widely adopted, as they have been in other European nations, there could be better opportunities to use electricity for household heating and reduce the demand for woodfuels from forests. A significant expansion of the woodfuel market without domestic management could cause larger-scale woodchip operations and imports from as far away as the south-eastern United States, where fast-growing trees for wood pellets have surged in production over the past 10 years.

heat used for distribution throughout cities or buildings has emerged as a low-cost method to deliver critical renewable energy services to European households.

7.7 Large-Scale Energy Infrastructure Development and Impacts on Forests and Forest-Reliant People

Many emerging economies with low levels of electricity access view hydropower as a way to meet SDG 7 goals. There are an estimated 450 planned hydropower dams expected to generate dozens of gigawatts of electricity capacity across the Amazon, Democratic Republic of Congo and the Mekong River Basin (Myanmar, Laos and Vietnam) in the coming decade (Winemiller et al. 2016). If built to satisfy SDG 7 targets of clean and affordable energy without design precautions and consideration of environmental and social safeguards, these plants could drastically alter forest cover, biodiversity and local livelihoods. Widespread forest cover loss and concerns about displacing people from their homes are major concerns (Winemiller et al. 2016). For example, in Brazil, hydropower supplies more than two-thirds of electricity. Forest-dependent populations are displaced by dam construction, and new roads associated with dam development indirectly lead to agricultural expansion and increased forest cover losses (Barber et al. 2014, Zarfl et al. 2015). Plants are often justified as providing electricity to affected rural populations, even though they frequently fail to serve low-income or last-mile populations.

Hydropower often draws the attention of climate financiers that consider it a low-carbon electricity source. However, hydropower projects greater than 1 megawatt in size carry a substantial land footprint and require reservoirs spanning several hundred square kilometres, as is the case along the Amazon where reservoirs displace tropical forests to meet Brazil's demand for electricity (de Faria et al. 2015). Carbon emissions associated with these hydropower reservoirs include methane off-gassing, the carbon release from converted tropical forestland during dam construction and associated ecological changes in land use along the riparian zones (de Faria et al. 2015, Räsänen et al. 2018). In the Mekong, some hydropower reservoirs rival GHG emissions from fossil-fuel plants when considering the methane flux from reservoirs (Räsänen 2018).

Hydropower is also controversial due to uncertainty about whether plants can provide low-cost electricity access when alternative technologies are available (de Faria and Jaramillo 2017, Deshmukh et al. 2018). This includes options to use forest-based biomass for electrification or gasification and the adoption of solar or small hydropower-based mini-grids. At present, hydropower is appealing as basic solar home systems often fail to meet the demand required for rice milling or cooking that many populations without electricity access desire. Smaller, more ecologically friendly types of hydropower dams exist that can meet SDG 7 goals without destroying forests and displacing people. Mini hydropower projects with localised distribution are likely to have a far lower impact than large-scale efforts. Higher capacity mini-grids in Nepal, Myanmar and Laos provide new opportunities to utilise larger-scale solar photovoltaics or hydropower dams in complementary ways. A focus on the diversity of renewable energy options available, including those from solar, wind and biomass, can mitigate larger risks for land management, tropical forests and people who are seeking access to electricity.

7.8 SDG 7 and Its Relationship to Other SDGs

In order to understand the implications of fulfilling SDG 7 as it relates to other SDGs, we consider each of the four forest energy pathways reviewed and present the hypothesised impacts for both forests and forest-reliant peoples should SDG 7 be realised (see Table 7.3). Our assumption is that as progress towards SDG 7 increases, the role of traditional woodfuels will decline and the role of modern woodfuels and biofuels will increase.

7.9 Conclusion

This chapter reviews the role that forest-derived energy will play in the realisation of SDG 7, focusing on four pathways for forests to contribute to energy service provision: traditional woodfuels, modern woodfuels, liquid biofuels and biopower/cogeneration. Energy transitions in low- and middle-income countries will likely involve reductions in traditional woodfuel reliance for heating, cooking and small-scale industrial energy provision, whereas countries currently seeking to diversify renewable energy portfolios may see an increase in forest-based bioenergy as long as it remains competitive and cost-effective. The cost of other renewables will play a major role in determining how important forest-based energy sources are for electricity, heating, cooking and transportation. A recent and growing literature addresses various aspects of SDG 7 and the role of forests. Calzadilla and Mauger (2017) cite wind and solar as the most promising energy sources for developing countries while indicating concerns about the lack of attention to equity issues in case studies from Chile, India, Kenya and Mexico. In most settings, our expectation is a transition that involves the diversification of energy sources that households and businesses rely on rather than a complete transition away from current fuels and technologies. Baptista and Plananska (2017) cite problems of path dependence and inertia in the implementation of energy

Table 7.3 Trade-offs and synergies between fulfilling SDG 7 and other SDGs

SDG	Reduction in use of traditional woodfuels		Increase in processed woodfuels, liquid biofuels and biopower/cogeneration	
	Forests	People	Forests	People
1 No poverty	Reduced pressure on forests improves ecosystem services (+)	Reduced woodfuel reliance (+); Loss of employment (–)	Loss of ecosystems services (–)	Employment in renewables sector (+); Poor and last-mile populations left out of the transition (–)
2 Zero hunger	Reduced degradation allowing forest foods to flourish (+)	More efficient technologies requiring less fuel for cooking, more frequent/ diverse cooked meals (+)	Land degradation and loss of agricultural land from pressure to develop biofuels sector (–)	Potential decrease in food security in biofuel planation development areas (–)
3 Good health and well-being	Preservation of forests supporting human health and well-being (+)	Reduced exposure to household air pollution (+); Reduced risk of injury/ harm (+)	Loss of natural areas due to development of bioenergy (–)	Reductions in exposure to household air pollution (+)
4 Quality education		Reduced fuel collection and cooking time freeing people to go to school (+)		

Table 7.3 (cont.)

SDG	Reduction in use of traditional woodfuels		Increase in processed woodfuels, liquid biofuels and biopower/cogeneration	
	Forests	People	Forests	People
5 Gender equality	Improved access for society to women's forest management capabilities (+)	Reduced fuel-collection time freeing women of drudgery; Improved cooking conditions increasing safety (+)		
6 Clean water and sanitation	Reduced impact on forest ensuring high-quality water (+)		Water tables affected by emphasis on fast-growing species (–)	Reduced cost and time to treat water by boiling (+)
8 Decent work and economic growth		Reduced harvest time for woodfuels decreasing dangerous activity (+); Loss of connection with forests and social aspects of woodfuel collection (–)		New sector development, employment generation (+)

Table 7.3 (cont.)

SDG	Reduction in use of traditional woodfuels		Increase in processed woodfuels, liquid biofuels and biopower/cogeneration	
	Forests	People	Forests	People
9 Industry, innovation and infrastructure		Transition away from inefficient technologies (+)	New innovations in forest plantation use (+)	Emergence of biofuels sector as new in many countries – leading to diversified economies (+)
10 Reduced inequalities		Closing gap between those reliant on biomass and those with access to modern energy (+)	New opportunities for engagement in forest management (+)	
11 Sustainable cities and communities	Reduced pressure on urban trees and forests in rural areas supporting more sustainable environments (+)	Household adoption of modern fuels (+)		Commitment to renewable energy portfolios reduces household air pollution (+)
12 Responsible consumption and production	Reduces pressure on forests (+)			Increased use of more efficient technologies (+)

Table 7.3 (cont.)

SDG	Reduction in use of traditional woodfuels		Increase in processed woodfuels, liquid biofuels and biopower/cogeneration	
	Forests	People	Forests	People
13 Climate action	Reduced GHG emissions from deforestation/ forest degradation and from improved combustion processes (+)	Mitigation of ambient and household air pollution exposure (+)		
14 Life below water	Reduced land degradation leading to less run-off and water pollution (+)		Increased pressure on water resources to irrigate bioenergy crops (–)	
15 Life on land	Greater biodiversity results from reducing woodfuel pressure on forest (+)	Securing ecosystem services for human well-being (+)	Increased role of biofuels in energy portfolios (+/–)	
16 Peace, justice and strong institutions	Reduced corruption in traditional woodfuel sector leading to decreased deforestation and forest degradation (+)	Reduced rent-seeking behaviour with respect to traditional woodfuels to improve livelihoods (+)	Increased focus on forest plantations as energy source reinforcing property rights (+)	Support for renewable energy targets and links to global climate institutions can enhance economies (+)
17 Partnerships for the goals				

initiatives in sub-Saharan Africa, suggesting that transitions will be slow and likely support the use of multiple energy sources, making the energy stacking hypothesis most plausible. The case studies highlight the different trade-offs to consider when implementing SDG 7 targets and provide insights into the challenge of integrating forests into the transition to cleaner and more affordable energy systems.

Recognising the co-benefits associated with forest-based energy pathways generally supports the realisation of other SDGs. Partnerships with other SDGs that acknowledge the role of forests in energy service provision are particularly essential to improving livelihoods and conditions in forest regions (Gratzer and Keeton 2017). In contrast, if SDG 7 is realised through the promotion of large-scale energy infrastructure projects, including hydropower and land-intensive solar and wind farms, forest ecosystems and forest livelihoods could be at risk, compromising other SDG outcomes.

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