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Development of Standards and Labeling Program for Packaged Boilers in India

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Abbreviations

BEE	Bureau of Energy Efficiency
BIS	Bureau of Indian Standards
BS	British Standards
CAGR	Compound annual growth rate
CO_2	Carbon dioxide
EE	Energy efficiency
FY	Financial year
GCV	Gross calorific value (equivalent to higher heating value)
IBR	Indian Boiler Regulation
IIP	Index of Industrial Production
IS	Indian Standard
MEPS	Minimum Energy Performance Standards
MoP	Ministry of Power
MPa	Mega pascal
$MtCO_2$	Million tonne of CO_2 equivalent
TOE	Tonne of oil equivalent
NABL	National Accreditation Board for Testing and Calibration Laboratories
NCV	Net calorific value
NDC	Nationally Determined Contribution
NPC	National Productivity Council
PCRA	Petroleum Conservation Research Association
S&L	Standards & labeling
TPH	Tonne per hour
YoY	Year over year

Executive Summary

A steam boiler is a type of closed vessel with a steel plate that generates steam by heating water through the combustion of various fuels, for example, oil, coal, gas, and biomass. A packaged boiler is a factory-made, ready-to-use boiler. Boilers are the principal equipment used to meet both steam and hot water requirements in almost all process industries. They are used in the textile industry, thermal power plants, the metals and mining industries, the chemical industry, the cement industry, pharmaceuticals, food processing, rice mills, sugar plants, paper mills, wood processing plants, and automobile plants. Boilers account for a major portion of the thermal energy consumption in the commercial sector, for instance, in hotels and hospitals.

The Ministry of Power (MoP) aims to improve the efficiency of packaged boilers to reduce India's overall fossil fuel consumption. This is in line with India's Nationally Determined Contribution, wherein it has undertaken to reduce its energy consumption and CO_2 emissions intensity. The Bureau of Energy Efficiency (BEE), under the MoP, has developed a Standards & Labeling (S&L) program for packaged boilers. Towards this end, CLASP provided technical assistance to BEE in conducting a market and technical assessment study of packaged boilers. BEE in collaboration with CLASP reached out to major industry players to estimate the current market size of boilers in India, assess the energy performance of boilers available in the country, and understand the processes used to test boilers. A structured questionnaire, in-depth interviews, and secondary research provided the following insights:

1. The boiler industry in India is dominated by domestic players. The market size for packaged steam boilers up to a capacity of 30 TPH stood at about 2,400 units in 2019, as reported by manufacturers.
2. The market for packaged steam boilers is expected to grow at 3.8% over the next 11 years and reach ~3,600 units by 2030.
3. Major players in the packaged boiler market in India include Thermax, Industrial Boilers, Forbes Marshall, Transparent Systems, and Elite Thermal.
4. The largest clusters of boiler manufacturing are in Maharashtra, Gujarat, and Karnataka, representing about 90% of the total units manufactured in 2019.

5. The steam output capacity of packaged boilers ranges between 0.1–30 TPH. The market share of packaged boilers with a capacity less than 10 TPH is about 81%, followed by 16.5% for 10–20 TPH, and 2.5% for 20–30 TPH.
6. Thermal efficiency data for 168 models of coal-, oil-, gas-, and biomass-fired boilers was collected and analyzed.

The study recommends the Indian Standard (IS) 13979:1994 for developing BEE's labeling program for packaged boilers. The proposed energy efficiency (EE) metric for the packaged boiler labeling program is thermal efficiency (%), based on the net calorific value (NCV) of the fuel. It is calculated using an indirect method as prescribed by the IS. A star rating plan is proposed for packaged boilers of all capacities under the Indian Boiler Regulation (IBR), as shown in the following table.

Star Rating	Thermal Efficiency Based on NCV (%)		
	Coal	Biomass	Oil & Natural Gas
1 star	≥75 and <79	≥80 and <82	≥90 and <92
2 star	≥79 and <82	≥82 and <84	≥92 and <94
3 star	≥82 and <85	≥84 and <86	≥94 and <96
4 star	≥85 and <88	≥86 and <88	≥96 and <98
5 star	≥88	≥88	≥98

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1. Packaged Boilers

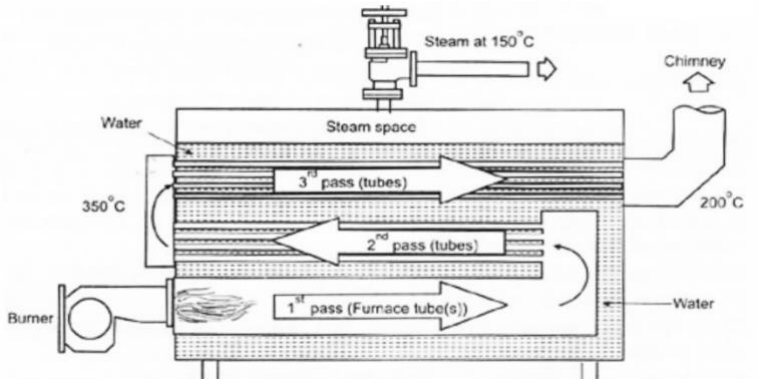
Introduction

A **steam boiler** is a type of closed vessel with a steel plate that generates steam by heating water through the combustion of various fuels, including oil, coal, gas, and biomass. Steam boilers are used in various applications, including power generation, process industries, and heating for residential and commercial buildings. Depending on the application and type, steam boilers can be large systems that need to be assembled at the installation site.

A **packaged boiler** is a factory-made device. Packaged boilers are available in a range of standard designs. They are used for heating and steam generation in applications such as self-powered industrial plants. A packaged boiler is compact and can fit into tight engineering spaces. One of the great advantages of this boiler type is that it does not need to be assembled at the installation site – it can be delivered fully assembled. It has high thermal wear levels, and its maintenance is inexpensive. It is easy to install and requires less manpower to operate.

Operating Principle

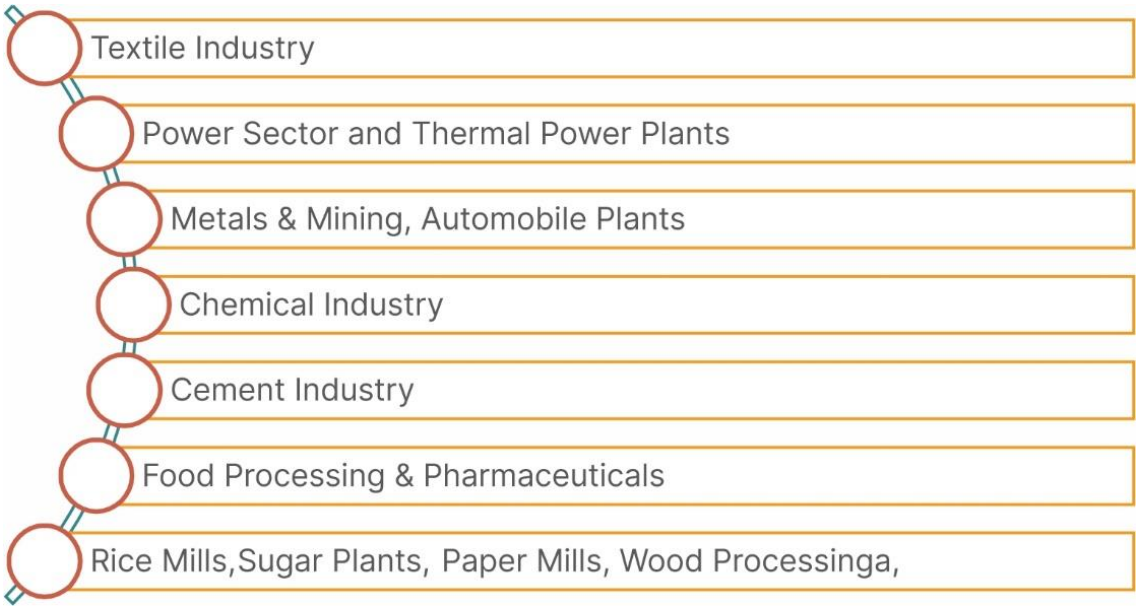
A packaged boiler can be of the water-tube or fire-tube type. It uses fuel in the form of coal, oil, natural gas, or biomass. Igniting the fuel in the combustion chamber creates an explosion inside the boiler. A fan forces air into the chamber and creates a tornado effect. The airflow creates turbulence and keeps the furnace pressurized and the flame ignited. The pressure in the boiler is controlled and the extra pressure is safely released into the outside environment. The water-tube type heats up the water inside the boiler and turns the water into steam. Meanwhile, fire-tube boilers transfer heat through physical contact. Packaged boilers usually have an internal furnace tube and include two- or three-pass fire-tube systems.



PICTURE 1: FIRE-TUBE PACKAGED BOILER

Applications

Packaged boilers have wide application in industries such as



Classification

CLASSIFICATION OF BOILERS BASED ON THE INDIAN BOILER REGULATION

1. **Indian Boiler Regulation (IBR)–compliant boilers:** In compliance with IBR regulations, these boilers exhibit a water holding capacity of 25 liters and steam pressure of 3.5 kg/cm^2. They support varying capacities, in the range of 1–1,650 tonnes/hour, and are extensively used in the automobile, pharmaceuticals, chemical, sugar, cement, and power sectors.
2. **Non-IBR boilers:** These comply in part with the IBR regulations, ensuring that either the water holding capacity or the steam pressure is kept constant. They are available in 0.05–0.85 tonnes/hour capacity, and they are widely used in both the industrial and commercial segments.

CLASSIFICATION OF BOILERS BASED ON FUEL TYPE

- **Coal-fired boilers:** Coal-fired steam boilers combust coal to produce thermal energy. Different types of coal are used in steam boilers, such as pet coal, lignite coal, sub-bituminous coal, bituminous coal, semi-bituminous coal, semi-anthracite coal, anthracite coal, and super anthracite. Anthracite is the most widely used as it produces more heat and less smoke than the other coal types.

- **Oil-fired boilers:** Oil-fired steam boilers use different types of fuel oil, including petrol, diesel, kerosene oil, artificial oil, and other fuel oils to produce hot gas by combusting the fuel in the boiler. The hot gases produced are used to evaporate water and produce steam. The advantages of oil fuels are that they have high calorific value and undergo complete combustion.
- **Gas-fired boilers:** Gaseous fuels used in steam boilers include natural gas, coke oven gas, coal gas, and producer gas. Natural gas is widely used in gas-fired steam boilers. In power generation applications, power is generated through the combustion of natural gas using the steam boiler.
- **Biomass-fired boilers:** Biomass-fired boilers use fuels obtained from agriculture, food processing waste, fuel crops, sewage sludge, and animal manure. They operate similarly to coal-fired and gas-fired steam boilers. Biomass-fired steam boilers have some advantages – renewability, reduced dependence on fossil fuels, and waste reduction – which are projected to propel the demand for them in the coming years.

2. Market Assessment

This chapter explains the approach and methodology used for data collection in this study. In particular, it outlines the data sources used to arrive at the market size, forecasted growth rate, major manufacturers, and supply chain for boilers in India.

Approach & Methodology

A robust approach comprising both primary and secondary research was adopted to collect relevant market data on packaged boilers. The data collection steps used are illustrated in Figure 1.

- **Primary research was conducted through**

    - In-depth individual interviews and interactions with manufacturers.
    - A structured questionnaire that was shared with almost all major manufacturers to collate the required information. It included questions on the following key parameters:
        - **Market data**: Boiler sales data (import/export) for the last five years based on capacity, construction type, tube type, and fuel type.
        - **Model performance data**: Model thermal efficiency data (estimated using an indirect method based on net calorific value [NCV] data as per IS 13979) along with capacity, heating area, design pressure, construction type, tube type, and fuel type.
        - **Testing lab details**: Information about in-house and third-party testing agencies used by manufacturers for performance testing of boilers.
        - **Component supply chain**: Information about the manufacturing and import of components for the manufacturing and assembly of packaged boilers.

    - Test reports of models from manufacturers:
        - Secondary research and analysis including market reports available on web-based sources. Brochures of models were collected from manufacturer websites. Data on installed boilers was collected from the Central Boiler Board website.
        - The Bureau of Energy Efficiency (BEE), in collaboration with the National Productivity Council (NPC), published a report on the market and technology of boilers (up to 10 TPH) and developed the Minimum Energy Performance Standards (MEPS) for India in 2011.

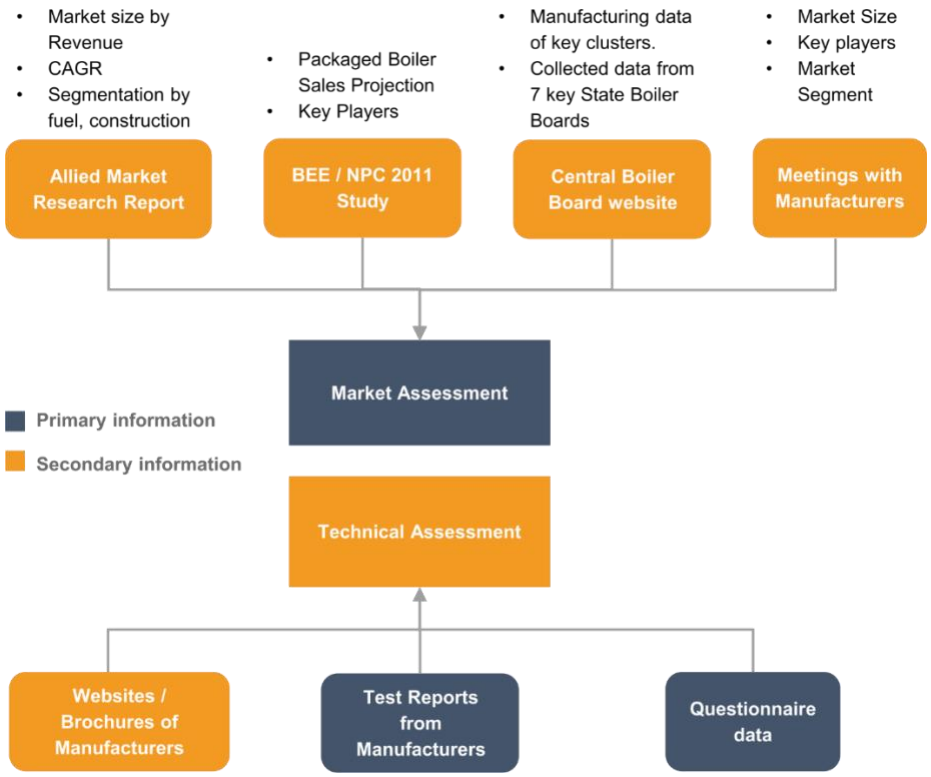


FIGURE 1: DATA COLLECTION METHODOLOGY

Market Characteristics

MARKET SIZE

The market size for packaged boilers was estimated using four sources. The final estimation of the market is based on the converging point of these sources. The findings from each data source are discussed next.

DATA FROM THE MARKET RESEARCH REPORT

The steam boiler market in India, which caters to industries such as power generation, the oil and gas sector, chemical industry, and other sectors, is expected to grow from ₹5,859 INR crore in FY19 to ₹8,831 INR crore in FY30. It is expected to have a compound annual growth rate (CAGR) of 3.8%. The data is sourced from the Allied Market Research (AMR) report.[1] The report considers the steam boiler market and covers all types of installations including packaged boilers.

PROJECTIONS FROM THE 2011 BEE-NPC STUDY

- The number of boilers below 10 TPH sold in FY10 was 1,574.

- The CAGR for FY11–20 is 3.4% as per the Index of Industrial Production (IIP) manufacturing growth rate.
- The projected sales for FY20 is around 2,200 units.

MEETINGS WITH MANUFACTURERS

- Thermax shared that the market size of the IBR boiler industry is about 2,000–2,500 units annually.
- Forbes Marshall reported that the market size of IBR boilers in India, accounting for the combined sales of oil- and gas-fired boilers, is around 500–600 units annually. Meanwhile, for solid fuel–fired boilers (including biomass), the market size is estimated to be 1,500–1,800 units annually.

BOILER INSTALLATION DATA FROM STATE BOILER BOARDS

The largest clusters of boiler manufacturing are present in Maharashtra, Gujarat, and Karnataka, representing about 90% of the market, with a total of 2,187 units manufactured in 2019. Other clusters are located in Punjab, Haryana, Delhi NCR, and Odisha. Based on this, the estimated market size of steam packaged boilers in India was around 2,400 units in 2019 (Figure 2). The expected CAGR for the boiler market in FY21–30 is ~3.8%.[2] The projected market sales for steam packaged boilers, as shown in Figure 3, is 3,617 units in 2030.

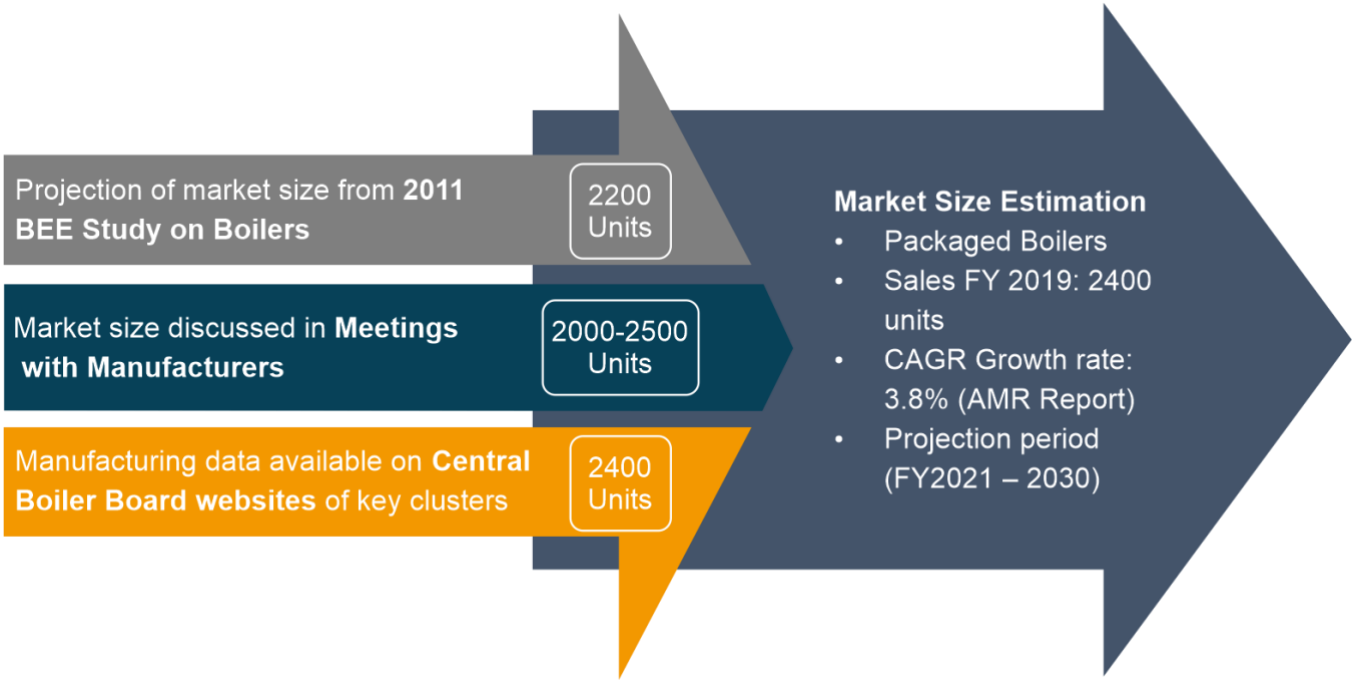


FIGURE 2: APPROACH TO ESTIMATING THE MARKET SIZE AND CAGR OF STEAM BOILERS

Key Manufacturers in the Organized Sector

The boiler industry in India is dominated by domestic players. The market is concentrated in the western and southern regions of the country, especially in Mumbai, Pune, Ahmedabad, Hyderabad, Coimbatore, and Nagpur. Discussions with manufacturers and stakeholders revealed that the packaged boiler market in India has two broad categories – IBR-compliant boilers and non-IBR boilers. The IBR-compliant boiler market comprises organized players. Based on discussions with manufacturers, the market shares of Thermax, Industrial Boilers, and Forbes Marshall are 40%, 12.5%, and 12.5%, respectively. Collectively, these three manufacturers constitute 65% of the steam boiler market in India. Other players include Transparent Systems, Elite Thermal, Cheema Boilers, Ashwini Engineering, and Pressels Pvt Ltd.

FIGURE 3: ESTIMATED PACKAGED BOILER MARKET BY VOLUME (2019–2030)

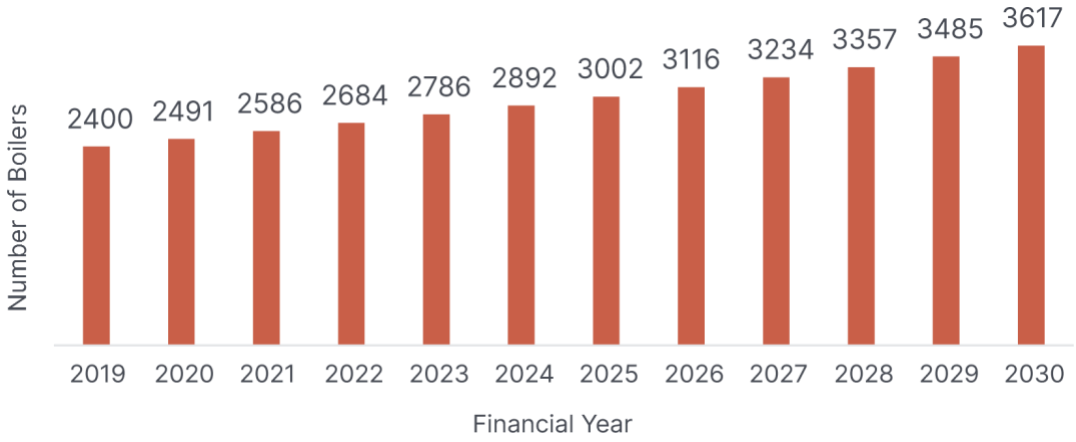


Figure 4 shows the market segmentation of packaged boilers into IBR and non-IBR boilers. IBR packaged boilers can be further classified based on the steam output in TPH.

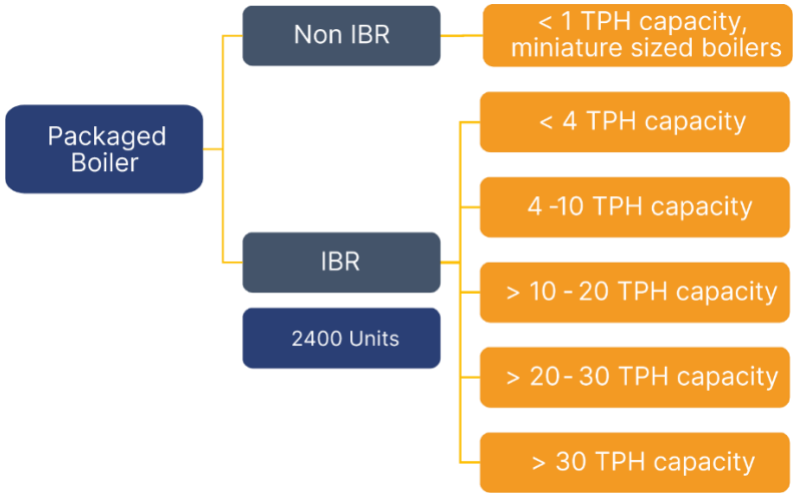


FIGURE 4: MARKET SEGMENTATION BY IBR CATEGORY AND STEAM OUTPUT (TPH)

Non-IBR boilers have a volumetric capacity of less than 25 liters and produce steam below 1 kg/cm^2 design gauge pressure and working gauge pressure. They generally have a steam output capacity of 0.05–0.5 TPH (50–500 kg/hr) and heat water below 100°C. Hundreds of MSMEs are engaged in manufacturing such boilers.

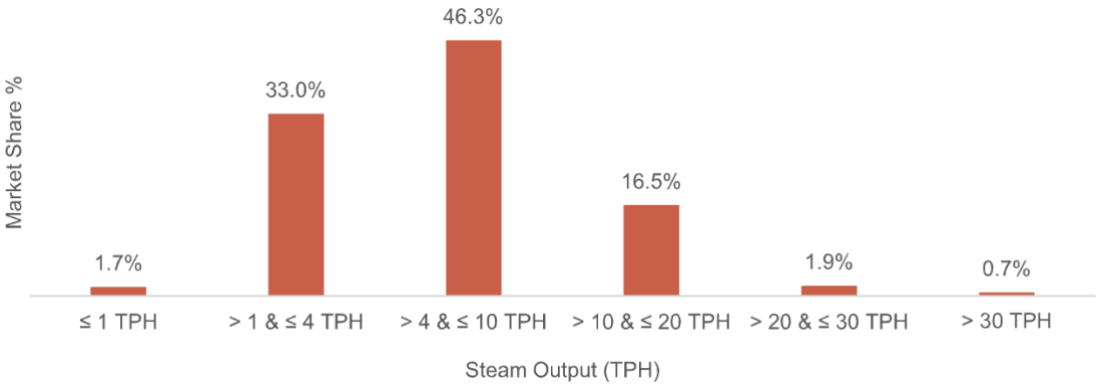


FIGURE 5: BOILER CAPACITY (STEAM OUTPUT) WISE SEGMENTATION

According to the interviewed manufacturers, about 2,400 units are sold in the IBR category and approximately 1.7% of the market falls into the non-IBR category. The market share of IBR boilers with a capacity less than 10 TPH is about 79% and that of boilers with 10–20 TPH capacity is about 16.5%.

Extent of Localization in Manufacturing and the Supply Chain

Packaged boilers' components are fabricated in-house by manufacturers or procured from local suppliers. Components such as burners, combustion chambers, heat exchangers, exhaust stacks, super heaters, and economizers are primarily manufactured in-house. Components such as circulator pumps, fans, and controls and instrumentation are generally procured from local equipment manufacturers.

TABLE 1: PROCUREMENT OF BOILER COMPONENTS

S. No.	Component	Source
1	Burner	Manufactured in-house
2	Combustion chamber	Manufactured in-house
3	Heat exchanger	Manufactured in-house
4	Exhaust stack	Manufactured in-house (designed and fabricated)
5	Super heaters	Manufactured in-house
6	Economizer	Manufactured in-house
7	Circulator pumps	Procured locally
8	Fans	Procured locally
9	Controls and instrumentation	Procured locally

3. Review of Performance Standards

This chapter reviews and compares performance test standards for boilers. The review covers both Indian and international standards. Table 2 provides the relevant standards available for boiler performance assessments.

TABLE 2: RELEVANT STANDARDS FOR BOILERS

S. No.	Standard	Published	Description
1	Indian Standard (IS) 13979	1994	Method of calculating the thermal efficiency of packaged steam boilers
2	British Standard (BS) 845-1	1987	Method for assessing the thermal performance of boilers for steam, hot water, and high temperature heat transfer fluids

Comparative Analysis of Performance Standards

Table 3 compares the two relevant standards, IS 13979 and BS 845-1. It highlights testing requirements and energy performance calculation procedures.

TABLE 3: COMPARISON OF TEST STANDARDS FOR BOILERS

S. No.	Parameters	IS 13979	BS 845-1
1	Scope	This standard describes a method of calculating the efficiency of packaged boilers using both direct and indirect methods	BS 845-1 describes a concise procedure for conducting thermal performance assessments, using the indirect (losses) procedure, to give results with a tolerance of ±2% for boilers for steam, hot water, or high temperature heat transfer fluids, and for presenting the results in tabular form. Test

S. No.	Parameters	IS 13979	BS 845-1
			results are based on either the gross calorific value (GCV) or NCV of the fuel
2	Calorific value	GCV or NCV	GCV or NCV
3	Efficiency calculation method	Direct and indirect	Indirect only
4	Test duration	Four hours for units fired by liquid and gas Six hours for units fired by solid fuels	For oil- and gas-fired boilers, a minimum test period of one hour is recommended For solid fuel–fired boilers, a minimum test period of two hours is recommended
5	Frequency of observation	15 minutes	10 minutes
6	Radiation loss estimation	Based on the table for standard boiler types	Based on the table for standard boiler types
7	Corrections	Applicable for deviations from design conditions	No provisions
8	Loss due to flue gas (divided into four components, as shown next)		
	Dry flue gas loss	✓	✓
	Loss due to hydrogen in fuel	✓	✓
	Loss due to moisture in fuel	✓	✓
	Losses due to moisture in the air	X	✓
9	Loss due to combustible in refuse	✓	✓
10	Loss due to radiation, convection, and	✓	✓

S. No.	Parameters	IS 13979	BS 845-1
	conduction from boiler surface		
11	Other losses – sensible heat loss from boiler furnace, heat recovery system, bag filter, and dust collector	✓	X
12	Loss due to unburnt gases in the flue gas	✓ (Assumed between 0.1–0.3%)	✓
13	Heat loss due to heat pickup by cooling water	✓ (Assumed between 0.1–0.3%)	X

Based on this comparison of test procedures, IS 13979:1994 is proposed as the reference standard for the development of BEE's labeling program for packaged boilers, as it is based on BS 845-1:1987 and is specific to packaged boilers. Both standards are well known to boiler manufacturers and are used in the performance testing of boilers.

Insights on Performance Testing in the Boiler Industry

- The performance of **small, packaged boilers** is generally demonstrated by **manufacturers** at the manufacturing facility. On the other hand, **large boilers**, like those installed for power generation/high-pressure requirements, are demonstrated by **third-party testing agencies at the installation site**.
- Some manufacturers have in-house infrastructure for assessing energy performance and safety testing. However, these are not accredited by the National Accreditation Board for Testing and Calibration Laboratories (NABL) or the Bureau of Indian Standards (BIS). Still, they are used to test the performance and quality of boiler models based on non-standard and internalized methods to ensure that they meet the client's requirements.
- There are three components of the performance guarantee test:
    - **Fuel and unburnt ash analysis**: Samples are collected by the manufacturer or third-party agency and the test is conducted at a NABL-accredited laboratory.

    - **Measurement equipment**: Portable instruments are used to measure the operating parameters of the boiler. This equipment has a calibration certificate from a NABL-accredited laboratory and/or one that is traceable to a NABL-accredited laboratory.
    - **Method of test**: The test runs as per the IS 13979 or BS 845 standard, as agreed between the manufacturer and customer.
- Manufacturers guarantee performance and use performance correction curves. Manufacturers use correction curves as per the test standard to correct measurement conditions, such as humidity and the fuel's calorific value, which may differ from those used in the design conditions. This is applicable only to relatively large boilers.
- The test standard specifies that variations in efficiency within 10% in the GCV is expected. However, this should be clearly declared before the testing commences.
- Boiler inspectors conduct checks related to safety aspects and provide a unique identification code for every inspected boiler. Therefore, installation and commissioning data on every installed boiler is available at the respective state boiler boards.

Testing Facilities in India

Boiler testing in India predominantly depends on third-party laboratories. Some manufacturers engage with the Petroleum Conservation Research Association (PCRA) to conduct performance testing of boilers installed at customer sites. Table 4 presents a list of independent testing agencies for boilers in India.

TABLE 4: LIST OF TESTING LABORATORIES AND CERTIFICATION AGENCIES

Testing Laboratories				
S. No.	**Name**	**Accreditation**	**Applicable Standard**	**Location**
1	TÜV Nord	NABL	IS 13979 and BS 845-1	801, Raheja Plaza-1, LBS Marg, Ghatkopar (West), Mumbai
2	Lloyd's Register	NABL	IS 13979 and BS 845-1	63–64, Kalpataru Square, 6th Floor, Kondivita Lane, Off. Andheri-Kurla Road Andheri (East), Mumbai
3	Intertek India	NABL	IS 13979 and BS 845-1	E-20, Block-B1, Mohan Co-operative Industrial Estate, Mathura Road, New Delhi

Certification Agencies				
S. No.	**Name**	**Accreditation**	**Applicable Standard**	**Location**
1	Bureau Veritas (India)	–	IS 13979 and BS 845-1	72 Business Park, 8th Floor, Marol Industrial Area, Opposite Seepz Gate No. 2, MIDC CrossRoad "C," Andheri (East), Mumbai
2	PCRA	–	IS 13979 and BS 845-1	C-5, Kesva Building, Gr Floor, Bandra Kurla Complex, Bandra (East), Mumbai

4. Review of International Labeling Programs

This chapter compares international labeling programs for boilers. The comparison covers both the MEPS and other comparative labels relevant to boilers.

Comparative Assessment of International Labeling Programs

Table 5 provides a comparative snapshot of different international labeling programs.

TABLE 5: COMPARATIVE ASSESSMENT OF INTERNATIONAL LABELING PROGRAMS FOR BOILERS

S. No.		China	United States	Canada	European Union
1	**Scope**	Stationary grate, travelling grate, FBC and oil, coal, natural gas, biomass, electricity	Oil-fired, gas-fired, hot water/steam commercial packaged boilers	Gas- and oil-fired commercial boilers	Space and combination heaters
2	**Coverage**	Industrial boilers	Commercial space heating and service water heating in buildings	Building space heating applications or for service water heating applications	Water-based central heating systems for buildings
3	**Program type**	MEPS and comparative	MEPS	MEPS	MEPS
4	**Test standard used**	CNS 2141; GB/T 10180-2003; GB 24500-2020	ANSI/AHRI Standard 1500-2015	ANSI/AHRI Standard 1500-2015	–
5	**Assessment criteria**	Thermal efficiency by indirect method on NCV basis	Thermal efficiency (ET); combustion efficiency (CE)	ET; EC	Seasonal space heating EE

S. No.		China	United States	Canada	European Union
6	**Implementing authority**	China Quality Certification Centre (CQC)	Department of Energy	Natural Resources Canada Office of Energy Efficiency	European Commission – DG Energy

The China Energy Label for Boilers

SCOPE

China's GB 24500-2020 standard defines the minimum allowable values of energy efficiency (EE) and the EE grades of industrial boilers. There are mandatory requirements for the EE of industrial boilers. The EE standard for industrial boilers in China covers the following kinds of equipment:

- Stationary boilers
- Steam boilers with a rated steam pressure of ≥0.1 MPa or <3.8 MPa
- Hot water boilers with a rated discharge pressure of ≥0.1 MPa and rated power of ≥0.1 MW
- Organic heat carrier boilers with a rated medium outlet pressure of ≥0.1 MPa
- Coal, natural gas, oil, and biomass as fuel sources, under the MEPS and efficiency grading
- Electricity as a heat source, under only the MEPS
- Both water and organic heat carriers as mediums
- Gas-fired condensing boilers – separate grading (efficiency 98–103% NCV)

LABEL TYPE & EE RATING SYSTEM

The Chinese program for industrial boilers has comparative labels. The EE grades of industrial boilers are divided into three grades. Grade 3 defines the MEPS level and Grade 1 is for the highest efficiency level.

STATUS

The GB 24500 standard for industrial boilers was first launched in 2009 and then revised in 2020.

ENERGY PERFORMANCE METRIC

The energy performance metric for industrial boilers is based on thermal efficiency (NCV basis).[1] The thermal efficiency of industrial boilers under rated conditions is tested in accordance with GB/T 10180. The thermal efficiency of gas-fired condensing boilers can be tested in accordance with NB/T 47066.

[1] Net calorific value (NCV), lower heating value (LHV), or lower calorific value (LCV) is determined by subtracting the heat of the water vapor from the higher heating value.

RATING PLAN

The rating plan for energy labels for industrial boilers in China is based on fuel type, NCV (Qnet, var), volatile content in fuel on a dry ash basis (Vdaf), and boiler capacity or duty (D) in TPH. The thermal efficiency of boilers is based on the NCV. The rating plan for industrial boilers contains the following categories, based on fuel types:

- Layered combustion coal-fired boiler fuel types: Bituminous coal, lean coal, anthracite, and lignite (Table 6).
- Fluidized bed combustion coal-fired boiler fuel types: Bituminous coal, lean coal, anthracite, and lignite (Table 7).
- Chamber-fired boiler fuel types: Natural gas (condensing/non-condensing), oil, and coal (Table 8).
- Biomass boilers (Table 9).

TABLE 6: ENERGY EFFICIENCY GRADES OF LAYERED COMBUSTION COAL-FIRED BOILERS WITH THE CHINA ENERGY LABEL

Fuel Variety & Characteristics				Energy Efficiency Grade D <20 TPH	Boiler Thermal Efficiency (%)	
					Boiler Duty (D)	
Fuel Variety		Fuel Received Based on NCV (Qnet,var) (kJ/kg)	Fuel on a Dry Ash-free, Volatile Basis (Vdaf) (%)		D >20 TPH	D <20 TPH
Bituminous coal	Type-II Type-III	17,700 ≤ Qnet, var ≤ 21,000	Vdaf > 20	Grade 1	85	86
				Grade 2	82	83
				Grade 3	80	81
		Qnet,var ≥ 21,000	Vdaf > 20	Grade 1	87	89
				Grade 2	84	86
				Grade 3	82	84
Lean coal		Qnet, var ≥ 17,700	10 < Vdaf <20	Grade 1	85	86
				Grade 2	82	83
				Grade 3	80	81
Anthracite	Type-II Type-III	Qnet, var ≥ 21,000	Vdaf < 6.5	Grade 1	85	86
				Grade 2	82	83
				Grade 3	80	81
		Qnet, var ≥ 21,000	6.5 Vdaf < 10	Grade 1	85	86
				Grade 2	82	83

Fuel Variety & Characteristics				Energy Efficiency Grade D <20 TPH	Boiler Thermal Efficiency (%)	
Fuel Variety		Fuel Received Based on NCV (Qnet,var) (kJ/kg)	Fuel on a Dry Ash-free, Volatile Basis (Vdaf) (%)		Boiler Duty (D)	
					D >20 TPH	D <20 TPH
				Grade 3	80	81
Lignite		Qnet, var ≥ 11,500	Vdaf > 37	Grade 1	85	87
				Grade 2	82	84
				Grade 3	80	82

TABLE 7: ENERGY EFFICIENCY GRADES OF FLUIDIZED BED COMBUSTION COAL-FIRED BOILERS WITH THE CHINA ENERGY LABEL

Fuel Variety & Characteristics				Energy Efficiency Grade	Boiler Thermal Efficiency NCV (%)
Fuel Variety		Fuel Received Based on NCV (Qnet,var) (kJ/kg)	Fuel on a Dry Ash-free, Volatile Basis (Vdaf) (%)		
Bituminous coal	Type-I	14,400 ≤ Qnet, var < 17,700	Vdaf > 20	Grade 1	89
				Grade 2	85
				Grade 3	82
	Type-II	17,700 ≤ Qnet, var ≤ 21,000	Vdaf > 20	Grade 1	90
				Grade 2	89
				Grade 3	86
	Type-III	Qnet, var > 21,000	Vdaf > 20	Grade 1	91
				Grade 2	90
				Grade 3	88
Lean coal		Qnet, var ≥ 17,700	10 < Vdaf <2 0	Grade 1	90
				Grade 2	88
				Grade 3	86
Anthracite	Type-II	Qnet, var ≥ 21,000	Vdaf < 6.5	Grade 1	89
				Grade 2	88
				Grade 3	86
	Type-III		6.5 < Vdaf < 10	Grade 1	90

		Qnet, var ≥ 21,000		Grade 2	88
				Grade 3	86
Lignite		Qnet, var ≥ 11,500	Vdaf > 37	Grade 1	91
				Grade 2	89
				Grade 3	86

TABLE 8: ENERGY EFFICIENCY GRADES OF CHAMBER-FIRED BOILERS WITH THE CHINA ENERGY LABEL

Fuel Variety & Characteristics		Energy Efficiency Grade	Boiler Thermal Efficiency NCV (GCV) (%)	
Fuel Variety	Fuel Received Based on NCV (Qnet, var) (kJ/kg)			
Natural gas	According to the actual test value of the fuel	Grade 1	96	103[2] (93)[3]
		Grade 2	94	101 (91)
		Grade 3	92	98 (88)
Fuel oil	According to the actual test value of the fuel	Grade 1	95	
		Grade 2	93	
		Grade 3	90	
Coal	According to the actual test value of the fuel	Grade 1	92	
		Grade 2	90	
		Grade 3	88	

TABLE 9: ENERGY EFFICIENCY GRADES OF BIOMASS BOILERS WITH THE CHINA ENERGY LABEL

Fuel Variety & Characteristics		Energy Efficiency Grade	Boiler Thermal Efficiency NCV (%)	
			Boiler Duty (D)	
Fuel Variety	Fuel Received Based on NCV (Qnet, var) (kJ/kg)		D <10 TPH	D >10 TPH
Biomass	According to the actual test value of the fuel	Grade 1	88	91
		Grade 2	84	88
		Grade 3	80	86

[2] The thermal efficiency value of each EE grade of the gas-fired condensing boiler under rated conditions.
[3] The thermal efficiency that is calculated according to the higher heating value of the fuel received.

China's Inspection and Supervision Mechanism for Boilers

The following process is used to inspect the thermal efficiency of an installed boiler in China:

- Boiler users are required to conduct efficiency tests as per standard TSG G003[4] every two years via a certified testing agency.
- As per the standard, the thermal efficiency of an in-service boiler should be greater than 90% of that of a new product. It also sets limits on the exhaust gas temperature and excess air coefficient of the boiler.
- Certified testing organizations conduct efficiency tests and provide reports to boiler users. The organizations are required to maintain fairness in testing.
- Testing organizations also conduct external inspections and efficiency tests.
- Testing organizations provide efficiency compliance certificates to boiler users and report any non-compliance to China's inspection body, the General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ).
- If the thermal efficiency of an in-service boiler is found to be less than 90% of the guaranteed thermal efficiency at the time of installation, the testing organization must report non-compliance to the regulator, the AQSIQ.
- In case of non-compliance, the AQSIQ asks the manufacturer to improve the installed boiler and conduct a re-test or discontinue the product.

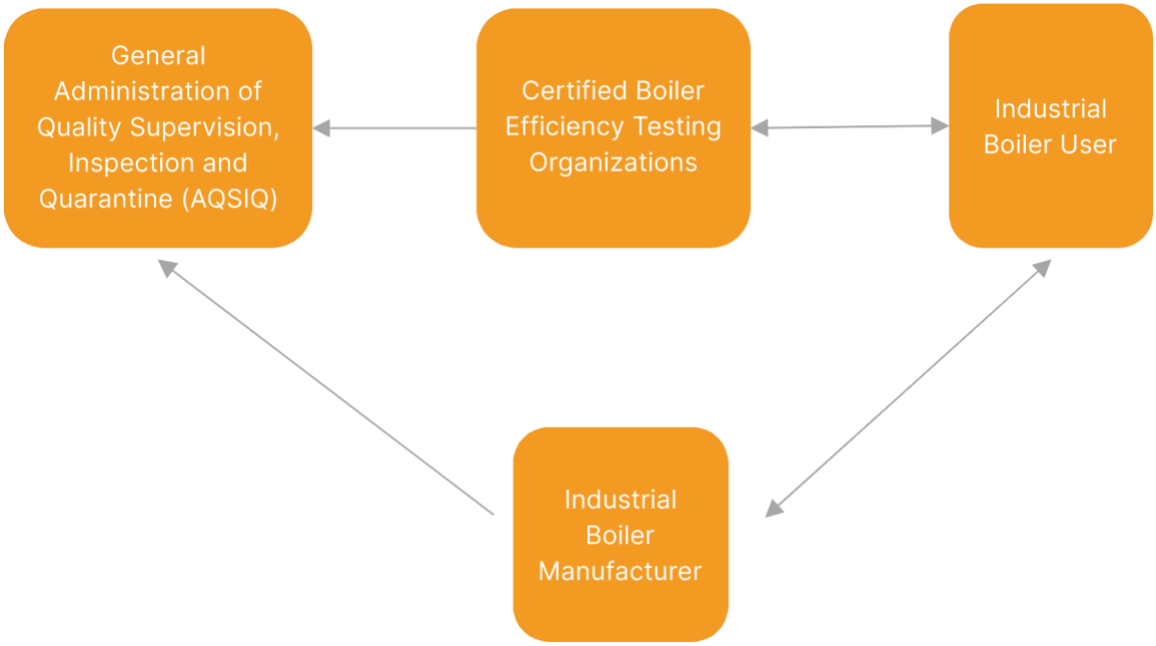


FIGURE 6: INSPECTION & SUPERVISION MECHANISM FOR BOILERS IN CHINA

[4] TSG G003 is the energy efficiency test and evaluation regulation for industrial boilers issued by the AQSIQ.

5. Energy Efficiency Metric for Star Labeling

This chapter proposes EE thresholds and other criteria for the labeling program for packaged boilers, based on energy performance data collected from various sources. The labeling program in India covers solid fuel–, biomass-, oil-, and natural gas–fired packaged boilers. The program includes packaged boilers with a capacity of up to and including 20 TPH, with or without an air pre-heater, economizer, or waste heat recovery system. Star ratings shall be allotted under the labeling program based on "thermal efficiency by indirect method on NCV basis." The thermal efficiency test shall be carried out as per IS 13979:1994.

Table 10 summarizes the thermal efficiency data collected from various sources. Key points to be noted about the thermal efficiency data used for the analysis are as follows:

- **Manufacturer data**: Data was collected from major players in the packaged boiler industry, namely, Thermax, Industrial Boilers, Forbes Marshall, Elite Thermal, and Transparent Systems. These organizations represent a market share of more than 70% in the packaged boilers segment.
- **Secondary sources**: Thermal efficiency data was collected from brochures, websites, and questionnaire data.
- **Data points**: Thermal efficiency data for 168 models was collected from secondary sources.
- **Data reliability**: The efficiency ratings provided by manufacturers are based on previously tested models.
- **Tolerance**: Almost all manufacturers declared thermal efficiency with a tolerance of ±2%.

TABLE 10: MANUFACTURER DATA ON THERMAL EFFICIENCY AND THEIR SOURCES

Manufacturer	Data Source	Thermal Efficiency Range on an NCV Basis for Different Fuels (%)						
		Oil	Natural Gas	Diesel	Lignite Coal	Indian Coal	Indonesian Coal	Biomass
Manufacturer A	Website	93–93.5	95	94	84.5	85.5	86.5	–
Manufacturer B	Questionnaire	92.6	94.5	–	–	–	85.1	84.5
Manufacturer C	Test reports/brochures	92–98	92–98	–	–	–	87	85.6
Manufacturer D	Questionnaire	92.8	92.6–96	–	–	–	87.1–88.8	85.8–89.6
Manufacturer E	Questionnaire	92.3–93. 1	–	–	–	–	–	–

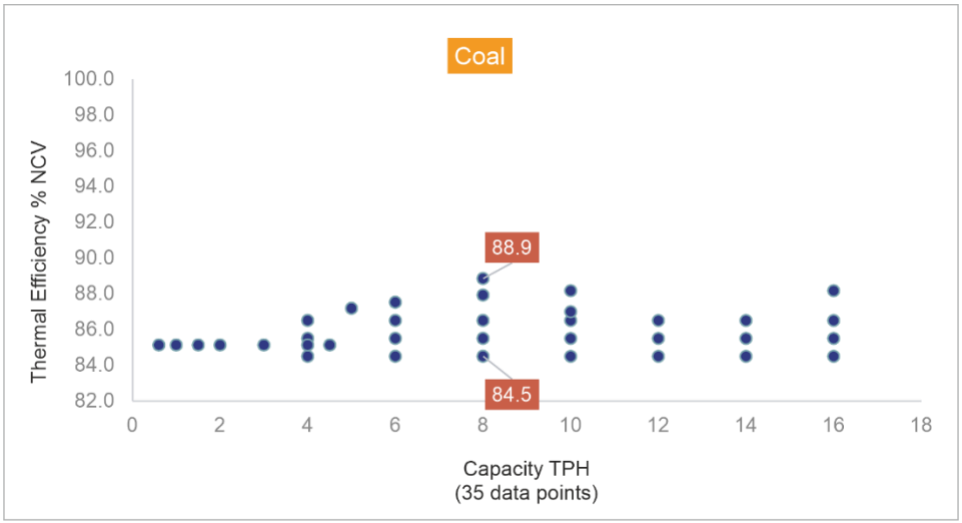


FIGURE 7: THERMAL EFFICIENCY OF COAL-FIRED BOILERS

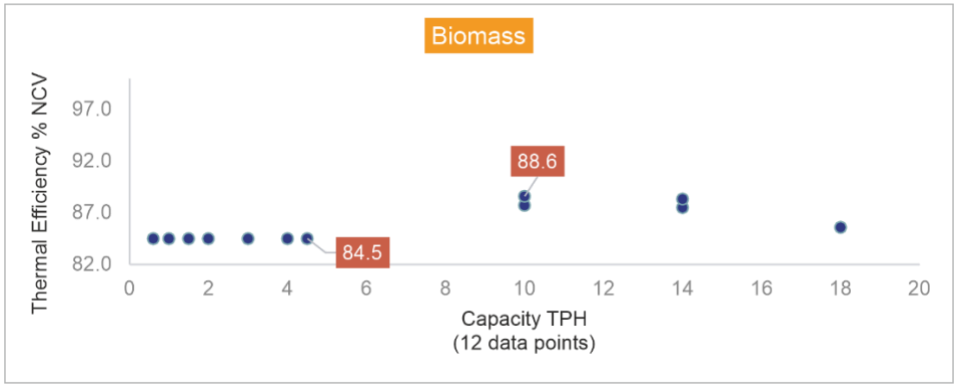


FIGURE 8: THERMAL EFFICIENCY OF BIOMASS-FIRED BOILERS

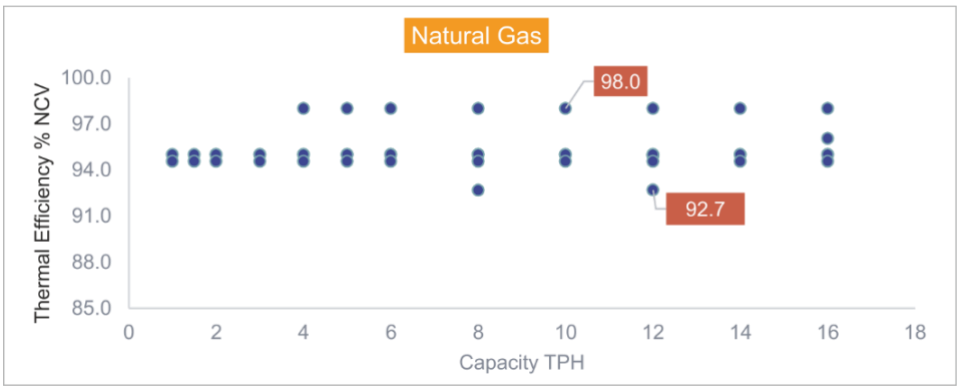


FIGURE 9: THERMAL EFFICIENCY OF NATURAL GAS–FIRED BOILERS

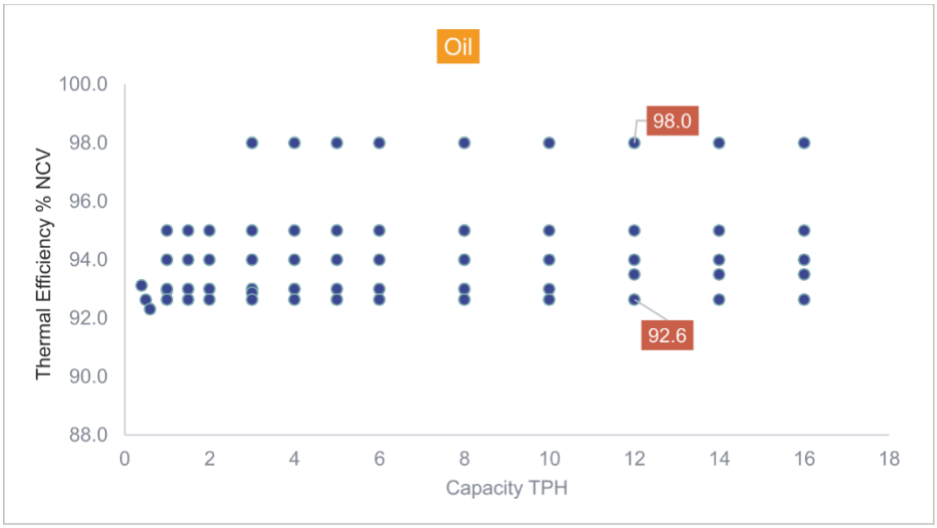


FIGURE 10: THERMAL EFFICIENCY OF OIL-FIRED BOILERS

KEY POINTS TO BE NOTED

- Non-condensing oil and natural gas boilers have an efficiency range of 92.6–95% while condensing oil and natural gas boilers have an efficiency of 96–99.5%. Higher efficiency can be achieved with economizers, air pre-heaters, and waste heat recovery.
- The thermal efficiency of steam boilers varies by 3–6% across fuel types.
- The boiler efficiencies mentioned here were taken from the brochures of manufacturers with a high market share (and high-efficiency products). Therefore, it is possible that some systems in the packaged boiler market may have efficiencies below the minimum efficiency, as mentioned in Table 11.

TABLE 11: RANGE OF THERMAL EFFICIENCY IN DATA COLLECTED

Parameter	Thermal Efficiency Range on an NCV Basis for Different Fuels (%)			
	Natural Gas/Oil (Condensing Type)	Natural Gas/Oil (Non-condensing Type)	Coal	Biomass
Minimum	96	92.6	84.5	84.5
Maximum	99.5	95	88.9	88.6
Variation in thermal efficiency	6	2.4	4.4	4.1

Thermal Efficiency Thresholds for the Star Rating of Boilers

The proposed star rating for packaged boilers based on thermal efficiency (NCV) is shown in Table 12.

TABLE 12: STAR RATING PLAN FOR PACKAGED BOILERS

Star Rating	Thermal Efficiency on NCV Basis (%)		
	Coal	Biomass	Oil & Natural Gas
1 star	≥75 and <79	≥80 and <82	≥90 and <92

2 star	≥79 and <82	≥82 and <84	≥92 and <94
3 star	≥82 and <85	≥84 and <86	≥94 and <96
4 star	≥85 and <88	≥86 and <88	≥96 and <98
5 star	≥88	≥88	≥98

KEY POINTS TO BE NOTED

- According to this rating plan, all the models of the major market players in packaged boilers will be 3 stars and above.
- The requirements for 1-star and 2 star ratings have been lowered to allow for smaller market players and MSME manufacturers with less efficient models to register for the program.
- The solid fuel rating table comprises all the different grades of coal used as fuel. Segregation by grade (calorific value) of coal is based on the availability of data.
- Condensing and non-condensing types for oil and natural gas boilers have been combined as sufficient data for each type is not available.

6. Potential Energy Savings & CO_2 Emissions Reduction

This chapter estimates the energy savings and CO_2 emissions reduction from the star rating program based on certain inputs and assumptions.

Assumptions for Energy Savings Projections

The data points and assumptions for energy savings projections are shown in Table 13.

TABLE 13: ASSUMPTIONS FOR BASELINE ENERGY CONSUMPTION AND PROJECTIONS

Baseline Data Point	Value	Remarks
Energy consumption of 0–4 TPH million TOE (2010)	0.526	This has been taken from a BEE-NPC market assessment study
Energy consumption of 4–10 TPH million TOE (2010)	0.678	This has been taken from a BEE-NPC market assessment study
Energy consumption of 10–20 TPH million TOE (2010)	0.454	Assumption based on the market share and amount of fuel used
Energy consumption of all boilers sold in million TOE (2010)	1.658	Sum of energy consumption of all boilers up to 20 TPH
Baseline energy consumption of boilers in million TOE (2022)	2.59	Based on the increase in energy consumption from 2011 to 2022
Market growth rate	3.8% (year over year) YoY	Based on the AMR report

Baseline Data Point	Value	Remarks
▪ Baseline energy consumption for boilers in 2022 is estimated based on a BEE-NPC study from 2011, considering a growth rate of 3.8% YoY. ▪ The market growth rate for boilers from 2023 to 2033 is taken as 3.8%, based on the AMR report. ▪ Energy consumption for boilers increases along with the market growth in the baseline case. ▪ Scope of efficiency improvement is taken as 5%, based on technical assessment data and learnings from scenario building in a secondary research report.[iii] ▪ Realized expected improvement potential due to market penetration of EE label boilers increases from 10% in 2024 to 100% in 2033. ▪ EE potential is taken as uniform for all boiler/fuel types.		

CO_2 Emissions Calculation

The data points used for the CO_2 emissions savings calculations are shown in Table 14. The annual baseline energy consumption for boilers in 2022 was estimated by projecting the energy consumption data from the 2011 BEE-NPC market assessment study of boilers. The annual baseline energy consumption from 2024 to 2033 is projected to have a growth rate of 3.8%, based on secondary research. The actual energy consumption was estimated using data on the scope of EE improvement and its realized potential due to the penetration of the star labeling program. The difference between the annual baseline and actual energy consumption provides the annual energy savings. Annual energy savings are multiplied by the number of years remaining in the assessment period.

TABLE 14: CO_2 EMISSIONS CALCULATION

Factors for CO_2 Emissions Calculation	Coal	Oil	Biomass	Natural Gas
Share of different fuel types (%)[iv]	41	6.30	24.50	28.20
Energy savings from different fuel types in million TOE	1.27	0.20	0.76	0.88
CO_2 emissions factors gCO_2/MJ, from a 2021 CEA report	90.6	71.9	0	49.4

Energy Savings & CO_2 Emissions Reduction

Based on the energy consumption projections and assumptions considered in Tables 13 and 14, the energy savings and corresponding CO_2 emissions reductions are presented in Table 15.

TABLE 15: CUMULATIVE ENERGY SAVINGS AND CO2 EMISSIONS REDUCTIONS FROM 2024 TO 2033

Equipment	Cumulative Energy Savings	Cumulative CO_2 Emissions Reduction
Packaged boiler	3.1 million TOE	7.23 $MtCO_2e$

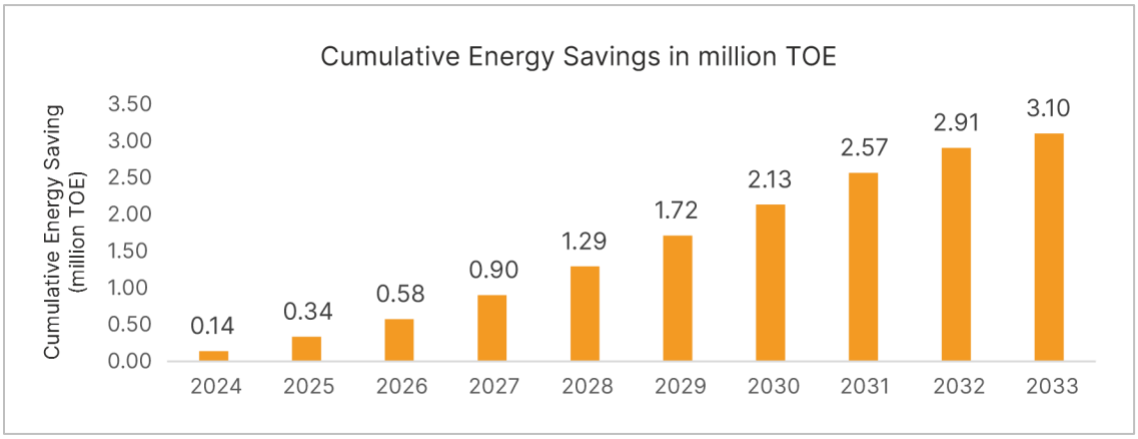


FIGURE 11: CUMULATIVE ENERGY SAVINGS IN MILLION TOE

Annexure A: Energy Savings Calculation

ENERGY CONSUMPTION ESTIMATION

Remarks	Energy Consumption Estimation	Value
Source: 2011 boiler market assessment study by BEE-NPC	Energy consumption of 0–4 TPH million TOE (2010)	0.526
Source: 2011 boiler market assessment study by BEE-NPC	Energy consumption of 4–10 TPH million TOE (2010)	0.678
Estimation: Energy consumption of 10–20 TPH boilers in 2010	Energy consumption of 10–20 TPH million TOE	0.454
Sum of energy consumption of all boilers up to 20 TPH in 2010	Total energy consumption for 0–20 TPH boilers sold in million TOE (2010)	1.66
Source: 2019 AMR report	Market growth rate (%)	3.80
Estimation: Baseline energy consumption of 0–20 TPH packaged boilers for 2022 was estimated using the total energy consumption in 2010 and multiplying it with a YoY growth rate of 3.8% from 2011 to 2022	Baseline energy consumption in boilers in million TOE (2022)	2.59

ENERGY SAVINGS ESTIMATION TILL 2033

			Voluntary Phase			Mandatory Phase						
Year	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
Baseline energy consumption of boilers (million TOE)	2.59	2.69	2.80	2.90	3.01	3.13	3.24	3.37	3.50	3.63	3.77	3.91
Technical EE potential (%)	5	5	5	5	5	5	5	5	5	5	5	5
Realized potential due to the penetration of EE labeled boilers (% of technical EE potential)	0	0	10	15	20	30	40	50	60	80	90	100
Actual energy consumption (million TOE)			2.78	2.88	2.98	3.08	3.18	3.28	3.39	3.48	3.60	3.71
Energy savings for the year (million TOE)			0.01	0.02	0.03	0.05	0.06	0.08	0.10	0.15	0.17	0.20
Years multiplier			10	9	8	7	6	5	4	3	2	1
Total energy savings (million TOE)			0.14	0.20	0.24	0.33	0.39	0.42	0.42	0.44	0.34	0.20
Cumulative energy savings (million TOE)			**0.14**	**0.34**	**0.58**	**0.90**	**1.29**	**1.72**	**2.13**	**2.57**	**2.91**	**3.10**

EMISSIONS REDUCTION ESTIMATION TILL 2033

Emissions Reduction Estimation	Coal	Oil	Biomass	Natural Gas
Energy consumption from different fuel types (%)[v]	41	6.30	24.50	28.20
Energy savings from different fuel types (million TOE)	1.27	0.20	0.76	0.88
Energy savings from different fuel types (million MJ)	53,289	8,212	31,799	36,691
Emissions factor (gCO_2/MJ)	90.6	71.9	–	49.4
Emissions reduction (million gCO_2e)	4,828,011.30	590,428.06	–	1,812,535.35
Emissions reduction ($MtCO_2e$)	4.83	0.59	–	1.81
Total emissions reduction ($MtCO_2e$)	**7.23**			

Endnotes

1. Allied Market Research Report, 2019.
2. Allied Market Research Report, 2019.
3. UNIDO, “Energy Efficiency Potentials in Industrial Steam Systems in China” (Vienna: United Nations Industrial Development Organization, 2014).
4. “Asia Pacific Industrial Boiler Market to 2027,” The Insights Partners, 2020.
5. “Asia Pacific Industrial Boiler Market to 2027,” The Insights Partners, 2020.

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