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BURNING BIOMASS FOR ELECTRICITY

ANALYZING RISKS AND
SEARCHING FOR BETTER
ALTERNATIVES IN INDONESIA





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Public Policy Problem

The energy mix planned for Indonesia's upcoming energy transition is still dominated by coal; while the introduction of renewable energy sources is increasing, they are still far too low. The opportunities of optimizing biomass usage (e.g., its decline in coal co-firing) are close to being wasted, prolonging the phasing out of coal-based plants and even leading to increased greenhouse gas emissions. Hence, the specific policy problem is the high level of biomass usage in the energy transition plans for Indonesia. This can also be restated as an opportunity to make the Indonesian energy transition more sustainable and equitable and to formulate policy recommendations in light of an international comparative policy perspective (the United Kingdom, the European Union, and the United States of America) to achieve the most optimal policy design and implementation of the Indonesian energy transition. We understand the policy problem as a negative externality susceptible to economic analysis as well as a public choice issue because of politico-economic interests driving different alternatives.

Executive Summary

This study focuses primarily on the risks related to biomass usage for electricity generation, especially through co-firing and partially for biofuels production, and it provides a consequent policy recommendation for Indonesian energy transition. We made a thorough review of scientific studies from different fields, including chemistry, physics, environmental sciences, economics, and public policy. We examined policy papers on empirical case studies from the US, as well as from specific US states (North Carolina, Virginia, and Massachusetts), and from the European Union (EU), as well as in individual EU states (Finland, Denmark, Germany, the Netherlands). Additionally, we conducted 26 semi-structured interviews with experts from North America, Asia, and Europe on the issue of biomass as an energy source as well as national policies on biomass, renewable energy, and environmental regulations.

Based on the arguments and evidence provided, we do not consider biomass co-firing for electricity as a carbon neutral process; according to scientific knowledge evaluating different types of biomass like crops and switchgrass, the carbon payback of biomass ranges from 0 to 1,000 years. This range makes it difficult to project reliable future modelling about the benefits of biomass – at best, it provides guesstimates. Most importantly, this carbon payback time frame shows that biomass is unable to capture the time urgency of climate change. In other words, to receive benefits from biomass to face current climate change risks, we need to plant millions of trees, wait decades for them to grow enough to capture the desired carbon from the atmosphere, never cut them down, and prevent natural causes (e.g., disease or disaster) from destroying them – this is clearly ambitious. Hence, the evidence provides enough arguments about the environmental aspects, energy performance, and economic risks related to biomass co-firing for electricity. The key findings of our research are as follows:

A. From the scientific perspective, biomass usage is a wicked problem because:

1. There is too much uncertainty and limited knowledge in the efforts to make future estimates or modelling about the possible positive impacts of biomass.
2. There is too little reliable data on biomass in general, and even this data is accompanied by too much assumption in trying to fill the knowledge gaps.
3. The reporting system on biomass usage is very weak, and a considerable inconsistency exists in different reporting systems, which leads to a considerable lack of knowledge about the origin of biomass. This is likely to suggest that valuable wood is used for biomass rather than municipal waste.

B. From the empirical findings, biomass is neither a climate-friendly nor economically sustainable solution because:

1. Biomass co-firing results in more greenhouse gas (GHG) emissions than fossil fuels per unit of energy produced.
2. In general, it is less energy intensive (i.e., lower calorific value) than fossil fuels, so it provides less energy. It contains lower bulk density, higher moisture, and greater water affinity properties of biomass.
3. Combustion efficiencies during biomass co-firing for electricity are lower than for coal, especially because the plants were not designed for biomass co-firing.
4. Co-firing prolongs the time required to phase out the coal plants and are artificially prolonging their life cycle; in the worst case, it even encourages the construction of co-firing power plants.

5. It might decrease national security even more due to high risks related to domestic supply, thus causing greater reliance on external supply and imports.
6. It leads to inefficient and harmful forestry policies based on a mistaken notion about the carbon neutrality of biomass and the omitted or miscalculated effect of time required for the carbon released during wood harvest to be “recaptured” by newly planted and managed forests. It will take decades, if not centuries, to reach the point at which there will be net reductions in GHG emissions compared to burning fossil fuels. Carbon sequestered in plantations will likely never offset carbon released from the original forest.
7. Growth in wood harvest for bioenergy causes a steady increase in atmospheric CO₂ because the initial carbon debt incurred each year exceeds what is repaid.
8. Compared to solar, hydro, or wind energy for electricity, biomass is performing worse in terms of the environment and is less clean. Biomass performs better than coal only in the long run (decades to centuries).
9. Without subsidies in different forms, either for biomass for electricity generation or biofuels production, biomass would not be a feasible economic choice.
10. Subsidizing biomass has a negative effect on the secondary markets of renewable and clean energy sources as solar, wind, or hydro. In particular, it makes these sources more expensive and less competitive at large and small scales alike.
11. Subsidizing biomass might yield other secondary consequences related to land use – more land used for the biomass market rather than for food and agriculture might

increase the price of food while halting the production of food, and it may also increase the price of other woody products.

12. The projected demand for biomass, supported by governmental subsidies, is likely to exceed the supply of residues and waste biomass, which leads to a high risk of processing valuable wood for biomass and additional deforestation.

13. The projected demand for biomass connected with deforestation will likely have negative impacts on the biodiversity of forests.

14. The projected demand for biomass is likely to lead to the creation of biomass markets in many countries, especially the Global South, with poor or non-existing regulation; this will likely yield short-run economic profits over any environmental risk consideration.

15. Firing and co-firing woody biomass now has more negative health impacts than burning coal in many (US) states and is a trend that may continue. Biomass and wood have the fastest-growing share of early deaths in the major energy-consuming sectors. In 2008, early deaths attributed to burning biomass and wood accounted for around 14–17% of average total deaths from stationary sources. By 2017, they increased to 39–47% of total averaged early deaths.

16. Biomass for energy and carbon capture and storage will likely lead to problems with water scarcity. In 2100, the BECCS water needs could represent more than 30% of the total precipitation in several regions, like Europe or Asia (Séférián et al., 2018).

The policy recommendations for how to address these risks and decrease the usage of coal while not incentivizing biomass for co-firing through carbon pricing (carbon tax and cap and trade) and other instruments are listed in the policy recommendations section.

Introduction

Energy transition in Indonesia requires special attention, as the country contains the world's third largest area of rainforest.¹ In 2018, Indonesia produced 61% of electric power from coal; in the same year, Indonesia lost 16% of the tree cover it had back in 2000.² Additionally, Indonesia is in the group of the global highest greenhouse gas (GHG) emitters, with a share of 1.7% of global GHG emissions.³ Through its Nationally Determined Contribution (NDC), Indonesia aims to reduce GHG emissions by 29% (voluntarily) or 41% (with international support) compared to the business-as-usual scenario by 2030. The current NDC, however, is far from what is needed to achieve the Paris Agreement (Langer et al., 2021; IESR, 2022).

Total consumption per capita is 0.8 toe, while electricity consumption per capita is 939 kWh (2020). Total energy consumption increased by 3.4% per year from 2013 to 2019 and declined by around 7% in 2020. Oil is the country's dominant source of energy, providing 30% of the total (2020), but its market share is decreasing (37.5% in 2013). Coal comes in second with 29%, while gas accounts for 15%, biomass for 13%, and geothermal and hydro for 13% (2020). The share of coal is increasing (+14 points since 2013), largely at the expense of oil.⁴ Despite both national and international pressure for more effective energy market administration and liberalization, the energy market is not yet reformed; this has been accompanied by the comprehensive reconstruction of the state-owned utility PLN, which is the main actor and main barrier to the reform and entry of other players. Additionally, a clear inventory of Indonesian fossil fuel subsidies, including government tax expenditures that in might in some ways support fossil fuels, would yield higher

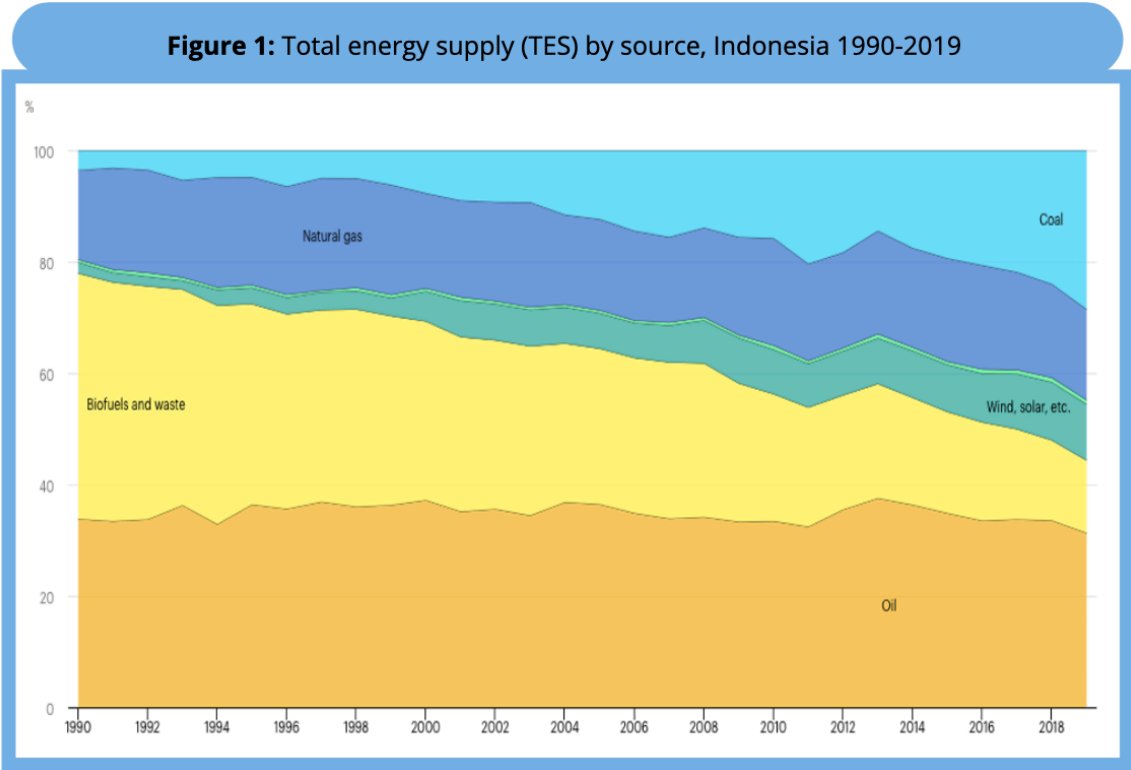
¹ More here: <https://www.theguardian.com/world/2013/may/26/sumatra-borneo-deforestation-tigers-palm-oil>

² More here: http://iesr.or.id/v2/publikasi_file/Brown-to-Green-2019-Executive-Summary-and-Indonesia-Country-Profile.pdf

³ More here: <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-co2-emissions.pdf>

⁴ More here: <https://www.enerdata.net/estore/energy-market/indonesia/>

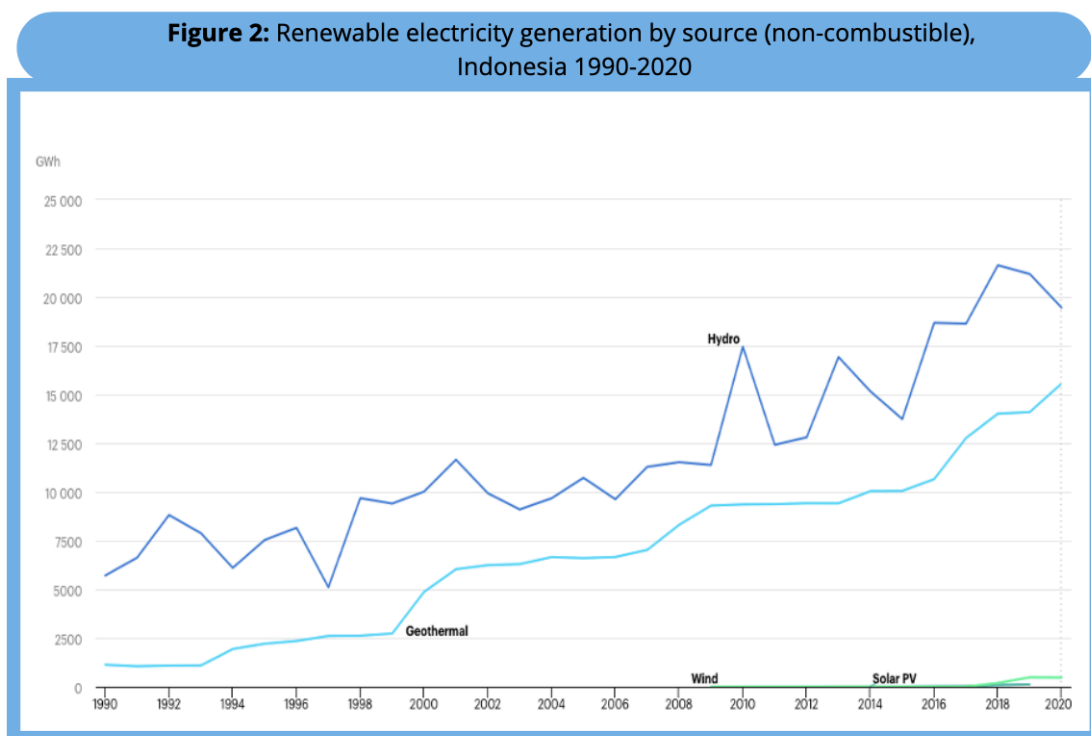
transparency and accountability.⁵ Below, we see the total energy share graph by the International Energy Agency.⁶



In summer 2021, Indonesia published an energy transition plan known as the RUPTL, which aims to add 40.6 GW of electricity between 2021 and 2030. The forecasted plan is that 13.8 GW of this amount will come from coal and 20.9 GW will come from renewable sources. Figure 2 clearly shows that there is an immense potential for non-combustible renewable energy growth in Indonesia. Of course, this will not happen overnight and for free, especially given the investments needed in grid integration for renewable energy entry – but the benefits outweigh these costs. According to an IRENA report, investments in renewable energy can bring annual savings to the energy system by 2030 of 1.7 billion USD

⁵ More here: https://www.oecd.org/fossil-fuels/publication/G20%20peer%20review%20Indonesia_Final-v2.pdf
⁶ More here: <https://www.iea.org/countries/indonesia>

yearly.⁷ In Figure 2, we see the trends regarding non-combustible renewable electricity generation in Indonesia.⁸ It is striking to note the low level of electricity generated by solar and wind power. We attribute this situation to the prices of solar and wind power (indicated also in Figure 11).



At first glance, the RUPTL visions look promising; however, there are several risks, especially with the increase of co-firing biomass with coal, which might lead to the prolonged phasing out of coal plants, and the vague definition of renewable energy sources, which also include biomass and power generated by co-firing with coal (which is now mandatory in Indonesia).⁹ Figure 3¹⁰ shows a concerning trend in electricity generation from biofuels and

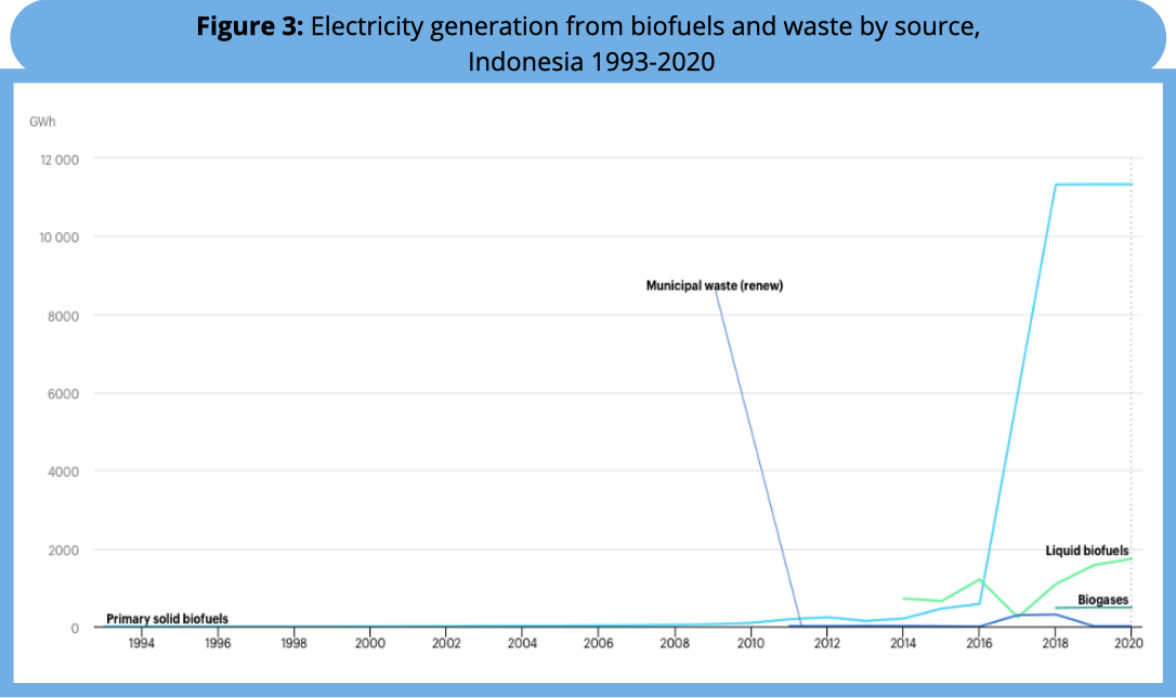
⁷ More here: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Mar/IRENA_REmap_Indonesia_report_2017.pdf?la=en&hash=79237811C02D9722E35F5049ACBA278B126493BB

⁸ More here: <https://www.iea.org/countries/indonesia>

⁹ More here: <https://news.mongabay.com/2021/10/indonesias-green-electricity-plan-undermines-its-climate-vows-activists-say/>

¹⁰ More here: <https://www.iea.org/countries/indonesia>

waste. While we see a decline in waste processing, the consumption of primary solid biomass is skyrocketing. Primary solid biomass includes woody biomass for electricity generation.



We assume that co-firing biomass with coal would lead to increased GHG emissions in total numbers, affecting not only Indonesia but having global effects. Secondly, it will have a negative impact on the effectiveness of Indonesia’s energy transition. The reason is that biomass is likely to be a feasible option only due to subsidies. Evidence from other countries shows that, without subsidies, the costs of biomass supply would be higher compared to other sources of renewable and clean energy. Thirdly, it will have negative public health and other environmental effects connected with land use and the quality of soil and water in Indonesia. According to a recent Harvard study, “taken together, biomass and wood have the fastest-growing share of early deaths in the major energy-consuming sectors” in the US (Buonocore et al., 2021). There are serious concerns that existing co-firing plans will require “nothing less than the creation of a large-scale biomass industry” (Putra, 2021).

Discussion Around Biomass

The key is to understand the risks related to the use of biomass and, secondly, the interests driving policy makers' decision to give biomass such a premium role. In both academic and policy literature, there is evidence pointing to the benefits that biomass can provide, including processing plant- and animal-based waste in rural and urban areas, effective planting and forestation policy, and usage of already degraded land to grow energy crops, which can serve as carbon storage as well (Roni et al., 2017; Kumar et al., 2015). A useful attempt to understand the debate on biomass is **the constructivist discourse analysis** elaborated by Mather-Gratton et al. (2021). Even though this analysis is more focused on European discourse, we believe the results possess external validity as well, based on other literature and on interviews we have conducted.

Figure 4: Biomass Discourse Analysis Table

Storyline element	Storyline 1: Forestry focussed	Storyline 2: Climate focussed	Storyline 3: Critical
Carbon neutrality	Forest biomass is a carbon neutral energy source	Is overly simplistic and instead a detailed case by case basis should be employed	Is an incorrect assumption based on false climate impact accounting
C cycle time scale and climate	Is unimportant as cumulative CO ₂ emissions are reduced in the long term	Regulations must ensure short term benefit to climate	Large-scale biomass always harms the climate
Forests are expanding	This additional wood volume should be utilised. These forests also require further management	Because they are recovering from centuries of over harvesting. This is an opportunity for climate change mitigation via storage	-
Forest management	Good forest management through SFM practices will ensure sustainable biomass	SFM goals and renewable energy don't need to be combined in legislation	SFM goals and other sourcing criteria are insufficient and open to manipulation, representing greenwashing
Which biomass can be used?	All biomass, regulated by markets	That which an LCA determines will provide climate benefit. Not "whole trees", but restricted to wastes and residues	None to be supported by the EU RED. Potentially small-scale local schemes
On progress and the bioeconomy	Forest management is an integral part of the bioeconomy and forests should be fully exploited as capital	Forests should be managed to maximise the ecosystem services they provide	The technocratic assumptions and growth based goals of the bioeconomy concept are dangerous
Ecological impacts	Are manageable through regulation or certification. SFM rules govern good practice, and forests and biodiversity benefit from management	Current and proposed sourcing presents several major risks to biodiversity worldwide, and regulation and certification may be weakly enforced.	The current and future level of biomass utilisation crosses numerous ecological limits even when certified. Therefore biomass should not be defined as renewable
Social impacts	Benefits rural communities through job creation	Climate and environment given priority. Threats and opportunities exist for society	Major threat to societies worldwide
Global impacts	Negligible: sourcing is mostly "local" from EU forests. Imports are well regulated	Europe is setting a global bad example: meeting renewable energy targets with forest biomass here will encourage others to follow	Matches storyline 2, plus major impacts on the 'global south'
Human health	-	Not specifically addressed but could be added in future	Combustion exerts major unavoidable impacts on health
Natural capital	Forest ecosystems are cultivated natural capital	Forest Ecosystems are critical natural capital, but can be monetized in a ecosystem services concept	Rejects natural capital. Forest ecosystems are beyond valuation in monetary terms

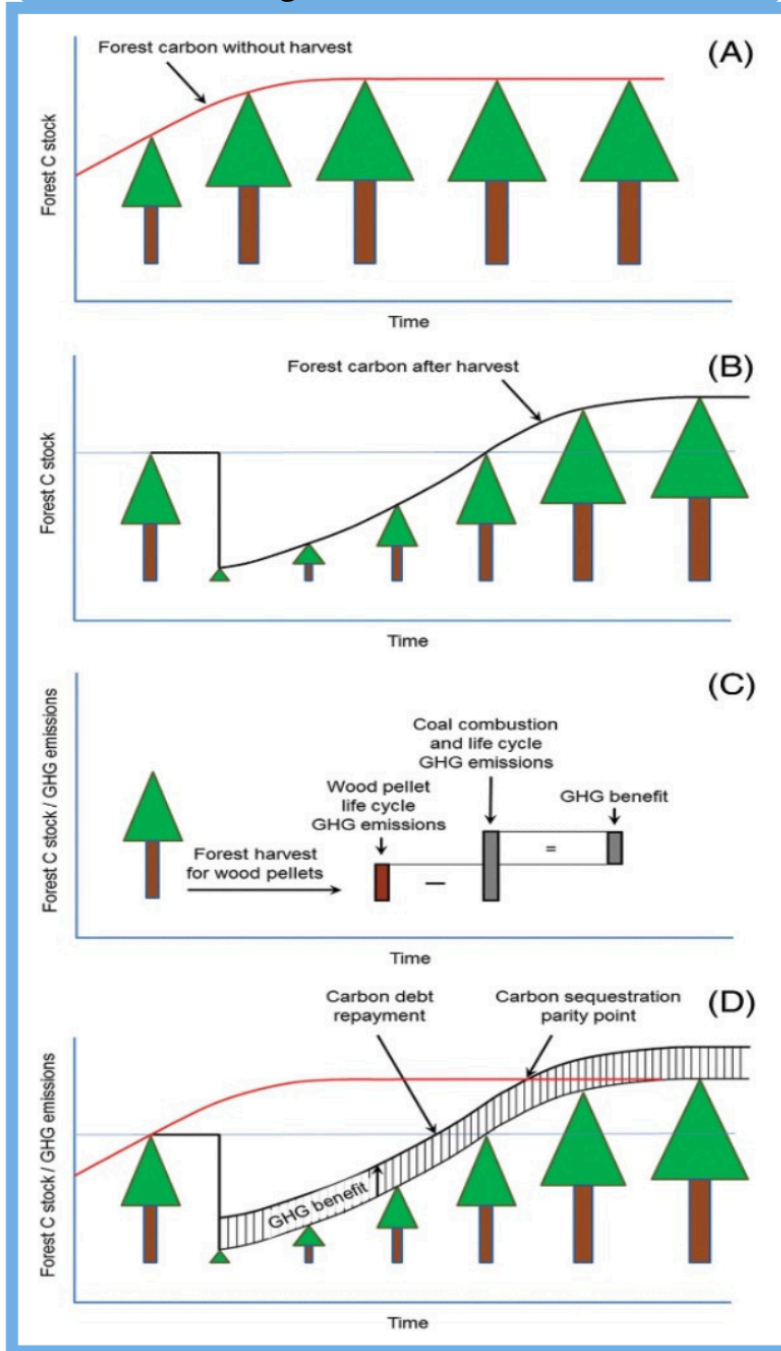
<https://doi.org/10.1371/journal.pone.0246873.t001>

The authors of the study developed three main forest biomass storylines based on the texts they gathered – forestry prioritized (storyline 1), climate focused (storyline 2), and critical (storyline 3). Storyline 1 puts a lot of emphasis on – and mistakenly presents as scientific fact – the assumption of the carbon neutrality and sustainability of biomass. This storyline is closer to bioenergy business perceptions. Storyline 2 provides some space for the benefits of biomass; however, it operates under strong assumptions of a holistic assessment of carbon balance, minimized risks to ecosystems, and strong legislative control and regulation. The last one, storyline 3, rejects any attempt to use biomass as a pillar of the European Union’s renewable energy policy due to ecological limits crossed by forest biomass. These limits include physical impacts on the climate, biodiversity, water, and soil, as well as less tangible influences on the status of forest ecosystems as natural or artificial (Mather-Gratton et al., 2021).

However, most of the research focuses on biomass as an alternative to coal¹¹ rather than as an alternative to, for example, solar, wind, or hydro energy. Moreover, there is an uncertainty in the classification of biomass as a carbon neutral source of renewable energy. The classification of forest biomass as “renewable” is based on the reasoning that, since biomass carbon comes from atmospheric CO₂ and regrowth absorbs CO₂ over time, it can be regarded as being “carbon neutral,” with net emissions over the harvesting/regrowth cycle of zero. **The “carbon neutrality” concept is, however, a gross misrepresentation of the atmosphere’s CO₂ balance** since it ignores the slowness of the photosynthesis process – trees take several decades to reach maturity (Norton et al., 2019; Sterman et al., 2018).

¹¹ Woody biomass contains less energy than coal (biomass pellets 9.6–12.2 GJ/m³; coal 18.4–23.8 GJ/m³; IEABioenergy, [2017](#)), so that CO₂ emissions for the same energy output are higher (110 kg CO₂/GJ for solid biomass, 94.6–96 kg CO₂/GJ for coal in IPCC, [2006](#)). Combined with the energy needs to gather from diffuse sources and intermediate treatment (drying and pelleting), replacing fossil fuels in electricity generation results in significant increases in emissions of CO₂ per kWh. The net effect of switching to biomass is usually to increase emissions and thus increase atmospheric levels of CO₂. This is the reverse effect of the original objectives of the RED to “decrease GHG emissions” (Norton et al., 2019).

Figure 5: Forest stock



“Effect of harvest for bioenergy used to replace coal on forest carbon stock changes and total greenhouse gas (GHG) emissions (stand level, from Ter-Mikaelian et al., 2014b). A. Accumulation of carbon in an unharvested forest stand. B. Carbon in the stand regenerating after harvest. C. Harvested biomass is used to produce wood pellets; life cycle GHG emissions from obtaining and producing wood pellets are lower than life cycle and combustion emissions of coal, resulting in a GHG benefit of using wood pellets to replace coal. D. Carbon sequestration parity is achieved when the sum of carbon in the regenerating stand and the GHG benefits of using wood pellets to replace coal reaches the amount of carbon in the stand if it had remained unharvested; carbon debt repayment is achieved when the sum of carbon in the regenerating stand and GHG benefits of using wood pellets to replace coal reaches the preharvest amount of carbon in the stand.” (Ter-Mikaelian et al., 2015)

In other words, removing forest carbon stocks for pellets and woody biomass (i.e., cutting down trees for pellets) leads to increased emissions in the short run. In the long run, there might be a change of this effect, especially under the assumption of effective and sustainable forestry policies, which are not possible to assess properly at this moment. While forest regrowth can remove carbon dioxide from the atmosphere that was added by cutting down trees, “regrowth takes time, a century or more for native forests, assuming they don’t fall victim to wildfire or disease,” and “regrowth never occurs if the land is developed or converted to pasture or farmland.”¹² That being said, even an ideal forestry management approach does not address the urgency of the climate change risks at this moment, which leads to the fact that biomass does not have the potential to fulfill the Paris Agreement provisions.

In this analysis, we will identify the challenges connected with biomass usage, especially focusing on the effect of subsidies, effect on other renewable energy markets, and effect on land use. As Tilman et al. (2009) state, “the massive projected increases in global energy and food consumption will greatly elevate atmospheric greenhouse-gas levels from fossil fuel combustion, land clearing, and livestock production and will create immense biodiversity loss from habitat destruction and climate change”; in addition to compromising the quality of human life, the issue of “how the environmental impacts and potential benefits associated with meeting the global demand for food and energy can be internalized into our economic systems” will be central in the next decades (p. 271).

¹² More here: <https://www.nytimes.com/2018/05/03/opinion/pruitt-forests-burning-energy.html>

The Environmental Risks and the Hidden Effect of Subsidies

To meet the NDCs set in the Paris Agreement, states are committed to changing their energy mix to decrease GHG emissions while simultaneously assuring reliable and affordable energy (mostly in the form of electricity and heating) for their citizens and economy in general. These decarbonization efforts are increasing considerably; by 2050, a major part of electric power and heat should come from renewable energy sources, while energy based on coal and other carbon intensive sources should be phased out. Countries have different approaches to do this. Often, they set a carbon tax or apply the cap-and-trade system. While governments set the price for each ton of GHG emitted to the emitters through the carbon tax (price), the cap-and-trade system leaves this price setting to markets and the government sets the quantity (not the price). Subsidies to different sources of (mostly renewable) energy are another tool to scale these sources up and use these economies of scale to decrease their overall cost. However, **deciding which type of energy to subsidize is not a straightforward process, and it often tends to ignore environmental and social risks as well as risks related to equity and justice.**

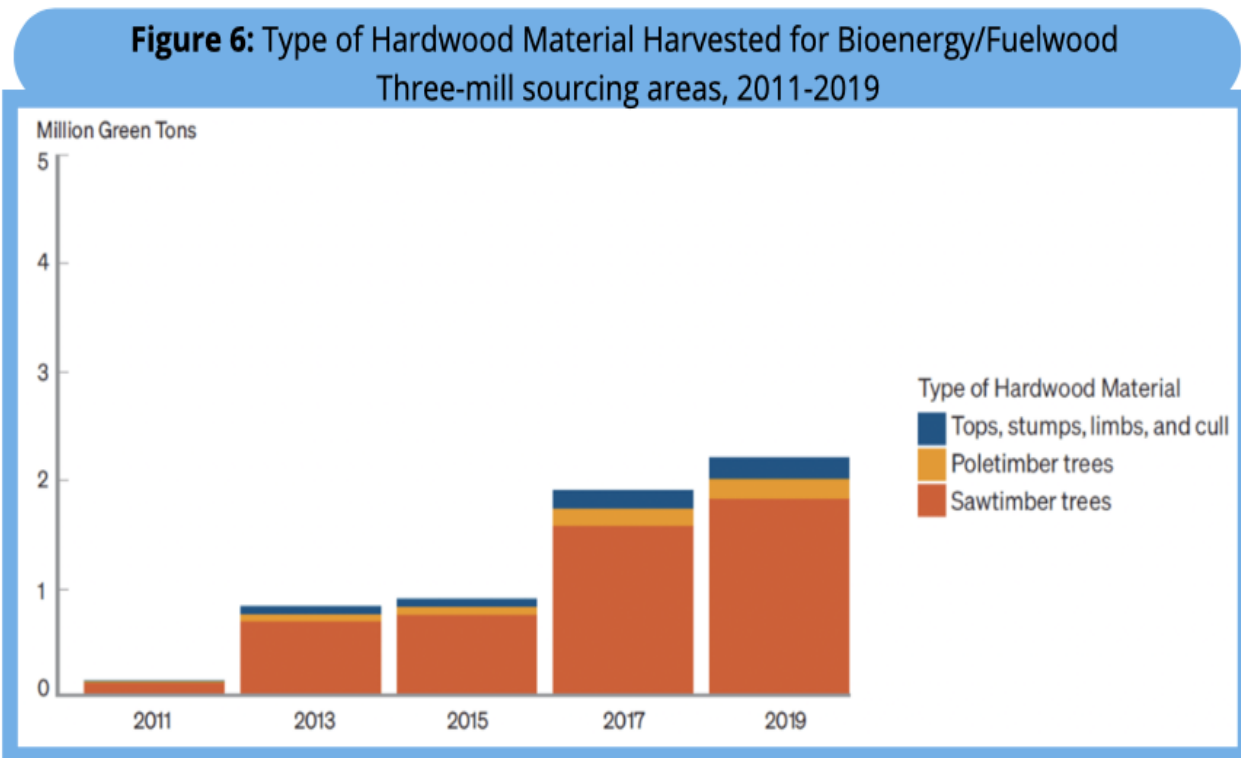
From **Finland**, based on a study of feed-in tariffs and a subsidy to renewable energy, together with the CO₂ emission price in the national electricity and heat market, we know there are several risks related to subsidizing biomass. It “decreases the investment in pure renewable technology (wind power),” while “the use of fossil fuels (coal and gas) increases modestly when the carbon emission price is set at low levels”; regardless of whether biomass co-combustion is subsidized, the “CO₂ intensity of electricity production is nearly equal,” and since “subsidizing wood with coal co-fired electricity production results in lower electricity marginal costs, the use of both coal and wood pellets can increase when the CO₂ emission price level is low” (Lintunen & Kangas, 2010; Moiseyev et al., 2014). This could lead to the so-called “Green Paradox,” where subsidizing biomass causes the increased use of fossil fuels.

In general, **the Green Paradox occurs when well-intentioned policies to decrease carbon lead to results that are not socially optimal and are even counterproductive.** This is because such policies cause fossil fuel producers to fear a decrease in their revenues. Hence, they exploit fossil fuel more quickly, which contributes to increased global warming in the short run. As van der Ploeg and Withagen (2015) distinguish, a weak Green Paradox “occurs if fossil fuel is extracted more quickly and thus global warming accelerates in the short run in anticipation of a gradual tightening of climate policy,” while a strong Green Paradox “occurs if the present value of the costs of global warming in terms of reduced output, which is the converse of green welfare, falls in anticipation of a gradual tightening of climate policy” (p. 286).

Grafton et al. tested whether subsidies on biofuel and its production have increased the rate of fossil fuel exploitation and CO₂ emissions in **the United States**; their results confirm the weak Green Paradox. They calculated that “if the CO₂ emissions reduction from a one-for-one substitution of biofuels for fossil use is less than 26 percent [...] then US biofuels subsidies would not only have increased fossil fuel production, but also resulted in a rise in total US net CO₂ emissions,” and if this “were to be the case then over the past 30 years, US subsidies for first generation biofuels may have resulted in a Strong Green Paradox” (Grafton et al., 2014, p. 554). In other words, US public support for first generation biofuels could, paradoxically, have increased the US’s net CO₂ emissions.¹³ Another piece of evidence on the potential risks of biomass usage for energy/biofuels comes from the states of **North Carolina and Virginia** in the US. Researchers used satellite technology to visualize and quantify the deforestation level near four wood pellet plants in Southampton, Northampton, Ahooskie, and Sampson – all owned by the company Enviva. According to the results, “more than 6.6 million green tons of forest were cut for bioenergy or fuelwood in these areas,” which is “the equivalent of 71,000 acres of forests cut, with Enviva being a

¹³ vary depending on the characteristics of the bioenergy combustion technology, the fossil fuel technology it replaces, and the biophysical and forest management characteristics of the forests from which the biomass is harvested. Forest biomass generally emits more greenhouse gases than fossil fuels per unit of energy produced. More here: <https://www.mass.gov/doc/manometbiomassreportfullhirezpdf/download>

primary user of this wood” (Southern Environmental Law Center, 2020). Moreover, this wood was not waste; it is likely that most of the wood used were tree trunk or boles.



Similar conclusions are drawn from a study on **Massachusetts**: on average, forest biomass emits more GHG than fossil fuels per unit of energy produced. The authors talk about GHG excess as carbon debt. They assume that regrowth of the harvested forest will remove carbon from the atmosphere after some decades. In other words, this is carbon debt, and after the point where the debt is repaid, biomass begins to provide results in the form of carbon dividends – see the figure below. However, like other authors, they express serious doubts about the full recovery of the biomass carbon debt due to strong assumptions about forest management quality and the occurrence of natural disasters (Manomet Center for Conservation Sciences, 2010). Figure 7 visualizes hypothetical harvesting in southeast US forests for bioenergy (Birdsey et al., 2018).

Figure 7: Hypothetical effect of harvesting a southeast US forest for bioenergy

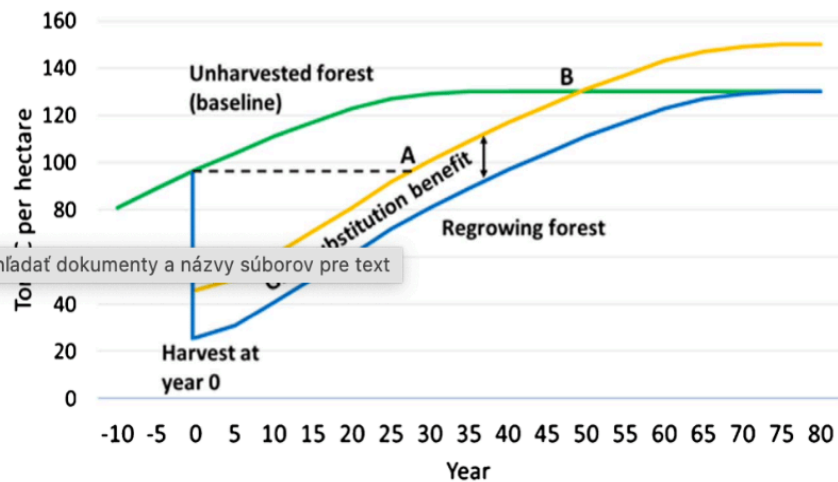


Figure 3. Hypothetical effect of harvesting a southeast US forest for bioenergy, replacing coal used to generate electricity. ‘GHG substitution benefit’ represents the reduction in life cycle GHG emissions from using wood instead of coal, not counting the effect on forest CO₂ net emissions. The ‘carbon debt’ from harvesting at year 0 is ‘repaid’ when the regrowing forest plus the GHG benefit equals the carbon stock in the forest at time of harvest (point A). The net benefit of harvesting, regrowth, and GHG substitution equals the baseline at point B, after which decreases in atmospheric GHGs occur. Adapted from Ter-Mikaelian *et al* (2015). Copyright © 2015 Society of American Foresters.

The study concludes that **extensive logging for wood pellet plants results in increased levels of deforestation, carbon loss, GHG emissions, and decreased forest carbon stock.** Instead of meeting climate goals, subsidizing large-scale firing of biomass actually leads to the opposite – worsened climate performance. The pellets business is growing in the US because of demand from the EU and the UK, encouraged by substantial subsidies from national governments due to the classification of biomass as a carbon neutral source. Without these subsidies, biomass would not be a rational economic choice.

A similar conclusion is derived from a study by Moiseyev et al., focusing on the large-scale power and heat sector in **Denmark, Germany, the Netherlands, and the United Kingdom.** It examines the potential demand for wood fuel by plants firing coal and wood for power and heat. The authors also analyze the question of how this demand depends upon different kinds of subsidies and different developments of the CO₂ prices. Based on their conclusions, even “relatively modest subsidy or bonus of 30 EUR/MWh for electricity generation (3

eurocents/kWh) used in just a few EU member countries leads to a substantial increase in the use of industrial wood use for energy, even under a modest carbon price” (Moiseyev et al., 2014, p. 166). These subsidies can “boost the demand for wood for electricity and heat more than increasing carbon emission prices,” but “they are not cost-efficient from the point of view of reduction of the carbon emissions in the whole energy sector” (Moiseyev et al., 2014, p. 166). They further conclude that subsidies for coal with wood co-firing improve coal power competitiveness, which basically contravenes the global emission goals, not excluding Indonesia. This proves our concerns regarding the prolonged decommissioning of coal operated power plants. Such subsidies may increase the use of wood for energy substantially in the short term. However, **when the subsidies are lifted, the use of wood for coal co-firing may cease to be an economical alternative.** The same conclusion was made by Walker et al. (2015) in their analysis of **the United Kingdom’s** biomass subsidies, especially in the electricity generation sector.

Biomass as a Wicked Problem

The comprehensive study “Use of Woody Biomass for Energy” in the **European Union** by the Joint Research Center (2021) provides very useful insights. While the study has rather humble direct policy recommendations, as the authors’ goal was to scientifically analyze the use of biomass in the context of climate change mitigation as envisioned in the Renewable Energy Directive of the EU (REDII), there are several important takeaways from this study.

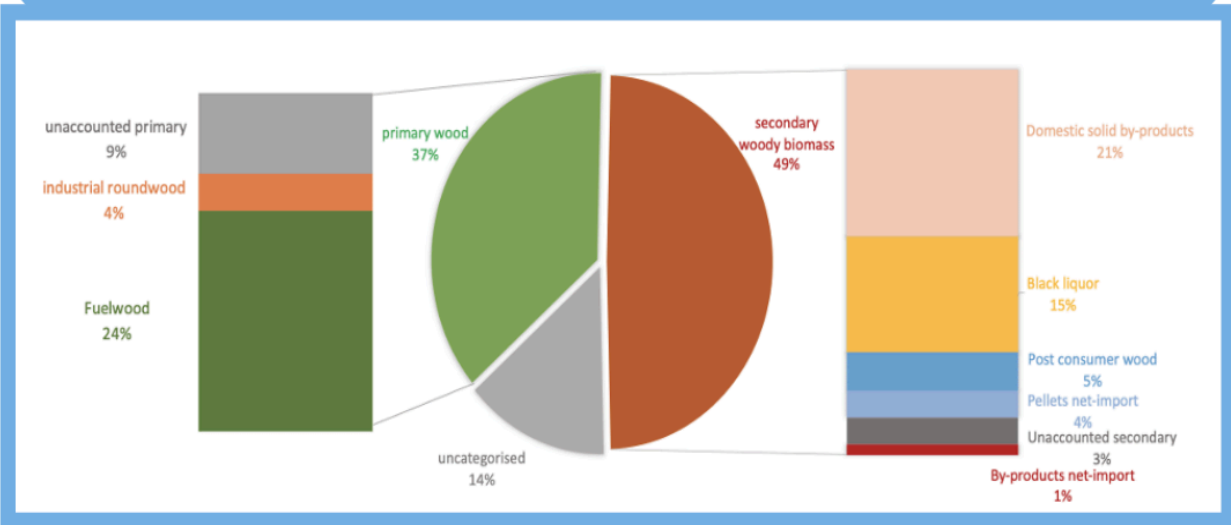
First, the authors label the governance of bioenergy sustainability as a “wicked problem” due to the complexity, conflicting knowledge claims, and uncertainty involved. In this context, a **wicked problem means that the knowledge and evidence about biomass cannot be interpreted in an easy and straightforward way from a scientific point of view, not even with additional research.** The authors say that the question of whether forest bioenergy is sustainable is ill-posed and, basically, a wicked problem. Creutzig et al. (2015, p. 952) note that the causes of the uncertainty include **incomplete knowledge of global economic**

dynamics (trade patterns, land-use productivity, diets, use of byproducts, fuel prices, elasticities); the selection of specific policies modeled; and the treatment of emissions over time. Thus, the question is: Why lose so much time focusing on a wicked problem when we can better redirect our focus to less uncertain technologies in clean energy, such as solar, hydro, and wind?

Second, the study asks a different question: How can we “ensure that pathways for the provision of woody biomass, following increased demand for wood, are not detrimental to climate and to biodiversity?” They frame the answers into management pathways that minimize trade-offs between climate mitigation and biodiversity conservation, assessing three categories of intervention and their potential impacts: removal of logging residues, afforestation, and conversion of natural forests to plantations. In their words, the “Win-win management practices that benefit climate change mitigation and have either a neutral or positive effect on biodiversity include removal of slash (fine, woody debris) below thresholds defined according to local conditions, and afforestation of former arable land with mixed forest or naturally regenerating forests.”

Third, the authors point to the problem of availability of reliable data – they use the Joint Wood Energy Enquiry (JWEE) and the National Renewable Energy Action Plan (NREAP). The most detailed source at the European level to describe the primary supply of wood and its primary transformation is the Joint Forest Sector Questionnaire (JFSQ). Across the EU, there is an inconsistency in national reporting statistics – they “are found in numerous reporting schemes with different scope, coverage, aggregation levels, completeness, and reporting units” (European Commission Joint Research Centre, 2021), which leads to gaps in proper analysis regarding which type of biomass is being used for bioenergy. Based on the data available, Joint Research Centre researchers estimated the composition of woody biomass mix, shown in Figure 8.

Figure 8: Detailed composition of the woody biomass input mix used for bioenergy in the EU

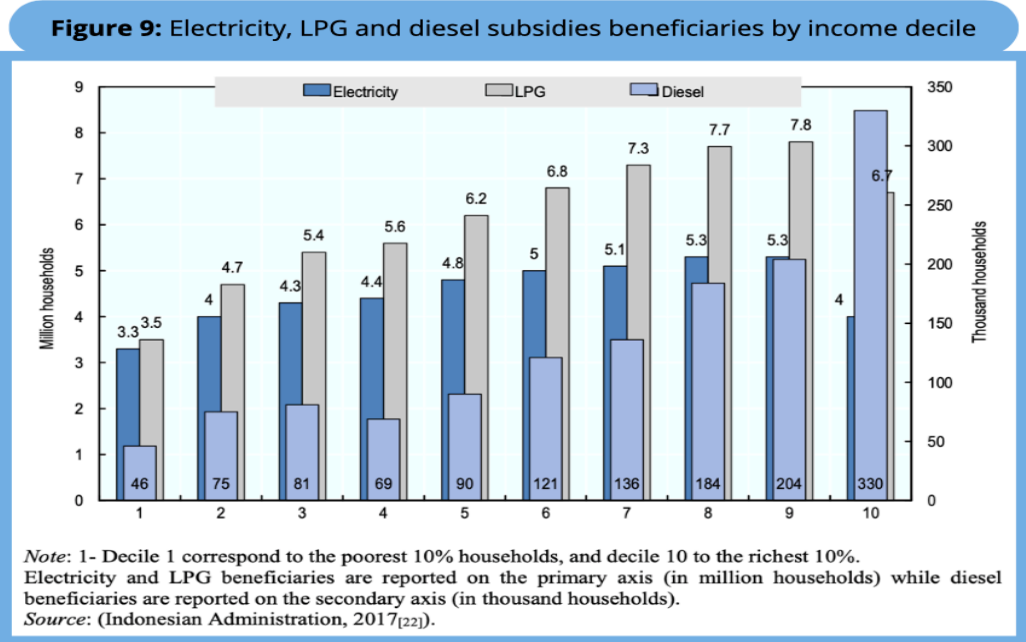


This study uncovers several perils and problems associated with biomass at the EU level. From the policy perspective, it is possible to read this complex study as a warning for policy makers intending to increase the share of biomass in the overall energy mix of any country. Furthermore, it also serves as a risk evaluation of subsidies provided to biomass, which is likely inefficient and does not support energy or a climate-friendly, well-performing alternative.

Finally, there is also **the problem of the statutory and economic incidence of subsidies** (direct or indirect). Policy makers and legislators often aim to help broader segments of the population that are relatively more affected by inequality and/or low income, using subsidies that aim to increase demand and supply. Hence, they design policies and laws with the goal of helping such segments of the population – this is the so-called statutory incidence of the subsidy, when the law or policy says who should be positively affected. However, **it often has an opposite effect; instead of statutory incidence, the economic incidence prevails.** The economic incidence rules for who benefits from the subsidy, regardless of the intent of the laws or policies.

In Indonesia, fossil fuel and electricity subsidies have been regarded as a form of social welfare policy. These policies have been intended to support the poor by lowering the costs of transport and direct energy use, but these benefits have not been achieved efficiently. Large spending on energy subsidies – a fifth of total government expenditure in 2012, about four times the amount spent on social assistance – has had low effectiveness in reducing income inequality and poverty, especially compared with social assistance programs. This can largely be explained by the poor targeting of these policies: low domestic prices for fuels and electricity have been available to all. Overall, **the growing middle- and high-income segments of the population in Indonesia have captured a larger share of energy subsidies** (G20 Peer Review, 2019).

There are more beneficiaries of diesel, electricity, and LPG subsidies in the highest income deciles of the population. Fuel subsidies have been mostly enjoyed by rich individuals who own a private vehicle. Most poor households directly consume no diesel and gasoline at all. Industrial users have also benefited from energy subsidies. In 2013, 24% of the total electricity subsidy went to 10,931 large-scale industrial customers, while 39.5 million small household customers – using 450 VA and 900 VA power connections – received only 40% of the total electricity subsidies (G20 Peer Review, 2019).



This is important because biomass utilization outside the electricity sector in Indonesia is in the form of biodiesel. In 2019, about 7.9 billion liters (compared to 3.7 liters in 2016) were produced in Indonesia, making it the top producer of biodiesel in the world.¹⁴ Biofuel production and domestic consumption are encouraged through the “biofuel mandatory program.”

Land Use and Biomass

The role of land is constantly growing in the context of limiting global warming and limiting CO₂ emissions, and it is directly connected with biomass energy production. As mentioned above, there are knowledge gaps at the EU level about the origin and types of biomasses that are being used for bioenergy, which leads to a significant level of uncertainty about the “renewability” aspect of biomass and its carbon neutrality. This also has a direct connection on the study of increased biomass demand effect on land use, land-use change, and forestry (LULUCF). The combination of the questionable carbon neutrality of forest-based biomass energy and risks related to LULUCF means that the likely socially beneficial focus of the policies should be on increasing carbon sinks (Favero et al., 2020). According to Creutzig et al. (2015, p. 928), “Direct land-use change (LUC) occurs when bioenergy crops displace other crops, pastures or forests, while ILUC results from bioenergy deployment triggering the conversion to cropland or pasture of lands, somewhere on the globe, to replace a fraction of the displaced crops.” Indirect land-use change is difficult to ascertain because the magnitude of these effects must be modeled, raising important questions about model validity and uncertainty, as well as about the policy implications.

Not only does land clearance for agricultural processes require a significant amount of energy, but it also contributes to increased GHG emissions. **In fact, the LULUCF sector is the greatest contributor of GHG emissions in Indonesia – 695 MtCO₂e, around 48% of**

¹⁴ More here: <https://www.statista.com/statistics/271472/biodiesel-production-in-selected-countries/>

the country's total emissions in 2015 (Prananta & Kubiszewski, 2021). This is an important fact also in the context of efforts to decrease global warming through increased afforestation, eliminated deforestation, and biomass energy with carbon capture and storage (BECCS) – all these efforts are connected to land use. There are strong indications that meeting the 1.5 °C target could result in net losses of carbon from the land. Under some assumptions (e.g., choice of biomass, existing above ground biomass, fossil fuel emissions offset in the energy system), the carbon removed from the atmosphere by BECCS might likely be outweighed by carbon emitted by the land-use change. BECCS proves to be inefficient¹⁵ in regions where bioenergy crops replace ecosystems with high carbon content, including Indonesia, and such actions are likely to yield higher levels of carbon in the atmosphere. **Therefore, forest conservation and afforestation are likely to be more effective policies for decreasing carbon emissions to meet the 1.5 °C climate target; they also bring a number of positive externalities, including biodiversity, income generation, flood control, and improvements to soil, air, and water quality** (Heck et al., 2018; Harper et al., 2018).

The biomass energy and land-use discussion inevitably tackle the issue of forest management and forest-based biomass. From the perspective of microeconomic theory, the key question is: What would be the effect of increased demand on (woody) biomass on land-use supply (including forests)? The answer has a lot to do with perceptions and very strong assumptions about what effective forest management means and what impact it has on biodiversity.¹⁶ Higher demand for woody biomass may incentivize investments in afforestation and forest management; however, at the same time, they may lead to premature harvesting and cutting down trees that have not yet reached their maximum carbon stock potential. Also, this may lead to a competition between the land being used for food (agricultural) production and being used for bioenergy products. In such a scenario, it may become more profitable to plant trees and then cut them down, rather than using the land

¹⁵ If BECCS involves replacing high-carbon content ecosystems with crops, then forest-based mitigation could be more efficient for atmospheric CO₂ removal than BECCS.

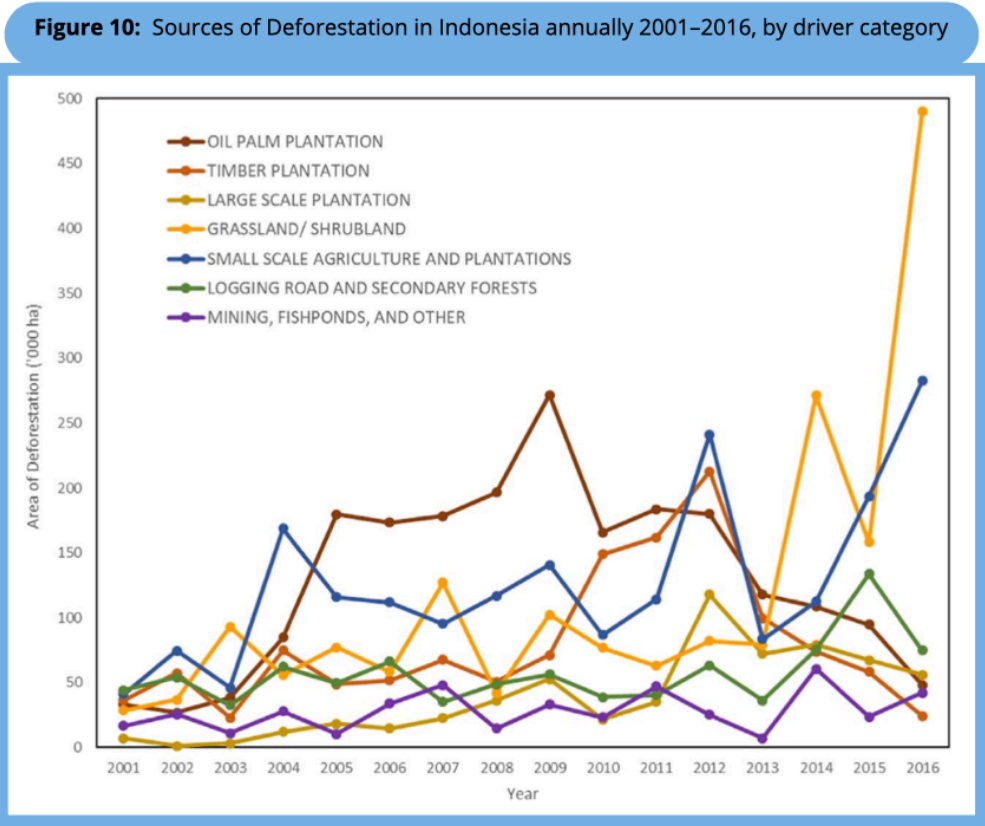
¹⁶ An efficient carbon management approach incentivizes both sequestration and avoidance of emissions, while an inefficient approach only uses a carbon tax to incentivize the avoidance of emissions from woody biomass production.

to growing food, which may lead to increased food prices and thus increased food insecurity for low-income communities (according to the UN, 2.37 billion people did not have adequate access to food in 2020, which is every third person in the world).¹⁷ Hence, in case there is limited “sustainable” and “efficient” forest management, the bioenergy demand will increase carbon emissions and lead to deforestation. In any case, **the role of management on forest carbon stocks plays a key assumption**. An interesting idea is that **policy responses should not only penalize and incentivize avoidance of biomass emissions (carbon tax) but also incentivize carbon stock and afforestation (carbon rental)**. As Favero et al. (2020) suggest, “a policy that taxes forest-based bioenergy without recognizing that forests also sequester carbon through growth is inefficient and will lead to too little carbon in forests and too much carbon in the atmosphere.”

Now, what is the deforestation reality in Indonesia? The most important and biggest single driver of deforestation is palm oil plantations, with a 23% share of the overall deforestation in Indonesia, followed by timber and other large-scale plantations, which together result in 21% of national deforestation (14% and 7%, respectively) – see Figure 10 (Austin et al., 2019). One study estimating the impact of large-scale (industrial) and smallholder oil palm plantations on natural old-growth (“primary”) forests from 2001 to 2019 concludes that the area mapped under oil palm doubled over that period, reaching 16.24 Mha in 2019 (64% industrial, 36% smallholder), more than the official estimates of 14.72 Mha. The decline of forest area is 11% (9.79 Mha), including 32% (3.09 Mha) ultimately converted into oil palm and 29% (2.85 Mha) cleared and converted in the same year. Deforestation can be attributed to industrial plantations rather than to smallholder plantations (2.13 Mha vs 0.72 Mha). Another important fact is the correlation between forest loss and palm oil prices. A price decline of 1% was associated with a 1.08% decrease in new industrial plantations and with a 0.68% decrease of forest loss. Deforestation fell below pre-2004 levels in 2017–2019, providing an opportunity to focus on sustainable management. As the price of palm

¹⁷ More here: <https://www.un.org/en/global-issues/food>

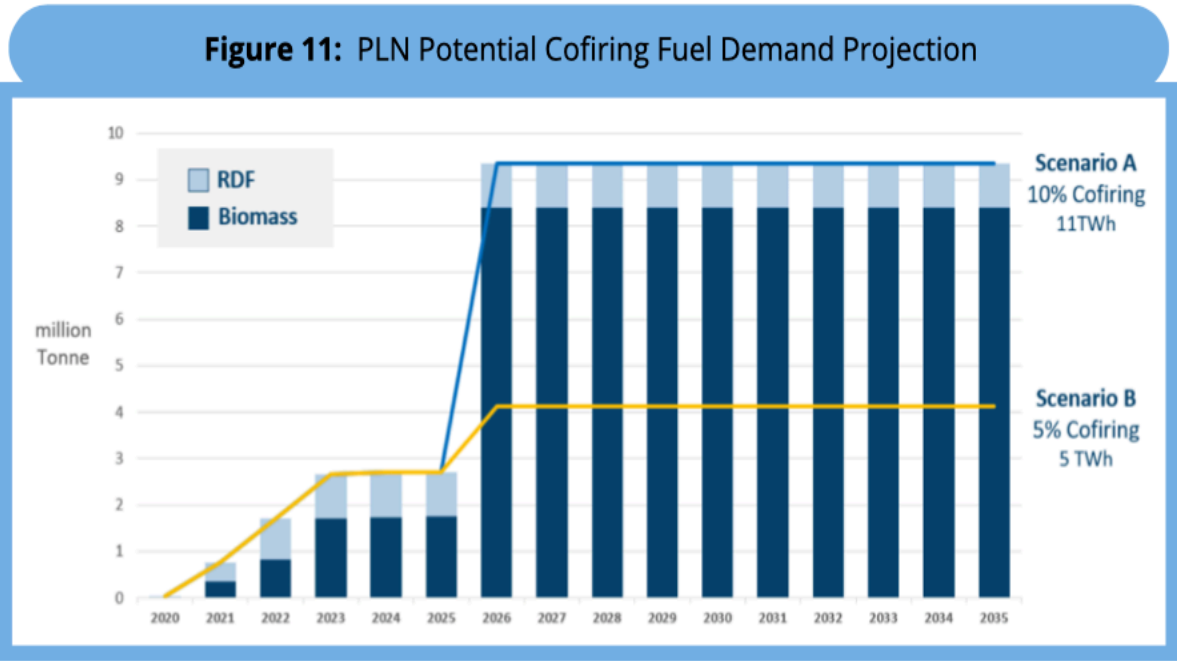
oil has doubled since the start of the COVID-19 pandemic, effective regulation is key to minimizing future forest conversion (Gaveau et al., 2022).



The area ('000 ha) of deforestation in Indonesia annually 2001–2016, by driver category: To improve legibility, we combine mining, fishponds, and other driver categories; secondary forest and logging road categories; and small-scale agriculture and small-scale plantation categories (Austin et al., 2019).

Today, we see a rising price of palm oil (and its scarcity on the world market due to supply chain problems), which, according to the correlation logic above, is likely to lead to deforestation. Furthermore, connecting the context to the Indonesian energy market and demand, PLN’s co-firing roadmap proposes to migrate its 114 existing coal-fired power plants to co-firing by 2024. The plan includes “feedstock increases” between 2021 and 2023. **The co-firing plan advanced by the Ministry of Energy and Mineral Resources (MEMR) will require nothing less than the creation of a large-scale biomass industry to provide stable co-firing fuel supplies anywhere between four to nine million tons annually,**

as seen in Figure 11 (Putra, 2021). In case of weak regulations and accountability mechanisms, this might lead to additional deforestation as well.



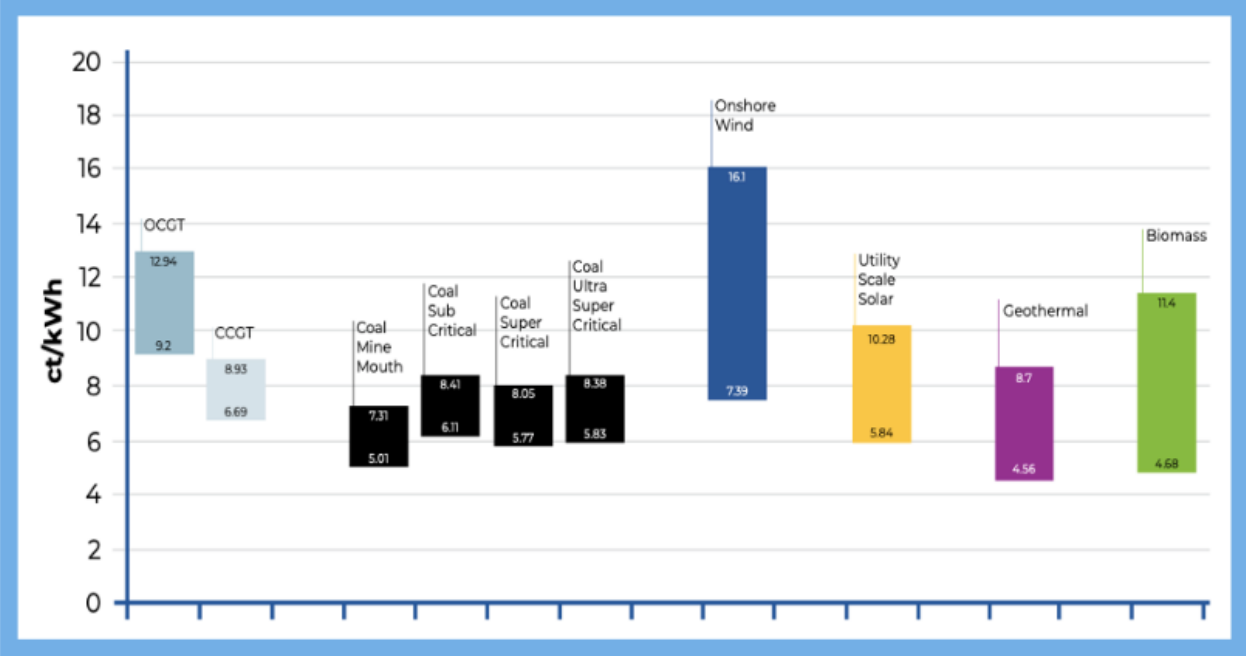
Instead of a Conclusion

Based on the evidence provided, the method of co-firing biomass together with coal – as well as the use of biomass for biofuel production – is not an environmentally friendly, economically reasonable, or socially responsible and equitable solution for Indonesian energy transition plans. Before we outline specific policy recommendations below, it is worth discussing the rationale of giving biomass such prominence in the current and future energy mix of Indonesia. Many links lead to the political-economic situation in the country, especially the role of the PLN, which is a state-owned utility. Many international partners, including the Asian Development Bank, the World Bank, IRENA, and others, together with national experts, are calling for the reform of the Indonesian energy market, its liberalization, and, especially, the reform of the PLN itself. The main reason is that there are serious doubts about the efficiency and transparency of the work of the PLN and the backstage managers, who allegedly prefer the status quo that benefits coal as well as biomass (and palm oil) business. Hence, **the *sine qua non* of any policy recommendation on renewable energy is the political will to implement them.**

The elephant in the room is the economic (oligarchic) elites managing the PLN and the Indonesian energy sector. How can this actor be dealt with? There is a big tradeoff between the urgency of renewable energy introductions and climate change on the one side and democratic good governance and markets on the other side. If there is a chance to reform the PLN following the example of many other countries that have gone a similar way, that is undoubtedly the right direction. If this option is not on the table or is unrealistic in the long and short terms, it might be worth developing the idea of promoting the economic and not only the environmental benefits of renewable energy and the possible revenue coming from public and private investments in solar, wind, geothermal, and hydro technologies in the short and long runs, in a limited form of cooperation with these elites. Such a solution is far from perfect; however, it might be a feasible way to address the urgency of the negative effects of climate change in Indonesia.

A good indicator that might help in thinking about the costs and benefits of different types of energy in Indonesia is the levelized cost of electricity (LCOE) concept – see Figure 12 (IESR, 2019). Due to the lack of reliable data and time constraints, we were not able to provide more accurate calculations using the price elasticities and cross-price elasticities that would help us better identify the role of subsidies in the biomass market, as well as their effect on other renewable energy markets. Nonetheless, the figure below shows that there are other economically well performing alternatives to biomass. We believe that investing in other sources of energy will likely yield even higher profits than in biomass while assuring better environmental performance. We base this argument on two assumptions – the availability of large amounts of international finance in different forms (loans, equity, grants) and the redirection of the current system of subsidies in Indonesia away from biomass. The global trend will play in favor of decreased LCOE of non-combustible renewable energy such as solar, wind, and hydro, bringing technological know-how and more secure and sustainable revenue.

Figure 12: Levelized cost of renewables and fossil power plant in Indonesia in 2019



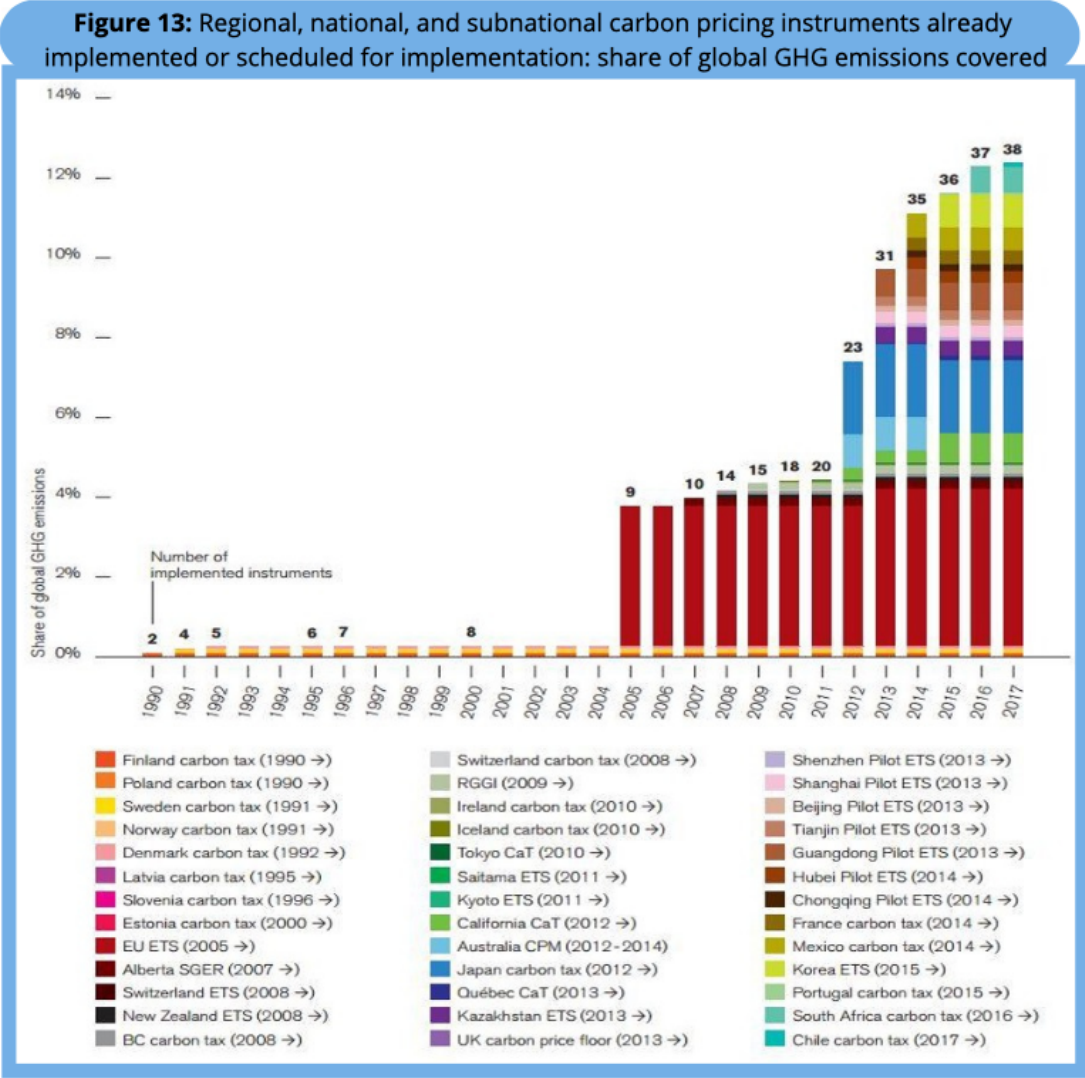
Policy Recommendations

When thinking about policy recommendations on biomass and renewable energy in general, urgency and the time aspect of climate change, biomass carbon neutrality, and benefits from clean non-combustible renewable energy are concepts that need to be addressed correctly, on a scientific basis. Millions of dollars are locked in power purchase agreements that support the status quo and even contribute to increased GHG emissions, deforestation, worsened public health, and inefficient public spending accompanied by lack of transparency. More research is needed regarding cost-benefit analysis for public spending, factoring in negative externalities. That would help us better assess the impact of billions of subsidies to (co-firing) biomass business – compared not only to coal but also to non-combustible clean sources of renewable energy. Norton et al. (2022) call for policy makers to have “a more transparent and objective accounting and reporting system to allow them to prioritize their renewable energy subsidies according to their actual effectiveness in climate change mitigation.”

When talking about reductions to GHG emissions, there are two general approaches: market-based solutions and regulatory solutions. Market-based solutions involve carbon taxes, subsidies, and tradable permits – so-called cap and trade. Regulatory solutions involve non-tradable permits, technology and emissions standards, product bans, and government investment. In general, market-based approaches have a higher level of flexibility and ingenuity in the private sector, which leads to higher efficiency. That being said, both solutions can work in a complementary way.

The difference between the carbon tax and cap and trade has to do with the carbon price that governments set for each ton of GHG emitted for the emitters. Tax-based regulatory systems provide incentives for polluters to find cost-effective solutions to control emissions. Firms will either pay the tax or, if it is cheaper, they will reduce emissions to avoid the tax. In the case of emission taxes, the cost of compliance is known, but emission levels may be uncertain. The cap-and-trade system leaves this price setting to markets, and the government

sets the quantity (not the price). Polluters that can reduce their emissions more cost-effectively have an incentive to abate more to avoid purchasing allowances or to sell their excess emission allowances to polluters facing higher costs of compliance. Under this type of market-based approach, emissions are set by the cap, but the overall compliance costs may be uncertain.¹⁸ Subsidies are another tool for different sources of (mostly renewable) energy to scale them up and use these economies of scale to decrease their overall cost. All of these instruments can also work in a complementary, hybrid version – see Figure 13.¹⁹



¹⁸ More here: <https://www.epa.gov/environmental-economics/economics-climate-change>

¹⁹ More here: https://documents1.worldbank.org/curated/pt/636161467995665933/122290272_2015113481001120/additional/99533-REVISED-PUB-P153405-Box393205B.pdf

An interesting finding is that both the carbon tax and cap and trade yield a decrease of GHG emissions; they also introduce more clean innovation. However, the cap and trade system results in better performance in reducing GHG emissions and also in more clean technology innovations compared to carbon tax only (Chen et al., 2020).

However, the cap-and-trade system tends to support the “second cheapest” alternative, which is risky. As an example: cap and trade might reduce coal usage but lead to switching to the next cheapest version – biomass, perhaps. Based on the text above, this is not a feasible solution. This is a good example of how the cap-and-trade system and the carbon tax or a redirection of subsidies from biomass can work together to reach the effect of reducing coal usage while simultaneously not incentivizing biomass.

There is a rich literature speaking about the pros and cons of each approach; however, the overwhelming majority agrees that success depends on the specific cases, with some transferrable lessons learned, especially from the cap-and-trade system. Most importantly, there is almost absolute consensus that the success of any climate policy depends on its design and implementation.

Recommendations on cap-and-trade policy design in Indonesia:

1. No need for prior government approval of trades. This will lead to lower transaction costs and higher efficiency.
2. The cap needs to be significantly below the business-as-usual emissions level to bring a positive change.
3. Often, there is an issue with price volatility connected to the allocation of allowances under cap and trade. To minimize the risks, the “rules of play” need to be discussed and known in advance, before the real operation of the system, so that companies have time to adjust.

4. Accurate monitoring of emissions with significant penalties must be in place to assure the compliance of pollution emitters (Shapiro, 2022).
5. Regarding the element of banking, provisions allowing companies to save permits for later use have proven to be very important. According to Bosetti et al. (2008), banking increases economic efficiency as well as climate policy effectiveness in the short term: “Indeed, banking increases the amount of emissions abated in the first decades of this century, thus reducing the risk of irreversible environmental impacts of climate change.”
6. Lower costs providing more stable prices that facilitate investment planning can be achieved by price collars. Stavins and Schmalensee (2019) explain that “A changing economy can reduce emissions below a cap, rendering it non-binding, or a growing economy can increase emissions and drive allowance prices to excessive levels”; “combining a price floor at which the program administrator will buy allowances with an allowance reserve from which it will sell at a price ceiling” can reduce volatility, though the “resulting hybrid system will have less certain emissions reductions,” and “economy-wide systems are feasible, although sectoral programs have been more commonly employed.”

Other recommendations on carbon pricing in Indonesia

There is a considerable gap between the World Bank recommendation on carbon price, which is 50–100 USD/tCO₂, if converted into a range of 712,000–1,423,000/tCO₂ in 2030, and the current tax rate in Indonesia, which is Rp. 30/kilogram of carbon dioxide equivalent, resp. Rp. 30,000/tCO₂, resp. 1.43 EUR/tCO₂ in 2021.²⁰ Effective carbon rates are highest in the road sector, which accounts for 20.5% of the country’s total CO₂ emissions from energy use. Emissions are unpriced in industry, electricity, buildings, off-road transport, and agriculture and fisheries. Together, these sectors account for 79.5% of CO₂ emissions from energy use in Indonesia (OECD, 2021).

²⁰ More here: https://www.ircorner.com/carbon-pricing-and-its-potential-application-in-indonesia/#_ftn6

- The price set on pollutants must cover a wide range of greenhouse gases – the wider the range of gases covered, the bigger the reduction of emissions. Additionally, it leads to an equalization of marginal incentives for abatement across the economy with the risk of switching to the “second cheapest” option.
- Also, the higher the price of carbon (the higher the tax), the bigger the carbon abatement that occurs, often accompanied by costly economic consequences for companies.
- Creating a formula for the price that factors in the time element would provide a more desirable outcome in emissions reduction, as well as provide accurate information and certain security for emitters (Morris, 2016).
- Revenue collected by this tax would be very useful if invested back into local communities affected by negative environmental externalities so that the energy transition is more just and equitable, as well as into the development of national capacities in clean technologies.

Any policy in Indonesia dealing directly with biomass, necessarily at the price of increased costs, must assure the following:

- Precise definitions on what constitutes waste biomass, avoiding any attempts to cover up the cutting valuable trees as waste biomass
- Strong monitoring mechanisms about the origin of biomass to make sure it comes solely from waste and not from valuable wood
- A strong reporting system to keep sufficient, up-to-date data for further policy analysis and implications

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