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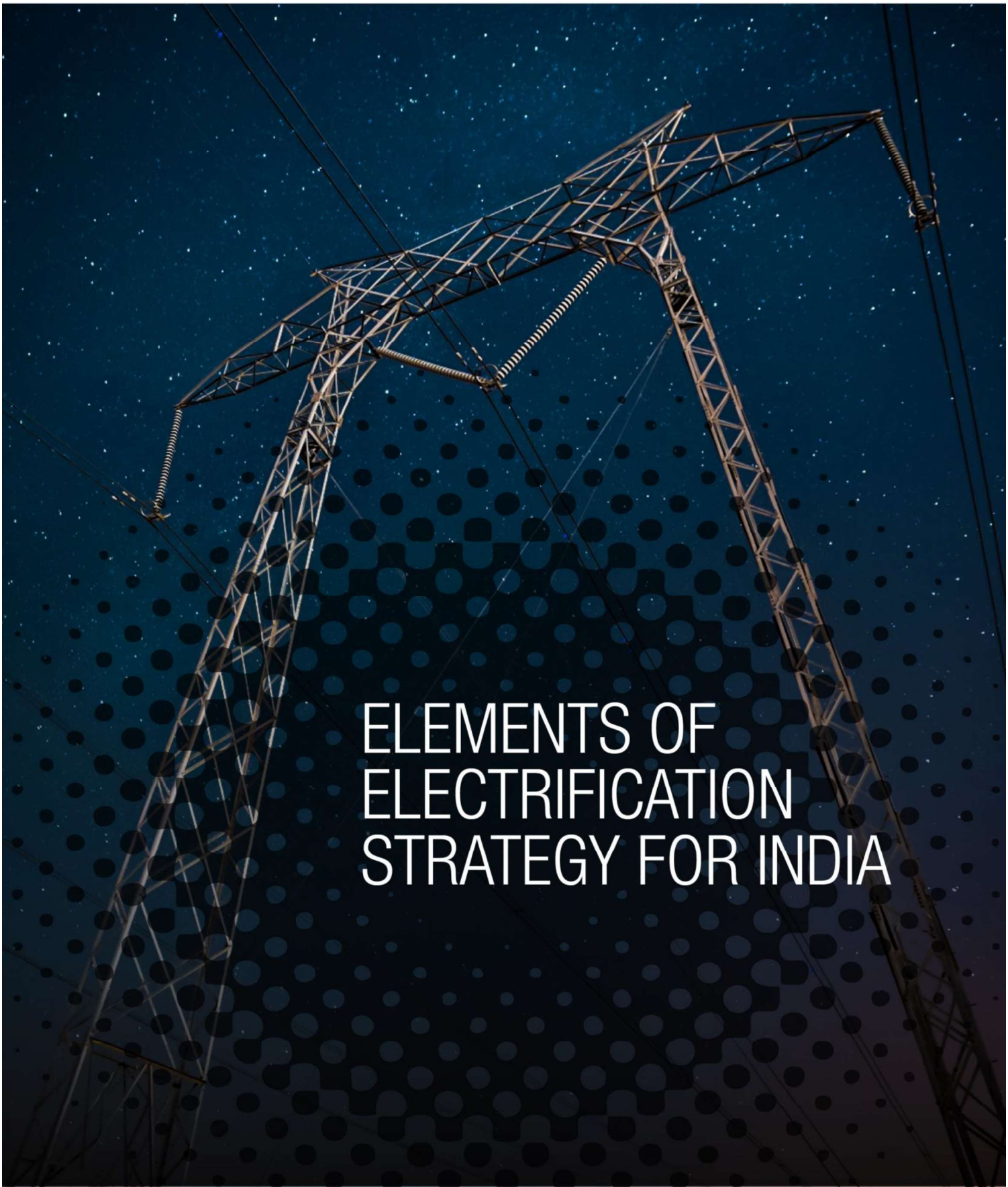

ELEMENTS OF ELECTRIFICATION STRATEGY FOR INDIA

Imprint

Bureau of Energy Efficiency (BEE)
Statutory body under Ministry of Power, Government of India
4th Floor, Sewa Bhawan, Sector-1, R.K. Puram
New Delhi, 110066, India

EU-India Clean Energy and Climate Partnership (CECP)

Version: New Delhi, May 2022

Foreword: Ambassador of the European Union to India and Bhutan

Cooperation in the area of clean energy and climate action is a key priority under the EU-India Strategic Partnership.

Both the EU and India are strongly committed to increasing energy efficiency and the share of renewable energy in our energy mix. To this end, we are working together on grid integration, storage, sustainable finance, climate mitigation and adaptation, green hydrogen - all crucial areas for a green, digital and resilient recovery post pandemic.

In this framework, the EU has been cooperating with the Bureau of Energy Efficiency (BEE), Ministry of Power, in a number of topical areas such as the Energy Conservation Building Code for commercial buildings, nearly zero energy buildings, smart readiness indicators for buildings, low embodied energy building materials, the "energy efficiency first principle". In the Common Implementation Forum, the EU, EU Member States, BEE and Indian States and Union Territories, share information about our policies, technologies and experiences.

In the EU, the European Green Deal has set the stage for this transformational change. The European Climate Law has enshrined into legal obligations the goal to become climate-neutral by 2050 and to reduce net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels. With the European Green Deal, Europe has put clean energy and climate action at the top of its domestic and external agenda. Moving forward, the implementation of the green deal and its objectives in terms of energy efficiency, electrification of the economy and increasing the share of renewables, will contribute to sustainable economic growth, new job opportunities, cleaner air and a healthier environment.

An important aspect of the clean energy strategy is the electrification of the economy and the production of electricity through clean energy sources. This study, undertaken under the Clean Energy and Climate Partnership project together with the BEE, offers an assessment of the current electrification status in Europe and India and considers the potential for further electrification of the Indian economy.

The study assesses best practices in technology and policy frameworks and their relevance in the Indian context. I trust that this report will serve as a useful reference for policy makers and stakeholders in the climate community working in India and in the EU.

New Delhi

May 2022

H.E. Mr. Ugo Astuto

Ambassador of the European Union to India and Bhutan

Foreword: Director General, Bureau of Energy Efficiency

The Government of India set up the Bureau of Energy Efficiency (BEE) on 1st March 2002 under the provisions of the Energy Conservation Act, 2001. The mission of the Bureau of Energy Efficiency is to assist in developing policies and strategies with a focus on self-regulation and market principles within the overall framework of the Energy Conservation Act, 2001 with the primary objective of reducing the energy intensity of the Indian economy. BEE coordinates with designated agencies, designated consumers, and other organizations working in the field of energy conservation/efficiency to recognize and utilize the existing resources and infrastructure in performing the functions assigned to the Bureau under the Energy Conservation Act.

BEE has implemented various successful programs such as the globally recognized industrial efficiency program of India – Perform, Achieve and Trade (PAT) scheme which currently is in its sixth cycle, the Standard and Labelling (S&L) program for appliances and industrial equipment, Energy Conservation Building Codes (ECBC) for commercial buildings, Energy Conservation Building Code-Residential (Eco-Niwas Samhita) for residential buildings, and Certification of Energy Managers and Auditors and many more.

BEE has developed the 'Elements of Electrification Strategy for India' as a strategic document to discuss electrification and its role in ensuring energy efficiency as well as the potential for decarbonization on the demand side. The document focuses on the present status and the potential of electrification at sectoral and sub-sectoral level and its possible impact on the profitability of the DISCOMs. The document also discusses the EU strategy for electrification to assess the possible elements which are relevant to the Indian context, as well as the EU policy approach and sectoral developments towards electrification in the EU which can be used as a reference of best practices by India.

The document presents a deep dive into sector-specific strategies and interventions which will help drive deep electrification in the country. This guiding document has been made to provide an impetus for policymakers to take the best practices from the EU and apply them to the Indian context, to firmly set India's path towards a successful green transformation that does not disrupt its development aspirations. A wide range of stakeholders must come together to envision a future of decarbonized future and realize India's global commitments to Net Zero and sustainable growth going forward.

I would request all policymakers and relevant stakeholders to make themselves familiar with the various interventions and possible strategies outlined in this document so that the nation can embark on a new, greener development paradigm incorporating the best practices from across the European Union. I am confident that with our collective efforts, the ambitious targets set out by India at the Paris Agreement as well as the 2021 Climate Change Conference can be successfully achieved.

Shri Abhay Bakre

Director General, BEE

New Delhi

May 2022

Acknowledgement

This study 'Elements of the Electrification Strategy for India' was developed by PricewaterhouseCoopers Private Limited (PwC India) team including Amit Kumar (Partner), Rajeev Ralhan (Executive Director), Kulbhushan Kumar (Director), Bhaskar Nath (Associate Director) and Ram Joshi (Senior Associate) and the NIRAS team including Niels Bahnsen (Project Director) and Jesper Graa Andreasen (Project member).

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Abbreviations

ACS	Average Cost of Supply
APSRTC	Andhra Pradesh State Road Transport Corporation
ARR	Average Revenue Realized
BEE	Bureau of Energy Efficiency
BPL	Below Poverty Line
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
DHI	Department of Heavy Industries
DISCOMs	Distribution Companies
DMRC	Delhi Metro Rail Corporation
EC	European Commission
ECBC	Energy Conservation Building Code
EED	Energy Efficiency Directive
EESL	Energy Efficiency Services Limited
EIIs	Energy Intensive Industries
ENS	Eco Niwas Samhita
EPBD	Energy Performance of Buildings Directive
ETS	Emissions Trading System
EU	European Union
EV	Electric Vehicle
FAME	Faster Adoption and Manufacturing of Hybrid & Electric Vehicles
FPPCA	Fuel and Power Purchase Cost Adjustment
GDP	Gross Domestic Product
GHG	Greenhouse Gases
HDV	Heavy Duty Vehicles
ICAP	India Cooling Action Plan
ICE	Internal Combustion Engines
ICT	Information and Communications Technology
IIT	Indian Institute of Technology
LCoE	Levelized Cost of Energy
LDV	Light Duty Vehicles
LPG	Liquified Petroleum Gas
MSME	Micro, Small and Medium Enterprises
NHEM	National Hydrogen Energy Mission
PAT	Perform, Achieve and Trade
PM KUSUM	Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan
PV	Photo Voltaics
RACs	Room Air Conditioners
S&L	Standards and Labelling
SDAs	State Designated Agencies
SDS	Sustainable Development Scenario
STU	State Transport Undertakings
TCO	Total Cost of Ownership
UDAY	Ujwal DISCOM Assurance Yojana

01

INTRODUCTION

1 INTRODUCTION

Improving energy efficiency of sectors and sub-sectors through technology upgrade together with maximum fuel switching to electricity is being increasingly recognized as the main strategy for a clean energy transition, as an electrified demand side is necessary to absorb the increasing share of renewable energy on the supply side. To achieve this objective, the increasing electricity demand must be met through clean energy sources on the generation side, thus reducing its carbon intensity. The fact that the Levelized Cost of Energy (LCoE) of renewable energy sources has decreased over time and is projected to decrease further, thus making it cheaper than fossil fuels[1], is a strong argument in favour of electrification as a way of decarbonizing the economy. It is understood that the possibility and feasibility of total electrification of processes may be limited in some sectors or sub-sectors. In such cases, other clean energy sources such as green hydrogen could be explored to transition away from fossil fuels, in order to meet the objectives of the Paris Agreement.

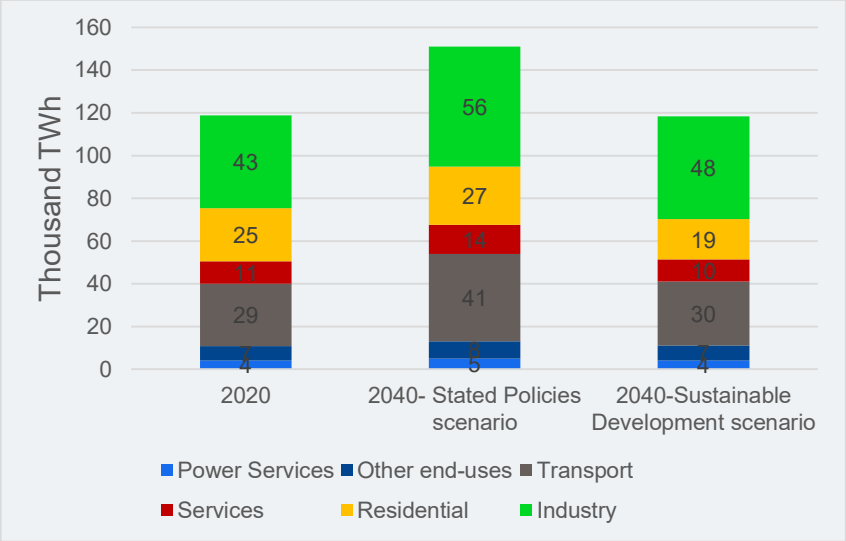


Figure 1.1: Global electricity demand by sector and scenario (Source: IEA)

The World Energy Outlook 2021 is designed as a guidebook for United Nations Climate Change Conference (COP26) meeting in Glasgow and relies on the document, 'Net Zero by 2050: A Roadmap for the Global Energy Sector' to create various future scenarios. One of the scenarios in the World Energy Outlook 2021 is the Sustainable Development Scenario (SDS)[i] wherein the penetration of electricity increases with increasing penetration of renewable energy sources on the supply side. Outcomes of analysis carried out in the previous World Energy Outlook indicated 25% share of electricity in the final energy consumption in 2040. The demand of electricity overtakes that of oil by 2050. Energy Efficient alternatives also help the overall demand to reduce by 5% in 2050, compared to 2020. Government policies, market conditions and technological advances are expected to drive the electricity supply towards low-carbon sources. This could limit the use of fossil fuels up to 20% in the final energy supply mix in 2050 compared to 48% in 2020.[4] The prices of natural gas, coal and

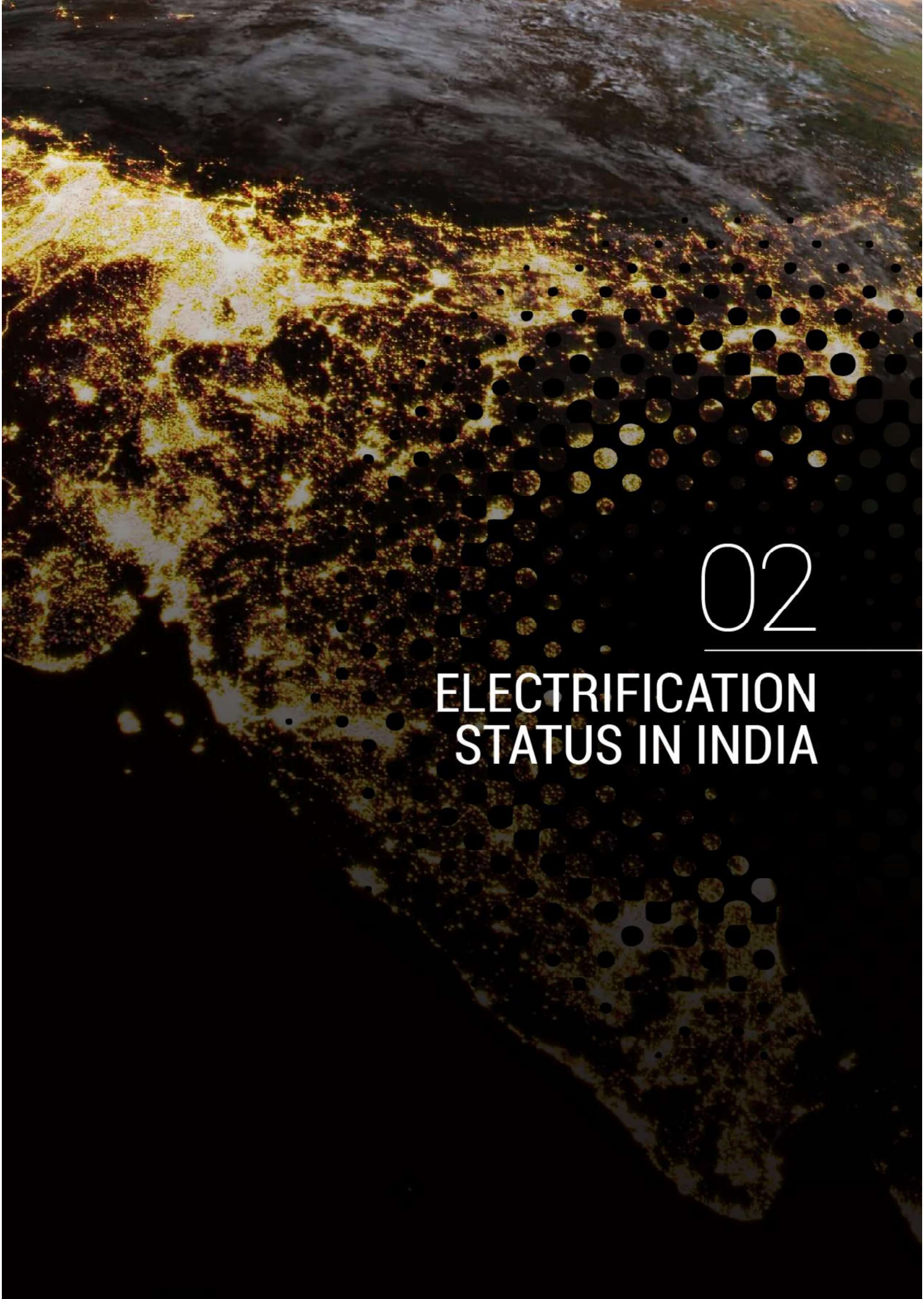
[1] https://iea.blob.core.windows.net/assets/88dec0c7-3a11-4d3b-99dc8323ebfb388b/WorldEnergyOutlook2021.pdf

electricity are rising, due to a rapid economic rebound from last year's pandemic-induced recession, weather-related factors, and some planned and unplanned outages on the supply side. In the run-up to COP26, more than 50 countries, as well as the entire European Union, have pledged to meet net zero emissions targets. Today's pledges cover less than 20% of the gap in emissions reductions that need to be closed by 2030 to keep a 1.5 °C path within reach. Solutions such as additional push for clean electrification, focus on energy efficiency, drive to cut methane emissions from fossil fuel operations, and a boost to clean energy innovation.

The India Energy Security Scenarios 2047 projects an electricity demand of 5,518 TWh/year in 2047[2] resulting from population increase to 1.7 billion, GDP of 1,031.7 trillion INR, increasing share of manufacturing and increase in urbanization to 51%.[3] Another major driver could be the increased access to electricity through Saubhagya scheme in the recent years.[4] Various initiatives and programmes are in progress to improve energy efficiency in sectors and sub-sectors, with a potential to increase their stringency. On the supply side, India has set a target of 500GW of renewable installed capacity[5] by 2030, which is one of the five commitments made by India at the COP26. This will increase eventually increase the share of renewable energy in the cooling sector and provide balancing services to the power sector. This paper builds upon the existing initiatives and recommends new strategies to increase the penetration of electrification. The paper also draws inputs from the EU programmes to strengthen the recommendations.

The objective of this document is to explore the potential and elements for a possible strategy to drive deep electrification in India. The document will focus on the current status of electrification in the industry, residential, transport and services sectors and their sub-sectors, opportunities to increase electrification and possible strategies to drive this transition. It looks at the European strategies and initiatives to increase electrification and highlights the best practices in technology and policy framework and assesses its relevance for the Indian context. Increasing electrification and consequent increase in electricity demand could impact the operability and sustainability of DISCOMs. Thus, apart from the demand side, the document also reviews the state of DISCOMs in the country, challenges faced by them, and presents strategies including technological development, policy measures and developing profitable business case for them to meet the increasing electricity demand.

[2] India Energy Security Scenarios 2047
[3] India Energy Security Scenarios 2047
[4] https://saubhagya.gov.in/
[5] https://pib.gov.in/PressReleseDetail.aspx?PRID=1768712



02

ELECTRIFICATION STATUS IN INDIA

2 ELECTRIFICATION STATUS IN INDIA

India's electricity consumption in 2019-20 was around 1.2 million GWh, which increased by 6.74% from 2010-11 to 2019-20. The industry sector consumed 42.7%, followed by services (including commercial and agriculture) and residential consuming 25.7% and 24%, respectively. Transport consumed 1.5% of the total electricity consumption. In the same period, consumption in industrial and residential sectors increased by 8.14% and 6.96%, respectively, which is higher than the rate of increase of total electricity consumption.[6]

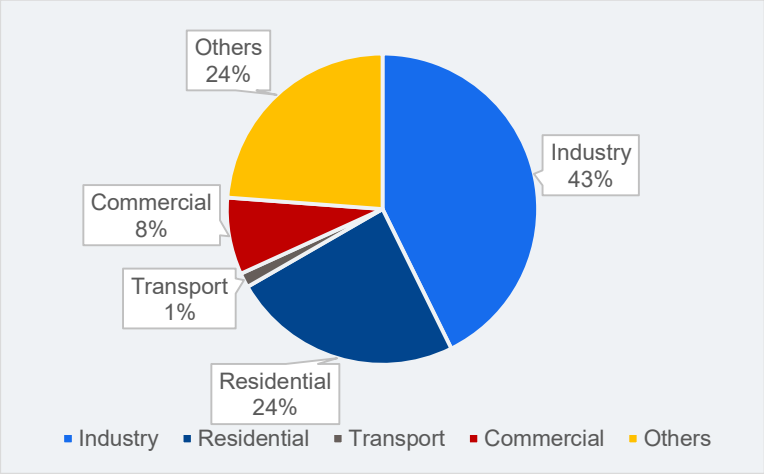


Figure 2.1: Electricity consumption by various sector in 2020 (Source: MoSPI)

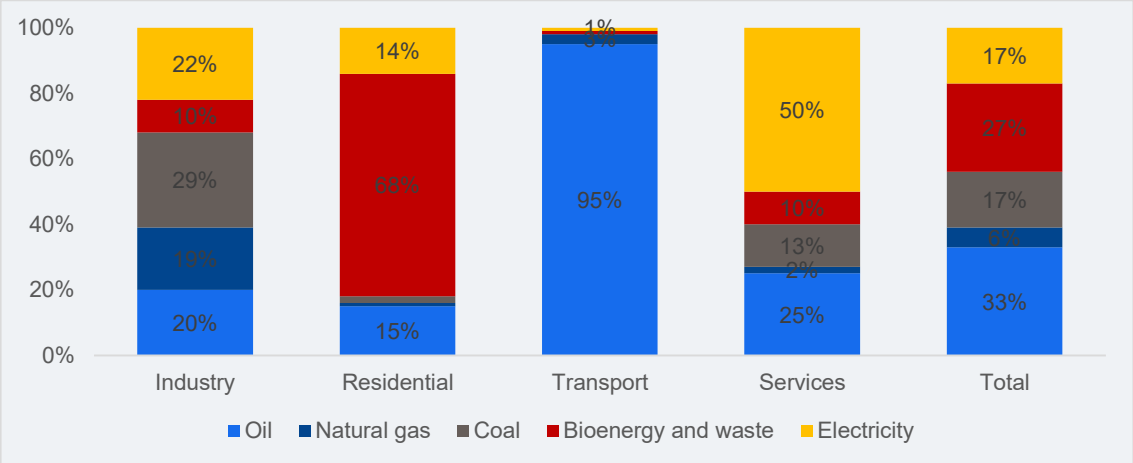


Figure 2.2: Fuel-wise breakdown of energy use in various sectors in 2019-20 (Source: IEA)

Figure 2.2 shows the fuel-wise breakdown of energy use at sectoral level in 2019-20, as per the India Energy Outlook 2021[7]. It is to be noted that the share of electricity in the industrial sector does not account for the electricity consumed in the power sector.

[6] http://mospi.nic.in/sites/default/files/reports_and_publication/ES/chapter%206%20Consumption%20of%20Energy%20Resources.pdf

[7] India Energy Outlook 2021, IEA

2.1 Industry

The industrial sector mainly comprises of Iron & steel, Cement, Paper, Textile, Fertilizers & Chemicals, Sponge iron, Bricks and a diversified Micro, Small and Medium Enterprises (MSME) sector.

As showcased in Figure 2.2, consumption of electricity by the industrial sector more than doubled during 2010-11 to 2019-20 (2,72,589 GWh to 5,51,362 GWh).[8] Among the energy intensive industries, the iron and steel industries have the highest consumption (~24%), followed by chemical and petrochemical (~17%), non-metallic minerals (9%) and other industries (~48%[9]). The penetration of electrification is high in the MSME sector. Almost 76% of the energy demand in this sector is met by electricity, followed by oil (11%), coal (6%) and rest by traditional sources.[10]

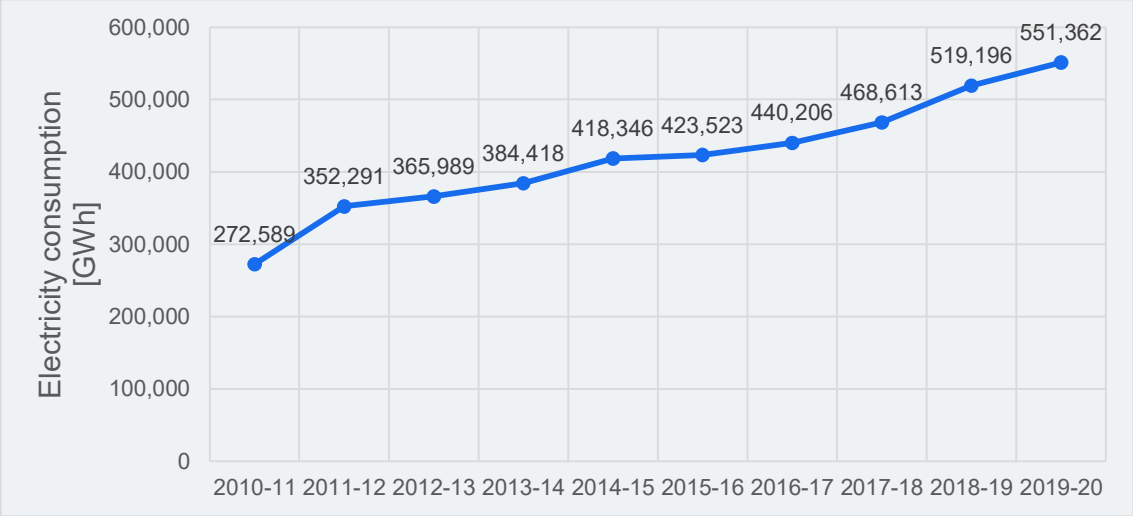


Figure 2.3: Growth in industrial electricity consumption during 2010-11 to 2019-20 (Source: MoSPI)

The Indian manufacturing sector was heavily dependent on coal (29%), followed by oil (20%), electricity (22%), natural gas (19%), renewables (6%) and heat (4%) in 2020.[11] Industrial sector including iron & steel industry, cement, fertilizers & chemicals, and paper are dependent on coal for their specific processes, which predominantly involve firing of the furnaces. It is interesting to note that except Iron and Steel, all other industries have reduced their coal usage by 6-23% over

[8] http://mospi.nic.in/sites/default/files/reports_and_publication/ES/chapter%206%20Consumption%20of%20Energy%20Resources.pdf
[9] http://mospi.nic.in/sites/default/files/reports_and_publication/ES/chapter%206%20Consumption%20of%20Energy%20Resources.pdf
[10] https://iea.blob.core.windows.net/assets/2571ae38-c895-430e-8b62-bc19019c6807/India_2020_Energy_Policy_Review.pdf
[11] https://iea.blob.core.windows.net/assets/88dec0c7-3a11-4d3b-99dc-8323ebfb388b/WorldEnergyOutlook2021.pdf

the period of 2009-10 to 2018-19[12]. This could be attributed to the technological advances, fuel switching to natural gas and electricity, and government initiatives such as the Perform, Achieve and Trade (PAT) scheme.[13] The fertilizers and chemicals, textile and leather industries are in principle dependent on oil and petroleum products. Use of oil has increased in all these industries by 5% during 2010-11 to 2019-20[14], except in the Fertilizers industry due to fuel switching from oil to natural gas. Captive power plants powered by gas turbines have helped achieved high levels of energy efficiency in the fertilizer and alkali industry. Along with the fertilizers industry, petrochemicals and sponge iron are the other industries for which use of electricity has steadily increased in the aforementioned period.

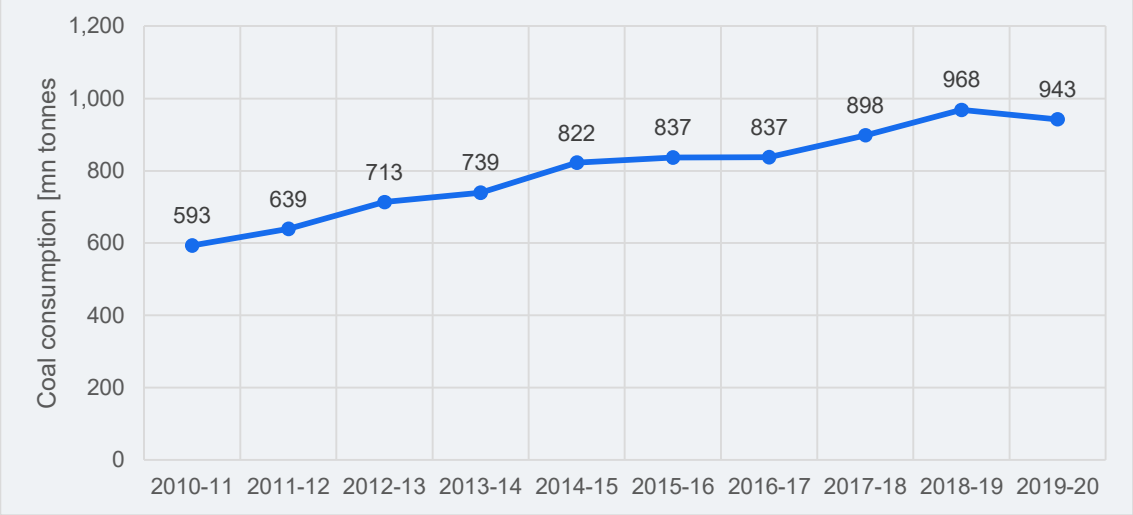


Figure 2.4: Trends in coal consumption in the industry sector between 2010-11 and 2019-20 (Source: MoSPI)

It is important to note that although the use of electricity increased two-folds during 2010-11 to 2019-20, coal consumption followed a similar trend. One of the explanations could be the increase in electricity consumption in processes that are already electrified rather than electrification of coal-based processes. For industries to transition to electrification, it is important that the consumption of coal decreases with increase in electricity use.

The Iron and Steel industry has been identified as the major consumer of fossil fuels in the industrial sector (barring power sector). Certain processes including melting and iron-ore reduction have the potential to transition towards electricity and electrofuels. Additionally, coal, diesel and natural gas boilers used for general industrial processes could be transferred to direct heating, conventional and high temperature heat pumps and direct heating using renewables.

[12] http://mospi.nic.in/sites/default/files/reports_and_publication/ES/chapter%206%20Consumption%20of%20Energy%20Resources.pdf
[13] https://beeindia.gov.in/content/pat-cycle#:~:text=PAT%20scheme%20is%20a%20regulatory,saving%20which%20can%20be%20traded
[14] http://www.mospi.nic.in/sites/default/files/publication_reports/Energy%20Statistics%202019-finall.pdf

There is a push to switch partially towards cleaner fuels such as hydrogen, however viability of such a transition is being looked at.

2.2 Residential

The residential electricity consumption increased from 169,326 GWh to 310,151 GWh in the period of 2010-11 to 2019-20, at a CAGR of 6.96%[15]. This could be attributed to the increasing purchasing power, ownership of electric appliances and demand for space cooling and to a lesser extent heating equipment. Another major driver could be the increased access to electricity in the recent years. Under the Saubhagya Scheme launched by the Government of India, 99.92% of villages and 99.99% of households have been provided access to electricity.[16] The Saubhagya Scheme is launched with a purpose to provide energy access to all households by last mile connectivity and electricity connections to all remaining un-electrified households in rural as well as urban areas to achieve universal household electrification.[17]

Residential building stock and cooling

The residential building stock is projected to increase from 272 million[18] households (over 15 billion m^2) in 2017-2018 to 386 million (over 28 billion m^2) by 2037-2038, as described in Figure 2.5.[19] The Bureau of Energy Efficiency has launched Eco Niwas Samhita (ENS), residential building energy code for India, which focuses on energy efficient building envelope[20], and Part 2 focusing on building energy services was launched recently. Space cooling is a major end use in Indian buildings, due to its predominantly warm and humid weather conditions. The current penetration of air conditioning in residential and commercial buildings is projected to increase from 8% to 40% by 2037-2038.[21] This can be attributed to an increase in disposable income and, more importantly, an increasing need for cooling as the temperatures rises. The share of Room

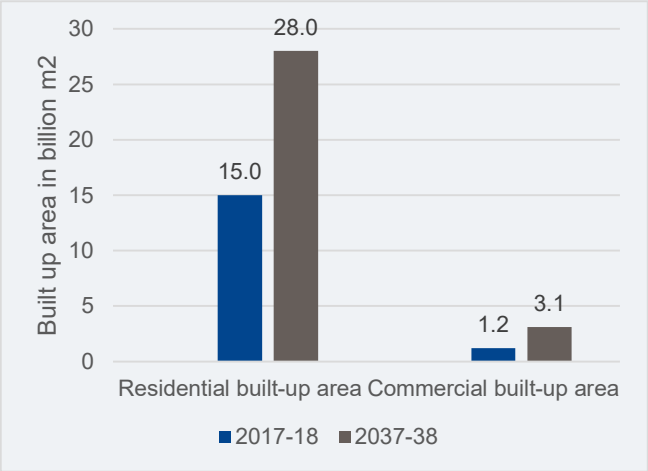


Figure 2.5: Projected increase in residential and commercial built-up area

[15] http://mospi.nic.in/sites/default/files/reports_and_publication/ES/chapter%206%20Consumption%20of%20Energy%20Resources.pdf
[16] https://saubhagya.gov.in/
[17] https://www.india.gov.in/spotlight/pradhan-mantri-sahaj-bijli-har-ghar-yojana-saubhagya
[18] https://censusindia.gov.in/census_and_you/housing.aspx

[19] http://ozonecell.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf
[20] https://www.beeindia.gov.in/sites/default/files/ECBC_BOOK_Web.pdf
[21] ICAP 2019

Air Conditioners (RACs) is almost 60%.[22] These require considerably higher starting power than their average running power consumption; such momentary surges raise the burden on already-stressed electricity grids, leading to blackouts and burnouts. They also contribute to increasing electricity consumption, which causes indirect GHG emissions as most power generation in India is coal-based, therefore requiring a shift towards low energy and low carbon cooling technologies. Smart home technologies have the potential to reduce the operational expenses by around 30%[23] and are essential to de-couple growth in buildings and electricity consumption. Thus, smart home technologies are recommended as an integral element of energy efficiency in the residential sector.

Electric appliances

Air distribution (fans, coolers, etc.) is the highest end-use (57% in rural and 30% in urban), followed by lighting (24% in rural and 20% in urban). Differences in access, ownership and affordability of appliances is also a differentiating factor in electricity consumption. Thus, the rest 19% and 50% in rural and urban consumption, respectively, constitutes household appliances and entertainment.[24] This also affects the urban and rural usage pattern of electricity.

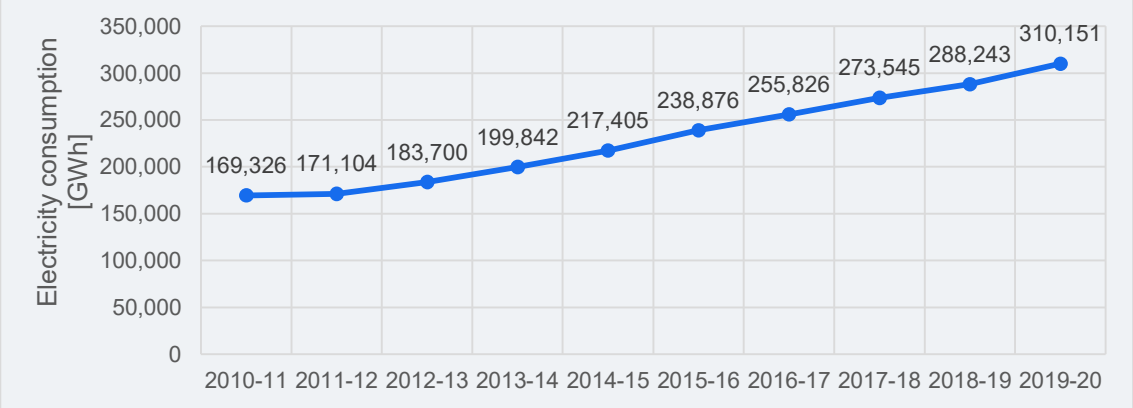


Figure 2.6: Growth in residential electricity consumption during 2010-11 to 2019-20 (Source: MoSPI)

[22] https://wwfin.awsassets.panda.org/downloads/wwf_india_report_on_low_carbon_cooling_solutions_for_buildings_in_india_final_web_ver.pdf
[23] https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_Smart%20building%20-%20energy%20efficiency%20v1.pdf
[24] https://smartpowerindia.org/media/1230/report_rural-electrification-in-india_customer-behaviour-and-demand.pdf

The electric end uses include home appliances, cooling/heating equipment, kitchen appliances and lights. The electricity usage pattern is different in the rural and urban areas. In urban areas, more than 60% of households consume up to 100 kWh of electricity on a monthly basis and more than 35% households consume electricity in the range of 101-300 kWh. Compared to this, almost 90% of rural households consume less than 100 kWh per month (39 kWh on an average[25]) and only 10% households consume more than 100 kWh. At the national level, 80% households consume less than 100 kWh monthly and 18% consume more than 100 kWh in a month.[26] The ownership of medium-to-high wattage appliances in rural households is still low. It can be understood from the fact that around 60% of the demand is formed by low wattage appliances such as lighting, ceiling fans and desert coolers and less than 20% households own home refrigerators, irons, food processors, water pumps, etc. Moreover, although almost all the rural households have been electrified as per Saubhagya[ii] Dashboard, round the clock supply of quality power remains a challenge. These issues explain the significant difference in the electricity consumption pattern in urban and rural households. These issues also mean that rural households are using at least one back-up source of lighting, which is kerosene for more than 90%[27] of the cases. This points towards electrification of rural domestic lighting to be solidified at priority.

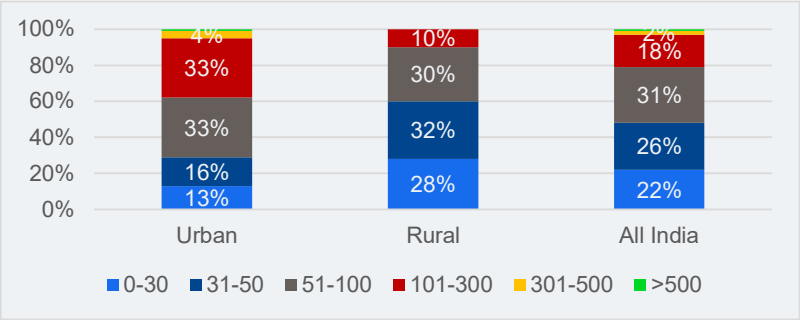


Figure 2.7: Urban and rural households by monthly electricity consumption (Source: Prayas Foundation)

Cooking

Cooking, which is predominantly non-electric[28], was responsible for 1,104 TWh in 2019[29]. This was more than four times the energy consumed by cooling, heating, lighting, and appliances in the same time period[30]. This drives the majority of the energy consumption by the residential towards non-electric fuel usage. The split of fuel used for cooking is very different for rural and urban areas. The Ujjwala Scheme has been successful in providing access of subsidized LPG connection to more than 80 million below poverty line households. However, the access is not sustained due to lack of distribution network and affordability. As a compounded impact, the

[25] https://www.rockefellerfoundation.org/wp-content/uploads/Rural-Electrification-in-India-Customer-Behaviour-and-Demand.pdf
[26] https://www.prayaspune.org/peg/trends-in-india-s-residential-electricity-consumption
[27] https://smartpowerindia.org/media/1230/report_rural-electrification-in-india_customer-behaviour-and-demand.pdf
[28] http://iess2047.gov.in/assets/onepage/Cooking.pdf
[29] https://www.downtoearth.org.in/blog/energy/overcoming-india-s-clean-cooking-challenge-68562
[30] http://iess2047.gov.in/pathways/22202222222222220222222222201222220222222221140222022202220222/primary_energy_chart#

rural households have been found to shift back to biomass and kerosene.[31] In terms of numbers, despite 80% of rural households having an LPG connection, only 28% of the households use LPG, 33% use LPG as primary cooking fuel and depend on biomass and kerosene as secondary fuel, 19% use biomass and kerosene as primary fuel and 20% are dependent only on biomass and kerosene. In urban areas, 91% households use LPG, 6% use LPG as the primary fuel, and only 2% use biomass and kerosene[32]. Leapfrogging to electric or induction cookstoves is a simulating strategy that could form a key element of clean cooking strategy for rural households and could be combined with the PM KUSUM scheme (details in section 2.4). Electric cooking is more efficient (with efficiency of >88%) compared to LPG (with efficiency of 70-75%) and firewood (with efficiency of <40%), although the Levelized Cost of Energy (LCoE) is marginally higher for electric cooking compared to other modes.[33] With the launch of 'Go Electric campaign' emphasis on the use of Clean and Safe Electric Cooking has been emphasized. [34]

2.3 Transportation

The transportation sector, specifically road transport, is majorly dominated by petrol and diesel-operated vehicles. 95% of the vehicles are run by oil and 3% by natural gas. The sub-division of fuel use in 2019-20 was 29,975 thousand tons of petrol, 6,015 thousand tons diesel, 7,999 thousand tons of other petroleum products and 19,577 GWh of electricity.[35] The total energy demand has doubled since 2010 and tripled since 2000. In terms of energy use breakdown by modes of transport, road transport accounted for 75% of the energy used followed by rail, domestic aviation, and others.[36]

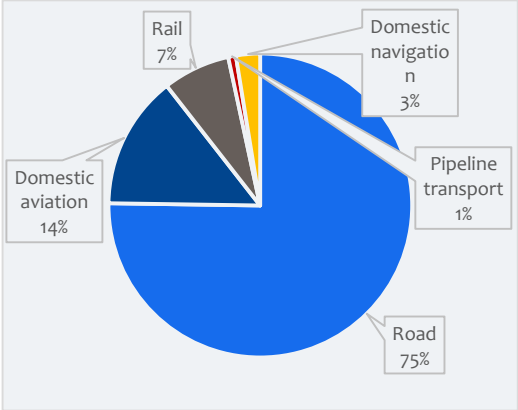


Figure 2.8: Energy Consumption by different modes of transportation (Source: IEA)

The penetration of electricity in the transportation sector was about 3% in 2019-20.[37] Table 1 shows segment-wise growth of electric vehicles as per Vahan registrations data provided by the Ministry of Road Transport and Highways.[38] The highest registrations are observed in the three wheelers segment (83%), followed by two wheelers segment (16%).[39] These two segments are early adopters primarily because they have local manufacturing support and eased implementation. Moreover, shorter trip length of the two-wheelers means that these depend minimally on public charging infrastructure and can be

[31] https://www.downtoearth.org.in/blog/energy/overcoming-india-s-clean-cooking-challenge-68562
[32] https://www.ceew.in/sites/default/files/ires-report-on-state-of-clean-cooking-energy-access-in-india.pdf
[33] https://www.ceew.in/sites/default/files/CEEW-Clean-affordable-and-sustainable-cooking-energy-in-India-Feb2015.pdf
[34] https://pib.gov.in/PressReleasePage.aspx?PRID=1699386
[35] http://www.mospi.gov.in/sites/default/files/publication_reports/ES_2020_240420m.pdf
[36] https://webstore.iea.org/download/direct/4035
[37] http://niti.gov.in/writereaddata/files/document_publication/EV_report.pdf
[38] https://vahan.nic.in/nrservices/
[39] https://www.pwc.in/assets/pdfs/industries/capital-projects-and-infrastructure-publications/towards-emobility.pdf

charged at home. In the two-wheeler category though, high registrations are observed in the personal usage category. In 2020, some registrations were in the non-transport or the commercial category. With respect to cars, there has been an increase in the number of both personal and commercial vehicles. The number of personal cars is more than electric commercial cars. The major constraint for the adoption of a four-wheeler is the high price range, insufficient charging ecosystem and limited availability of the models, which can compete with the much-progressed Internal Combustion Engines (ICE)-based counterparts. The minimal numbers that are likely to increase are also due to adoption by the cab aggregators. In the goods category, mostly light goods vehicles are registered. With its policies and schemes, the government is pushing for electric bus adoption, thereby supporting state transport undertakings (STU's) to procure electric buses.

Table 1: Segment-wise registration of electric vehicles during 2015-2020

Vehicle Segment	Vehicle Category Group													
	Two-Wheeler		Three-Wheeler		Cars		Passenger Vehicle				Goods Vehicle			Others
Year	2W NT	2W T	3W NT	3W T	LMV	LPV/ cabs	MMV	HMV	MMV	HPV	LGV	MGV	HGV	
2020	21,971	1,853	45	80,842	2,764	984	0	0	35	44	10	0	0	23
2019	26255	1462	26	1,31,597	678	732	0	0	90	370	58	0	0	13
2018	15094	332	117	1,13,449	770	844	2	0	8	35	763	4	3	135
2017	1458	8	39	83696	908	347	0	1	4	9	917	1	3	182
2016	1523	0	28	48584	729	89	1	8	0	2	97	4	10	117
2015	1462	0	9	6642	769	97	1	2	2	1	56	3	7	10

*Non-Transport- NT, Transport- T, Light Motor Vehicle- LMV, Light Passenger Vehicle- LPV, Medium Motor Vehicle-MMV, Heavy Motor Vehicle-HMV, Medium Passenger Vehicle-MPV, Heavy Passenger Vehicle-HPV, Light Goods Vehicle-LGV, Medium Goods Vehicle-MGV, Heavy Goods Vehicle-HGV

According to NITI Aayog, the EV market is expected to be around 28 million units by 2030.[40] This can be attributed to public sector initiatives such as Faster Adoption and Manufacturing of (Hybrid &) Electric vehicles in India (FAME I and FAME II) from the Department of Heavy Industries (DHI). The FAME I was active from 2015 to 2019 and the scheme allocated a budget of ₹8.95 billion and engaged 22 OEMs who have registered 80 models of electric/hybrid vehicles. The FAME II is a three-year extension to the FAME I Scheme with a total budget allocation of ₹100 billion. The FAME II project aims to generate demand by supporting 7,000 Electric Buses (e-bus), 5 lakh Electric Three Wheelers (e-3W), 55000 Electric Four-Wheeler Passenger Cars (including Strong Hybrid) (e-4W) and 10 lakh Electric Two Wheelers (e-2W).[41] Additionally, DHI sanctioned 5,095 electric buses to 64 cities/STUs/State government entities for intracity operations, 400 electric buses for intercity operations and 100 electric buses to Delhi Metro Rail Corporation (DMRC) for feeder services. Among these, 424 electric buses are in operational phase and 327 electric charging stations are being installed under the scheme. Energy Efficiency

[40] https://niti.gov.in/writereaddata/files/document_publication/RMI_India_Report_web.pdf
[41] https://fame2.heavyindustry.gov.in/content/english/13_1_brief.aspx

Services Limited (EESL) has launched a programme for electric vehicles based on the ESCO route.[42] Through demand aggregation, EESL aims to replace 500,000 cars with electric vehicles and till date, 1,725 electric vehicles have been deployed.[43]

Parallelly, various states have issued state-level policies and have provided incentives for faster penetration of Electric vehicles. Some of the salient features of these policies are mentioned in the table below.

Table 2: Features of electric vehicles policy of different states

Policies	Features
Karnataka	• Investment target – ₹310 billion • Create 55,000 jobs • Venture Capital fund for research in electric mobility
Maharashtra	• Number of electric vehicles to go up by 500,000 • ₹250 million investment in electric vehicles and related infra • Create 100,000 jobs
Uttar Pradesh	• 1,000 electric buses to be introduced by 2030. • Tax exemption to buyers, 100% interest free loans, 30% subsidy on road price of electric vehicle • Electric Vehicle Incubation centres to be set up at IIT-Kanpur, other leading institutions
Andhra Pradesh	• Target to have ₹300 billion investment in 5 years • Target to have 10 GWh EV battery manufacturing in the state • Convert 100% APSRTC bus fleet in the state to electric bus fleet by 2030 • Target to have 1 million electric vehicles by 2024 in the state
Kerala	• Target to have 1 million EVs by 2022 • Over 6,000 electric buses under public transport by 2025
Delhi	• 50% electric buses in public transport by 2023 • Pollution Cess on petrol and diesel vehicles starting April 2019
Telangana	• Attract investments worth ₹219.2 billion • Create 50,000 jobs by 2022 • Innovation fund by the government to support EVs
Uttarakhand	• Investors to have 100% electricity duty exemption • To provide term loans of ₹100-500 million to MSMEs to manufacture

[42] https://www.eeslindia.org/content/raj/eesl/en/Programs/ElectricVehicles/e-Vehicles.html
[43] https://ev.eeslindia.org/evdashboard/#/

Policies	Features
	electric vehicles

Go Electric campaign was launched by the Ministry of Power on 19 February 2021 to spread awareness on the benefits of e-mobility, charging and electric cooking. The campaign is aimed at creating awareness at the national level and aims to boost the confidence of electric vehicle manufacturers and consumers. To ensure a wide reach of the information campaign, BEE will provide technical assistance to the State Designated Agencies (SDAs). An exhibition was organized by the industry players displaying different electric vehicles including e-buses, e-cars, 3-wheelers, and 2-wheelers apart from available charging options such as fast chargers and slow chargers.[44] [45]

Thus, India has a robust policy landscape supporting penetration of electric vehicles. Various cities also have adopted pilots for electric vehicles. With significant initiatives in place for promoting electric vehicles, it is imperative at the same time to make these competitive through technology-based instruments to escalate their penetration. Mainstreaming the usage of electric vehicles would also require target-based strategies.

Railways

India's rail transportation is electrified to a significant degree with electricity accounting for over 40% of energy consumption in 2020. 100% of the metro transit, 54% of conventional passenger rail activity and 65% of freight activity is powered by electricity. Rail transportation is also reducing its energy demand. In 2018, it consumed 18 toe less per million passenger kilometre than small and medium-sized cars, and almost 18 toe less per million ton-kilometre than medium-sized freight trucks.[46] The government is aspiring to achieve total electrification of the railways by 2023-24 through electrification of broad gauge, improve energy efficiency and switch to renewable energy sources.[47] Further, the government also aspires to upgrade the railways to the world's first Net Zero Emissions railways by 2030.[48] Thus, the railway sector is making significant progress in the direction of clean electrification.

2.4 Services

The services sector includes commercial and public services, agriculture, and forestry. This sector has the highest penetration of electrification among all sectors (50%). Electricity in the services sector has increased by more than 300% since 2000. Commercial and public services represented almost 60% of the energy consumption in this sector, while about 40% was accounted for by agriculture and forestry in 2017-18.[49]

[44] https://pib.gov.in/PressReleasePage.aspx?PRID=1699386
[45] https://pib.gov.in/PressReleasePage.aspx?PRID=1699386
[46] https://www.iea.org/statistics/mods/
[47] https://www.business-standard.com/article/indian-railways/railways-sets-target-of-becoming-net-zero-carbon-emitter-by-2030-120071301044_1.html
[48] https://energy.economictimes.indiatimes.com/news/power/railways-to-move-to-100-pc-electrification-in-next-3-5-years-piyush-goyal/76996594
[49] https://niti.gov.in/sites/default/files/2020-01/IEA-India%202020-In-depth-EnergyPolicy_0.pdf

Commercial building stock and cooling

The commercial building sector is projected to increase from 1.2 billion m^2 in 2017-2018 to 3.1 billion m^2 in 2037-38[50], as described in Figure 2.5. Electricity consumption in buildings accounts for more than 31% of India's electricity consumption.[51] Electricity consumption in the commercial sector is regulated to a significant extent and the energy efficiency initiatives have been taken to reduce energy consumption in new buildings (viz. ECBC 2017 to improve energy efficiency in commercial buildings), existing buildings (Star rating program) and appliances (viz. Star Rating program to promote energy efficiency in heavy appliances and consumer durables, super efficiency program to promote high efficiency cooling appliances) are in place to achieve the desired targets. Commercial establishments such as hotels and airports have been brought under the ambit of PAT scheme.[52] A pilot programme to provide technical assistance to 100 existing commercial buildings to upgrade them to Nearly Zero Energy buildings is ongoing (commercial and public). The penetration of cooling in the commercial sector is projected to increase from 26% to 54%, respectively, by 2037-2038.[53] Thus, shift towards low energy and low carbon cooling technologies such as radiant cooling, district cooling, etc. is recommended. Smart building technologies, which could potentially reduce the operating energy use by 30% are recommended to reduce the impact of increasing building stock on the operations of DISCOMs.

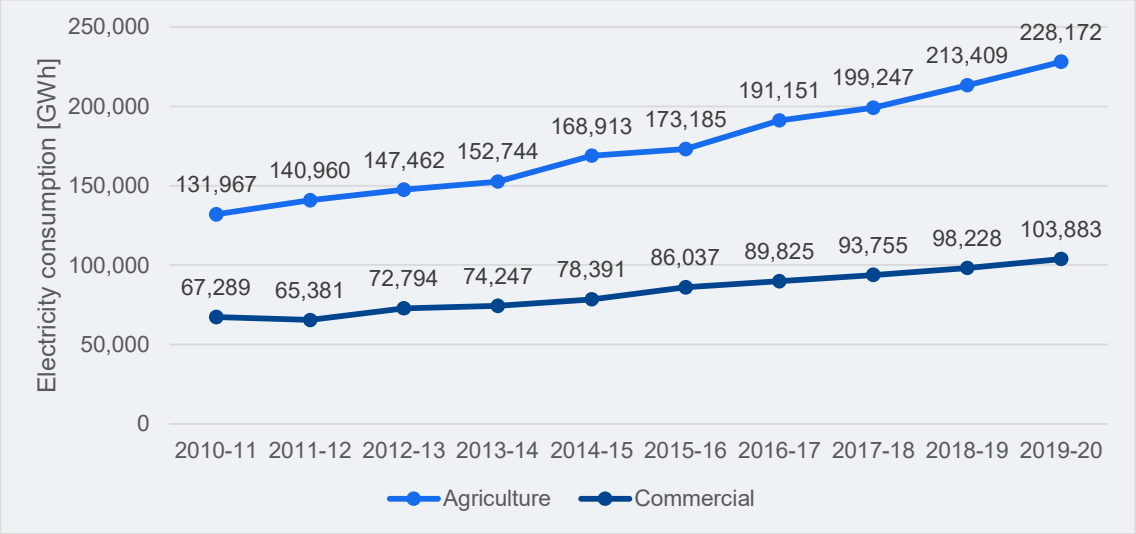


Figure 2.9: Growth in agriculture and commercial electricity consumption during 2010-11 to 2019-20 (Source: MoSPI)

Agriculture

[50] http://iess2047.gov.in
[51] http://www.indiaenergy.gov.in/edm/#elecConsumption
[52] https://beeindia.gov.in/sites/default/files/Perform%20Achieve%20and%20Trade%20-%20Hotel%20under%20PAT%20sectors.pdf
[53] ICAP 2019

The agriculture sector consumed 228,172 GWh of electricity in 2019-20, which was third highest (18%) after industry and residential sector.[54] Unmetered provision of electricity, pumps with low efficiency, incorrect sizing, and insufficient maintenance contributes to wastage of electricity in the agriculture sector. Several initiatives are in place to conserve energy and improve energy efficiency in this sector. Feeder separation to separate agriculture feeders from village feeders for accurately estimating agriculture consumption is one the important measures taken by the government. Some states are planning to shift the demand from night-time to daytime to match it with the solar PV generation. Other demand side management initiatives include replacement of old pumps with BEE 5 Star rated energy efficient pumps. EESL is offering to replace inefficient pumps with high-efficiency pumps integrated with smart sensors at no cost to the farmers. The programme targets replacing 200,000 pump sets to the farmers.[55] In attempts to increase the penetration of renewable energy, the Government has launched Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan (PM KUSUM) Scheme. The scheme aims to add renewable capacity of 25,750 MW by 2022. The scheme targets to set up 10,000 MW decentralized grid-connected renewable power plants of 2 MW each; install 1.75 million standalone solar powered pumps of 7.5 HP and solarize 1 million grid-connected agricultural pumps of 7.5 HP capacity.[56] Through the improvements carried out in the transmission and distribution sector through Ujwal DISCOM Assurance Yojana (UDAY)[57] scheme, the Government is working on improving the quality of electricity supply provided to this sector and boost it with standalone Solar PV plants. To further unlock energy efficiency in the agriculture sector, smart controls and demand shifting to daytime to harness the maximum solar PV generation is the key. Thus, smart, and centralized controls for irrigations pumps and daytime watering strategies are recommended.

[54] http://mospi.nic.in/sites/default/files/publication_reports/ES_2020_240420m.pdf
[55] https://webstore.iea.org/download/direct/4035
[56] https://mnre.gov.in/img/documents/uploads/8065c8f7b9614c5ab2e8a7e30dfc29d5.pdf
[57] https://www.uday.gov.in/about.php

03

EU STRATEGY FOR ELECTRIFICATION

3 EU STRATEGY FOR ELECTRIFICATION

This chapter will set out the context for the electrification of the energy services in the EU, on the basis of which it will assess the elements that are relevant for the Indian context.

3.1 EU electrification status

Per capita energy consumption was 138,164 MJ in the EU during 2017-18 compared to India's 23.355 MJ. This varied from 83,736 MJ for less energy intensive countries to 251,208 MJ for the more energy intensive countries.[58] In comparison, the per capita energy consumption in India is only 24,620 MJ, which is only 18% of the average EU consumption.

Per capita electricity consumption in EU in 2019 was 5,345 kWh per capita compared to India's 1,141 kWh. The EU's consumption varies from less than 3,500 kWh to more than 12,000 kWh.[59] **Figure 3.1** shows the fuel-wise breakdown of energy use in various sectors in the EU.[60] [61]

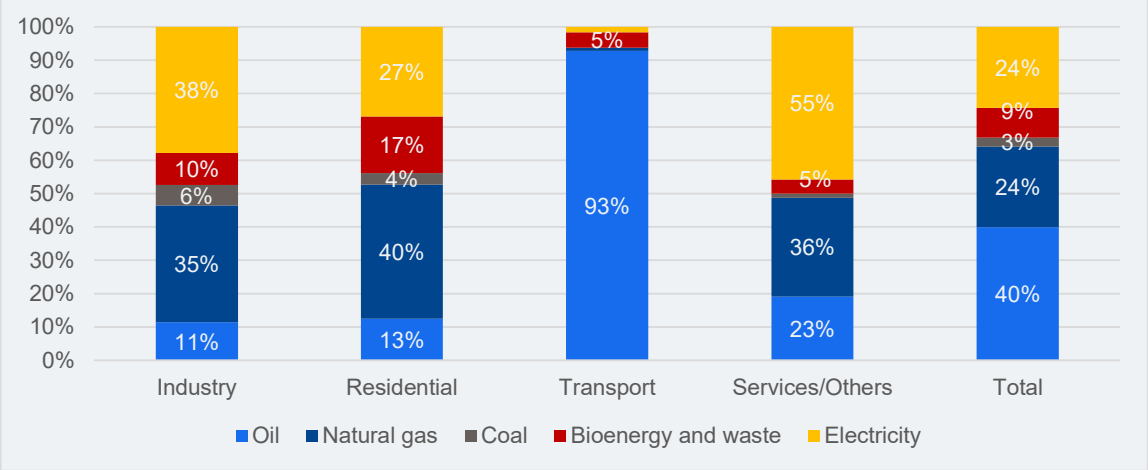


Figure 3.1: Fuel-wise breakdown of energy use in various sectors in 2017-18 in the EU (Source: European Environmental Agency, ETIP Bioenergy)

The transportation sector is the highest energy consuming sector (34%). This sector is dependent on oil (93%), followed by bioenergy (5%). The EU is promoting Electric Vehicles (EVs) and is increasing its share. Residential sector is the second highest-energy consuming sector. The major end-use in this sector is space heating, which is heavily dependent on fossil fuels (>80%). Penetration of electricity in the residential sector is about 27%. Electric heating is being promoted to increase the penetration of energy efficient, electricity-based heating. In contrast to the Indian scenario, the highest consumed energy is electricity (~38%) in the industrial sector. Natural gas is the second highest consumed fuel. Although much manufacturing has been outsourced to South

[58] https://ec.europa.eu/eurostat/statistics-explained/pdfscache/29046.pdf
[59] https://ourworldindata.org/energy/country/india?country=~IND#how-much-electricity-does-the-country-consume-each-year
[60] https://www.etipbioenergy.eu/images/ETIP_B_Factsheet_Bioenergy%20in%20Europe_rev_feb2020.pdf
[61] https://www.eea.europa.eu/data-and-maps/indicators/final-energy-consumption-by-sector-10/assessment

East Asia, the high penetration of electricity in the industrial processes is a key takeaway for the Indian counterpart. The penetration of electricity (55%) in the commercial and services sector is similar to India. Natural gas-based heating is a likely reason behind natural gas being the second highest energy fuel.

3.2 EU 2020 strategy

The electrification of various sectors has been ongoing for the last many years. Since 2010, the strategy "Europe 2020" has set the targets for the energy related policies until 2020. The "20-20-20" strategy stated:

Climate change & energy:

- Greenhouse gas emissions to be reduced by 20% compared to 1990.
- Share of renewable energy sources in final energy consumption to be increased to 20%.
- Energy efficiency to be improved by 20%.

The focus of the EU energy policies after 2000 has thus mainly been on energy efficiency in the end use and implementation of renewable energy in the electricity production, which as a secondary result has slightly increased the electrification of most of the consumption sectors as shown in Figure 3.2[62].

3.3 EU Green Deal

Through the European Green Deal proposed in December 2019, the European Union has set the aim to be climate-neutral by 2050. This means an economy with net-zero greenhouse gas emissions.

With the aim to be climate-neutral EU by 2050, the European Parliament and the Council of the European Union adopted the European Climate Law in June 2021. In addition to the goal of climate-neutrality, the European Climate law sets a binding EU climate target of a reduction of net greenhouse gas emissions of at least 55% by 2030 compared to 1990. The law aims to ensure that all EU policies contribute to this goal and that all sectors of the economy and society play their part.

The climate law has been followed up by the "Fit for 55" package, that was presented on 14 July 2021[63], which builds on an extensive impact assessment. Without changes to the current policy framework and legislation, the European Commission communication projects only a 60 % emissions reduction by 2050. To implement the increased ambition, the 'Fit for 55' package contains legislative proposals to revise the entire EU 2030 climate and energy framework, including the following set of proposals:

- The EU Emissions Trading System (ETS) puts a price on carbon and lowers the cap on emissions from certain economic sectors every year. It has successfully brought down

[62]Energy consumption and energy efficiency trends on the EU-28 for the period 2000-2016
[63] https://ec.europa.eu/commission/presscorner/detail/en/IP_21_3541

emissions from power generation and energy-intensive industries by 42.8% in the past 16 years. In the "fit for 55" package the European Commission is proposing to lower the overall emission cap even further and increase its annual rate of reduction. The Commission is also proposing to phase out free emission allowances for aviation and aligning with the global Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) to include shipping emissions for the first time in the EU ETS. To address the lack of emissions reductions in road transport and buildings, a separate new emissions trading system is set up for fuel distribution for road transport and buildings. The Commission also proposes to increase the size of the Innovation and Modernisation Funds.

- To complement the substantial spending on climate in the EU budget, Member States should spend the entirety of their emissions trading revenues on climate and energy-related projects. A dedicated part of the revenues from the new system for road transport and buildings should address the possible social impact on vulnerable households, micro-enterprises, and transport users.

- The Effort Sharing Regulation assigns strengthened emissions reduction targets to each EU Member State for buildings, road and domestic maritime transport, agriculture, waste, and small industries. Recognising the different starting points and capacities of each Member State, these targets are based on their GDP per capita, with adjustments made to take cost efficiency into account.

- EU Member States also share responsibility for removing carbon from the atmosphere, so the Regulation on Land Use, Forestry and Agriculture sets an overall EU target for carbon removals by natural sinks, equivalent to 310 million tonnes of CO_2 emissions by 2030. National targets will require Member States to care for and expand their carbon sinks to meet this target. By 2035, according to the proposals, the EU should aim to reach climate neutrality in the land use, forestry, and agriculture sectors, including agricultural non-CO_2 emissions, such as those from fertiliser use and livestock. The EU Forest Strategy aims to improve the quality, quantity, and resilience of EU forests. It supports foresters and the forest-based bioeconomy while keeping harvesting and biomass use sustainable, preserving biodiversity, and setting out a plan to plant three billion trees across Europe by 2030.

- Energy production and use accounts for 75% of EU emissions; hence, accelerating the transition to a greener energy system is crucial. The Renewable Energy Directive will set an increased target to produce 40% of our energy from renewable sources by 2030. All EU Member States will contribute to this goal, and specific targets are proposed for renewable energy use in transport, heating and cooling, buildings, and industry. To meet both the EU's climate and environmental goals, sustainability criteria for the use of bioenergy are strengthened and EU Member States must design any support schemes for bioenergy in a way that respects the cascading principle of uses for woody biomass.

- To reduce overall energy use, cut emissions and tackle energy poverty, the Energy Efficiency Directive will set a more ambitious binding annual target for reducing energy use at EU level. It will guide how national contributions are established and almost double the annual energy saving obligation for Member States. The public sector will be required to renovate 3% of its buildings each year to drive the renovation wave, create jobs and bring down energy use and costs to the taxpayer.

- A combination of measures is required to tackle rising emissions in road transport to complement emissions trading. Stronger CO_2 emissions standards for cars and vans will accelerate the transition to zero-emission mobility by requiring average emissions of new cars to come down by 55% from 2030 and 100% from 2035 compared to 2021 levels. As a result, all new cars registered as of 2035 will be zero-emission. To ensure that drivers are able to charge or fuel their vehicles at a reliable network across Europe, the revised Alternative Fuels Infrastructure Regulation will require EU Member States to expand charging capacity in line with zero-emission car sales, and to install charging and fuelling points at regular intervals on major highways: every 60 kilometres for electric charging and every 150 kilometres for hydrogen refuelling.

- Aviation and maritime fuels cause significant pollution and also require dedicated action to complement emissions trading. The Alternative Fuels Infrastructure Regulation requires that aircraft and ships have access to clean electricity supply in major ports and airports. The ReFuelEU Aviation Initiative will oblige fuel suppliers to blend increasing levels of sustainable aviation fuels in jet fuel taken on-board at EU airports, including synthetic low carbon fuels, known as e-fuels. Similarly, the FuelEU Maritime Initiative will stimulate the uptake of sustainable maritime fuels and zero-emission technologies by setting a maximum limit on the greenhouse gas content of energy used by ships calling at European ports.

- The tax system for energy products must safeguard and improve the Single Market and support the green transition by setting the right incentives. A revision of the Energy Taxation Directive proposes to align the taxation of energy products with EU energy and climate policies, promoting clean technologies and removing outdated exemptions and reduced rates that currently encourage the use of fossil fuels. The new rules aim at reducing the harmful effects of energy tax competition, helping secure revenues for Member States from green taxes, which are less detrimental to growth than taxes on labour.

- Finally, a new Carbon Border Adjustment Mechanism will put a carbon price on imports of a targeted selection of products to ensure that ambitious climate action in Europe does not lead to ‘carbon leakage'.

- These proposals are all connected and complementary. The proposals still need to be discussed and approved by the European Parliament and the Council of the European Union.

Figure 3.2: Elements of the Green Deal. Source: EC note COM (2020) 299, Powering a climate-neutral economy: An EU Strategy for Energy System Integration

The Green Deal emphasizes smart and clean electrification, which would bring significant benefits to the European citizens and the economy. Some of the major benefits enlisted are economic prosperity, energy savings, energy resilience and security, promoting and supporting e-mobility and protection against increasing air pollution.[64] This is also expected to facilitate integration of power, buildings and transport sector through sector coupling approach.[65]

As part of the European Green Deal, the Commission presented an EU strategy for energy system integration on 8 July 2020. The energy system integration will be facilitated by the correct and timely implementation of the eight legal acts of the Clean energy for all Europeans package, adopted in 2018-2019. The strategy intends to design a more efficient and integrated system that links energy sources and infrastructure to support decarbonization and build a climate neutral EU by 2050.[66] This will be accomplished through three levels:

[64] https://www.eurelectric.org/media/4053/electrification-alliance-final.pdf
[65] https://www.bruegel.org/2019/07/the-european-union-energy-transition-key-priorities-for-the-next-five-years/
[66] https://ec.europa.eu/energy/sites/ener/files/energy_system_integration_strategy_.pdf

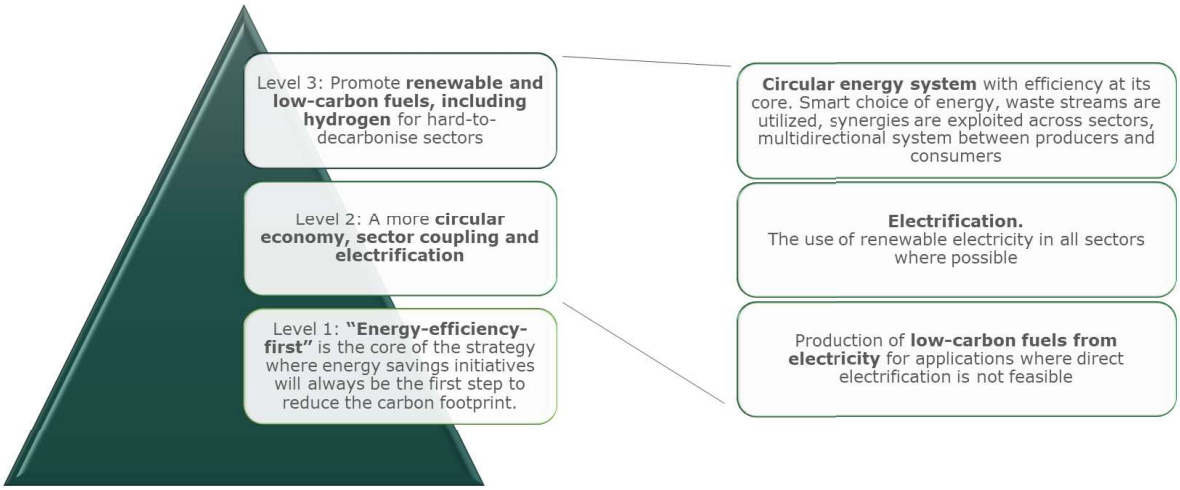


Figure 3.3: Levels of strategies. Sources: An EU Strategy for Energy System Integration, COM (2020) 299, The European Green Deal, COM (2019) 640

1. **"Energy-efficiency-first" is the core of the strategy** where energy savings initiatives will always be the first step to reduce the carbon footprint. The least energy intensive choices are prioritised, unavoidable waste streams are reused for energy purposes, and synergies are exploited across sectors. This is happening already in combined heat and power plants or through the use of certain waste and residues. There is however further potential, for example, in reusing waste heat from industrial processes, data centres, or energy produced from bio-waste or in wastewater treatment plants. This important aspect of the Green Deal is also applicable to India but is out of scope of this strategy note.

2. **A more circular economy, sector coupling and electrification.** The rapid growth and cost competitiveness of renewable electricity production can service a growing share of energy demand – for instance using heat pumps for space heating or low-temperature industrial processes, electric vehicles for transport, or electric furnaces in certain industries. This is the main focus of this document. The current energy system in the EU is linear, i.e. supply to demand is unidirectional. The system also does not account for fuel sharing or waste heat utilization. The penetration of renewables and other low-carbon fuels is also limited. In the future scenario following the strategy on energy system integration, the system is expected to become more flexible to cater multiple low-carbon fuel sources. The system will also allow for waste heat utilization for secondary and tertiary uses, increasing the overall system efficiency. Linking the sectors will allow the optimisation of the energy system as a whole, rather than decarbonising and making separate efficiency gains in each sector independently. This new EU strategy will involve various existing and emerging technologies, processes and business models, such as ICT and digitalisation, smart grids and meters and flexibility markets.

3. **Promotion of renewable and low-carbon fuels, including hydrogen for hard-to-decarbonise sectors.** While direct electrification presents the most cost-effective and energy efficient decarbonisation option in many cases, there are a number of end-use applications where it might not be feasible or affordable. In such case, a number of

renewable or low-carbon fuels could be used, such as sustainable biogas, biomethane and biofuels, renewable and low-carbon hydrogen or synthetic fuels. These cases include a number of industrial processes, but also transport modes such as aviation and maritime, where sustainable alternative fuels such as advanced liquid biofuels and synthetic fuels will have an essential role to play.

In the backdrop of the current crisis caused by the COVID-19 pandemic the EU Commission has proposed a new recovery package "Next Generation EU" with €390 billion grants and €360 billion loans. The budgets have been endorsed by the EU Council and EU Parliament in November 2020. One focus point in the stimulus package is green energy, giving further funding to the green transition. Raising the 2030 ambition now helps give certainty to policymakers and investors, so that decisions made in the coming years do not lock in emission levels inconsistent with the EU's goal to be climate-neutral by 2050.

The boosted funding under this scheme will be channelled through focused strengthening of existing programmes.[67].

3.4 Hydrogen as a bridge to electrification

Hydrogen will be an important element of the EU Strategy on Energy System Integration, but its key role and its wider scope warrant a specific approach. In this context, the Commission adopted a new dedicated strategy on hydrogen in Europe, in parallel with the strategy on energy system integration, on 8 July 2020. The new hydrogen strategy will explore the potential of clean hydrogen to help the process of decarbonising the EU economy in a cost-effective way. Hydrogen has a strong potential to bridge the gap from renewable electricity to renewable fuels, either through the direct use of hydrogen as a fuel or as the prime energy source for electro-fuels in Power-to-X plants.

3.4.1 Green hydrogen in industrial processes

Hydrogen for industrial purposes such as refineries, fertilizer and steel industry are mainly produced through processing of natural gas or oil derivatives, which counts for 99% of the currently produced hydrogen. With an electrolyser, the hydrogen can be made by using electricity to split water, thus making the electrification of certain processes possible. Examples of demonstration projects are: RefHyne 10 MW electrolyser in Cologne, Germany, development of electrolysers for ammonia synthesis plants (SOC4NH3), or replacement of coal in a steel plant in Sweden (Hybrid project).

3.4.2 Hydrogen as direct fuel

Hydrogen can be stored at high pressures and be used as a fuel for vehicles. A network of 137 active hydrogen fuelling stations have been created – mostly in Germany[68]. Most fuelling stations include an electrolyser creating the hydrogen from green electricity through certificates. A small number of car manufacturers offer fuel cell vehicles for hydrogen, including Daimler, Toyota and

[67] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12228-EU-Green-Deal-carbon-border-adjustment-mechanism-

[68] https://h2-map.eu/

Honda. The hydrogen fuel cell cars do not have the same momentum currently as battery driven electric vehicles or hybrids.

3.4.3 Hydrogen for transport fuel

By combining the hydrogen made from electricity with carbon-based molecules such as CO_2 or methane, synthetic and "green" fuels can be made from renewable energy. This is the process named Power-to-X[69], which is also considered as a future strategy in the EU. Fuels such as methanol, ethanol, ammonia, or jet fuels can be produced without the need of fossil fuels. The fuel can then be used in the transport sector in the many situations where direct electrical propulsion is not readily possible such as in heavy road transport, ships, and airplanes. The development of this complex area of the European energy system is funded by the Horizon 2020 funds and the European Innovation Fund and examples of new consortia are emerging such as the Copenhagen Power-to-X consortia[70] for the installation of a Power-to-X plant based on dedicated wind turbines and carbon capture of waste incineration emissions, or the German Kopernikus project[71], where the focus is on storage of excess electricity into other energy carriers through hydrogen electrolysis.

[69] Power-to-X is the summarizing term for Power-to-Gas, Power-to-Liquid and Power-to-Chemicals and more.

[70] https://investindk.com/insights/danish-companies-joins-forces-in-an-ambitious-and-sensational-power-to-x-project

[71] https://www.rwth-aachen.de/go/id/kvyv/lidx/1

04

SECTORAL DEVELOPMENTS TOWARDS ELECTRIFICATION IN THE EU

4 SECTORAL DEVELOPMENTS TOWARDS ELECTRIFICATION IN THE EU

The previous EU strategies for greenhouse gas emission reductions have had some influence on the electrification of the various sectors, but still leave large potential for further electrification.

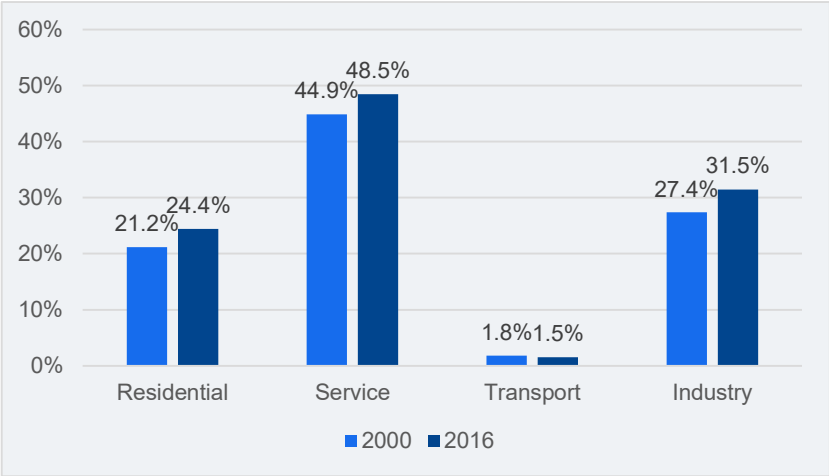


Figure 4.1: Trend of electricity share of total energy consumption per sector in EU before recent initiatives

This increase in electrification has been achieved in a period since 2000, where the Gross Domestic Product of the total EU has risen with 25% (2000-2016)[72] while the final energy consumption in the same period has been kept at an almost constant value as is shown in **Figure 4.2.**

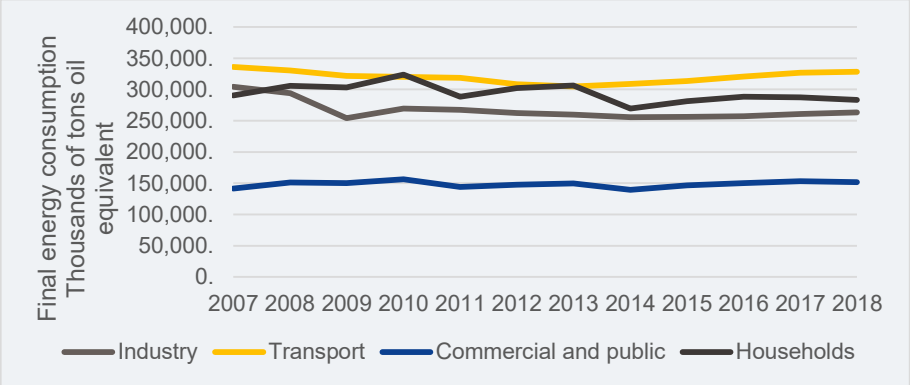


Figure 4.2: The trend in final energy consumption in EU-28

In recent years, the electrification has accelerated as it is an important measure in order to utilize the renewable energy from wind, solar and hydropower as described above. More recent initiatives are elaborated in the forthcoming sections.

[72] https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/EURO/EUQ

4.1 Industry

Industrial emissions contributed to 20% of all the EU CO_2 emissions in 2015. Around 30% of industrial emissions were related to non-energy related processes, which are more difficult to reduce due to the intrinsic nature of the processes. The rest of the 70% of the emissions have reduced by 42% between 1990 and 2015. The key reasons behind this reduction have been:

- Energy efficiency improvements
- Fuel-switching to biomass
- Capacity closures and structural shifts in the economy
- Significant reductions in non-CO2 GHG emissions

4.1.1 Status

The industrial sector is considerably electrified in the current state, though its penetration is not uniform across all the industries. For instance, the chemicals and steel industries are still largely dependent on coal. The energy intensive industries (EIIs) are responsible for 15% of the EU's emissions. The push towards efficiency improvements at EIIs are supported by the European Emission Trading Scheme (EU ETS) as a "cap and trade" system for emissions. By increasing the cost of emissions, the ETS has become a major driver for fuel switch towards less carbon intensive energy, of which electricity from renewable sources is one of the most favourable options. This had led to increased demand for green electricity and motivated producers to increase supply of electricity from renewable sources as the most competitive source of green electricity. This along with other regulatory initiatives and innovation funding schemes have resulted in introduction of new technologies such as:

- Direct reduction of iron[iii] substituting coal with green hydrogen and electrolysers[iv]
- Direct use of renewables for industrial heating, especially where the required temperatures are less than 200°C
- Substituting electricity for coal and peat in industrial processes. Example is mineral wool production by electrical melting furnace[73]
- Utilization of waste heat for district heating and cooling is also being explored. Example is to use the free heat from the wastewater leaving a wastewater treatment plant as input to industrial size heat pumps for supply of heat to district heating network. This is a feasible and popular development in especially Sweden and Denmark.

Heat pumps can also be used internally in industrial plants where simultaneous heating and cooling is used, which traditionally is served by an industrial cooling plant for cooling and a gas burner for heating. Examples of potential feasible installations could be in dairy plants or drying plants. The installation of industrial size heat pumps is booming over the last few years, but still the potential is much larger.[74] [75]

[73] https://cdn01.rockwoolgroup.com/globalassets/sustainability/sustainability-report/2019_rockwool-sustainability-report.pdf?f=20200331013316
[74] https://industrialheatpumps.nl/en/practices/

High temperature heat pumps (>120°C) are maturing and are now commercially available and will open up for even more electrification with heat pumps for e.g. boiling processes.

Furthermore, the electrification of hydrogen for use in chemical plants or refineries is another large potential for electrifying large energy consumptions. Hydrogen as a means for electrification is discussed in Section **Error! Reference source not found.**

4.1.2 EU targets relevant for electrification

The industry sector does not have a common target for electrification, but rather focuses on reducing the CO_2 emissions of the sector.

The industry sector does not have one common CO_2-reduction target, as "European industry is diverse, with different sizes, risks and needs. It needs targeted solutions, not a 'one-size fits all' approach."[76]

4.1.3 EU policy approach

The most energy intensive industries with a net heat excess of 20 MW are however regulated by the EU Emission Trading Scheme (ETS), which is also the tool with which the sector also reaches climate neutrality in 2050. The ETS scheme accounts for 40% of the energy used in the industry sector and has shown to be a valuable tool for reducing CO_2 emissions.

The larger energy consumers will be met with increasingly stricter ETS quotas, which will be adjusted to meet the emission targets. A share of the CO_2 emission quotas is auctioned off, and will thus generate a revenue, which becomes a source of financing of further CO_2 reducing initiatives.

Furthermore, the EU Commission focuses on initiatives known as alliances across large companies, SMEs, service providers, public authorities and academia, which get support and funding by the EU. Examples of these types of alliances are found within batteries, plastics and microelectronics. Building on the successful template of industrial alliances, a new European Clean Hydrogen Alliance will be launched, and an alliance on Low Carbon Industries will follow when ready.

4.2 Residential

4.2.1 Status

Around 60% of final electricity consumption and about two-thirds of space heating and cooling demand comes from buildings, of which residential stock represents a major share. As a result, buildings accounted for the largest share of the final energy consumption. 75% of the European stock was built without any energy efficiency considerations and due to low renovation rate, most of these would still be energy inefficient in 2050.

[75] https://www.ehpa.org/fileadmin/red/03._Media/03.02_Studies_and_reports/Large_heat_pumps_in_Europe_MDN_II_final4_small.pdf

[76] https://ec.europa.eu/commission/presscorner/api/files/attachment/863067/EU_industrial_strategy_en.pdf.pdf

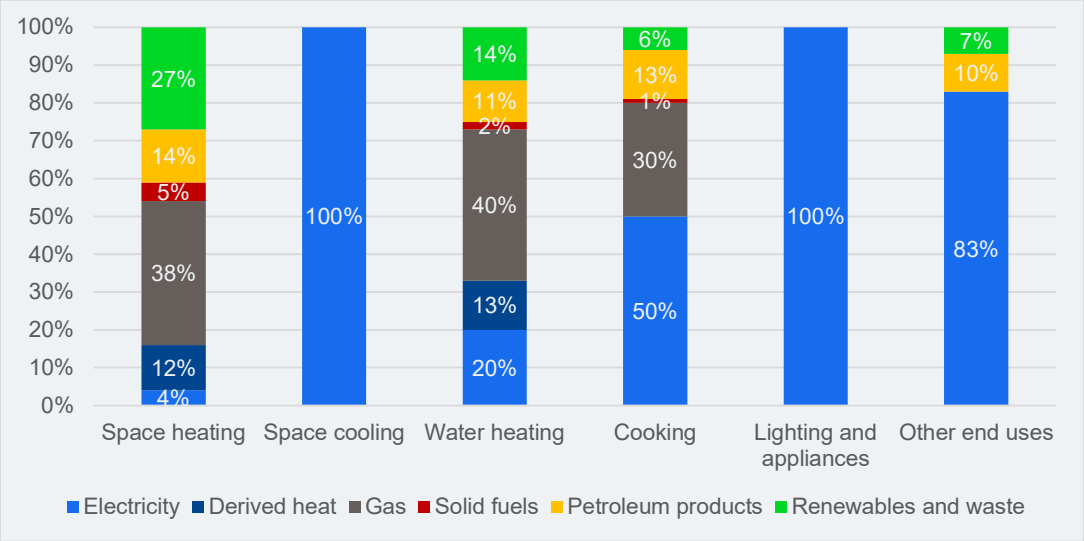


Figure 4.3: Fuel-wise breakdown of residential end-uses in the EU (Source: EuroStat)

Figure 4.3 highlights the areas where electrification can still be increased in the EU residential households, i.e. space heating, water heating and cooking.[77]

Space heating

In terms of end-use split, space heating represents more than 60% of the total energy use. In 2018, almost 60% of the heating demand was met by fossil fuels and only 5% came from electricity. Moreover, 50% of the buildings are heated by inefficient, fossil fuel-heated boilers, which have exceeded their serviceable lifetime.[78] In order to meet the 2030 and 2050 targets, electric heating, heat pumps and efficient district systems are being explored, which would be eventually fuelled by renewable energy including solar, thermal, geothermal and biomass. Furthermore, electric heating and cooling means higher integration with industrial and transportation sector.

The maturation of small heat pumps for residential heating has resulted in the substitution of natural gas or petroleum-based heating appliances. Even in a country like Denmark where district heating is dominant, the sales of residential heat pumps have increased from about 18,000 units in 2009 to 47,000 units in 2019[79]. The district heating networks in Northern Europe (e.g. Germany, the Netherlands, Denmark) are also changing heat source from traditional combined heat and power from fossil fuels to biomass boilers or large-scale electrical heat pumps and even resistive electrical heaters. This is pushed by the various national incentive plans and the European Emissions Trading System, which makes the business case for heat pumps better than fossil fuel district heating.

Space cooling

[77] https://db.nomics.world/Eurostat/nrg_d_hhq
[78] https://ec.europa.eu/energy/sites/ener/files/documents/Report%20WP2.pdf
[79] https://ens.dk/sites/ens.dk/files/Statistik/udvikling_i_salg_af_varmepumper_fra_2009.pdf

The residential cooling demand is almost exclusively covered by electricity through air conditioning units. However, cities are looking into the use of district cooling as a means to utilize natural cooling from nearby water bodies or from the excess heat from power plants for cooling through absorption chiller units. This will not increase the electrification of the service but will further improve the sector coupling of the various energy services.

Smart buildings

Another important aspect of the EU strategy is to encourage the development of smarter energy systems and smarter buildings. By ways of making the components of a building, energy system or electrical appliances "smart", i.e. able to communicate with each other, it is possible to optimize the performance of the integrated systems. An example could be a washing machine that automatically selects the best time of the night to start a cycle, or a ventilation system controlled by activity sensors in the house. EU is building standards for supporting the development and interoperability of smart devices[80].

Domestic water heating

In Northern Europe, the water heaters are usually integrated with the space heating system, e.g. natural gas boiler or district heating. In warmer locations the use of stand-alone electrical heaters is more dominant, but these account for only 20% of the water heating. For water heating, heat pumps are also being pushed as a feasible technology by several of the member states.

Residential cooking

For cooking, less than 50% is on electrical stoves with natural gas, city gas or LPG as the main other sources. In many areas it is cheaper to heat by gas stoves than electricity. The number of gas-based ovens are decreasing in the EU, e.g. in Spain the share of households with gas ovens have decreased from 36% in 2010 to 23% in 2017[81].

4.2.2 EU targets for residential electrification

The targets for electrification defined in the EU Strategy for Energy System Integration are to reach 40% by 2030 and 50-70% by 2050.

4.2.3 EU policy approach

The policies related to the electrification of the residential sector and all buildings are:

- Energy Performance of Buildings Directive 2010/31/EU (EPBD)
- Energy Efficiency Directive 2012/27/EU
- Directive amending the Energy Performance of Buildings Directive (2018/844/EU) in the Clean Energy for All Europeans package[82]
- 'Renovation Wave' Initiative and Strategy on the built environment as part of Green New Deal.

[80] https://ec.europa.eu/digital-single-market/en/blog/new-standard-smart-appliances-smart-home
[81] https://www.statista.com/statistics/1174565/cooker-oven-microwaves-ownership-rate-european-countries/
[82] https://ec.europa.eu/energy/topics/energy-strategy/clean-energy-all-europeans_en

- Sector coupling, e.g. use of waste heat from industry

4.3 Transportation

4.3.1 Status

Transportation is the largest individual sector in terms of emissions and the only sector with increasing emissions in the EU. The European transport sector is dominated by road transport which contributes 73% of the total transport-related emissions. Biofuels and electric vehicles constitute only 4% and 1-2%, respectively.

In order to electrify the transport sector, green electricity from renewables is being explored as a key strategy as it is more efficient than electrofuels. Battery costs are a major determinant for the uptake of electric vehicles. With battery costs going down by as high as 80% compared to 2010, it is expected to increase the uptake of electric vehicles. Resultantly, electricity is anticipated to satisfy 4% of the transport energy demand in 2030 and 15-26% in 2050. The EU Member States are propelling the electric vehicles market using a combination of technological, financial, and regulatory instruments. There is an emphasis on expanding public charging infrastructure, expansion of battery production, strengthening electricity infrastructure, integration of renewable energy and promotion of technical advancements to the consumers. There are incentive programmes introduced by Member States to promote the purchase of electric vehicles[83]. Examples are the German "Umweltbonus" programme with EV purchase grants of up to EUR 9,000 per vehicle as well as motor vehicle tax exemption or the new Italian programme "Eco-Bonus" with dedicated EUR 70 million to subsidize electric or very low-emission hybrid vehicles up to EUR 10,000 per vehicle.

Electrification of road transport

Light Duty Vehicles (LDV), cars and vans, represent the majority of transport emissions and are responsible for 15% of overall CO_2 emissions within the EU.

Significant efforts will be needed after 2020 to achieve the European GHG emission targets. The Transport White Paper[84] sets out additional goals and benchmarks: a 50% reduction of conventionally fuelled cars in urban transport by 2030 and phasing them out in cities by 2050.

Electric mobility is expected to play a major role for achieving these goals for three reasons: (a) electric powertrains are significantly more energy efficient than conventional ones, (b) electricity can make direct use of energy from renewable sources available for transport, and (c) when connected to the power grid, batteries of electric vehicles could stabilize the grid and balance supply and demand facilitating the integration of renewable sources.

Other technologies are also being developed and demonstrated in the EU, while still not mature enough to be part of the strategy for electrification of the transport sector. In Germany and

[83] An overview of European member states EV incentives programmes can be found here: https://wallbox.com/en_us/guide-to-ev-incentives-europe

[84] https://ec.europa.eu/transport/themes/strategies/2011_white_paper_en

Sweden, projects are demonstrating the use of electrified roads through electrified tracks in the road or overhead cables on main roads to complement batteries for the longer road stretches. [85]

Electrification of EU railroads

Rail in Europe is mostly electrified and moving transport to rail is therefore key to decarbonising transport. Especially in cities, rail almost exclusively runs on electricity already today. Regarding main lines, 60% of the European rail network is already electrified and 80% of traffic is running on these lines.[86]

There are no technical obstacles to further electrification, and further electrification is only limited by cost, which needs to be considered for each case.

New vehicle concepts for non-electrified railway lines are being developed. For example, manufacturers of rail vehicles are testing emission-free trains equipped with fuel cell drives. Hybrid diesel-electric locomotives can operate in emission-free mode as well. In parallel, the European rail supply industry has declared energy efficiency as one of the key topics to be addressed by the Shift2Rail Joint Undertaking[87].

4.3.2 EU targets relevant for electrification

The EU Green Deal sets an overall target of 90% GHG emission reduction from transport by 2050. The new "Sustainable and Smart Mobility Strategy" from December 2020, as detailed below, sets out that electrification of the transport sector is a key driver:

- By 2030:
  - at least 30 million zero-emission vehicles will be in operation on European roads
  - 100 European cities will be climate neutral
  - high-speed rail traffic will double
  - scheduled collective travel of under 500 km should be carbon neutral within the EU
  - zero-emission vessels will become ready for market
- By 2035:
  - zero-emission large aircraft will become ready for market
- By 2050:
  - nearly all cars, vans, buses as well as new heavy-duty vehicles will be zero-emission
  - rail freight traffic will double
  - high-speed rail traffic will triple

[85] https://www.volkswagenag.com/en/news/2020/08/scania_e_road_trial.html#
[86] https://ec.europa.eu/newsroom/horizon2020/document.cfm?doc_id=46368
[87] https://shift2rail.org/ - a EU funded Joint Undertaking with the vision to deliver the most sustainable, cost-efficient, high-performing, time driven, digital and competitive customer-centred transport mode for Europe since 2014. Budget for 2020 is EUR 151.5 million

4.3.3 EU policy approach

To achieve the systemic change in the transport sector the EU needs to (1) make all transport modes more sustainable, (2) make sustainable alternatives widely available in a multimodal transport system and (3) put in place the right incentives to drive the transition[88].

The policy related to battery-powered vehicles is mainly focused on technological optimisation and market development. Future challenges in this field include reliability and durability of batteries and super-capacitors, reducing battery weight and volume, safety, cost reduction, improved hybrid electric power trains charging infrastructure and plug-in solutions.

Electrification of transport (electromobility) is a priority in the EU research programmes. It also figured prominently in the European Economic Recovery Plan presented in November 2008, within the framework of the Green Car Initiative, worth €5 billion for boosting the car industry.

Relevant recent legislature promoting electrification in the transport sector:

- Comprehensive Strategy for Sustainable and Smart Mobility (published 2020-12-09) COM (2020) 789.
- Regulation (EU) 2019/631 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles.
- Council Regulation (EC) No 521/2008 of 30 May 2008 setting up the Fuel Cells and Hydrogen Joint Undertaking was created to deliver robust hydrogen supply and fuel cell technologies developed to the point of commercial take-off.

Public procurement of low- and zero-emission vehicles

The directive 2019/631 sets national targets for each member state on the procuring of clean vehicles. The required aggregated share of public procured clean vehicles varies by member state between 17.6% and 38.5%. Until 2025 a "clean" vehicle is defined as less than 50 g/km CO_2, but from 2026 only zero-emission vehicles count.

CO_2 emission performance standards for cars and vans

The former legislation (EC) 443/2009 set specific emission targets (g CO2/km) for cars and soon also vans with continuous stricter demands year over year phasing in from 2015 until now. New legislation Regulation 2019/631 has continued these emission targets, and in 2021 the target will be 95 g CO2/km for all new cars as an average per manufacturer. **These strict emission requirements are difficult to achieve by gasoline or diesel alone and thereby push the manufacturers towards electrification** by including other technologies, mainly hybrids, plug-in hybrids, and electrical vehicles. Manufacturers can group together and act jointly to meet their emissions target, so that emissions can be shared. An example of this is the cooperation between Fiat-Chrysler and Tesla. Not complying with the emission limits will result in large fines for the manufacturer.

[88] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12438-Sustainable-and-Smart-Mobility-Strategy

Similar emission targets are in place for vans[89], which is regulated with the same rules in the same directive. The resulting average emission limit for vans in 2021 is 147 g CO_2/km.

CO_2 emission performance standards for heavy vehicles

Heavy Duty Vehicles (HDV) – trucks, buses and coaches – on the other hand, are responsible for 25% of CO2 emissions from road transport, i.e. about 5% to the EU's total greenhouse gas emissions. Despite some improvements in fuel efficiency, their emissions rose by some 36% between 1990 and 2010 and another significant increase is expected between 2010 and 2030 because of increased freight. The electrification of HDV is still limited and electrical alternatives to fossil-based fuels are scarce.

A new legislation Regulation 2019/1242 is in place employing a similar fleet-wide average CO_2-limit mechanism as for light vehicles and is likewise technology neutral but will be difficult to achieve without mixing in battery or hydrogen/e-fuels based vehicles in the fleet. The targets will require manufacturers to cut CO2 emissions from new trucks on average by 15% from 2025 and by 30% from 2030, compared with 2019 levels.

Improving the EU's recharging infrastructure

Since 2014 a directive on the deployment of alternative fuels (2014/94/EU) has been in place which among other initiatives set the requirements for the deployment of EV charging infrastructure in the EU. Each member state must ensure that the deployment is carried out and that certain standards are implemented. One target was to ensure that one EV charger was in place for every 10 EVs in urban areas.

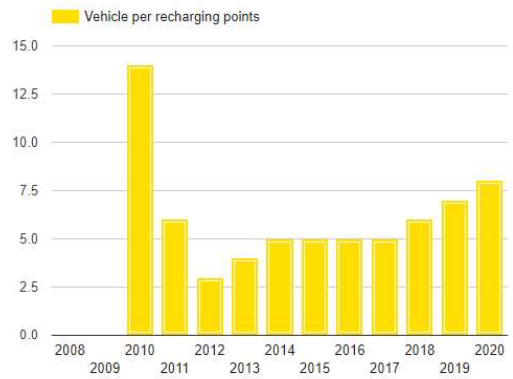


Figure 4.4: Vehicles per charging point. eafo.eu

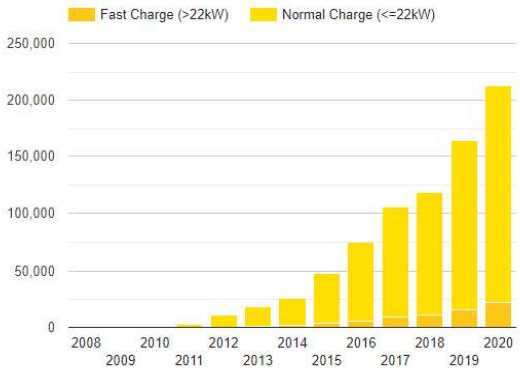


Figure 4.5: Installed charging points in EU. Source:

The 2020 goals of the 2014/94/EU directive on charging points have been met, but with the rapid expansion in EVs in EU, even more charging points are needed. A new initiative[90] is in process, which aims to greatly expand the EU's network of recharging and refuelling stations for

[89] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R0631
[90] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12251-Revision-of-Alternative-Fuels-Infrastructure-Directive

alternative vehicle fuels – mainly batteries, natural gas and hydrogen and ensuring cross-border solutions in the EU.

From the inception impact assessment report: "*Following the policy ambition set out by the European Green Deal, building-up a dense, widespread, reliable and easy-to-use-alternative fuels infrastructure network for vehicles, vessels and aircrafts is an important enabler for the transition to a carbon-neutral economy. The European Green Deal makes a clear reference to have at least 1 million public accessible recharging and refuelling points for road vehicles in place by 2025.*"

4.4 Service sector

4.4.1 Status

The services sector is the sector having the highest penetration of electricity (55%) among all the sectors of the economy, followed by natural gas (36%). The commercial sector is majorly represented in the services sector. Space heating and cooling are among the major end-uses. Space heating in commercial sector is shifting towards electricity-based, faster than residential sector.

Data centres are large electrical consumers in the service sector. From 2007 to 2020, the energy consumption has risen from 57 TWh/yr to 104 TWh/yr representing up to 4% of the annual energy consumption in the EU.[91] Focus from the EU is on improving the overall efficiency of such data centres by implementing code of conduct and best practices, and utilising free cooling, where applicable.

The data centres will produce large quantities of low temperature heat, which is usually vented away. Newer data centres are placed in Northern Europe with good access to renewable energy from wind turbines, general cooler outdoor temperatures and with possibility of reusing the heat in local district heating circuits.[92] In some cases, the heat needs to be boosted by heat pumps in order to reach the desired temperature for district heating. Studies have shown that data centres with these surroundings are more efficient.

Part of the new EU Green Deal is the farm to fork strategy[93] encompassing agriculture and the food industry. Electrification is not considered a primary tool to reach the sustainability goals of the strategy. Still, many of the initiatives from other sectors could also be applicable to agriculture such as the integration of smart electricity consumption in the production units. This could be smart pumping of irrigation water when the electricity is most renewable and abundant.

4.4.2 EU targets

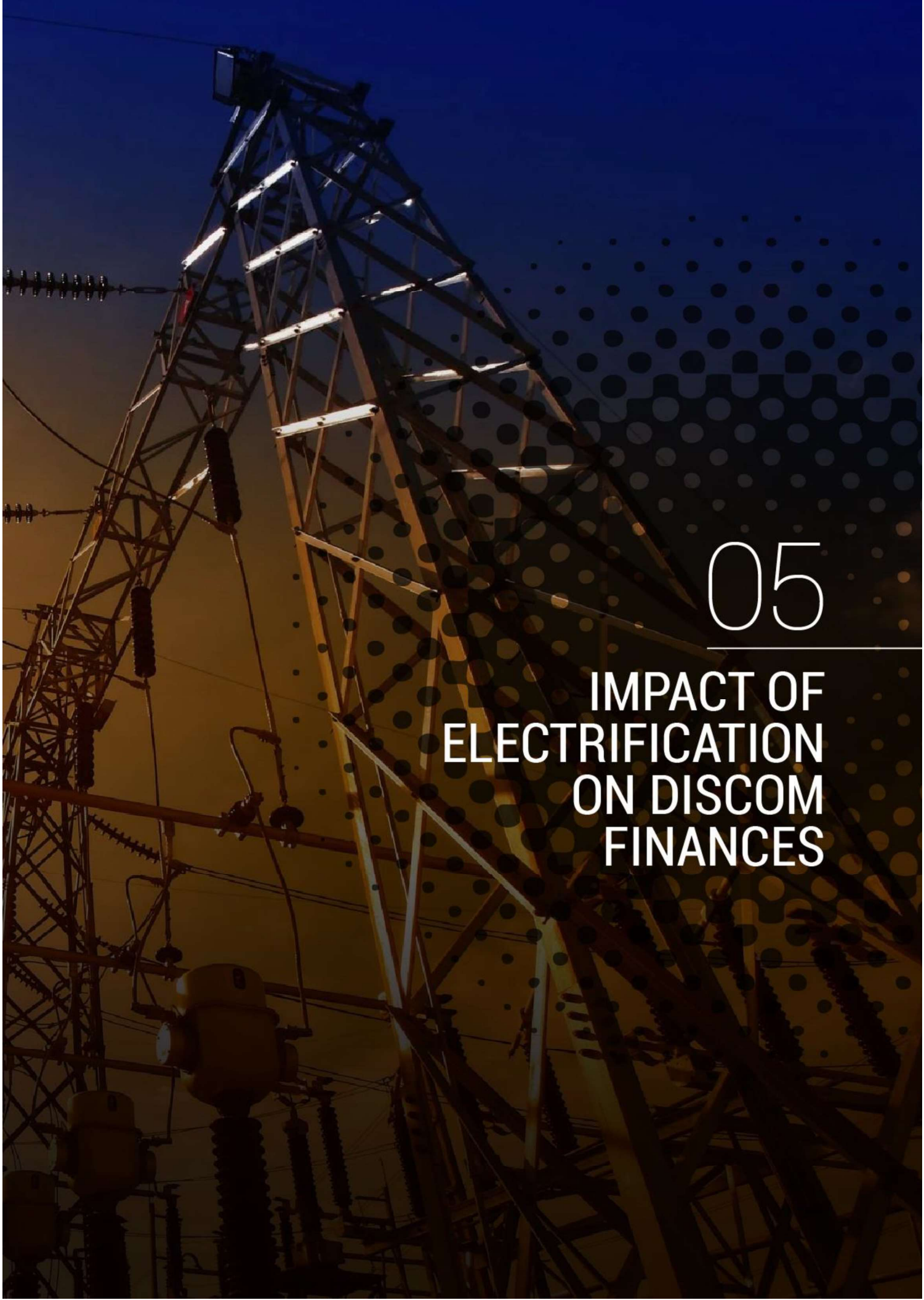
Through the EU Strategy for Energy System Integration, the goals for electrification in the service sector are to reach 65% by 2030 and 80% by 2050[94].

[91] https://publications.jrc.ec.europa.eu/repository/bitstream/JRC108354/kjna28874enn.pdf
[92] https://www.greendatacenterplatform.com/project/royal-haskoning/
[93] https://ec.europa.eu/food/farm2fork_en
[94] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0299&from=EN

4.4.3 EU policy approach

The electrification of the Service sector is closely related to the residential sector, as much of the potential for electrification is in the space heating. Policies to promote electrification include:

- 2018 Energy Efficiency directive
- 'Renovation Wave' Initiative and Strategy on the built environment.
- Sector coupling, e.g. use of waste heat from industry



05

IMPACT OF ELECTRIFICATION ON DISCOM FINANCES

5 IMPACT OF ELECTRIFICATION ON DISCOM FINANCES

Distribution Companies (DISCOMs) provide the only consumer interface in the power sector in India. They are also the primary source of cash inflow to the sector. Power distribution companies collect payments from consumers against their energy supplies (purchased from generators) to provide necessary cash flows to the generation and transmission sectors to operate. Due to the perennial cash collection shortfall, often due to payment delays from consumers, DISCOMs are unable to make timely payments for their energy purchases from the generators. This gap/shortfall is met by borrowings (debt), government subsidies, and possibly, through reduced expenditure. This increases the DISCOMs' cost of borrowing (interest), which is inevitably borne by the consumer. This also undermines the ability of the DISCOMs to purchase and distribute power to fulfil their Universal Supply Obligation (USO) as defined in the Electricity Act 2003 or borrow for capital expenditure to meet load augmentation and growth requirements. DISCOMs must therefore, (a) buy cost-efficient power for consumers, (b) ensure supply reliability with quality by minimizing losses/leakages (c) accurately meter, bill, and collect payments from the consumers, and (d) thereby, enable timely payments to the generators. These are key steps towards sustaining the entire energy value chain without power supply disruptions. Customer service and financial health must mutually reinforce each other in improving DISCOMs' finances and services provided. Hence sustainability, which includes financial viability of DISCOMs, is of great importance.

The power sector has seen multiple interventions by the government for financial restructuring, operations, infrastructure and technology improvements like R-APDRP, SAUBHAGYA, DDUGJY, etc. UDAY (Ujwal DISCOM Assurance Yojana) scheme, launched in November 2015, is the latest attempt to address the severe financial stress due to accumulation of debt by the DISCOMs, with a focus on improving the overall efficiency and financial turnaround. It outlays the following key parameters for analyzing the financial health of the DISCOMs viz. AT&C Losses, ACS-ARR Gap (gap of Average Cost of Supply (ACS) per unit of power and per unit average revenue realized (ARR)), Feeder Metering, DT Metering, Consumer Indexing/GIS, Upgradation of DT, meters, and Smart Meters Installation. Thus, impact on DISCOMs is of prime importance for analysis with reference to increased electrification and for the same, ACS vs ARR is one of the key parameters.

Table 3: Financial performance of Discoms in the period of 2012-13 to 2019-20

	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2019-20
Discom loss on subsidy received basis (₹ billion)	716.21	682.57	569.39	486.19	387.45	335.94	613.60
Subsidy received (₹ billion)	361.00	367.58	455.84	745.15	789.38	889.19	986.53

ACS-ARR gap on subsidy received basis (₹/kWh)	0.84	0.78	0.58	0.48	0.37	0.30	0.52
Accumulated loss as per balance sheet (₹ billion)	2,537.00	3,063.17	3,585.81	4,139.33	4,117.53	4,408.26	4,886.86
Total outstanding debt (₹ billion)	3,042.28	3,650.66	4,038.16	4,219.78	4,169.57	4,547.73	4,784.52
AT&D losses (%)	25.48	22.62	25.72	23.96	23.50	22.33	22.01
Outstanding dues by DISCOMs (₹ billion)	NA	NA	NA	NA	317.04	420.63	666.52

Note: "Subsidy received basis" stands for the subsidy disbursed by the state government against the actual subsidy/grants amount booked by the discoms for the given year

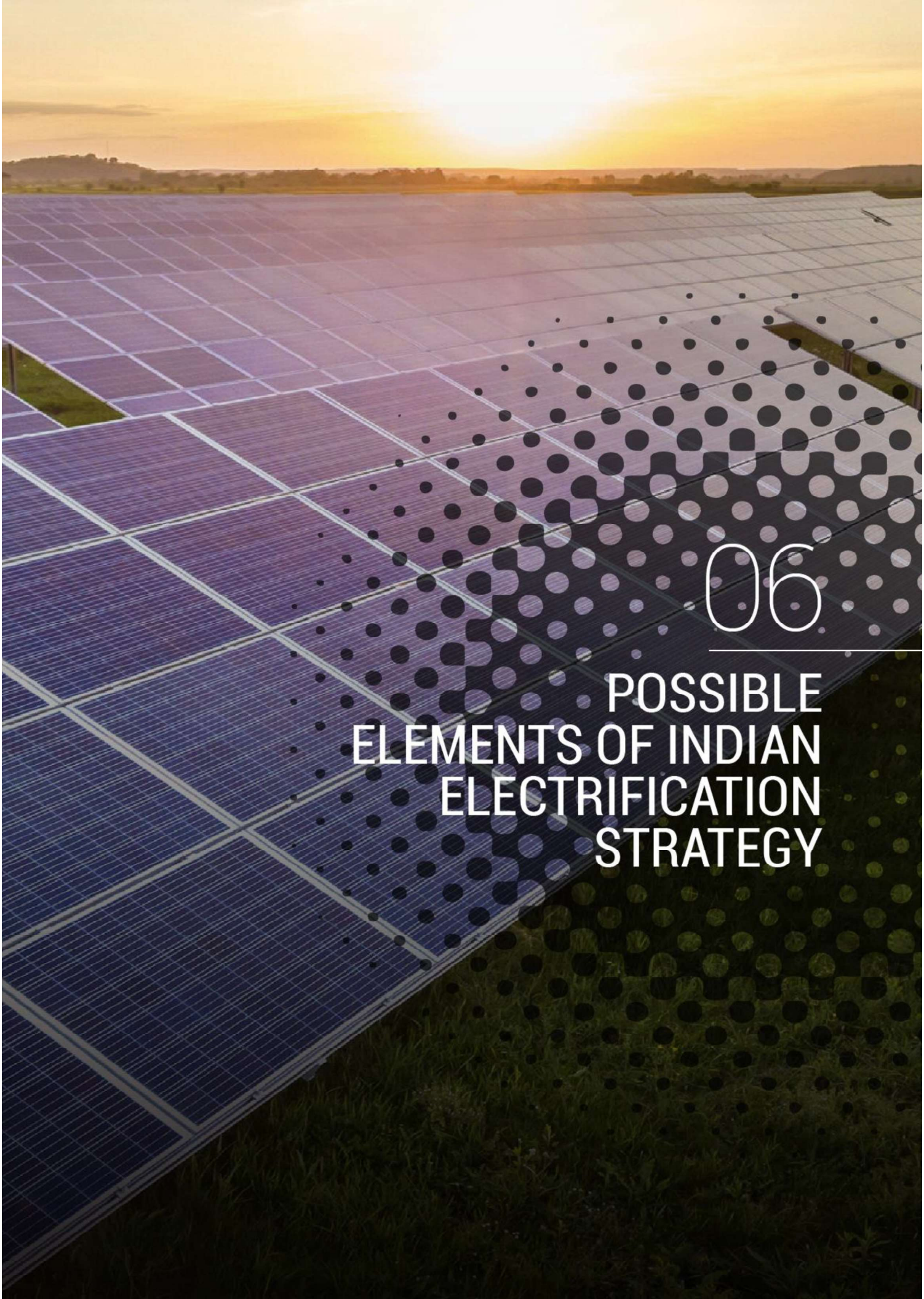
The difference of the ACS and ARR is an important indicator of the financial viability of DISCOM operations. A DISCOM's operations will be profitable if its ARR exceeds the ACS in a given year of operation. ACS is the sum of all costs associated in supplying power such as the cost of purchasing power from various generators (conventional, non-conventional, power exchanges, etc.), cost of operating and maintaining the distribution network (such as service lines and distribution transformers), employee cost, depreciation, interest and finance costs divided by the total unit of sales to consumers. On the other hand, ARR is the sum of the total revenue earned — by charging consumers at specified tariffs for the energy supplied, incentives or subsidy received from the state government, sale of surplus power, if any, FPPCA and Regulatory Surcharge and Non-tariff income divided by the total unit of sales to the consumers.

At the national level, the gap between ACS and ARR has reduced from INR 0.65/kWh (2015-16) to INR 0.39/kWh (present data from UDAY portal). For states like Himachal Pradesh, Gujarat, Karnataka & Maharashtra ACS-ARR gap is negative, which is a positive development[95]. Jammu &

[95] https://www.eqmagpro.com/wp-content/uploads/2019/11/INDIAS-ELECTRICITY-DISTRIBUTION-COMPANIES_compressed-26-32.pdf

Kashmir (erstwhile state), Punjab, Assam, Rajasthan, Jharkhand and Bihar, however, still have very high ACS-ARR gap.

Since commercial, industrial, etc. pay more than the cost of supply to cover the shortfall in revenue from other categories of consumers such as domestic, agriculture, etc. higher electricity consumption in these sectors would lead to a higher ARR for DISCOMs, thus resulting in better financial performance, whereas higher electricity consumption in the subsidized sectors would lead to more burden on the distribution sector and increasing debt. Thus, increasing the overall sales is less sensitive to ACS-ARR gap, whereas increasing the sales for cross-subsidizing categories is more beneficial to the DISCOMs.



06

POSSIBLE ELEMENTS OF INDIAN ELECTRIFICATION STRATEGY

6 POSSIBLE ELEMENTS OF INDIAN ELECTRIFICATION STRATEGY

This section introduces possible elements of an electrification strategy for India. These elements have been derived from the status of electrification in various sectors in India, the status of different programmes to promote electrification, learnings from the policies introduced by the EU and the EU Member States, and India's Paris Agreement objectives. The possible impact of the recommended strategies has also been assessed.

It is important to state that this study focuses on the demand side electrification as a means to mitigate climate change. Greenhouse gas emissions are only reduced, if in parallel the production of electricity is gradually shifted towards renewable sources such as wind and solar. This would be a prerequisite for the true benefit of electrification and should be addressed in other parts of the Indian strategies for climate change mitigation.

Electrification may not be a strategy to stand alone but can be integrated in an over-arching strategy that combines multiple purposes and elements. An overarching strategy would combat climate change, reduce pollution in major cities, ensure independence from fossil fuels, ensure 24/7 access to affordable energy and energy security, and increase efficiency and profitability of the Indian industry and power sector. In the EU Strategy on System Integration for example, electrification is a sub-strategy.

6.1 Industry

Industry is the second largest sector of the Indian economy. It is the highest energy consuming sector. The energy mix for the industry sector consists of coal, oil, natural gas, biomass, and electricity. The penetration of electricity in the energy mix is notably low (15%) (see section 2) compared to the industry sector of other economies such as the EU where electricity constitutes the highest share in the energy mix (35%). The Indian industry sector is predominantly dependent on coal (36%) as most of the industrial processes are still fossil-based (see section 2.1). A few sub-sectors including cement, fertilizers & chemicals, paper, and bricks have reduced their coal consumption in the period of 2009-19, which could be attributed to technology improvements, fuel switching to natural gas and regulatory requirements under the PAT scheme. However, coal consumption increased by almost 40% in the same period in the iron & steel industry, which highlights the urgency for technological and regulatory improvements in the existing setup of the overall industry sector to increase energy efficiency and enable decarbonization.

As indicated in section 4.1.3, the EU industry sector has transitioned towards cleaner energy sources and reduced its carbon footprint through a mix of technological and policy measures. Majority of the industrial processes have been shifted to electricity and biomass. Heat pumps for temperature-specific heating, renewable energy, hydrogen and electrofuel-based heating solutions are some of the successful technological advancements that have enabled this shift. On the policy and regulatory front, the EU Emission Trading Scheme (ETS) is the key enabling instrument. By increasing the cost of emissions, the ETS has become a major driver for fuel switch towards less carbon intensive energy, of which electricity from renewable sources is one of the most favourable options. This had led to increased demand for green electricity and motivated

producers to increase supply of electricity from renewable sources as the most competitive way (see section 4.1).

In order to improve energy efficiency and increase the penetration of clean electrification, there are several technological, market-based and policy and regulatory measures that could be applied. A general focus for electrification of industry, should be on heat services, where gas, oil and coal can be substituted with electricity. For relatively low temperature process, heat pumps would be competitive with fossil fuel, and for higher temperatures special heat pumps, electro-fuels or direct electrical heating should be promoted in contrast to especially coal fired processes. This is one of the areas with least degree of electrification and with a large potential for utilizing new technology. The strategy could be based on the EU ETS inspired schemes or incentives for investing in heat pumps or electrical heating such as rebates on electricity tariffs.

Referring also to the EU's hydrogen strategy as set out in chapter 3.4, another possible strategy could be to exchange fossil-based hydrogen with renewable based hydrogen in industrial processes. Especially industries using large amounts of hydrogen, such as refineries, fertilizer plants, steel works and other chemical industries could reduce the climate impact substantially. Traditionally in these industries hydrogen for the production of steel, aluminium or ammonia is produced from natural gas. By using green electricity in an electrolyser, green hydrogen can be produced, and it can significantly lower the carbon footprint of these large subsectors.

6.1.1 Recommended strategies

Based on the current situation in India as set out in section 2.1 and the EU experiences as set out in section 3 and 4.1, the following possible strategies are recommended:

Strategy 1: Prioritizing energy efficiency in industrial processes

Energy efficiency should be the first strategy to reduce the overall energy demand of the industrial sector and reduce the investment on the supply side infrastructure. Energy efficiency first principle is also at the core of the circular economy concept through reducing energy waste and reusing industrial waste in processes or any other sectors, similar to the approach developed under the EU strategy for energy system integration.

Key interventions:

- ***Deep dive to identify energy intensive industrial processes and measures to make them energy efficient:*** In order to introduce and implement energy efficiency, it is essential to first benchmark the existing energy intensive processes, review the new technologies that could increase the efficiency of the existing ones and assess their impact. The assessment should result into a national energy efficiency repository with benchmarks. This exercise could be carried out to implement the objectives of the PAT scheme and circular economy concept to identify the potential of reuse of waste heat.
- ***Assessing the possibility of increasing stringency of allowances of the PAT scheme and creation of a carbon reduction programme:*** The EU ETS, through stringent allowances and carbon pricing, has been successful as a regulatory instrument in reducing the energy intensity of the European industry sector. Since the size and diversification of the Indian industry sector is

different compared to its EU counterpart, an impact assessment analysis needs to be conducted prior to increasing stringency of the PAT scheme and development of carbon pricing programme.

- ***Promote alliances across large companies, SMEs, Service providers:*** Alliances within the sector and across other sectors including residential and services are important from the perspective of circular economy and sector coupling. For instance, waste heat from the industry could be used as an input for some industrial processes and could also be used to power absorption cooling machines and micro turbines.

Strategy 2: Direct electrification of industrial processes, wherever possible

Electrification of the economy, as mentioned earlier in section 1, is a crucial step towards deep decarbonization and has also been recognized by the EU in the EU strategy for energy system integration (see section 3). Thus, wherever possible, non-electric industrial processes could be replaced by efficient electric equipment. Consequent increase in electricity demand would be met by clean electricity generated by renewable energy, thus also contributing to India's NDCs to the Paris Agreement.

Key interventions:

- ***Sectoral readiness assessments to identify the potential of electrification in various industrial sectors:*** In order to introduce and implement sector-specific and effective electrification measures, it is essential to first benchmark the existing processes, review the new technologies (including direct heating using renewables, heat pumps, electro-fuels, etc.) that could be used as electric or green substitutes of the existing ones and assess their impact. This exercise could be carried out to implement the objectives of different initiatives including PAT scheme and India's NDC to fulfil an overarching impact.
- ***Promote R&D initiatives in electrification of industrial processes:*** R&D activities need to be initiated in collaboration with national and international research bodies, industry associations and think tanks to develop and test new technologies for the Indian industrial processes and applications. R&D initiatives in the EU have led to successful deployment of heat pumps, direct heating using renewable and electro-fuels.
- ***Technology and knowledge transfer, and capacity building on new technologies viz. renewable energy-based heating, electrolysis:*** Technology and knowledge transfer would be an integral element of this strategy. As newer technologies are introduced in the market, their applicability and integration with the existing processes would require learning and capacity building from other countries, including EU MS.

Strategy 3: Renewable, Hydrogen-based and Power-to-X based industrial processes

For the sub-sectors and industrial processes, where direct electrification is not possible, renewable, hydrogen or power-to-x solutions could be explored. Although direct electrification is more efficient than this option, such low carbon fuels would contribute to the decarbonization of the sector. For hard-to-decarbonize industries, Carbon Capture and Storage could be explored, as being done in the EU.

Key interventions:

- ***Identification of specific focus areas for green hydrogen applications through the recently announced National Hydrogen Energy Mission (NHEM)[v]:*** A detailed assessment of non-electric and hard-to-electrify industrial processes would be required to identify the potential of using hydrogen for instance in direct reduction of iron substituting coal with green hydrogen, electrification of hydrogen for use in chemical plants or refineries. Under the NHEM, the government is considering making the purchase of green hydrogen for fertilizer plants and oil refineries, with an intent to reduce dependence on fossil fuels.[96]
- ***Promote alliances across large companies, SMEs, Service providers for hydrogen and power-to-x:*** Industries could enhance their efforts towards decarbonization of their processes through cross-industry alliances. Such alliances have been successful in the EU such as alliances found within batteries, plastics and microelectronics; New EU Clean Hydrogen Alliance; Alliances on Low Carbon Industries, etc.

6.1.2 Impact on Discoms

For the industrial category of consumers, the Actual Cost of Supply (ACoS) is less than the retail tariff that is charged. Thus, the strategies outlined here to replace existing primary energy-based processes with electricity run systems would lead to higher revenues for DISCOMs and hence have a positive impact on DISCOM finances.

6.2 Residential

As noted in section 2.2, cooking is one of the end-use areas under the residential sector which is predominantly non-electric, and it offers huge potential for green electrification. Cooking in rural India has been largely dependent on firewood, leading to health problems for the households and air pollutions. Considering the negative and unintended consequences of conventional fossil fuel-based cooking, the Government of India has prioritized the transition to LPG through the Pradhan Mantri Ujjwala Yojana to distribute 80 million LPG connections to women of Below Poverty Line (BPL) families by March 2020[97]. However, 83% of the households, who received a free first LPG cylinder, did not adopt to LPG as the primary cooking source. High cost of refill and poor accessibility of refill depot are cited as the major reasons.[98] (see section 2.2). Increasing demand of LPG could also lead to energy security issues. Electric cooking has the potential to enable transition towards energy efficient and clean cooking. Apart from being an efficient, clean, safe and sustainable solution, induction hob/electric cooking offers ease of operation and resilience. Thus, firewood or LPG based cooking to clean electricity-based cooking can be explored in order to decarbonize the sector. However, market readiness assessment in terms of cost efficiency, user behavior, local manufacturing capacity, R&D needs, etc. is the need of the hour. This transition in the EU is already underway with electric cooking accounting for more than 50% of the fuel used for cooking (see section 4.2).

[96] https://pib.gov.in/PressReleasePage.aspx?PRID=1747647

Cooling is another important end-use area under the residential sector. The requirement for cooling both in the urban and rural areas in India is on the rise as mentioned in section 2.2. To mitigate the negative impact of air-conditioning, a transition from conventional cooling to low carbon cooling technologies such as super-efficient room-air-conditioners, evaporative cooling systems, community-level district cooling, etc. are recommended. Efforts are made in the EU towards community-scale cooling using the sector coupling approach (see section 4.2). Smart home technologies further present the potential to save operational energy and is being used as a key demand response measure, globally. The EU is encouraging the development of smarter energy systems and smarter buildings. Building standards are also being developed to support the development and interoperability of smart devices.

6.2.1 Recommended strategies

Based on the issues identified with the current scenario of cooking and cooling energy use in India in section 2.2, and the EU experiences described in section 4.2.3. transition to electric cooking, promotion of energy efficient and low carbon cooling and efficient integration of cooling and building appliances in energy management systems are recommended as key strategies for electrification. Electric cooking is the most energy efficient cooking solution[99] and has also been included in the recently launched 'Go Electric' campaign by BEE. The campaign is aimed at reducing India's energy import dependence and a step towards cleaner and greener future.[100]

Strategy 1: Increasing energy efficiency of residential end-uses

Increasing energy efficiency is the first step towards decarbonization of the residential sector. There are several initiatives in place such as Eco Niwas Samhita (ENS), star rating of homes and star rating of appliances, in order to improve energy efficiency in this sector. Efforts need to be made to further the enhancement and implementation of these initiatives.

Key interventions:

- ***Expanding the scope of S&L programme for other domestic appliances:*** BEE has developed S&L programmes for 15 domestic appliances and consumer durables. However, more domestic appliances are yet to brought under the ambit of the S&L programme, which would increase the energy efficiency of the residential end-uses. A study could be carried out to identify and rank appliances for development of S&L programme.

Strategy 2: Promotion of electric cooking

India's dependence on firewood for cooking, especially in rural areas, and recent initiatives to switch to LPG have been highlighted earlier. Electric cooking provides an option to leapfrog to clean cooking from energy and emission-intensive firewood-based cooking. Apart from being most energy efficient in the segment of cooking solutions, electric cooking also provides clean environment and eliminates health issues associated with firewood-based cooking.

[99] https://www.ceew.in/sites/default/files/CEEW-Clean-Cooking-Energy-Access-in-India-21Oct17.pdf
[100] https://pib.gov.in/PressReleasePage.aspx?PRID=1699386

Key interventions:

- ***A market readiness assessment for transition to electric cooking solutions:*** Market readiness assessments to understand user behaviour, local manufacturing capacity, affordability, R&D needs, etc. is the first step to implement the strategy. The assessment should also capture possible sustainable financing mechanisms, business models and technology/know how for market transformation. Furthermore, there is a need to develop a roadmap for near and long term roll out of electric cooking across the country. Possible integration of the roll out plan with PM Kusum scheme (see section 2.4), Atmanirbhar scheme[vi] and Skill India mission[vii] could also be explored.
- ***Standards and Labelling (S&L) for electric cooking solutions:*** On the policy front, standard & labelling for electric cooking solutions could be developed and notified.

Strategy 3: Promotion of energy efficient and low carbon cooling

The ICAP 2019 emphasises the need for switching to efficient and low carbon cooling and provides a set of recommendations encompassing diverse aspects like reduction of cooling demand, refrigerant transition, ways of enhancing energy efficiency, and better technology options (see section 2.2).

Thus, an implementation roadmap for ICAP in the residential sector could be developed on priority basis. The roadmap should capture the business side of all low carbon cooling technologies providing possible innovative and competitive business models to increase uptake of low carbon cooling solutions such as cooling as a service.

There is also a need for harmonization of ENS with ICAP. Thus, efforts could be made towards development and implementation of harmonized guidelines catering to dual objectives of ENS and ICAP recommendations for different climate zones in India.

Key interventions:

- Development of an implementation roadmap for the India Cooling Action Plan (ICAP) (see section 2.2)
- Harmonization of ENS with ICAP: development and implementation of harmonized guidelines catering to dual objectives of ENS and ICAP recommendations for different climate zones in India

Strategy 3: Cross-sectoral integration of cooling and domestic appliances

Cross-sectoral integration means that energy exchange between different sectors is enabled, which would lead to a circular economy. For instance, waste heat from industries could be used to run absorption cooling machines in district cooling systems, providing free cooling. Such initiatives are being explored in the EU for district heating and cooling purposes.

There is a need to assess the possibility of alliances with industries for Power-to-X collaboration to enable sector coupling and circular economy, encourage development of smarter energy systems and smarter buildings to promote integrated systems with a focus on market

assessment/policy integration for smart appliances and controls, user acceptance, local manufacturing capacity, affordability, etc.

6.2.2 Impact on DISCOMs

The residential sector is cross-subsidized and hence the overall retail tariff is less than the ACoS. Replacing existing primary non-electric cooking methods with induction cookstoves would lead to higher energy consumption. This would thus have a negative impact on DISCOM finances. Use of heat pumps, evaporative cooling and district cooling technologies would lead to an overall reduction in energy consumption, as compared to the usage of traditional air conditioning technologies. A reduction in energy consumption would have a positive impact on the DISCOM finances.

6.3 Transport

As discussed in section 2.3, the transportation sector in India, specifically road transport, is majorly dominated by petrol and diesel-operated vehicles. The penetration of electricity in the transportation sector is about 1% in 2019. India currently has a target of 30% electric vehicles in 2030 in accordance with the EV30@30 campaign. There is an increasing awareness of the fact that access to charging points is crucial to deployment of electrical vehicles, so any strategy for electrification of vehicles must be accompanied by a strategy for access to charging points (see section 4.3.3 on EU charging policies)

Use of electrofuels, which can be another strategy for a typical segment of heavy duty and long-haul transportation system. With regard to electrofuels, they all rely on hydrogen from electrolysis of water as a feedstock. An electrofuels strategy is recommended, including pathways from electrolysis to fuel, be it directly as hydrogen in compressed or liquid form, or combined with carbon for synthetic drop-in fuels or with Nitrogen for ammonia as a fuel. Though ammonia is toxic, it is a serious contender for electrification of sea transport. It is recommended to start the process of building an Indian strategy on electrofuels to follow the development in the EU, as electrofuels will be a necessary part of the future energy mix. However, the exact choices of electrofuels and technologies to pursuit should not be fixated at this point.

Indian railways has announced plans to achieve net zero emissions in 2030 and full electrification of the nationally owned railroads already by 2024. This will be achieved by the Central Office for Railway Electrification, who has been tasked to fulfil these goals. 59% of the rails are now electrified, and with an expected rate of 6,000 km/annum, the goals seem to be achievable with the current efforts.

However, it should be investigated whether electrification of the railroads is feasible in all areas or whether alternative solutions (hydrogen or battery trains) should be supported. This should be part of the strategy work on electrofuels, especially hydrogen.

6.3.1 Recommended strategies

Section 2.3 highlights the current status of India's activities towards electrification of different modes of transportation. In sync with the current activities (see section 2.3) and drawing inspiration from the EU initiatives (see section 4.3), this document recommends enhancing

penetration of electric vehicles, hydrogen and biofuel as replacement of fossil fuel and electrification of railways.

Strategy 1: Electrification of Indian railways

- Action plans towards implementation of Indian Railways target on electrification of routes on broad gauge planned by 2023 and goal of becoming "Green railway" (Net Zero Emissions) by 2030

Strategy 2: Enhance electric vehicle penetration level

- Designing EV mandates specific to Indian manufacturing eco-system
- Designing better incentives, financing schemes, business models for segments with higher Total Cost of Ownership (TCO) including polluting segments on passenger 4-wheelers, urban freight and HDVs
- Linking of narratives on clean air, climate change, affordable transport and jobs with policies and programmes on the electric mobility.[101]
- Developing interoperability of charging stations by setting a common charging infra for all types of vehicles.[102]
- Developing innovative business models, incentives, and financing schemes

Strategy 3: Hydrogen and electro-fuel as replacement of fossil fuel

- Assessment of potential of electrification across all locations and hydrogen as an alternative under NHEM
- Development of an electro fuel strategy defining the pathways from electrolysis to fuel for transport application (both road and rail transport)

6.3.2 Impact on DISCOMs

Higher electrification of fleets and passenger vehicles would lead to higher electricity consumption. Currently, the EV tariffs across states in India is higher than the ACoS. Thus, EV charging could prove to be profitable for DISCOMs once the penetration of EVs is higher.

[101] There is a lack of awareness amongst the general consumer about electric mobility as well as policy makers. Most city level action plans have no linkage to electric mobility. Electric mobility is a significant route for cities to drive clean air, jobs and encourage efficient and sustainable transport. There is a need to link such narratives at the administrative level with electric mobility.

[102] Issues in which conflicting standards and approaches still exist include open access and payment, charger to network communication, network to network communication, and vehicle to charger communication. With interoperability, EV drivers can access public charge points from any owner/operator through a common platform and a single network subscription or contract. Just like cellular networks, there is a need to ensure that EVs have access to charging stations across the country.

6.4 Services

As discussed in section 2.4, the services sector in India includes commercial and public services, agriculture and forestry. The services sector has the highest penetration of electricity (50%) among all the sectors of the Indian economy.

The commercial building sector, as noted in section 2.4, is projected to grow from 1.2 billion m^2 to 3.1 billion m^2 within the period of 2018-2038 (see section 2.4), thus having a high impact on the energy consumption. With an aim to increase energy efficiency in commercial buildings, the ECBC has been revised and launched in 2017. However, its implementation is still at a voluntary stage. To further regulate energy use in sub-sectoral level, BEE has brought hotels under the ambit of PAT scheme and launched star rating for commercial buildings. Hospitals and airports are other energy intensive sub-sectors and need to be regulated under the PAT scheme. The EU has been successful in reducing energy intensity of its building stock through various initiatives including implementation of EPBD, EED and recent programmes including Renovation Wave and Nearly Zero Energy buildings.

Space cooling is among the major end-use areas for electricity consumption under the commercial buildings. Growing commercial building sector also means growth in cooling demand. ICAP estimates cooling in the commercial sector to increase by more than 200% by 2037-38 (see section 2.4). Although the share of efficient cooling technologies such as chillers and VRFs is higher (37% and 23%, respectively) in commercial sector and Room Air Conditioners account only for 8%[103], there is nonetheless a scope to further improve the energy efficiency of space cooling through low energy and low carbon cooling technologies such as heat pumps, radiant cooling, district cooling and absorption cooling. The role of smart building technologies to reduce peak demand and enable grid interactivity is also vital. The EU is progressing towards renewable based cooling in process cooling applications such as data center cooling. There are also initiatives on sector coupling to use waste heat to provide comfort cooling (see section 4.4).

Agriculture is another important sector and it was the third highest consumer of electricity in 2019, after industry and residential sector. Initiatives such as PM KUSUM are introduced with an objective of solarizing the pumping applications in the agriculture sector and the next logical step in this direction can be the installation of smart pumping controls to centrally monitor and regulate pumping operations, maximize the benefits from solar energy and reduce the impact on DISCOMs.

6.4.1 Recommended strategies

The Services sector is the sector with the maximum penetration of electricity in India, as mentioned in section 2.4. To enhance the efficiency of electricity use in this sector, it is recommended to promote efficient cooling, integration of building systems in energy management systems, and smart pumping for agriculture.

Strategy 1: Prioritizing energy efficiency in the commercial and agriculture sector

Similar to the residential sector, there are several initiatives in place to increase energy efficiency in the services sector, especially in commercial buildings. These initiatives include ECBC 2017, star rating of commercial buildings, S&L programme for appliances and ICAP 2019. For the agriculture sector, PM KUSUM is launched which focuses on decentralized solar power for farming-related activities. The recommendation is to develop roadmaps and harmonize these polices/programmes, wherever possible, to expedite the implementation of these initiatives to fully realize their potential.

Key interventions:

- ***Expanding the scope of S&L programme for commercial appliances:*** BEE has developed S&L programmes for more than 10 commercial appliances. There is a potential to expand the scope of the programme and include more appliances. Assessment studies could be carried out to identify and rank commercial appliances and develop S&L programmes to promote energy efficient appliances.

Strategy 2: Promotion of energy efficient and low carbon cooling

The ICAP 2019 emphasizes on switching to efficient and low carbon cooling and recommends reduction in cooling demand, refrigerant transition, use of low carbon cooling technologies (see section 2.4). Thus, an implementation roadmap for ICAP in the commercial sector could be developed on priority basis, which focuses on developing market for low carbon cooling technologies and innovative and competitive business models to increase uptake of low carbon cooling solutions such as cooling as a service, etc.

There is also a need for harmonization of ECBC 2017 with ICAP. Thus, efforts could be made towards development and implementation of harmonized guidelines catering to dual objectives of ECBC 2017 and ICAP recommendations for different climate zones in India. R&D activities on low carbon and alternative cooling technologies need to be parallelly promoted.

Key interventions:

- Development of an implementation roadmap for India Cooling Action Plan (ICAP) for commercial building sector (see section 2.2)
- Harmonization of ECBC 2017 with ICAP - development and implementation of harmonized guidelines catering to dual objectives of ECBC 2017 and ICAP recommendations for different climate zones in India

Strategy 2: Increase smart electrification in agriculture sector

PM KUSUM scheme primarily focuses on solarization of pumps. Smart pumping control could be the next logical step in this direction and could be included withing the existing scheme.

Key intervention:

- In order to realize the ambition on smart pumping, it may require market readiness studies to identify local manufacturers including SMEs, startups, economics of scaling-up, develop

smart pumping roadmap and integration possibility with Atmanirbhar Bharat, Startup India and other initiatives, apart from PM KUSUM scheme.

Strategy 3: Cross-sectoral and energy management system integration of cooling and commercial appliances

Cross-sectoral integration may have greater potential for collaboration and coupling with other sectors to power its energy and cooling demand. Business districts and data centers are a few potential possible applications. Several EU MS are working in this direction, particularly for data centers (see section 4.4.1).

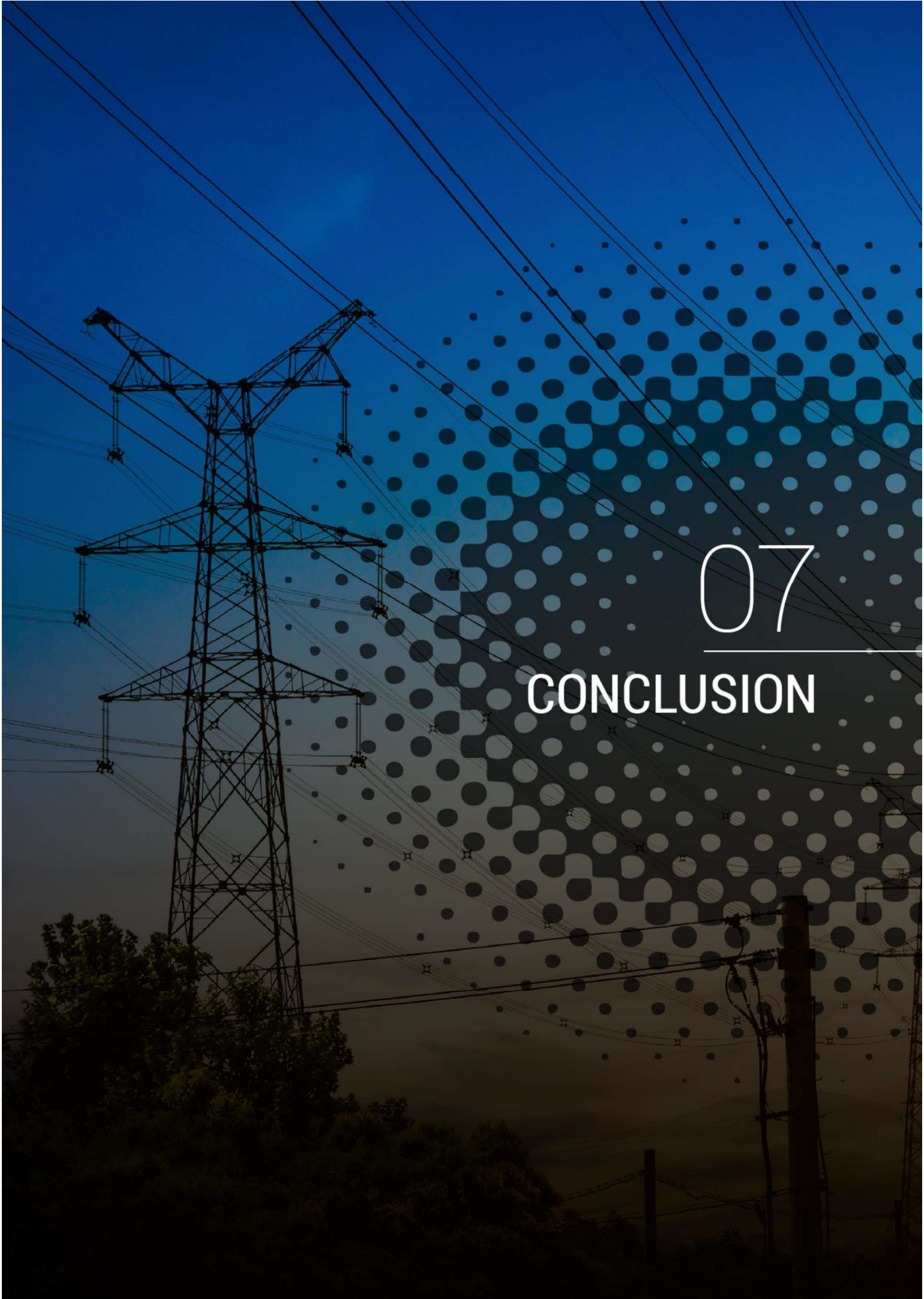
Key interventions:

- Pre-assessment on market readiness for smart building systems and controls for grid interactivity and integration with energy management system, user acceptance, availability of locally manufactured products, economics, etc. would be needed to strategize efforts in this area.
- There is also a need to develop strategy for nearly Zero Energy development in the services sector. Possible integration with ongoing Smart Cities programme and other initiatives can be explored.
- To power the sector coupling possibility, there is a need to assess the feasibility of alliances with industries for Power-to-X collaboration to enable sector coupling and circular economy.

6.4.2 Impact on DISCOMs

Use of heat pumps, evaporative cooling and district cooling technologies would lead to an overall reduction in energy consumption, as compared to the usage of traditional air conditioning technologies. A reduction in energy consumption would have a negative impact on the DISCOM finances (for the commercial sector, ACoS is lower than retail tariff). Demand Response (Price or incentive based) leads to lower peak demand. This would mean a negative impact on DISCOM revenues when carried out for the commercial sector.

Introduction of smart pumping controls would lead to a significant reduction in indiscriminate use of pumping of groundwater. This would have a positive impact on DISCOMs since the agriculture consumer is cross-subsidized.



07

CONCLUSION

7 CONCLUSION

This strategy document discusses the increasing role and necessity of electrification of the demand side. Electrification ensures energy efficiency as well the potential for decarbonization once the supply side transitions towards clean, renewable energy sources (see section 1). The document also focuses on the status and potential of economy-wide electrification in India and its possible impact on the profitability of DISCOMs (see section 2 and 5). To bring in European experiences, the document throws light on the initiatives undertaken in the EU with electrification at its core and sectoral penetration of electricity and factors and policies leading up to it (see section 3 and 4). Recommendations have been provided in section 6 based on potentially relevant learnings from the EU experience to increase the penetration of electricity in India.

Section 2 discusses the current status of electrification in the industry, residential, industry and services sector in India, specific policies and targets focused on electrification and energy efficiency, and challenges and barriers. The penetration of electricity in India's demand side is considerably lower (17%) compared to the EU (24%). The Services sector, which includes commercial buildings and agriculture, is the most electrified sector (50%) while transport has the lowest penetration of electricity (3%). The challenges are of varied nature viz. fossil-fuel dependent manufacturing processes (industrial), heavy dependence on solid fuel for cooking (residential), nascent nature of electric vehicles (transport). The government has launched several initiatives to promote direct electrification such as the Go Electric campaign, FAME I and II programmes and targeted electrification of railways, (see section 2.3), PM KUSUM (see section 2.4) etc. Under various sector-specific programmes such as the PAT scheme for industries, ECBC and ENS for commercial and residential buildings, respectively, S&L scheme for industrial equipment and consumer durables, etc. the government is pushing for increased energy efficiency which in turn would lead to electrification owing to the virtue of electricity-based equipment and appliances.

The EU has made significant transition towards electrification. The penetration of electricity in the demand side is 24%. At sectoral level, the penetration level is 55% in service, 37% in industry and 27% in residential sector, which is considerably higher than its Indian counterparts. This can be attributed to the technological and policy-level interventions under the EU 2020 strategy, EU Green Deal encompassing the EU Strategy for Energy System Integration. The interventions include the EU ETS for industries which has led to electrification of major industrial processes (see section 4.1.3), transition of space heating from fossil fuel-based to electric heating, Renovation Wave to enhance resource efficiency of buildings, sector coupling for space heating and cooling (see section 4.2.3 and 4.4.3), public procurement of electric vehicles, stringent CO_2 emission performance standard for cars, vans and heavy vehicles which could be difficult for manufactures to meet through gasoline-based vehicles, improving recharging infrastructure (see section 4.3.3).

Drawing from relevant experiences in the EU, the document presents a set of sector-specific strategies and interventions to promote economy-wide electrification in India. The document also maps the impact of these strategies on the profitability of DISCOMS. The strategies and interventions are mentioned in the table below.

Sr.	Strategy	Interventions
Industry		
1	**Prioritizing energy efficiency in industrial processes**	• Deep dive to identify energy intensive industrial processes and measures to make them energy efficient - a national energy efficiency repository with benchmarks • Assessing possibility of increasing stringency of allowances of the PAT scheme and creation of a carbon reduction programme - The EU ETS has been successful as a regulatory instrument in reducing the energy intensity of the European industry sector • Promote alliances across large companies, SMEs, Service providers - similar to Industrial alliances in the EU
2	**Direct electrification of industrial processes, wherever possible**	• Sectoral readiness assessments to identify potential for electrification in various industrial sectors • Promote R&D initiatives in electrification of industrial processes - R&D initiatives in the EU has led to successful deployment of heat pumps, direct heating using renewable and electro-fuels • Technology and knowledge transfer, and capacity building on new technologies viz. renewable energy-based heating, electrolysis
3	**Renewable, Hydrogen-based and Power-to-X based industrial processes**	• Identification of specific focus areas for green hydrogen applications through the recently announced National Hydrogen Energy Mission (NHEM) • Promote alliances across large companies, SMEs, Service providers for hydrogen and power-to-x. Example - New EU Clean Hydrogen Alliance; EU alliances on Low Carbon Industries, etc.
Residential		
4	**Increasing energy efficiency of residential end-uses**	• Increasing energy efficiency is the first step towards decarbonization of the residential sector (like EU Energy system integration)- Expanding the scope of S&L programme for other domestic appliances - A study could be carried out to identify and rank appliances for development of S&L programme
5	**Promotion of electric cooking**	• A market readiness assessment to understand user behavior, local manufacturing capacity, affordability, R&D

Sr.	Strategy	Interventions
		needs, etc. • Develop a roadmap for near and long term roll out of electric cooking across the country • Possible integration of the roll out plan with PM Kusum scheme, Atmanirbhar scheme and Skill India mission could also be explored
6	**Promotion of energy efficient and low carbon cooling**	• Development of an implementation roadmap for the ICAP - including possible innovative and competitive business models to increase uptake of low carbon cooling solutions such as cooling as a service
7	**Cross-sectoral integration of cooling and domestic appliances**	• Assess cross-sectoral integration with circular economy approach – similar to the EU approach for district heating and cooling purposes • Assess the possibility of alliances with industries for Power-to-X collaboration to enable sector coupling and circular economy • Encourage development of smarter energy systems and smarter buildings to promote integrated systems
Transportation		
8	**Electrification of Indian railways**	• Streamlining the actions towards implementation of Indian Railways target on electrification of routes on broad gauge planned by 2023 and goal of becoming "Green railway" (Net Zero Emissions) by 2030
9	**Enhance electric vehicle penetration level**	• Designing EV mandates specific to Indian manufacturing eco-system • Designing better incentives, financing schemes, business models for segments with higher TCO including polluting segments on passenger 4-wheelers, urban freight and HDVs • Linking of narratives on clean air, climate change, affordable transport and jobs with electric mobility and increasing outreach of current central and state level initiatives to promote EVs • Developing interoperability of charging stations • Developing innovative business models, incentives, and financing schemes • Policy support on registration of e-autos and transition

Sr.	Strategy	Interventions
		from ICE-based autos to e-autos • Increasing focus towards electric buses and trucks through the lens of technological updates, demand generation and conducive policies
10	**Hydrogen and electrofuel as replacement of fossil fuel**	• Assessment of potential of electrification across all locations and hydrogen as an alternative under NHEM • Development of an electro fuel strategy defining the pathways from electrolysis to fuel for transport application (both road and rail transport)
Services		
11	**Prioritizing energy efficiency in the commercial and agriculture sector**	• Expanding the scope of S&L programme for commercial appliances - A study could be carried out to identify and rank appliances for development of S&L programme
12	**Promotion of energy efficient and low carbon cooling**	• Development of an implementation roadmap for ICAP for commercial building sector - - including possible innovative and competitive business models to increase uptake of low carbon cooling solutions such as cooling as a service
13	**Increase smart electrification in agriculture sector**	• Smart pumping controls for agricultural pumps. A market readiness study to identify local manufacturers including SMEs, startups; economics of scaling-up • Develop smart pumping roadmap and integration possibility with Atmanirbhar Bharat, Startup India and other initiatives, apart from PM KUSUM scheme
14	**Cross-sectoral and energy management system integration of cooling and commercial appliances**	• Pre-assessment on market readiness for smart building systems and controls for grid interactivity and integration with energy management system, user acceptance, availability of locally manufactured products, economics, etc. • Need to develop strategy for Nearly Zero Energy development in the services sector. • Possible integration with ongoing Smart Cities programme and other initiatives can be explored. • Need to assess the feasibility of alliances with industries for Power-to-X collaboration to enable sector coupling and circular economy - EU MS are working in this direction,

Sr.	Strategy	Interventions
		particularly for data centers

The impact of adopting the above-mentioned strategies on the profitability of DISCOMs would depend on the ACS and ARR. A DISCOM's operations will be profitable if the difference ARR and ACS is positive. The sector-wise impact would be as mapped below.

Sr.	Sectors	Strategies	Average Revenue Realized - Actual Cost of Supply
1	**Industry**	Replacing existing fossil fuel-based system with electric system	Positive
2	**Residential**	Replacing existing primary non-electric cooking methods with electric cooking	Negative
		Use of energy efficient and low carbon cooling technologies	Negative
3	**Transport**	Electrification of fleets and passenger vehicles	Positive
4	**Services**	Use of energy efficient and low carbon cooling technologies	Positive
		Demand response strategies	Positive
		Smart pumping in agriculture	Negative

END NOTES

[i] As a "well below 2 °C" pathway, the SDS represents a gateway to the outcomes targeted by the Paris Agreement. Like the NZE, the SDS is based on a surge in clean energy policies and investment that puts the energy system on track for key SDGs. In this scenario, all current net zero pledges are achieved in full and there are extensive efforts to realise near-term emissions reductions; advanced economies reach net zero emissions by 2050, China around 2060, and all other countries by 2070 at the latest. Without assuming any net negative emissions, this scenario is consistent with limiting the global temperature rise to 1.65 °C (with a 50% probability). With some level of net negative emissions after 2070, the temperature rise could be reduced to 1.5 °C in 2100. (https://www.iea.org/reports/world-energy-model/sustainable-development-scenario-sds)

[ii] Pradhan Mantri Sahaj Bijli Har Ghar Yojana - Saubhagya is to provide energy access to all by last mile connectivity and electricity connections to all remaining un-electrified households in rural as well as urban areas to achieve universal household electrification in the country. The electricity connection to households includes release of electricity connections by drawing a service cable from the nearest pole to the household premise, installation of energy meter, wiring for a single light point with LED bulb and a mobile charging point. In case the electricity pole is not available nearby from household for drawing service cable, the erection of additional pole along with conductor and associated accessories shall also be covered under the scheme. (https://www.india.gov.in/spotlight/pradhan-mantri-sahaj-bijli-har-ghar-yojana-saubhagya)

[iii] Direct reduction of iron is the removal of oxygen from iron ore or other iron bearing materials in the solid state, i.e. without melting, as in the blast furnace. The reducing agents are carbon monoxide and hydrogen, coming from reformed natural gas, syngas, or coal. Iron ore is used mostly in pellet and/or lumpy form.

iv Electrolysers use electricity to break water into hydrogen and oxygen. The electrolysis of water occurs through an electrochemical reaction that does not require external components or moving parts. It is very reliable and can produce ultra-pure hydrogen (> 99.999%) in a non-polluting manner when the electrical source is renewable energy.

[v] For a green and sustainable future, the Finance Minister proposed to launch a comprehensive National Hydrogen Energy Mission in 2021-22 for generating Hydrogen from green power sources fulfilling the announcement made by Prime Minister in November 2020. (https://pib.gov.in/PressReleasePage.aspx?PRID=1696498)

[vi] Atmanirbhar Bharat Abhiyaan or Self-reliant India campaign is the vision of new India envisaged by the Hon'ble Prime Minister Shri Narendra Modi. On 12 May 2020, our PM raised a clarion call to the nation giving a kick start to the Atmanirbhar Bharat Abhiyaan (Self-reliant India campaign) and announced the Special economic and comprehensive package of INR 20 lakh crores - equivalent to 10% of India's GDP – to fight COVID-19 pandemic in India. The aim is to make the country and its citizens independent and self-reliant in all senses. He further outlined five pillars of Atmanirbhar Bharat – Economy, Infrastructure, System, Vibrant Demography and Demand. Finance Minister further announces Government Reforms and Enablers across Seven Sectors under Atmanirbhar Bharat Abhiyaan. (https://pib.gov.in/PressReleseDetail.aspx?PRID=1623418)

[vii] Skill India is a project that involves every segment of the Indian society, local and foreign companies, and governments. Every ministry of the Government of India is involved in the massive Skill India program, billed as the world's largest initiative to train manpower in a single country or geographic location. (https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1736799)