BCCI-K

Global Green Growth Institute

Transitioning towards a Green Economy in Karnataka

CSTEP

CENTER FOR STUDY OF SCIENCE, TECHNOLOGY & POLICY

Transitioning towards a Green Economy in Karnataka

Center for Study of Science, Technology and Policy

December 2014

This report forms deliverables of the project initiated by the Global Green Growth Institute (GGGI) and the Bangalore Climate Change Initiative-Karnataka (BCCI-K) with its consortium partners: Center for Study of Science, Technology and Policy (CSTEP, Bengaluru), Indian Institute of Science (IISc, Bengaluru), University of Agricultural Sciences (UAS, Bengaluru), Institute for Social and Economic Change (ISEC, Bengaluru), Integrated Natural Resource Management (INRM, New Delhi) and the London School of Economics-India Observatory (LSE-IO, London).

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Foreword

India's present emissions are about 2,000 million tonnes, 1.5 tonnes per capita, well below those of the U.S. and China. Even though India is the world's third largest CO_2 emitter, it is third by a distance, with just 6% of the total emissions. Even under robust growth scenario assumptions, India's emissions in 2030 are expected to be about 4,000 to 5,000 million tonnes, or 3-4 tonnes per capita. Yet, the country's commitment towards the global commons was firmly grounded in Copenhagen, where India committed to reduce the emissions intensity of its GDP by 20-25% by 2020 in comparison to 2005 levels.

Several studies since have shown that the proposed climate mitigation efforts of India appear modest in the face of the enormity of the climate change challenge. States such as Karnataka, meanwhile, have begun identifying areas of action via the State Action Plans. Karnataka prides itself on being a progressive state. It is the fifth most industrialised in the nation and boasts of a flourishing services sector. As Karnataka proceeds on a path of accelerated development, its demand for energy, water and other natural resources will grow rapidly; local and greenhouse gas emissions too will grow. In this context, this report, 'Transitioning towards a Green Economy in Karnataka', prepared by the Center for Study of Science, Technology and Policy (CSTEP) under the aegis of Prof. B. K. Chandrashekar and the Bangalore Climate Change Initiative-Karnataka (BCCI-K) and supported by the Global Green Growth Institute (GGGI) is of utmost value and importance.

This report highlights that to balance its long-term goals (environmental sustainability) and short term objectives (economic progress through industrialisation and job creation), the state will have to pursue a green growth paradigm. Access to modern energy services and resources for industrial growth and urbanisation needs to be prioritised. However, the focus needs to equally be on technological changes to improve efficiency and reduce the rate of emissions growth. The state can do a lot more to alleviate the stress on the climate and the environment while ensuring its development through effective policy formulation and implementation.

I would like congratulate the researchers for their pioneering analyses. Several other Indian states can also draw important insights from the approach and the analyses. I sincerely hope that the recommendations for Karnataka are put into good effect by its policymakers.

Dr. Anshu Bharadwaj

Acknowledgement

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Agricultural Demand Side Management (AgDSM)

Bangalore Climate Change Initiative-Karnataka (BCCI-K)

Bangalore Metropolitan Transport Corporation (BMTC)

Bangalore Water Supply and Sewerage Board (BWSSB)

Billion Cubic Meter (BCM)

Billion Passenger Kilometer (BPKM)

Billion Tonne Kilometer (BTKM)

Bureau of Energy Efficiency (BEE)

Business-as-Usual Scenario (BAU)

Central Pollution Control Board (CPCB)

Common Effluent Treatment Plant (CETP)

Compound Annual Growth Rate (CAGR)

Compressed Natural Gas (CNG)

Dabhol-Bangalore Natural Gas Pipeline (DBNP)

Demand Side Management based Efficient Lighting Programme (DELP)

Distribution Transformer (DT)

Distribution Transformer Center (DTC)

Domestic Waste Water (DWW)

Electric Vehicle (EV)

Electric 2 Wheeler (E2W)

Electric 4 Wheeler (E4W)

Energy Conservation Building Code (ECBC)

Energy Efficiency Services Limited (EESL)

Energy Performance Index (EPI)

Gigawatt (GW)

Global Green Growth Institute (GGGI)

Greenhouse Gas (GHG)

Green Growth Scenario (GG)

Gross State Domestic Product (GSDP)

Heating, Ventilation, Air Conditioning (HVAC)

Heavy Commodity Vehicle (HCV)

High Voltage Distribution System (HVDS)

Indian Rupees (INR)

Industrial Waste Water (IWW)

Information Technology & Information Technology Enabled Services (IT & ITES)

Karnataka Renewable Energy Development Limited (KREDL)

Kilo Tonne (kt)

Kilo Tonne Per Day (ktpd)

Light Commodity Vehicle (LCV)

Liquefied Petroleum Gas (LPG)

Marginal Abatement Cost Curve (MACC)

Micro, Small and Medium Enterprises (MSMEs)

Million Cubic Meter (MCM)

Million Litres Per Day (MLD)

Million Tonnes of Oil Equivalent (Mtoe)

Million Tonnes of Carbon Dioxide Equivalent ($MtCO_2e$)

Monitoring & Verification (M&V)

National Ambient Air Quality Standards (NAAQS)

National Electric Mobility Mission Plan (NEMMP)

New Industrial Processes (NIP)

Niranthara Jyothi Yojana (NJY)

Non-Motorised Transport (NMT)

Oxides of Nitrogen (NO_x)

Particulate Matter (PM)

Perform, Achieve and Trade (PAT)

Piped Natural Gas (PNG)

Plant Load Factor (PLF)

Rajiv Gandhi Gramin LPG Vitaran Yojana (RGGLVY)

Rashtriya Krishi Vikas Yojana (RKVY)

Renewable Purchase Obligation (RPO)

Representative Concentration Pathway (RCP)

Restructured Accelerated Power Development and Reforms Program (RAPDRP)

Specific Energy Consumption (SEC)

State Action Plan on Climate Change (SAPCC)

Sulphur Dioxide (SO_2)

Terawatt Hour (TWh)

Tertiary Treatment Capacity (TTC)

The Integrated MARKAL EFOM System (TIMES)

Tonnes per Day (tpd)

Transmission and Distribution (T&D)

Underground Drainage Facility (UGD)

Urban Local Body (ULB)

Waste Heat Recovery (WHR)

Executive Summary

As a progressive state, Karnataka envisions job-oriented, inclusive economic growth through sustainable industrialisation and accelerated urbanisation. These transitions are likely to increase the demand for resources and energy significantly. The achievement of this vision may be threatened by limits on resources such as fossil fuels, land and water, and adverse impact on quality of life from air pollution, climate change and traffic congestion. To address these challenges, a green economy strategy that can enable the state to meet the allied developmental imperatives of economic growth along with natural resource and environmental sustainability is presented.

This report focused on agriculture, buildings, industries, transport, and power supply – sectors that account for all the state's energy requirement and over 70% of its Greenhouse Gas (GHG) emissions. Current policies in these sectors may not be sustainable in the long-term. To summarise:

- Due to industrialisation, energy demand in industries is projected to grow by three times, reaching 32 Million Tonnes of Oil Equivalent (Mtoe) by 2030, with thermal energy demand growing faster than electricity demand. Over 90% of this thermal demand will be met by industrial grade coal, much of which will have to be imported. Cement and Steel industry will account for over 80% of the industrial energy demand
- Bangalore's commercial floor space area will increase almost three fold to reach 300 million sq. feet by 2030 driven by high growth in services. In this context, commercial sector electricity demand in the state is projected to increase from 4 Terawatt Hour (TWh) in 2010 to 48 TWh in 2030. Together the demand from commercial and residential buildings is set to grow seven-fold from what it is today, contributing more than half of the state's electricity consumption by then
- If the current inefficiency in irrigation pumping continues, the state would have cumulatively spent INR 400 billion by 2020, and INR 1 trillion by 2030 on electricity subsidies
- By 2030, more than half of Karnataka's 72 million people will live in cities. Coupled with increasing urban sprawl, this will mean a four-fold increase in mobility demand over the next 20 years. Despite the ongoing efforts to build metro trains and expand bus network, the number of vehicles on road is likely to grow by over three times to reach 20 million, thereby worsening congestion, road safety and air quality. Oil consumption from freight and passenger transport will also increase to 15 Mtoe, from about 4 Mtoe currently
- Electricity demand in the state would grow four-fold to about 150 TWh by 2030. In order to meet this demand, the installed capacity in the state would need to increase to 40 Gigawatt (GW) by 2030, over three times the current capacity of 12 GW. If ongoing policy efforts on renewable energy are not accelerated further, coal capacity of about 18 GW would be required by 2030, which will have substantial implications for energy security of the state
- Water demand from the power generation sector driven largely by cooling for coal fired plants is likely to double to about 1.7 Billion Cubic Meter (BCM) in 2030. Approximately 840 Million Cubic Meter (MCM) of domestic waste water (DWW) will be generated in 2030, of which half will remain untreated. Meanwhile, 60-65% of

the 1 BCM of industrial waste water (IWW) generated by 2030 will be unfit for reuse and contribute to water pollution. This, along with the growing demand for agricultural produce and rapid urbanisation is likely to stress limited water resources

- Annual Particulate Matter (PM) and Oxides of Nitrogen (NO_x) emissions from the transport sector are estimated to increase by 1.5 times to 50 tonnes per day (tpd) and 480 tpd respectively while Sulphur Dioxide (SO_2) emissions from the power sector are likely to grow by around five times to about 2,730 tpd in 2030. The rise in overall energy demand coupled with an increasing share of coal in energy supply would also result in a near four-fold increase in GHG emissions to over 300 Million Tonnes of Carbon Dioxide Equivalent ($MtCO_2e$)

This study identified and evaluated sixteen opportunities based on their feasibility for implementation in the state, potential to reduce GHG emissions, and ability to fulfil the state's vision for sustainable growth. Together these opportunities have the following key impacts:

- The overall demand for fossil fuels can be reduced by about 19% through greening opportunities. Industries can avoid 8 Mt of annual coal use through increased energy efficiency, thereby reducing expenditure on energy and improving competitiveness. Further, annual demand for petroleum products can also be reduced by 4 Mtoe through initiatives such as intensifying public transport, improving fuel efficiencies across the board, and increasing thrust on electric vehicles
- Electricity demand in the state can be reduced by about 20 TWh through improved energy efficiency in buildings, industry, and agriculture. Along with other *green* interventions, such as aggressive reduction in Transmission and Distribution (T&D) losses (limited to 8%) and increase in the share of renewable energy (to at least 30%), coal requirement for the power sector can be reduced by 20 Mt in 2030 – nearly double the consumption by the sector in 2010
- Green opportunities can also reduce water stress in the state. Lower thermal electricity generation can reduce water demand of the power sector by 304 MCM in 2030 while improvement in secondary and tertiary waste-water treatment can cumulatively free up an additional 3.1 BCM of water till 2030
- Concerns over air quality, particularly in Bangalore, can be significantly mitigated by implementing greening options for transport, particularly the transition of buses and taxis from diesel to Compressed Natural Gas (CNG) and improvements in fuel efficiencies of new vehicles. Green growth opportunities can also avoid 70 $MtCO_2e$ in 2030, reducing the emissions intensity of the Gross State Domestic Product (GSDP) by 37%

Using multi criteria analysis, assessment of current policy landscape, and consultation with a wide set of stakeholders, this report concludes by laying out key green growth opportunities for the state, i.e. increasing energy efficiency in industry, reducing T&D losses, intensifying public transport, and generating more electricity from wind power. To pursue a green growth paradigm, the state should create a policy action plan to implement this strategy. This study presents policy recommendations and identifies specific research studies that could inform such an action plan.

Introduction

Karnataka is the eighth largest state in India. It has a population of about 61 million people, which is 5% of the national population. The state contributed 5.46% of the Gross Domestic Product (GDP) of India in 2011-12. During the 11th Five Year Plan period (2007-08 to 2011-12), Karnataka's GSDP grew at a Compound Annual Growth Rate (CAGR) of about 7.2% to INR 2,864 billion (about USD 47 billion).[i] The state showed steady growth over the last decade, and with a progressive industrial and trade policy it is also known to be investor friendly. It is also amongst the top urbanised states with a strong base of education and research institutions.

Karnataka's service economy, riding high on the success of the Information Technology and Information Technology Enabled Services (IT & ITES) boom, contributes highest to the economy (around 60%) followed by industry and agriculture.
Over the past few decades, a sectoral shift has occurred in the state economy from agriculture to the services sector. However, because of low employment elasticity of the services sector, labour has not shifted commensurately from agriculture. By 2030, 66% of the total population will be a part of the work force, i.e. an additional 270,000 each year[ii]. With this in mind, the Karnataka Vision 2020 aimed at a job-oriented, inclusive economic growth. The vision also identified that 'sustainable and orderly process of industrialization' and accelerated, planned urbanisation will drive this growth.[iii]

Karnataka aims at a job-oriented, inclusive economic growth through sustainable industrialisation and planned urbanisation.

Karnataka's development strategy envisions a CAGR of 8.65% between 2010 and 2020 to attain a GSDP of INR 7,693 billion. A majority of the additional workforce is envisaged to be absorbed as low-skilled or semi-skilled labour in industry. This implies an increased reliance on the sector, with its value addition to GSDP doubling by 2020 (Figure 1).[1] However, industrial growth needs to be complemented with economic infrastructure such as power provision, material and fuel linkages. Further, rapid urbanisation will likely increase the demand for goods and services such as housing, electricity provision, municipal services like water supply, sanitation and waste management, roads and public transport infrastructure.

The state's policy objective may hence be interpreted as green growth, i.e. to meet the allied developmental imperatives of job-oriented inclusive growth and environmental sustainability. In order to ascertain effectiveness of any policy action in achieving these goals, the complexities emerging from future socio-economic transitions such as rapid urbanisation and competing pressures on natural resources need to be understood. Thus, this study examined the energy-economy-environment nexus and developed a green economy strategy for Karnataka.

More than half of Karnataka's 72 million population in 2030 will live in cities; the state's economy will rely on doubling of industrial output by 2020.

[1] Karnataka Vision 2020 document estimates a CAGR of 0.8%, 7.9%, 10.1% in the primary (agriculture), industry and services sectors respectively, until 2020. From then on, until 2030, the industries and services sectors are assumed to grow at 1% lower CAGR.

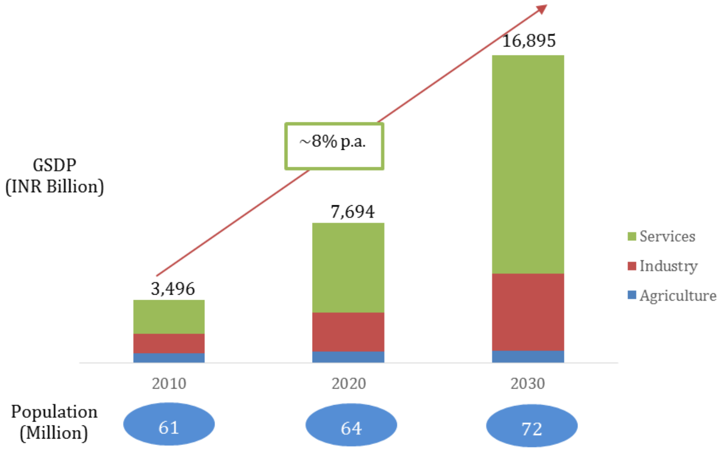


Figure 1: GSDP and Population Projections for Karnataka

Karnataka's State Action Plan on Climate Change (SAPCC)[2] identified several opportunities for the state to mitigate climate change.[iv] Under the Green Economy Strategy, the report identified key green growth opportunities for the state based on: 1) relevance and feasibility for implementation in the state, 2) potential to reduce GHG emissions, and 3) fulfil the state's vision for sustainable growth. Based on this classification, the report focused on buildings, agriculture, industries, transport, and power supply – sectors which account for all the energy requirement of the state and over 70% of the state's 2010 GHG emissions. Further, the ability of these key opportunities to meet multiple green growth objectives over the long term was considered in order to arrive at a prioritised set of relevant interventions that can be taken up by the state in the short-term. The approach and brief methodology for developing the strategy is presented in Figure 2.

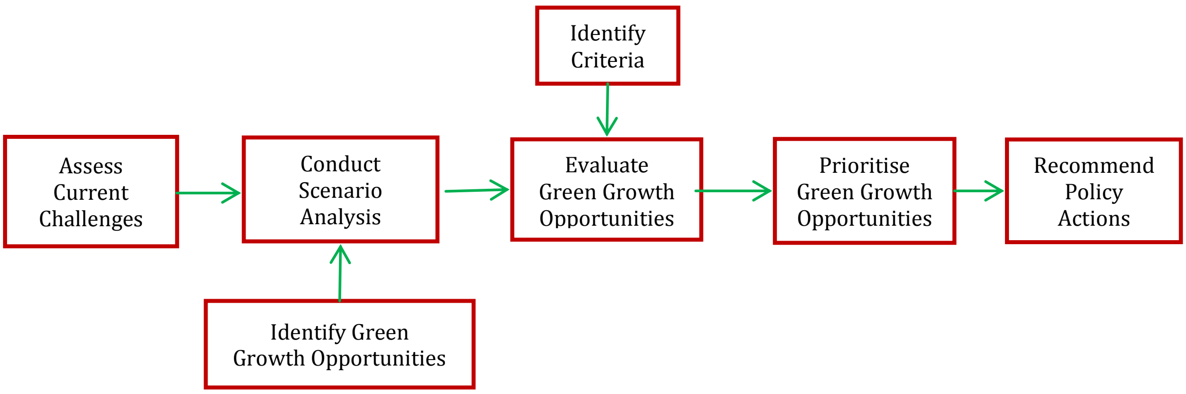


Figure 2: Approach to Green Economy Strategy

To assess the current challenges faced in energy intensive sectors, a review of policy evaluation documents and government data sources was undertaken. The analysis considered future trends in the demand and supply of key resources, and their impact on the environment with

2 The SAPCC is the first action plan document that identifies over 200 action areas for enhancing climate resilience and mitigation efforts across various sectors. It was prepared under a national directive derived from the National Action Plan on Climate Change.

the use of an energy modelling suite – The Integrated MARKAL EFOM System (TIMES)[3]. The model was developed to provide a consistent framework to analyse long-term trends short-term decisions, and their systemic effects. This was supplemented with stakeholder consultation, literature review and qualitative assessments. A scenario highlighting the impacts of the current policy architecture, or the Business-as-Usual Scenario (BAU), was developed as a baseline to evaluate greening opportunities using identified criteria. The feasibility of green interventions mentioned in SAPCC and the potential for their aggressive uptake was studied.

Sectoral government plans, annual reports and policy documents such as the SAPCC were used to identify key criteria to guide prioritisation. The criteria included green growth benefits beyond mitigation such as energy security, job creation, pollution reduction, and land and water availability. These criteria, along with a financial evaluation of various greening opportunities were evaluated using a multi-criteria analysis framework to prioritise opportunities requiring policy focus or/and deeper analysis. An analysis of challenges to realising the key opportunities was then conducted to inform policy recommendations.

The TIMES Model

To analyse the future implications of Karnataka's growth path on energy, and correspondingly on environment, the study engaged the TIMES platform. TIMES is an energy system optimisation tool that enables user to consistently analyse interactions of growth with energy demand and its impact on supply, evaluated in the context of resource availability, technology and policy.

[3] The waste sector and residential cooking have been modelled outside the TIMES framework

The Business-as-Usual Scenario

Karnataka has instituted several policies to enable sustainable growth. This section evaluates the extent to which current policies in each sector may succeed in meeting this objective in the long-term[4] and presents the challenges likely to be faced, such as meeting demand for energy and resources. Further, cross-sectoral implications, namely the state's fossil fuel dependence, environmental degradation from waste generation, air pollution and water scarcity have been highlighted.

Sectoral Assessment

Industry

Karnataka is the fifth most industrialised state in India and among the top producers of cement (~15 Mt) and iron and steel (~10 Mt). It is also, the leading producer of iron ore, and has significant limestone reserves. It hosts one of India's largest COREX-based steel plants (JSW, Vijayanagar) and one of the world's largest cement plants (ACC, Wadi). It processes almost 13 Mt of crude oil per year[v], and produces over 1 Mt of urea for agricultural use.

Iron and steel sector is the major industrial energy consumer, and accounts for 63% of industrial energy demand. Apart from large players such as JSW and KIOCL, there are 24 coal-based sponge iron plants which account for over 15% of production.[vi] However, these operate at low efficiencies and are unable to employ automation and efficient technologies because of their low operating margins.

Karnataka may be largest steel producer, and among the largest cement producers in India in 2030.

Based on past trends of industrial production and Karnataka's growth aspirations, the production of steel and cement may grow four-fold to 40 and 43 Mt respectively (Karnataka could become the largest steel producer in India). Aluminium production may grow seven-fold to 0.70 Mt, and other industries (such as textiles, paper, and fertilisers) may almost double their production. Karnataka's industry could become crucial in fuelling the country's infrastructure development.

The recognition of inefficient energy utilisation in steel and other large industries led to the design of the Perform, Achieve and Trade (PAT) scheme under the National Mission for Enhanced Energy Efficiency. This is currently the guiding principle for industrial energy efficiency. Even if Karnataka's industries were to achieve the PAT targets of 5-7% reduction in Specific Energy Consumption (SEC), the total size of industrial activity will dwarf the gains from PAT savings (see Figure 3).[vii]

[4] Appendix 1 lists out the sector-wise assumptions considered in BAU.

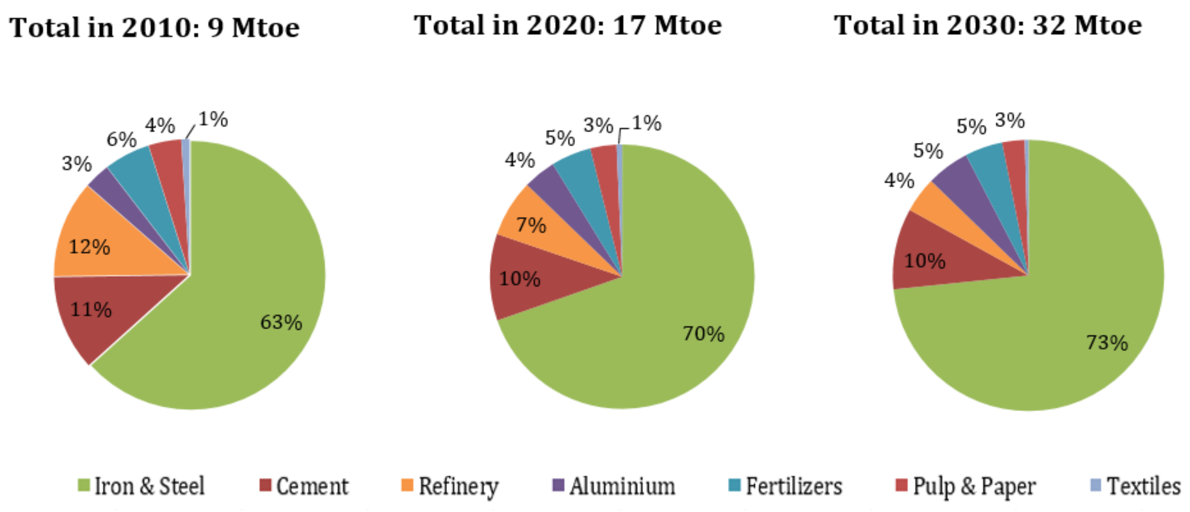


Figure 3: Sector-wise Industrial Energy Consumption in BAU

Overall, industry will remain the dominant consumer of energy in the state, with its share in total energy demand declining only marginally from 57% currently to 54% by 2030. The total energy demand from industries will grow more than three-fold, from 9 Mtoe in 2010 to 32 Mtoe in 2030. Iron and steel sector will be the chief consumer, contributing 73% of the total industrial energy demand; cement will rank a distant second at 10%. Though aluminium production will register a strong growth in this period, its share of energy demand would only increase from 3 to 5%, owing to its relatively small size.

Rapid growth in industry will increase requirement for electricity and imported coal.

Thermal energy requirement, mostly for producing cement and steel, will grow from 9 Mtoe to 32 Mtoe, with coal supplying over 90% of this demand. Electricity requirement will grow three-fold to 32 TWh by 2030, putting serious pressure on the electricity grid. Captive generation, which is inherently inefficient and expensive,[5] is expected to meet most of this demand, and most of this electricity will be generated through coal.

Most industrial grade coal is imported and the share of imported coal for power is also rapidly increasing. This could subject industries to uncertainty in fuel costs. As energy costs account for up to 40% of manufacturing costs in large industries, failure to improve energy efficiency could adversely impact competitiveness in the long-term.

Buildings

Residential Buildings

By 2021, around 1.5 million additional houses would be required, mostly to accommodate the expanding urban populace[viii]. More houses and increased affluence will lead to a high demand for appliances (both in number and type) resulting in greater electricity demand. In rural Karnataka, under the *Niranthara Jyothi Yojana* (NJY), uninterrupted power for residential use is expected to increase energy demand. Meanwhile, state policies such as the *Belaku* scheme that

[5] Thermal captive plants operate on lower PLFs than grid-based plants, and their generation efficiencies are in the order of 30% compared to national average of 33%.

aims to improve lighting efficiency, will only help in offsetting a fraction of the new electricity demand.

Further, the demand for modern cooking fuels will rise as incomes increase. While the share of urban households using Liquefied Petroleum Gas (LPG) has increased significantly from 44% to 65% over the last decade, the share of rural households with access to LPG has witnessed a modest improvement from 5% in 2001 to 11% in 2011. Consequently, over 80% of the rural population still relies on traditional biomass as the primary fuel for cooking. To address this disparity, the *Rajiv Gandhi Gramin LPG Vitaran Yojana* (RGGLVY) was launched in 2009 across the country.

Commercial Buildings

The services-led economy of the state implies that the demand for commercial buildings will continue to rise steeply. A majority of these are likely to be concentrated in and around Bangalore, with the commercial floor space increasing from 100 million sq. feet to 291 million sq. feet by 2030.[ix] Heating, Ventilation, and Air-Conditioning (HVAC) and server loads are likely to become significant drivers of energy demand. In general, growth in the stock of air-conditioners will be the key factor in driving electricity demand.

A surge in built-up commercial and residential floor space will increase electricity demand in buildings to seven times.

Karnataka has already notified the Bureau of Energy Efficiency (BEE) Energy Conservation Building Code (ECBC) for large commercial buildings, but progress in terms of reducing energy intensity has been slow. The Energy Performance Index (EPI) of commercial buildings has been in the range of 250-302 kWh/m^2, whereas the ECBC compliance threshold lies at 180 kWh/m^2.[x]

Energy Demand from Buildings

Commercial sector electricity demand, which grew by more than three times between 2005 and 2012[xi], is projected to increase almost 12 times by 2030, rising from 4 TWh in 2010 to 48 TWh in 2030.

Residential demand doubled over the same period (2005-2012)[xii], and is likely to grow to 35 TWh in 2030, increasing by five times from 7 TWh in 2010. In addition, the household demand for modern cooking fuels is likely to increase from about 0.6 Mtoe to 1.6 Mtoe, with LPG and Piped Natural Gas (PNG) meeting nearly two-thirds of the cooking energy requirement in 2030.

Figure 4 provides the electricity demand from residential and commercial buildings.

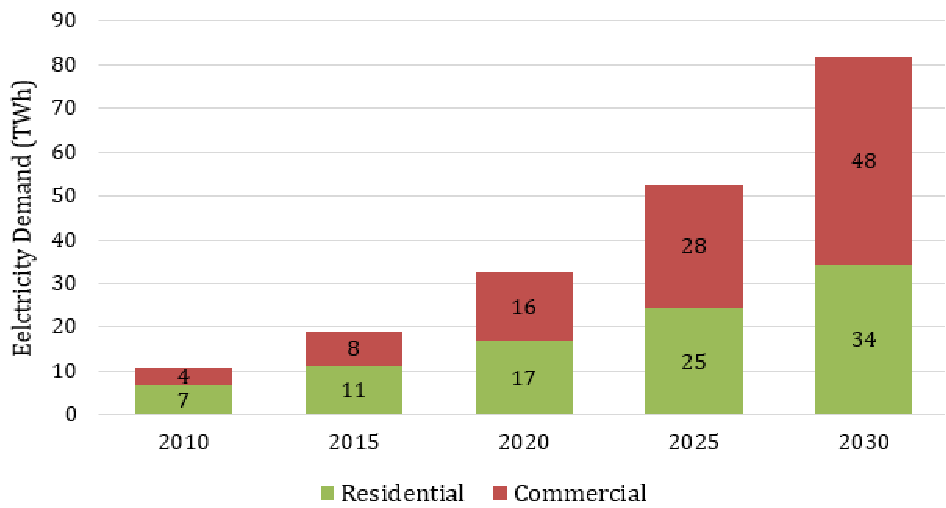


Figure 4: Electricity Demand from Buildings in BAU

With rapid increase in built-up area, municipal services such as solid waste management, sewage treatment, street-lighting, and water pumping[6] will need to be expanded, putting a strain on municipal budgets.

Transport

> Urban transport infrastructure would be under severe stress due to a four-fold increase in demand for mobility.

This analysis considered freight and passenger road transport. Nationally, road is the principal mode for passenger transport, meeting over 80% of the passenger transport demand.[xiii] The passenger transport demand in Karnataka from road in 2010 is estimated to have been about 180 Billion Passenger Kilometres (BPKM), with urban transport accounting for about 100 BPKM. About 80% of the urban transport demand is currently met by buses and two-wheelers, servicing nearly half and one-third of the demand respectively. In the next 20 years, a steady economic growth, higher working population, and longer trips due to urban sprawl[xiv] will lead to a four-fold increase in the demand for urban transport, nearly tripling the demand for passenger transport as a whole.

Bangalore, which accommodates over 40% of the vehicles in the state[xv], is expected to account for a significant share of urban transport demand. Though the city has a relatively dense public transport network – at 6,110 buses, its bus fleet is amongst the largest for an Indian city[xvi] – the number of buses per million people has reduced from about 800 in 2008 to less than 700 today (cite). Further, the number of private vehicles in the city has been increasing by about 25,000 per month.[xvii] If these trends continue, current initiatives to extend the bus network and build over 110 km of the Bangalore Metro would fall short in meeting the projected increase in demand for mobility. Consequently, the share of public transport is likely to decline further and the number of cars will increase to four times the present stock.

This would significantly worsen the challenges of urban transport in Bangalore. The city is planned primarily for motorised travel and ranks amongst the lowest in the country on walkability.[xviii] It scores particularly low on amenities for pedestrians, availability of quality

[6] Electricity requirement for these services will grow nearly five-fold from 3 TWh in 2010 to 14 TWh in 2030.

pavements and safe crossings, and motorist behaviour. In fact, nearly half of the 771 deaths and one-third of the 4,200 injuries from road accidents in 2013 involved pedestrians.[xix] Further, congestion in the city would also worsen. The travel time in the city is becoming longer every year and the average waiting time due to congestion has risen from about 12 minutes in 2008 to over half an hour.[xx] At this rate, the present average speed of 15-25 kmph in the city may reduce to just 10 kmph by 2030.

In the absence of integrated land-use and transport planning, other cities in the state will also experience similar mobility challenges. Cities such as Mysore, Hubli-Dharwar, and Mangalore are currently characterised by a high share of non-motorised transport (25-40%), low car use (less than 10%), and relatively short trips (ranging from 1-6 km). As these cities witness a period of rapid population growth, there would be a need to implement measures to check sprawl, retain a high share of non-motorised transport, and develop public transport. Otherwise, the reliance on private vehicles could increase their number in these cities by three to four-fold by 2030.

Even for freight transport, the national modal share of road is higher than 70%. Road was estimated to supply about 80 Billion Tonne Kilometres (BTKM) of freight volume in Karnataka in 2010. At over 150,000, the number of Light Commodity Vehicles (LCVs) is close to the number of Heavy Commodity Vehicles (HCVs) in the state. However, because of their low tonnage, LCVs contribute less than 15% to the total freight volume. As the economy grows, both the production and consumption of goods would rise, and the demand for freight transport would increase to almost 300 BTKM by 2030. The contribution of LCVs to meet this requirement is likely to reduce further as the sector becomes better organised. Yet, fuel efficiency may not improve significantly unless standards announced by the BEE, currently limited to cars, are extended to include trucks and lorries as well.

Oil consumption will increase four-fold worsening air pollution and adversely impacting the import bill.

The resulting demand for energy from freight and passenger road transport would increase from about 4 Mtoe in 2010 to nearly 15 Mtoe by 2030. Without greater policy effort to diversify and clean the fuel mix in transport, diesel and petrol are likely to meet most of this requirement.[7] While auto rickshaws in Bangalore have switched from diesel and petrol to LPG, the state's response to CNG has been cautious due to concerns over gas pricing. Similarly, the high procurement and battery costs of Electric Vehicles (EVs) has also meant that only about 1 in every 100 cars being sold in the state runs on electricity.[xxi] A recent pilot to introduce electric buses by the Bangalore Metropolitan Transport Corporation (BMTC), if successfully scaled up and replicated, could give the necessary thrust to electric vehicles. Otherwise, oil consumption will increase nearly four-fold by 2030, not only worsening air pollution in the state but also adversely impacting energy security and the import bill.

[7] 10% ethanol blending for petrol as per state plans has been considered.

Agriculture

Irrigation Water Pumping

Lack of institutional incentives for energy efficient pumping could lead to the state cumulatively spending INR 400 billion in subsidies by 2020.

Agriculture currently consumes 84% of the water resources of the state, and around 45% of the irrigation requirement is met through underground resources. Between 2004 and 2009, there was a decline of 3% in net groundwater availability in the state due to extraction exceeding replenishment. Average head[8] has dropped in some districts from 15-20 feet to 150-1,200 feet in the last decade.[xxii] Thus, a high demand for water pumping and rapidly depleting groundwater resources have resulted in increased electricity demand from agriculture.

Since power supply to irrigation pumps is largely unmetered and there are a large number of unaccounted pump-sets,[9] a reliable account of electricity consumption in agriculture is difficult to obtain. However, official estimates suggest that 35% of grid electricity is used for irrigation pumping, and the sector reportedly consumed 12 TWh in 2010.[xxiii]

Average efficiency of agricultural pump-sets across the country remains very low at around 30-35% since the inefficient locally manufactured pumps work out to be cheaper due to subsidised electricity.[10] Though the SAPCC advises re-structuring of agricultural power tariffs to disincentivise wasteful electricity consumption, implementing this recommendation is politically challenging. Further, a ban on manufacturing inefficient pump-sets may also not be feasible due to risk to livelihoods in the informal economy.

Farmers are sceptical of the Agricultural Demand Side Management (AgDSM)[11] scheme as the replacements for inefficient larger pumps are often lower size star-rated pump-sets. Moreover, inadequate utility support in monitoring and verification (M&V) of the scheme reduces the bankability of AgDSM projects. Hence, a market transformation towards efficient pump-sets is unlikely without a significant policy push.

The subsidy for electricity to agriculture is estimated to be around INR 56 billion. If the current inefficiency continues, the state would have cumulatively spent INR 400 billion by 2020, and INR 1 trillion by 2030,[12] when the electricity consumption reaches 21 TWh.

[8] Depth from which water is drawn.

[9] Various estimates suggest that unaccounted pump-sets are 10% to 50% of the current official number of 2 million,

[10] In 2008, the state government relieved its farmers of paying their electricity bills for pumps less than 10 HP, which continues till today.

[11] Ag DSM is an initiative launched by BEE that seeks to bring energy efficient transformation in the agriculture sector. Under this scheme, ESCOs undertake free pump-set replacements and finance their investments by demonstrating savings over baseline consumption. The revenues so obtained are shared between state designated agency, utility and ESCO.

[12] Accounting for electricity supplied to unregistered pump-sets.

Sensitivity of Agricultural Energy Demand to Groundwater Availability

The future energy demand for irrigation pumping is critically dependent on the availability of ground-water, especially in the water-stressed districts. The report on climate resilience[xxiv] highlights how climate variability and change, higher temperatures and changing precipitation patterns could lead to reduced availability and increased requirement of water for irrigation. For instance, the percentage of districts under "highly vulnerable" category during South-West Monsoon periods[13] could increase from 30% at present to 47-57%[14] by mid-century. This could not only impact crop productivity, but also alter energy demand for water pumping.

Accordingly, the electricity demand trajectory from agriculture may vary from BAU.[15] Two cases to illustrate the sensitivity of energy demand to groundwater availability have been presented in Figure 5.

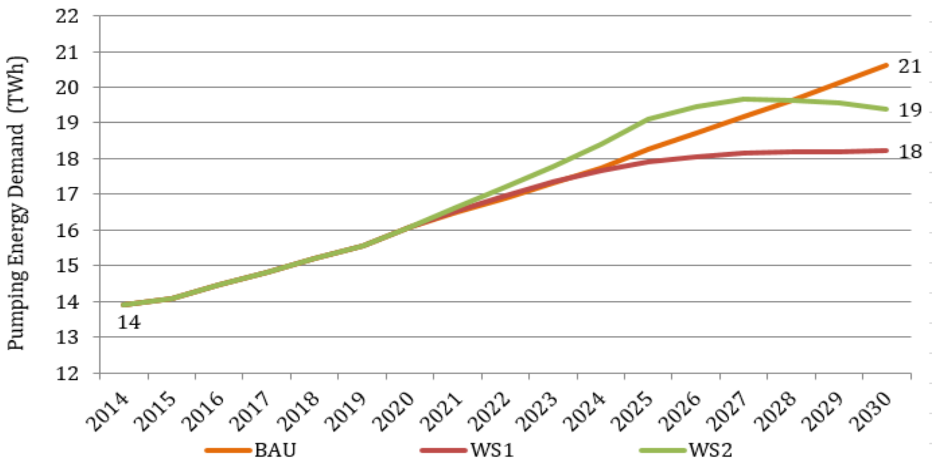


Figure 5: Sensitivity of Pumping Energy Demand to Water Availability

While the BAU electricity demand trajectory grows roughly at 4% p.a. till 2030,[xxv] in Water Sensitivity 1 (WS1) and in Water Sensitivity 2 (WS2) the energy demand trajectories are seen to diverge from 2020 onwards. In WS1, the growth in demand dips reflecting a *rational response* to reduced groundwater availability. WS2 reflects *panic and overdrawal* in the initial years after 2020, when farmers may install higher HP pumps in response to depleting water-tables. After a few years the growth of demand could fall sharply and even turn negative for a short period, reflecting an adjustment in water-stressed regions. Both scenarios call for intervention in terms of early climate warning systems, increased irrigation cover, water conservation and better water-use efficiencies. These may also include adopting micro irrigation and rainwater harvesting techniques.

Farm Mechanisation

Currently, farm mechanisation in India is quite low at 40% compared to 75% in Brazil and Argentina and 95% in US and Western Europe.[16] In Karnataka, more than 70% of rural households have landholding size of less than 1 hectare, and about half the total landholdings are marginal with an average size of 0.45 ha, making farm mechanisation uneconomical. [xxvi]

Based on national trends, the number of tractors in Karnataka is estimated to grow from 320,000 currently to about 1.2 million by 2030. The drivers for this growth include accelerated mechanisation facilitated by larger landholding sizes, pull of workers out of agriculture,

[13] South-West Monsoons are responsible for 80% of average annual rainfall; and nearly 68% of the total cultivated area is under rain-fed farming.
[14] Under Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 scenarios.
[15] BAU considers historical growth as well as growth projections from Central Electricity Authority's 18th Electric Power Survey to arrive at agricultural energy demand projections till 2030 for Karnataka.
[16] This is because of high share of labour involved in agriculture in India (55%), compared to 15% in Brazil and 2.5% in Europe.

availability of institutional credit, opportunities for income generation by renting out tractors to the booming construction and transportation sectors, and policies promoting farm mechanisation such as *Rashtriya Krishi Vikas Yojana (RKVY)*.

Commensurately, diesel consumption from tractors will grow four-fold from 310 kilo tonnes (kt) in 2010 to almost 1,200 kt by 2030, resulting in a likely fuel subsidy of INR 22 billion,[17] part of which may come from state's exchequer.

Power Supply

The state already faces several challenges in meeting its electricity demand. First, it faces a large and growing power deficit. Though the supply has increased significantly in the recent past, it has not kept pace with the yearly 9% growth in the demand. In 2012-13, Karnataka had about 12 GW of grid-connected capacity and supplied about 57 TWh of electricity.[xxvii] In comparison, the unrestricted electricity demand was about 66 TWh, leading to electricity and peak deficits of about 14% – higher than the remaining southern states.

Improving PLFs of State Thermal Plants

The declining PLFs of state thermal plants has also worsened the energy deficit in the state. Starting in 2015, an effort to increase the PLFs of state thermal plants by 2% per year till PLFs of 85% are reached could result in almost 15 TWh of surplus energy in the state in 2020 and avoid capacity addition of over 1 GW in thermal power by 2030.

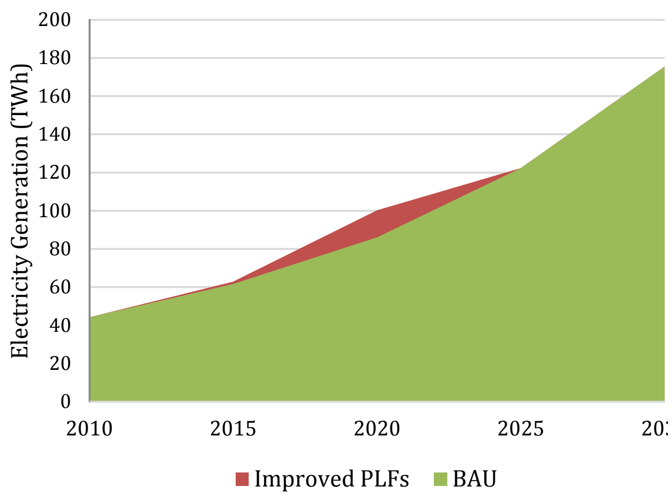


Figure 6: Electricity Generation with Improved PLFs

Second, financial constraints faced by the state and the public sector enterprises (particularly the utilities) have resulted in a slow pace of improvement in the T&D sector. Transmission losses in the state have reduced by nearly half, from about 7% in 2002-03 to 4% in 2010-11,[xxviii] and there has been a significant reduction in distribution losses from about 38% in 1999-2000 to about 18% at present.[xxix] Nevertheless, Karnataka still lags behind Andhra Pradesh and Tamil Nadu in distributional efficiency. Other challenges in reducing T&D losses include lack of metering in agricultural sector and low efficiency of distribution transformers.

[17] Estimated at a subsidy of approximately INR 15/litre.

Third, much of the state's capacity is under-utilised. The Plant Load Factors (PLFs) for the Raichur and Bellary thermal power stations – which account for over 2.5 GW of thermal capacity in the state – average only about 65%, in comparison to an average of about 80% for Central Generating Stations.[xxx] The factors that reduce the PLFs of state thermal plants include poor quality of coal, frequent technical failures, and lack of spares for old equipment. This, amongst other factors, has contributed to increased reliance on short-term purchases, often at expensive rates, to meet the growing energy demand. In 2012-13, around 19% of electricity supplied was through short-term purchases and nearly 20% was obtained from central generating stations located outside the state.[xxxi]

The state will still require an expanded coal-fired capacity of 18 GW by 2030 to meet the rapidly rising demand for electricity.

Fourth, the share of hydro in Karnataka's fuel mix is inevitably going to reduce in the future. Hydro power accounts for about one-third of installed capacity and generation. Though only half of the 7.75 GW of estimated hydro potential has been exploited for electricity generation, concerns over environmental and social impacts of large hydro power projects and inter-state river disputes will make it very difficult to increase capacity of hydro power in the state.

Fifth, though the state has the highest Renewable Purchase Obligation (RPO) achievement (10%) in the country, it has the opportunity to exploit renewable resources even more aggressively. Karnataka is relatively rich in renewable resources, with a wind potential of over 30 GW[xxxii], and over 10 GW of solar potential.[18] However, out of 12.8 GW of wind capacity allotted, only about 2.6 GW capacity has been commissioned.[xxxiii] Similarly, deployment of solar power has been negligible with the current capacity at 74 MW.[xxxiv] Barriers to RE deployment include delayed environmental clearances, lack of evacuation facilities, problems with land acquisition, lack of robust site assessments, and high financing costs. With a potential of about 1-2 GW[xxxv], biomass power can also contribute to decentralised generation in the state, but faces challenges with feedstock availability and a rigid tariff structure.

The demand for electricity from all

Reference Scenario vs. BAU

BAU may be considered as an optimistic scenario by some, particularly on account of the share of renewable energy in total electricity generation and the diffusion of energy efficient lighting, appliances, and pump sets. It assumes that renewable energy sources will contribute at least 20% to the electricity generation in the state by 2020, and continue to do so thereafter. Further, more than half the electrical appliances in use by 2030 are assumed to be of a 5-star rating or above. If the short- and medium-term trends in RE and EE diverge from this scenario, the sustainability challenges highlighted in this section could become more limited.

As an example, consider a more pessimistic scenario for renewable energy deployment and uptake of energy efficient appliances. If the diffusion of energy efficient appliances is limited because of their high capital costs and long payback periods, total electricity demand could increase by as much as 8 TWh over BAU by 2030. At the same time, the share of renewable in electricity generation in the state could increase to 15% by 2020, but gradually decline to 12.5% by 2030 because of policy uncertainty, limited expansion in domestic manufacturing capacity, and only a marginal reduction in prices of RE technologies. The corresponding increase in generation from coal power could be as much as 17 TWh in 2030. This would lead to a 7 Mt increase in annual coal requirement (> 10%), 118 MCM higher water consumption, and 15 Mt of additional CO_2 emissions in 2030.

[18] This considers that 5% of the total wasteland area is available for installation of solar power.

sectors could increase to about 150 TWh by 2030. The state would need to generate 175 TWh to meet this demand if T&D losses reduce to about 15%. Even with 20% share of renewable energy, the state will require an expanded coal-fired capacity of 18 GW by 2030, about 1.5 times the current grid-connected capacity in the state and 50% of the total generation capacity in 2030.

Sourcing such an enormous amount of coal will be a major challenge for Karnataka, which does not have any reserves of its own. Moreover, the availability of imported coal is not a foregone conclusion due to uncertainty of supply and prices in the international markets. Carbon tax regimes across the world could also put upward pressure on prices, which is going to impact the cost of electricity generation. Even if the state manages to secure coal supplies at reasonable prices, the negative impact of coal generation on air pollution and GHG emissions is likely to be significant. Further, thermal plants in other parts of the country including neighbouring Maharashtra have been facing closure in summer months due to the non-availability of water.[xxxvi] Non-availability of water in coal bearing states like Orissa, Jharkhand and Chhattisgarh is already causing siting difficulties.

Cross-Sectoral Assessment

Fossil Fuel Dependence

The state's current energy system is primarily dependent on coal and petroleum products. In 2010, nearly half of Karnataka's energy supply came from coal (Figure 7). A fair share of its current primary energy consumption is still met from renewable energy sources, mainly because of traditional biomass for cooking. However, the share of biomass in cooking is likely to decline with access to modern cooking fuels. At the same time, the demand for electric and industrial grade coal will become five-fold while the demand for petroleum products will become three-fold. Consequently, despite an increase in the share of renewable energy in electricity supply, its share in total primary energy will reduce to 9% by 2030.

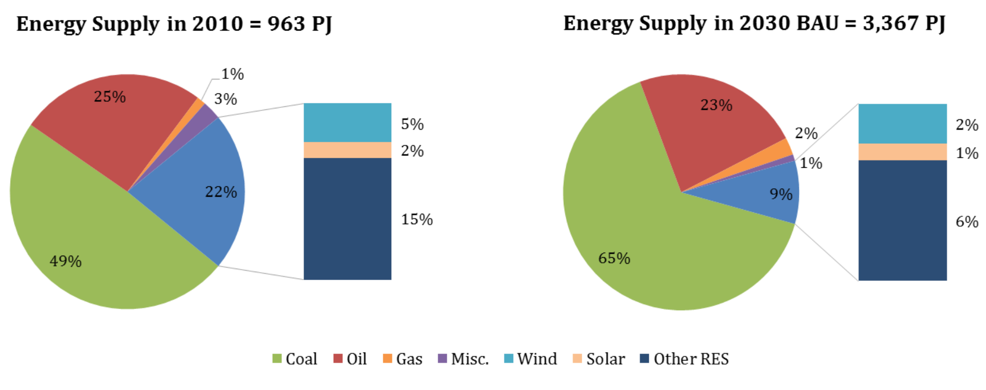


Figure 7: Share of Fuel Sources in BAU[19]

[19] Miscellaneous sources include large hydro and nuclear power while other RES comprises of Biomass and Small Hydel Power (SHP).

Water Scarcity

The Central Water Commission has identified Karnataka as a water scarce state.[xxxvii] [20] Though Karnataka accounts for about 43 BCM, or 6%, of the country's surface water; only 45% can be economically used owing to ecological constraints on westward flowing rivers. The state has about 16 BCM) of annual replenishable groundwater, which comprises less than 4% of the national number. This is only slightly higher than Rajasthan and significantly lower than Gujarat. In 2004, groundwater exploitation reached critical or semi-critical stages in 15 out of Karnataka's 27 districts.[xxxviii]

Increased water demand for electricity generation and insufficient treatment and recycling of waste water will add to the water stress in the state.

The agriculture sector consumes about 84% of the total water in the state followed by power generation, industry and household demand. In BAU, water demand from the power generation sector driven largely by cooling for coal fired plants is likely to double to about 1.7 BCM in 2030. This, along with the growing demand for agricultural produce, rapid industrialisation and urbanisation, is likely to stress limited water resources. SAPCC estimates that industry sector will demand nearly three times the current demand, while the demand from households will double. Hence, addressing the competing water demands will be challenging.[xxxix]

Environmental Degradation from Waste Generation

Municipal Solid Waste

Growing urbanisation and rising incomes pose an additional challenge of waste production and disposal. In 2008, Karnataka generated 8.3 kilo tonnes per day (ktpd) of waste and the collection rate was 87%, of which 80% of the waste was landfilled.[xl] While no engineered landfill with waste recycling provisions exists in Karnataka, open burning and illegal dumping of waste pose serious health hazards due to poisonous gases and toxic fumes. High organic (62%) and moisture content (40%) poses an additional problem of leachate that percolates underground and is responsible for contamination of water bodies and land degradation.[xli] By 2030, almost 22 ktpd of waste will be generated and over 250 ha of land would be required for dumping this waste. In Bangalore, an additional 72 ha will be required, implying a doubling of existing landfill capacity. Moreover, the existing exposure to toxic gases and materials for the population and water bodies is likely to worsen.

By 2030, unsegregated waste would require over 250 hectares of land for dumping, and also contaminate adjoining land and water.

Domestic Waste Water

Almost 85% of rural population in Karnataka does not have access to sanitation, raising considerable health problems and related issues of pollution of surface water bodies.[xlii] In urban Karnataka, only 36% of Urban Local Bodies (ULBs) possess underground drainage facilities (UGDs). Only 40% of Bangalore's sewage is treated at present. Much of the 721 Million

[20] With 500-1,000 m³ per capita replenishable water resources.

Litres Per Day (MLD) of Secondary Treatment Capacity (STC) is unused, and only 10% of 73 MLD of Tertiary Treatment Capacity (TTC) is utilised. Bangalore Water Supply and Sewerage Board (BWSSB) aims to add 339 MLD of TTC and provide UGDs to 7 CMCs and 1 TMC by 2021.[xliii] By 2036, it aims to cover an additional 110 villages.[xliv] The total DWW generated from Class I and Class II towns is 1,287 MLD, which will grow to almost two-fold to 2,300 MLD by 2030, of which half will remain untreated going by present trends and announced plans.

Industrial Waste Water

Industrial effluents carry high levels of metal, dissolved solids, and nitrates. Samples of tank water, wells and bore-wells in the state indicate toxic levels of nitrate- between 5 to 30 times of US EPA's safe limit. Of the seven major industries considered here, most belong to '17 category' of the most polluting industries.[xlv] The average compliance levels based on the Central Pollution Control Board (CPCB) 'Corporate Responsibility for Environmental Protection' stipulations for 17 category industries were found to be lowest in cement (59%),[xlvi] and highest in aluminium and refinery (100%). IWW generation is set to grow four-fold to almost 1 BCM by 2030 owing to rapid expansion of industrial production. Based on current compliance levels, 60-65% of IWW will be unfit for reuse, and contribute to water pollution.

Air Pollution

Air pollution from transport and coal-based electricity generation will increase significantly, impacting the health and quality of life in the state.

In Bangalore, PM[21] concentrations have been recorded in violation of the National Ambient Air Quality Standards (NAAQS). In fact, a recent CPCB report highlighted that Bangalore violated the standard in all years between 2000 and 2006. By contrast, SO_2 and NO_x[22] are currently less of a problem.[xlvii] Most cities are below the NAAQS for these pollutants. According to a 2010 TERI report[xlviii], transport contributes to a large share of pollution in the city accounting for around 42% of the PM_{10} emission load and 68% of the NO_x emission load. The PM and NO_x emissions from the transport sector are estimated to increase by 1.5 times to 50 tpd and 480 tpd respectively. Considering that Bangalore would continue to dominate the urban transport demand in 2020, the impact in the city is likely to be significant.

A recent publication by Urban Emissions indicated that emissions from SO_2 and other noxious pollutants such as carbon monoxide and NO_x from thermal power generation are currently considered to be low in the state when compared with states that have high coal-based generation, like Maharashtra, Orissa and Chhattisgarh.[xlix] These emissions are responsible for high premature infant mortality, respiratory illness and lost work days. With increasing dependence on coal-based power generation SO_2 emissions are likely to grow by around five times to about 2,730 tpd in 2030. Commensurately, emissions of noxious gases could increase by around five times.

21 Particulate emissions are regarded as criteria pollutants and include components of other pollutants. They are an important cause of cardiovascular and pulmonary diseases, and lung cancer. These emissions are recognised among the most important in terms of their negative health effects, followed by oxides of nitrogen and sulphur.

22 Attributed to impact on visibility and oxidised to form heavier ozone.

Greenhouse Gas Emissions

The rise in overall energy demand coupled with an increasing share of coal in energy supply would result in a near four-fold increase in the GHG emissions to over 300 $MtCO_2e$ by 2030[23] (Figure 8). This will translate to per capita emissions of 5 tCO_2e per person in 2030 as compared to 1.3 tCO_2e per person in 2010.[24] The reduction in emissions intensity of GSDP would also be moderate at 19% compared to the 2010 level.

Industries will continue to account for over half of these emissions over the next 20 years, mainly driven by energy use in steel and cement, and process emissions from clinker production in cement. If steps are not taken to increase energy efficiency in residential and commercial buildings, emissions from this sector will contribute nearly one-fourth to the total GHG emissions in 2030 (as compared to 16% in 2010).[25]

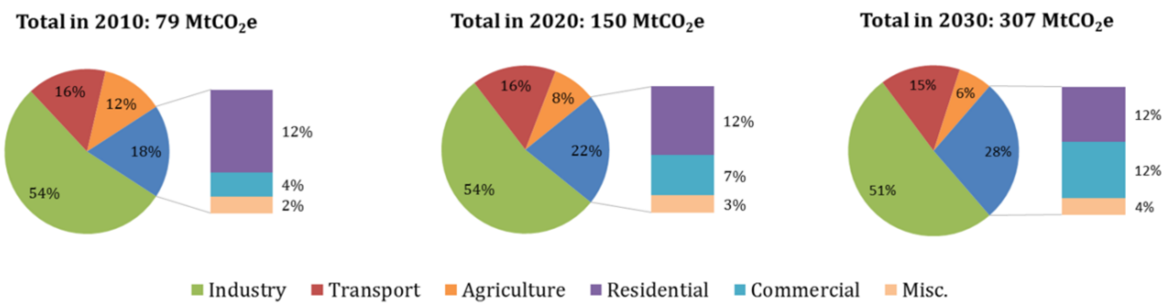


Figure 8: GHG Emissions in BAU[26]

[23] Miscellaneous category refers to the emissions from energy demand for municipal services.
[24] For these sectors alone.
[25] Residential buildings emissions occur due to electricity use and cooking. The base year estimate for emissions from cooking is calculated using 2011 data.
[26] Miscellaneous sources of GHG emissions include municipal street lighting and water pumping (due to electricity use).

The Green Growth Scenario

The analysis of trends and projections in BAU reveals that current policies may not meet green growth objectives. Though Karnataka has been a front runner in devising and identifying specific sectoral strategies via the SAPCC, the technical feasibility and efficacy of these greening interventions over a long-term horizon has not been assessed. This analysis selected opportunities from the gamut of strategies and action areas listed in the SAPCC and evaluated their potential in contributing to green growth.

The green growth opportunities considered reflect the most promising set from global and national best practices and technologies. These are also well-suited to Karnataka's context and are found to have a positive impact on Karnataka's development objectives such as job creation and inclusive growth. The targets for these opportunities were based on an assessment of existing national and sub-national policies and the potential for greater uptake of greening measures (Table 1). For example, as Karnataka is a renewable rich state, the share of renewable energy in electricity generation is pegged at 30% as compared to the national goal of 18%.[l] In the case of solar power, the green growth target is considered at a minimum of 5% of total electricity generation by 2022 against the 3% solar RPO under the National Tariff Policy. Similarly, the reduction of T&D losses to 7% by 2030 is based on international benchmarks in the sector. In comparison, the national aim for T&D losses is about 10% in a low carbon scenario.[li]

Further, various mobility plans for cities in Karnataka suggested that the demand for motorised transport can be reduced by at least 10%. At the same time, experts opine that the state also has an opportunity to retain a high share of public transport in cities. Bangalore can also benefit from the recently commissioned Dabhol-Bangalore Natural Gas Pipeline (DBNP) by switching city buses and taxis to CNG. Meanwhile, electric vehicles provide an important opportunity in the state given the increasing share of private vehicles, moderate trip lengths and low average speeds in cities. However, the National Electric Mobility Mission Plan (NEMMP) target till 2020, particularly for four wheelers, is considered to be aggressive given current sales and manufacturing capacity. The Green Growth scenario (GG) adopts a more conservative timeline.

Each of the seven industries analysed is targeted to reach the current world best SEC levels by 2030 in GG. India is already one of the most efficient producers of cement and nitrogenous fertilisers. If Karnataka's industrial sector receives a policy push towards energy efficiency in addition to the national PAT mandate, much higher energy savings can accrue.[lii] Market transformation towards energy efficient lighting and appliances can be accelerated in GG through additional state and national-level policy actions, lowering the retail costs of efficient technologies. This will result in a higher share of LED lights and super-efficient HVAC systems. Through appropriate institutional measures and end-use incentives for irrigation pumping, the state can aim to replace all inefficient electrical pump-sets by 2030. Also, a reasonable penetration of solar-based irrigation pump-sets can be achieved if Karnataka applies relevant lessons from Rajasthan on this front.[liii]

Table 1: Green Growth Opportunities: Achievements and Targets in BAU and GG Scenarios

Green Growth Opportunity	**Achievement in BAU**	**Target in GG**
Industries		
General Energy Efficiency (EE) Measures *Eg.: variable frequency drives, increased blending of waste materials in cement*	5-10% SEC reduction in most industries by 2020, constant SEC thereafter	20-45% SEC reduction in most industries by 2030
New Industrial Processes (NIP) *Eg.; continuous casting, switching to cleaner fuel/feedstock*		
Waste Heat Recovery (WHR) Measures *With top-gas-recovery turbines, coke dry quenching technology (in steel)*		
Power (Demand)		
Agricultural Demand-side Management (AgDSM)	About 50% of the electrical pump sets in use in 2030 are rated as 5-star; 5% of the total pump sets run on solar power	100% of the electrical pump sets in use in 2030 are rated as 5-star; 10% of the total pump sets run on solar power
Energy efficient (EE) Appliances	About 40-50% of the appliances in use in 2030 are rated as 5-star; low uptake of super-efficient appliances	About 60-80% of the appliances in use in 2030 are rated as 5-star or super-efficient
Energy efficient (EE) Lighting	About 80% of lighting demand is met by CFLs and 5-star tube lights; low uptake of LED lighting	About 50% of lighting demand is met by CFLs and 5-star tube lights; the remaining demand is met by LED lighting
Power (Supply)		
Solar Power	Share of solar energy in electricity generation increases to 4% by 2022; constant thereafter	Share of solar energy in electricity generation increases to 5% by 2022; constant thereafter
T&D Loss Reduction	T&D losses reduce from 18% in 2010 to about 15% by 2020; negligible reduction thereafter	T&D losses reduce from 18% in 2010 to 12% in 2020 and about 7% by 2030
Wind Power	20% state RPO by 2020 leads to increase in wind power capacity; constant RPO thereafter	30% renewable energy in electricity generation by 2030 leads to increase in wind power capacity

Transport		
Demand Reduction and Non-motorised Transport (NMT) *Discourage car use and promote cycling and walking*	Demand for motorised urban transport increases to about 340 BPKM by 2030	Demand for motorised urban transport reduces by 10% by 2030
Electric Vehicles (EV)	Share of Electric 2 Wheelers (E2W) in new two-wheeler sales increases to 15% by 2030; share of E4W in new sales increases to 7%	Share of E2W in new two-wheeler sales increases to 25% by 2030; share of Electric 4 Wheelers (E4W) in new sales increases to 19%
Fuel Efficiency (FE)	Negligible improvement in average fuel efficiencies	Average fuel efficiencies of all freight and passenger vehicles sold after 2020 increase by 15%
Fuel Switch to CNG	Negligible use of CNG for transport	All buses and taxis in Bangalore (assumed to be 50% of total bus and taxi fleet) operate on CNG after 2020
Intensification of Public Transport *Improve urban bus services; Faster deployment of the Bangalore metro*	Share of public transport in urban transport reduces from about 50% in 2010 to about 40% by 2030; the metro meets about 4% of the urban transport demand	Share of public transport in urban transport is retained at about 50% till 2030; the metro meets about 6% of the urban transport demand
Waste		
Advanced Waste Water Treatment (AWWT) *Improve secondary and tertiary treatment capacity and its utilisation for WW generated in houses, and commercial and industrial establishments; Enhance methane recovery from industrial waste water*	50% sanitation in rural areas; 10% sludge removal from domestic waste water by 2030; 35% sludge removal and 10% methane recovery from industrial waste water by 2030	100% sanitation in rural areas; 20% sludge removal from domestic waste water by 2030; 60% sludge removal and 30% methane recovery from industrial waste water by 2030
Integrated Solid Waste Management (ISWM) *Revamp solid waste value chain from collection to disposal*	90% waste collection; 65% of total waste generated dumped at landfill sites by 2030	100% waste collection; 40% of total waste generated dumped at landfill sites; 10% methane recovery by 2030

Focus on these opportunities would significantly alleviate the sustainability challenges faced in BAU. The cumulative impact of green growth opportunities is highlighted below.

Power

Electricity demand in the state can be reduced by about 20 TWh through improved energy efficiency in buildings, industries, and agriculture.[27] Coupled with T&D measures, the generation required in 2030 would be lowered by 37 TWh, which is equivalent to the state's total electricity consumption in 2010 (Figure 9). Policies to promote wind and solar power can increase their share in generation to nearly 20% and 5% respectively, reducing the state's dependence on thermal power from 70% in BAU to less than 60%.

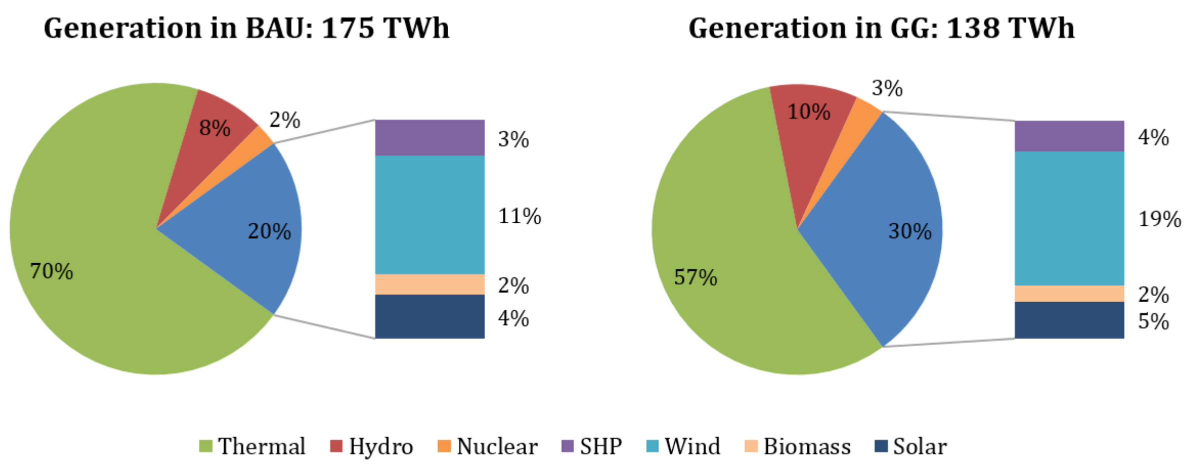


Figure 9: Source-wise Electricity Generation in BAU and GG (2030)

To meet the RE generation target of 30%, the installed capacity of wind power can increase from the present 2.5 GW to 11 GW while that of solar power could exceed 4 GW.[28] Much of the increase in renewable energy is observed in wind power as it is a cheaper electricity source for Karnataka. With demand side management, T&D measures, and increased renewable energy share, about 6 GW of capacity addition in coal power can be avoided in comparison to BAU (Figure 10).

[27] The current scenarios do not take behavioural tendencies such as the rebound effect of energy efficiency into account. Studies indicate that while higher efficiency may lead to some increase in hours of use of lighting and appliances, its impact on energy consumption is not likely to be significant.

[28] The solar power capacity in GG does not reflect a significant addition over BAU because of overall reduction in electricity demand due to higher energy efficiency.

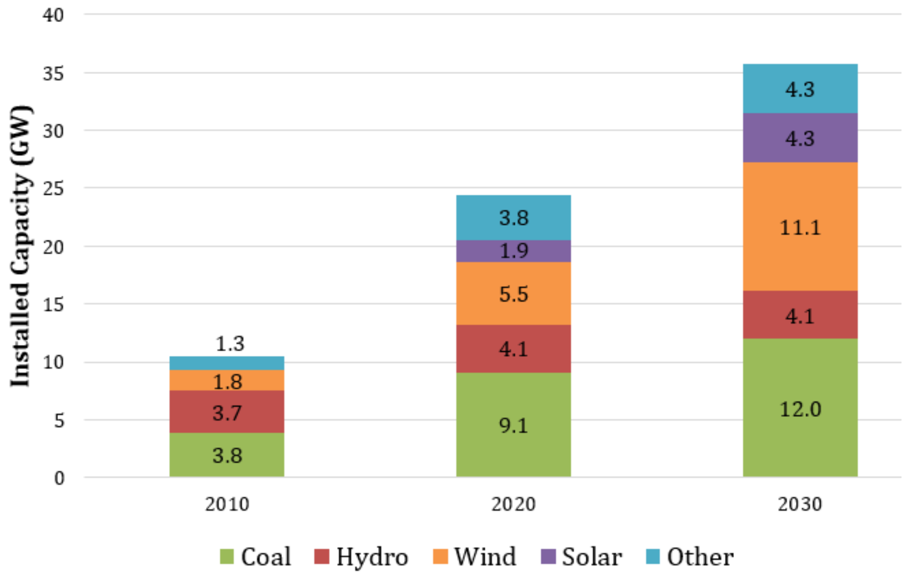


Figure 10: Fuel-wise Installed Capacity in GG

Land Availability for Renewable Energy

The land requirement of the power sector could increase by over 350 sq. km in GG, primarily because of 3 GW of additional installed capacity of wind (from 8 GW in BAU to 11 GW in GG). However, this is less than 10% of the total suitable wasteland and agricultural land in districts with the highest wind potential, i.e. Chitradurga, Hassan, Bellary, Koppal, Chikkamagalur and Chamraj Nagar (Appendix 1). Further, though the total land area required may be high, wind power has a relatively small footprint – only about 5% of the land is needed for proper operation of the power plant and the rest of the land can be put to other use. In addition, the state has existing installed capacity of over 2 GW and has allocated capacity for over 10 GW of wind power. By ensuring that wind power on these sites is harnessed through more recent turbine technologies, which operate at higher hub heights (>100 m) and benefit from higher capacity factors, the state can decrease land requirement without reducing generation from wind energy. Nevertheless, the state government needs to address challenges in conversion of private land that the wind industry currently faces in Karnataka. Further, in case allocated capacity does not translate into commissioned plants in a time-bound manner, Karnataka Renewable Energy Development Limited (KREDL) should re-allocate the capacity to another developer to prevent squatting on public land.

Fossil Fuel Dependence

The overall demand for fossil fuels can be reduced by about 19% (about 15 Mtoe) through the opportunities identified above. Three initiatives can achieve over two-thirds of this reduction: SEC reduction of about 25% in Iron & Steel and about 30% in Cement, aggressive reduction in transmission and distribution losses to about 7%, and installed capacity of about 11 GW in wind and 4 GW in solar by 2030. The reduction in annual coal burnt for the power sector alone would be about 20 Mt – nearly double the consumption by the sector in 2010. In addition, industries can avoid 8 Mt of annual coal use, thereby reducing expenditure on energy and improving competitiveness. Further, initiatives in transport can reduce annual demand for petroleum products by 4 Mtoe.

Improvement in waste-water treatment can recycle about 400 MCM of water in 2030. This, along with water savings of 300 MCM from the power sector can significantly alleviate water stress.

Water Availability

Water requirement for electricity generation can be lowered by 18% or 304 MCM in 2030 mainly on account of reduction in thermal generation. This reduction is primarily due to increase in renewable energy, reduction in T&D losses, and promotion of waste heat recovery in industries. Lower water demand in the power sector would not only reduce the vulnerability of the sector to water shortages but can also free up water for nearly 4.5 million people.[29] Energy-efficient pump-sets, chosen based on the agro-climatic zone and ground water availability, would also lead to lower withdrawals and accrue water savings in agriculture.

Improvement in secondary and tertiary waste-water treatment can cumulatively recycle about 3 BCM of water till 2030, of which 52% is contributed by industrial water treatment. Strict enforcement of CPCB norms for the 'red' category industries, adequate incentives for small scale industrial clusters to set up Common Effluent Treatment Plants (CETPs), and rapid capacity expansion and utilisation of advanced treatment methods in urban municipalities can help bring about the change. This can reduce the demand for fresh water for industrial processes and irrigation. Avoiding open burning and landfill dumping, and recycling waste will also lead to reduction in water degradation from new landfill sites that would have otherwise have come up in the absence of integrated solid waste management practices.

Air pollution from transport and power can be cut by a third. Improved air quality would in turn reduce pollution-related health issues and improve quality of life.

Impact on Land

With segregation at source, proper collection, and scientific disposal, about 5.5 ktpd of waste can be put to alternative uses instead of being dumped at landfill sites. This would eliminate urban land requirement of about 100 hectares (ha) in Karnataka, including 56 ha in Bangalore. Further, it will prevent the degradation of adjoining land and also improve urban aesthetics. Given the rapidly expanding scale of economic activity in the state, even conservative cost savings for municipalities from the avoided land could be as high as INR 300 million.[30]

Air Quality

Concerns over air quality, particularly in Bangalore, can be significantly mitigated by implementing greening options for transport. In comparison to BAU, annual PM_{10} emissions from transport reduce by nearly 30% (about 8 tpd in 2030), primarily because of the transition of buses and taxis from diesel to CNG and improvements in fuel efficiencies of new vehicles. Similarly, greening the power sector can reduce thermal generation and decrease its SO_2 emissions by one-third. Improved air quality would in turn help reduce pollution-related health issues and improve quality of life.

[29] ~304 MCM of water saved in GG can cater to the annual consumption of about 4.5 million people (based on 200 litres per capita per day norm).

[30] At a price of INR 1,000/sq. foot. The actual payment according to the land acquisition laws may be double or triple of the prevalent market value.

Greenhouse Gas Emissions

The green growth opportunities outlined above can avoid about 70 $MtCO_2e$ in 2030 (Figure 11). The largest reduction in emissions is observed in industries (26 $MtCO_2e$). Improving fuel efficiency of freight and passenger vehicles and converting buses and taxis to CNG are the primary mitigation options in the transport sector. Emissions reduction in residential and commercial buildings occurs primarily because of lower emissions intensity of the power sector in GG. Consequently, per capita emissions could reduce to about 4 tCO_2e (in comparison to 5 tCO_2e in BAU) and the emissions intensity of GSDP could reduce by 37% (as opposed to 19% in BAU) in 2030.

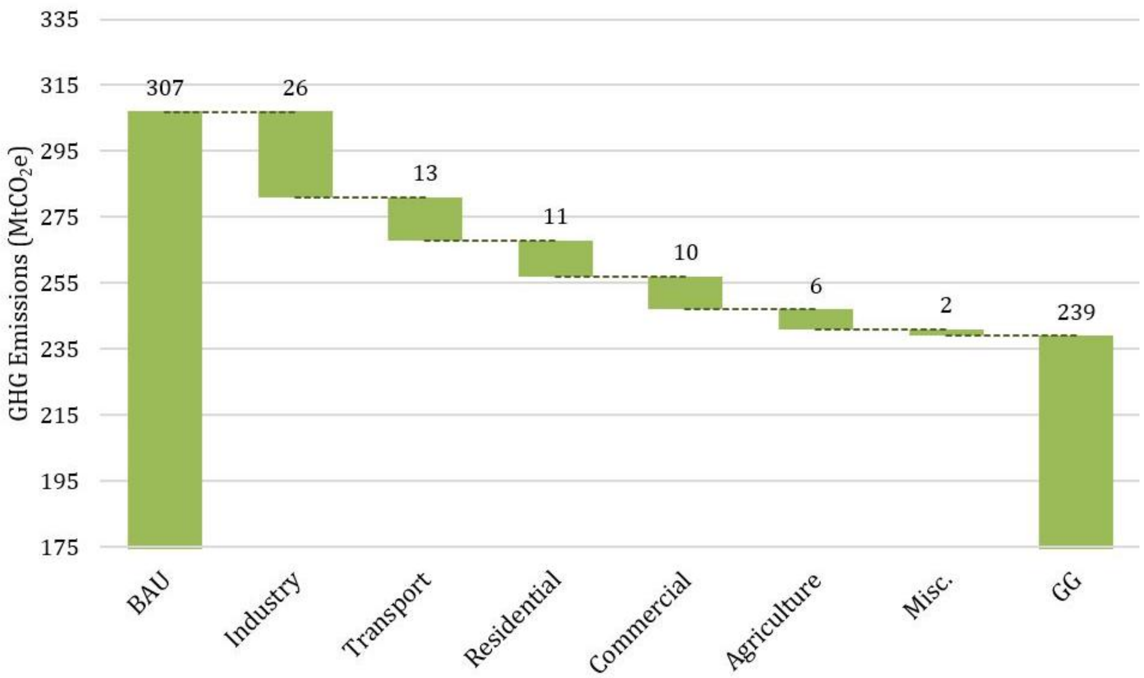


Figure 11: GHG Emissions Reduction in GG[31]

[31] Miscellaneous sources of GHG emissions include municipal street lighting and water pumping (due to electricity use).

Greening Cities in Karnataka

By 2030, more than half of Karnataka's 72 million people will live in cities. How Karnataka's cities evolve in this phase of ongoing population and economic growth will be pivotal for green growth. Some challenges that cities will face in the course of their evolution are:

- Providing affordable housing and transport to the increasing population
- Meeting the eight-fold rise in electricity demand from buildings
- Catering to increasing urban water demand amongst competing uses
- Managing the collection and disposal of waste
- Ensuring liveability despite congestion and pollution from the three-fold increase in on-road vehicles

BAU compels the question: what are the alternatives and to what extent can they solve the challenges mentioned above? The opportunities examined address several of the challenges that cities will face in BAU. For example:

- Improving the public transport network, encouraging non-motorised transport, and providing better last mile connectivity can reduce vehicles on road in 2030 by 3 million
- Increasing overall efficiency of lighting and appliances in buildings can avoid 8.5 GW of generation capacity in 2030
- Improving fuel economy of vehicles and shifting buses and taxis to CNG can also reduce air pollution in cities by one-third
- Shifting to renewable energy and installing energy-efficient irrigation pump-sets can save at least 300 MCM of water in 2030 while recycling wastewater can provide up to 400 MCM of water for alternative uses
- Upgrading waste management to ensure 100% collection and segregation along with recycling, composting, and material recovery can prevent environmental degradation and avoid 100 hectares of urban land-fill area in 2030

For these benefits to be realised, appropriate policies with well-defined targets, price and non-price incentives, and institutional mechanisms are needed. However, other city-specific greening measures such as development of green spaces, rain-water harvesting, energy conservation laws for large buildings, and intelligent traffic management systems will also be needed to make cities in the state sustainable.

Evaluation of Green Growth Opportunities

In order to realise the benefits of the green growth opportunities identified above, the state will have to provide policy focus in the near term. To this end, the green growth opportunities were evaluated and prioritised to arrive at a set of key opportunities (Figure 12). Each opportunity was treated as a separate scenario and evaluated with respect to its relative contribution towards green growth imperatives over BAU.

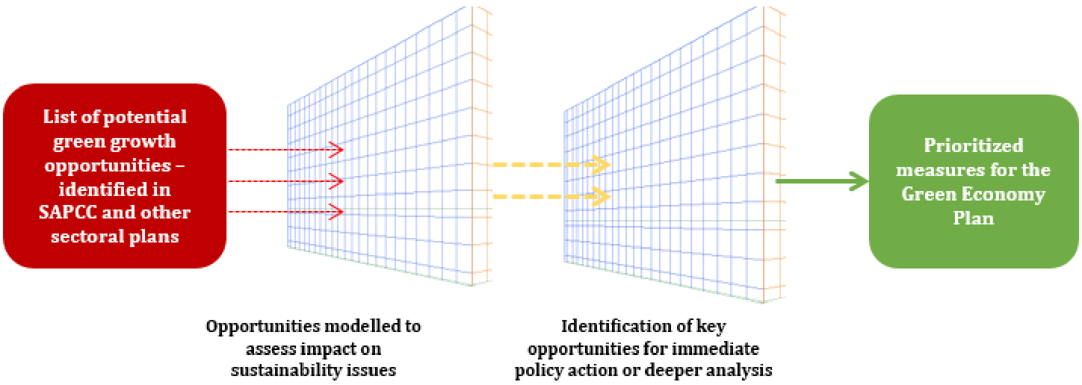


Figure 12: Approach to Assess Green Growth Opportunities

For further evaluation for prioritisation, the benefits have been categorised into two broad categories: green growth benefits, i.e. non-financial economic, social, local environmental and mitigation [liv] and financial attractiveness, which reflects the total required public and private investment as well as the payback period.

INDUSTRY

GREEN GROWTH OPPORTUNITIES

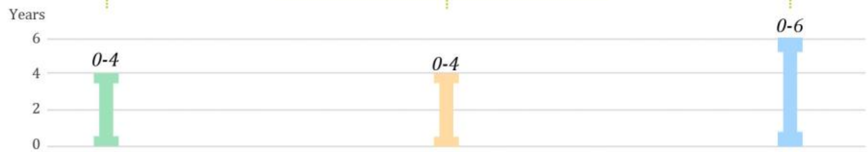
General Energy Efficiency | New Industrial Processes | Waste Heat Recovery

TARGET BY 2030

20-45% reduction in SEC

NET INVESTMENT BY 2030

PAYBACK PERIOD

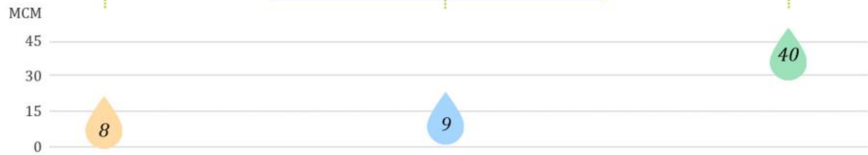


FUEL SAVINGS

ELECTRICITY SAVINGS

SO_2 REDUCTION

WATER SAVINGS



LAND SAVINGS

GHG REDUCTION

1) All estimates reflect comparison with BAU in 2030 unless mentioned otherwise. 2) Fuel savings reflect monetised value of coal, fuel oil, naptha, gas and electricity savings.

POWER DEMAND

GREEN GROWTH OPPORTUNITIES

Efficient Lighting | **Efficient Appliances** | **Ag DSM**

TARGET BY 2030

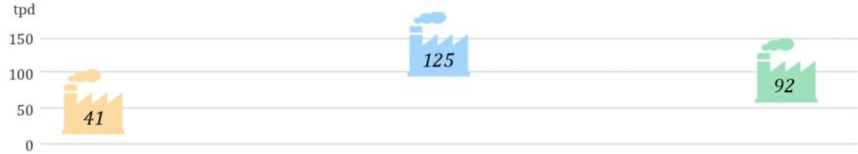
Efficient Lighting	Efficient Appliances	Ag DSM
50% of lights are LEDs and remaining are CFLs	60-80% of appliances are efficient	All electrical pumps are efficient & 10% of all pumps are solar
Avoid 500 MW	Avoid 1500 MW	Avoid 1100 MW

NET INVESTMENT BY 2030

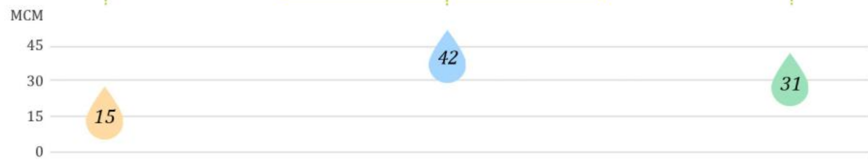
PAYBACK PERIOD

ELECTRICITY SAVINGS

SO_2 REDUCTION



WATER SAVINGS



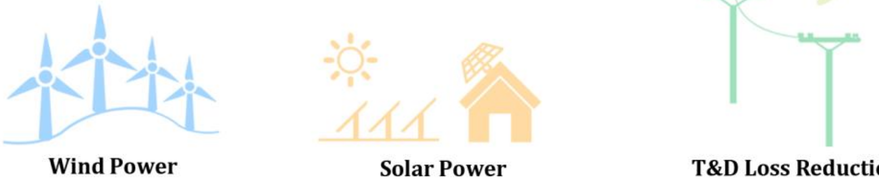
LAND SAVINGS

GHG REDUCTION

All estimates reflect comparison with BAU in 2030 unless mentioned otherwise.

POWER SUPPLY

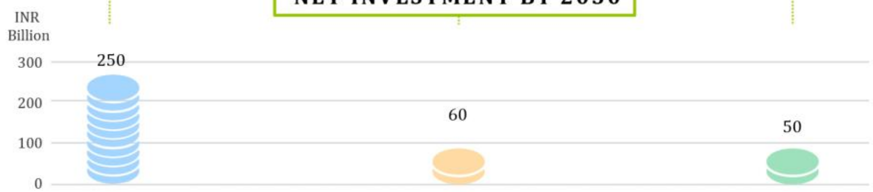
GREEN GROWTH OPPORTUNITIES



TARGET BY 2030

Wind Power	Solar Power	T&D Loss Reduction
18% share in electricity generation	5% share in electricity generation	Only 7% losses
Add 9 GW	Add 4 GW	Avoid 3 GW

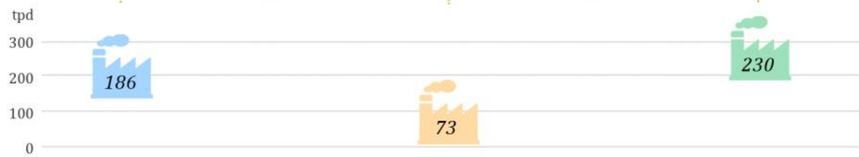
NET INVESTMENT BY 2030



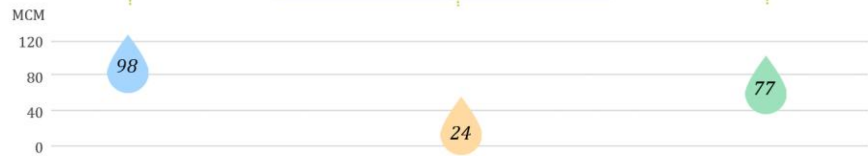
FUEL SAVINGS

DIRECT JOBS

SO_2 REDUCTION



WATER SAVINGS



LAND SAVINGS

GHG REDUCTION

1) All estimates reflect comparison with BAU in 2030 unless mentioned otherwise. 2) Jobs in full-time equivalent terms. 3) For wind power, footprint land requirement of 5% has been considered.

TRANSPORT

GREEN GROWTH OPPORTUNITIES

- NMT & Demand reduction
- Public Transport
- Electric Vehicles
- Fuel Switch to CNG
- Fuel Efficiency

TARGET BY 2030

- 10% reduction in demand for motorised transport over BAU
- 50% share in urban transport
- 25% of bikes sold & 19% of cars sold are electric
- Buses & taxis in Bangalore switch to CNG
- 15% improvement over BAU

Avoid 33 BPKM

Add 40,000 buses

Add 460,000 E2Ws & 260,000 E4Ws

Ensure 9 mmscmd CNG supply

Avoid 1.3 Mtoe of petrol and diesel

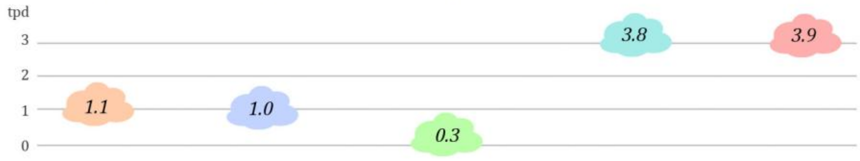
NET INVESTMENT BY 2030

- High
- Low — Avoid INR 565 Billion in vehicles
- High — INR 44 Billion
- High — INR 20 Billion
- High

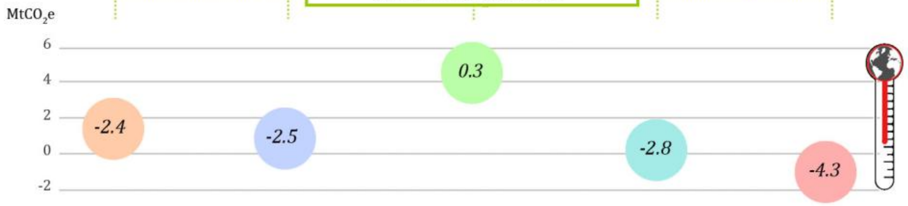
FUEL SAVINGS

CONGESTION REDUCTION

PM_{10} REDUCTION



GHG EMISSIONS



All estimates reflect comparison with BAU in 2030 unless mentioned otherwise.

WASTE

GREEN GROWTH OPPORTUNITIES

Integrated Solid Waste Management

Advanced Waste Water Treatment

LOCAL ENVIRONMENT

100 hectare of landfill avoided
(worth INR 300 Million)
Reduced CO and other noxious emissions

400 MCM of recycled water
(worth INR 6 Billion)
Reduced water contamination

TARGET BY 2030

100% collection & segregation
Only 40% of MSW is dumped

100% treatment of municipal waste water
100% CPCB compliance in industries
Total sanitation in villages

Process 1,300 tpd of MSW through composting, material recovery and waste to energy

Add 1,500 MLD muncipal treatment capacity

INCLUSIVITY

Reduced drudgery & improved income generating prospects for waste pickers

Improved health outcomes for rural poor

PAYBACK PERIOD

GHG REDUCTION

1) All estimates reflect comparison with BAU in 2030 unless mentioned otherwise. 2) Land price assumed to be INR 100/sq. ft. 3) Water price assumed to be INR 15/kl.

Green Growth Benefit Criteria

The sub-criteria within the green growth benefits categories were selected based on emphasis laid in policy documents such as Vision 2020, SAPCC, State of Environment Reports, and other sectoral plans (Table 2).

Table 2: Categorisation of Green Growth Benefits

(Non-Financial) Economic Benefits	Local Environment Benefits
• Additional direct job creation • Reduction in fossil fuel dependency • Congestion	• Reduction in air pollution • Reduction in land and water degradation
Social Benefits	**Mitigation Benefit**
• Impact on social equity • Improved access to goods and services	• Reduction in GHG emissions

To evaluate (non-financial) economic benefits, job creation, energy security and reduction in congestion were considered. This analysis reflects the potential direct employment from specific opportunities within the state.[lv] Indirect jobs (i.e. jobs from further activities in the value chain) or induced jobs (jobs from expenditure-induced effects in the economy) are beyond the scope. Reduction in fossil fuel dependence has been considered as the state has no known fossil fuel reserves. As various studies indicate the negative economic costs of congestion, the impact of transport sector options on congestion was also evaluated.

Local environment benefits have become increasingly important and more stringent regulations have been suggested to prevent environmental degradation. The benefits of each opportunity were characterised on the basis of sectoral impacts on the environment. For the power sector, additional land[lvi] and water requirement[lvii] as well as increase in annual SO_X emissions were considered.[lviii] On the other hand, the transport opportunities were evaluated based on their ability to lower PM_{10} emissions, as particulate emissions affect health most adversely.[lix] Waste management interventions have been evaluated for their impact on reducing land and water degradation.

The equity mandate stated in the state's development plans is covered under the social benefits category, wherein impact of the opportunity on improving access especially for lower income groups has been considered. Finally, mitigation benefit has been clearly identified as a mandate under SAPCC. Here, the relative impact of each opportunity on reducing carbon emissions over BAU has been considered.

Based on the evaluation of benefits from each opportunity (most of which have been highlighted in the earlier infographic) qualitative scoring was done for each of the societal benefits categories listed above.[32] The sector-wise scoring is given below.

[32] The quantified values of impacts from the modelling exercise were normalised between 0 and 100% for scoring between 1 and 5.

The greening opportunities considered in industries can significantly reduce demand for energy and mitigate environmental impact. Within industries, general energy efficiency measures are the most promising with highest economic and mitigation benefits.

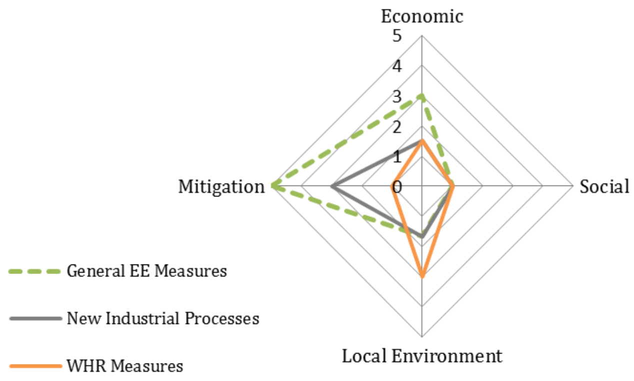


Figure 13: Scores of Green Growth Opportunities in Industry[33]

Amongst the demand side measures, AgDSM has high social benefits as it enables water-use efficiency in the agriculture and maximises ground water resources availability. Of the two efforts considered in buildings, efficient appliances are likely to be more beneficial because they have a higher energy savings potential.

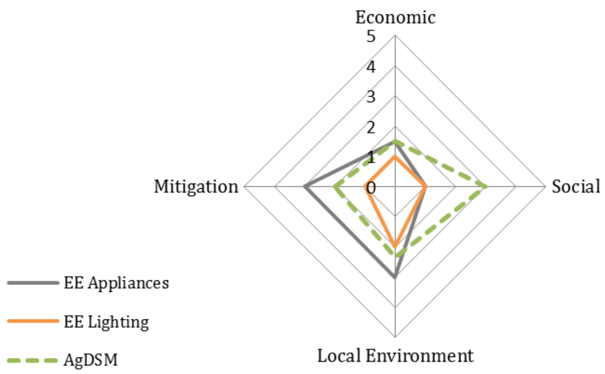


Figure 14: Scores of Green Growth Opportunities in Power (Demand)

Amongst the power supply interventions, wind power has the highest potential benefits primarily owing to its high economic or job benefits and carbon benefits. T&D loss reduction efforts also offer significant environment and economic benefits in the form of reduced fossil fuel dependence.

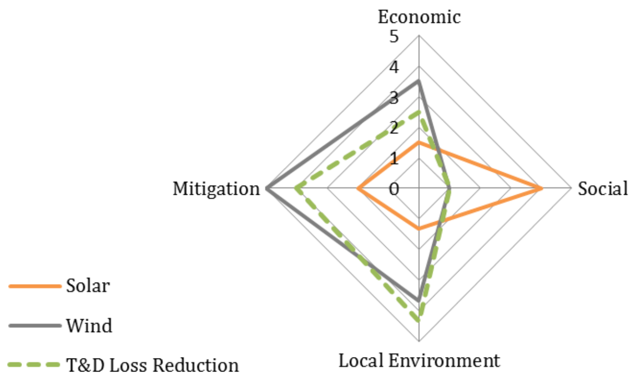


Figure 15: Scores of Green Growth Opportunities in Power (Supply)

[33] The quadrilateral with the largest area represents the most lucrative opportunity in that sector.

Mitigation benefits from this opportunity are also much higher than those from efficiency efforts in the buildings or industries. Meanwhile, solar offers access to energy services for people living in remote or poorly electrified areas.

Amongst greening opportunities in transport, improving public transport accrues relatively higher benefits than remaining options primarily owing to high score on social equity. This is because public transport can enable urban mobility and cost-effective access for a wide cross section of society. Fuel switch to CNG (for 50% of taxis and buses) and improved fuel efficiency also have significant local environmental benefits.

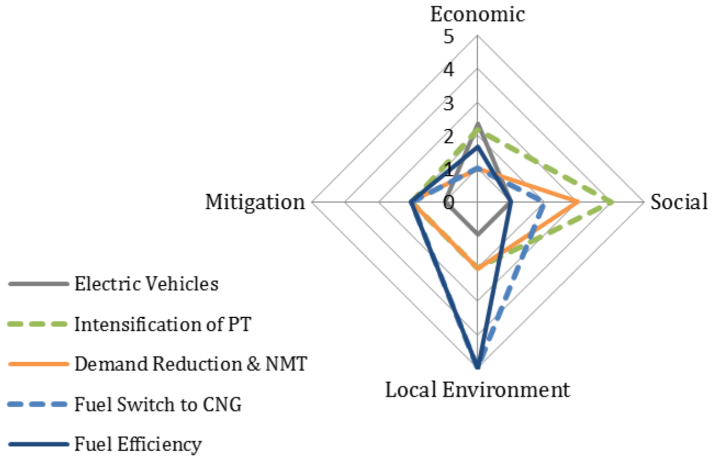


Figure 16: Scores of Green Growth Opportunities in Transport

Greater penetration of EVs doesn't yield significant reduction in pollution since EVs account for only 5% of the total private vehicle fleet in 2030. In comparison, fuel efficiency improvement, or fuel switch for high emitting vehicles are more widely applicable across the sector. However, EV penetration in buses or higher emitting public transport vehicles could reduce pollution considerably. Further, EVs offer an economic opportunity to decrease import of crude oil and boost domestic automobile manufacturing industry.

Within the waste sector, advanced waste water treatment has considerable local environment benefits in terms of reducing water degradation and making water available for reuse. Integrated solid waste management also yields important local environment benefits by reducing pressures on urban land and limiting degradation of land and water resources.

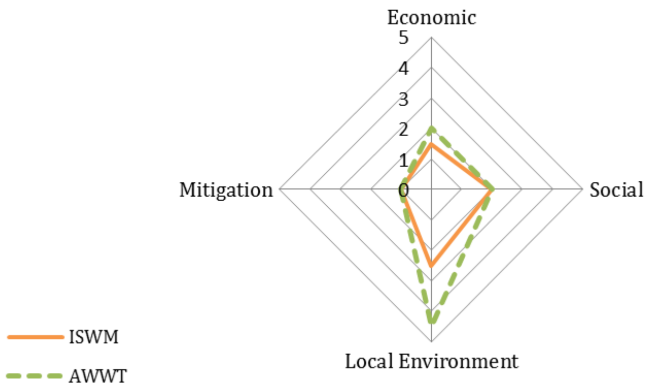


Figure 17: Scores of Green Growth Opportunities in Waste

Financial Criteria

To make the best use of available resources, financial attractiveness of competing opportunities was assessed. Given that developing countries are sensitive to upfront economic costs, the financial attractiveness criteria considered the additional investment of the individual green growth opportunity over BAU.[34] While investment requirements for most opportunities were derived from quantitative analysis, for the rest (such as NMT and integrated solid waste management), they were assessed qualitatively based on literature review and expert consultation.

In addition, another sub-criteria, financial payback period was considered to reflect the time in which the additional economic costs of the opportunity may be recovered. The payback period analysis considered for the scoring is presented in Appendix 3. Figure 18 presents the relative scoring for the greening opportunities on the two sub-criteria of financial attractiveness. A higher investment or payback period is represented with a lower score.

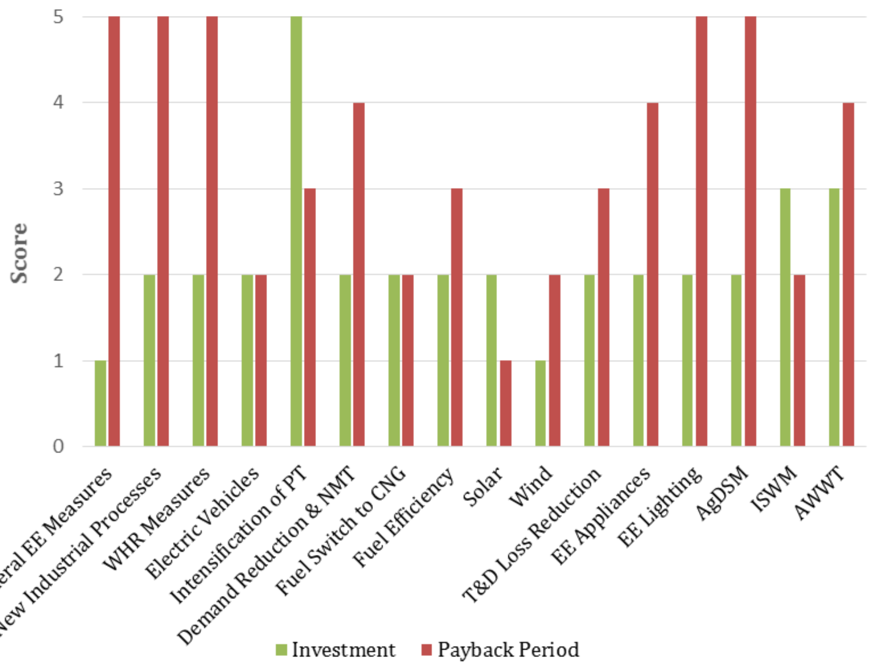


Figure 18: Scores on Sub-Criteria for Financial Attractiveness

General EE measures, NIP, WHR score poorly on investment criteria as they require considerable upfront investments. However, as industries usually adopt only technologies with a reasonable payback period, these investments can be recovered quickly because of energy savings.

The score for electric vehicles on investment and payback period criteria is poor as EVs are currently costlier than diesel or petrol counterparts. It is estimated that not-withstanding the subsidy component available to EV manufactures, the total incremental investment of this green growth opportunity over BAU would be considerable and the average payback period across E2W and E4W would be over 10 years.

Meanwhile, intensification of public transport is highly favourable on investment criteria as the additional investment required is negligible if upfront private investments of avoided petrol or diesel vehicles are considered. On the other hand, NMT scores lower on investment as it does not avoid the upfront cost of vehicles but scores better on payback period criteria because it does not consume any fuel.

[34] Considers net economic cost to society without distinguishing between public/private investment.

Further, it is unlikely that the capital cost of renewable sources will reduce below that of coal-based power generation in the near future and both solar power and wind power score unfavourably on investment. The cumulative investment required in solar power is relatively lower than in wind power because of a more aggressive uptake of the latter in GG. Further, managing large grid-connected wind farms also require considerable transmission and operations infrastructure investments to manage variability of the resource better.

Finally, nearly all remaining demand side measures (EE Lighting, EE Appliances, and AgDSM) score favourably as they have low upfront costs and low payback periods with significant energy and fuel savings over their lifetime.

Prioritisation

All the green growth measures considered in this analysis yield significant benefits and are important to ensure Karnataka's green growth transition. However, key opportunities have been prioritised in order to initiate requisite and timely policy action. The relative green growth benefits and the financial attractiveness of the sixteen opportunities considered are shown Figure 19.[35]

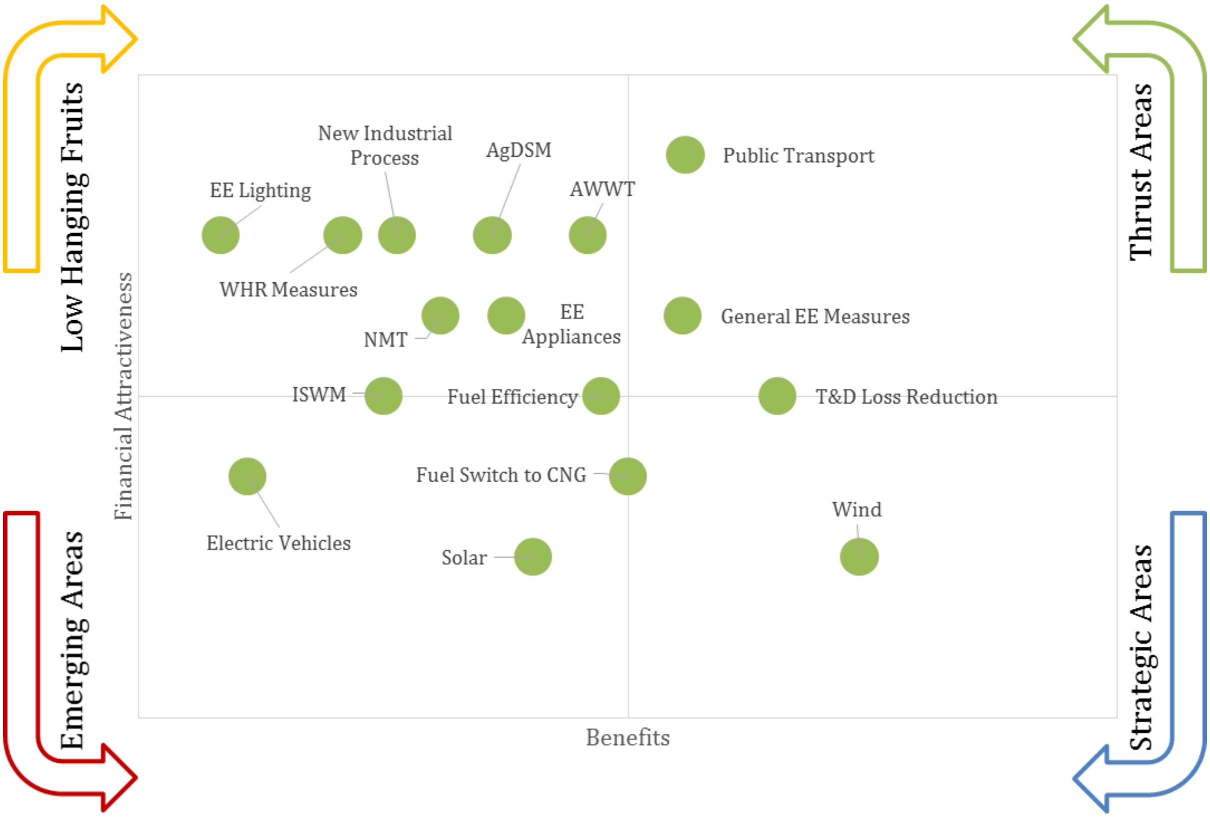


Figure 19: Prioritised Green Growth Opportunities

A notional threshold of 2.5 for the average score (for both benefits and financial attractiveness criteria) enables the following categorisation of the greening efforts.

[35] The weightage for each sub-criteria (benefits and financial) is given in Appendix 4.

Thrust Areas

General energy efficiency measures in industries, T&D loss reduction, and intensification of public transport emerge as opportunities that have relatively high green growth benefits and are financially more attractive. Hence, these merit immediate attention to ensure that their benefits may be captured without significant economic burden.

The current policy progress on these opportunities has been slow. State programmes have focused on pilots or broad-based measures, but a clear policy roadmap or support for T&D loss reduction or energy efficiency measures in industries, especially Micro, Small and Medium Enterprises (MSMEs), is lacking. In order to realise the benefits of enhanced public transport system, considerable effort is needed to expand the existing bus fleet and the metro network in a timely manner, along with better inter-modal integration.

General energy efficiency measures in industries, T&D loss reduction, and intensification of public transport emerge as *thrust areas*. Wind power offers the highest green growth benefit potential, making it strategically significant for the state.

Strategic Areas

Wind is strategically significant as it has the highest green growth benefits over BAU, including fuel savings worth INR 17 billion in 2030. Further, with coal prices projected to rise in the future, it is likely to become more financially attractive over time. However, the additional cumulative investment required is very high (~INR 250 billion). Thus, the opportunity would need an appropriate enabling environment and policy support to address technical (and other challenges) associated with its development.

The National Wind Energy Mission is in the offing[lx], and given the state's high wind resource potential, wind park development and improved evacuation infrastructure along with appropriate financing incentives will play a key role in realising the benefits from wind power (More details are available in a separate wind case study).[lxi]

Detailed policy recommendations for the key opportunities, i.e. *Thrust Areas* and *Strategic Areas* have been identified in next section based on adequacy of current policies to foster deployment.

Low Hanging Fruits

Majority of the green growth opportunities are seen to be financially attractive but have modest green growth benefits in comparison to the key opportunities identified above. These may be considered as low hanging fruits. Many of them are efficiency improvement measures (such as EE Appliances, EE Lighting and AgDSM) and some integral to planning some of the supply-side measures (e.g. NMT infrastructure is key in enabling integrated public transport).

Most of the low hanging fruits could be taken up with relative ease in the near-term to enable GG. Illustratively, in order to maximise realisation of green growth benefits from the AWWT opportunity, the government would need to strictly enhance municipal waste water treatment facilities in a timely manner and enforce CETP for industrial units, especially MSMEs. Further, creation of a State Clean Energy Fund (SCEF) could facilitate all demand-side measures in the power sector.

Specifically, AgDSM projects are already being implemented in a phased manner with collaboration between the Karnataka government and Energy Efficiency Services Limited (EESL). Case studies from EESL indicate that returns from efficient pumping are high, and an initial corpus from SCEF can enable rollout throughout the state with considerable ease through public-private partnerships.[lxii]

In addition, WHR measures and new industrial processes are low hanging fruits for the industry sector. By recovering thermal losses in industrial plants, WHR presents an opportunity to reduce electricity consumption and increase energy efficiency. States such as Andhra Pradesh and Rajasthan consider WHR as cogeneration, which is counted as a renewable energy source under the states' RPO. Karnataka could use similar incentives (More details are available in a separate WHR case study). [lxiii]

Table 3 provides a summary of key policy actions required to tap into the benefits from Low Hanging Fruits.

Table 3: Policy Actions for Low Hanging Fruits

Opportunity	Policy Actions
WHR Measures	• Include WHR as a renewable energy source in the state's Renewable Energy Policy
EE Lighting	• Accelerate implementation of the *Belaku* scheme • Undertake DELP[36] projects • Retrofit office spaces
EE Appliances	• Strictly enforce ECBC • Prescribe norms for AC-use in large buildings • Pilot Demand Response projects
New Industrial Processes	• Facilitate efficient process switches in large industries (e.g. feed-stock and fuel switching)
NMT	• Provide dedicated bicycle lanes • Price congestion and add fuel cess • Improve walkability
Fuel Efficiency	• Monitor adherence to standards • Link road taxes and permit fees to fuel efficiency
ISWM	• Ensure 100% collection and prohibit open burning of Municipal Solid Waste

[36] DELP stands for Demand Side Management based Efficient Lighting Programme which aims to overcome the first cost barrier to promote efficient lighting (LEDs) using the basic architecture of its predecessor, *Bachat Lamp Yojana.* The initiative has been launched by BEE and supported by EESL.

	• Enforce segregation at source • Provide incentives for alternate treatments such as recovery and composting • Pilot waste to energy projects
AWWT	• Build more treatment capacity • Ensure high capacity utilisation • Provide CETPs to MSMEs • Ensure 100% CPCB compliance in large industries
AgDSM	• Build institutional capacity in KREDL and Bangalore Electricity Supply Company (BESCOM) • Pilot solar pumping • Provide financing and subsidy mechanisms

Emerging Areas

This categorisation refers to the opportunities that yield relatively lesser benefits in comparison to other options and are less financially attractive. However, these opportunities could become *Low Hanging Fruits* or *Thrust Areas* in the future.

The recent policy push from the government on solar is a step in the right direction, and will aid the development of solar power in the state. Solar rooftop can be exploited to offset the high land footprint of grid-connected solar power, and solar technologies coupled with mini-grids can also provide electricity access in the energy deprived areas. However, there is a strong need to address the key implementation bottlenecks, which will be crucial in achieving the ambitious targets (More details are available in a separate solar case study).[lxiv]

Similarly, EVs have the highest job creation potential and contribute significantly to improving air quality in cities (More details are available in a separate EV case study). [lxv] The job potential could be further enhanced if Karnataka, already a leader in electric car manufacturing, expands its manufacturing capacity for sales domestically and internationally.

It is important to evaluate whether these emerging areas can be taken up aggressively as they become financially more attractive or technically feasible. Further, if these technologies are considered for wider application, it may lead to greater green growth benefits. As an example, electric buses, which are at a pilot stage in India, could become commercially viable if the storage technology improves. EVs could then potentially come under *Thrust Areas* with a wider application in public transport.

Table 4 provides a summary of key policy actions required to benefit from the Emerging Opportunities for green growth.

Table 4: Policy Actions for Emerging Areas

Opportunity	Policy Actions
Fuel Switch to CNG	• Promote green cabs and buses • Secure supplies to DBNP • Construct refuelling stations • Roll-out phase-wise implementation
Electric Vehicles	• Scale up pilot projects for EV buses • Promote use of EVs by public officials • Encourage EV manufacturing
Solar Power	• Enforce solar RPOs • Expedite land acquisition and clearances • Identify potential for micro-grids • Promote Roof-top Photovoltaic in buildings

The Way Forward

This report has evaluated Karnataka's long-term sustainability challenges (going up to 2030) and created a green economy strategy for the state by identifying, assessing, and prioritising relevant and feasible opportunities for green growth. Based on the green growth benefits and financial viability, adoption of energy efficient technologies in industries, further development of public transport, scaling up of wind power and aggressive reduction of T&D losses emerge as the biggest opportunities. However, their implementation requires focused policies and appropriate action plans.

As these opportunities have previously been stressed at the national and state level, several policies exist for them. A detailed policy gap assessment was conducted to arrive at key recommendations for bridging gaps in existing policies and overcoming barriers to implementation. In addition, areas for further research to facilitate these interventions were also identified.

Industrial Energy Efficiency

The imperative for EE in industries exists at the national and state level. Table 5 examines relevant policies at both levels and suggests how Karnataka can play a more active role in monitoring and incentivising judicial use of resources in industries. A database of the status of production and energy-use in current industries, both large and MSMEs, to establish baselines is a prerequisite to this. Building capacity in state bodies and universities to understand the technological feasibility and private cost-benefit implications for various EE measures will also help in formulating concrete policies, setting expectations, and supporting appropriate technologies.

Public Transport

Table 6 presents an overview of the policy gap in public transport in the state and presents specific recommendations to retain a high share of public transport. In addition, research on enabling intermodal integration and feasibility of commuter rail services for Bangalore should also be investigated. BRT systems could provide a cost-effective means of transport in smaller cities and should be evaluated.

Wind

Though Karnataka has high wind potential (> 30 GW in waste land itself), deployment of this technology has been slow. Challenges to realizing this potential include land availability, evacuation, and grid integration. Table 7 provides the gap and barrier analysis for wind sector policies, and provides recommendations to enable the state to reach 11 GW of installed capacity by 2030. Studies on feasibility of wind farms in the state, framework for repowering existing sites, assessment of solar-wind hybrids to reduce land requirement and improve utilization of transmission infrastructure, and renewable energy integration would provide useful insights to frame policies in this domain. Region or zone wise wind forecasting techniques need to be developed in order to respond to variability and plan dispatch to maintain grid stability.

T&D Loss Reduction

Table 8 lists the gaps and barriers in current policies initiated by Government of India and Karnataka to reduce high T&D losses. An assessment of T&D losses at the feeder level would be useful to prioritise efforts on reducing losses. This could be followed by cost-benefit analysis of various options to reduce losses, such as deployment of High Voltage Distribution System (HVDS) and replacement of inefficient distribution transformers. Evaluation of pilot projects taken up under Restructured Accelerated Power Development and Reforms Program (RAPDRP) would also inform policies to reduce losses. Further, the role of smart grid technologies in strengthening the grid also needs to be investigated in further detail.

Table 5: Policy Gap Assessment for Industrial Energy Efficiency

<table>
<tr><td colspan="6">Reduce Specific Energy Consumption of industries by 20-45%</td></tr>
<tr><th colspan="2">Status</th><th>Current Policies</th><th>Gaps</th><th>Barriers</th><th>Recommendations</th></tr>
<tr><td>Current SECs</td><td>World Best SECs</td><td>Perform, Achieve and Trade (PAT)</td><td></td><td></td><td></td></tr>
<tr><td rowspan="6">Iron and Steel- 29-30 GJ/ tonne of crude steel

Cement- 3.3-5 GJ/ tonne of cement

Aluminium- 262 GJ/ tonne of aluminium

Fertilisers- 24-31 GJ/ tonne of urea; 38-48 GJ/ tonne of ammonia

Refinery- 3.7 GJ/ tonne of crude processed

Paper- 22-44 GJ/ air dried tonne of paper

Textiles- 2.13 MJ of steam/ meter of fabric</td><td rowspan="6">15-19 GJ/tonne of crude steel

2.7 GJ/ tonne cement

174 GJ/ tonne aluminium

19-21 GJ/tonne of urea; 25-33 GJ/ tonne of ammonia

2.9 GJ/ tonne of crude processed

18-23 GJ/ air dried tonne of paper

0.95 MJ of steam/ meter of fabric</td><td>Less than 20 plants from these 7 sectors are listed under PAT, which mandates SEC improvements of around 5-7% in Cycle I (2012-2015)</td><td>Targets far below best SECs achieved globally</td><td>High up-front cost of energy efficient technologies and sunk costs to dispose inefficient machinery/equipment</td><td>KREDL could recommend more ambitious SEC improvements for state plants in Cycle II</td></tr>
<tr><td></td><td>Lack of clarity about the trading mechanism for Energy Savings Certificates (ESCs) and penalties for non-fulfilment of targets</td><td></td><td>KREDL may ask BEE to notify the details of trading mechanism and disseminate among the Designated Consumers</td></tr>
<tr><td></td><td>Inadequate coverage in Karnataka</td><td>Limited capacity of KREDL to identify new plants and monitor progress</td><td>KREDL could draw out plans for PAT widening and deepening in Karnataka</td></tr>
<tr><td>Karnataka Industrial Policy (2014-19)[lxvi]</td><td colspan="3"></td></tr>
<tr><td>Subsidies of up to INR 0.75 million each on capital cost for enabling energy efficiency and non-conventional energy technologies for MSME</td><td></td><td>Due to limited awareness in MSME sector about such schemes, the funds may remain under-utilised</td><td rowspan="2">Ensure timely disbursal of subsidies and revise allocation based on savings potential of EE and Renewable Energy technologies. Provide supply side/ policy push for effective utilisation of funds and increase the schemes' visibility</td></tr>
<tr><td>Up to 0.5 million of subsidies per plant for adoption of clean and green practices</td><td></td><td></td></tr>
</table>

Reduce Specific Energy Consumption of industries by 20-45%				
Status	**Current Policies**	**Gaps**	**Barriers**	**Recommendations**
	INR 1 billion dedicated to Technology Development fund for development of MSMEs	Inadequate research on bankable EE technologies with quick gains		Identify institutions for research and technical support on proven EE technologies and assist Karnataka Council for Technological Upgradation (KCTU) and Karnataka State Small Industries Development Corporation Ltd. (KSSIDCL) in deployment
	Special package of incentives and concessions for 'focussed sector industries' such as Automotive, Machine Tools, Aerospace, Iron and Steel and Cement	No provision for enhancing EE		Make EE in focussed sector industries an explicit criteria
Technologies Over half of State's steel produced using efficient COREX- BOF technology at JSW, Bellary Small-scale sponge iron plants using inefficient coal-based DRI process Over 90% cement produced is blended but room for improvement in technology and blending proportions Over 50% of nitrogenous fertilisers produced using inefficient fuel-oil feedstock; virtually no gas-based	High Level Departmental Monitoring Committee for enabling government orders, recommending mid-course corrections, providing progress on implementation, etc	Monitoring of EE and resource conservation left out		Increasing EE and RE adoption in Large industries and MSME's could be made an explicit objective to the industrial policy with the overarching goal of making Karnataka a model state for industrial energy efficiency
	Karnataka Renewable Energy Policy (2009-14)[lxvii]			
	Promotion of bagasse based co-generation plants	Waste Heat Recovery based electricity generation		Include WHR as a renewable energy source in industries to make the option attractive and tap

Reduce Specific Energy Consumption of industries by 20-45%				
Status	**Current Policies**	**Gaps**	**Barriers**	**Recommendations**
production Only 10% paper production via the efficient recycled fibre process Inefficient steam generation technology in textiles		missing as RES		into the savings potential
	Large industries to source 5% of their electricity requirements through captive plants using RES	No targets for use of renewables for thermal use in industries where relatively less temperatures are required in the production cycle	Large industries such as Iron and Steel, Cement, Aluminium, etc. require power supply of a consistent quality during the manufacturing cycle. In sectors such as paper, there is high potential for biomass use.	Specify large plants in paper, textiles and other sectors where potential exists for high renewable energy use.
	Reduce industrial electricity consumption by 25%	Blanket 25% reduction target across all consumer segments	Such drastic reductions are unlikely to occur during the five year period of policy framing	Specify realistic targets based on a more rigorous assessment of savings potential
	Setting up of *Akshaya Shakthi Nithi* fund allocation of 10% (INR 50 million) for EE and energy conservation		The fund is not in operation due to lack of bankable projects	Utilities and KREDL could submit proposals for projects in EE and energy conservation in industries
	Energy auditing of industries		Lack of adequate capacity in KREDL to undertake rigorous energy auditing	Engage with consultants and Energy Efficiency Services Limited to build capacity and strengthen M&V

Table 6: Policy Gap Assessment for Public Transport

<table>
<tr><td colspan="6">Achieve 50% share of public transport by 2030</td></tr>
<tr><th>Status</th><th>Gaps</th><th>Barriers</th><th>Current Policies</th><th>Policy Effectiveness</th><th>Recommendation</th></tr>
<tr>
<td rowspan="3">Estimated to meet about 50% of the current demand; However, share could fall to about 40% by 2030 unless action is taken</td>
<td><u>Access</u>
Last mile connectivity for public transport is generally poor

The current fleet of buses is almost of identical size and thus unable to reach narrow lanes or mud roads</td>
<td>Trip lengths and trip rates are rising rapidly</td>
<td rowspan="3">1. National Urban Transport Policy

2. City Development Plans

3. City Master Plans

4. City Mobility Plans

5. Comprehensive Traffic and Transport Plan for Bangalore</td>
<td rowspan="3">1. Effective. Highlighted the importance of local transport policy; Mandated the creation of City Mobility Plans; Emphasised the need for land-use transport integration

2. Partially Effective. Municipalities lack capacity to develop and modify the plans periodically

3. Ineffective. Land-use transport integration missing in City Master Plans

4. Partially Effective. Municipalities lack capacity to develop and modify the plans periodically

5. Partially Effective/Ineffective. Focused on moving vehicles rather than moving people; Limited emphasis on TDM (traffic demand management)</td>
<td>Improve accessibility to mass transit (bus/metro/rail) through footpaths, pedestrian crossings, feeder services, intermediate public transport, signages, and park and ride facilities

Provide universal accessibility that caters to the needs of children, the elderly, and the differently abled

Increase diversity in the size and variety of the bus fleet</td>
</tr>
<tr>
<td><u>Affordability</u>
The current fare structure is slightly high</td>
<td>Two wheelers are affordable and easy to use</td>
<td>Rationalise the fare structure based on service demand and trip distance</td>
</tr>
<tr>
<td><u>Efficiency</u>
Reliability and punctuality of public transport is not given sufficient focus

Public transport takes more time than private transport

The schedule and real-time status of buses is not well-publicised</td>
<td>1. Centralised or circuitous routes and congestion increase journey time

2. The coordination mechanism amongst government agencies is weak</td>
<td>Prioritise buses through dedicated lanes to improve the speed and reliability

Plan routes and trips based on demand assessment to reduce trip length and travel time

Create Intelligent Transportation Systems (ITS) applications for real-time information

Develop an integrated mass transit plan to include more citizens into public transport network</td>
</tr>
</table>

Achieve 50% share of public transport by 2030					
Status	**Gaps**	**Barriers**	**Current Policies**	**Policy Effectiveness**	**Recommendation**
	The public transport network is not planned in an integrated manner			and soft infrastructure	
	Integrated Planning Various plans and policies do not speak to one another	The coordination mechanism amongst government agencies is weak			Integrate economic, land-use, and transport planning for each city and undertake station area planning to facilitate the same

Table 7: Policy Gap Assessment for Wind

Increase wind generation capacity to 11 GW by 2030					
Status	**Gaps**	**Barriers**	**Current Policies**	**Policy Effectiveness**	**Recommendation**
Current capacity : 2.5 GW	Installed capacity on ground has not increased in recent years	High capital cost	Accelerated Depreciation, Generation Based Incentive and Feed-in-tariffs; IT exemption on earnings for 10 years; waiver of state electricity duty; excise exemption for wind turbine generators	Very Effective	KREDL can set up a state level database with updates on union and state policy for clear communication to developers on status; maybe jointly maintained by KREDL and Industry
		Difficulty in land acquisition for wind projects	Right to Fair Compensation and Transparency in Land Acquisition, (Rehabilitation and Resettlement Act), 2013 has sought to bring about transparency and grant fair compensation; Karnataka Renewable Energy Policy (KREP) terms wind as 'industry' allowing for long-term land lease	Partially Effective/Ineffective	Develop an alternate model for land acquisition and conversion for wind power. State can determine lease norms for mixed usage of privately-owned agricultural land. The state should also initiate investment grade resource assessment for wastelands.
		High transaction costs for obtaining required permits	Provision for single window clearance via KREDL in KREP(2009-14)	Not effective	Karnataka Evaluation Agency should evaluate the KREP 2009-2014 specifically for this aspect

Increase wind generation capacity to 11 GW by 2030					
Status	**Gaps**	**Barriers**	**Current Policies**	**Policy Effectiveness**	**Recommendation**
		Allocated capacity not getting commissioned due to squatting	Karnataka Land Reforms and Certain Other Law (Amendment) Bill 2014 mandates allottees should surrender their land to the government within 10 years if they have not utilised it for the purpose it was sanctioned. [lxviii]	Not Known	KREDL should re-allocate capacity in a time-bound manner to prevent squatting
	Generation not significant; only ~7% of total generation	High potential sites are underutilised,; wind resource rich sites in Chikkamagalur and Chitradurga lie in forested areas	No policy framework to incentivise repowering; limited guidelines from CERC for setting tariffs based on state-level CUF		Evaluate capital subsidy requirement for repowering wind projects to higher hub heights. KREDL should inform KERC on state level CUFs to ensure tariff revisions. This could serve as the framework to rationalise wind tariffs.
	Transmission infrastructure inadequate for future capacity	High capital cost; low CUFs would lead to idle capacity if used only for evacuating wind power	KPTCL has plans for transmission capacity improvement		KPTCL should take into consideration wind zones and an estimate of the projects that could come into fruition in the long term during the planning stage. This requires coordination with KREDL and Energy Department

Increase wind generation capacity to 11 GW by 2030					
Status	**Gaps**	**Barriers**	**Current Policies**	**Policy Effectiveness**	**Recommendation**
	Current management of intermittency with day ahead schedule may be inadequate in future	Lack of quick-ramp sources or storage options to ensure grid stability	KREP does not cover capacity requirement from quick ramp sources.		Incentivise quick ramping generating sources like hydro power and natural gas to ensure grid flexibility and stability
		Lack of forecasting and scheduling systems; field level wind assessments involve high costs	Penalty or UI charges for exceeding uncertainty range		Improve grid response systems and efficient scheduling based on better data collection and forecasting techniques
	Environmental and social impacts of wind plants unknown		Forest Conservation Act and the new Land Acquisition Act mandate appropriate environmental and social impact assessments especially in scheduled areas	Effective in ensuring land rights but deterrent for developers looking to explore project viability	KREDL should mandate environmental and social impact assessments in wind-rich districts, identify suitable sites and expedite forest clearances of sites with least impact

Table 8: Policy Gap Assessment for T&D Loss Reduction

Reduce T&D losses to 12% of net generation by 2020; 8% by 2030					
Status	**Gaps**	**Barriers**	**Current Policies**	**Policy Effectiveness**	**Recommendation**
Currently, T&D losses area at 18%	Engage IT & ITES in Transmission Sector	Sophisticated technology which requires personnel to be fully equipped to address the issue	None	Not Applicable	Use Dynamic Line Rating for congestion relief, improved grid reliability, optimized asset utilization and integration of renewables
	No incentive or penalty to pursue metering	Farmers reluctant to meter their IP sets Unavailability of quality and timely power supply	KERC Directive: 100% Metering of Irrigation Pump sets and *Bhagya Jyoti/Kutir Jyoti* consumer households and Distribution Transformer Centers (DTC)	Poor	Offer incentives for 100% metering; Baseline measurement and reading should be conducted which would lead to accurate estimates of loss DTC wise energy audit should be mandated in all ESCOMs
	Less emphasis on overall execution and strategy/efforts towards course correction In RAPDRP, Power Finance Corporation has been designated as the nodal agency which has poor understanding of the functioning of the distribution sector	Poor understanding of the readiness of utility to absorb and drive the project In RAPDRP, ESCOMs have been assigned targets with	RAPDRP/Non-RAPDRP	Partially Effective - Low disbursement of sanctioned amount towards distribution strengthening; M&V yet to be conducted	Strengthen and where necessary provide backbone Infrastructure - IT & ITES Ensure measurement of loss which currently is not happening (at the Distribution Transformer (DT) end) Implement smart grid projects on pilot basis and evaluate it

Reduce T&D losses to 12% of net generation by 2020; 8% by 2030					
Status	**Gaps**	**Barriers**	**Current Policies**	**Policy Effectiveness**	**Recommendation**
		stringent timelines failing which grant component turns into a loan which adds to existing financial woes			Provide Distribution Automation System which also reduces power interruption time
	Provide uninterrupted and quality power supply Improve environment for seeking international financial support to the sector	High capital cost Poor financial state of ESCOMs which makes it difficult to secure loans	RAPDRP	Poor	Strengthen distribution network by introducing HVDS in economically feasible locations Quality of power supplied is also expected to improve Could be coupled with *NJY*
	Addressing reliable and quality power supply for IP sets	Poor cost benefit ratio and low or negative return on investment	RAPDRP	Partially Effective	Distribution Strengthening: Reconductoring old or overloaded lines and use appropriate quality conductors Optimal placement of capacitor bank to the DTs
	No incentive or penalty for utility to install high star rated DT Installation of higher capacity transformer is preferred in rural and remote region which results in higher iron losses Imbalance in the load of different phases in the network Lack of IT & ITES to continuously monitor the load parameters in the network		Star Labeling Program	Not Known	Distribution Strengthening: Use high star rated DT and optimize transformer capacities

Knowledge Gaps

This is the first state-level research effort in India to use a long-term energy model based on the sophisticated TIMES platform. However, as such a model requires considerable data, which are not always available or easy to operationalise, certain gaps remain which may be addressed in future analyses.

- This report has focussed on key demand and supply sectors for energy. However, some sectors require further detailing in the future. This includes assessment of railways, building envelopes, commercial cooking, energy use from other farm equipment, and other significant Industries
- Bottom-up assessment of energy demand from buildings and estimation of efficiency improvements in technologies such as cook stoves and tractors would also result in a more comprehensive green growth assessment.

The benefits assessment can also be enriched by including indirect and induced jobs in the analysis, examining water use in other sectors, incorporating pollution from industries, and assessing congestion in cities. However, some of this analysis may require primary data collection.

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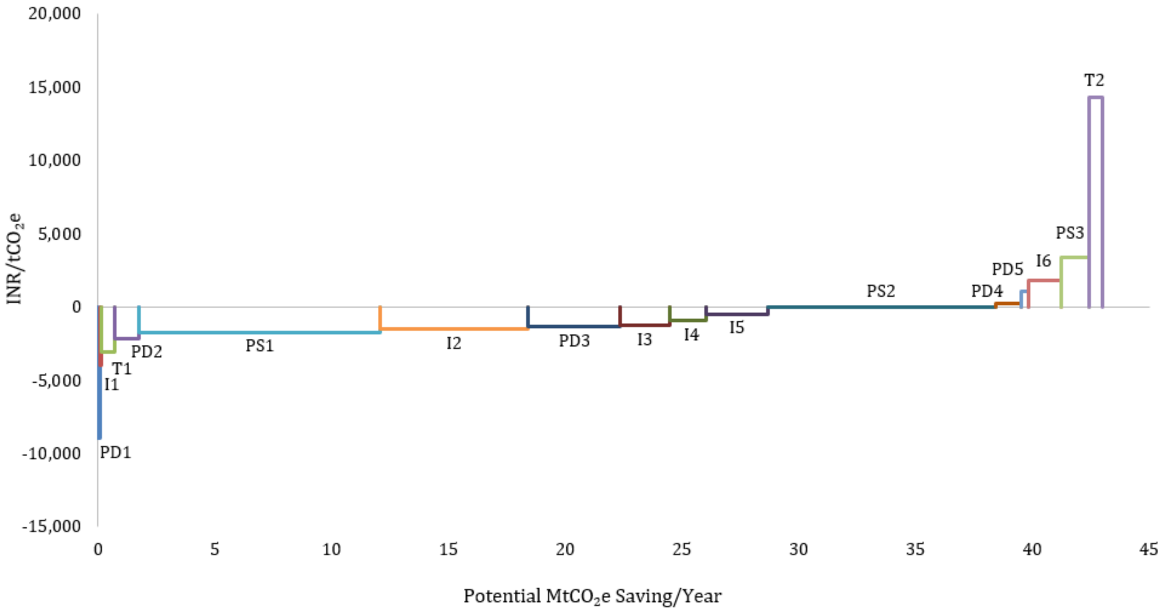
Appendix 1: Wind Potential in Select Districts in Karnataka

Table 9: Total Area and Wind Potential at 80 and 100m Hub Heights for Wind Rich Districts

Hub Heights	Total Area of Suitable 2% Waste and Agricultural Lands (in sq. km)	Potential (in MW)	Total Area of Suitable 10% Waste and Agricultural Lands (in sq. km)	Potential (in MW)
80m				
Chitradurga	104	658	526	3,311
Bellary	73	462	367	2,309
Koppal	67	425	337	2,123
Hassan	82	516	410	2,580
Chamraj Nagar	16	100	79	500
Chikkamagalur	36	224	178	1,121
Total	**379**	**2,385**	**1,896**	**11,944**
120m				
Chitradurga	124	778	618	3,892
Bellary	110	694	551	3,468
Koppal	86	539	428	2,697
Hassan	101	634	503	3,168
Chamraj Nagar	17	107	85	536
Chikkamagalur	60	377	299	1,883
Total	**497**	**3,129**	**2483**	**15,644**

Appendix 2: Marginal Abatement Cost Curve

Figure 20 places the greening opportunities on a Marginal Abatement Cost Curve (MACC). MACC curves plot the cost of reducing a unit of carbon dioxide against the abatement potential for different technologies in an increasing order of costs, such that it resembles a supply curve of mitigation technologies. Unlike the financial assessment below, which is a technology-centric analysis, MACC curves have been constructed on a scenario-based assessment. This means that each green growth opportunity as defined in GG was run over BAU to evaluate the impact on that opportunity on total system costs (investments and running costs), energy demand and/or supply, and therefore emissions. Based on this, the MACC was derived for 2030.



Power (Supply)		Power (Demand)		Industry		Transport	
PS1	Wind	PD1	Efficient Commercial Lighting	I1	New Industrial Processes (NIP) in Other Industries (Oth.)	T1	Scheduled Implementation of MRT Plan
PS2	T&D Loss Reduction	PD2	Efficient Commercial HVAC systems	I2	General Energy Efficiency (EE) in Iron and Steel (I&S)	T2	Electric Vehicles
PS3	Solar	PD3	AgDSM	I3	NIP in I&S		
		PD4	Efficient Residential Appliances	I4	Waste Heat Recovery (WHR) in I&S		
		PD5	Efficient Residential Lighting	I5	EE in Cement		
				I6	EE in Others		

Figure 20: MACC for Green Growth Opportunities

From the MACC, Energy Efficiency in Industries,[37] Wind Power and T&D loss reduction emerge as biggest opportunities to mitigate emissions. Most opportunities lie on negative part of the y-axis and therefore denote net economic benefit for every tonne of CO_2 abated. Efficient commercial lighting offers the highest return on mitigation achieved, whereas solar power deployment leads to additional costs for every tonne of carbon abated.

[37] EE in Industry is broken down into EE in Iron & Steel, EE Cement and EE Others.

Appendix 3: Payback Period Analysis

Payback periods of the greening opportunities are based on incremental cost of investment, any other operations and maintenance cost, and/or annual savings of fuel or electricity associated with these opportunities. Table 10 presents the basis of comparison of green growth opportunities with baseline technologies over their respective lifetimes.[38]

Table 10: Technology Comparison for Calculating Payback Periods

Area	Opportunity	Base case
Appliances (RES APP)	5 Star or Super-Efficient Appliances	3 Star Appliances
Lighting (RES LIGHT)	CFL or LED	Incandescent Bulb
Agricultural Pump-Sets (PUMPS)	5 Star Pump-Set	Inefficient Pump-Set
Private Transport (E2W)	Electric Two-Wheeler	Petrol Two-Wheeler
Private Transport (E4W)	Electric Four-Wheeler	Diesel or Petrol Four-Wheeler
Public Transport (MRT)	Scheduled Implementation of MRT Plan	Delayed Implementation
Industry (IND EE)	General Energy Efficiency Technologies	Base Technology
Industry (IND WHR)	Waste-Heat Recovery Technologies	Base Technology
Industry (IND NIP)	New Industrial Processes/Sub-Processes	Base Technology
Power Generation (WIND)	Wind-Based Power	Coal-Based Power
Power Generation (SOLAR)	Solar-Based Power	Coal-Based Power

[38] Technologies dominant in BAU.

Figure 21 presents the range of discounted payback periods (DPP)[39] in each area of intervention based on the comparisons above. The DPPs for only those opportunities that yield payback over their lifetimes are displayed.

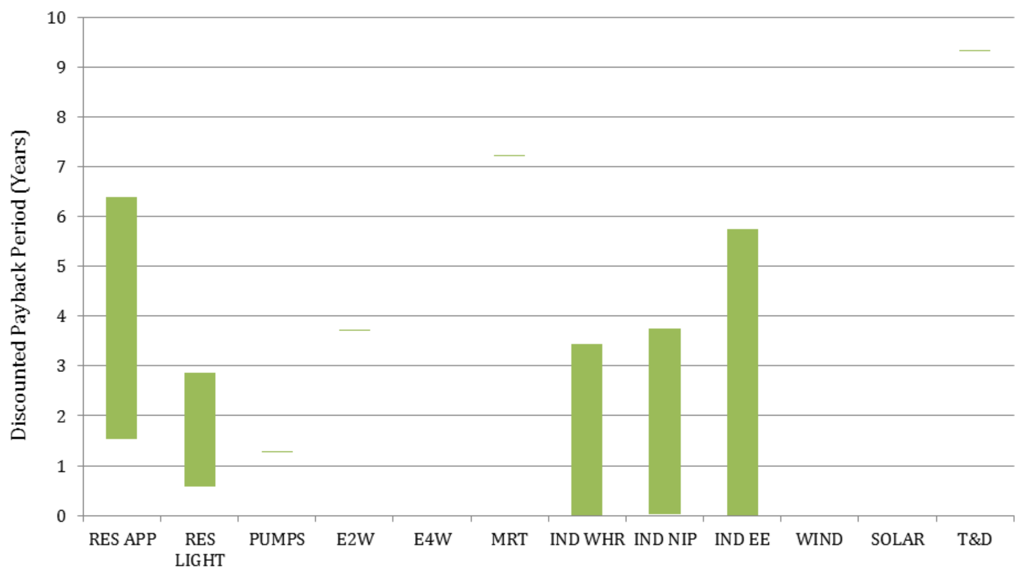


Figure 21: Payback Periods of Green Growth Opportunities

It is seen that besides wind and solar power, all interventions result in payback of incremental investments over their lifetimes. Therefore, there is a definite economic case for most opportunities. It is also highly likely that in the longer term, renewable energy prices may actually reach parity with that of coal based power owing to rising prices of coal and falling capital costs of renewable energy. Spending on infrastructure for reducing T&D losses has a relatively lengthy payback period of over 9 years, but the capital invested yields returns (in terms of power generation saved) over many more years. Demand-side technologies such as efficient appliances, pump-sets and industrial energy efficiency, WHR and NIP yield attractive returns on investment and their payback periods are low. However, switching to 5 Star air-conditioners or from CFLs to LEDs for households does not yield a payback period at current prices. This is important from the perspective of prioritising between greening opportunities, given that the penetration of efficient air-conditioning and LEDs by 2030 is high. In such a case, the scores for financial attractiveness have been adjusted for the purpose of prioritisation. E4W are not yet commercially viable owing to high battery costs, and relatively smaller lives of the batteries. Implementing MRT on schedule is also beneficial compared to delayed implementation considered in BAU.

[39] Cash flows have been discounted at 10%.

Appendix 4: Weights for Prioritisation

The weights considered for the green growth benefits or the x-axis of Figure 19 are presented by sector in the table below:

Table 11: Weights Considered for Green Growth Benefits Criteria

Sector	Non-Financial Economic Benefit			Local Environmental Benefit			Social Benefit	Mitigation Benefit
	Direct Job	**Fossil fuel dependence**	**Congestion**	**Local Air Pollution**	**Land**	**Water**		
Industry	12.5%	12.5%	0%	8.33%	8.33%	8.33%	25%	25%
Power (Demand)	12.5%	12.5%	0%	8.33%	8.33%	8.33%	25%	25%
Power (Supply)	12.5%	12.5%	0%	8.33%	8.33%	8.33%	25%	25%
Transport	8.33%	8.33%	8.33%	25%	0%	0%	25%	25%
Waste	12.5%	12.5%	0%	0%	12.5%	12.5%	25%	25%

For the y-axis of the figure, financial sub-criteria of investment requirement and technology payback period were given equal weights, of 50% each.