Can India Grow and Live Within a 1.5 Degree GHG Emissions Budget?

Integrated Research and Action for Development

(Energy Policy, Volume 120, May 2018, Pages 24–37) Kirit Parikh, Jyoti Parikh and Probal Pratap Ghosh

1. Background

- The Paris Agreement aims to keep global temperature rise below 2^0 Celsius and to pursue efforts to further limit it to below 1.5^0 Celsius above pre-industrial levels.
- Past studies (Parikh K et al, 2010, 2012 and 2014) have shown that NDCs and low carbon pathways for India is possible with some costs to the economy.
- The dramatic progress in the world to increase energy efficiency and reduce costs of renewable power opens possibilities to reach 1.5^0
- What is a fair share of India in global carbon budget till 2050 for a 1.5^0 C world? Could India live within this budget while meeting its human development goals? What will be the levels of emissions? What are the implications for India's power sector, economic development and policies?

2. Approach

- Energy system optimization model used generally to assess GHG pathways are technology rich but do not correctly account for linkages with infrastructure, manufacturing, construction, transport etc. and hence under estimate the impact of policies.
- A Macroeconomic full economy model accounts for economic feedback effects, also called rebound effects.
- We use an economy wide model based on the Social Accounting Matrix (SAM) for the year 2007-08 to represent the whole economy and the sectoral inter linkages.
- Model has hard linkage between the economy and technological options for low carbon development as they are integrated in one model. Feedback and demand structure changes are endogenous.
- We develop three scenarios- DAU, AMBA and TC1.5 for the period 2010 to 2050.
  - DAU scenario represents continuation of current policies and trends
  - AMBA scenario shows achievement of India's NDC pledge through implementation of Government's policies and programmes
  - TC1.5 scenario examines the feasibility for India to grow within a carbon budget consistent with 1.5^0 C aided by technological progress and energy efficiency increase.
- The three scenarios are compared to show that India's current pledges will help its emission remain with 2^0 C budget but technological progress and energy efficiency will help it achieve a emissions reduction consistent with 1.5^0 C temperature rise

3. Scenarios

The broad characteristics of these scenarios are as follows: All scenarios provide for human development policies (SDGs) for housing, health, education, water and sanitation. Real discount rate 4 %; Foreign inflows 5.5 % of GDP in 2010 going down to 0.8 % by 2050; Marginal savings rate 35 %; Government consumption grows at 7% per year; private consumption must grow monotonically but not more than at 9 % in any year. Population projection as per median variant of United Nations (2014).

Dynamics as Usual Scenario (DAU): This is a reference case scenario

- Current trend of Renewables; Hydro and Nuclear expansion are assumed to continue.
- Total Factor Productivity rate of 1% per year in Agriculture and Power and 1.5% for rest.
- All new Coal based power generation plants are assumed to be of super critical variety after 2017.
- Maximum of 40 % of domestic gas available for power generation, No limit on imported gas
- Autonomous Energy Efficiency Improvements (AEEI) for coal, oil, natural gas and power is assumed to be 0.75% per year reducing energy use by 28% in 2050.
- AEEI of coal in subcritical plants is assumed at 0.5% and T&D losses in auxiliary consumption reduce from 20% to 10%.
- Efficiency of use of petroleum products and electricity by households assumed to increase by 0.5% and of electricity by 1% respectively.
- Penetration rates for vehicles using electricity and gas assumed to be 0.2% and 0.3% respectively 2016 onwards.

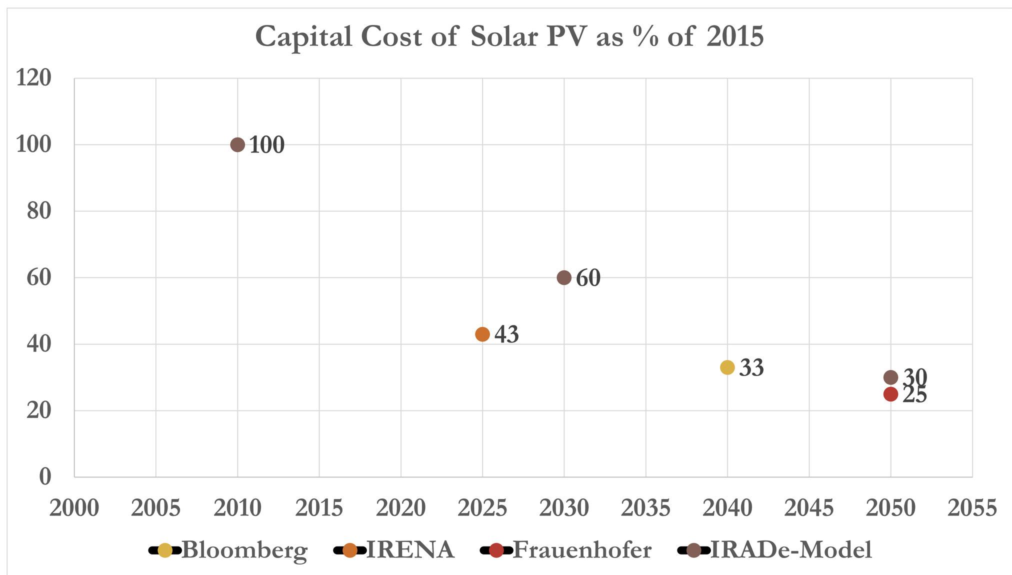
Ambitious Action (AMBA): We assume aggressive efforts in technological cost reduction, increasing capacity building efforts, higher efforts for energy efficiency, cleaner transportation options and emphasis on making efficient buildings more affordable.

- 175 GW of renewable capacity by 2022 and trend of increasing share of renewable continued thereafter
  - 100 GW of solar power by 2022
  - 60 GW of Wind Power by 2022
  - 10 GW of Biomass by 2022
  - 5 GW of Small Hydro by 2022
- Nuclear capacity growth stepped up to 70 GW by 2050
- Hydro capacity growth stepped up
- AEEI of Coal, Oil and Gas increased to 1.5% in non-power sectors and to 1% in power sector technologies except sub-critical coal.
- Efficiency of use of petroleum products and electricity by households will decrease demand for a given level of income by 1.5% and 2% respectively by 2050. Electricity demand will be 55 % lower than in 2010.
- Penetration rates for vehicles using electricity and gas stepped up to 0.32% and 0.48% respectively after 2032.
- Increasing share of Energy Conservation Building Code (ECBC) compliant buildings.
- increasing share of Railways in freight transport

TC1.5 (Technical change (TC) scenario): The assumptions on reduction in costs of renewables, storage technology, energy efficiency and carbon budget assumed for India is provided below. The assumptions are presented as additional policy changes over AMBA scenario (which satisfies NDC and 2^0 C global temperature rise) to now satisfy 1.5^0 C Carbon budget for India.

Reduction in Solar costs

- We assume solar PV cost reductions of 40 % by 2030 and 70 % by 2050, which are conservative compared with other models like Bloomberg (2017), IRENA (2016), USEIA (2016), Frauenhofer- ISE (2015)
- This implies a learning rate of 24 % which is comparable to the mean learning rate of 23% estimated over 1959 to 2011 by Rubin et al (2015).



Reduction in Battery costs

- Schmidt et al (2017) estimates lithium ion battery cost to reduce from \$350/kWh in 2015 to \$75/kWh by 2040 and extending the trend to 2050 would bring the cost down further to \$ 60/kWh.
- Noah K. et al (2017) estimates learning rate of 15.47 % over 1991 to 2015 resulting in battery cost to be \$ 50/kWh by 2050.
- We assume battery cost of US\$ 100/kWh by 2025 and with a learning rate of 15.5 % we have a battery cost of \$ 50/kWh by 2050
- We also assume a battery life of 5 years and the annual operating cost is adjusted to account for battery replacement.

We assume Solar and Wind costs reduce by 40% in 2030 and by 70% in 2050. Nuclear costs decrease by 60% in 2050.

Assumptions of energy efficiency and demand

Energy Efficiency in Production: AEEI of Coal, Oil and Gas increased to 2 % in non-power sectors

Energy Efficiency in Commercial Buildings: Considering gains from more efficient equipment, Electricity savings in new commercial buildings assumed be 50 % with an additional investment cost of 10 %.

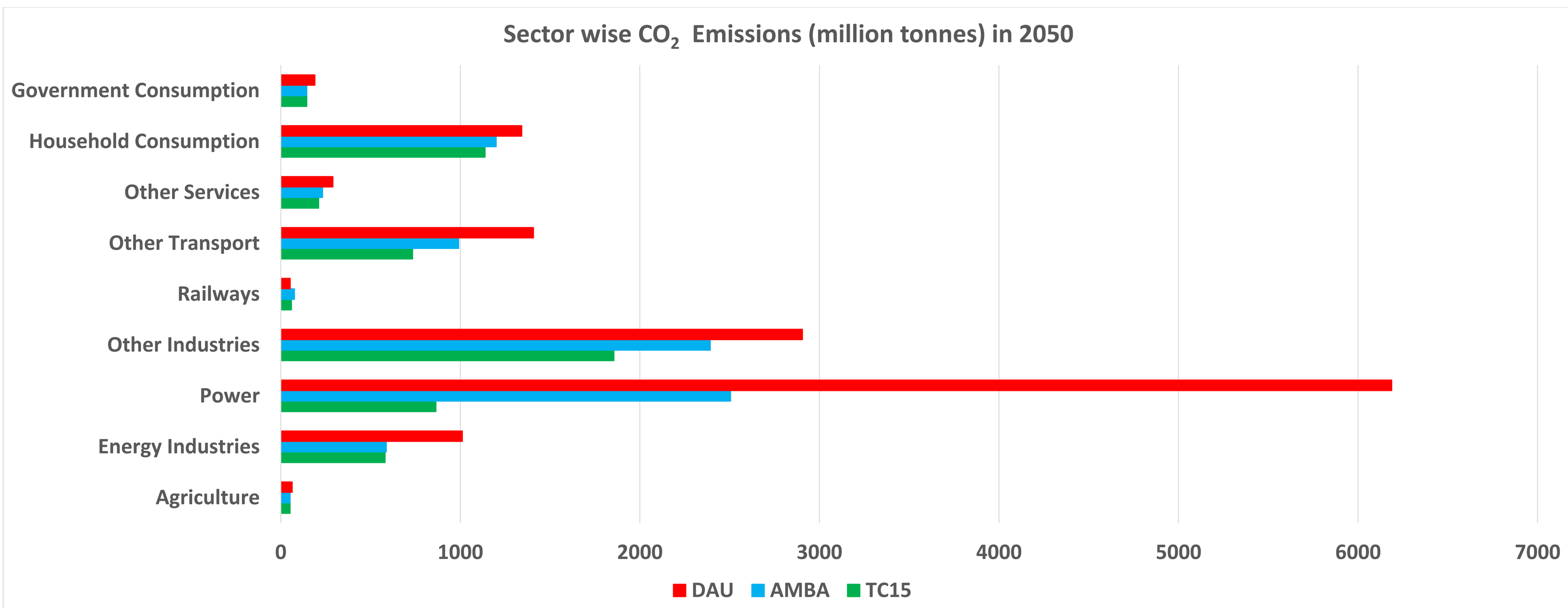
Electric Mobility: Increased share of vehicles using electricity and gas replacing conventional vehicles using Petroleum products.

- Penetration rates for vehicles using electricity is stepped up to 1.6% in 2016-2032 and to 2% from 2033-2050.
- Penetration rates for vehicles using Gas is stepped up to 0.4% in 2016-2032 and to 0.5% in 2033-2050
- This implies 45% of the vehicles would be EV and 10% will run on gas by 2050.

4. India's Share in Global Environmental Space

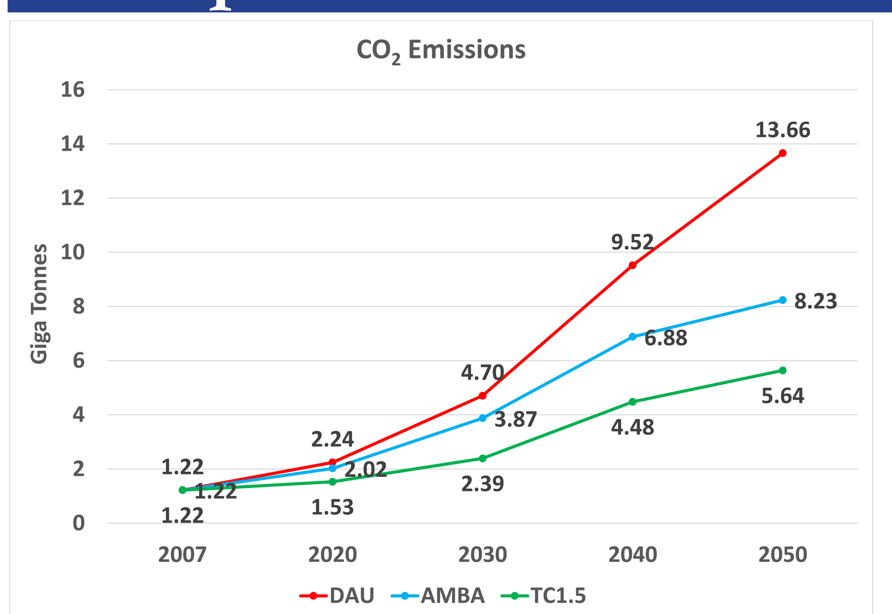
- The carbon budget for the world and for India which corresponding to 1.5^0 C warming is computed using the RCP2.6 scenario which has a mean warming of 1^0 C with a range from 0.3^0 to 1.7^0 C.
- The carbon budget for India is obtained from the global carbon budget using equal per-capita allocation as a basis for allocating emission rights among all the countries.
- Considering the mean value of RCP 2.6 scenarios (990 GT CO2), with 18% as India's share in global population, if India's cumulative emissions over 2012 to 2050 remains below **160 GtCO2**, then it will be consistent with the RCP 2.6 scenario.
- Ideally however, the global carbon budget in GT-years of residence of the emissions should be considered.
- With 2050 as horizon a Giga tons of emission in 2010 should count for 40 GT-years, whereas one Giga tons of emission in 2050 should count as one Gt-year. Such a measure would be more equitable to developing countries whose emissions will be increasing over the development period.
- The RCP scenarios have implicit assumptions of time profiles of emissions (Fuss et al (2014)) which is used to compute the carbon budget in GT and GT years.
- The cumulative GT-years for 2012 to 2050 for the RCP2.6 scenarios is calculated as GT-years (2012 to 2050) = Sum over 2012 to 2050 [(Emissions in year t) x (2050-t)] = 20240 GT-years
- The cumulative global budget in GT-years for 2012 to 2050 is 20240 GT-years and India's share will be **3600 GT-years** of the global environmental space.
- With the lower limit of RCP 2.6 scenarios (510 GT CO2), India's share in global space should be (510/990) x 3600 = **1854 GT-years** of CO_2.
- **We compare the emissions profiles from the three scenarios to the carbon budget in GT (160 GT) and GT-Years (3600 and 1854 GT-Years).**

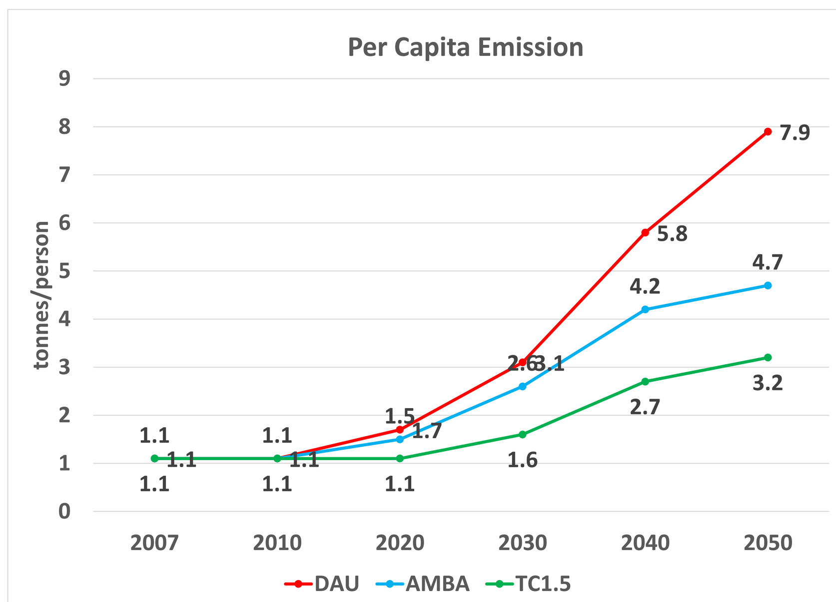
5. Impact on CO_2 emissions structure



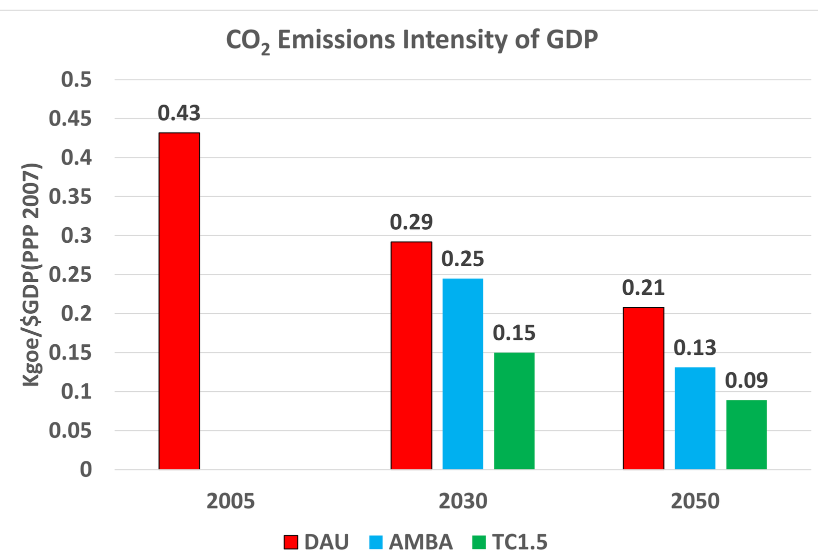
- Power sector emissions are one third of AMBA and one seventh of DAU.
- Technological cost reductions and energy efficiency assumed in the power sector contribute to this decline
- After the power sector 'other industries' are the major emitters even though no substitution of fossil fuels by alternatives has been stipulated in the industrial sector. With such substitution even lower emission levels can be achieved.
- Transport sector emissions are half as DAU and three fourths as AMBA due to vehicle efficiency and electric vehicles.
- Households restructure their consumption basket to spend the savings they make from energy efficiency improvements resulting in modest reductions
- Household emissions reductions in TC1.5 are modest at 15 per cent and 1 % compared with DAU and AMBA respectively
- **Technological progress and energy efficiency enables India to cut emissions in important sectors of power, other industries and transport which may contribute to future emissions growth.**

6. Impacts on Emissions





- CO_2 emissions in AMBA and TC1.5 fall to 3.9 GT and 2.4 GT compared to 4.7 GT in DAU in 2030.
- CO_2 emissions in AMBA and TC1.5 reduce to 8.23 and 5.64 Gt compared with 13.7 Gt in DAU in 2050.
- Per capita emissions are only 4.7 and 3.2 tonnes in AMBA and TC1.5 compared with 7.9 tonnes in DAU in 2050.
- Emissions intensity of GDP in AMBA reduces to 0.25 in 2030 and TC1.5 reduces it further to 0.15 compared to 0.29 in DAU in 2030
- AMBA reduces emissions intensity of GDP by 41% and TC1.5 reduces by 65% in 2030 compared to 2005.
- By 2050, AMBA reduces emissions intensity by 70% and TC1.5 reduces by 80% compared to 2005
- Both AMBA and TC1.5 satisfy emissions intensity reduction target
- **TC1.5 can contain emissions within 1.5^0 C despite the requirement to meet HDI indicators for India**



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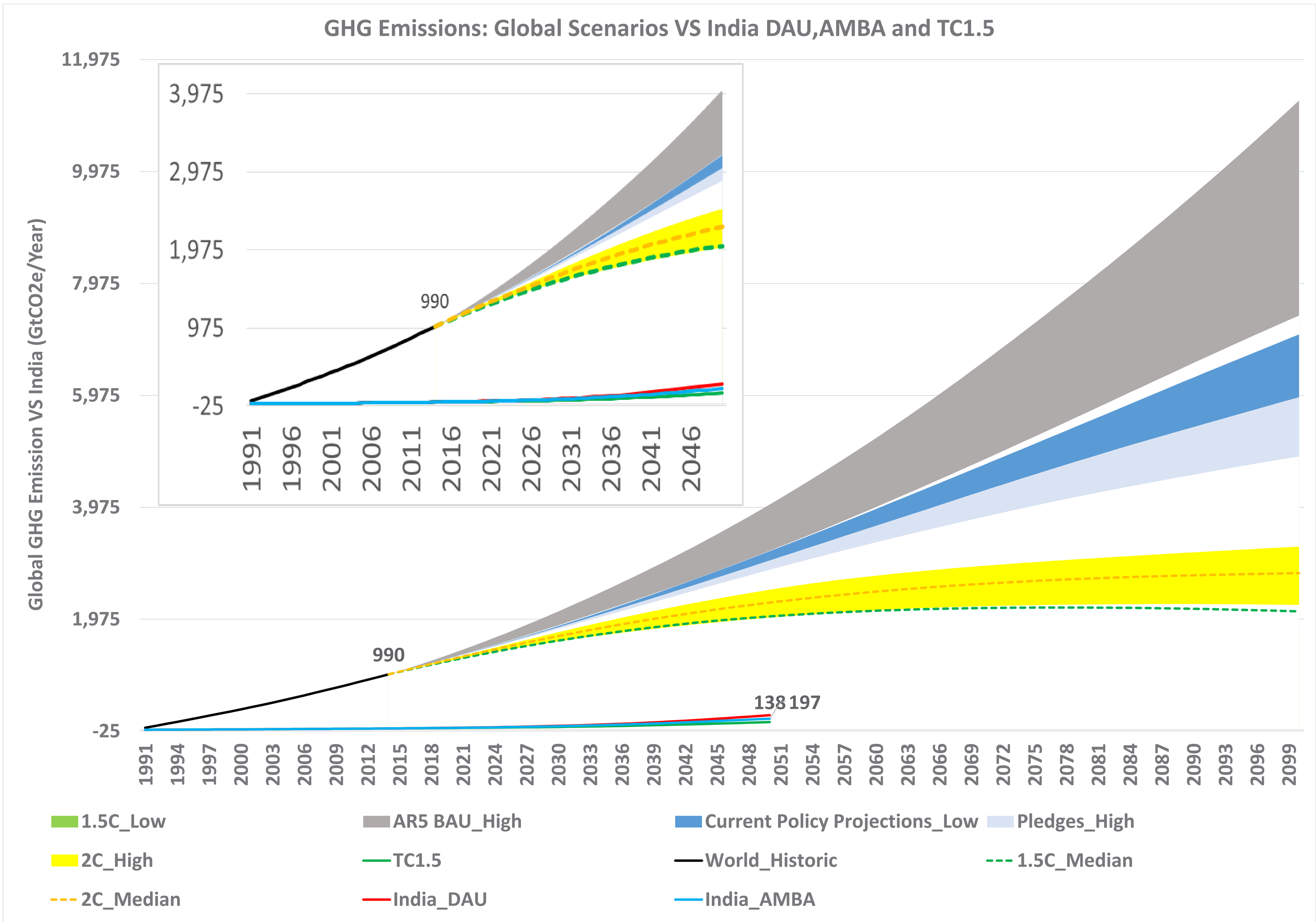
7. Are Emissions within Quota?

Cumulative Emissions	Gt CO2			GT-years CO2*		
	DAU	AMBA	TC1.5	DAU	AMBA	TC1.5
2012-2030	50	44	31	1403	1246	903
2012-2040	121	99	65	2466	2067	1416
2012-2050	242	178	119	3096	2493	1698

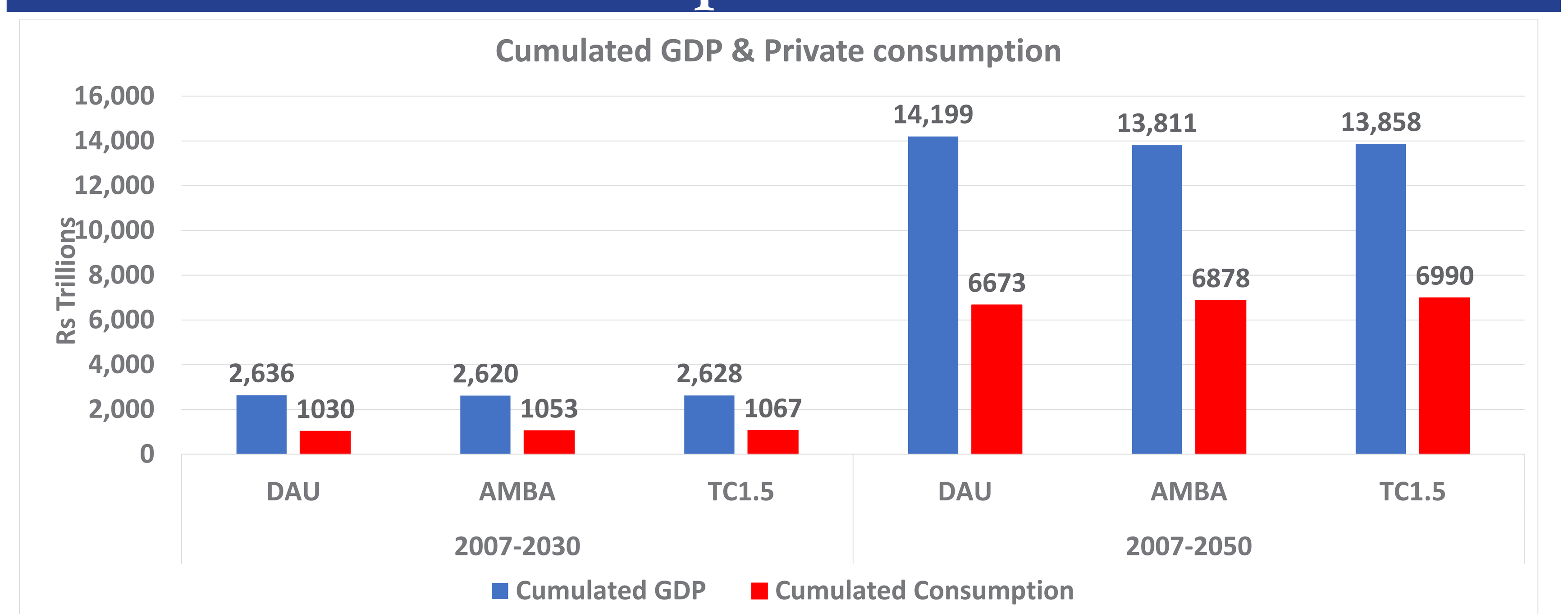
- The cumulative emissions in TC1.5 are way below 160 Gt CO_2 as per India's share in the RCP2.6 scenario for the 1.5^0 C target.
- The cumulative emissions of all scenarios are below 273 GT CO_2 (1685×0.18×0.9) as per India's share in RCP8.5 scenario consistent with 2^0 C temperature rise.
- India's emissions from current policies and current pledges are likely to keep its emissions within the 2^0 C temperature rise however technological progress and energy efficiency can help it cut its emissions further to be within the 1.5^0 C carbon budget
- In terms of GT-years in RCP 2.6 scenario, if we consider the mean value, India's share in GT-years is 3600 and if we consider lower bound, India's share comes to 1854 GT-years over 2012 to 2050
- All three scenarios stay within the limit of 3600 GT-years
- Emissions in TC 1.5 scenario with 1698 Gt-years, is preferable as it stays within the limit set by the lower bound.
- **Globally and in India there should be a concerted R&D effort to realize these technological cost reductions and energy efficiency.**



Source: https://climateactiontracker.org/global/temperatures/

The above graph shows how model projections for India stack up compared to the global projections and that India's emissions in all possible futures are likely to remain within emissions bounds for 2^0 C and 1.5^0 C global temperature rise.

8. Macroeconomic impact

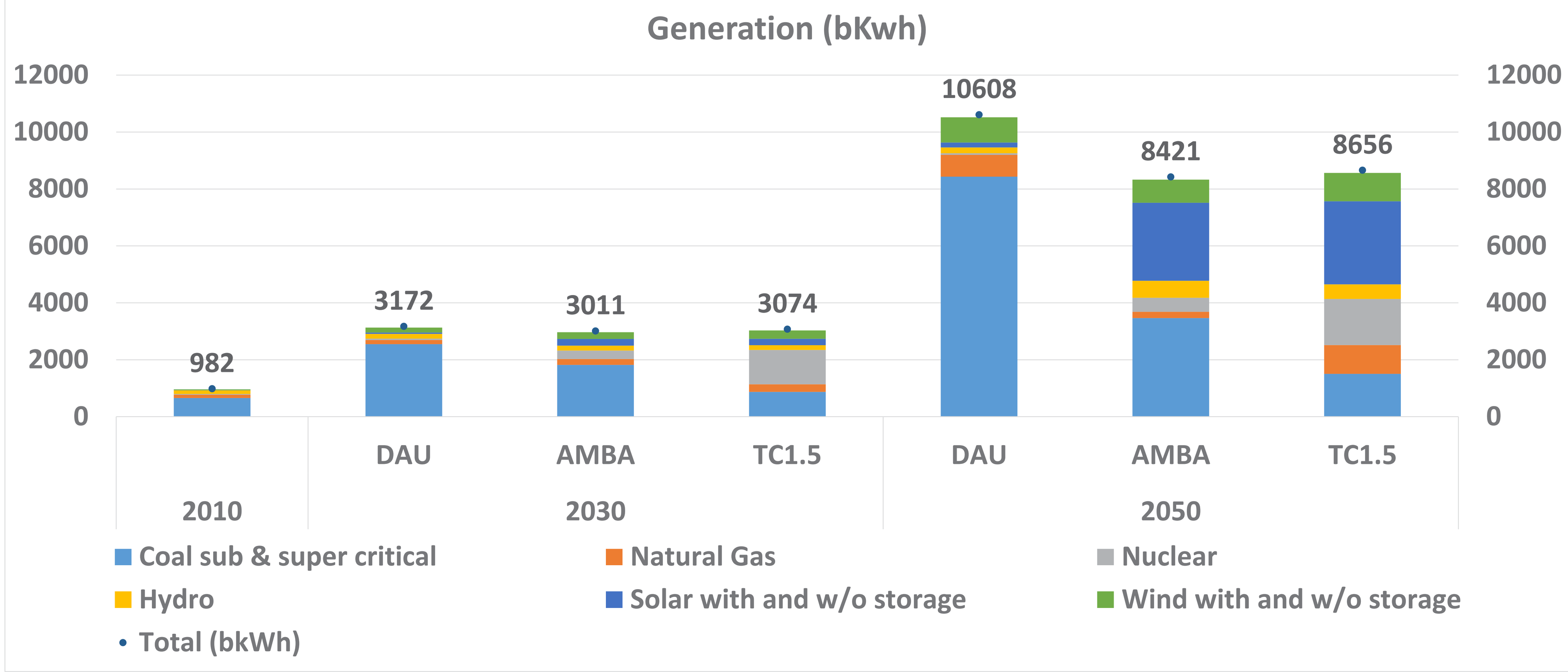


Macroeconomic channels through which mitigation policies impact the economy

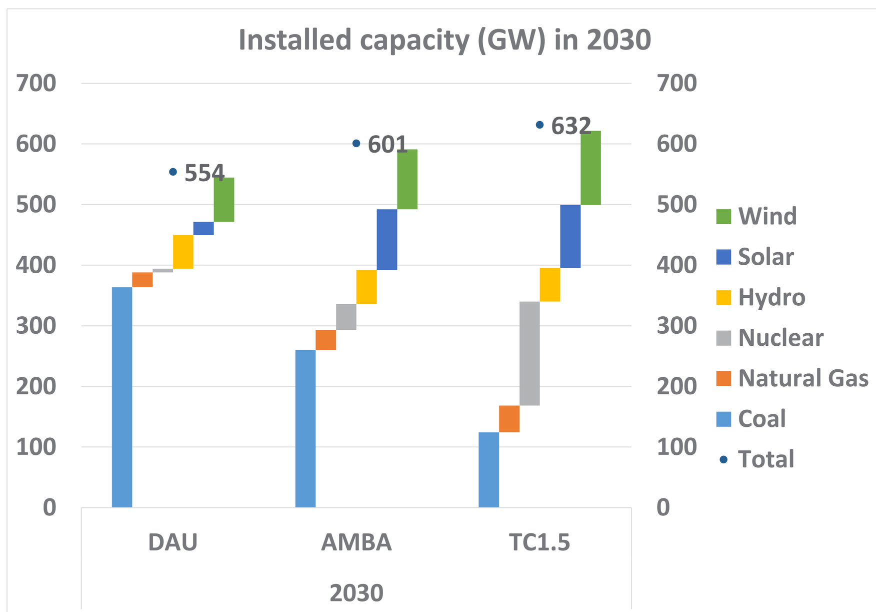
- Pushing costlier technologies like Renewables and Nuclear over cheaper technologies like coal crowds out investment from other sectors to meet the higher investment requirements in the power sector resulting in lower GDP and power demand.
- Energy efficiency provides for higher output for the same level of fossil fuel use (rebound effect) resulting in higher GDP, higher consumption and power demand
- Reduction in petroleum products use leads to lower oil import bill which results in higher GDP and consumption due to a favorable Balance of payment impact.

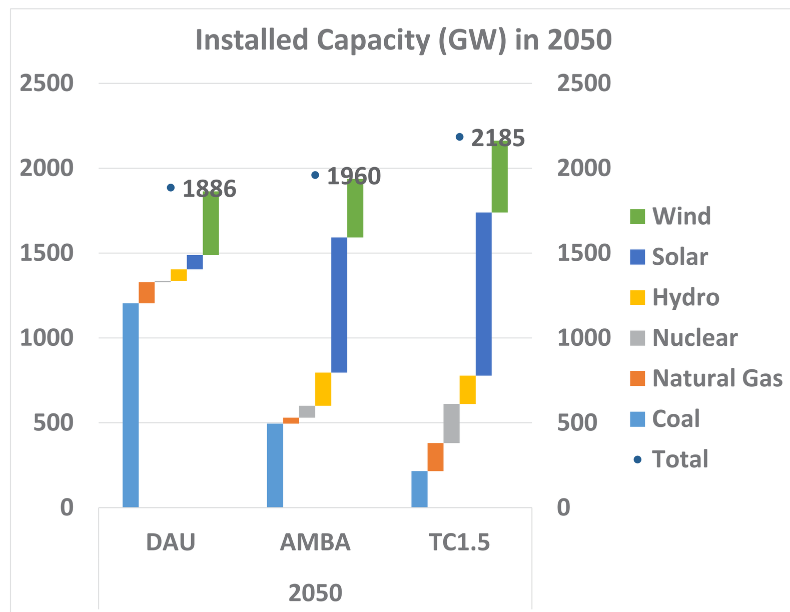
- Per capita consumption is around 6 % higher in 2045 and around 1% higher in 2050 in TC1.5 compared to DAU.
- Cumulated consumption is around 3% higher in AMBA and 5% higher in TC1.5 compared to DAU in 2050.
- The CAGR of GDP over 2012 to 2050 is 7.44 %, 7.34% and 7.33% in DAU, AMBA and TC1.5 respectively.
- The impact on GDP is small, GDP is lower by around 4 % in 2050 in AMBA and TC1.5 compared to DAU.
- **Lower GDP does not result in lower consumption. AMBA and TC1.5 do not impose any cost on human wellbeing as reflected in per capita consumption.**

9. Impact on Power generation and capacity



- In AMBA the impact of crowding out dominates and total generation in is 20 per cent lower in 2050 compared to 10608 bkWh in DAU
- Technological cost reduction decreases the crowding out impact and the rebound effect of higher rates of energy efficiency increase and changes in the household behavioral pattern increases total generation in TC1.5 than in AMBA in 2050.
- Coal provides 80 % of generation in DAU in 2050 which reduces to 41 % in AMBA and 17 % in TC1.5.
- The share of fossil fuels goes down from 87 % in DAU to 44 % in AMBA to 29 % in TC1.5.
- The share of renewables in 2050 increases from 10 % in DAU to 43 % and 46 % in AMBA and TC1.5 respectively.
- In the TC1.5 scenario generation from storage plants in 2050 is 2310 bkWh. The net storage is thus 2310 x 0.35 x 0.9 = 738 bkWh, which is 8.4 % of the total generation of 8656 bkWh (35 % is stored with storage efficiency of 90 %)





- Total installed capacity in 2030 is 554 GW in DAU, 601 GW in AMBA and to 632 GW in TC1.5
- In 2050 installed capacity increases to 1886 GW in DAU, 1960 GW in AMBA and 2185 GW in TC1.5
- Total Capacity increases in the low carbon scenarios of AMBA and TC1.5 due to increasing renewable technologies with lower PLFs
- Share of renewables in total capacity is 17% in DAU and this increases to 33% and 36% in AMBA and TC1.5 in 2030 and in 2050, renewable share is 24% in DAU and increases to 58% and 73% in AMBA and TC1.5
- Non fossil fuel share in total capacity is 30% in 2030 to 2050 in DAU and this increases to 51% and 63% in AMBA and TC1.5 in 2030 and further to 73% and 83% for AMBA and TC1.5 in 2050.
- **Clearly compared to AMBA (2^0 C), In the TC1.5 (1.5^0 C) scenario nuclear capacity needs to increase significantly more in 2030 but in 2050 solar and wind based capacity needs to expand much more**

10. Conclusions

- An equitable share of global environmental space for India over 2012-2050 would be 160 GTCO2 based on median value of the RCP2.6 scenarios.
- In terms of GT-years based on the lower bound value of 510 GTCO2 of AR5's RCP2.6 scenarios, India's share comes to 1854 GT-years.
- India's per capita emissions reach 3.0 tonnes/year in 2045 - 50% of the current world average of 6 tonnes- and remain at that level till 2050.
- If the world needs to move from 2^0 C warming target to a 1.5^0 C target and India needs to bring down cost of nuclear, renewables, storage technologies, invest in energy efficiency and concentrate efforts on increasing its nuclear and renewable capacity.
- solar PV cost projected to come down by 50 % from US$ 0.60/peak W installed in 2015 to US$ 0.30/peak W installed in 2050
- Battery cost to come down from US$200/kWh in 2015 to US$ 50/kWh in 2050.
- Even if projected cost for 2050 are 25 % higher, India's emissions still remain within the limit of 1854 GT-years.
- India's emissions can be within its equitable share of environmental space, provided the reduction in costs of solar power and storage technologies occurs.

11.Policy Implications

- Concerted programme of R&D to achieve technological changes.
- Global effort or by the International Solar Alliance to further reduce cost of PV, increase its efficiency and reduce the cost of electricity storage should be mounted
- The reductions in electricity storage costs will ease the penetration of electric vehicles.
- India is among the very few major GHG emitter who has to close the huge human development gap
- The target to limit global warming to 1.5 degree has to be achieved by market mechanism, the non-fossil technologies have to be a lot cheaper.
- Human development goals can be achieved by India while still being within a carbon budget consistent with 1.5-degree warming, if technology cost projections are realized with India's modest consumption patterns.

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