Flexibility concepts for the electrical power supply of Southern Thailand 2050: On the way to a sustainable energy system

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Abstract

Electrical energy production of Southern Thailand currently depends mainly on gas and diesel fired power plants as well as hydro power, with plans to add 3,000 MW of coal based energy in the near future, in Krabi Province at the Andaman Sea and in Songkhla Province at the Gulf of Thailand, with coal shipped from Australia, Indonesia, and South Africa via new deep see ports. At both places the plans face intense resistance by the local population and beyond. Although 'clean technology' might be applied the new coal fired power plants will increase the overall CO_2 emissions of Thailand, contradicting any 'climate change' efforts. This might increase the ongoing acidification of the ocean leading to the death of corals. The coal economy worldwide already has changed due to the ongoing climate change. Several countries either restrict the financial support of new coal fired power plants overseas or shut down their existing ones. Over the last years the price of electricity production from coal is getting less competitive compared to renewable energy sources. Possible energy scenarios for Southern Thailand for 2050 show a promising mix of alternative energy sources for electricity production. It is the role of science and research to develop alternative options with the final decision resting with the political decision makers, businesses, and the civil society; a process, which requires flexibility, creativity, and a constant dialogue.

Keywords: *Electrical energy, southern Thailand, renewable energy, coal, energy scenarios*

1. Current situation in southern Thailand

The electrical energy supply for Southern Thailand is currently maintained by mainly conventional gas and diesel powered units as well as hydro dams and to a minor extent by biogas systems, mostly related to the palm oil industry [1]. Located in Songkhla's Chana District is a combined 1,531 MW gas fired power plant, which receives its gas from the gas field of the Joint Development Area (JDA) in the Gulf of Thailand via a pipeline. Smaller units are in Surat Thani's Phun Phin District, 244 MW natural gas and diesel powered, in Krabi's Nuea Khlong District, 340 MW natural gas and fuel oil powered, and in Nakhon Si Thammarat's Khanom District, a 930 MW natural gas power plant. A new plant at the later site is set to start in June 2016. The Krabi plant was a former lignite fired power plant as lignite deposits were found in the area nearby (Krabi Basin) but mining has finished since more than a decade. Two major hydropower dams are located in Southern Thailand, the 240 MW Rajjaprabha Dam in Surat Thani and the 72 MW Bang Lang Dam in Yala's Bannang Sata District [2]. Smaller electricity producing units are, for example, a 2.062 MW biogas unit in Krabi using palm oil wastewater for methane production [3]. Additional electricity is channeled to the southern part via 115 kV and 230 kV transmission lines from the central region and also purchased from Malaysia via a 300 kV DC line of maximal 300 MW [4].

The electricity demand side comprises mainly of the main tourist areas in Phuket, Krabi, and parts of Phang Nga and Surat Thani (e.g. Koh Samui), located near the shore lines of the Andaman Sea and the Gulf of Thailand. Where, the sea food processing and cold storage facilities are located. Further significant demand is coming from the larger area of HatYai, a commercial center for Southern Thailand, and Songkhla, both with seafood processing and rubber processing companies.
The situation in the southern part of Thailand reflects the overall situation of the country, where the electricity generation is dominated by gas due to the discovery of gas fields in the Gulf of Thailand [1,

5]. Therefore, one aim of the current power plan is to diversify the fuel sources used for electricity generation. Currently, coal as lignite is produced in northern Thailand with the Mae Moh Mine and associated power plant [2].

2. Power plan for the foreseen future

Due to increasing electricity demand and according to the recent Thailand Power Development Plan 2015 (PDA 2015) the government via the Electricity Generating Authority of Thailand (EGAT) proposed the construction of two coal-fired power plants in Southern Thailand, an 800-MW coal fired power plant in Krabi's Nuea Khlong District by 2019 and a 2,200-MW coal fired power plant in Songkhla Thepa District by 2024; here half of the power production is set to be available by 2021 [6]. For both power plants coal will come via new and yet to build deep sea ports with shipments from Indonesia, Australia, and South Africa. For the entire country of Thailand, coal will take up to 13% of the installed electricity generating capacities planned for 2015-2036 according to the PDA 2015. The main share will go to natural gas with 30%; 19% will be imported, and 20.11% will come from renewable sources (up from 9.87 in 2014); however, from that amount 44% will be purchased from neighboring countries. The overall capacity increase planned for 2015-2036 is 57,459 MW [7,8]. The main sources for the renewable energy in 2014 are biomass (55%) and solar (29%); however according to the Thailand Alternative Energy Development Plan, AEDP 2015, solar (30%), biomass (28%), and wind (15%) are planned to dominate in 2036 [8].

3. Coal - Social, environmental, economic issues

3.1. Local resistance

Plans for the two proposed coal fired power plants in Southern Thailand created and still create intense resistance among local populations in Krabi and Songkhla, and it is still going on, especially pointing out flaws and injustice regarding the public participation related to the environmental and social impact assessments required for these plants [9]. Figure 1 shows an example of a banner along a road in Krabi's Nuea Khlong District demonstrating the strong opposition of coal as the new proposed energy source. The current oil/gas pipeline from Krabi's Andaman coastline to the power station however is so far accepted by the local communities. EGAT claims the public participation of the Tepha power plant in Songkhla Province a success, calling it the *'Thepa Model'* that can be used for similar projects in Thailand, although large police and military presence have helped, that in July 2015 a public review concluded peacefully and without any clashes [10,11]. The situation in Songkhla's Thepa District is especially difficult as the proposed power plant and nearby deep sea port is located in an area with large Muslim communities and in the area of the South Thailand insurgency. Some see signs that the power plant resistance might mix with the insurgency and by this get more violent [12].

Figure 1 Banner in Krabi' Nuea Khlong District displaying the resistance against coal ("*100% no coal*"), Photo taken in May 2016.

3.2. CO_2 emission and climate change

Today, all electricity generation technologies emit CO_2 at some point during their life cycle, coal, gas, biomass, photovoltaic, hydropower, wind and nuclear energy, as none of these technologies are entirely 'carbon free', see Table 1, [13]. Coal and gas power sources present the highest values, with coal on the top of the list. However, ultra-supercritical pulverized coal power plants, known as '*clean coal'* technology, provide a way forward [14]. They are mainly characterized by higher efficiencies, around 46% [12] (35-38% for conventional, subcritical pulverized coal plants), thus reducing the CO_2 emission per unit electricity, but still standing at around 700-800 gCO_2eq/kWh carbon dioxide emission [15]. Carbon capture storage (CCS) technology is available and its application can reduce the gCO_2eq/kWh-values significantly, but on the other hand this capture technology is decreasing substantially the overall efficiency of a power plant in comparison with no-capture [14]. Another factor is the higher costs associated with CCS, which have to be shouldered by either consumers or taxpayers, or both. The Kemper coal plant in the USA with capture technology, designed as a model for future coal fired power plants, is an example for that [16]. As currently Thailand is producing electricity mainly from gas fired power plants the construction of new coal fired power plants would result in an increase in the overall CO_2 emissions, even when using *'clean coal'* technology. This comes parallel with Thailand's signature under the Paris Climate Agreement on 22 April 2016 [17]. In 2013, Thailand produced 3.69 tCO_2 per capita, compared to a value of 1.54 tCO_2 per capita for the Asia region without China, and an average value of 4.52 tCO_2 per capita for all countries [18]. According to [19], the majority (12) of the G20 states experience that their CO_2 emissions are no longer increasing, however the average of per capita energy-related CO_2 emissions for all G20 states is at 5.7 tCO_2/year for 2013, with maximal values of around 16-17 tCO_2/year, for example for U.S.A. or Australia. Among the G20 member states Indonesia has one of the lowest per capita energy-related CO_2 emissions. One reason here is that Indonesia has one of the highest shares of renewable energy in total primary energy supply among all G20 states combined with a positive growth rate [19].

There is a general understanding that climate change is already going and that significantly reducing greenhouse gas emissions is an urgent task in order to keep the global temperature at 2 °C or below [14]. For Thailand, the consequences are clear, with sea level rise as one of the visible consequences of climate change that will directly affect coastal areas [20], as well as higher ocean water temperatures and ocean acidification. The latter two are direct threats to the biodiversity of the coral reefs and the marine habitats in the Gulf of Thailand as well as in the Andaman Sea [21]. Subsequently, this will have direct consequences on the tourism industry and economy.

Table 1: Lifecycle CO_2 equivalent (including albedo effect) from selected electricity supply technologies. Median values in gCO_2eq/kWh [13].

Technology	**Median**
Coal – pulverized coal	820
Biomass – co-firing with coal	740
Gas – combined cycle	490
Biomass – dedicated	230
Solar PV – utility scale	48
Solar PV – rooftop	41
Geothermal	38
Concentrated solar power	27
Hydropower	24
Wind offshore	12
Nuclear	12
Wind onshore	11

3.3. Coal economy

Coal is a declining sector, with the latest sign to be observed in April 2016 when Peabody Energy, which is the biggest coal miner in the U.S. and the largest private-sector coal company in the world, filed bankruptcy. Industry sources named cheaper (shale) gas as the immediate threat, but the combination of cheaper gas and cheaper renewable energy sources are a longer-term threat to coal

(Figure 2, [22]). In April 2016 PR China announced that it halted plans for new coal-fired power stations in many parts of the country, and construction of some approved plants will be postponed until at least 2018 [23]. In 2015, the OECD agreed to set restriction but not completely stop the financial support for building new coal fired power plants in other countries [24]; a move the World Bank has done already in 2013 [25]. South Korea will shut down ten old coal fired power plants by 2025 in order to reduce pollution by toxic particular matter, mainly PM_{10} and $PM_{2.5}$ [26]. For the EU, a recent study based on emission data from 2013 calculated that coal-fired power plants were responsible for about 22,900 premature deaths [27].

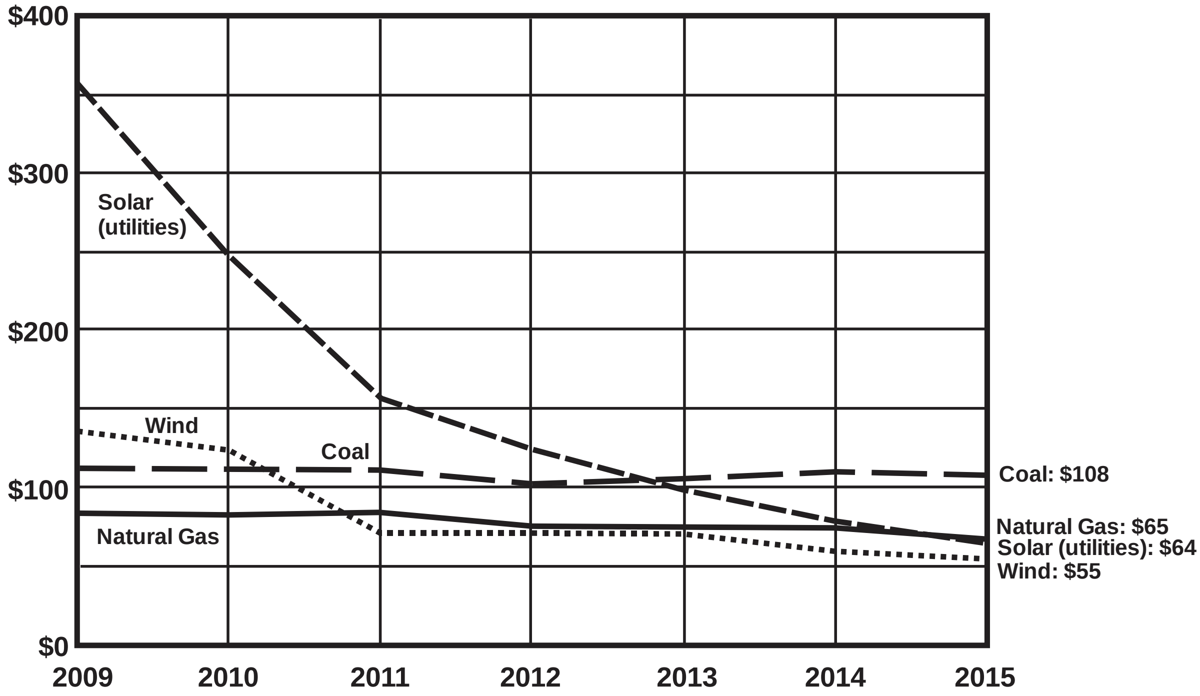

Figure 2: Average cost of energy for coal, natural gas, solar and wind, unsubsidized, in dollars per MW-hours. Values shown are average costs for 2015 [after 22].

4. The way to a sustainable energy system

As other countries, e.g. Germany, are already *on the way* to a sustainable energy system Thailand is now on the crossroad to decide what way to go, because the lifetime of coal fired power plants are around 40 years. In order to make the planned investment economic feasible the plants have to run for such a time, by this limiting energy choices the next generation have. However, as outlined earlier [28], any "energy transition" needs to be based on three main principles: (1) The energy supply of Thailand is a system with multiple cross-sectoral interactions between energy, raw materials and resources, technology, economy, society and law. (2) The aim of the energy transition is and has to be sustainability. The base for that is a force square made out of the supply security force, economic efficiency force, environmental sustainability force, and the force of social acceptability and social justice; all forces pulling in different directions (see Figure 3). The current situation in Thailand is dominated by the first two forces (Figure 3a). A real (force) square is desired with all forces having more or less equal magnitude (Figure 3b). Finally, (3), it is the role of science and research to develop alternative options, and to specify advantages and disadvantages of each solution. By this, the final decision rests with the political decision makers, businesses, and the civil society, at the end of a process which requires a constant dialogue.

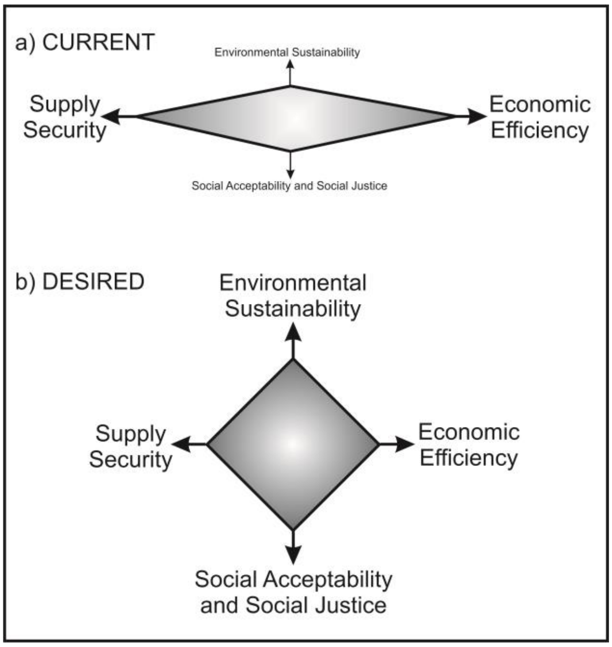

Figure 3 Force square as the base for a sustainable energy transition, with a) the current situation in Thailand, and b) representing the desired situation for the country. All force vectors are directed outwards and the thickness of the vector line represents the magnitude of the force.

5. Evaluation of energy choices

Thailand's current plan to add 3,000 MW of coal based energy to the electricity supply in the southern part would have a significant effect on future energy choices of the country as the coal fired power plants would have to run for about four decades. The question is what other choices or mixes of choices are feasible if the security of the energy supplies for electricity production has to play the central role. Besides coal and gas other, choices comprise of photovoltaic (solar), wind (onshore, offshore), bioenergy, hydropower, geothermal, and nuclear energy. As wind and solar energy and also bioenergy can be characterized as volatile sources further emphasis has to be put on the evaluation of energy storage systems, the power grid, and also the demand-side management.
An assessment scheme for the interdisciplinary evaluation of various energy choices has been developed by using a traffic light scale with five different levels from green to red, [29], as shown in Table 2. This scheme takes the following parameters into consideration: Material availability; acceptance by society, energy-management legislation (incl. regulations), building, environmental and pollution/emission laws/regulations, and technology. This scheme can be applied to different energy sources, also to energy storage systems, power grid, and demand-side management, and for each topic a SWOT analysis can be carried out in order to show the strengths, weaknesses, opportunities, and threats [29]. The assessment of the different energy choices using the scheme above including SWOT analysis is currently in progress for the main energy sources in Thailand. With these datasets different energy scenarios can be modeled, which are based on different political-social environments, different CO_2 emission reduction goals, different preferences regarding technology choices, or different geopolitical risks. With these outcomes political decision makers and civil society get the necessary information to make their choices. This is based on the fact that every technology regarding energy production can be replaced within an acceptable cost frame [30].

Table 2: Assessment scheme for the interdisciplinary evaluation of various energy choices using a traffic light scale with five different levels from green to red, after [29].

	Material Availability	**Acceptance by Society**	**Energy-Management Legislation (incl. Regulations)**	**Building, Environmental and Pollution/ Emission Laws/ Regulations**	**Technology**
green	High availability is no limit for use, no requirements needed for resource assurance	High acceptance, no objections are expected at local and national level	No action required as development is line with existing laws	No conflicts can be seen	Technology already developed, sufficient operational experiences exist
light green	Availability is given, but longer term measures for resource assurance required	In general high acceptance: but small influencing factors are possible, which have to be considered	Problems can be solved by adjusting certain regulations	Problems can be solved by adjusting certain regulations	Technology is developed far; long term operational experience with pilot projects under realistic scenarios exists
yellow	Under certain circumstances the availability can be critical, significant measures needed for resource assurance	Acceptance on local and national level questionable; significant clarifications required, awareness of acceptance problems	Significant changes and new laws are required	Problems can be solved by adjusting certain regulations without lowering existing standards	No experience with industrial scale technology; significant research and development (R&D) required
orange	Availability critical, so that alternatives have to be considered if the availability cannot improved significantly	Low acceptance; in order to implement technology in a relevant extent public participation is required	Significant changes required, which might not be implemented	Significant changes required of specific laws and regulations; lowering of standards necessary	Technology in early develop-ment; feasibility of the technology until 2050 even with significant R&D not ensured
red	Availability is so low that the technology cannot be used in a relevant extent	No acceptance; technology cannot be implement in the country	Law framework required for the use of the technology cannot be implemented or is not reasonable	Changes of the law framework required for the use of the technology cannot be implemented	Industrial scale technology not available until 2050

6. Energy scenario for Southern Thailand

As the assessment of the energy choices and subsequent modeling of energy scenarios is under way with quantitative output to be presented later, as it is not the aim of this study. Based on an evaluation of the current situation this study presents possible pathways for future electricity generation by applying flexibility concepts. As outlined in the earlier section the assessment of each energy choice

takes more efforts as all aspects discussed above have to be looked into and have to be evaluated. However, based on data and information presented a concise qualitative energy scenario for Southern Thailand can be drawn using the presented concepts.
In Thailand, public distrust towards coal (incl. lignite) and nuclear has grown over the past and the current resistance in the southern part of Thailand might be only the beginning. In the northeastern region villagers also protest a plan for a coal fired power plant that should support a potash mine [31]. Further, national and international goals on CO_2 emission reduction are contradicted by such plans, and thus having an impact on Thailand, with sea level rise and coral bleaching. As this then might have an effect on the tourist arrival numbers it is also of economic importance for the country. However, the reliance of natural gas as the main energy source for electricity productions needs to be diversified in order to minimize any impact from supply shortage or disruption, e.g. shut down of a gas pipeline or lower local production in the future. Therefore, as a possible scenario, a mix of various renewable resources gradually developed in line with increasing power demand might be possible. Wind and solar energy are not stable sources (fluctuations), but hydropower dams can be used as energy storage systems. It seems that news dams might be not build anymore due to local resistance related to environmental concerns and biodiversity threats. Geothermal plants based on low enthalpy systems and of medium scale, however, can provide base load capacity and by this reduce the volatility of other sources. Natural gas plants can be used as energy buffers for high peak demand as they can be easier and more economically stopped and restarted, [30]. All this might find a higher acceptance in the society, is more sustainable than coal and nuclear. Nuclear energy might possess low CO_2 emission characteristics, but the nuclear waste is another form of toxic material, which is a significant threat to people and environment. Storing it inside the nuclear plant in radiation-resistant containers [32] is only a short term solution as the radioactive elements have a longer lifetime than the power plant itself. Independent of the way Thailand will choose, the decarbonization of the electricity production will have positive long term benefits regarding climate change and the livelihood of the people, respectively quality of life, in Thailand and around the world. Uncertainties and possible higher costs need to be modeled and evaluated as outline above.

7. Conclusions

Southern Thailand is at the crossroad between conventional energy systems with high CO_2 emissions and low public acceptance on one side and a mix of renewable energy system with less CO_2 emissions and higher social acceptance on the other. This is the short form of quite complex issues and processes, but shows the real questions Southern Thailand is facing today. The answers will have an impact until 2050 and beyond. Recently, also the National Legislative Assembly (NLA) understood that renewable energy sources present a preferred way to go [33]. As outlined above this requires flexibility, creativity, and a dialogue, as there is no universal answer available that is applicable to all countries [34]. For Thailand, the largest electricity producer, the Electricity Generating Authority of Thailand, is still in the process to adjust to the new environment [35,36]. All parties involved try use data and information to justify their cause; for example, nuclear power plants would be totally safe as claimed by EGAT according to [32], but has been proven wrong by nuclear disasters, like in Tschernobyl, Ukraine, and Fukushima, Japan. According to the PDP 2015, Thailand plans to build two 1,000 MW nuclear power plants before 2036 [7]. On the other side Thailand as an emerging nation needs electricity for economic growth. Political decision makers, businesses, and the civil society have to discuss the way to go, whereas science and research has to develop options and to specify advantages and disadvantages of each solution.

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