Linking the Quest for Renewable Power to Ecosystem Healing in Southeast Asia[1]

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Abstract

Biomass power potential is usually estimated based on agricultural and forestry residues, which constrains it as mid-merit power due to supply inconsistency. This paper provides a logic model in words and quantity-type numbers, setting out the elements that are happening, for estimating biomass power potential based on developing tree plantations on deforested and degraded land in Southeast Asia. This opens the potential of biomass for baseload power. Doing this successfully requires understanding and embodying the principle of symbiosis. A power supply that develops ecosystem understanding and healing at the same time will lead us closer to sustainability

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1. Introduction

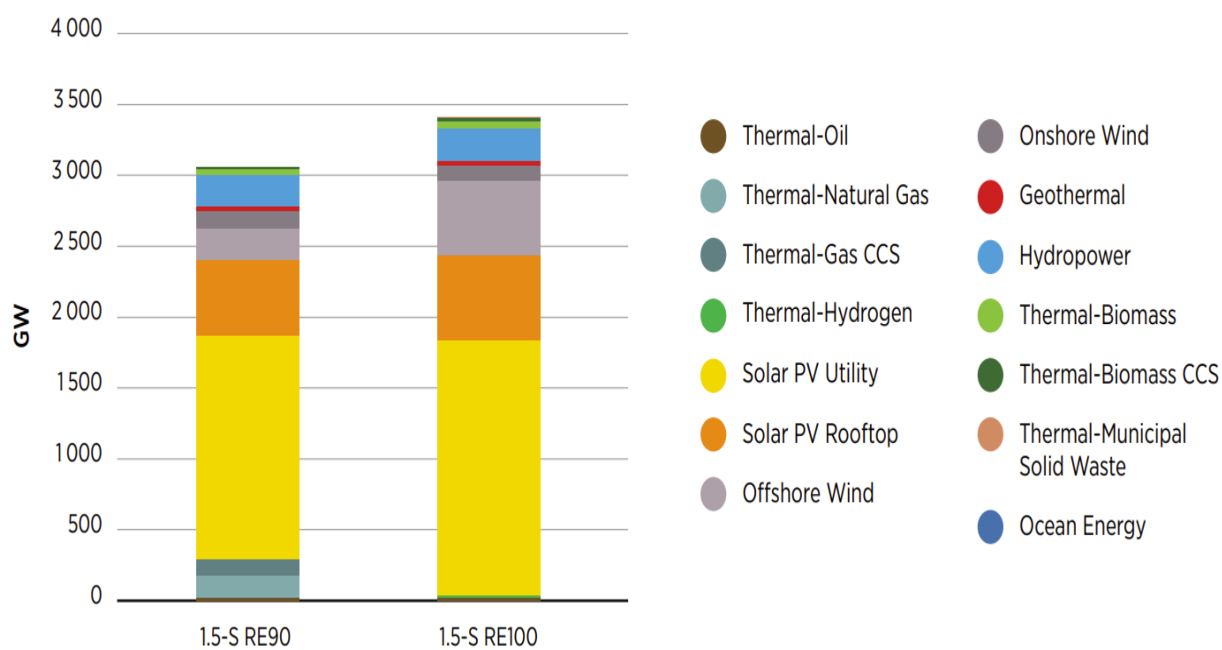
The renewable energy share in Southeast Asia's energy mix is expected to increase, driven by significant technological cost reductions, combined with governments' commitments to promote cleaner energy systems. The four key renewable energy sources for Southeast Asia are hydropower, solar, wind and bioenergy. More than 40% of power generation in Southeast Asia comes from coal (Fallin, Lee and Poling 2023). Natural gas is counted on as a key transition fuel away from coal by many governments on the assumption of cheaper cost compared to a complete immediate switch to renewables. However, natural gas still emits 490 gCO2-eq per kWh and the cheaper cost assumption no longer holds due to the ongoing conflict in Ukraine.

Solar and wind power technologies require the mining of many minerals. Greater adoption of these technologies will lead to more strain on the environment and society. By pursuing a renewable power that develops ecosystem understanding and healing at the same time, we might get closer to shifting nightmares to dreams.

2. Renewable power generation in Southeast Asia

In a high renewable energy scenario in Southeast Asia, the key technology will be solar PV, followed by wind, hydro, and biomass. (Figure 1)

Figure 1: Southeast Asia's power capacity alternatives for 1.5°C Scenario for ASEAN aligned with the Wind Energy Technologies Office (WETO) targeting net-zero emissions globally by 2050 (1.5-S)



Source: International Renewable Energy Agency; ASEAN Centre for Energy 2022

Southeast Asian countries have a regional target of 35% renewable energy share in installed capacity by 2025. To reach the target, the region needs to develop at least 40.3 GW of solar and 5.4 GW of wind power. (ASEAN Centre for Energy, 2022)

To enable higher variable renewable energy penetration, a flexible energy system is required. This can be achieved through:

i. More mid-merit power and peak generation in the system. The former is electrical generation that fills the gap between baseload power and peaking power, e.g. natural gas combined cycle plants, coal-fired plants, nuclear power plants, hydroelectric plants, and large-scale solar and wind farms with battery storage. The latter is electrical generation that meets sudden or unexpected spikes in demand, e.g. natural gas combustion turbines, diesel generators and hydroelectric plants with pumped storage. These plants are typically used for a few hours each day, during the periods when demand is highest.
ii. More storage capacity, for example batteries, pumped hydropower, thermal storage, and hydrogen.
iii. More power interconnection between countries

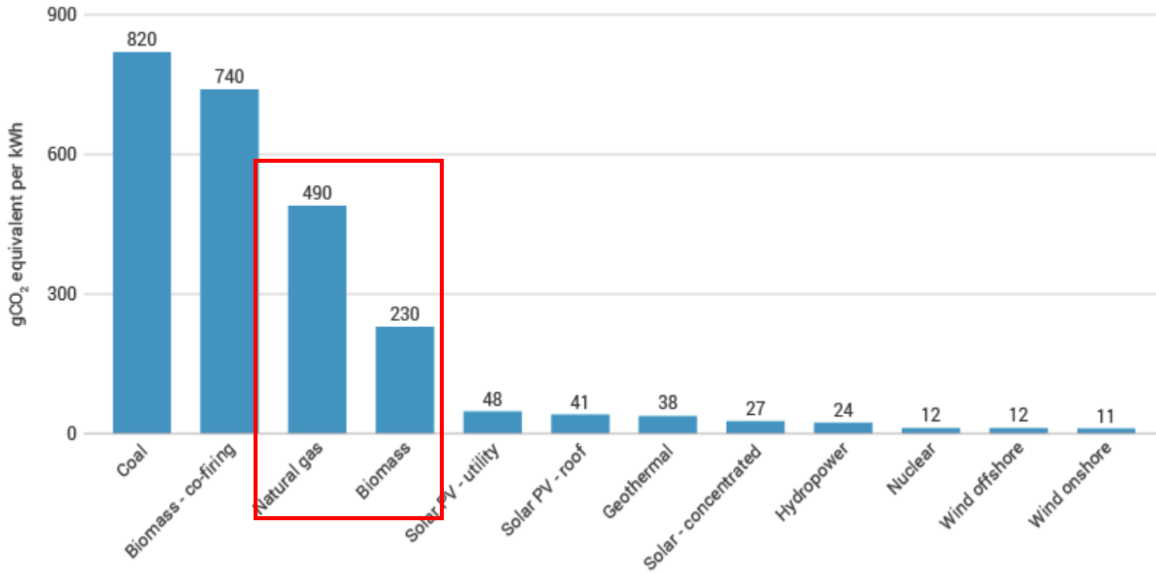
2.1 Fossil power generation in Southeast Asia

Southeast Asia is the world's fourth-largest energy consumer. The region's current energy structure is skewed towards traditional forms of power generation, with fossil fuels making up 83% of its energy mix, and energy demand is expected to increase (ASEAN Centre for Energy, 2022).

In the power system, natural gas is considered pivotal in ensuring grid stability whilst more variable renewables are added (ASEAN Centre for Energy, 2022). Although gas-fired generators are the lowest emission fossil fuel for generating electricity, it still emits 490 gCO2-eq per kWh (Figure 2).

What can be a better alternative to gas-fired generators to replace coal-fired plant's baseload power and support a high renewable energy penetration scenario? Figure 2 suggests biomass, which has half the emission intensity of natural gas.

Figure 2: Average lifecycle CO2 equivalent emissions



Source: IPCC

2.2 Biomass power generation: the Cinderella of renewables in Southeast Asia

Biomass power generation has met with obstacles such as security of feedstock, stability of biomass prices, biomass scalability and seasonality, and collection challenges in Southeast Asia. Hence, it is present, but usually does not take centre stage as a renewable fuel and investment opportunity like solar and wind, despite the expectation that biomass will be a key contributor in the bioenergy space moving forward (Figure 3).

At the G20 Summit in New Delhi in September 2023, a Global Biofuel Alliance (GBA) was formed to expedite the global uptake of biofuels. A similar alliance is needed for biomass to facilitate technology advancements, intensify utilisation of sustainable biomass, shape robust standard setting and certification through the participation of a wide spectrum of stakeholders.

In 2020, the biomass power generation capacity of Southeast Asia was around 6 GW, mainly installed in Thailand (2.2 GW) and Indonesia (1.9 GW) (ASiANPOWER, 2023). There are two types of energy related biomass utilisation in Southeast Asia – modern biomass power generation and traditional biomass demand by households – as summarised in Table 1.

Figure 3: Share of bioenergy in the total final energy consumption (TFEC) in ASEAN, by scenario

Source: International Renewable Energy Agency; ASEAN Centre for Energy 2022

Thailand and Indonesia's existing and target biomass power generation capacities are in the range of thousands of MW whilst Vietnam, Malaysia, Philippines, Myanmar, and Singapore are in the range of hundreds of MW. Out of all the Southeast Asian countries, only Vietnam has set the target of 100% coal replacement with biomass for power generation. Vietnam can set such a target because the country is the second largest wood pellets producer in the world after the US.

Biomass is the highest contributor to the total final energy consumption (TFEC) in Myanmar, Cambodia, and Lao PDR where households use biomass for cooking and heating. Cottage industries in Myanmar use biomass for power generation. Brunei does not have biomass power generation, neither does the country's residential sector use biomass for cooking.

Table 1: Overview of Energy Related Biomass Utilisation in Southeast Asia

Modern Biomass Power Generation
Thailand (Muramatsu, 2022) • Major producer of rice, sugarcane, and cassava • Industries such as Ajinomoto and Siam Cement Group Biomass utilise co-generation systems fed by rice husk, biomass pellets made from sugarcane and rice farms waste, and wood.

- Biomass is leading the way in mainstreaming renewable energy, even more so than solar

Indonesia (Perusahaan Listrik Negara, 2021)

- Perusahaan Listrik Negara (PLN) targets 18,895 MW of co-firing capacity in 114 coal-fired power plants in 52 locations by 2025. Currently, biomass co-firing pilot projects have been implemented at 32 locations using 5% biomass fuel (palm kernel shell, wood pellets).
- Future expansion of the scheme is expected to include coal-fired power plants owned and operated by independent power producers.
- The design of new coal-fired power plants that will start operating after 2025 are required to have a minimum 30% biomass fuel co-firing.

Vietnam (Barnes, 2023; Bich, 2023)

- The Power Development Plan 8 issued by the Government of Vietnam on 15 May 2023 requires coal power plants to burn biomass and ammonia fuel after 20 years of operation, starting at 20% and increasing to 100%, as the country moves to phase out coal by 2050.
- By 2030, the combined capacity of biomass and waste-to-energy plants is planned to reach 2,270 MW, with an aim to increase to 6,015 MW by 2050.
- Biomass sources: bagasse, straw, rice husks, coffee husks, coconut shells, and sawdust

Malaysia

- The National Energy Transition Roadmap (Ministry of Economy, 2023) has six energy transition levers with bioenergy as one of them. It will involve biomass clustering and piloting biomass co-firing at the exiting 2,100 MW Tanjung Bin Power Plant in 2024, with an intention to scale up to a minimum of 15% biomass co-firing capacity by 2027.
- Biomass sources: palm empty fruit bunch pellets, wood chips, wood pellets, bamboo pellets, coconut husk and rice husk.

Philippines

- Biomass power capacities were reported at 356 MW in 2019 and potential capacity at 4,400 MW (Dia, 2023)
- Bagasse is used as boiler fuel for cogeneration; rice and coconut husks dryers for crop drying; biomass gasifiers for mechanical and electrical applications; fuelwood and agricultural wastes for oven kilns; furnaces and cooking stoves for cooking and heating purposes. These biomass technologies installations' capacity is higher than the other renewable energy or energy-efficient and greenhouse gas abating technologies' capacities (Shead, 2017).
- Biomass sources: rice husk, rice straw, coconut husk, coconut shell, banana, pineapple, and general bagasse

Singapore

- Does not have agriculture and forestry sectors but pursues biomass power generation through horticultural biomass and waste-to-energy. Tree branches, leaves and grass cuttings are combusted for energy production at Gardens by the Bay and Jurong Island.
- The Tembusu Multi-Utilities Complex (TMUC) on Jurong Island co-fires cleaner coal (i.e. low-ash and low sulphur) and biomass to generate steam and electricity with low emissions. Total output is 134 MW. (Tan, 2023; Gan, 2022)

Myanmar

- Biomass sources: rice husk, rice straw, bagasse, corn cob, cassava stalk, residues from sugarcane, coconut and oil palm, wood residues and fuelwood
- 45% forest cover
- Biomass contributes 64% of the total final energy consumption (TFEC) (Pode, Pode, & Diouf, 2016):
  - Cooking and heating in rural areas: 70% of the country's population live in rural areas.
  - Cottage industries: over 1000 rice mills across Myanmar are powered by small scale rice husk gasifiers. Rural cooperatives/committees installed several rice husk biomass power plants for rural electrification after 2001.
- The biomass rick husk power plant business model has the potential to provide grid quality power to the rural population without grant or subsidy (Pode, Pode, & Diouf, 2016).
- Total capacity potential from biomass is 6,899 MW. In 2013, the total installed capacity of biomass and biogas in 2013 was reported at 115 MW (Tun, Juchelkova, Win, & Puchor, 2019).

Traditional Biomass Demand by Household

Cambodia

- 57% forest cover
- Wood and wood charcoal account for approximately 80% of TFEC, which the residential sector uses for cooking.
- Other major biomass sources come from agricultural residues: rice husk, rice straw, corn cob, cassava stalk, bagasse, groundnut shell and husk, and coconut shell and frond.
- 2019: total installed capacity for biomass was about 23 MW. Target to reach 73 MW of installed capacity by 2030. (Tun, Juchelkova, Win, & Puchor, 2019)

Lao PDR

- 68% forest cover
- Agriculture economy
- Biomass consumption has the highest share in the TFEC, with the residential sector as the main consumer (Phouthonesy, 2021) - 80% of the households rely on firewood and charcoal.
- Installed biomass energy capacity: 40 MW; target: 58 MW by 2025 (Tun, Juchelkova, Win, & Puchor, 2019).

The biomass power generation obstacles mentioned earlier result in a supply consistency challenge that constrains it as a mid-merit power. To transcend this constraint, strategic thinking needs to go beyond improving the collection efficiency of agricultural and forestry residues.

Biomass power plants that are fuelled by wood pellets can provide baseload power because it is a standardised fuel that can be easily transported, traded, purchased, and stockpiled in advance of need. Tree plantations are necessary to ensure a reliable supply of feedstock for producing wood pellets.

Wood pellets' commercial inception as a heating source in both residential and commercial structures started in the 1980's. Global utilities and large-scale power generators subsequently adopted it as a renewable fuel to produce reliable baseload power, either in stand-alone biomass power stations or co-firing in coal-fired power stations.

One example of a large biomass power station fuelled by pellets is Drax in the UK, which supplies on average 9.3% of the UK's electricity needs. Drax was the biggest coal-fired power station (3906 MW) ever built in Britain, and the last too. By 2010, the station was co-firing biomass. Four out of six 650 MW generating units are now fully powered by wood pellets, and the plan is to convert the remaining two coal units to combined cycle gas turbine units and 200 MW of battery storage (Wikipedia, 2023). This is an example of combining baseload power (wood pellets) and mid-merit power (natural gas combined cycle and battery storage).

The pellets used at Drax are mostly made from sawmill refuse and other by-products in America; they are then transported by rail, ship, and rail to the site where they will be pulverised and burned (The Economist, 2013). In 2021, Drax acquired its Canadian biomass pellet supplier, Pinnacle Renewable Energy, a key producer of wood pellets. At that time, Pinnacle had C$6.7 billion of long-term contracts with high quality Asian and European customers, including Drax, and a significant volume contracted beyond 2027 (Gardiner, 2021).

The Drax example is instructive for Southeast Asia's power generation because the tropical region has the advantage of local sourcing of woody fuels. Trees grow faster in the tropics than in temperate countries like Northern America and Europe. When power generators get serious about sourcing biomass fuel, it will stimulate local investment in wood pellet production.

2.3 Global wood pellet market

Wood pellet production is a global business because wood pellets are widely used in Sweden, Finland, Italy, UK, US, Canada, South Korea, and Japan as a fuel for boiler and furnaces to generate heat for residential and industrial requirements (Jara, Daracan, Devera, & Acda, 2016). Implementation of the European Union Renewable Energy Directive has triggered rapid growth in trading of wood pellets. Over 18 million tons of wood pellets were traded by EU member countries in 2018 (Eurostat, 2019), (Proskurina, Junginger, Heinimö, Tekinel, & Vakkilainen, 2018).

The index of wood-pellet prices published by Argus Biomass Markets rose from an average of USD152/MT in August 2010 to USD166/MT at the end of 2012. These are the delivered prices into the ports of Amsterdam, Rotterdam, and Antwerp (The Economist, 2013). A decade later, in January 2023, the 90-days spot price of wood pellet for deliveries to northwest Europe was USD303.06 a tonne (Argus, 2023).

In Southeast Asia, wood pellet price is USD130-150/MT FOB MVT. The high price in northwest Europe is due to the Russia-Ukraine war and soaring shipping cost. Most of the wood pellets used in Europe comes from America and Canada. For the same reason, Europe's import price for LNG from the US is four times the indigenous price in the US.

In Southeast Asia, Vietnam is the largest wood pellet producer and exporter, and the second largest in the world after the US. Vietnam's shipment of pellets rocketed to 3.2 million tonnes in 2020 (mainly to Japan and South Korea for biomass energy production) from just 175.5 tonnes in 2013. The export revenue increased 15.3-fold from nearly US$23 million in 2013 to $351 million in 2020. (Phuc, 2021)

Wood pellets there are typically made from waste wood such as sawdust, shavings, and tree branches. Some large-scale producers have their own acacia or eucalyptus plantations, some of which are Forest Stewardship Council (FSC) certified. It is noteworthy that Vietnam's wood pellet industry grew rapidly without industry association support or government attention and regulation on production and export. (Viet Nam News, 2021; Phuc, 2021).

3. Deforestation in Southeast Asia and the challenges of replanting

During the period 2001-2019, Southeast Asia lost 61 million hectares of forest - an area larger than Thailand - 31% of which occurred in mountainous regions where highland forest was converted to cropland and plantation in less than two decades. This is equivalent to a rate of 3.22 million ha per annum. (Feng, et al., 2021) Mining is another major driver of deforestation.

National governments usually mandate timber and mining companies to replant on areas that they have deforested, and even have measures to induce compliance. In Indonesia, for example, mining companies are required to pay the government a high deposit per hectare that will only be returned after their required replanting work has been verified. The replanting verification is needed for mining permit renewal too. The government also requires the mining companies to engage a replanting consultant for three years to ensure that the newly planted tree seedlings are taken care of sufficiently and have a chance to grow to maturity.

Besides replanting trees in ex-mining areas, the Indonesian government also requires mining companies to seek out nearby riverbeds and plant trees by the river, which will improve water quality and reduce flooding. Despite these government measures, the replanting results are often unsatisfactory. The reasons are both human and technical as summarised in Table 2.

Table 2: Reasons for unsatisfactory replanting

Human
• Timber companies use people whom they trust as contractors. Some of these people whom they trust are not qualified. Some are qualified, but not ethical. Timber companies are short of management talent who are ethical. • Contractors who are engaged to do the replanting work do not execute the work seriously. This is the reason why some timber companies' forest plantations are doing poorly despite them doing logging according to the book and replanting. • Replanting consultants propose budgets that are too low (e.g. 63% below what is needed) for good quality replanting in their quest to win the job. Such unprofessional practice tends to come together with a consultant's demand for a 10% commission, which is drawn from the already inadequate budget. • Timber companies engaging a replanting consultant for one year, instead of the required period of three years. • Local government officers not enforcing the replanting mandate, but signing off papers confirm that the mining companies have done the replanting so that their mining permits can be renewed
Technical
• The soil on deforested and mining land are poor in fertility. Soil rehabilitation is required for tree seedling to have a better chance of surviving and thrive. • Quality of planting materials is not good enough due to inadequate budget

All the reasons identified in Table 2 could be attributed to the lack of intent for replanting to be successful because the economic benefit is not clear to the timber and mining companies. By pursuing replanting and tree plantation development together, both environmental and economic goals can be achieved.

Having an economic motivation is necessary, but insufficient, for successful tree planting in degraded areas.

4. Soil fertility: the principle of symbiosis

For replanting in degraded areas to be successful, timber and mining companies and their replanting consultants need to first work on improving soil fertility. This begins with the realisation that soil is a living being that needs to be fed appropriately, so that the symbiotic relationships between microbes in the soil and plants can be vibrant. The fertility that lives in the soil – the microbes - is the productive capital asset. Not nurturing this capital asset is a crippling blindness that will lead to much lower yields and far more plant sickness. (Platts & Leong, 2020)

This involves thinking at the level of first principles, and embodying the principles in systems and public practice so that those principles have their proper influence in society's thinking, decision making and acting. Vocabulary reflects the mindset and influences the way systems are designed and implemented.

When ecosystems are damaged or destroyed, their ability to regenerate naturally is impeded. Hence, healing ecosystems requires planting materials. Establishing planting material nurseries requires access to fertile land and water, seeds and cuttings, knowledge of pest and disease management, and qualified workers.

Nurseries growing new seedlings and the planting out of new seedlings will require organic matter and microbial soil ameliorant. In Kalimantan, Dr. Yusanto Nugroho from the University of Lambung Mangkurat found that two rounds of soil improvement are required in the planting process. The first is at the time of planting, and the second is when the seedling has grown, and the roots are reaching the boundaries of the improved soil environment. The second round of soil improvement expands the space of the improved soil environment for the roots to continue growing. Two rounds of improvement are sufficient for a tree seedling to grow to maturity.

Soil fertility is the starting point of a successful tree planting exercise. When a forest ecosystem is restored, the populations of insects, birds, animals improve too, and they will feed back into the soil ecosystem and strengthen its vitality. This is the principle of symbiosis, and the cycle reinforces itself.

Wherever the principle of symbiosis is practised – be it is in the remote areas of Borneo Island or cosmopolitan Hong Kong (e.g. the Kadoorie Farm and Botanic Garden), vibrancy can be seen all round in the flora, fauna, and humans. "Vibrancy" is the flow of life (the "qi") that can be seen and shared in (Platts, 2021).

5. Conclusion

Solar and wind power technologies require the mining of many minerals such as silicon, copper, rare earth elements, silver, aluminium, cadmium, tellurium, and selenium. Mining can lead to deforestation, water pollution, air pollution, displace indigenous communities and contribute to human rights abuses. More adoption of these technologies will lead to more strain on the environment and society. Biomass power generation with wood pellets, on the other hand, can be a vehicle for ecosystem healing and properly establishing the existential relationship between humans and the environment.

The nightmare of climate change can become a good dream when decarbonization efforts are aligned with the principles of nature. Doing more will then improve ecosystems all round, restore the balance of nature, and not trigger imbalances elsewhere. When we work with nature, rather than against it, we can create a more sustainable and resilient future.

Integrated Assessment Models (IAMs) can help us understand the complex interactions between developing tree plantation on degraded land, wood pellet production, biomass power generation and ecosystems.

ASEAN Green Future (AGF) is a multi-year research project that involves the UN Sustainable Development Solutions Network (SDSN), *Climateworks Centre* and nine country teams from leading universities and think tanks across Southeast Asia. The researchers undertake quantitative and qualitative climate policy analysis and develop net zero pathways to inform policy recommendations and support the strategic foresight of policy makers.

AGF is currently in a stage of optimising the amount of renewable energy possible in the Southeast Asian countries with storage. The biomass power generation scenario outlined in this paper, which involves developing tree plantations on degraded land, will lead to a different biomass power potential estimation from what is currently estimated by governments based on agricultural and forestry residues.

If this dream can come true, this is how Southeast Asia's renewable power mix may look like in the future:

i. Baseload power: biomass, hydro
ii. Mid-merit power: solar, wind, storage
iii. Peak power: pumped hydro storage, green hydrogen

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Bibliography

Argus. 2023. *Argust Biomass Market.* Argus Media Group. https://www.argusmedia.com/-/media/Files/sample-reports/argus-biomass-markets.ashx?la=en%26hash=872E2C03A0A78FE3F236BBF00E7729E3114326E0.

ASEAN Centre for Energy. 2022. *The 7th ASEAN Energy Outlook 2020 - 2050.* Jakarta: ASEAN Centre for Energy. https://aseanenergy.org/the-7th-asean-energy-outlook/.

ASiANPOWER. 2023. *Asia turns to biomass co-firing in coal plants for energy security, transition.* https://asian-power.com/power-utility/exclusive/asia-turns-biomass-co-firing-in-coal-plants-energy-security-transition.

Barnes, Mark. 2023. "Vietnam Government Approves Power Development Plan 8." *Vietnam Briefing.* May 17. https://www.vietnam-briefing.com/news/vietnam-power-development-plan-approved.html/.

Bich, Dao. 2023. "Co-firing technology to promote energy transition in Vietnam." *VietnamNet Global.* September 18. Accessed October 17, 2023. https://vietnamnet.vn/en/co-firing-technology-to-promote-energy-transition-in-vietnam-2189003.html.

Dia, Don Mario Y. 2023. *Biomass Power in the Philippines: Realising Our True Potential.* Biomass Renewable Energy Reliance. October 17. https://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/2019_events/PPTS_Manila_2019/PPTs_Manila_26/12.b.Don_Mario_Dia.pdf.

Eurostat. 2019. *International trade, EU trade since 1988 by HS6. Product 440131.* https://ec.europa.eu/eurostat/web/international-trade-in-goods/data/database.

Fallin, Danielle, Karen Lee, and Gregory B. Poling. 2023. *Clean Energy and Decarbonization in Southeast Asia: Overview, Obstacles, and Opportunities.* Center for Strategic and International Studies. May 1. https://www.csis.org/analysis/clean-energy-and-decarbonization-southeast-asia-overview-obstacles-and-opportunities.

Feng, Yu, Alan D. Ziegler, Paul R. Elsen, Yang Liu, Xinyue He, DOminick V. Spracklen, Joseph Holden, et al. 2021. "Upward expansion and acceleration of forest clearance in the mountains of Southeast Asia." *Nature Sustainability* 4: 892-899. https://www.nature.com/articles/s41893-021-00738-y.epdf?sharing_token=WnQ5nNagyCeHt3dr_QaM1dRgN0jAjWel9jnR3ZoTv0NC9Zpr--jMDlS6JyjRhUu0rLBmG5C02NQ5E7L4epsNjOr6L4qaHF0unKFW6bLfj6qER751

SN37z6wr8wlxRda9h485aVPoNLJhKsyhDvxG7x_bkAUbnNKHIxqb3hIwIZyPBvDWtMUf9Zj2S.

Gan, Kim Yong. 2022. *Written reply to PQ on electricity generation of coal.* Ministry of Trade and Industry Singapore. January 10. https://www.mti.gov.sg/Newsroom/Parliamentary-Replies/2022/01/Written-reply-to-PQ-on-electricity-generation-of-coal.

Gardiner, Will. 2021. *The world's leading sustainable biomass generation and supply business.* April 13. Accessed June 10, 2023. https://www.drax.com/opinion/the-worlds-leading-sustainable-biomass-generation-and-supply-business/.

Hlaing, Zar Ni. 2023. "Biomass Enegy in Myanmar." January. https://www.researchgate.net/publication/372860208_Biomass_Energy_in_Myanmar.

International Renewable Energy Agency; ASEAN Centre for Energy. 2022. *Renewable Energy Outlook for ASEAN: Towards a Regional Energy Transition.* IRENA & ACE. Accessed October 14, 2023. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Sep/IRENA_Renewable_energy_outlook_ASEAN_2022.pdf?rev=ef7557c64c3b4750be08f9590601634c.

Jara, AA, VC Daracan, EE Devera, and MN Acda. 2016. "TECHNO-FINANCIAL ANALYSIS OF WOOD PELLET PRODUCTION IN THE PHILIPPINES." *Journal of Tropical Forest Science* 28 (4): 517–526 . https://www.frim.gov.my/v1/jtfsonline/jtfs/v28n4/517-526.pdf.

Ministry of Economy. 2023. *Natinoal Energy Transition Roadmap.* Ministry of Economy.

Muramatsu, Yohei. 2022. *Thailand taps rice, sugar biomass to wean itself from fossil fuels.* May 12. https://asia.nikkei.com/Spotlight/Environment/Thailand-taps-rice-sugar-biomass-to-wean-itself-from-fossil-fuels.

Nam, K.Y., W.M. Cham, and P.R. Halili. 2015. "Power Sector Development in Myanmar." *Economics Working Paper Series-460* (Asian Development Bank) 1-30.

Perusahaan Listrik Negara. 2022. *Gantikan Batu Bara, PLN Sukses Gunakan 100 Persen Biomassa Jadi Bahan Bakar PLTU Tembilahan.* June 16. https://web.pln.co.id/media/2022/06/gantikan-batu-bara-pln-sukses-gunakan-100-persen-biomassa-jadi-bahan-bakar-pltu-tembilahan.

Perusahaan Listrik Negara. 2021. *Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PT PLN (PERSERO) 2021-2030.* Menteri Energi dan Sumber Daya Mineral Republik Indonesia. Accessed October 15, 2023. https://web.pln.co.id/statics/uploads/2021/10/ruptl-2021-2030.pdf.

Phouthonesy, Phaysone. 2021. "The Lao PDR Country Report." In *Energy Outlook and Energy Saving Potential in East Asia 2020*, edited by P. Han and S. Kimura. Accessed October 18, 2023. https://www.eria.org/uploads/media/Books/2021-Energy-Outlook-and-Saving-Potential-East-Asia-2020/17_Ch.10-Lao.pdf.

Phuc, To Xuan. 2021. *Vietnam's Production and Export of Wood Pellet - Status and Some Concerns.* Forest Policy Trade and Finance Initiative, Forest Trends. https://www.forest-trends.org/publications/vietnams-production-and-export-of-wood-pellets/.

Platts, M. J. 2021. "Achieving Sustainability." *Natural Sciences* 13 (7): 273-281. doi:10.4236/ns.2021.137023 .

Platts, M. J., and Y. Y. Leong. 2020. "Soil Fertility is a Productive Capital Asset." *Agricultural Sciences* (Scientific Research Publishing) 11: 744-776. doi:https://doi.org/10.4236/as.2020.118049.

Pode, Ramchandra, Gayatri Pode, and Boucar Diouf. 2016. "Solution to sustainable rural electrification in Myanmar." *Renewable and Sustainable Energy Review* 57: 107-118. https://www.sciencedirect.com/science/article/abs/pii/S1364032115017037?via%3Dihub.

Proskurina, S., M. Junginger, J. Heinimö, B. Tekinel, and E. Vakkilainen. 2018. "Global biomass trade for energy—Part 2: Production and trade streams of wood pellets, liquid biofuels, charcoal, industrial roundwood and emerging energy biomass." *Biofuels Bioprod. Biorefining* 13: 371–387.

Shead, Bob. 2017. "Biomass Industry in the Philippines." *ASEAN Briefing.* May 19. Accessed October 17, 2023. https://www.aseanbriefing.com/news/biomass-industry-philippines/.

Tan, Cheryl. 2023. *S'pore looking into wider adoption of biofuels, bioresources to hit net-zero emissions target.* Prod. The Straits Times. Singapore, April 22. https://www.straitstimes.com/singapore/s-pore-looking-into-wider-adoption-of-biofuels-bioresources-to-hit-net-zero-emissions-target.

The Economist. 2019. *Climate policy needs negative carbon-dioxide emissions.* December 5. Accessed June 10, 2023. https://www.economist.com/briefing/2019/12/05/climate-policy-needs-negative-carbon-dioxide-emissions.

The Economist. 2013. *The Fuel of the Future.* April 6. https://www.economist.com/business/2013/04/06/the-fuel-of-the-future.

To, Xuan Phuc. 2021. *VIETNAM'S PRODUCTION AND EXPORT OF WOOD PELLETS: STATUS AND SOME CONCERNS.* Forest Policy Trade and Incnetive | Brief, Forest Trends.

Tun, Maw Maw, Dagmar Juchelkova, Myo Min Win, and Tomáš Puchor. 2019. "Biomass Energy: An Overview of Biomass Sources, Energy Potential, and Management in Southeast Asian Countries." *Resources* 8 (81). doi:10.3390/resources8020081.

Viet Nam News. 2021. *Việt Nam now world's second-largest fuel pellet exporter.* July 8. Accessed June 11, 2023. https://vietnamnews.vn/economy/988017/viet-nam-now-worlds-second-largest-fuel-pellet-exporter.html.

Wikipedia. 2023. *Drax Power Station.* May 19. Accessed June 10, 2023. https://en.wikipedia.org/wiki/Drax_Power_Station.