Capital Stock intensive planning for India's energy transition

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Abstract:

In the global energy context, India has been in between the cross hairs as a developing country with unchecked emissions. India, along with China has always been a major emitter of greenhouse gases after the liberalization economic reforms and industrial revolution (1) in the 1990s. With India's agreement to reduce its carbon intensity by 31 percent from its 1990 levels at the COP 21 Paris summit in 2015, several pathways have been proposed and analyzed by several notable energy research groups (2)(3) . Most of these analyses point towards a major increase in solar Photo-Voltaic (PV) and wind capacity installations in India in an attempt to reduce its carbon intensity of electricity generation by 2030. With regards to this goal, India has already drafted a plan to have at least 175 GW of solar PV and Wind capacity by 2025 (4). In this study, an alternative analysis on the sustainability of a long term capital stock intensive strategy for India has been conducted, with a focus on long term sustainability in conjunction to the country's short- and medium-term goals.

Keywords: Energy transition, Capital stock, India

1 Introduction

The Indian electricity sector can be almost compared to the European electricity sector, both in capacity and size. However, the European sector has already progressed in the energy transition process towards green energy, while the Indian sector is still in the initial phase. Also, the magnitude of the changes to be made in the highly carbon intensive Indian electricity sector is on a completely different level, as the challenge to maintain economic growth along with the energy transition is going to be extremely difficult. The main reason for the high carbon intensity in the electricity sector in the country is its unplanned addition of cheap coal power plant capacities, in accordance to the economic reforms introduced in the 1990s (1) However, with the new 'make in India' industrial initiative, India now has the opportunity to plan its capacity expansion for the next few years, and it is crucial that the country learns from its past to make the right decision.

In this study, an analysis on the long-term capital stock intensive energy planning to smoothen the energy transition in India has been conducted, with all the challenges faced by the Indian electricity sector in mind. Most of the alternative electricity generation technologies available globally at this point of time are highly capital intensive, considering that development of such technologies on a large scale have only happened in the recent past. Thus, care has to be taken to select these technologies, while also considering their economic and technical useful life times. Capital stock gives us a measure of the value/ wealth of the invested assets, over their lifetimes. Therefore, a capital stock intensive planning is very much necessary, when it comes to long term sustainable energy planning. On the other hand, the financial situation of the Indian electricity sector is almost practically in ruins, with a significantly large portion of unpaid loans, losses over the years and semi-liberalization of the electricity market. This situation calls for an even more strategic planning, where the investments have to be much more carefully made.

2 The Indian electricity sector

The Indian electricity sector is significantly huge, with a transmission system spanning over more than 145400 circuit kilometers, over a billion consumers and around 900 TWh of annual electricity consumption. The sector is also characterized by an exponential demand growth rate of almost 6,9 percent, and is expected to be the core of many challenges to be faced in the future. Also, the sector is in the middle of an energy transition process, from conventional energy to carbon free energy. The uniqueness of this position is that the country has to maintain this transition process without hampering its economic growth.

The Indian electricity sector as discussed previously, is highly carbon intensive. As of the year 2017, the country had an installed capacity of 329,226 GW (3), out of which coal-based technologies occupy a major share of around 60 percent. The power plant fleet has new capacity additions of renewable energy technologies like Solar Photo-Voltaic (PV), onshore wind and biomass over the last few years, which add up to a total of around 18 percent. The development of the renewable share in the capacity mix has been significantly exponential over the years, considering the fact that the country had only around 2 percent of installed renewable capacity in 2006. The development of the renewable energy share can be credited to the many initiatives taken up by the Indian government, including subsidies and specified targets for renewables along with any new coal power addition.

Hydro power traditionally played a major role in the Indian electricity sector, but now has a moderately large share of around 14 percent, and the development of this share has been relatively saturated, considering the problems faced by hydro power installations in the Indian sub-continent (5). However, there has been developments in the small hydro sector, a large portion of the small hydro capacity in the country has been added in the recent past, over a few years. The nuclear power plant capacity in India is presently at 6,78 GW, the reason for such a small share is the fact that India is not a part of the non-proliferation treaty. However, several new reactor technologies are being experimented (6) for the use of Thorium as a fissile material for power generation. The classification of the Indian power plant fleet is as illustrated in the Figure (1), with respect to different generation technologies.

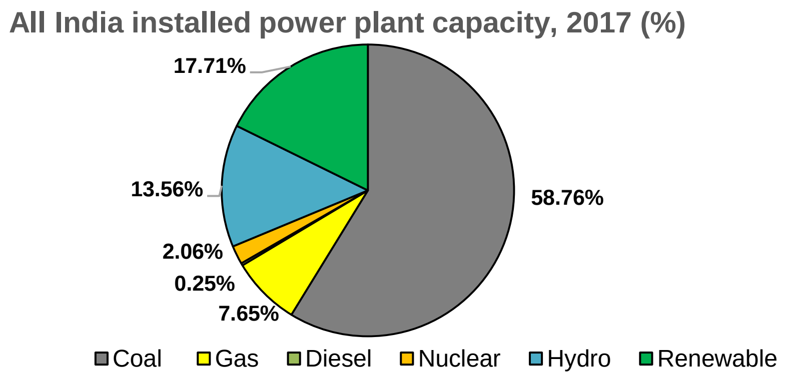

Figure (1) All India installed capacity by generation technology type, 2017, CEA

The liberalization initiative for the Indian market also brought in a lot of private investors to the sector, and over the years, made the growth in the development of the renewable energy and the small hydro shares in the country. Over the next few chapters, the previous situation that lead to the large capacity of coal power plants in India and the problems created by this process is discussed in detail.

3 The economic reforms of 1991

The Indian economy had a boost after the economic reforms introduced in the year 1991, bringing the manufacturing sector of India into priority. With subsequent economic benefits, a large number of manufacturing-based industries were established, over a short duration of time. Electricity generation in India is heavily dependent on conventional thermal power plant technology. Based on a relatively easy access to cheap coal from Indonesia, Australia and China, and the availability of domestic coal and peat, large capacities of coal fired thermal power plants were added to meet the unexpectedly high increase in the electricity demand after the economic and industrial reforms of 1990. The Figure (3) shows the capacity addition over the years after 1990.

Though, with the advent of renewable energy technologies like wind and solar PV in the last few years, the share of coal in the generation mix has decreased by a small extent of around 2 percent, the dependency of Indian electricity sector on coal is still predominant. With the recent reforms in laws and improvements in the domestic coal mining, coal easily becomes the cheapest source of electrical power in the country (3). Most of the domestically mined coal is usually exported to countries like china, Sri Lanka and other countries, and most of the available coal generation capacities are fired by imported high quality bituminous coal from Australia and Indonesia. Given the high dependency factor on imported coal, it can be expected that in the coal-import market, several governmental and private lobbies exist.

Even though India has made its commitment to decrease its energy related emissions by 2030 very specific and clear, coal is still expected to form a considerable share in the final electricity generation mix. Efforts are being made by the GoI to promote and increase the use of 'clean coal technology', as outlined by the National Action Plan for Climate Change (NAPCC) in 2008 (6). The NAPCC recommends that, in the immediate future, in view of the major coal –based power generation in the next decade, 'Supercritical' boilers are to be used and the introduction of ''ultra-supercritical' boiler technology, at least when the commercial viability of such a technology is verified.

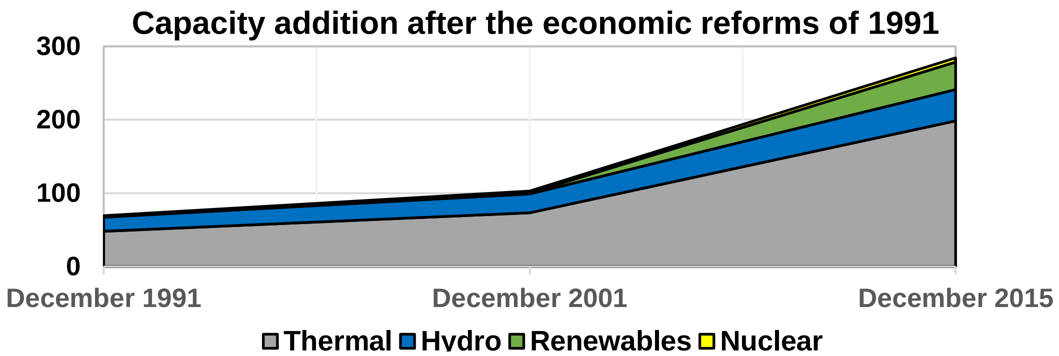

Figure (3) unchecked addition of coal fired capacities after the economic reforms of 1990, in India (CEA)

4 Challenges for India's energy transition

After the paris agreement in the COP 21, India agreed to curtail its energy related emissions by 30 percent by 2030 from its 1990 levels (1). To lose its dependency on coal fired power, India was already in the process of increasing the share of renewables in the capacity mix, albeit very slowly. With the curtailment of emissions goal, the transition process to the country's energy sector had to be subsequently accelerated. Several challenges were identified, for an accelerated transision of the Indian energy sector, and are summarized as follows:

4.1. High demand growth rate

India has been observing a large increase in electricity demand almost forever, especially more since the economic reforms of 1991. An observation of 6,9 percent annual increase in electricity demand leads to a challenge of increasing generating capacities in a much more sustainable way, other than increasing coal fired power plants.

4.2. Huge dependency on coal

Almost 60 percent of India's power generating capacity is coal fired, and almost 75 percent of its annual electricity generation comes from coal fired capacities. This huge dependency on coal fired electric power could be a significant obstacle to manage the energy transition process along with maintaining the economic stability of the country.

4.3. Nuclear power

India's long-lasting dreams of becoming a nuclear independent nation is yet to be fulfilled, as nuclear power faces several different obstacles in the country. The country has not signed the Non-proliferation treaty, thus limiting its ability to trade nuclear fuel and technology. However, India is on the cusp of developing a thorium-based fast breeder reactor (), which could help the country expand its nuclear power plant fleet, in the coming future.

4.4. CO2 emissions: Paris agreement, 30% reduction in intensity

Energy related emissions form at least 35 percent of India's overall emissions, making it a large challenge to sustain electricity generation while decreasing its emissions considerably. The ambitious target of 175 GW of solar PV and onshore wind by India could actually prove to be beneficial in reaching the emissions target by 2030.

4.5. Transmission and Distribution losses

The transmission network, and especially the distribution network in the country is inadequate, and existing networks are far from efficient. A study (2) showed that the transmission and distribution losses in the country amounted up to 20 percent, which would mean that every power plant utility would have to produce 1 extra unit in 5 units to satisfy the requirement. This would actually be a large financial burden to the generating utility, thus creating a financial problem in the Indian power sector.

4.6. Large scale renewable energy technology

The Large-scale renewable energy technology options available to the country at the moment would be solar PV and onshore wind, considering the large potential observed in the region. However, solar PV and onshore wind are quite expensive compared to the cheap electricity from coal. Also, a sudden increase in the renewable penetration in the energy system would probably create a large amount of complications in the already problem-riddled power transmission network.

As the power sector is already riddled with financial troubles, the expansion of large-scale renewable capacities would clearly pose a challenge, both economic and technical, for the country's power sector.

4.7. Energy Efficiency Targets

One of the easiest solutions to satisfy India's ever-growing electricity demand would be to improve the efficiency of electrical usage in the country, which has been proven to be a great strategy by many western countries in the world. However, with a large country like India and its many inhabitants, it would pose a significantly larger challenge to change the electrical appliance of each household in a short duration of time.

To discuss these challenges on a single platform would be yet another great challenge, hence they need to be tackled one at a time, by order of priority. And to prioritize these challenges, a systematic approach to study the Indian electricity sector has to be used. Analysing the capital stock could prove to be a really good approach to the financial crisis-struck Indian electricity sector.

5 ATLANTIS_India

ATLANTIS_India (7) is a techno economic simulation model developed at the Institute of Electricity Economics and Energy Innovation, Graz University of Technology. The model ATLANITS_India focuses on simulating the electricity economics of the Indian subcontinent, covering India and its five power regions, including the regions Bangladesh (BA), Bhutan (BH), Nepal (NP), and Sri Lanka (SL). The five power regions of India in the model are defined as per the definition from the Indian Transmission system operators (POWERGRID). A visual representation of the physical structure of the model ATLANTIS_India is as shown in the figure (4) given below.

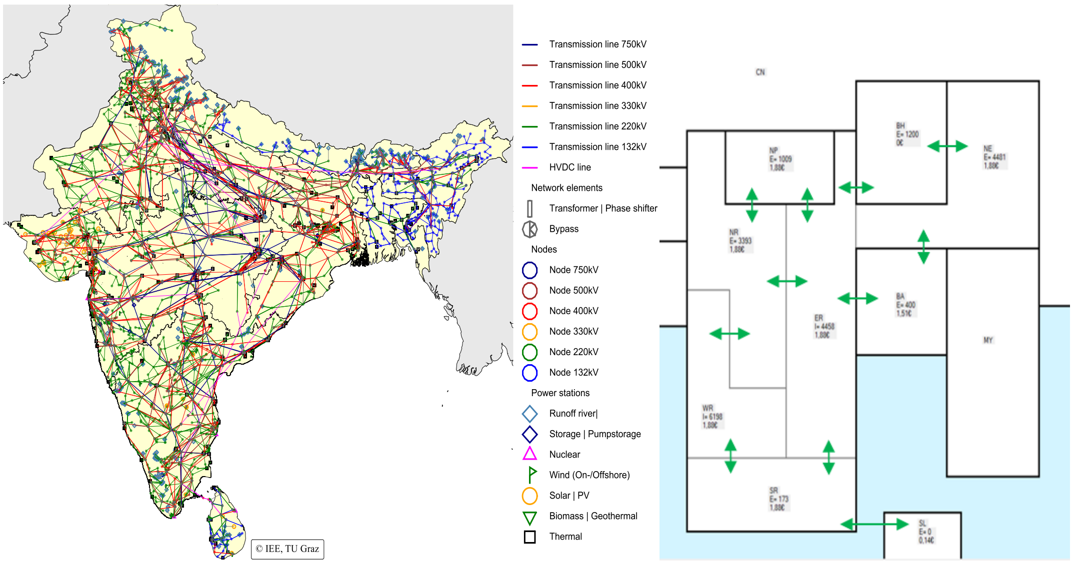

Figure (4) Representation of the physical structure (left) and the market model example (right) of the model ATLANTIS_India

With the model ATLANTIS_India, the electricity economics of the Indian subcontinent can be clearly analysed, and several futures for the region can be simulated. This provides us an opportunity to explore several different pathways to the development of the electricity sector in the Indian subcontinent region.

Another add-on to the ATLANTIS_India is the possibility to calculate the capital stock of the electricity system defined in the model. As the economic parameters of power plants, transmission network and scenario parameters are defined clearly in the model, it can export such parameters to the capital stock add-on, developed at the IEE, TU Graz, and the capital stock of several components of the energy system can be calculated. The capital stock calculations provide us with a variety of economic views, both on the existing system, and on the possible future.

For a possible calculation of Capital stock, the complete data set, both technical and the economic, have to be defined for the assets in the system. For example, the investments, the age of power plants, the expected lifetimes et cetera have all to be considered. A figure (5) shows the age structure of the power plant fleet in the southern region (SR) of India, as defined in ATLANTIS_India. The figure shows that the power plant fleet in the region is relatively young, under 30 years of lifetime used.

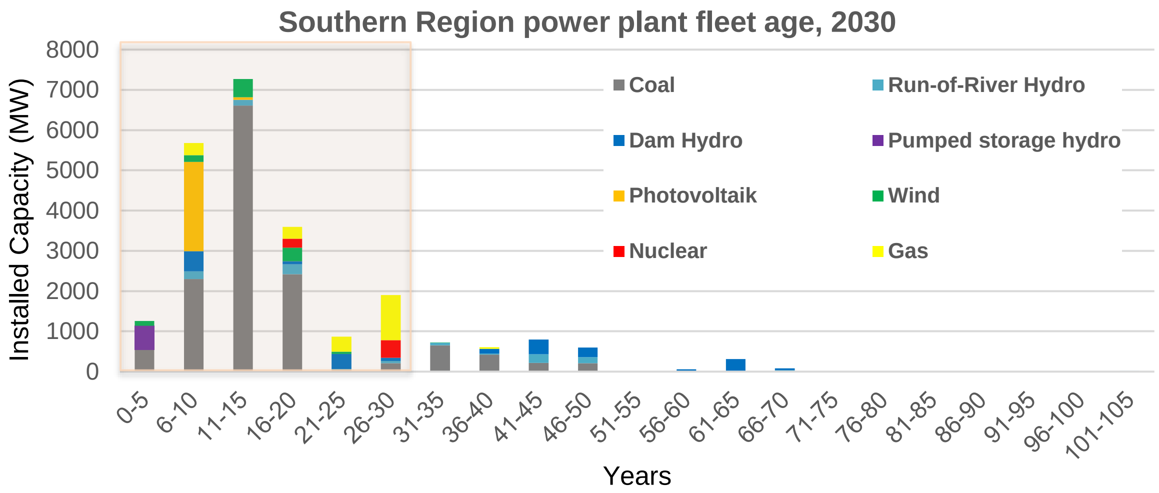

Figure (5) Age structure of the power plant fleet in the region SR, 2030

6 Capital Stock Analysis

Capital stock can be economically termed as the wealth /fortune of a company. The capital stock basically represents the total amount of capital invested by a company on assets. The capital stock concept for evaluation of assets highlights the preservation of long-lasting assets over their nominal capital. In our case, assets are power plants, transmission lines, and transformers. All such assets are invested upon with long term usage in mind. Each of such power plant types have specific investment costs, fixed variable costs and other economic parameters. Most of the power plants have high capital intensity, so a capital stock intensive plan to optimize the usefulness of such power plant types is really important. Transmission lines can also be classified according to overhead lines, cables and also based on terrain. Each of the investments are specified with an investment capital per kilometre of the type of the transmission lines.

The accounting of such assets in the books of the company is usually done using the historical acquisition values, which tend to under evaluate such assets, as they do not consider the replacement values. Under evaluation of assets which are invested upon with long term usage in mind, would lead to serious complications in the futuristic planning of the energy sector. This would mean that a power plant installed in the 1980s would cost almost the same as a power plant installed in the year 2020. However, capital stock calculations involve the use of replacement values over the lifetime of the asset, which is a better measure of the asset value than historical acquisition values. This measure of capital stock is called the Gross Capital stock, which does not take into considerations the depreciation values. The Gross capital stock values form the basis for the Net capital stock calculations, which is a much fairer measure of the asset value- as it considers the concept of depreciation. Depreciation considers the decrease of the assets value over the usage and lifetime, year by year, until the end of its useful life.

6.1. Capital Stock evaluation of power plant assets

Normally power plant type has specific investment costs based on the generation technology, fixed assets involved, availability of fuel and their geographical location. However, in the scope of this thesis, the investment costs are only specified per MW of generating capacity by power plant type. The net capital stock calculations can also differ based on the technical and economic useful times of the power plant assets. Considering the technical useful times would be a fair assumption as the power plant operates throughout the technical useful life than the economic lifetime which is usually mentioned in the accounting books of the owner company. The technical and the economic useful life times of various generation technology types are as mentioned in the table below.

Power Plant Type	Economical Life Time	Technical Life Time
Biomass	20	25
Lignite	20	25
Gas Turbine	40	45
Gas CCGT	30	35
Bituminous Coal	45	50
Nuclear BWR	50	60
Nuclear CANDU	50	60
Nuclear Thorium	60	100
Oil	40	45
PV	25	30
Pumped Storage	60	100
Dam Hydro	60	100
Run of the River Hydro	75	120
Wind Onshore	25	30

Table (1) Economic and Technical Useful times of power plant assets by technology type

The depreciation values of the installed power plants in each region are also taken from the simulation results of the economic model, from the base year till the target year. The capital investment, interest rates, fuel costs, personnel costs and other costs are all used to calculate the Goss Capital cost using the excel model by (8). Subsequently, the net capital costs are also calculated. The investment values if not available are scaled down from European values, as the data for the latter can be easily found. For the scaling down of values to Indian levels, the purchasing power parity of India versus the European Union aggregate comparison has been used.

7 Results: Capital Stock Calculations

After the detailed definition of the scenario for the calculation of the capital stock of the power plant fleet in the Indian subcontinent region, the Gross and Net capital stocks were subsequently calculated for each region defined in the model ATLANTIS_India.

An overall comparison of the increase in the Gross and Net Capital stocks for all the regions combined, was initially made, to get a bird's eye view of the capital stock situation in the subcontinent power plant fleet. This is represented in the figure (6) as shown.

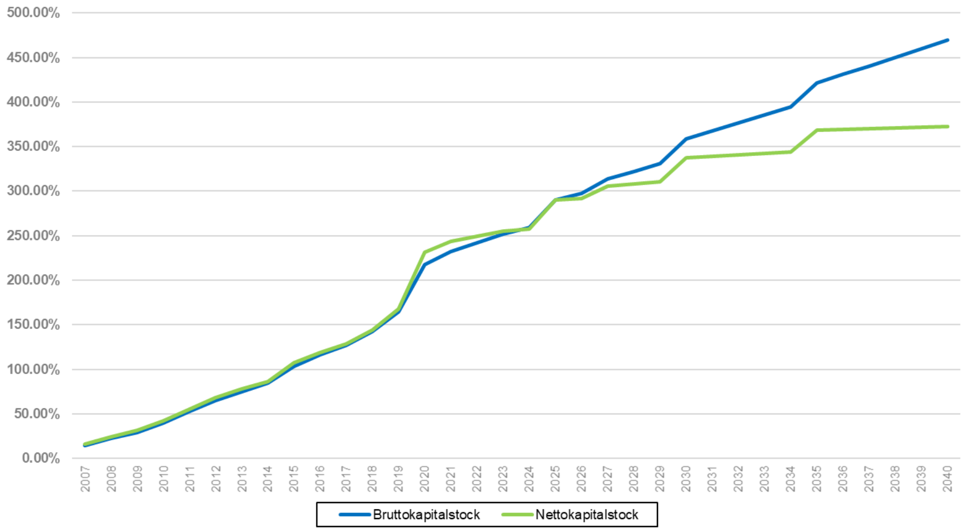

Figure (6) Comparison of the increase in Gross and Net capital stocks of all the regions defined in the ATLANTIS_India

We can see that there is a large increase in the overall capital stock of the power plant fleet. As most of the power plants in the power plant fleet are relatively new, the difference in the Gross and net capital stock is observed in the later stages of the timeline, especially when the thermal power plant fleet depreciates.

Also, a comparison of the Gross and Net capital stocks calculated for each region defined is as shown in the figure (7)

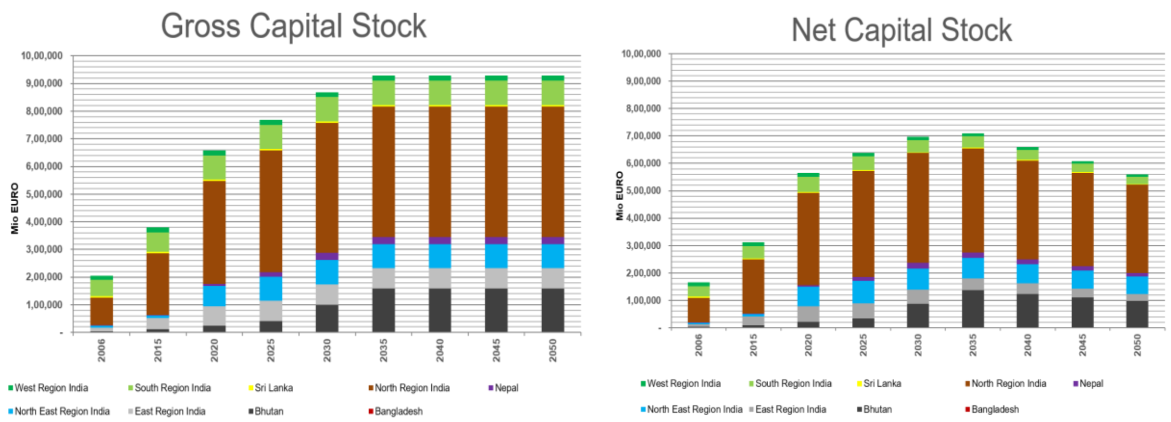

Figure (7) comparison of the gross (left) and net capital stocks (right) in each power region of Atlantis_India

A seemingly large increase in the capital stocks of the region of NR is observed, with the subsequent addition of hydro power capacities. The major Solar PV and Onshore wind installations in the SR and the WR fail to create an overall effect in the increasing of capital stocks in the respective regions. With several new hydro power plants planned by the Indian government and the Bhutanese government in the year 2030, the capital stock of the Bhutanese power sector gets a tremendous boost. With larger life times of hydro power capacities, the capital stock of the Bhutanese power sector gains a large share of wealth for a long duration of time.

A figure (8) provides us with an overview of the investment required over time, showing large scale investments in the 2020, 2025, 2030 and 2035 in renewable energy. The conventional power plant investments remain small but stable in comparison with the RES investments in the subcontinent,

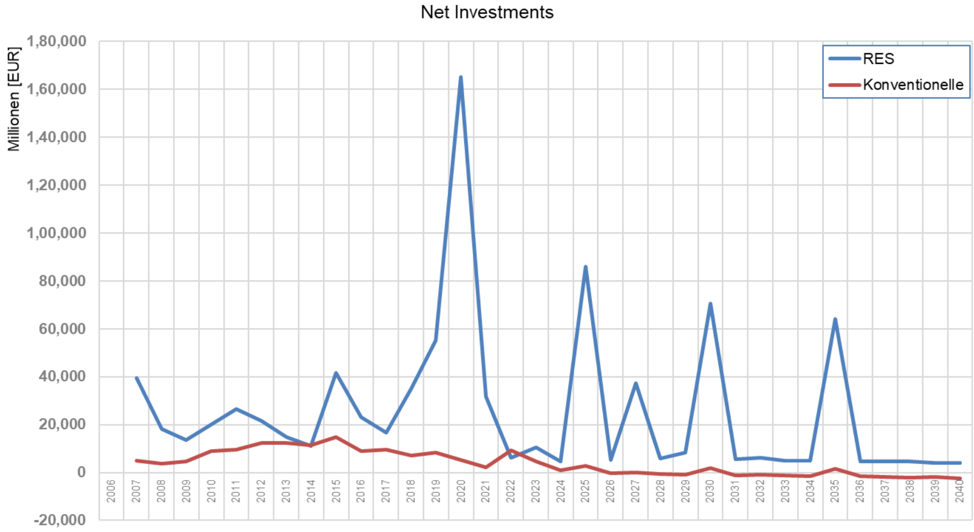

Figure (8) Investments over the years in the Indian subcontinent region

A comparison of the depreciation values gives us an estimation of the loss of value of installed capacities, in the year 2040. A figure (9) gives us the comparison of depreciation values by power plant type in the base year 2006 vs the target year 2040.

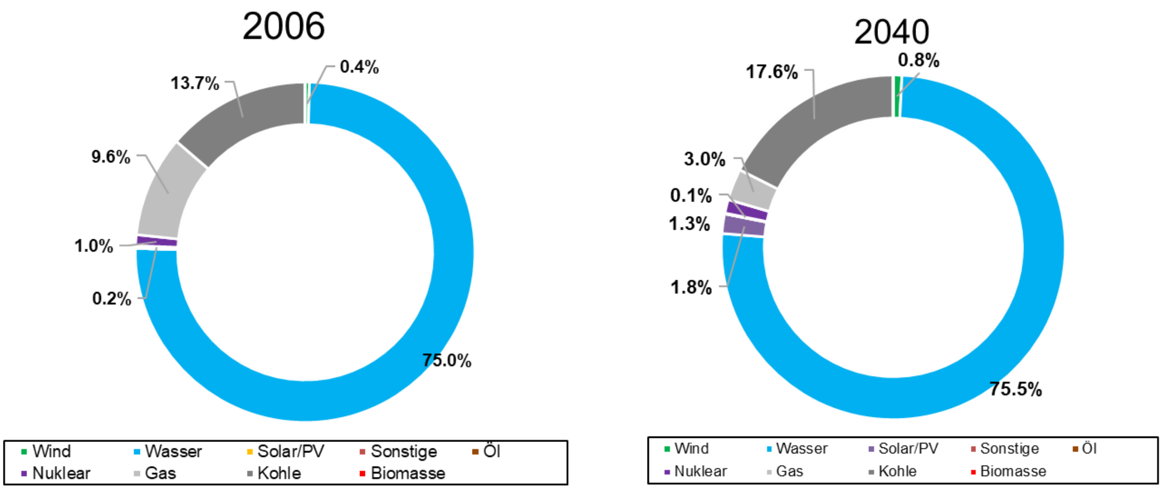

Figure (9) Depriciation values by power plant types in 2006 (left), and 2040 (right)

It can be observed that that the depreciation value of the hydro power share remains almost the same, while there is an increase in the depreciation values of the thermal power shares, including coal and gas. Coal power plants show the largest depreciation values in the thermal power share.

8 Discussion:

The results of the Gross and net capital stock calculations and their comparisons in each separate region give us a great deal of understanding about the situations in the respective regions. However, the results are too several to be discussed in the scope of this thesis. Therefore, a short summary of the significant results of each region are as discussed:

In the NR, BH, and NP regions, the hydro power capacity expansion practically build up almost all their respective capital stocks, thus showing the importance of hydro power installations in their subsequent regions. Even though a large capacity of thermal capacity like Coal in NR and gas in NP regions are planned, they falter in comparison with the capital stock contribution of the hydro power plant fleet.

In the WR and SR regions, thermal power takes a chunk of the capital stock share, while hydro power capacity still forms the major share in the capital stock of the respective power plant fleets. However, the thermal power contribution eventually decreases in the later years till the target year due to high depreciation values. The solar PV and wind power capacity expansions contribute relatively almost nothing to the build up of the capital stock in the respective regions. They still form a large part of the required investments over the subsequent years.

In BA and SL regions, the gas power capacity expansions form a major chunk in their respective capital stock shares. This could mean more RES and hydro investments are necessary for the sustainable development of the BA and SL power sectors.

Also, the following study only focuses on a Business-As-Usual case scenario, where the current policies of the Indian power ministry are included, and new capacities are not added as per strategical targets. However, with the build up of specific scenarios, a clear and accurate calculations of the power plant fleet in the region can be made. These scenarios would then focus on the several different pathways the future of the power sector of the subcontinent would take, as the power regions, the policies and their development are heavily dependent on each other. For further studies and for the scope of accurate capital stock evaluations, a scheme for scenario build up is proposed. The major priorities being market liberalization and increase of RES penetration, four pathways are worth looking in to. The representation of the pathways and their subsequent scenario definition can be shown in the figure (10)

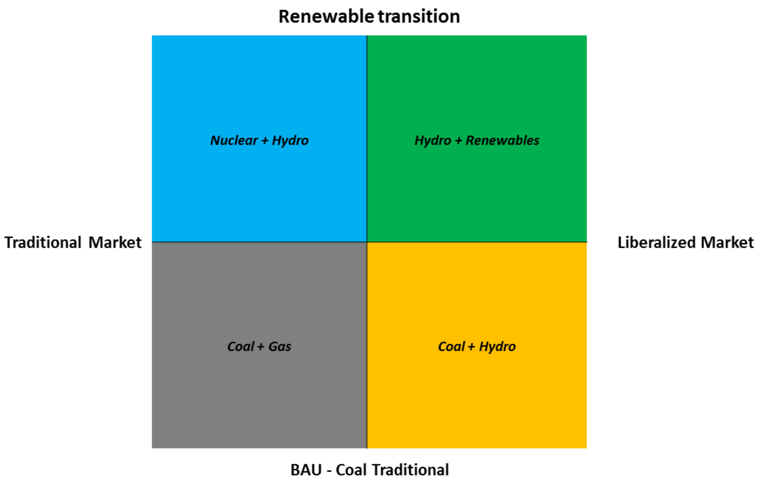

Figure (10) Scenario build up for future work

9 Conclusions:

With the Gross and net capital stock values of the power plant fleet, several observations and inferences were made for the Indian subcontinent power regions. Most of the thermal capacities planned are going to be depreciated by the end of the target year, so they would not contribute majorly to the net capital stock of most of the regions in the subcontinent. Hydro power obviously is the best choice when it comes to increasing the net capital stock of the power plant fleet, with large operational lifetimes and lower depreciation values. In fact, the huge boost in the capital stock of the Bhutanese power sector is solely due to the increase of the hydro power capacity. The economic and the social welfare of the region would follow with the eventual increase in the capital stock of their power sector.

Hence the focus should be on power plant technologies with high capital and large lifetimes, unlike the solar PV and wind power who have higher capitals and smaller lifetimes. Blind investments in solar PV and wind power could be then problematic, as they could lead to several asset stranded. Hence the solar PV and wind power strategy of India has to be sustainably planned. In the Indian power regions, encouragement to small hydro power plant installations should be increased, to add up to the capital stock pool of the Indian power sector.

All in all, if energy plans and strategies are done carefully, with long term sustainable focus, the transition towards carbon free energy could be possible in the subcontinent region.

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