IETP
India Energy Transformation Platform
Decarbonising India

TRANSITION TOWARDS EFFICIENT PRACTICES AND CLEANER FUEL TO MEET RISING INDUSTRIAL PROCESS HEAT DEMAND

Disclaimer

The views/analysis expressed in this report/document do not necessarily reflect the views of Shakti Sustainable Energy Foundation. The Foundation also does not guarantee the accuracy of any data included in this publication nor does it accept any responsibility for the consequences of its use.

For private circulation only

Knowledge partner: *Development Environergy Services Ltd.*

Secretariat: *Center for study of Science, Technology & Policy*

Supported by: *Shakti Sustainable Energy Foundation and Swiss Agency for Development & Cooperation*

India Energy Transformation Platform (IETP)

The India Energy Transformation Platform is a multi-stakeholder group of experts in the field of energy, technology and policy. The Platform identifies crucial developments and technology solutions to look at long-term pathways for decarbonising India's energy sector up to 2050. IETP was conceptualised by the Swiss Agency for Development and Cooperation (SDC) and Shakti Sustainable Energy Foundation (SSEF), with Center for Study of Science, Technology and Policy as the secretariat. In its first year, the Platform identified four themes - decentralised energy systems, renewable energy technologies, industrial process heating and urban space cooling - to look at non-linear, transformational technology and policy solutions for decarbonising India.

Center for Study of Science, Technology and Policy

CSTEP is one of India's leading think tanks. Our research leverages the power of technology through innovative ideas, to solve developmental challenges. Our vision is to be the foremost institution for policy analysis in India.

Shakti Sustainable Energy Foundation

Shakti Sustainable Energy Foundation (Shakti) seeks to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the following sectors: clean power, energy efficiency, sustainable urban transport, climate policy and clean energy finance.

Swiss Agency for Development and Cooperation

The Swiss Agency for Development and Cooperation (SDC) is an international cooperation agency within the Swiss Federal Department of Foreign Affairs (FDFA). In operating with other federal offices concerned, SDC is responsible for the overall coordination of Swiss development activities and cooperation, as well as for the humanitarian aid delivered by the Swiss Confederation.

Table of Contents

List of Tables

List of Figures

1 Introduction

Climate change is one of the most compelling global challenges. An Intergovernmental panel on climate change (IPCC) special report on the impacts of global warming of 1.5°C says, "*Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C. Global warming is likely to reach 1.5°C between 2030 and 2050 if it continues to increase at the current rate*".

In 2015, India had committed to Intended Nationally Determined Contribution (INDC), which established certain targets to reduce the emissions intensity of Gross Domestic Product (GDP), increase fossil fuel free power generation capacity and create additional carbon sink by 2030. However, more ambitious goals are to be achieved for higher contributions towards restricting warming to 1.5°C.

Shakti Sustainable Energy Foundation (SSEF) along with 14 renowned experts and Centre for the Study of Science, Technology & Policy (CSTEP) have come together to discuss transformative and non-linear opportunities for a deeply de-carbonized energy future for India in 2050. One of the shortlisted ideas is the "Transitioning towards efficient practices and cleaner fuels to meet the rising industrial process heat demand" targeting the steam generation process in energy intensive industries.

The objectives of the project is the identification of transformative and non-linear opportunities for decarbonization of the steam generation in industrial sectors along with necessary policy support required for promotion of the identified opportunities.

The desired activities to fulfill the objectives include the following:

a. Estimate the baseline carbon intensity in process heat (steam generation process) in selected industrial sectors
b. Identification of list of blue sky technologies for each steam end use with de- carbonization potential and identify R&D needs
c. Develop a set of qualitative and quantitative criteria to prioritize applications or technologies
d. Detailed research of high priority technologies for development of a concept paper for each technology, leading to de-carbonization roadmap through 2050
e. Develop a stakeholder engagement strategy for IETP
f. During the research period, engage regularly with the mentors and core group through interim review meetings, presentations, communication briefs or reports
g. Support the IETP in carrying out stakeholder engagement and outreach efforts

2 GHG emissions from industrial process heat

The GHG emissions from industrial process heat in different industrial sectors was reviewed using the following methodology:

Table 1: Methodology for GHG emissions from industrial process heat

Type of Data	Data source	Remarks
Sectors in which steam is used in the process	Review of manufacturing processes in past DESL audit reports & desk research, NIC codes	Petroleum refinery, Aluminium and Zinc sectors excluded due to high presence of WHRB. Cement and Iron & steel (except cold rolled steel) excluded as most of the steam is used for power generation only (out of project scope).
Annual production and annual steam consumption (through sp. steam, sp. fuel or boiler specs.) for each identified industrial sectors	Review of manufacturing processes in past audit reports & desk research, Annual report of Ministries, boiler data of industries in Gujarat - Gujarat Boiler Board	Except chemical, pharma and petrochemical sectors, evaluation was done based on present production levels and either sp. steam or sp. fuel consumption. For the chemical, pharma and petrochemicals sectors, data extracted from the Gujarat boiler board website was extrapolated to country level (boiler loading considered at 60%)
Fuel share used in boiler in the identified industrial sectors	Coal & Crude oil derivatives - NITI Aayog, Annual Survey of Industries document, Biomass - CMIE databank, boiler data of industries in Gujarat - Gujarat Boiler Board. Natural gas - CGD licensees, ASI data	Evaluation of available data reported by CGD licensees, CMIE databank and extrapolation to sector
Baseline fuel consumption and GHG emissions	Emission factors - IPCC Guidelines 2006, CEA for grid	Using the gathered data of each product of different sectors and emission factor of different fuel
Projected emissions for 2050	Desk research for CAGR for industrial growth	Considered the fuel share to be similar for the baseline and the year 2050

There were various challenges faced in the harmonization of dis-aggregated information gathered from various sources. The key inferences from the analysis are as follows:

- The estimated GHG emissions are expected to rise from the present 100 Mn tCO_2/y to 570 Mn tCO_2/y in 2050
- Top 4 sectors major contributors to GHG emissions – Textile, Petrochemical, Chemical & fertilizer and Pharmaceuticals
- Primary fuels contributing to 90% of GHG emissions – Coal, Naphtha and Furnace oil
- Sectors with high usage of crude oil derivatives – Petrochemical, Chemical & Fertilizers and Pharmaceutical
- Sectors with high anticipated capacity addition – Pulp & Paper. Food & beverage and Textile

3 Decarbonization technologies

The different technologies relevant for decarbonization of the industrial process heat were reviewed using the following methodology:

Table 2: Methodology for decarbonization technologies

Type of data	Source	Remarks
Identification of decarbonization technologies	Peer reviewed journal papers, Global reference documents for decarbonization pathways, DESL past audit reports and experience	-
Maturity of technologies	Peer reviewed journal papers, stakeholders consultation	Poor response to feedback sought from international experts, Granular data on TRL estimation was not available for many technologies
Cost of technologies	Peer reviewed journal papers, stakeholder consultation	A mix of figures either converted from international estimates or taken from national estimates
Issues related to application of technologies/innovative ideas in boiler	Peer reviewed journal papers, stakeholders consultation, DESL past audit reports and experience	Limitations in responses to data requests from different stakeholders ; assessment of relevance of innovative ideas in the Indian context
Efficiency levels of technologies	DESL past audit reports and peer reviewed journal papers	Limitations in responses to data requests from different stakeholders

There were various challenges faced in the harmonization of dis-aggregated information gathered from various sources.

3.1. Identification of decarbonization technologies

The decarbonization roadmap documents of different countries were reviewed and the most relevant technologies were identified as presented in the below table:

Table 3: Review of decarbonization technologies (global documents)

Country	Technologies for industrial sector targeting 2050
Australia, 2014	Short term – Heat pump, Bioenergy Long term – CCS technology
UK, 2013	Short term – Energy efficiency opportunities, CHP and heat pump Long term – CCS technology
Germany, 2016	Short term – Electricity, biomass Long term – CCS Technology
IRENA, 2019	Industry relocation to areas where RE is plentiful ; circular economy ; Bioenergy

The identified technology options for the Indian context is depicted in the below figure:

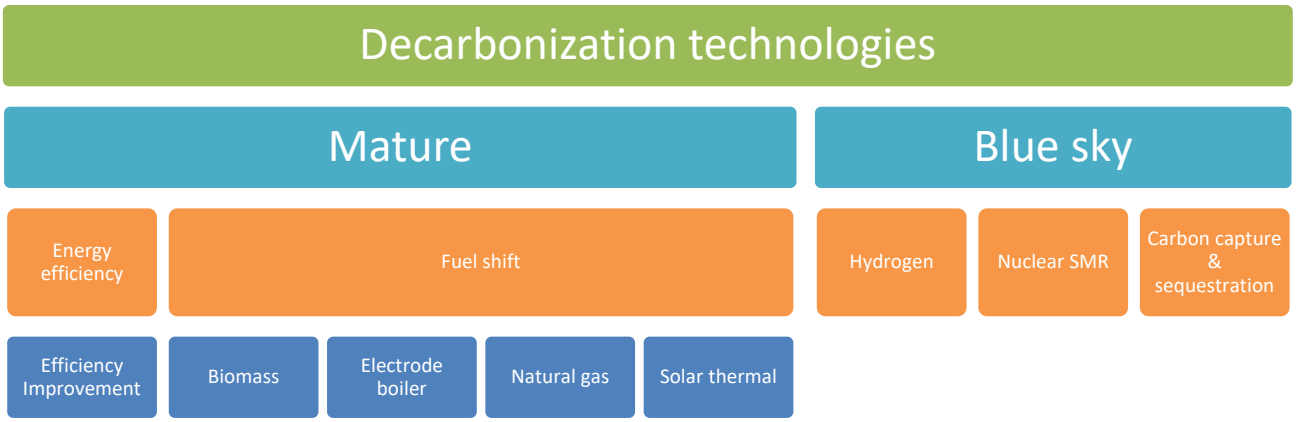

Figure 1: Decarbonization technology options

3.2. Review of mature technologies

Improvement of energy efficiency in boilers:

A review of past energy audit assignments in various industries (especially the SME industries) in India reveal the applicable low hanging fruit technological options for improvement of energy efficiency in boilers. Some of them are listed as follows:

- Control of excess air being fed into the boiler
- Improvement in the insulation on the boiler
- Increase of condensate recovery
- Waste heat recovery

All the technologies were found to be applicable and with a simple payback period of 1.5 to 2.0 years. However, the lack of proper information about the ongoing performance of the boilers, confidence on the technology performance, coupled with the cost of getting an energy audit done are prominent hurdles towards the improvement of the boiler performance.

In addition, there are opportunities related to reduction of specific steam consumption like the Supercritical carbon di-oxide dyeing technology for the textile dyeing sector. The textile dyeing industry is believed to be one of the biggest consumers of water. In conventional textile dyeing, large amounts of water is used both in terms of intake of fresh water and disposal of wastewater. An estimated 100–150 liters of water is needed to process 1 kg of textile material. Water is used as a solvent in many pretreatment and finishing processes, such as washing, scouring, bleaching and dyeing. Hence, the elimination of process-water and chemicals would be a real breakthrough for the textile dyeing industry, and it seems that this has now come to fruition, with the launch of the world's first ever-industrial dyeing machines that uses supercritical carbon dioxide as a replacement for water by a company named Dyecoo.

Fuel shift – Biomass:

Biomass is a renewable source of energy, which contains complex mix of carbon, nitrogen, hydrogen and oxygen. Biomass is obtained from living or dead plants, by product of crop production, wood and agro based industry. When used through sustainable means, biomass emits roughly the same amount of carbon during

conversion as is taken up during plant growth. The use of biomass therefore does not contribute to a net GHG emissions in the atmosphere.

The preparation of biomass as a fuel involves two types of processes: one is thermochemical conversion and other is physio-chemical conversion of dry biomass. Thermochemical conversion involves pelletization, pyrolysis, gasification/ combustion to produce solid and gaseous fuel, which is used in boiler while physio-chemical, involves liquefaction of dry waste to produce oil fuel for boiler. The value chain analysis of biomass has been captured in the below table:

Table 4: Value chain analysis of biomass resource for industrial process heat

Source	Production	Storage and transport	Use in boiler
Agricultural residue	Issue – Seasonal availability, lack of structured information for biomass collection and high cost of imported machinery for biomass densification	Issue – low bulk density in dispersed locations leading to high transportation cost.	Mature (Biomass combustion) Issue – Present technologies are experimented with 20% blending of biomass with coal. Further torrefaction of biomass may lead to increase in more blending; Price volatility
Forest residue and energy plantation	Issue – Occasional auction of forest residue. Difficulty in getting allocation of wasteland for private energy plantation	Issue – Processing of residue before transportation	

Fuel shift – Electricity:

The various dimensions of electrode boilers are summarized as follows:

- Maturity of technology: Mature, as commercial products are available worldwide
- Technical specification: International suppliers (85 TPH @ 8/17 kg/cm^2) ; National suppliers (2 TPH @ 15 kg/cm^2)
- Efficiency: >99%
- Applications: District heating system, Food & beverage, Mining etc. (Thematically for grid regulation, meet peak load and for sites where conventional fuel is costly)
- Cost of steam: An estimated 6.8 Rs. /kg (@ an electrical tariff of 5 Rs./kWh)
- Issues for widespread use: High cost of electricity leading to high cost of steam; Emission reduction linked to greening of grid electricity

Fuel shift – Natural gas:

The various dimensions of natural gas boilers are summarized as follows:

- Maturity of technology: Mature
- Technical specification: Can meet any desired boiler capacity
- Efficiency: >85%
- Applications: Food & beverage, pharmaceutical etc. (typically due to sensitivity to direct emissions/pollution and complying to international buyer's requirement)
- Specific emissions: About 48% lower than coal
- Issues for widespread use: High price volatility and therefore more uncertain; Higher import dependence of natural gas (NITI Aayog predicted the import dependence to change from the current 55% to either 63% or 17% depending on the various government initiatives)

The value chain analysis of natural gas has been captured in the below table:

Table 5: Value chain analysis of natural gas resource for industrial process heat

Source	Production	Storage and transport	Use in boiler
Allocation from City gas distribution licensee	Issues – Resource shortage, thereby higher import dependence	Issue – Linked to existing geographical pipeline infrastructure	Issue – Volatility of price
Tankers of R-LNG liquefied at plant site	Issues – Higher import dependence for the country	Issue – Linked to nearness to R-LNG plants to remain an economic solution	Issue – Volatility of price

Higher import dependence/price and its volatility are the challenges associated with the widespread use of natural gas as a suitable fuel shift option. However, as a stop gap arrangement, natural gas may be an option.

Fuel shift – Solar:

The various dimensions of solar thermal are summarized as follows:

- Maturity of technology: Mature
- Technical specification: Upto 10-20 TPH capacity
- Applications: Demonstration projects in place in several sectors (Paper, dairy etc.) by local technology suppliers
- Specific emissions: Nil
- Issues for widespread use: Space constraints leading to partial shifting of steam load along with high cost of the glass component (typically imported) and poor awareness levels

3.3. Review of blue sky technologies

Hydrogen:

Hydrogen is regarded as clean future energy carrier due to low GHG emissions. The main application of hydrogen is in the manufacturing of ammonia production, oil refineries, methanol production etc. The major technology for production of hydrogen is based on non-renewable sources. The value chain analysis of hydrogen fuel is summarized in the below tables:

Table 6: Review of production of hydrogen

Feedstock	Methods	TRL*	Issues
Fossil fuel	Coal gasification	8-9	High emissions, depends on fossil fuels
	Fossil fuel reforming	8-9	High emissions, depends on fossil fuels
Biomass	Gasification	4-5	Tar formation, varying H2 content due to seasonal availability and feedstock impurities.
	Biomass conversion	5-6	Fatty acids removal, low H2 rates and yields, low conversion efficiency, requirement of large reactor volume.
Water	Electrolysis	7-8	Low overall efficiency, high capital costs.
	Water splitting	4-5	Elements toxicity, corrosive problems, high capital costs.
	Photo electrolysis	3-4	Requires sunlight, low conversion efficiency, non-effective photocatalytic material.

*DESL estimate after review of various literature

The other aspects of storage, transport and use of hydrogen for steam generation is shown in the below table:

Table 7: Review of storage, transport and use of hydrogen

Methods	TRL*	Issues
STORAGE OF HYDROGEN		
High pressure gaseous Hydrogen	8-9 (Commercially used)	Chances of leakages, high weight and volume of such system due to low density of H2.
Cryogenic liquid	7-8	High Liquid Boil off, not economical
Adsorbed on metal hydrides/carbon nanotubes	Not Available	Requires Additional facility for H2 separation
TRANSPORT OF HYDROGEN		
Pipelines	Not available	Pipeline embrittlement leading to shortage of pipeline life for transport of hydrogen.
Transport vehicles	Not available	Limited infrastructure, materials are used for high pressure hydrogen.
USE OF HYDROGEN		
Catalytic combustion (using Palladium as a catalyst)	3-4	Durability and activity of catalyst, High cost

*DESL estimate after review of various literature

MNRE has been working on the research and development of hydrogen fuel. A few recommendations of a "Sub-Committee on Research, Development & Demonstration for Hydrogen Energy and Fuel Cells" in 2016 are as follows:

- Development & demonstration of hydrogen production by Auto-thermal Process (up to 2020)
- Basic / Fundamental Research for dissociation of gaseous hydrocarbon fuels to hydrogen using solar energy (up to 2022)
- Research and development for hydrogen production by gasification of biomass including demonstration of technology at pilot scale (up to 2020)
- Hydrogen production by water splitting through photolysis using solar energy may be undertaken upto 2022 in Mission Mode
- Development and demonstration of Hydrogen production by splitting water using RE (by 2022)

Hydrogen is a promising fuel switch option for the industrial sector. The ambitious targets in India for the technological development of low GHG hydrogen production is encouraging. However, the R&D activities for the other downstream aspects of storage, transport and use as fuel in boiler needs to be focused for this sector.

Fuel shift – Nuclear small modular reactor (SMR):

SMRs are relatively small and flexible, they have a power capacity of up to 300 MW_e and their output can fluctuate in line with demand. This makes them particularly attractive for remote regions with less developed grids, but also for use as a complement to renewable and for non-electric applications of nuclear power. SMRs can be manufactured and then shipped and installed on site, so they are expected to be more

affordable to build. Review of the parameters of the technology with relevance to the current study is summarized as follows:

- Maturity of technology: Concept level; mainly focused on power generation
- Associated steam generation capacity ranging from < 10 TPH to > 300 TPH
- Temperature: 100 – 900°C
- Efficiency: 80 – 94%
- Life cycle: 40 – 60 years
- Investment including capital, O&M and decommissioning: Rs. 50 – 80 Crore/MW

However, nuclear SMR has not been considered for further review due to cost, safety and environmental social concerns.

Carbon capture and storage:

CCS is one of the novel technologies to capture carbon dioxide from the exhaust flue gas and to reduce GHG emission in surroundings. In addition, CO_2 separated from flue gases can be used in enhanced oil recovery (EOR) operations where CO_2 is injected into oil reservoirs to increase mobility of oil and reservoir recovery. Carbon capture and storage (CCS) consists of three basic stages: (a) Separation of CO_2, (b) transportation and (c) storage. The separation of CO_2 is quite expensive but it can reduce CO_2 emissions effectively. There are various uses of pure CO_2, if captured, transported and stored safely like: as a raw material in processing of various chemicals, fire extinguishers, for treatment of alkaline solution in Effluent Treatment Plant (ETP), as an injector in enhanced oil recovery (EOR) process.

The CCS technology is generally focused for large emission intensive units like chemical, petrochemical, iron, and steel sectors.

Issues related to CCS implement in INDIA[1]:

- Lack of R&D effort: Along with its research phase, its potential estimation of conversion into fuel or either its geo sequestration (potential site estimation) plays an important role.
- Need for comprehensive national study on Geological storage: The comprehensive geological assessment for CO2 storage potential is yet to be studied in India.
- Energy penalty: CCS requires additional energy input and India's power requirement is yet to be fulfilled. Thus, energy penalty plays as barrier in India.
- Lack of financing and inflow of foreign direct investment (FDI): Implementation of costly CCS technologies require financial incentives from local and central governments in India and good governance policies enabling to attract foreign FDI for the same.
- Environmental and legal concerns: Like land acquisition, groundwater contamination, fear of CO2 leakage.
- Cost scenario: Even after development for over 30 years, CCS technology is still proved costly to developing countries like India.

[1] Abhishek gupta, Akshoy Poul, Carbon capture and Sequestration potential in India: A comprehensive review, Energy Procedia, 160 (2019), 848 - 855.

3.4. Summary of decarbonization technologies

Summary of the decarbonization technologies reviewed are presented in the below table:

Table 8: Summary of decarbonization technologies

Technology	Potential reduction of GHG emissions	Development status	Market penetration	Priority of barriers for uptake of technology		
				High	Medium	Low
Energy efficiency	Medium	Mature (low hanging fruit) & Research	Low–Medium	Demonstrated & sustained performances Inadequate back up services	Innovation Information Cost	Financing
Biomass combustion	Medium	Mature	Low-Medium	Cost Reliability of supplies	Biomass logistical services Lower PLF-higher level of maintenance	Financing of working capital
Electrode boiler	High	Mature	Low	High operational cost		
Solar thermal		Mature	Low	Cost, Financing & Back-up services	Information & Demonstration	Availability
Hydrogen		Research	Low	At R&D stage		

4 Policy recommendations

Different barriers were identified for the higher uptake of the decarbonization technologies, as described in the previous section. The methodology to devise policy recommendations to overcome these barriers suitable for India was as follows:

Table 9: Methodology for review of relevant policies

Type of data	Source	Remarks
Review of global policies to identify best practices to overcome barriers for the identified technologies	Web-search; Roadmap documents for advanced countries	A few advanced countries were chosen based on data availability
Review of prevailing policies in India	Web-search; Stakeholder consultation	Focus was more on the regulatory policies under the various policy vision documents
Identification of gaps in Indian policies and propose policy options	Analysis of the gather data and opinions	

4.1. Review of global policies

A structured web-search was conducted to identify the countries which have roadmap documents for the decarbonization of various sectors and specifically for the industrial process heat, if available. In addition, other countries with leadership in any particular renewable energy technology was also reviewed. With these objectives the following countries were shortlisted:

1. United Kingdom (UK)
2. Germany
3. Australia
4. Canada
5. Lithuania
6. China

The prevailing and most relevant policy instruments for these countries are provided in the same order.

- **United Kingdom (UK)**
  - The Energy Technology List (ETL) & Enhanced Capital Allowances (ECA) scheme (2017)[2]: The Energy Technology List is part of Government's Enhanced Capital Allowances scheme. Under this scheme, a list of energy efficient technologies within the top 25% of energy efficient equipment for that technology category in the UK market (approved models) is maintained. Interested consumers can select the desired specification of the product, to verify the eligibility and **receive accelerated tax relief** on the purchase of that equipment, by claiming a 100% capital allowance in the year of purchase. There are at present 16 separate technology categories including **biomass boiler, boiler equipments, heat pump** etc. Even CHP is eligible for the ECA scheme, the equipment and design must be assessed by the government's Combined Heat and Power Quality Assurance Programme (CHPQA) and must receive a certificate of energy efficiency

[2] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/819673/ECA272_July_2019.pdf

- Climate Change Levy (CCL, 2001)[3]: CCL is an environmental tax charged on energy used by industrial, commercial, agricultural and public service consumers. The scheme is designed to encourage energy efficiency and is charged on 'taxable commodities' for heating, lighting and power purposes. The taxable commodities include electricity, gas and solid fuel (e.g. coal, coke, and lignite or petroleum coke). Energy intensive consumers can avail 65% to 90% reduction on the charges for which they must enter into a climate change agreement (CCA) with the Environment Agency. A CCA is a voluntary agreement to reduce energy use and CO2 emissions. Captive power/heat generation from low carbon technologies like biomass could be included as part of CCA to reduce the CCL charges.
- Energy Saving Opportunities Scheme (ESOS, 2014)[4]: ESOS scheme is for UK based firms (a minimum employee strength of 250 or annual turnover in excess of 50 Mn. Euro and annual balance sheet total in excess of 43 Mn. Euro), expected to conduct energy audit in their plants covering 90% of their energy consumption to identify energy saving opportunities, get the report assessed by a lead assessor and submit the report to the Environment Agency. This activity is supposed to be done once in 4 years.
- Scottish Government SME Loan (SGSL, 2008)[5]: SGSL provides unsecured, interest free loans (5% interest rate for renewable energy technologies) from £1,000 up to £100,000 for the installation of energy efficient measures such as lighting and heating upgrades, double glazing, insulation and much more. Resource Efficient Scotland offers a free consultation with a specialist to receive a report advising the SME on the best ways to reduce energy usage. Since its launch in 2008, the SGSL has provided Scottish businesses with over £26, 24 Mn in loans for over 968 projects, resulting in an estimated financial saving to businesses of over £48.02 Mn.
- CHP Quality Assurance Program (CHPQA, 2012)[6]: CHPQA is a program which helps in the certification of the CHP system to be of 'good quality' and allow for a range of financial benefits. The gas based CHP plants certified by the CHPQA would be availing the lower charges under CCL. The renewables (using Biomass/waste) based CHP to get renewable obligation certificates. In addition, the biomass based CHP plants can avail Renewable Heat Incentive solid biomass CHP tariff.

- **Germany**
  - Programme to Promote Investment in Highly Efficient Horizontal Technologies (2016)[7]: Currently focused on replacement of industrial pumps and actions to promote in-house use of waste heat. Investment support ranges from 30,000 Euro for individual system to 150,000 Euro for measures to improve entire system. For availing the higher investment support, the industry has to provide an energy conservation plan and submit proof of increase in system performance by 25%
  - Competitive tendering scheme for energy efficiency in industry (2019)[8]: The industries are encouraged to participate in competitive tender which aims to increase the energy efficiency while reducing the CO_2 emissions of industrial processes. Renewable energy and process heat are the areas of focus. The program awards the funding to bids with the most economic cost-benefit ratio (euro per saved ton of greenhouse gas emission). Germany has devised this policy after the successful execution of such policy in Switzerland, where the policy is in place since 2010. The results

[3] https://www.gazprom-energy.co.uk/help-and-support/bills-payments/what-is-the-climate-change-levy-ccl/
[4] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/842479/Complying-with-the-energy-savings-opportunity-scheme.pdf
[5] https://www.zerowastescotland.org.uk/content/resource-efficient-scotland-sme-loan-scottish-government
[6] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/790567/Simple_Guide_to_the_CHP_Quality_Assurance_2019.pdf
[7] https://climatepolicytracker.org/countries/germany/
[8] https://www.bmwi.de/Redaktion/EN/Publikationen/nape-national-action-plan-on-energy-efficiency.pdf?__blob=publicationFile&v=1

of the policy in Switzerland[9] for the period 2010 to 2015 shows that a small number of well-known technologies have taken a very significant part of the funding. This is in line with expectations for energy efficiency tenders, which supports the cheapest energy saving options and therefore risk marks up cannot be included.

- Industrial incentive program to increase energy efficiency and the use of renewable process heat (2019)[10]: Under the program, companies can choose between a direct subsidy or a loan combined with an amortization subsidy for investments in highly efficient plants and machinery, solar collectors, biomass installations or heat pumps to generate process heat, investments in technology and software for monitoring and controlling energy flows with an energy management system, holistic optimization of production processes.
- Pilot program 'Einsparzaehler' (2016)[11]: A pilot scheme for innovative IT-based pilot project for saving energy based on such "intelligent" IT-based pilot systems. The policy aims at enabling the building/industrial consumer to develop an understanding of the main drivers for his individual energy consumption and find opportunities to drive down his energy consumption at little cost and with small changes in energy use. The incentive level partially depends on achieved energy savings.
- Compulsory energy efficiency audits in large companies (2015)[12]: Large industries are required to conduct energy audit once in 4 years. Companies not complying are penalized with fines and Companies that have an ISO 50001 certified energy management system or an EMAS environmental management system are exempted from the obligation.
- Energy Efficiency Networks Initiative (2015)[13]: The German Federal Government and 21 industry associations have founded the Energy Efficiency Networks Initiative. The goal of the initiative is to establish 500 energy efficiency networks by the end of 2020 (with 5-15 companies per network), thereby reducing greenhouse gas emission by 5 Mn. t/y. Energy efficiency networks offer companies a structured exchange of experiences with energy efficiency projects. Each network formulates an energy saving goal that companies aspire to reach by the end of the network cooperation. At the end of a network cooperation, an independent monitoring institute verifies if stated measures have been implemented by participating companies. Starting point of the network cooperation is an assessment of efficiency potentials (energy audit) within each participating companies. Over the course of the network cooperation (generally 3-4 years), the participants meet regularly in workshops and on-site consultations. Experience with energy efficiency networks in Germany has shown that participation in a network results in motivational and organizational benefits for companies. The Energy Efficiency Networks Initiative aims at mobilizing companies of all sizes and from several sectors, including trade and commerce. About 216 networks founded from 2015-2018 and included about 2300 companies. The estimated cumulative annual primary energy savings has been 1,880 PJ/y and annual GHG emissions reduction of 1.253 Mn. t/y during the period 2015-18[14].
- Grants for consulting on Energy Performance Contracts (2015): Specifically for the SME industries, grants are made available for initial consulting, consulting on the implementation of energy performance contracting and on tender proceedings for ESPCs

[9] https://www.eceee.org/library/conference_proceedings/eceee_Industrial_Summer_Study/2016/1-policies-and-programmes/competitive-tenders-for-energy-efficiency-8211-lessons-learnt-in-switzerland/2016/1-036-16_Radgen_presentation.pdf/

[10] https://www.iea.org/policies/7713-industrial-incentive-program-to-increase-energy-efficiency-and-the-use-of-renewable-process-heat?country=Germany&sector=Industry

[11] https://www.eceee.org/library/conference_proceedings/eceee_Industrial_Summer_Study/2016/1-policies-and-programmes/pilot-support-scheme-for-smart-devices-and-efficiency-services-der-einsparzahler-energy-savings-meter/

[12] https://ec.europa.eu/energy/sites/ener/files/documents/EED-Art8-Implementation-Study_Task12_Report_FINAL-approved.pdf

[13] https://www.iea.org/policies/2306-energy-efficiency-networks-initiative?country=Germany&sector=Industry

[14] https://www.epatee-toolbox.eu/wp-content/uploads/2018/10/epatee_case_study_germany_energy_efficiency_networks_initiative_ok.pdf

- CHP Agreements with Industry (2012)[15]: All new CHP installations used by energy-intensive industrial companies will also pay 40% of the EEG surcharge. The EEG surcharge, payable by consumers as part of their electricity bills, covers the difference between the wholesale market price for power on the electricity exchange and the higher fixed remuneration rate for renewable energies.

- **Australia**
  - National Greenhouse and Energy Reporting (NGER) scheme (2007)[16]: NGER is a single national framework for reporting and disseminating company information about greenhouse gas emissions, energy production, energy consumption and other information specified under NGER legislation.
  - Federal Energy Efficiency Opportunities (EEO) program (2006): EEO program requires large energy-using businesses to identify, evaluate and report publicly on cost-effective energy saving opportunities. The EEO operates in five-year assessment and reporting cycles, the first being 2006 to 2011.
  - Industrial Energy Efficiency Data Analysis Project (2012)[17]: The IEEDA project consolidates and analyses company data already collected through NGER and EEO programs to create a comprehensive, national industrial energy use and energy savings dataset, based on real world data, which can be used to inform industry on areas of cost effective investment in energy efficiency as well as facilitating more prudent and informed government decision making. The latest database also includes geospatial information for future energy supply network planning.
  - Emissions Reduction Fund (2017)[18]: Businesses identify emissions reductions projects that go beyond their business-as-usual activities, that is, 'additional' to what they would normally do. Businesses must use an approved method to estimate the emissions that will be reduced by their project. To participate in the Emissions Reduction Fund businesses need to register their project with the Clean Energy Regulator. As businesses carry out their projects they must submit reports to verify the emissions that have been reduced. Businesses also need to have their project audited on a regular basis. The Clean Energy Regulator will issue Australian carbon credit units following receipt and assessment of these reports. The Regulator runs auctions to select the lowest cost abatement. If a business's bid is successful at auction, they automatically enter into a contract with the Clean Energy Regulator to deliver Australia carbon credit units. The business will receive payment for Australian carbon credit units delivered at the price they bid at auction. The first eight auctions have secured over 193 million tonnes of emissions reductions at an average price of $12 per ton.
  - Energy Efficient Communities Program – businesses (2019)[19]: Australian Government will deliver $50 Mn of grants to assist business and community organizations to improve energy efficiency practices and technologies and better manage energy consumption to reduce their power bills. This measure will deliver up to 3 million tonnes of abatement to 2030. Funding will support activities to help businesses save energy through:
    - equipment upgrades that reduce energy consumption, excluding energy generation equipment, such as solar PV panels
    - investment in energy and emissions monitoring and management systems to better manage energy use
    - completion of energy systems assessments according to the Australian Standard or feasibility studies to investigate energy efficiency opportunities.

[15] https://www.bmwi.de/Redaktion/EN/Pressemitteilungen/2018/20180508-important-agreement-achieved-chp-installations-altmaier-vestager.html
[16] http://www.cleanenergyregulator.gov.au/NGER/About-the-National-Greenhouse-and-Energy-Reporting-scheme
[17] https://www.iea.org/policies/2314-industrial-energy-efficiency-data-analysis-project?country=Australia&sector=Industry
[18] https://www.environment.gov.au/system/files/resources/20e963a0-0226-4131-9b88-ff0c754edea1/files/erf-what-it-means-you.pdf
[19] https://www.iea.org/policies/7880-energy-efficient-communities-program-businesses?country=Australia&sector=Industry

        - Eligible businesses will be able to apply for grants in early 2020. $10 million of the grants will be allocated for dairy farm businesses
    - Renewable Energy Targets (2001)[20]: The Renewable Energy Target (RET) is designed to deliver a 23.5% share for renewables in Australia's electricity mix by 2020. The RET legislation includes a legislated annual Large-Scale Renewable Generation Targets (LRET), rising to 33,000 gigawatt-hours of renewable energy by 2020, while the Small-Scale Renewable Energy Scheme (SRES) is uncapped. The LRET creates a financial incentive for the establishment and growth of renewable energy power stations, such as wind and solar farms, or hydro-electric power stations. It does this by legislating demand for Large-scale Generation Certificates (LGCs). The Small-Scale Renewable Energy Scheme (SRES) creates financial incentives for small businesses to install eligible small-scale renewable systems such as solar water heaters and heat pumps. It does this by legislating demand for Small-scale Technology Certificates (STCs). STCs are created for these installations according to the amount of electricity they produce or displace over the deemed life of the system. Liable entities have a legal obligation to buy STCs and surrender them on a quarterly basis. The STCs created can be sold or traded to receive an upfront cash support or a discount on the system purchased, which assists in reducing the capital cost of the system for the small businesses.
    - Energy audit standards AS/NZS 3598.2:2014 - industrial and related activities (2014)[21]: This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EN-001, Energy Auditing, to supersede, in part, AS/NZS 3598:2000, Energy audits. This Standard will assist organizations to decide on the appropriate type of audit for their industrial operations, provide a guide when commissioning energy audits and present a uniform basis for preparing and comparing energy audit proposals for industrial and related operations. It also aims to establish best practice for energy auditors, support the establishment of energy management systems and contribute to the quality of existing energy and other management systems.
    - National Carbon Offset Standard (NCOS, 2010)[22]: Carbon neutral certification against the NCOS provides a credible stamp showing that an organization, product, service, event, precinct or building, has met all the requirements of the Standard. Carbon neutral means reducing emissions where possible and compensating for the remainder by investing in carbon offset projects to achieve net zero overall emissions. A voluntary standard to manage greenhouse gas emissions and achieve carbon neutrality. It provides best-practice guidance on how to measure, reduce, offset, validate and report emissions that occur as a result of the operations of an organization. To compensate for emissions that cannot be completely reduced through energy efficiency, the procurement of renewable energy or supply chain management. The benefits of the certification is increased customer recognition, enhanced corporate social responsibility etc.
- **Canada**
    - Residual Forest Biomass Program (2017): Voluntary program for the benefit of industries, institutions and municipalities that use fossil fuels. The policy supports the industry and supply chain which values the production of residual forest biomass energy by encouraging the development of infrastructure and distribution networks.
- **Lithuania**
    - Rules on Accounting of Solid Biofuel ; Rules on Centralized Trade in Biomass ; BALTPOOL UAB Energy Exchange Trading Rules ; Rules on Energy Resources Market Surveillance (2012): Creation of a

[20] https://www.iea.org/policies/5915-renewable-energy-target-ret?country=Libya%2CAustralia&sector=Generation&type=Target
[21] https://www.iea.org/policies/7703-energy-audit-standards-asnzs-359822014-industrial-and-related-activities?country=Australia&sector=Industry
[22] http://www.environment.gov.au/system/files/resources/3a3ec083-76e3-41b9-84c3-004206f87b66/files/j-climate-active-carbon-neutral-standard-organisations.pdf

market hub for solid biomass trading (Baltpool Biomass Exchange), operating in Latvia and Lithuania. In 5 years of operations, the turnover has reached 225 Mn EUR, 346 market participants from 4 countries, contributing to more than 97% of biomass consumed in Lithuania.

- **China**
  - The institutional structure for the promotion of R&D activities in China promotes the handholding of responsibilities between clearly identified three level stakeholders. The universities are entrusted with the innovation on the concept of design at a science and technology level. This is further developed at the engineering design and industrial application level by the Design institutes (associated with the universities). The prototype is tested in a pilot industry. These three stakeholders are provided government funding based on the pre-identified success parameters. The funding to the institutions (university and Design institute) is linked to extent of technology diffusion for the identified technology in the market. The motivation of the designers is therefore towards market acceptance of the product.
- **Summary**

A summary of the review of the global policies in the different countries are as follows:

- Monetary incentives are most prevalent. The incentives were found to be linked to performance (lower ratio of money invested to GHG emission reduction, minimum threshold level of achievement of energy savings, proof of additionality, higher percentage of biomass blending etc.). Exceptions exist for thematic incentives or upfront subsidy for SMEs only.
- Fiscal incentives are linked to direct objectives of either promoting carbon tax or accelerated depreciation
- Regulations for compliance with energy audit standards, mandatory energy audit at a particular frequency, sharing of energy consumption/saving related information regularly, monetary support for installation of high end IT tools and creation of biomass exchange
- Institutional support provided for biomass supply chain establishment, better networking between peer organizations
- Voluntary regulations to meet carbon neutrality
- Institutional structure for the promotion of research and development

4.2. Review of prevailing policies in India

The prevailing policies in India were reviewed and the following table provides the details:

1. The program will provide Central Financial Assistance (CFA) for projects utilizing biomass like bagasse, agro-based industrial residue, crop residues, wood produced through energy plantations, wood waste produced in industrial operations, etc (excl. MSW). CFA will be provided at the rate of Rs. 25 Lakh/MW (for bagasse cogeneration projects) and Rs. 50 Lakh/MW (Non-bagasse Cogeneration projects), after successful commercial generation and performance testing of the plant. ***Scheme to Support Promotion Of Biomass-Based Cogeneration In Sugar Mills And Other Industries In The Country (Upto 2020), 2014***

2. Capital subsidy of 30% of the benchmark cost (Ascertained in INR/collector area in m^2) after 3 months of successful commissioning and third party inspection by designated agencies. ***Off-Grid and Decentralized Solar Thermal Technologies for Process Heat in Industries, 2014***

3. Accelerated depreciation @ 40% in the first year of installation is available for

- High efficiency boilers (>75% coal fired and 80 % oil/gas fired boilers)

- Instrumentation and monitoring system for monitoring energy flows
- Waste heat recovery equipment (incl. heat pump)
- Concentrating and pipe type solar collectors / Solar water heaters and systems

Accelerated depreciation under the Income Tax Act, Govt. of India, FY 2017-18

1. Perform Achieve and Trade (PAT) is an innovative policy mandated, market based mechanism designed to accelerate energy savings in energy intensive and large industries by incentivizing energy savings. ***Perform Achieve and Trade (PAT), 2012***

2. Largest public-private-partnership effort within the R&D domain in the country by synergizing the best competencies of publicly funded R&D institutions, academia and private industry, Both 'push' and 'pull' type of projects are evolved, which are appropriately named as (i) Nationally Evolved Projects (NEP) and (ii) Industry Originated Projects (IOP). ***New Millennium Initiative technology leadership India (NMITLI), 2000***

3. ZED certification is a voluntary scheme for the MSME sector to enhance the productivity and competitiveness of MSMEs through the adoption of zero defect production processes that have a low/no impact on the environment. ZED scheme introduces a new ZED Maturity Assessment Model. The MSMEs are provided financial assistance for the activities to be carried out for ZED certification i.e., Assessment / Rating, Gap Analysis, Handholding, Consultancy for improving the rating of MSMEs by Consultants and Re-Assessment / Re-Rating. ***Zero Defect Zero Effect (ZED) Certification Scheme, 2016***

4. Clean energy research initiative prefers to support interdisciplinary multi-institutional networked research projects, synergizing strengths' of respective partners to deliver efficient devices/systems meeting global benchmarks. The outcome of the scientific development should be scalable and lead to technology readiness in area of clean energy. The deliverables of the projects should have the potentials to change business as usual scenarios. ***Central energy research initiative, 2009***

5. Subsidy on the cost of energy audit and the cost of capital recommended in the energy audit for MSME units. ***Various state govt. schemes for MSME industries***

6. Common boiler project by SPV constituted by a minimum of 10 MSMEs. Project should be promoted by SPV of a minimum of 10 MSMEs using steam in the process and having independent boiler in their premises. New boiler should be energy efficient. Capital support of 35% or maximum of Rs. 2 Cr. (if solid fuel is used) and 50% or maximum Rs. 2 Cr. (if cleaner fuel is used). ***Scheme of assistance from common environmental infrastructure (Gujarat Industrial policy, 2015)***

7. Under the "Conservation of energy, technology absorption & foreign exchange dealing: Rule8(3)", the following are mandatory to be reported (i) the steps taken or impact on conservation of energy; (ii) the steps taken by the company for utilizing alternate sources of energy; (iii) the capital investment on energy conservation equipments. ***Disclosures in Director Report under Company's Act (Company's Act 2013)***

8. Biomass briquettes or solid bio fuel pellets - 5% ; Heat pumps and parts thereof – 5% ; Solar water heater and system – 5% ; Steam – 12% ***Goods & Sales Tax (GST)***

9. Comprehensive energy audit, technology gap assessment, DPRs, awareness creation workshops, capacity building of local service providers in selected 25 SME clusters. Implementation of 100 energy efficient technology demonstrations in 5 energy intensive clusters with provisions of back ended subsidy

of 50% of the total cost of the technology per unit subject to a max of Rs 10 Lakhs. ***National program on Energy Efficiency and Technology Up gradation of SMEs, 2007***

10. Creation of a Technology Development Fund for evolving cleaner / energy efficient / IT enabled technologies. ***MSME Department Policy Note 2018-19, Govt. of Tamil Nadu***

11. The state nodal agency of Rajasthan (RREC), shall assist biomass power plants to get supplementary biomass from energy plantation by allotting barren government land, waste land, Panchayat land and degraded forest land for the development of energy plantation (Maximum 500 Hectare/MW land shall be permissible). Identification of suitable land facilitated by the District Collector/CEO Zila Parishad /DFO. ***Policy for Promoting Generation of Electricity from Biomass, 2010 (Govt. of Rajasthan)***

12. MOP & CEA have issued an advisory to all the coal fired power plants/utilities to endeavor to use 5-10% blend of biomass pellets made, primarily, of agro residue along with coal after assessing the technical feasibility. Subsequently, CEA issued technical specification for agro-residue based biomass pellets (non-torrefied/ torrefied) in September 2018. ***Biomass utilization for power generation through co-firing in coal based power plants, 2017***

13. Scheme is to promote the concept of energy conservation and management in the small and medium industries sector. The energy consulting firm conducts walk through energy audit (WTEA), a simple visual investigative audit and table-top survey of the energy bills of the manufacturing facility. ***Walkthrough Energy Audit Scheme for MSMEs in Gujarat (2016/2017) & Maharashtra (2010/2013)***

14. The government notification mandates the use of solar water heating systems in Industrial buildings where hot water is required for processing. ***Mandatory use of solar water systems in Haryana (2005) & Rajasthan (2014)***

15. The PRGFEE is a risk-sharing mechanism to provide financial institutions (banks and NBFCs) with a partial coverage of risk in extending loans for energy efficiency projects. The guarantee will not exceed Rs. 10 crore per project or 50% of the loan amount, whichever is less. ***Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE), 2008***

16. A GEF funded project implemented by the World Bank, Small Industries Development Bank of India (SIDBI) and Energy Efficiency Services Limited. PRSF supports establishing and operating the Facility to provide Sub-Guarantees to Sub-Financiers and developing energy efficiency markets through end-to-end solutions and measurement and verification (M&V) activities. ***Partial Risk Sharing Facility in Energy Efficiency (PRSFEE), 2015***

17. A new "Hybrid Security" product allowing guarantee cover for the portion of credit facility not covered by collateral security. In the partial collateral security model, the FIs will be allowed to obtain collateral security for a part of the credit facility, whereas the remaining part of the credit facility, up to a maximum of 200 lakh, can be covered under Credit Guarantee Scheme of CGTMSE. ***Credit Guarantee Fund Trust for Micro and Small Enterprises (CGTMSE)***

18. Urja Mantra Programme (UMP) targets to spread awareness regarding energy conservation by reaching to all sections of the society through radio. An interactive radio program called HAREDA Urja Mantra is being aired from the AIR FM, Chandigarh twice a week since November 04, 2008. At the end of the program, a question is asked and the first correct entry is given a prize of 2 CFLs. ***Urja Mantra Programme (UMP), Govt. of Haryana, 2008***

4.3. Identification of gaps in Indian policies and propose policy options

The below table summarizes the details of the different best practices in policy design to overcome barriers in the identified technologies:

Technology	Major barriers	Identification of best practices
Energy efficiency	Demonstrated & sustained performances ; Innovation	**Global best practice policies** • Australia: Energy audit standards (2014) ; National Greenhouse and Energy Reporting scheme (2006), Federal Energy Efficiency Opportunities program (2006), Industrial Energy Efficiency Data Analysis Project (2012) • Germany: Competitive tendering scheme for energy efficiency in industry (2019), Energy Efficiency Networks Initiative (2019), Compulsory energy efficiency audits in large companies (2015), Intelligent IT based pilot systems for energy saving (2016) • UK & Germany: Carbon tax on fossil fuel consumption, as an integral part of their fuel bills. Rebate on carbon tax on committing and achieving GHG reduction through EE/RE measures (Biomass, Solar, CHP etc.) **Stakeholder consultation** • Industrial boilers in SME units have 6% to 10% scope in efficiency improvement and large industries have about 2% scope from regular technologies like excess air control, insulation improvement, condensate recovery, waste heat recovery. Cluster-level demonstration and sustained performance support by third party can help in developing trust on these technologies. Further, reduction in the specific steam consumption needs innovation at a sectoral process level. Supercritical CO2 dyeing is one such technology for the textile dyeing sector. Technology implemented in European countries by a particular (Dutch) technology supplier yielding good results. The technology helps in replacing water with supercritical CO_2 in textile dyeing industries thereby drastically reducing the demand for steam. However, no pilot implementation in India. • Also cluster level RE based common boilers could be targeted to reduce GHG emissions at a group level • Information availability regarding the ongoing performance of boilers can increase the probability of implementation of energy efficiency measures. Therefore development of a software for energy audit of boiler and mandate boiler manufacturers of > 5 TPH (tons per hour) to provide real time monitoring system can bring in a cultural change towards boiler performance improvement • Industries, especially SMEs, inherently have cluster level network for informal knowledge sharing. Formalizing these informal networks to have regular interaction meets over a timeframe of 2-4 years mentored by sectoral experts can help in healthy knowledge sharing, goal setting and encourage innovation • Programmatic approach of energy efficiency service and product procurement through competitive tendering can help bring down capital cost and encourage innovations
Biomass combustion	Cost and reliability of	**Global best practice policies** • Germany: Industrial incentive program to increase energy efficiency

	supplies	and the use of renewable process heat (2019)
		• Brazil, Denmark, Germany, Japan, Netherlands, UK and US: A variety of financial incentives like capital grants, feed-in-tariff, incremental cost converted as surcharge on the electricity bills for co-firing of biomass with coal
		• UK: Accelerated depreciation for biomass boilers and boiler related support equipments
		• Canada: Institutional support for biomass supply chain for industries around forest areas (2017)
		• Lithuania: Establishment of biomass exchange (2012)
		Stakeholder consultation
		• Availability of biomass at desired quality, quantity, and price is a major hurdle for fuel switch. Industrial boilers of less than 30 TPH capacity have lower demand for biomass quantity than coal-fired utility boilers, thereby having a lower possibility for fuel switch
		• Common boilers in SME clusters using biomass as fuel could be a wise pilot for demonstration and establishing learnings for upcoming industrial parks. Gujarat state industrial policy has provision for incentivizing common boilers using cleaner fuels.
		• Incentives are desired across the value chain of biomass (farmers, biomass suppliers, and industries)
		  • Farmers – Mandate to clear field without field burning can be modified into an incentive scheme to deliver biomass at a predetermined spot nearby in return to quick commercial transaction
		  • Biomass suppliers face a lot of problems in financing capital investments , working capital, low-cost space for storage of biomass and high costs for planning of deploying resources (manpower and machinery for harvesting) due to information gap on geographic biomass availability and timing of harvesting
		  • Industries with low motivation to fuel switch for industrial process heat

Futuristic technologies and carbon market	Quick research to commercialization ; High operational cost	**Global best practice policies** • China: Institutional mechanism of incentivizing stakeholders towards higher market diffusion of any new technology • UK: Climate Change Levy (2001) **Stakeholder consultation** • Technologies like electrode boiler and solar thermal are suffering from issue of high cost compared to fossil fuel like coal, furnace oil. Carbon market mechanism can unlock these potential technologies. Consultations are in progress under India's Partnership for Market Readiness (PMR) Proposal, in which 8 industrial clusters (targeting SME sector) have been chosen for a pilot assessment • Innovative products and services (like softwares) developed under funded assignments in India are limited to the pilots and the replication benefits as a market product is scarce • Hydrogen fuel has several hurdles towards the mainstreaming as a fuel switch option for industrial process boilers. The focus of the R&D activities has been more for the transport sector. However, a renewed focus for this sector would help in innovating as a fuel switch option

In view of the above mentioned identified best practices and stakeholder feedback, the following policy recommendations were made:

- **Energy efficiency of industrial boilers (Estimated mitigation potential of 15%-20%) (Probable identified stakeholder to initiate: Bureau of Energy Efficiency)**
  - Creation of cluster-level utility facilities and network of industries to make the systems more efficient and scaling up for making biomass fuel cost competitive against coal
  - Conducting competitive tendering in energy efficiency (EE) services/products by designated nodal agencies with probable parameters like lowest cost per greenhouse gas (GHG) saved, reduction in specific steam consumption etc.
  - Develop software for energy audit of boiler and mandate boiler manufacturers of > 5 TPH (tons per hour) to provide real time monitoring system
- **Fuel shift to biomass in industrial boilers (Estimated mitigation potential of 15%-20%) (Probable identified stakeholder to initiate: Ministry of New and Renewable Energy)**
  - Financial incentives for a competitive low cost of delivered biomass
    - Duty free import of biomass logistics & densification machineries
    - Incentives for fuel substitution, until a carbon market is developed
  - To develop a program for biomass densification covering aspects of indigenous technology development
  - Devise a methodology for development and operation of information system related to harvesting time for agricultural plots
- **Futuristic technologies and carbon market mechanism (Estimated mitigation potential of 40%-45%)**
  - Institutional mechanism for monitoring of performance of newly developed technologies in the market **(Probable identified stakeholder to initiate: NITI Aayog/Department of Science & Technology)**
  - Increased investments in research and pilot testing of new fuels like hydrogen from renewable energy (RE) sources (**Probable identified stakeholder to initiate: Ministry of New and Renewable Energy)**
  - Devising means for a voluntary carbon market for the industrial sector through cluster/sectoral cap and trade especially for the Micro, small and medium enterprises (MSMEs) **(Probable identified stakeholder to initiate: NITI Aayog)**

5 Conclusion

The estimated GHG emission in the industrial sectors with process-steam demand is expected to rise from the present 100 Mn. tCO_2/y to 570 Mn tCO_2/y in 2050. The average size of the process boilers is less than 30 TPH, enabling brighter prospects for decarbonization opportunities. A few policy recommendations have been identified which can help reduce GHG emissions by 70% to 85% by 2050. The perceived challenges in the implementation of the identified policy recommendations are as follows:

- Aligning of all the stakeholders through proper communication and confidence on financial benefits
- Quantification of carbon benefits
- Technology risk and bringing changes in the institutional process dealing with science and technology
- Industry consensus for the voluntary climate market

DESL™

www.deslenergy.com

CSTEP®
CENTER FOR STUDY OF SCIENCE, TECHNOLOGY & POLICY

www.cstep.in

SHAKTI
SUSTAINABLE ENERGY FOUNDATION

www.shaktifoundation.in

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

www.eda.admin.ch/sdc