CII-ITC Centre of Excellence
for Sustainable Development

Confederation of Indian Industry
125 Years - Since 1895

Resource Efficiency and Climate Change

A scoping study for the Indian context

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List of Abbreviations

AR	-	Assessment Report
CII	-	Confederation of Indian Industry
CO_2e	-	Carbon dioxide equivalent
CoP	-	Conference of Parties
ECBC	-	Energy Conservation Building Code
EOL	-	End-of-life
ETC	-	Energy Transitions Commission
GDP	-	Gross Domestic Produce
GHG	-	Greenhouse gas
GRIHA	-	Green Rating for Integrated Habitat Assessment
IPCC	-	Intergovernmental Panel on Climate Change
IPPU	-	Industrial Processes and Product Use
IRP	-	International Resource Panel
kWh	-	kilowatt hours
LED	-	Light-emitting diode
NDC	-	Nationally Determined Contributions
NMEEE	-	National Mission for Enhanced Energy Efficiency
NREP	-	National Resource Efficiency Policy
PAT	-	Perform, Achieve and Trade
PJ	-	peta joule
RE-CC	-	Resource Efficiency – Climate Change
UN	-	United Nations
UNEP	-	United Nations Environment Programme
UNFCCC	-	United Nations Framework Convention on Climate Change
WRF	-	World Resources Forum
ZED	-	Zero Effect Zero Defect

Introduction

Background

Globally, greenhouse gas emissions have been rising since the beginning of the industrial revolution in the 1850s. Emissions have grown from 35 Gt CO_2e in 1990, when the United Nations (UN) General Assembly negotiations on a framework convention for a global treaty on climate change first began, to 49 Gt CO_2e in 2016.[1] Between 2000 and 2010, annual anthropogenic GHG emissions have increased by 10 Gt CO_2e, with this increase directly coming from energy supply (47%), industry (30%), the transport (11%) and buildings (3%) sectors. If indirect emissions are also considered, a larger contribution can be attributed to the buildings and industry sectors. In 2010, the industry sector contributed to one-third of global emissions (21% direct emissions and 11% indirect emissions due to electricity generation for industry)[2]. Increased emissions contribute directly to climate change; there is a growing body of scientific evidence attributing to climate change different impacts on natural and human systems (Figure 1).

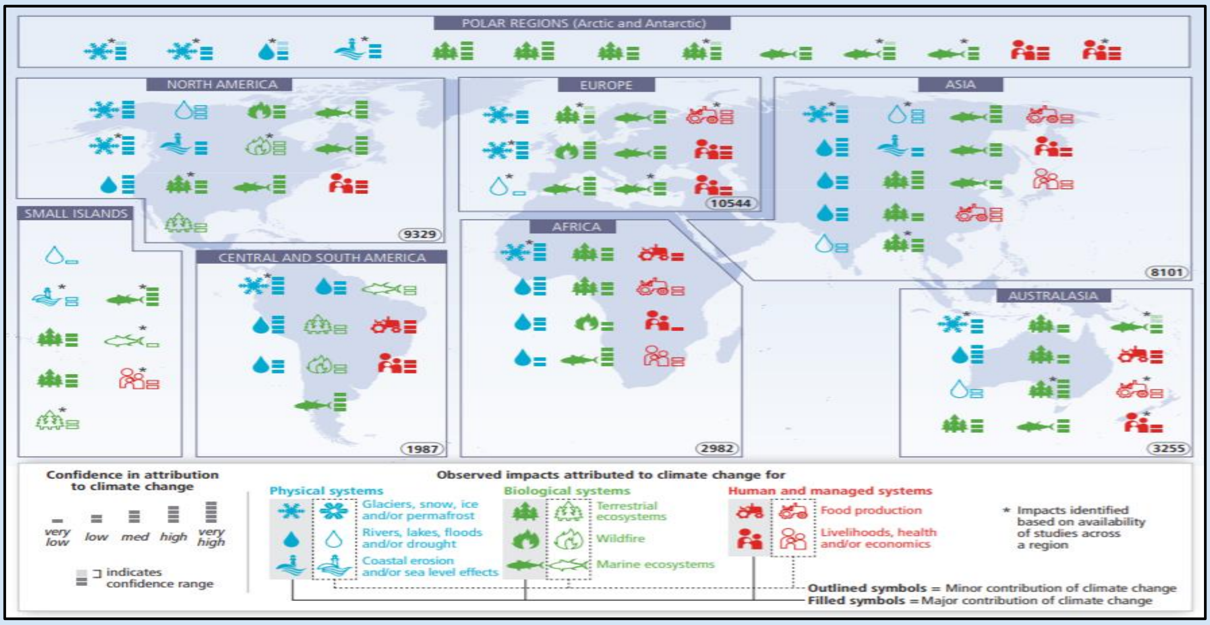

Figure 1: Widespread impacts attributed to climate change based on scientific evidence

To mitigate the impacts of climate change, the historic Paris Agreement of 2016 included a collective goal to limit Earth's warming to well below 2°C by 2100, with efforts to limit warming to 1.5°C. Central to this ability to curb warming and increase resilience are countries' own contributions to the global effort. In the lead up to and following the Paris Agreement negotiations in 2015, 165 post-2020 climate commitments—known as "intended nationally determined contributions, or INDCs"— of 192 countries, were submitted to the United Nations

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[1] ClimateWatch (n.d.). Global Historiacal GHG Emissions. Available at https://www.climatewatchdata.org/ghg-emissions?chartType=area&sectors=industrial-processes&source=CAIT

[2] IPCC (2014). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Available at https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_full.pdf

Framework Convention on Climate Change (UNFCCC) Secretariat.[3] If fully implemented, these NDCs would contribute significantly to reducing global warming. However, these commitments are still far short of those in the Paris Agreement. To achieve the 2°C and 1.5°C goal in 2030, annual emissions need to be 15 Gt CO_2e and 32 Gt CO_2e lower than the current projections (Figure 2).[4] By the decade 2006–2015, human activity had warmed the world by 0.87°C (±0.12°C) compared to pre-industrial times (1850–1900). If the current warming rate continues, the world would reach a human-induced global warming of 1.5°C around 2040.[5]

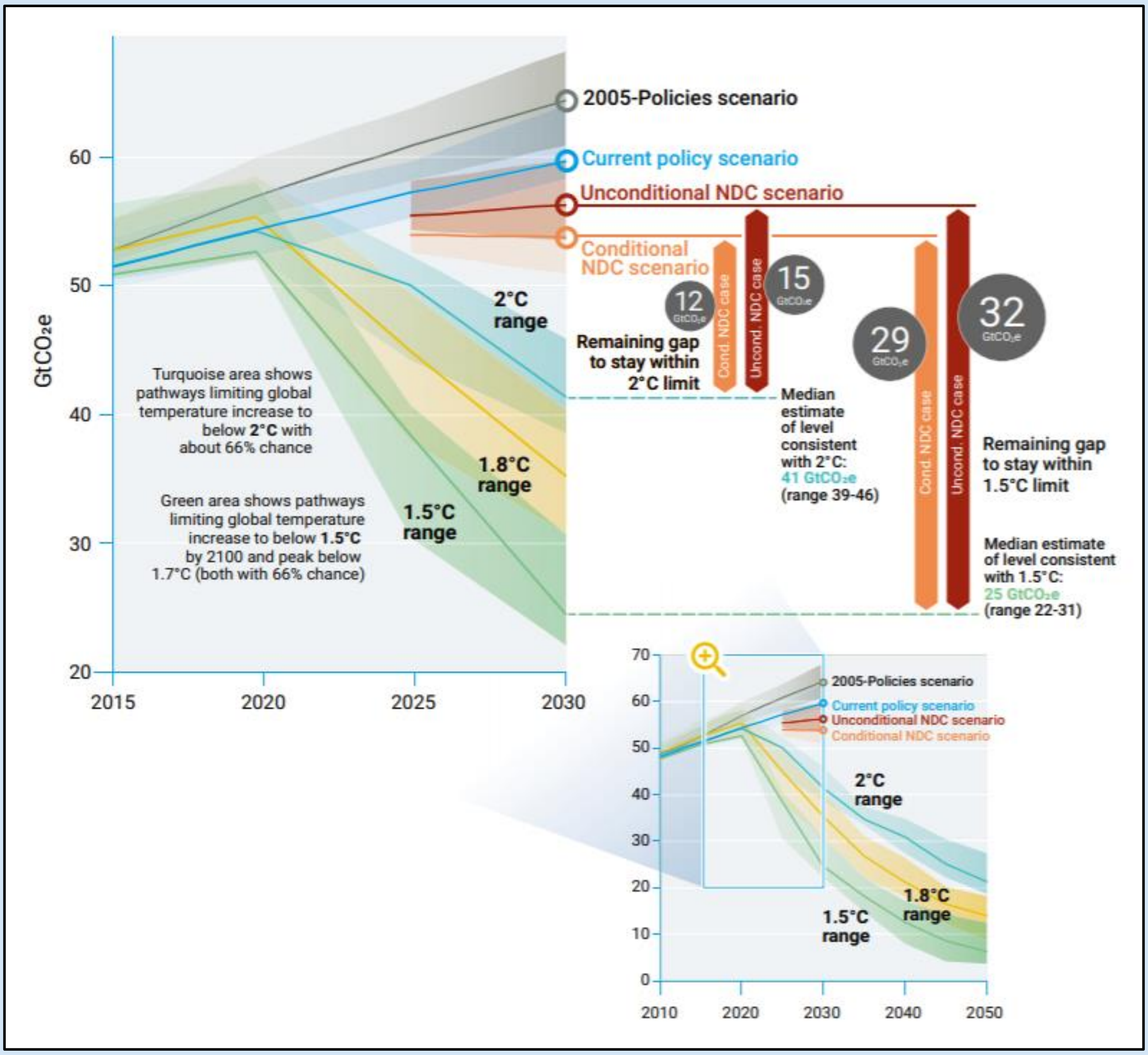

Figure 2: Global GHG emissions under different scenarios and the emission gaps by 2030

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[3] UNDP, UNEP, UNEP DTU & WRI (2020). Implementing Nationally Determined Contributions (NDCs). UNEP DTU Partnership Copenhagen, Denmark. Available at https://unepdtu.org/wp-content/uploads/2020/03/implementing-ndcs-report.pdf

[4] UNEP (2019). Emissions Gap Report 2019. Executive summary. United Nations Environment Programme, Nairobi. Available at https://wedocs.unep.org/bitstream/handle/20.500.11822/30798/EGR19ESEN.pdf?sequence=13

[5] IPCC (2018). Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Available at https://www.ipcc.ch/sr15/download/#full

In India, emissions have grown at a CAGR of 5% from 1.46 Gt CO_2e in 2005 to 2.38 Gt CO_2e in 2015.[6] Over the same period, the energy intensity of the Indian economy declined from 18.46 PJ/billion USD to 11.59 PJ/billion USD.[7] However, as observed worldwide, economic and population growth in India continue to be the most important drivers for increased emissions and outpace the reductions from improvements in energy intensity (Figure 3).

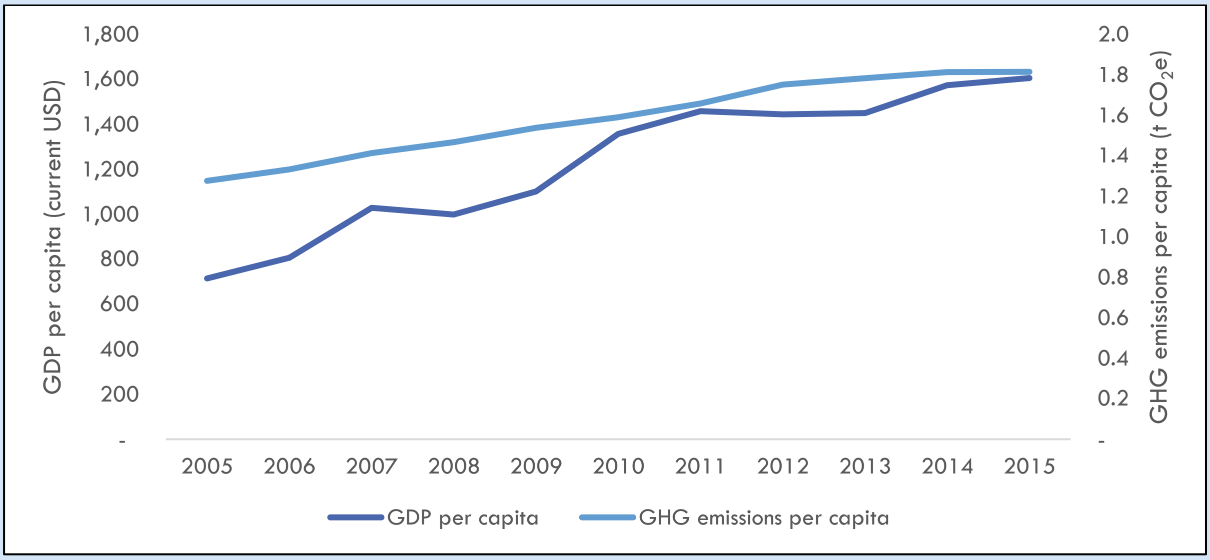

Figure 3: Comparison of economic growth and GHG emissions in India between 2005 and 2015[8]

Between 2005 and 2015, the largest contribution to emissions has been from the energy sector. However, the rate of growth has been largest in the industry sector (9%). The contribution of industries to total emissions has increased from one-fifth (21%), to one-fourth of total emissions (26%).[9] Given the renewed focus of government policies on domestic manufacturing this share is bound to increase in the future.

Resource Efficiency and Climate Change

Increased global demand for construction minerals, biomass for food and feed, and fossil energy sources have been the main drivers of the ever-increasing material extraction.[10] The

[6] GHG Platform India (n.d.). Sub-National Estimates: 2005-2015 series. Available at http://www.ghgplatform-india.org/economy-wide

[7] CII Analsysis based on MOSPI (2015). Energy Statistics 2015: Twenty Second Issue. Available at http://mospi.nic.in/sites/default/files/publication_reports/Energy_stats_2015_26mar15.pdf; MOSPI (2019). Energy Statistics 2019: Twenty Sixth Issue. Available at http://www.mospi.gov.in/sites/default/files/publication_reports/Energy%20Statistics%202019-finall.pdf and The World Bank (n.d.). Data Bank Micro Data Catalog: India. Available at https://data.worldbank.org/country/IN

[8] CII Analysis based on GHG Platform India (n.d.). Sub-National Estimates: 2005-2015 series. Available at http://www.ghgplatform-india.org/economy-wide and The World Bank (n.d.). Data Bank Micro Data Catalog: India. Available at https://data.worldbank.org/country/IN

[9] GHG Platform India (2017). Trend Analysis of GHG Emissions in India. Available at http://www.ghgplatform-india.org/Images/Publications/GHGPI-PhaseII-GHG%20Trend%20Analysis%202005-13-Sep17.pdf

[10] Wijkman, A. and Skanberg K. (n.d.). The Circular Economy and Benefits for Society Jobs and Climate Clear Winners in an Economy Based on Renewable Energy and Resource Efficiency: A study pertaining to Finland, France, the Netherlands, Spain and Sweden

total domestic extraction of materials increased 3.4 times between 1970 and 2017.[11] For most materials critical to growth of the world economy, global stocks are still sufficient to meet anticipated demand, but the environmental impacts of materials production and processing, particularly those related to energy, are rapidly becoming critical. Demand for these resources is anticipated to double over the next four decades, leading to an enormous increase in overall impacts. [12] The issue of expanding economic activities while reducing the rate of resource use and reducing the environmental impact of any such use poses a serious challenge to society. Thus, there is a need to decouple both resource use and environmental impact from economic growth (Figure 4).[13]

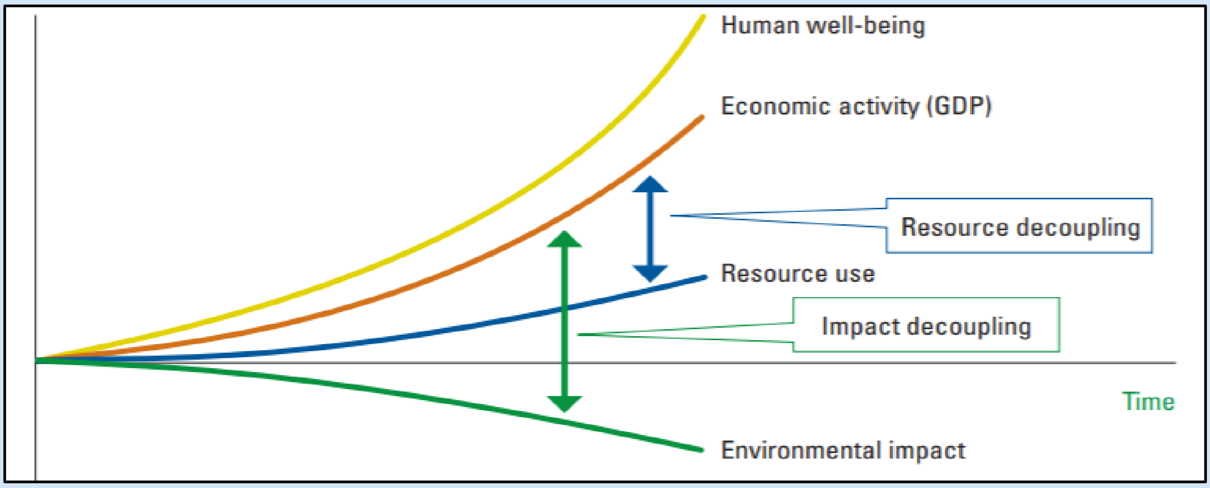

Figure 4: Diagrammatic representation of decoupling of economic activity from resource use and environmental impact

A significant portion of current discussion and action on reducing emissions has focussed on energy efficiency, yield improvements, increased recycling rates and decarbonization of energy systems; however, these approaches have technical and practical limitations. For instance, for materials such as iron and aluminium, the existing energy requirements are close to their thermodynamic limits, which implies that there may be less opportunity for future energy efficiency gains from process improvement for these metals.

In developed economies where labour costs are often greater than material costs, the incentive to reduce yield losses may be low. While recycling rates are increasing for certain materials, with ever-growing demand, the supply of recycled material can never meet that of demand.[14] Most global studies predict modest substitution of the energy mix by non-carbon emitting sources by 2050–for example, the scenarios of the International Energy Agency (IEA)[15]

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[11] UNEP and IRP (n.d.). Global Material Flows Database. Available at https://www.resourcepanel.org/global-material-flows-database

[12] Allwood, J.M., Ashby, M.F., Gutowski, G.G. and Worrell, E. (2011). Material efficiency: a white paper, *Resources, Conservation and Recycling*, *55*, pp 362-381.

[13] UNEP (2011) Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Available at https://www.resourcepanel.org/reports/decoupling-natural-resource-use-and-environmental-impacts-economic-growth

[14] Allwood, J.M., Ashby, M.F., Gutowski, G.G. and Worrell, E. (2011). Material efficiency: a white paper, *Resources, Conservation and Recycling*, *55*, pp 362-381.

[15] IEA (2008). Energy technology perspectives 2008: scenarios & strategies to 2050.

predict industrial emissions reduction by17–37% by 2050 due to carbon capture and storage (CCS). In the United States of America, only 20% of industrial energy use is currently supplied as electricity, so the potential for decarbonisation through new electricity supply is further limited, unless novel electrically-powered processing routes are widely adopted.[16] However in India, the scope for reducing emissions through decarbonization of the energy systems is higher, since about 42% of total electricity generated is consumed by industries.[17]

Given the technical ceiling (or limitation) in the above-mentioned interventions, there is an urgent need to reduce the total requirement for material production and processing to reduce overall GHG emissions. In this regard, material efficiency provides a significant reduction pathway in the total environmental impacts of the global economy.[18]

Globally there is growing consensus on the potential contribution of material resource efficiency to action on climate change mitigation. The Assessment Report 5 (AR5) of the Intergovernmental Panel on Climate Change (IPCC) concludes that in the industry sector, improvements in GHG emission efficiency and in the efficiency of material use, recycling and reuse of materials and products, and overall reductions in product demand (e.g., through a more intensive use of products) and service demand could, in addition to energy efficiency, help reduce GHG emissions below the baseline level.[19]

Estimates suggest that by 2050, in the European Union, a circular economy can cut emissions from heavy industry by 56%. This abatement opportunity is possible through three sets of interventions – material recirculation, material efficiency and new circular business models. Material recirculation has the potential to provide 178 Mt per year in savings. By 2050, interventions on material efficiency such as reduction of manufacturing material loss (for instance, at present, annually almost half the aluminium produced is converted to scrap during manufacturing, in construction 15% of building materials are wasted during construction), use of advanced materials (such as high-strength steel) and tailoring products better to specific use can lead to savings of 56 Mt annually. New business models through sharing in the mobility and buildings sector can lead to savings worth 62 Mt per year by 2050. This will lead to much greater and more efficient use of vehicles and buildings, which together constitute a significant portion of the demand for steel, cement and aluminium in Europe.[20]

Work by the International Resource Panel (IRP) indicates that resource efficiency combined with climate policy could reduce global resource use in 2050 by 28%, and greenhouse gas

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[16] Allwood, J.M., Ashby, M.F., Gutowski, G.G. and Worrell, E. (2011). Material efficiency: a white paper, *Resources, Conservation and Recycling*, 55, pp 362-381.
[17] MoSPI (2019). Energy Statistics 2019. Available at http://www.mospi.gov.in/sites/default/files/publication_reports/Energy%20Statistics%202019-finall.pdf
[18] Allwood, J.M., Ashby, M.F., Gutowski, G.G. and Worrell, E. (2011). Material efficiency: a white paper. *Resources, Conservation and Recycling*, 55, pp 362-381.
[19] IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, 151 pp. Available at https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf
[20] SITRA (2018). European Climate Foundation, Climate-KIC, ETC, EMF, MVA and Climate Works Foundation. Material Efficiency – A Powerful Force for Climate Mitigation

emissions by 20%, relative to existing trends. The study also estimates that such a trajectory would also deliver huge economic benefits, to the tune of USD 2 trillion annually, by 2050.[21]

Material efficiency strategies can also affect other stages of the life-cycle leading to synergistic reductions of energy use. For instance, in residential buildings looking at the whole building life-cycle, material efficiency strategies could reduce emissions in 2050 from the construction, operations, and dismantling of homes by 35-40% in the G7. Analogous savings could be up to 50-70% in China and India.[22]

National context on Resource Efficiency and Climate Change

Based on the above discussion, the need for a study linking/quantifying the benefits of improvements in resource-use efficiency with greenhouse gas (GHG) emissions in India is apparent. From a global perspective, with almost 17% of global consumers, and as one of the world's largest economies, India's resource use is a subject of high importance in terms of the impact on economy and environment. This assumes particular significance in view of the Government of India's renewed focus on expanding the manufacturing and infrastructure sectors in its overall effort to make India a $5 trillion economy.[23]

India's total material consumption increased by 184% between 1980 and 2009, accounting for 7.1% of global material consumption. If current trends continue, India's material requirements are projected to be 15 billion tonnes by 2030 and 25 billion tonnes by 2050.[24]

An intent to address resource security and environmental sustainability was clearly expressed in the Economic Survey of 2019, which also cited the International Resource Panel's estimate of benefits to GHG emissions from improvements to resource efficiency.[25] India's National Resource Efficiency Policy (NREP) is a step in the right direction. A logical outcome of this policy will be the establishment of the benefits to GHG emissions from measures to improve efficiency of resource-use.

However, the current focus of most national action has been limited to energy efficiency. For instance, the National Mission for Enhanced Energy Efficiency (NMEEE) aims to strengthen the market for energy efficiency by creating a conducive regulatory and policy regime. India has also launched an ambitious plan to replace all incandescent lamps with light-emitting diode (LED) bulbs leading to energy savings of up to 100 billion kilowatt hours (kWh) annually. To increase energy efficiency in buildings new standards (such as Energy Conservation Building

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[21] UNEP (2017). Resource Efficiency: Potential and Potential Economic Implications. A report of the International Resource Panel. Available at https://www.resourcepanel.org/reports/resource-efficiency

[22] IRP (2020). Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future. A report of the International Resource Panel. United Nations Environment Programme, Nairobi, Kenya.

[23] The Economic Times (2019). Working group suggests measures to achieve $5 trillion economy by 2025, The Economic Times, January 16, 2019. Available at https://economictimes.indiatimes.com/news/economy/policy/working-group-suggests-measures-to-achieve-5-trillion-economy-by-2025/articleshow/67562058.cms

[24] TERI, DA and GIZ (2016). Material Consumption Patterns in India: a baseline study of the automotive and construction sectors. Available at https://www.international-climate-initiative.com/fileadmin/Dokumente/2016/GIZBaselineReportSummary_SinglePages.pdf

[25] GoI (2019). Economic Survey 2018-19: Volume 2. Available at https://www.indiabudget.gov.in/budget2019-20/economicsurvey/index.php

Code (ECBC)) and rating systems (such as Green Rating for Integrated Habitat Assessment (GRIHA)) have been developed. Even in the industrial sector, where policies such as Make-in-India and creation of National Industrial Corridors have focussed on increasing economic output, as far as sustainability is concerned, the focus has remained on energy efficiency. The Perform, Achieve and Trade (PAT) scheme is a market-based energy efficiency trading mechanism targeted at energy-intensive sectors. For the medium and small industries, the Zero Effect Zero Defect (ZED) policy is a rating on quality control and certification for energy efficiency, enhanced resources efficiency, pollution control, use of renewable energy, waste management, and so on.

As per submissions to the UNFCCC, areas of action for the implementation of the NDCs include:[26]

- Introducing new, more efficient and cleaner technologies in thermal power generation.
- Promoting renewable energy generation and increasing the share of alternative fuels in the overall fuel mix.
- Reducing emissions from the transport sector.
- Promoting energy efficiency in the economy, notably in industry, transportation, buildings and appliances.
- Reducing emissions from waste.
- Developing climate-resilient infrastructure.
- Full implementation of Green India Mission and other programmes of afforestation.
- Planning and implementation of actions to enhance climate resilience and reduce vulnerability to climate change.

These policies form the backbone for achieving the commitments under the NDCs as part of the Paris Agreement. Current estimates suggest that India's climate commitments in 2030 is "2°C-compatible", or within the range of what is considered to be a fair share of global effort.[27] However, deeper reductions are required to limit warming to 1.5°C. In this context, the reduction in GHG emissions from an attempt to improve material resource efficiency can provide alternate pathways to achieve, if not better, the NDCs.

Current imperative

As the Covid-19 pandemic unfolded, The Energy Transitions Commission defined some key priorities in the document, *7 priorities to help the global economy recover while building a healthier, more resilient, net-zero-emissions economy* (2020): "We should learn the lessons from the COVID-19 crisis, which has dramatically demonstrated the unpreparedness of the global economy to systemic risks, despite early warning from scientists. In 2019, climate change was linked to at least 15 extreme weather events costing between US$1-10 billion each. The IPCC

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[26] GoI (2015). India's Intended Nationally Determined Contributions: Working Towards Climate Justice. Available at https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf

[27] Climate Action Tracker (n.d.). Country Summary: India. Available at https://climateactiontracker.org/countries/india/

predicts that such extreme weather events will likely become more frequent with the rise in global temperatures. Investing in high-carbon activities without climate conditionality in the hope that it will help the global economic recovery would only prepare the ground for future systemic crises. Economic stimulus packages should contribute to building a healthier, more resilient, net-zero-emissions economy."

To develop the contours of a nation-wide resource efficiency and climate change study the Confederation of Indian Industry (CII) held a consultation with international experts at the World Resources Forum in 2019.

International stakeholder consultation

CII held an international stakeholder consultation workshop at the World Resources Forum (WRF) Conference in Geneva, in 2019. A list of attendees of the workshop is provided in Annex I.

The discussions at the workshop validated the need to study GHG mitigation possibilities via improvements in resource-use efficiency, in the Indian context. One of the aims of the workshop was to choose or prioritise a sector from among several candidate sectors, for a deep-dive. A point-wise summary of the discussions during the workshop follows:

- Sectors with high emissions or resource-use should be prioritized
- Ease of availability of data should be considered
- Use UNEP's sustainability hotspot analysis toolkit to identify sectors
- Prioritize sectors likely to grow rapidly (such as electronics and air-conditioning)
- Prioritise sectors in which a study would add to the existing body of knowledge, nationally and internationally.

Overall, following the product life-cycle perspective was recommended, rather concentrating on only one life-cycle stage, say manufacturing.

The outcomes of the workshop provided direction for the:

1. sectors to be prioritized for study
2. methodology to be adopted.

Based on the inputs:

1. a more detailed analysis of sectors of the Indian economy would be carried out, and,
2. proposed tools and methodologies would be studied and those suited to the Indian context recommended.

The objectives of this scoping study are:

- develop a list of sectors, by priority, for a nationwide RE-CC study
- develop an understanding of the methods to be used for such a study
- propose a governance structure for implementing the study.

Prioritization of sectors

Background

In the Indian scenario, decarbonization at any level in any sector would benefit industry and the country, by reducing GHG emissions and increasing material-use efficiency. India aims to reduce the carbon intensity of its GDP by 33%-35% of 2005 levels, by 2030. In addition to improvements in energy efficiency, material or resource-use efficiency practiced in industry will help achieve this goal, especially when enabling strategies are adopted at all stages of the product life cycle. While these strategies are fairly well known, a parallel exercise would be identifying sectors in which the smallest interventions can bring about large reductions, or, sectors of particular relevance to the Indian context.

The International Resource Panel had selected the construction and transport sector for their study based on evidence for a major role for material efficiency as, "an avenue for reducing GHG emissions connected to material-intensive systems, including buildings and light-duty vehicles".[28]

However, we wanted to apply a selection or prioritization process to determine which sectors would be best/most appropriate for an Indian study. In considering criteria for selection, we also took into account previous studies, such as those carried out in the EU's Resource Efficiency Initiative (of whose consortium CII is member). The sectors studied in that project were construction and demolition, e-mobility, renewable energy and plastic waste.[29]

The SCP-Hotspot Analysis Tool recommended by workshop participants at WRF, 2019 to was found to be unsuitable because of way that sectors are grouped together within the model. The sectors used in the toolkit were found to be more diverse and expansive than the list of sectors identified for prioritization for the purpose of this study. For instance, plastics were part of the category, Petroleum, Chemical and Non-Metallic Mineral Products, and not considered separately. Similarly, extraction and processing of all metals are categorized as Mining & Quarrying, and Metal Products, respectively, in contrast to the way that sectors are considered in the Indian context – in this case, aluminium, and iron & steel, would be named separately. A one-to-one correspondence could not be achieved.

Since the SCP tool could not be used, a long list of candidate sectors was drawn up based on inputs received at the international consultation workshop, and a literature search related to RE and CC. The sectors mentioned most often in these two categories were (in alphabetical order):

1. Agriculture (minus fertilizer application)
2. Air-conditioning
3. Aluminium

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[28] Hertwich E. et al (2019). Material efficiency strategies to reducing greenhouse gas emissions associated with buildings, vehicles and electronics-a review, Environ. Res. Lett., 14, https://doi.org/10.1088/1748-9326/ab0fe3

[29] EU-REI (n.d.). Resource Efficiency Initiative (India): Focus Area. Available at https://www.eu-rei.com/focus-areas.html

4. Aviation
5. Brick-making
6. Cement
7. Electronic equipment (hardware)
8. Fertilizer
9. Transport (freight)
10. Glass
11. Iron and steel
12. Plastics

Since it would be practical to limit a detailed study to, perhaps two or three sectors, the longlist of sectors was assessed on the criteria mentioned below. This would help "grade" the sectors and arrive at a prioritised list which could then be discussed and finalised in a consultation with experts. The criteria identified are:

1. Current production volumes: to account for material consumption
2. Growth outlook: sectors which are not significant at this point, but have a potential for growth and hence might have a large future material footprint and GHG emissions.
3. GHG emissions
4. Relative ease of abatement: to provide an idea of the effort/input/investment required to bring about reductions in GHG emissions via improvements in resource efficiency.

Weights

Three scenarios were generated by assigning weights to each of the four criteria above (this would help assess that criterion's relative contribution to the final score). A change in weight might affect the final ranking of a sector.

Three scenarios were created:

1. Scenario 1 (S 1): Equal weights (0.25) to all parameters (since there are 4 criteria, 1/4=0.25)
2. Scenario 2 (S 2): Since the study focuses on reducing GHG emissions and material consumption, the GHG emissions and current production criteria are assigned higher weights (0.3), with other two at 0.2
3. Scenario 3 (S 3): GHG emissions and current production are assigned still higher weights (0.4) while others' weights are reduced, but equal, at 0.1.

The weights of the three scenarios are summarized in Table 1, below.

Table 1: Weights assigned to criteria used for prioritization exercise in three scenarios

	Parameter	Weights		
		Scenario 1	Scenario 2	Scenario 3
1	Current production	0.25	0.3	0.4
2	Growth outlook	0.25	0.2	0.1
3	GHG emissions	0.25	0.3	0.4
4	Ease of abatement	0.25	0.2	0.1

Scoring

The final score of a sector was computed using the formula:

$$S = \sum W_i \, X \, S_i$$

where,
W_i - weight assigned to ith parameter
S_i - score of the ith parameter

Grades, high (H), medium (M), or low (L), were assigned to each criterion: if no data were available or if a criterion did not apply to a particular sector, 'not applicable', (NA) was entered. The numerical values assigned to (the qualitative) H, M, L and NA were 1, 0.67, 0.33 and 0 (equal allocations were made between the four possible scores; changes in these numerical values will not affect the final ranking) and were used to compute the final score for a sector.

A combination of qualitative and quantitative information was used to assign grades, H, M or L (described in Annex II), after which, the sectors were ranked in descending order.

Data

Data were collected from Government of India sources or journal literature, and are described in Annex II.

Prioritized sectors

The prioritized list of sectors based on the methodology described in the previous section is presented in Table 2.

Table 2: Prioritized list of sectors for a Resource Efficiency-Climate Change study

Parameter / Sector	Current production volumes	Growth outlook	GHG emissions	Ease of abatement	Final ranking		
					Scenario 1	Scenario 2	Scenario 3
Agriculture (minus fertilizer application)	H	L	H	L	4	3	1
Air conditioning	L	H	L	M	5	7	8
Aluminium	L	M	L	L	8	8	9
Aviation	L	H	L	L	9	9	10
Brick-making	H	M	L	M	3	4	4
Cement	H	H	M	L	1	1	2
Electronic equipment (hardware)	L	L	L	L	12	12	12
Glass	L	M	L	L	10	11	11
Fertilizer	M	L	L	L	10	10	7
Iron and steel	H	H	M	L	1	1	2
Plastics	M	H	L	L	5	6	6
Transport (freight)	L	M	H	L	5	5	5

The following sectors (written in alphabetical order) are in the top five irrespective of the scenario:

1. Agriculture (minus fertilizer application)
2. Brick-making
3. Cement
4. Iron and steel
5. Transport (freight)

Plastics and air-conditioning are ranked 5th in scenario 1 (when equal weights are assigned to each criterion). Table 3 lists the top 5 sectors in each scenario.

Table 3: Top five sectors in the three scenarios

Scenario 1	Scenario 2	Scenario 3
Rank 1: Cement; Iron & Steel	Rank 1: Cement; Iron & Steel	Rank 1: Agriculture
Rank 3: Brick-making	Rank 3: Agriculture	Rank 2: Cement; Iron & Steel
Rank 4: Agriculture	Rank 4: Brick-making	Rank 4: Brick-making
Rank 5: Air-conditioning; Plastics; Transport (freight)	Rank 5: Transport (freight)	Rank 5: Transport (freight)

In the context of resource efficiency, it may be thought that social criteria should play a role in the Indian context. This would probably be true in cases where robotics or advanced automation would bring about large improvements or reductions in resource use but displace/replace a large body of workers. It could be argued that in the longer run circular economy approaches (considering the entire life cycle) would increase the number of employment opportunities and offset at least some of the job losses.

It is interesting to note that sectors such as cement, iron & steel, and brick-making are associated with large GHG emissions and material consumption in their manufacturing stage. However, freight transport and air-conditioning are associated with larger emissions in their in-use and end-of-life phase. While transitioning towards a circular economy might increase emissions in the end-of-life stage due to increased material processing, it will reduce emissions in the extraction and manufacturing stage where materials recovered at other lifecycle stages can be used to limit virgin material use.

By the end of the detailed study it would be possible to focus on the exact lifecycle stage associated with maximum climate impact and quantify the carbon abatement potential. Comparing results/data generated a few years ago with the current situation, it would also be possible to examine why certain strategies were successful (or not) and understand better how to address gaps in the implementation and strategy.

Next Steps

As a next step the following would be taken-up

1. Development of methodology
2. Setting-up of governance structure
3. Initiation of study for prioritized sectors

Annex I: List of participants at World Resources Forum 2019

Table 4: List of participants at the CII session titled "Scoping workshop for a nation-wide study on resource efficiency and climate change" held at the World Resources Forum on 23 October, 2019

	Name	Organization
1	Carl Vadenbo	EcoInvent
2	Astrid Schomaker	European Commission
3	XaverEclemanz	World Resources Forum
4	Andrea Wehrli	EMPA
5	Ibrahim Mansoori	Sofies
6	Sanjeevan Bajaj	SAEL
7	Dr. Reva Prakash	EU-Resource Efficiency Initiative/GIZ
8	Dr. Rachna Arora	EU-Resource Efficiency Initiative/GIZ
9	Nathalie Lefebvre	ETH Zurich
10	Farnaz Eslamishaa	EPFL
11	Anna Basel	EPFL
12	Adrien Legrain	EPFL
13	Ajay Patil	PSI
14	Ligia Noronha	United Nations Environment Programme
15	Henrike Peichert	GIZ
16	Pradip Kalbar	Indian Institute of Technology, Mumbai
17	Yogendra Shastri	Indian Institute of Technology, Mumbai
18	Prof. Raimund Bleischwitz	The Bartlett School of Environment, Energy and Resources
19	Prof. Ernst von Weizsäcker	Club of Rome
20	Dr. Peder Jensen	The International Resource Panel
21	Dr. Dieter Mutz	EU-Resource Efficiency Initiative/GIZ
22	Jessica Clement	World Resources Forum
23	Dr. Nandini Kumar	Confederation of Indian Industry
24	Shourjomay Chattopadhyay	Confederation of Indian Industry

Annex II: Data sources

GHG emissions

Data pertaining to GHG emissions was collated from India's second Biennial Update Report to the United Nations Framework Convention on Climate Change.[30]

Data from the IPCC's classification of sectors was used in the table.

To assign grades L, M and H, the GHG emissions data was categorised into a range. This was done by taking the lowest and highest GHG emissions data and dividing the data spread into three equal ranges. The ranges used were (all data in Gg-CO_2-eq):

- Low: less than 116,237
- Medium: 116,237 to 236,178
- High: greater than 236,178

Table 5: GHG emissions data

	Sector	Energy		IPPU		Agriculture		Total	
		Emission	IPCC Category	Emission	IPCC Category	Emission	IPCC Category	Emission	Score
1	Agriculture (minus fertilizer application)	2,383	1A4c			3 - 3D	3,50,122	**3,52,505**	**H**
2	Air conditioning			18,576	2E			**18,576**	**L**
3	Aluminium			26,606	2C3			**26,606**	**L**
4	Aviation (s)	13,861	1A3b					**13,861**	**L**
5	Brick-making	2,679	1A2j					**2,679**	**L**
6	Cement	47,045	1A2a	1,15,342	2A1			**1,62,386**	**M**
7	Electronics equipment (hardware) (m)								**L**
8	Fertilizer	6,028	1A2k			67,096	3D	**73,125**	**L**
9	Freight transport	2,50,173	1A3abcd					**2,50,173**	**H**
10	Glass			372	1A5			**372**	**L**
11	Iron and steel	1,54,678	1A2b					**1,54,678**	**M**
12	Plastics	50,051	1Ab					**50,051**	**L**

[30] MoEFCC (2018). India: Second Biennial Update Report to the United Nations Framework Convention on Climate Change. Ministry of Environment, Forest and Climate Change, Government of India. Available at https://unfccc.int/sites/default/files/resource/INDIA%20SECOND%20BUR%20High%20Res.pdf

Current Production

Current production volumes were used as a proxy for material consumption assuming that the larger the volumes produced, the larger would be the material consumed.

Scoring was done based on the following range

- Low: less than 10 million tonnes
- Medium: 10 to 100 million tonnes
- High: greater than 100 million tonnes

Table 6: Production data used for prioritization exercise

	Sector	Value	Year	Remark	Score
1	Agriculture (minus fertilizer application)	275 MT[31]	2017-18	Total production of food grains	**H**
2	Air conditioning				
3	Aluminium	3.4 MT[32]	2017-18	Total aluminium production	
4	Aviation (s)			Minor manufacturing of planes in India, significant portion imported or assembled.	**L**
5	Brick-making	750 MT[33]		Annual figure	**H**
6	Cement	337.3 MT[34]	2017-18	Total cement production	**H**
7	Electronics equipment (hardware) (m)				**L**
8	Fertilizer	41.4 MT[35]	2017-18	Production of all fertilizers in India	**H**
9	Freight transport	4.8 MT	2015-16	Number of units manufactured in 2015-16 were 7,77,789[36] (2,86,994 medium and heavy goods carriers, 3,90,979 light goods carriers and 99,816 three-wheeler goods carriers). Total weight of materials estimated based on assumption for heavy trucks weight as 6,980 kg and three-wheeler vehicles as 371 kg.[37]	**L**

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[31] FAO (n.d.). FAO in India. Available at http://www.fao.org/india/fao-in-india/india-at-a-glance/en/
[32] Ministry of Mines (2018). Indian Minerals Yearbook 2018 (Part II: Metals and Alloys) - 57th Edition – ALuminum and Alumina. Available at https://ibm.gov.in/writereaddata/files/11272019153425Aluminium%20and%20Alumina_2018_FR.pdf
[33] Bhushan C. (2019). No bricks in the wall. Down to Earth, May 27, 2019. Available at https://www.downtoearth.org.in/blog/air/no-bricks-in-the-wall-64510
[34] IBEF (n.d.). Indian Cement Industry Analysis. Available at https://www.ibef.org/industry/cement-presentation
[35] Ministry of Chemicals and Fertilizers (2019). Annual Report 2018-19. Available at http://fert.nic.in/sites/default/files/Annual-Report-English-1.pdf
[36] MoSPI (n.d.). Motor Vehicles - Statistical Year Book India 2017. Available at http://mospi.nic.in/statistical-year-book-india/2017/189
[37] TERI, DA and GIZ (2016). Material Consumption Patterns in India: a Baseline Study of the Automotive and Construction Sectors. Available at https://www.international-climate-initiative.com/fileadmin/Dokumente/2016/GIZBaselineEReport_Final.pdf

10	Glass	1.2 MT[38]	2010	Even though this is an old data, even if a 15% per annum growth rate is assumed, overall production will be below 5 MT in 2020	**L**
11	Iron and steel	101.3 MT[39]	2018-19	production of total finished steel (alloy/stainless + non alloy)	**H**
12	Plastics	11.5 MT[40]	2017-18	production of LDPE, HDPE, LLDPE, PS, PP, PVC, EPS, PET, EP and PUR	**H**

Ease of abatement

Table 7: Information used to grade the ease of abatement for identified sectors

	Sector	Rationale	Score
1	Agriculture (minus fertilizer application)	Sector is enormous, scattered and very diverse	L
2	Air conditioning	Technology available, some work underway, but challenges still there for widespread changes	M
3	Aluminium	Potential for abatement through recycling is high	M
4	Aviation (s)	Since transport is a ETC Harder-to-abate sector, small manufacturing within India, hence control over the value chain is less in the manufacturing stage	L
5	Brick-making	Technology available, some work underway, however sector is comprised of small-scale players and hence geographic spread is high.	M
6	Cement	ETC Harder-to-abate sector[41]	L
7	Electronics equipment (hardware) (m)	Control is low, since manufacturing within India is low currently.	L
8	Fertilizer		L
9	Freight transport	ETC Harder-to-abate sector[42]	L
10	Glass		L
11	Iron and steel	ETC Harder-to-abate sector[43]	L
12	Plastics	ETC Harder-to-abate sector[44]	L

[38] AIGMF (2010). Indian float glass industry review. Available at https://aigmf.com/GW32%2022,24.pdf
[39] Ministry of Steel (n.d.). An overview of steel sector. Available at https://steel.gov.in/overview-steel-sector
[40] Ministry of Chemicals and Fertilizers (2019). Chemical and Petrochemical Statistics at a Glance – 2018. Available at https://chemicals.nic.in/sites/default/files/Chemical%20and%20Petrochemical%20Statistics%20at%20a%20glance%20_2018.pdf
[41] ETC (2018). Mission Possible: Reaching Net-zero Carbon Emissions from Harder-to-abate sectors by mid-century – Report Summary. Available at http://www.energy-transitions.org/sites/default/files/ETC_MissionPossible_ReportSummary_English.pdf
[42] ETC (2018). Mission Possible: Reaching Net-zero Carbon Emissions from Harder-to-abate sectors by mid-century – Report Summary. Available at http://www.energy-transitions.org/sites/default/files/ETC_MissionPossible_ReportSummary_English.pdf
[43] ETC (2018). Mission Possible: Reaching Net-zero Carbon Emissions from Harder-to-abate sectors by mid-century – Report Summary. Available at http://www.energy-transitions.org/sites/default/files/ETC_MissionPossible_ReportSummary_English.pdf

[44] ETC (2018). Mission Possible: Reaching Net-zero Carbon Emissions from Harder-to-abate sectors by mid-century – Report Summary. Available at http://www.energy-transitions.org/sites/default/files/ETC_MissionPossible_ReportSummary_English.pdf

Growth Outlook

Table 8: Information used to grade growth outlook of identified sectors

	Sector	Rationale	Score
1	Agriculture (minus fertilizer application)	Growth will be most probably in-sync with population growth.	L
2	Air conditioning	Requirement of cooling service to grow as disposable income increases	H
3	Aluminium	Closely tied to construction sector	M
4	Aviation (s)	While the sector is bound to grow, domestic manufacturing is still negligible.	L
5	Brick-making	Increased demand due to construction boom, however greater use of alternative bricks (such as cement bricks) in new construction	M
6	Cement	With greater urbanization, infrastructure demand is bound to increase drastically and so will the consumption of materials such as cement, brick, iron & steel	H
7	Electronics equipment (hardware) (m)	While the growth in terms of consumption is high, since limited manufacturing occurring within India, it has been graded as low	L
8	Fertilizer	Tied to agriculture growth, also government policies at national level to move away from chemical fertilizers	L
9	Freight transport		M
10	Glass	Closely tied to construction sector	M
11	Iron and steel	With greater urbanization, infrastructure demand is bound to increase drastically	H
12	Plastics	Tied to with growth in construction, automobile sectors, along with increased disposable incomes	H

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