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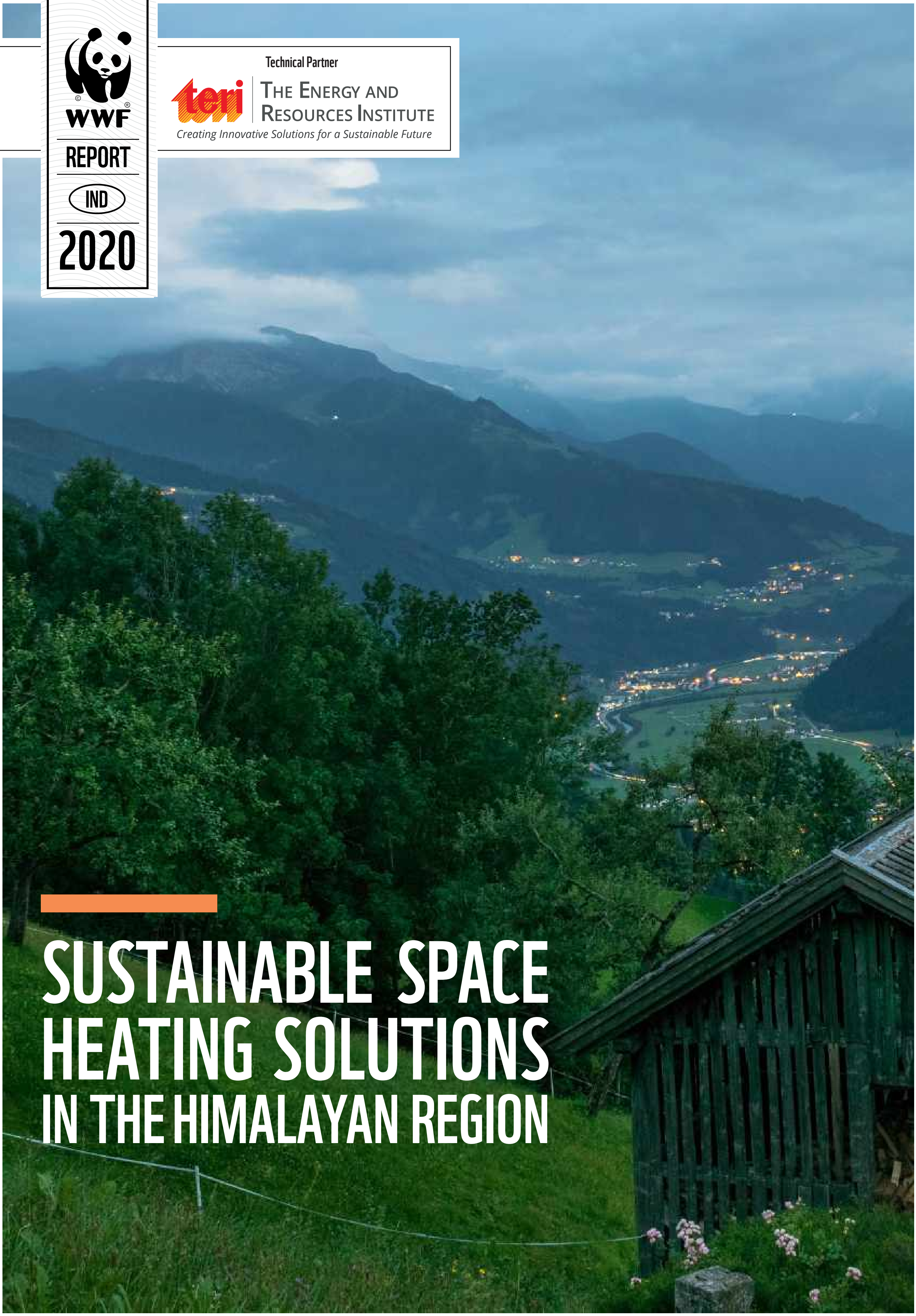

SUSTAINABLE SPACE HEATING SOLUTIONS IN THE HIMALAYAN REGION

Published by WWF-India

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Acknowledgements

WWF-India and TERI are grateful to all experts for providing insights during the preparation of this report. We also express our sincere gratitude to the government officials, experts from the academic institutes, research organizations, technology developers and innovators, for their valuable inputs that helped the study to maintain its relevance in the Indian Himalayan region (IHR) context.

We express our sincere gratitude to all the officials from various government organizations, including National Institute of Solar Energy; Department of Science and Technology, Himachal Pradesh; Himachal Pradesh State Designated Agency; Disaster Mitigation and Management Center, Uttarakhand; Department of IT Science and Technology, Arunachal Pradesh; Town and Country Planning Department, Nainital; and HIMURJA for their valuable guidance.

We would like to thank experts from IIT, Roorkee; Central Building Research Institute, Roorkee; G.B. Pant National Institute of Himalayan Environment and Sustainable Development; IIT Mandi and National Centre for Disease Control, New Delhi for their useful advice.

We are grateful to Himalayan Research Group, Himachal Pradesh; Neochlorus Energy Solutions; and Himalayan Rocket Stove for their constant support.

We would also like to convey our sincere gratitude to Mr Ravi Singh, Dr Sejal Worah and Ms Vidya Soundarajan for their support and encouragement.

The support by WWF-US and John D. and Catherine T. MacArthur Foundation is duly acknowledged.

Editorial and Design

Sushmita Ghosh, Ipshita Mitra, Rajiv Sharma, Raman Kumar Jha and Sudeep Pawar

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FOREWORD

Nature is our life-support system. WWF-India seeks to protect and restore nature for the benefit of people and the planet, supports efforts to create a stable climate and prevent wildlife extinction. The Himalayan region, due to its ecological significance, has been a priority area of focus for WWF-India. The Himalayas form the most important concentration of snow-cover outside the polar region. As part of its National Action Plan on Climate Change (NAPCC), the Government of India has launched the National Mission for Sustaining the Himalayan Ecosystem (NMSHE). This plan addresses important issues concerning Himalayan glaciers and the associated hydrological consequences; biodiversity conservation; protection of traditional knowledge societies and their livelihoods; and planning for the long term sustainable development of the Himalayan region.

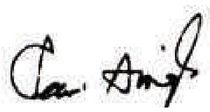
Due to the cold climate of the Himalayan region, community dependence on fuelwood to meet their energy needs is very high. This can lead to degradation of forests and emission of pollutants, causing health hazards and contributing to climate impacts. Tourism in the Himalayas also add to pressures on land, water and forest resources.

The energy needs for cooking have received considerable attention from the government, NGOs and other stakeholders. However, energy needs for space heating in the Himalayas have been largely neglected so far. Therefore, innovative technology for sustainable space heating needs to be developed and implemented across a range of climatic conditions in the Himalayas. Successful uptake of such technologies will be beneficial in many ways – from better comfort, reduced drudgery and reduced health risks, to environmental and climate benefits, while leading to an overall improvement in the quality of life.

WWF-India has been promoting climate innovation through its lead program Climate Solver. The program aims to strengthen the development and widespread use of low carbon technologies developed by small and medium enterprises (SMEs), which have the potential to significantly reduce carbon dioxide emissions or provide improved clean energy access. As part of this program, WWF-India associated with TERI, to study the energy and emission aspects related to space heating in the Himalayan region.

The study aims to identify the barriers and opportunities for sustainable space heating technologies, and provide recommendations for the various ecosystem actors to successfully support the deployment and scale-up of sustainable space heating solutions for the Himalayan region. A particular emphasis has been on the role that SMEs and startups can play in the wider roll-out of low carbon and energy efficient heating solutions catering to community needs in different regions in the Himalayas.

I am sure this report would serve as a useful knowledge resource to catalyse further action on Sustainable Space Heating in the Himalayan region.



Ravi Singh,
Secretary General & CEO,
WWF India

FOREWORD

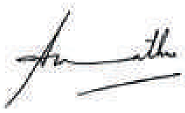
The Himalayan Region encompasses a broad spectrum of natural resources including freshwater sources, floral and faunal species, forests and ecological diversity. This region is a mélange of local climate patterns, hydrological and ecological systems. Globally, the Himalayas play an important role in atmospheric circulation, biological diversity and in the global hydrological cycle. It is the source of major rivers like the Yellow River or Hwang Ho, Yangtze, Mekong, Indus, Ganges, and Brahmaputra, and the Himalayan Mountains are often known as "Water Towers of Asia." The snow and ice of the Himalayan Region produce the largest river run-off in the world due to which they are also referred to as Earth's "Third Pole" and the Himalayan mountains are a part of the cryosphere in the Indian Sub-Continent.

The settlements located at higher altitude in the Indian Himalayan region shows a thin and dispersed human population, especially as compared to that in the plains at lower altitudes. Almost 100% villages in the region have access to electricity and cooking gas, yet there is a large gap in the usage of clean fuels, especially in rural areas. Most of the rural areas located remotely largely depend on forests for their energy requirements which are used inefficiently. Space Heating Techniques have never received the attention required to provide thermal comforts to the habitants of the region. The technologies used are hopefully obsolete and inefficient which besides contributing to the emissions of the region also have degrading impact on health of the people.

Climate change influences make the Himalayan region one of the most vulnerable ecosystems on Earth. The 'National Mission on Sustaining the Himalayan Ecosystem' (NMSHE) has been launched by Government of India as one of the eight missions under 'National Action Plan on Climate Change' (NAPCC) to understand the complex processes affecting the Himalayan eco-system and evolve suitable management and policy measures for sustaining and safeguarding the mountain ecosystem. Against this backdrop, it is imperative to divert our actions on reducing carbon emissions and improve the quality of life in Indian Himalayan Region. Sustainable space heating systems can greatly improve the comfort and well-being of people in addition to addressing the global issue of climate change and increasing emissions.

TERI has undertaken the present study on the behalf of World Wide Fund for Nature (WWF) to address issues of emissions generated from existing space heating technologies at varying altitudes and also recommend the near term and long term sustainable space heating solutions. The study also provides insights on the opportunities available for MSMEs, Innovators, NGOs and other stakeholders in shifting from the current emission-intensive use to more efficient technologies, cleaner fuels and renewable-based technologies in the future.

I would like to congratulate all participating experts for their in-depth analysis in drafting this report. I am sure that these insights would greatly benefit all stakeholders ranging from policymakers, academia and industry.



Ajay Mathur
Director General, TERI

EXECUTIVE SUMMARY

Global warming is causing a rapid rise in temperature in certain high-altitude zones, which include the Indian Himalayan region (IHR). Many glaciers in Nepal, India and China are receding at an alarming rate. Glacial melt will affect freshwater flows and have an adverse impact on biodiversity as well as human settlements and their livelihoods. Over a long term, these trends may also threaten regional food security. In conformity with the rising trends observed in global surface temperatures (0.85±0.18°C) since 1901 (IPCC 2014), the annual mean temperature in India for the period 1901–2017 has also shown a significant increasing trend of 0.66°C per 100 years. The rate of rise in the annual mean temperature is higher since the 1980s, mainly due to a sharp increase in the minimum temperatures. For the period 1981–2017, the mean, maximum and minimum temperatures increased by around 0.2°C per decade, which is higher than the trends for the period 1901–2017.[1] Unless the current emissions are radically curbed, it is possible that the future average temperatures could rise even more, as compared to the current estimates. Ice ecosystems are particularly fragile and could suffer an imbalance by such shifts in temperatures.

The IHR covers an area of about 5 lakh km^2 (16.2 per cent of the country's total geographical area) and forms the northern boundary of India. The IHR shows a small and dispersed human population as compared to the national average due to its physiographic condition and limited infrastructural development. However, the growth rate is much higher than the national average.

In 2010, India made a voluntary pledge to reduce the emissions intensity of its GDP by 20–25 per cent from 2005 levels by 2020 (excluding emissions from agriculture). In 2015, India submitted its Nationally Determined Contributions (NDCs) under the Paris Agreement, where India pushed up its target of reducing emissions intensity of its GDP by 33–35 per cent from 2005 levels by 2030. The emissions reduction through efficient space heating technologies and clean and renewable energy in the IHR can contribute significantly to the NDCs.

The present study of sustainable space heating solutions in the IHR has been carried out keeping in mind that these solutions will provide the required thermal comfort in built environment, meet the demand for space heating, while reducing CO_2 emissions, in sync with India's climate action plan.

This study focuses on the current and projected space heating energy consumption and emissions in residential and commercial/institutional buildings, and discusses potential for innovations in space heating technologies and solutions for bringing down the emissions. The study also identifies near- and long-term opportunities for space heating technologies and barriers for deployment apart from scale-up of technologies and the role of stakeholders such as NGOs, innovators, investors, end users and policymakers.

[1] MoEFCC. 2018. *India: Second Biennial Update Report to the United Nations Framework Convention on Climate Change*. Ministry of Environment, Forest and Climate Change, Government of India.

The current and future trends of CO_2 emissions are calculated based on the altitude ranges of settlements and the heating requirement, which in turn increases with higher altitudes. The study of heating requirement, fuel usage, and the duration for which heating is required was done for settlements in the altitude ranges of up to 1500m and above 1500m after consultations with research institutes such as IIT, Roorkee; Central Building Research Institute, Roorkee; G.B. Pant National Institute of Himalayan Environment and Sustainable Development; and Department of Science and Technology, Himachal Pradesh, among others, through telephonic interviews with government officials. The emissions calculated from space heating for 2020 of the entire Himalayan region is 15.9 million tonnes (MT) of CO_2. This is equivalent to cumulative emissions being generated from 27 numbers of 200MW thermal power plants or almost 1 per cent of India's overall emissions from 2005 levels – the baseline emissions for the NDCs.

The study of emissions shows, 3 per cent of the emissions from space heating comes from commercial buildings. For the remainder, about 19 per cent is recorded from residential buildings in urban areas and 78 per cent from residential buildings in rural areas. The projected scenarios in this study suggest that there is a likelihood of an increase in the share of emissions from 17.8MT CO_2 in 2030 to 18.9MT CO_2 in 2040. The northern states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand contribute to a majority of these emissions, i.e. 71.4 per cent, and about 28.6 per cent can be attributed to the Northeast states of Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya and the hill districts of West Bengal and Assam.

Focusing on the need to tackle emissions from space heating, about 26 types of existing and innovative space heating technologies in the context of the IHR have been studied. These space heating technologies were assessed for their sustainability and commercial viability. The data through primary and secondary literature were gathered for aspects such as cost, fuel consumption and emissions. Innovative technologies were distributed on the basis of energy/fuel savings and total emissions reduction. The analysis suggests, fuelwood-based technologies were used predominantly in rural areas whereas, urban households used electricity-based technologies for space heating. The inferences from the study are presented, as follows.

- Technologies such as mini Bukharis and rocket stoves have improved in terms of their efficiencies;
- LPG/PNG-based technologies have potential of reducing emissions in space heating, however, the upfront cost of these is a deterrent in their widespread adoption;
- Several renewable-based technologies can be implemented as building space heating solutions; some of these can also be used in conjunction with application for drying of agricultural produce.

This study also identifies near- and long-term space heating solutions based on the sustainability aspects of the chosen technologies. Emissions, costs, payback and overall impact of around 21 technologies were studied to identify 8 near-term and 9 long-term space heating solutions for the IHR. While the identified technologies in rural areas could be replaced by better technologies with lesser emissions, in urban areas, these technologies could not reap much benefit in terms of emissions but they did work in ensuring better indoor environment and thermal comfort. Renewable-based technologies could be adopted by inhabitants in both urban and rural areas but they would require a proper and functional backup system from grid energy in case renewable sources are unavailable.

- At higher altitudes, Bukharis and fireplaces are very common. Conventional Bukharis and fireplaces are large and have limitations in use for small households with limited space. For such scenarios, innovative mini Bukharis could work as a replacement of conventional Bukharis and, biomass briquettes could replace fuelwood, coal, etc., thereby immensely reducing the emissions.
- Solar energy-based (renewable) space heating solutions such as SolDry, evacuated tube heat pipe with fan coil unit can be a viable space heating solution in Uttarakhand, Himachal Pradesh and some parts of Jammu and Kashmir.
- Renewable-based space heating technologies are sized as per heating demand and involve equipment sets which interact with the building/space to create a comfortable environment. Some examples of such systems are solar hybrid heat pumps, parabolic solar thermal systems and SolarSheat. The building design and choice of construction material are key considerations in the operation of such systems to keep the heating demand low and control the overall cost. These systems also require suitable backup from grid energy.
- Oil-filled radiator heaters can be used in urban areas. Though these are costly, such systems ensure good indoor air quality and do not reduce the oxygen levels, unlike conventional electric blowers, and have the advantage of thermal mass coupled with thermostat control.
- Ceramic heaters are considered the safest option when compared to the more popular coil-based heaters.

The MSMEs can play an instrumental role in implementing near-term space heating solutions through their support in areas of outreach, supply chain network build-up, technology deployment, establishment of assembly/manufacturing units, etc. The near-term contributions by the MSMEs can pave the way for long-term solutions. Further, these long-term innovative solutions would require different levels of research and development support, supply and demand management for uptake.

This study also analyses how, in future, reduction in emissions can be achieved through the adoption of efficient space heating solutions in the IHR. The reduction potential of emissions by using efficient technologies for space heating is projected from current levels of **15.9MT CO_2** to **12.3MT CO_2** (30.7 per cent less than BAU) in 2030 and **14.1MT of CO_2** (25.3 per cent less than BAU) **in 2040,** respectively**.**

In the IHR, **the usage of space heating technologies is limited due to freely available biomass and other factors such as** the wide range of applications of fuelwood apart from space heating, and traditions and customs linked to the usage of fuelwood. These factors hamper the shift from conventional fuelwood-burning practice to new and clean technologies developed for space heating. The one-size-fits-all approach for the implementation of sustainable space heating solutions is the biggest barrier for remote locations such as the IHR due to their unique geographical placement and climatic conditions. With the **Indian government's current focus on infrastructural development, it would be key to concentrate on the IHR regions and residing communities that rely on fuelwood for energy needs**. Limited financial capacities of the cash-poor households and lack of awareness on the benefits and use have led to a slower than required transition from traditional fuelwood-based to more efficient and clean energy-based sustainable space heating technologies despite their availability.

MSMEs and start-ups are key enablers. However, there is a requirement of a robust institutional and implementation framework for their overall growth and success. While there are adequate innovative technologies for space heating present in the market ready to scale up, **inadequate access to capital and skilled workforce, along with dense legislation and statutory compliance are some of the major barriers**. Overall, there are limited national programmes that cater to technology innovation and very few that specifically focus on renewable-based space heating technologies. There is a need for easy access for greater funding with additional tax rebates. These should be made available to the MSMEs, innovators and start-ups working for development of environment-friendly technologies using local workforce in the IHR. This will also boost the overall development of the region by skill enhancement, job creation and reduced migration. Some of the key recommendations for the different stakeholders are as follows.

- The MSMEs based out of the IHR must co-create platforms and associations for formalization, better representation and internal connectivity. This could help them to stay abreast of the deployed technologies and gather user feedback to overcome challenges faced by innovators. This would further enable them to leverage on a network of local workforce for technology installation and maintenance.
- The IHR community should run on a self-sustainable model and develop local capacities by means of conducting capacity building and skill development programmes.
- A synergy between various stakeholders such as the MSMEs, start-ups, NGOs and academia, is imperative to develop replicable business models to deploy and scale up sustainable space heating solutions with support from the government and financial institutions.
- The state governments should develop a compendium of space heating technologies for their promotion and adoption in the respective IHR states. This would also enhance consumer confidence in the application of these technologies.

The members of several NGOs, academia and other relevant institutions can also help identify solutions unique to the region's climatic conditions and nature of settlements for wider uptake.

- There is a pressing need for developing strategies around enhanced outreach, digitization and formalization in the IHR. The creation of online MSME networking platforms would help aggregate demand and bring efficiencies to space heating technologies.

In 2018, NITI Aayog constituted the **Himalayan State Regional Council** to ensure sustainable development of the IHR. **The council was constituted with a mandate to develop, implement and monitor, and bring policy coherence to strengthen skill and entrepreneurship** with a focus on identified priority sectors among different action points. Considering the current priorities of the government and need for sustainable space heating solutions in the IHR, **there is promise for the MSMEs, innovators and start-ups to develop and mainstream sustainable technologies to reduce emissions** as well as create renewable solutions for the region.

This study aims to provide valuable inputs to the national and state governments, MSMEs and other stakeholders such as NGOs, research institutes on reduction of emissions, improved accessibility, and easy affordability of clean energy and renewable solutions in the Indian Himalayan region.

INTRODUCTION

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1.1 BACKGROUND

The Indian Himalayan Region (IHR) is a vast, diverse and the youngest mountain system on earth. The social, cultural and environmental setup of the Himalayas is as unique as its geography and geology. The IHR (see Figure 1) is spread over an area of 2500km in length and 80–300km in width (Valdiya 1977). Geographically, the IHR is divided into three parts, namely: 1) the Great Himalayas, 2) the Inner Himalayas – also known as the middle or lesser Himalayas – and 3) the Sub-Himalayan Foothills and the adjacent Terai and Daur plains (Karan 1966). The Great Himalayan region is one of the few remaining isolated and inaccessible regions in the world. Some high valleys in the Great Himalayas are occupied by small clustered settlements. Most of the settlements are located in the Inner Himalayas. The Inner Himalayas have remarkable uniformity in terms of height (1800–3100m) with complex mosaic of forest-covered ranges and intervening fertile valleys. These settlements are generally moderately populated except for major valley centres such as Srinagar and Kangra along with popular hill stations because of concentrated tourist activity. Some of the major hill stations in the IHR are Shimla, Nainital, Manali, Darjeeling, Gangtok, Srinagar, Shillong and Dharamshala. The Sub-Himalayas form the outermost and lowest zones of the Himalayas. These are characterized by longitudinal flat-bottomed valleys called “duns” and plains known as Terai and Duars.

There are 10 Indian states which cover the IHR (see Table 1), namely, Jammu and Kashmir (J&K), Himachal Pradesh (HP), Uttarakhand (UT) in North India and Sikkim (SK), Arunachal Pradesh (AR), Nagaland (NG), Manipur (MN), Mizoram (MZ), Tripura (TR) and Meghalaya (MG) in Northeast India. Additionally, there are hill districts of West Bengal, namely, Darjeeling, and the hill districts of Assam – North Cachar Hills and Karbi Anglong – which form an essential part of the IHR.

The IHR has a population of 44 million (Anon. 2011) living at varying altitudes and in tough environmental conditions. With an increase in altitudes the temperature decreases resulting in increase in the demand for space heating in buildings. Population distribution and settlement patterns in the IHR are greatly influenced by the variations in relief and climate. A large population in the Himalayas lives in remote settlements, with limited access to local markets and motorable roads. As per 2011 census data, the majority of the settlements depend on electricity as the only source of lighting, whereas, the occupants in rural settlements primarily use biomass for space heating and cooking. In large cities and towns, the use of electrical appliances for heating is prominent and LPG is used for cooking.

In recent years, the government has been working to provide clean fuels, i.e. electricity and LPG. In urban areas, clean energy has made significant penetration; however, in rural areas the uptake of clean fuels is limited. People residing in the IHR have access to biomass – available freely – and it is being used at a larger scale in the region.

Figure 1 Indian Himalayan region

Source *National Mission of Himalayan Studies (2020)*

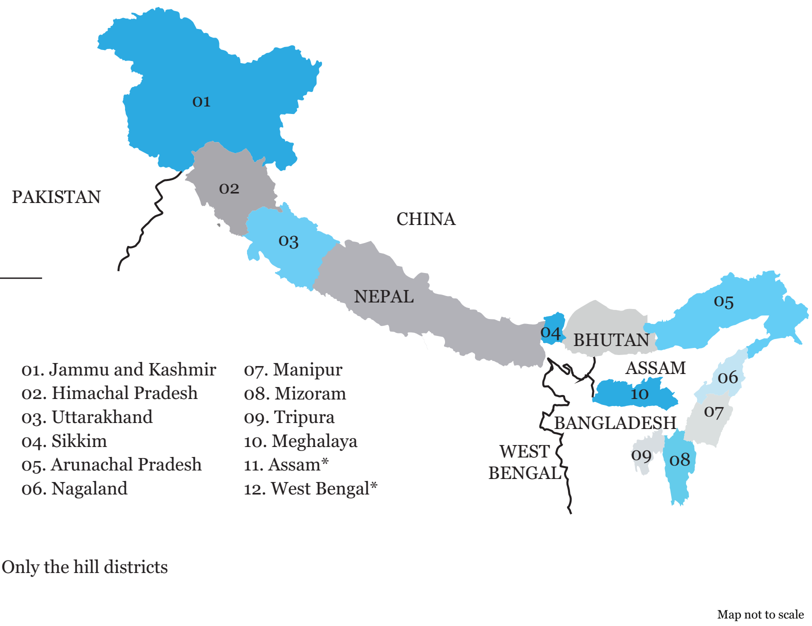


Table1: Comparison between area and population of different states in IHR

States in IHR	% share of geographical area in IHR (2020)	% share of population in IHR[2] (2020)
Jammu and Kashmir **	41.65	28.1
Himachal Pradesh	10.43	15.2
Uttarakhand	10.02	23.2
Sikkim	1.33	1.4
West Bengal hill districts	0.59	0.3*
Meghalaya	4.2	6.7
Assam hill districts	2.87	0.3*
Tripura	1.97	8.3
Mizoram	3.95	2.5
Manipur	4.18	6.5
Nagaland	3.11	4.5
Arunachal Pradesh	15.69	3.1

**Projected population of the hill districts for 2020 are calculated from the 2011 census data as per decadal population growth rate of the state (see Annexure 1)*
*** Union Territory of Jammu and Kashmir and Ladakh*

[2] As per population census 2011

There are many studies on the use of fuelwood in the IHR but studies on emissions specifically from space heating have not been done earlier. In the IHR, the reported use of biomass as a cooking fuel also serves an additional purpose of heating in the middle- and high-altitude regions of the Himalayas (Wester, Mishra, Mukherji, et al. 2019). This is true for rural settlements in the IHR. As per 2011 census data (see Table 2), in 85 per cent of the households in rural areas of the IHR, cooking takes place within the houses, out of which a majority (i.e. 78 per cent) uses biomass or fuelwood (Anon. 2011).

In urban areas, the primary source for cooking is either LPG or PNG while heating is done primarily by electrical appliances. Only 28 per cent of households in urban areas use fuelwood for their energy needs.

Table 2: Fuel usage in IHR households

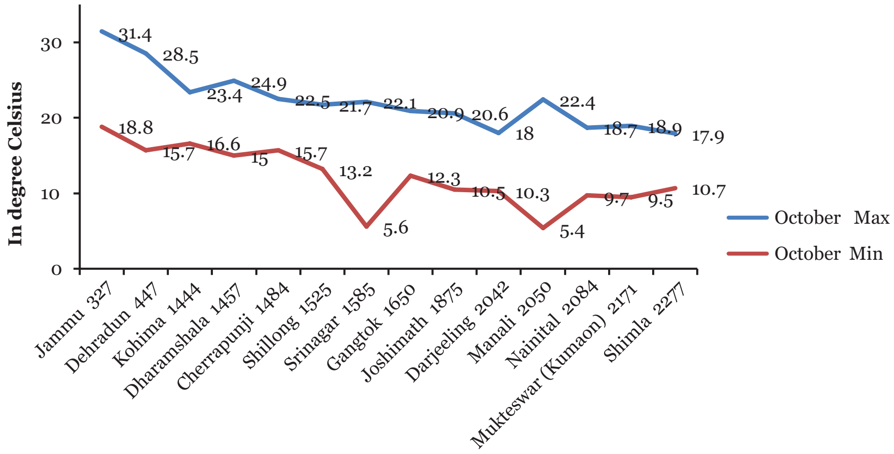
	Fuelwood	Crop residue	Cow dung cake	Coal, charcoal	Kerosene	LPG/ PNG	Electricity	Any other
Rural households	73%	2%	2%	0%	1%	22%	0%	0%
Urban households	28%	1%	1%	1%	5%	64%	1%	0%

Source (Census 2011)

Cooking consumes 37.2 per cent of the total fuelwood energy, irrespective of altitudinal variations, followed by space heating (19.4 per cent) in the western Himalayas (Bhatt, Rathore, Lemtur, et al. 2016). Several studies were conducted in the representative settlements at different altitudes to examine the use of biomass in different areas of the IHR. A summary of the findings is included in Annexure 2. These studies were also done in Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh and Meghalaya. The results of the earlier studies have been used in the present study to evaluate the amounts of fuel used for space heating.

A pattern was observed in the temperature profiles of those settlements located at different altitudes and latitudes. As a general observation, it was found that temperatures reduced with increasing altitudes. This is why, the eastern Himalayas, which are situated at a lower altitude than the western Himalayas, are relatively warmer.

Figure 2 shows the maximum and minimum temperatures (°C) recorded in the months of October, December, February and March for important settlements in the IHR.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18
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9.7
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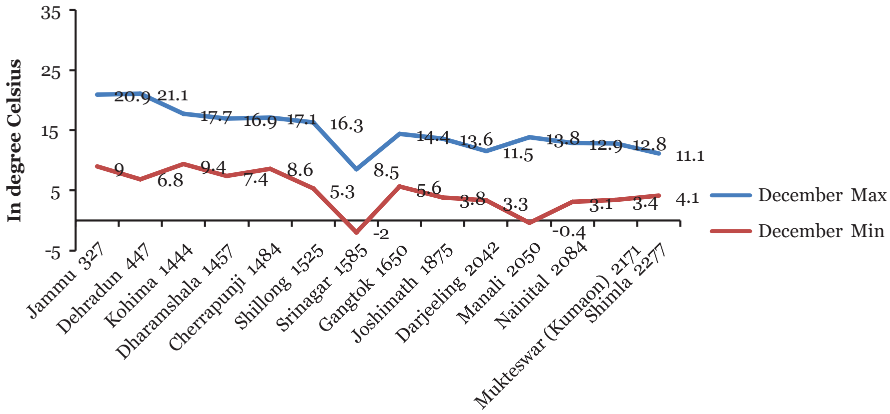
October Max
October Min
Jammu 327
Dehradun 447
Kohima 1444
Dharamshala 1457
Cherrapunji 1484
Shillong 1525
Srinagar 1585
Gangtok 1650
Joshimath 1875
Darjeeling 2042
Manali 2050
Nainital 2084
Mukteswar (Kumaon) 2171
Shimla 2277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December Max
December Min
Jammu 327
Dehradun 447
Kohima 1444
Dharamshala 1457
Cherrapunji 1484
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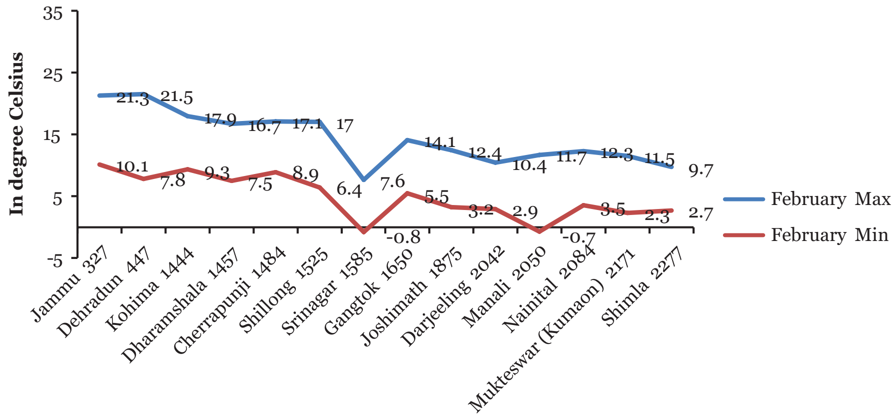
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February Max
February Min
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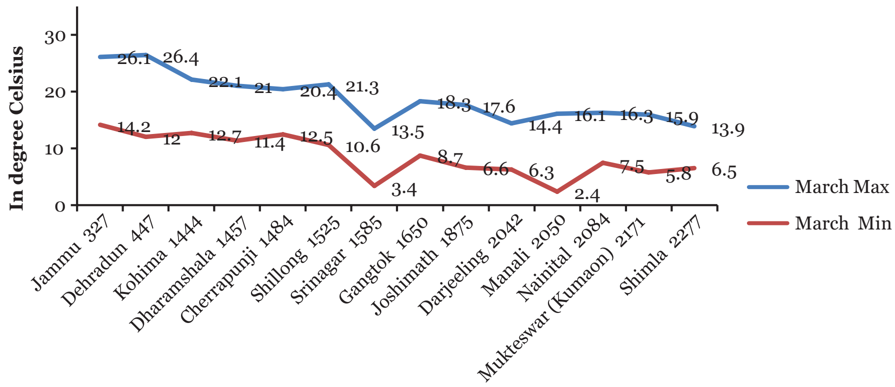
Dehradun 447
Kohima 1444
Dharamshala 1457
Cherrapunji 1484
Shillong 1525
Srinagar 1585
Gangtok 1650
Joshimath 1875
Darjeeling 2042
Manali 2050
Nainital 2084
Mukteswar (Kumaon) 2171
Shimla 2277

Figure 2 Maximum and minimum temperatures of important settlements in IHR during winter



It can be observed that the average minimum temperature for the month of October, recorded in Dharamshala at an elevation of 1457m, was 16.6°C. In the same month, the minimum temperature in Shimla – located at an elevation of 2271m – was about 10.7°C. For the average maximum temperature for the month of October, Dharamshala recorded 24.9°C and in Shimla, it was 17.9°C. A reducing trend could be seen as the height of the settlement increased. The analysis of the weather data is important as it determines the duration of the heating period. In this study, the analysis for identification of duration of winters at different altitudes was verified through interactions with research organizations working in the IHR.

Low temperatures were recorded for settlements situated at an altitude of 1500m and above (e.g. Srinagar, Gangtok and Joshimath) in October (maximum average monthly temperature was in the range of 20–22°C). The same temperature range was seen for settlements at lower altitudes (e.g. Jammu and Dehradun) much later in the month of December. Similarly, during the retreating winter season, at lower altitudes, the maximum average monthly temperature reached 20–22°C in February, whereas, the upper altitude settlements reached this temperature range only after March.

Local relief and location determine climatic variation not only in different parts of the Himalayas but even on different slopes of the same range. Once the sun goes down, there is a possibility of drastic changes in comfort levels. Wind also played an important role in providing comfort during the day (Chatterjee and Bishop 2019).

The distribution of population in the IHR is presented in Table 3. Almost 28.8 per cent of population living at altitudes greater than 1500m is exposed to more severe winter conditions for longer durations than the remaining 71.2 per cent of population living at lower altitude ranges.

Table 3: Altitude range of settlements in IHR and population (%)

	Up to 500m	500–1500m	1500–2500m	2500m and above
Population '000	15,670	18,699	12,709	1,190
% of population	32.5	38.7	26.3	2.5

Villagers consume more energy due to severe cold conditions in winter. As a result, the per capita consumption of fuelwood for heating increases with elevation of settlements. The inhabitants also required more time for cooking and heating because of low temperatures, further leading to more consumption of fuelwood (Kumar and Kumar 2015; Kumar and Garg 2014; Bhatt, Negi and Todaria 1994; Bhatt and Sachan 2004). This holds true even for commercial/institutional buildings. Commercial/institutional buildings, located at higher altitudes, require more heating and for longer durations. It may also be noted that establishments and educational institutions are mostly occupied during daytime, whereas hotels and hospitals are 24-hour occupancy buildings, whereby the heating demand varies as peak heating requirements during the night are higher than daytime. In commercial buildings, other than small establishments, the only source of heating is electricity. The establishments in rural areas often use wood for heating purposes. Rather than having individual heating equipment in shops, a community heating spot is created to cater to groups of 8–10 shops. Figures 3 and 4 show the temperature profiles of two cities – Dehradun and Nainital – at an altitude range of up to 1500m and above 1500m.

Figure 3: Temperature profile for Dehradun

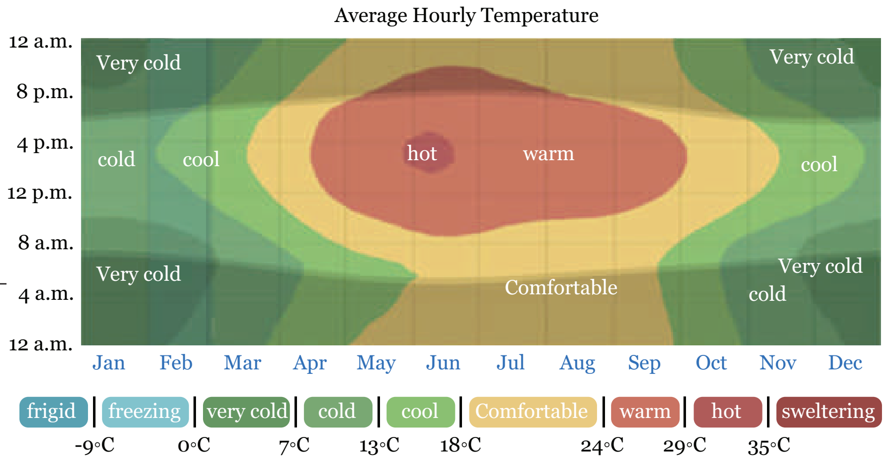
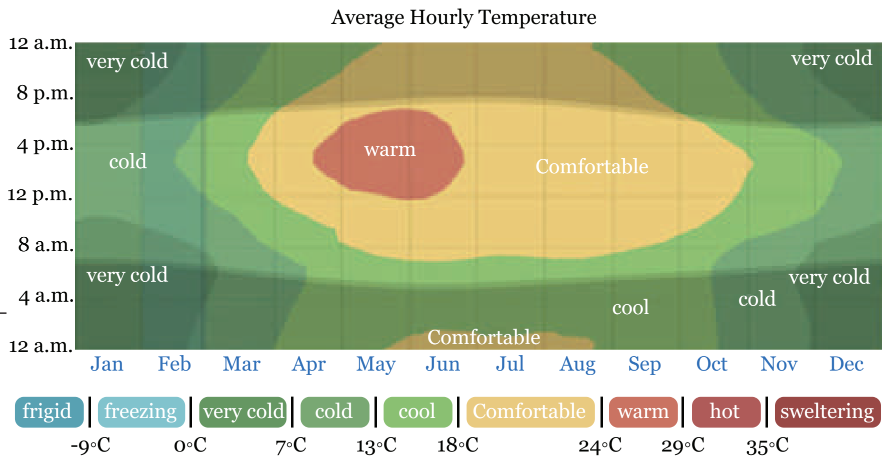


Figure 4: Temperature profile for Nainital

Image source *Weatherspark (2020)*



The duration of cold conditions in winter can be understood through the representation of temperatures at different times of year and day. At a lower altitude such as Dehradun, winter commences from late November. During the day, the duration of cold lasts from late afternoon to late morning. At daytime, the temperatures remain moderate, comfortable for the people. At a higher altitude such as Nainital, in winter, the duration of cold lasts longer through the year.

Another factor to be considered for the use of sustainable space heating solutions in the IHR is the building itself. The materials for construction used in traditional buildings of the IHR are varied. The traditional techniques range from lightweight construction to heavyweight construction. The modern buildings are mostly reinforced cement concrete (RCC) framed structures with bricks as infill material of wall.

The variation in usage of building materials is also evident in the buildings being constructed in rural areas in different regions of the IHR. There are various traditional construction techniques for walling. For instance, Kathi-Kuni and Koti Banal use stone and timber for wall constructions, Dhajji-Dewari (patch quilt wall) employs the use of timber stone and mud, and the Taaq system of indigenous construction uses timber, brick, unburnt bricks and dry stone (Kumar and Garg 2014). The roofs in the southern part of the Himalayas mostly have slopes due to the use of tiles, thatch, slate, while galvanized iron metal/asbestos sheets are prevalent in the Northeast states (Anon. 2011). In the cold desert regions of Ladakh, flat roofs are constructed with prominent use of stone and sun-dried bricks. Generally, with an increase in altitude, the use of panelling of timber on walls, floors and wooden internal partitions also increases. The heating demand of the buildings in this region varies depending on the altitude of the location, infiltration, thermal mass of the envelope and the socio-economic status of the occupants. Mostly, the heating needs are met by the use of fuelwood as it is the cheapest and most accessible fuel source for the main population in rural areas.

The United Nations' Sustainable Development Goal (SDG) 7 – "Ensuring access to affordable, reliable, sustainable and modern energy for all" – was studied in greater detail to meet future energy needs of the Hindu Kush Himalaya by ICIMOD in 2019. Based on the findings, it could be inferred that in the IHR too, energy provisioning must be done keeping in mind the mountainous terrain, which is characterized by low densities of population, low incomes, dispersed populations, grossly underdeveloped markets, low capabilities and poor economies of scale. As per the study of SDG 7, its 3 targets could be customized for the IHR. Box 1 highlights the importance of these targets for ensuring energy security.

Box 1 Customized SDG 7 targets for IHR (Wester, Mishra, Mukherji, et al. 2019)		
SDG 7: "Ensuring access to affordable, reliable, sustainable and modern energy for all"		
Target 7.1—"By 2030, ensure universal access to affordable, reliable and modern energy services." The Hindu Kush Himalaya (HKH) needs a multi-tier, mountain-specific assessment framework that captures improved quantity, quality and reliability of electricity supply. This should ensure the availability, efficiency, affordability, safety, health (reduced emissions of short-lived climate pollutants [SLCPs]), and convenience (reduced drudgery for women and children) of modern, clean cooking facilities, and allow progress on energy poverty to be more visible and measurable for national, regional and global public policymakers.	Target 7.2—"By 2030, increase substantially the share of renewable energy in the global energy mix." The objective could be to move toward a fossil fuel-free and energy-efficient future. Such renewable energy, in both centralized and decentralized forms, must serve local populations and meet their demands and fuel growth. Given the low current consumption levels, and the opportunity to provide customized energy, the objective of governments should be to meet all the energy demands of the region.	Target 7.3—"By 2030, double the global rate of improvement in energy efficiency." Policies should focus on the traditionally biomass-dependent residential sector, which has the highest energy use but the lowest energy efficiency. Each country should develop mountain-specific energy efficiency indicators (and should not use energy intensity as a proxy, a practice that can generate misleading results). These indicators should use final energy demand, at the most disaggregated end-use level, to accurately reflect energy efficiency improvements and to monitor progress towards the target.

The Indian government has already established programmes to promote clean energy in the IHR including uptake of renewable energy. In rural Himalayan settlements, commercial energy is generally beyond the reach of ordinary people due to their socio-economic conditions, lack of communication facilities, increasing prices and limited supply of reliable energy. The cost of renewable energy-based solutions is also prohibitively high. Therefore, a large percentage of population living in rural areas of the IHR depends entirely on the forests to fulfil the energy demands and needs.

Presently, the greater rate of cutting of trees than the recovery rate is causing massive deterioration of forests due to over exploitation, leading to associated hardship for rural residents (Bhatt and Sachan 2004). Due to population growth, forests have diminished and are now inaccessible to villagers, who would earlier get fuelwood easily, freely available in their immediate surroundings. As a result, sometimes, the womenfolk and children have to wander for many kilometres in search of unguarded trees of common ownership. Consequently, fuelwood has become too expensive because, now, it has to be transported over long distances. The time and effort required to collect fuelwood have increased considerably and as a result, less attention is being paid to other productive work (Bhatt and Sachan 2004).

Heavy reliance on traditional solid fuel entrenches poverty, erodes indoor air quality and affects environmental sustainability. Caught between poverty and environmental degradation, mountain communities find it increasingly difficult to meet their daily energy service needs in a sustainable manner (Wester, Mishra, Mukherji, et al. 2019). In 1996, the Supreme Court of India gave orders prohibiting the felling of trees in the Himalayas to protect the biodiversity and fragile ecosystem of the region.

However, studies carried out by the National Mission of Himalayan Studies in the last decade have established a close linkage between deforestation and energy demands of the occupants of the IHR. Higher consumption of fuelwood is mainly attributed to the lack of unconventional energy sources (Bhatt, Rathore, Lemtur, et al. 2016). Therefore, there is an urgent need to create demand for alternative technologies to ensure more efficient use of biomass and cleaner fuels in the IHR.

In the future, energy poverty must be minimized. A significant change in this regard could be prompted by using modern technologies that increase the efficiency of fuelwood, which is still the most important source of energy for cooking and heating purposes for the mountain-folk. This will also decrease the related carbon emissions (Wester, Mishra, Mukherji, et al. 2019). There are several technologies of space heating that are already mature and commercially available. These range from low-cost, simple product-based to high-cost sophisticated technologies. These technologies have different market segments considering the urban-rural divide, affordability of solutions, complexity of design, maintenance aspects and accessibility to markets among other factors. These are further influenced by prevailing traditions, values, norms and the social structure.

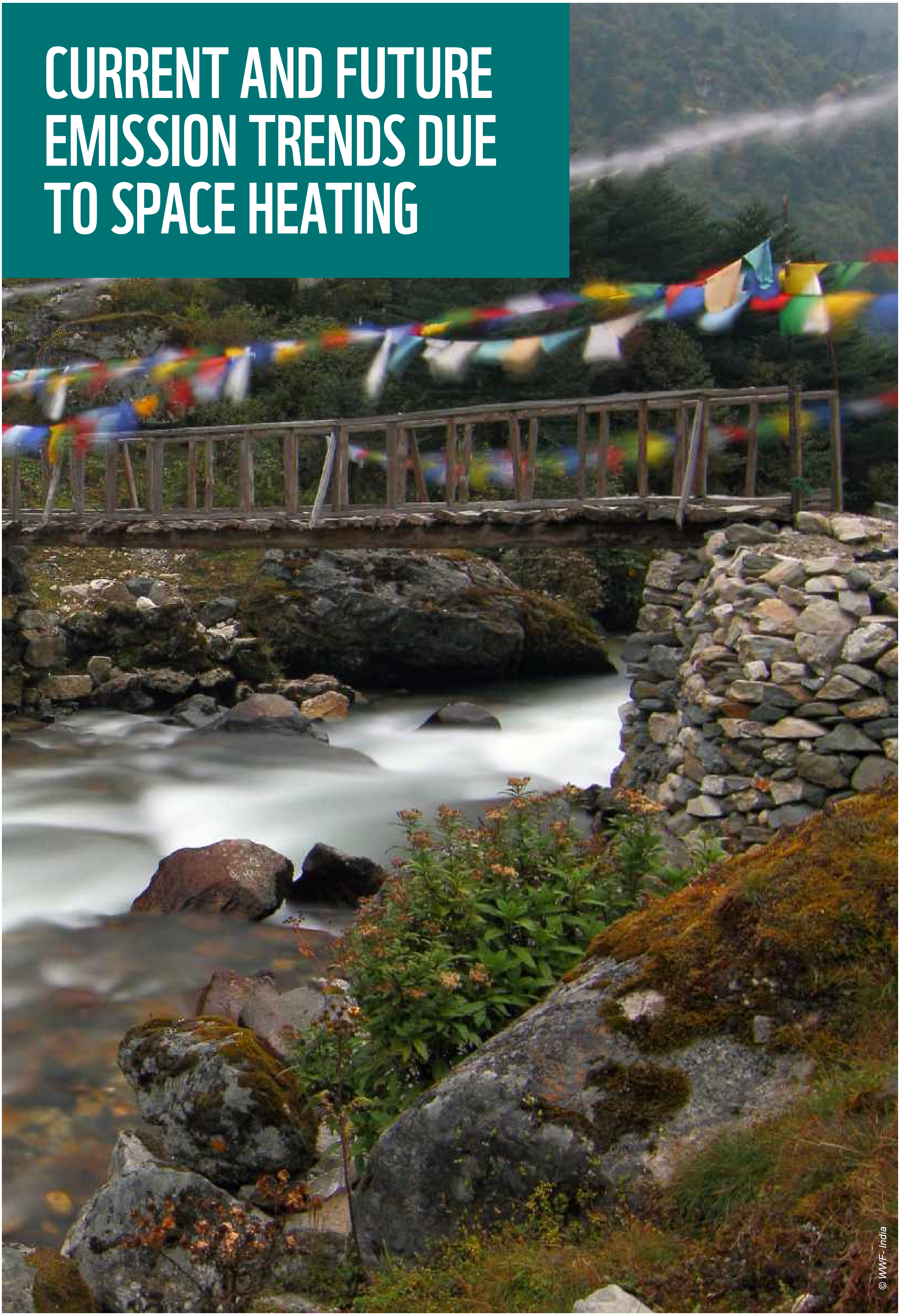
The present study focuses on identifying potential markets for specific existing and innovative technologies and the impact that they will have on emissions reduction in the near future. The study also provides recommendations on how Indian ecosystem actors (innovators, investors, end-user companies, NGOs and policymakers) can support the deployment and scale-up of sustainable space heating solutions in buildings within the context of mainstreaming sustainability in the IHR.

In 2019, NITI Aayog constituted Himalayan State Regional Council to ensure sustainable development of the IHR. The Himalayan State Regional Council is chaired by a member of NITI Aayog and comprises the chief secretaries of the Himalayan states, secretaries of key central ministries, senior officers of NITI Aayog and special invitees. The council was constituted with a mandate to develop, implement and monitor, and bring policy coherence to strengthen skill and entrepreneurship with a focus on identified priority sectors among different action points.

Considering the current priorities of the government and the need for sustainable space heating solutions in the IHR, there is an immense opportunity for the micro, small and medium enterprises (MSMEs), innovators and start-ups to develop mainstream technologies with reduced emissions and seek renewable energy-based solutions. The present study also focuses on the conditions of different states in the IHR, which will help identify potential markets for efficient space heating technologies and interventions required for improvement in energy security. Better indoor environments, emissions reduction and opportunities for improved living conditions and livelihoods are some of the key areas to ensure energy security. The following segment highlights the objectives of this study.

- Assess the current and projected space heating emissions and energy consumption in residential and commercial/institutional buildings to understand climate change linkages, and examine the potential market size for innovations in space heating in India;
- Review the status, potential and do a comparative analysis of sustainable space heating technology solutions with reference to residential and commercial/ institutional buildings, and further identify the near- and long-term barriers to their deployment and scale-up;
- Provide recommendations on how Indian ecosystem actors (innovators, investors, end-user companies, NGOs and policymakers) can support the deployment and scale-up of sustainable space heating solutions in buildings.

CURRENT AND FUTURE EMISSION TRENDS DUE TO SPACE HEATING



The fragile landscapes of the Himalayan region are highly susceptible to natural hazards. There is ongoing concern over the current and potential climate change risks such as floods, droughts and landslides, loss of biodiversity and threats to food security. In order to realise India's vision of sustainable development in the context of climate change, a National Action Plan on Climate Change was launched in June 2008. The National Action Plan specified eight objectives, including "National Mission for Sustaining the Himalayan Ecosystems" and "National Mission on Strategic Knowledge for Climate Change". These missions focus on the management of measures to ensure the sustenance and safeguarding of mountain ecosystems.

The IHR's population, which stands at 48.5 million in 2020, is projected to increase to 56.3 million in the next 20 years, according to a 2019 National Commission on Population report. The relationship between human population growth, expanding area under subsistence crops and increase in livestock numbers is interlinked to intensifying demands for forest resources. Therefore, to supply animal fodder and fuelwood, and land for farming, additional demands on the forest produce include the need for materials for making wooden implements, such as house thatch, and so on (Ives and Messerli 1989). In the IHR, fuelwood is considered one of the primary forest resources and its corresponding demand affects energy security. It not only contributes to emissions but also adds to the overall impact of climate change while altering the ecological balance in the IHR.

In 2015, India submitted its nationally determined contributions (NDCs) under the Paris Agreement, where India voluntarily pushed up its target of reducing the emissions intensity of its GDP by 33-35 per cent by 2030, bringing it below 2005 levels. The contribution of emissions reduction through energy efficiency in heating is important. Thus, the IHR, where the major source of heating is still biomass, especially in rural areas, provides major opportunities for increasing energy efficiency. In order to shift to cleaner energy sources or improved technologies for heating, it is vital to make an assessment of the current emissions and the projected emissions as a result of population growth and urbanization. This will help in selecting efficient technologies for reduction in emissions, thereby contributing to the security of mountain ecosystems by shedding light on the requirement for sustainable policies and the need to mainstream them.

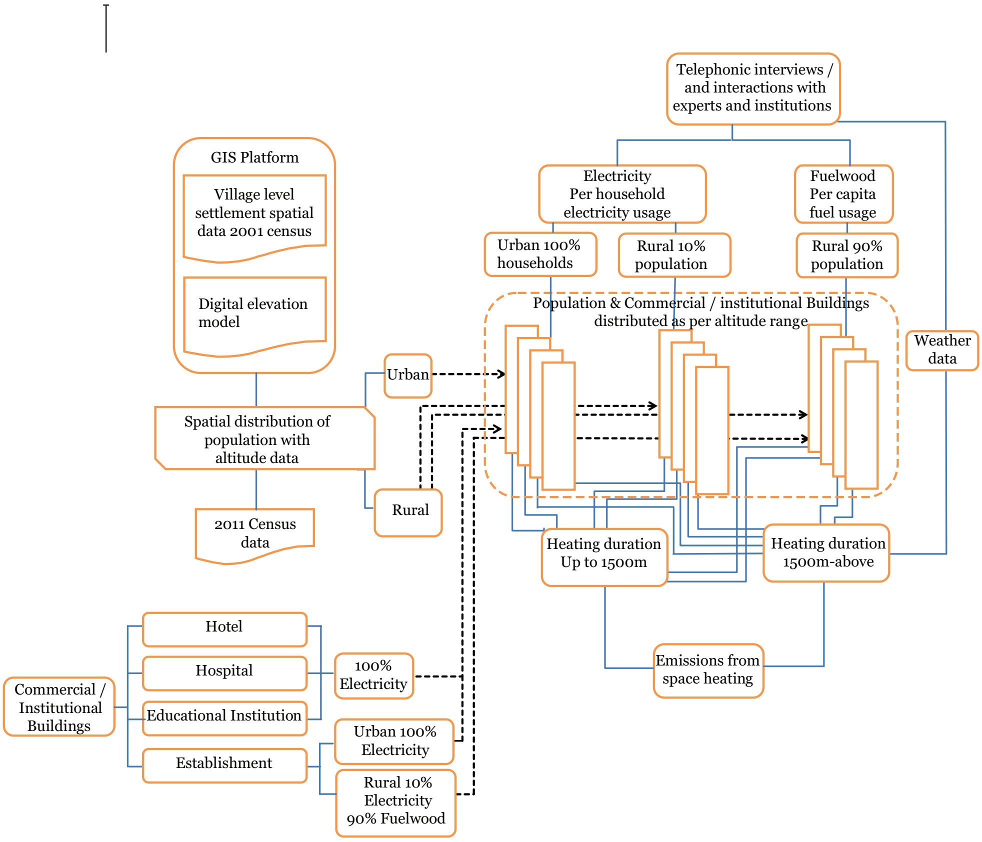
In this section, current and future emissions have been calculated with 2020 as the base year and projections have been done for 2030 and 2040. The emissions are calculated separately for the residential sector and the commercial/institutional sectors. The details of the methodology for the calculation of the emissions are discussed in the following segments.

2.1 METHODOLOGY

The calculation of emissions was done based on the duration of the heating requirement multiplied by the amount of energy consumed. In households where electrical energy was being consumed for heating, the kilowatt-hour (kWh) consumed was calculated for the duration of heating. For households where wood was being used for heating purposes, the per capita per day wood consumption was calculated. Calculations of fuelwood consumption for space heating purpose are based on several published studies on overall fuelwood consumption in various states of the IHR. The details of these calculations are given in Annexure 2. It was established that the per capita per day wood consumption below 1500m altitude is 1.6kg and above 1500m is 1.9kg.

The duration of the heating period and the technology type used were considered based on telephonic interviews and data collected during field visits in Himachal Pradesh and Uttarakhand. The major population in the IHR lives in altitudes lesser than 2500m. The period of the heating season was found to be consistent in altitude bands of up to 1500m and between 1500m and above where settlements are located. This formed the basis for the calculation of space heating emissions.

Figure 5: Methodology for calculation of emissions in residential buildings



For the residential sector (see Figure 5), the elevation data of settlements were referred to from the GIS data of urban and rural settlements in the 2001 census shapefiles on a GIS platform along with other data collected in the population census. The report of the technical group on population projections[3] gave population projections for the IHR states (2011–2036) for both urban and rural areas. Since the report considered 2020 as the base year and projections for emissions were calculated for the next two decades, the population was further projected from 2036 till 2040. The projected population is presented in Annexure 1. The division of population as per altitude ranges for both urban and rural settlements – for altitudes greater than 1500m and lesser than 1500m – was done using GIS. The population data from the projected populations of the states was used for segregating the population as per altitude ranges and urban-rural divide. For states in the Northeast, where the population was not divided as per rural and urban in the 2001 census, the division of population was carried out as per altitude ranges, and the same ratio was used for urban and rural populations as defined in the 2011 census.

The estimation of annual electrical and biomass consumptions was done based on the information collected through telephonic interviews conducted with the representative officials and academic institutes. The emissions were calculated for 2020 as the base year and projections for 2030 and 2040 were based on increased demand by growing population.

The commercial sector buildings were classified into educational institutions, hospitals, hotels and establishments. The estimation of energy consumption of commercial and institutional buildings was done by following a top-down approach.

The information on technologies used for heating in different typologies was collected through interviews. Research institutes in Himachal Pradesh and Uttarakhand along with state officials were also approached for gaining relevant information on systems being used in the respective states. The technologies being used for space heating were listed after extensive desk research and discussions with prominent institutes and agencies that work in the development of such technologies. In-person discussions were carried out with the representatives of the National Institute of Solar Energy, Gurugram, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) – German Development Agency, New Delhi, Indian Institute of Technology, Roorkee, Central Building Research Institute, Roorkee and Department of Science and Technology, Himachal Pradesh.

Details of various existing commercial and institutional buildings were gathered from the data received from the respective state departments. For hotels, official tourism websites and the ministry of tourism websites were referred. For data related to hospitals and educational institutions, the MSME industry report (2014–15)[4] on different states was studied. The 6th Economic Census (2013–14) was considered while gathering relevant data related to establishments.

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[3] Population projections for India and states 2011–2036, November 2019

[4] States industrial report for year 2014-15 published by Micro, Small & Medium Enterprises Development Institute, Govt. of India

Through the interviews, it was found that apart from establishments, all other commercial buildings used electricity for heating. In the case of establishments in rural areas, about 10 per cent of the establishments had electrical appliances for heating purposes, whereas the remaining 90 per cent used fuelwood. The wood used for heating is a community heating source. Generally, 7–8 shopkeepers and establishment owners/workers have access to a common heating source. For the calculation of heating emissions at different altitude ranges, the number of establishments was divided according to altitude ranges as per the ratio of the population.

Buildings such as shops, offices and schools operate during the daytime, whereas hotels and hospitals are 24-hour operational buildings. Based on the location and duration of the heating period for that location, the estimation of the heating energy requirement was done.

A major portion of the present study is based on the information gathered from telephonic interviews that were conducted with government officials, representatives of different sectors of the commercial/institutional buildings and selected institutes working in the IHR. The survey was carried out in two stages in Himachal Pradesh and Uttarakhand. In the first stage, personal interviews with the selected faculty members of the research institutes were done. During personal interactions on visits, the data was collected from site visits and case studies of innovative technologies that have been and are being implemented in the regions. In the second stage, the data was collected through telephonic interviews to identify the technologies and fuel usage in urban and rural areas as well as the duration of heating period, and the number of hours in a day for which heating was required.

For hotel buildings, a usage time of 6 hours per day with one heater per room was considered. Similarly, for educational institutions, 4 hours per day and one heater per school with a diversity factor of 0.6 were considered to account for non-continuous use of heaters in schools. For hospitals, 6 hours per day and one heater per two beds were noted. However, for commercial establishments, a combination of fuelwood and the electric heater was taken into account. Commercial establishments in urban areas use electricity. However, in rural areas, only 10 per cent of establishments have electrical heating equipment. The remainder 90 per cent rely on meeting heating needs from fuelwood using equipment such as “saggar”. Saggar is used as a community heating spot within a group of establishments. The following institutes were approached for data collection on various heating technologies being used and determining the duration of the heating period.

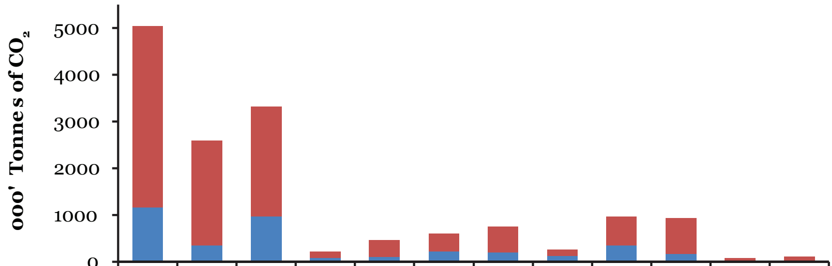
Himachal Pradesh	Uttarakhand
Department of Science and Technology	Indian Institute of Technology– Roorkee
Ministry of New and Renewable Energy	Central Building Research Institute
State Designated Agency for energy efficiency in buildings	G.B. Pant National Institute of Himalayan Environment and Sustainable Development
Indian Institute of Technology–Mandi	Urban Planning Department
HIMURJA–Shimla	Disaster Mitigation and Management Centre

2.2 CURRENT AND FUTURE EMISSIONS FROM RESIDENTIAL AND COMMERCIAL BUILDINGS

The analysis was done separately for each state to arrive at the emissions trends for residential and commercial/ institutional buildings. The steps followed to calculate the emissions rate for states with majority of contribution in emissions (Himachal Pradesh, Jammu and Kashmir and Uttarakhand) and the final emissions rates for all the states are presented in Annexure 3. The following section focuses on the emissions from residential buildings, commercial/institutional buildings and overall emissions from both.

The inferences of residential emissions are detailed in a graphical representation in Figure 6.

Figure 6: Emissions from space heating of residential buildings (2020)



	JK	HP	UT	SK	AR	NG	MN	MZ	TR	ML	WB*	AS*
Wood Emission	3877	2238	2349	134	359	383	556	131	613	767	60	84
Electricity Emission	1165	351	967	80	100	223	192	128	352	175	14	24

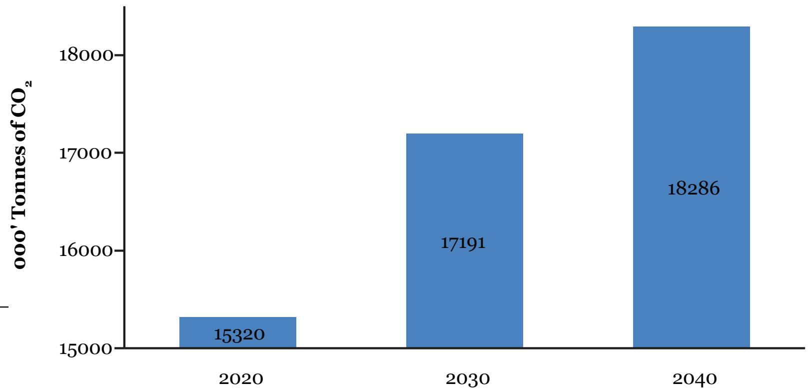
For residential buildings, maximum emissions were reported in Jammu and Kashmir, followed by Uttarakhand and Himachal Pradesh. These three states constituted about 72 per cent of total emissions (combined) in the IHR, whereas, the remaining 7 states of the Northeast constituted about 28 per cent of the total emissions. In the entire IHR, for the residential sector, 24.6 per cent emissions was reported from electricity usage and 75.4 per cent from fuelwood. The projection of emissions was done based on the population projections for 2030 and 2040 (see Table 4).

Table 4: Population projections for IHR

Year	2020	2030	2040
Population Projections '000	48,499	52,423	56,310
% increase	-	8	7.4

The results are given in Figure 7.

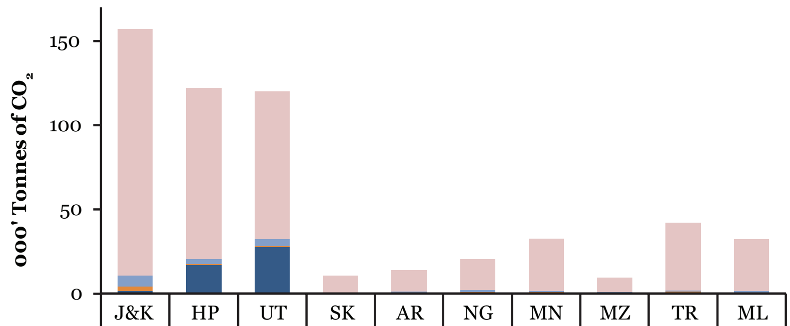
Figure 7: Projection of emissions from space heating for residential buildings



The growth rate of annual emissions in residential buildings from 2020 to 2030 is 12.2 per cent while the growth rate of annual emissions from 2030 to 2040 is 6.3 per cent. The reduction in the growth rate is primarily because of the high rate of urbanization, which is projected to be 23.9 per cent between 2020 and 2030 and 18.8 per cent for 2030–2040. The growth rate of the rural population is very less compared to the urban population and it is projected to be 1.6 per cent between 2020 and 2030 and 1.7 per cent during 2030–2040.

The results of the calculation of emissions from commercial and institutional buildings are presented in Figure 8.

Figure 8: Emissions from space heating for commercial/institutional buildings (2020)

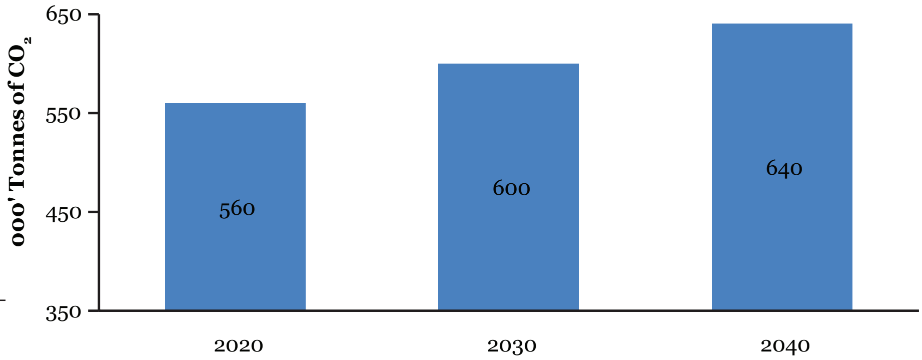


	J&K	HP	UT	SK	AR	NG	MN	MZ	TR	ML
Establishments	146.25	101.64	87.58	9.86	12.88	18.07	31.20	8.30	40.40	30.74
Educational Institutes	6.77	2.93	4.19	0.16	0.67	1.04	0.51	0.58	0.58	1.28
Hospitals	2.37	0.86	0.51	0.39	0.36	0.90	0.66	0.38	1.00	0.25
Hotels	1.53	16.66	27.56	0.10	0.02	0.00	0.24	0.01	0.12	0.02

Note The emissions from commercial/institutional buildings from hill districts of West Bengal and Assam are not included in the given analysis since state-level reports are used for compiling the data for commercial/institutional buildings

The calculation (see Figure 8) of emissions from commercial buildings showed that maximum emissions were from Jammu and Kashmir, followed by Himachal Pradesh and Uttarakhand. Out of the four typologies for commercial and institutional buildings, maximum emissions were reported from the establishments,[5] followed by hotels, educational institutes and hospitals. While the emissions from hotels, hospitals and educational institutes were attributed to electricity usage alone, the emissions from establishments were from electrical and wood usage. The percentage of emissions from wood was found to be 64 per cent and electricity consumed was 34 per cent, respectively.

Figure 9: Projection of emissions from space heating for commercial / institutional buildings



The projection of emissions was done based on the population growth projections for 2030 and 2040. The results are presented in Figure 9. The growth rate of annual emissions in commercial/institutional buildings from 2020 to 2030 is 7.2 per cent while the growth rate of annual emissions from 2030 to 2040 is 6.7 per cent.

The results and conclusions of state-wise space heating emissions for both residential and commercial buildings of the entire IHR for 2020 and the projected emissions for 2030 and 2040 are summarized in Table 5.

Table 5: Emissions calculated for 2020 and projections for 2030 and 2040

Emissions by space heating in 000' tonnes of CO2 (2020)								Total emissions 000' tonnes of CO_2		
		Residential buildings		Commercial/institutional buildings				Year		
		Electrical	Wood	Hotels	Hospitals	Educational institutes	Establishments	2020	2030	2040
1	J & K	1,165	3,877	1.53	2.37	6.77	146.3	5,199	5,770	6,105
2	HP	351	2,238	16.66	0.86	2.93	101.6	2,711	2,909	3,043
3	UT	967	2,349	27.56	0.51	4.19	87.6	3,435	3,947	4,254

[5] trade and services other than hotels, hospitals and education

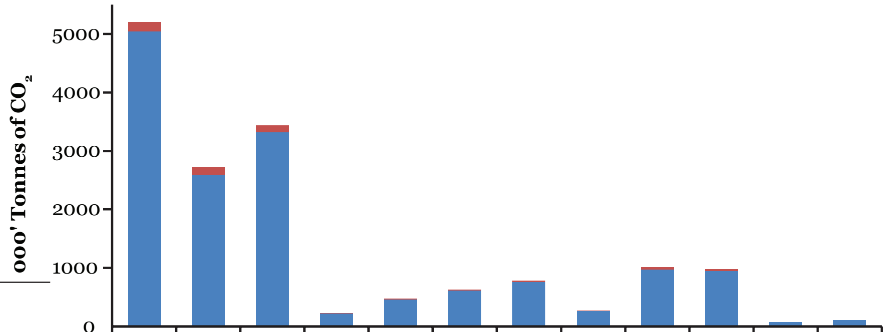
Table 5: Emissions calculated for 2020 and projections for 2030 and 2040

Emissions by space heating in 000' tonnes of CO2 (2020)								Total emissions 000' tonnes of CO_2		
		Residential buildings		Commercial/institutional buildings				Year		
		Electrical	Wood	Hotels	Hospitals	Educational institutes	Establishments	2020	2030	2040
4	SK	80	134	0.10	0.39	0.16	9.9	224	250	258
5	AR	100	359	0.02	0.36	0.67	12.9	473	534	573
6	NG	223	383	0.00	0.90	1.04	18.1	626	710	747
7	MN	192	556	0.24	0.66	0.51	31.2	780	886	949
8	MZ	128	131	0.01	0.38	0.58	8.3	268	320	344
9	TR	352	613	0.12	1.00	0.58	40.4	1,007	1,170	1,257
10	ML	175	767	0.02	0.25	1.28	30.7	974	1099	1185
11	WB*	14	60	-	-	-	-	74	77	78
12	AS*	24	84	-	-	-	-	108	122	130
Total								15,880	17,794	18,924

** Note Due to unavailability of relevant data for commerical/institutional buildings of the districts of West Bengal and Assam, these states have not been included in the representation of emissions in the present study.*

Figures 10 and 11 show the emissions for both residential and commercial buildings.

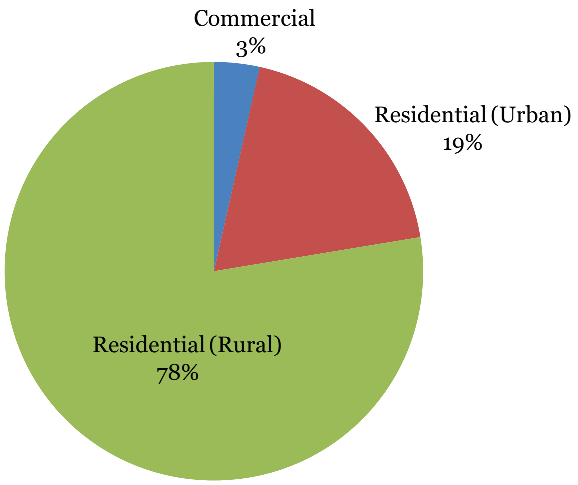
Figure 10: Emissions from space heating in commercial/residential buildings (2020)



	J&K	HP	UT	SK	AR	NG	MN	MZ	TR	ML	WB*	AS*
Commercial	157	122	120	11	14	20	33	9	42	32	0	0
Residential	5042	2589	3315	214	459	606	748	259	965	942	74	108

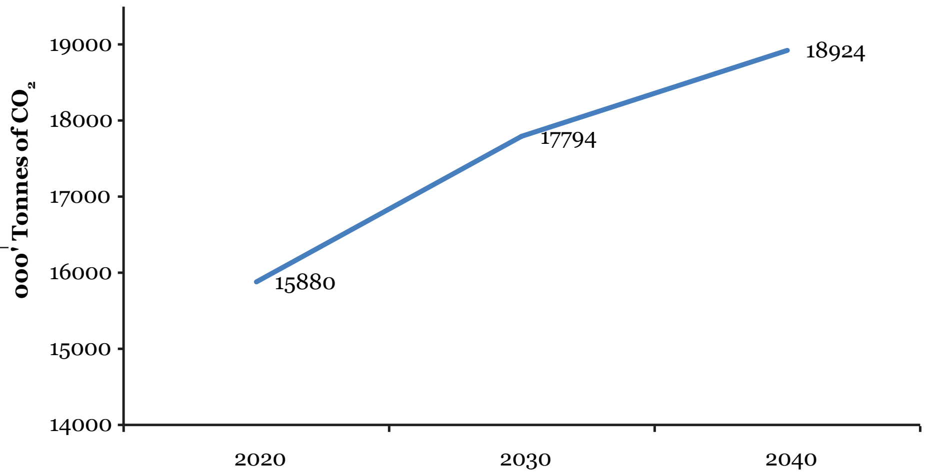
** Note Due to unavailability of relevant data on commercial buildings of the hill districts of West Bengal and Assam, these states have not been included in the representation of emissions in the present study.*

Figure 11: Percentage of emissions due to space heating in commercial/ institutional and residential buildings in IHR



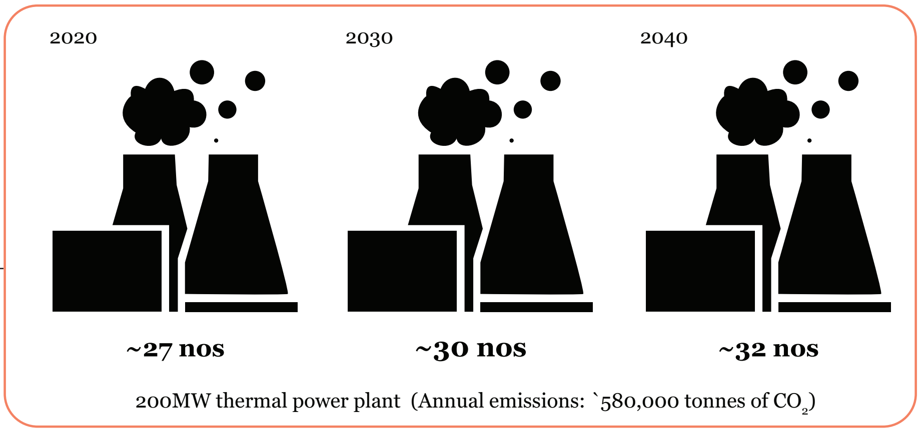
Around 3 per cent of overall emissions from space heating are attributed to commercial buildings, the remainder 97 per cent are reported residential buildings. Almost 19 per cent of overall emissions are from urban residential buildings and 78 per cent are from rural residential buildings.

Figure 12: Projection of space heating emissions from buildings in IHR



The projection of emissions was done based on the population growth projections for 2030 and 2040. The results are presented in Figure 12. The projections show an increase in annual emissions from 15.9MT to 17.8MT of CO_2 – an increase of 12 per cent for 2030, as compared to 2020; and from 17.8MT to 18.9MT of CO_2 – an increase of 6 per cent for 2040, as compared to 2030. For comparison, Figure 13 illustrates the number of thermal power plants emitting equivalent emissions for 2020, 2030 and 2040.

Figure 13: CO_2 equivalence of emissions from space heating in IHR



2.3 OBSERVATIONS AND FINDINGS

The calculation of emissions from space heating in the previous section uses data of the distribution of settlements as per altitude, segregation of urban and rural population and buildings used for commercial and institutional purposes. It was established that the emissions from the use of fuelwood for space heating account for a major share in both residential and commercial sectors.

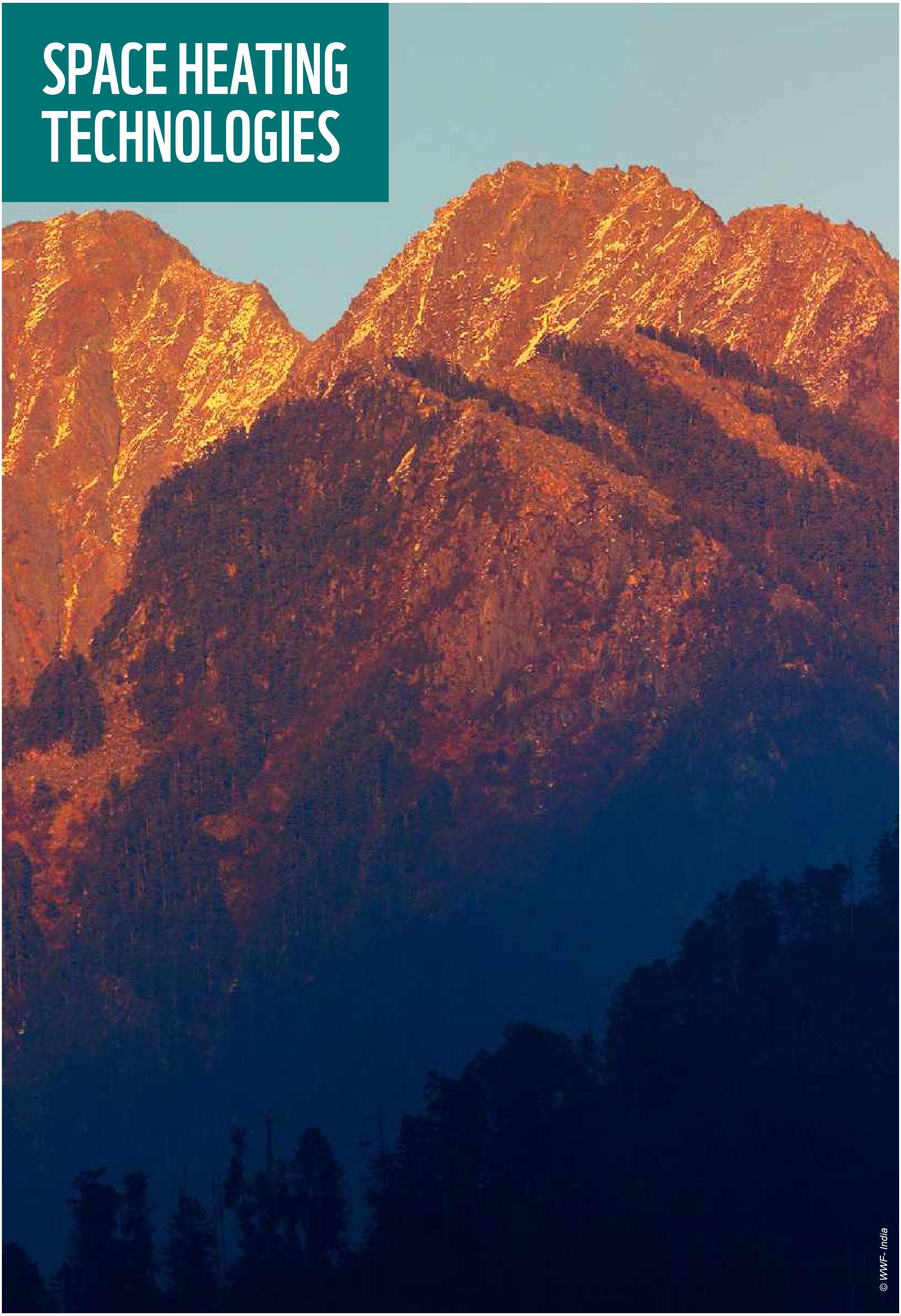
In the commercial sector, which is divided into four typologies – establishments, schools, hospitals and hotels – emissions from the establishments are the highest, which include emissions from both electrical appliances as well as the use of fuelwood. Emissions from hotels and hospitals are prominent in Himachal Pradesh and Uttarakhand, where the hospitality sector dominates the generation of emissions.

In the residential sector, building emissions generated from wood dominated the overall emissions scenario because of the large percentage share of the population in the northern states.

In the overall emissions scenario, 71.4 per cent was reported from Jammu and Kashmir, Himachal Pradesh and Uttarakhand, and only 28.6 per cent from the Northeast states of Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya and the hill districts of West Bengal and Assam.

It was observed that the ratio of emissions from electricity usage in rural areas was not uniform in the northern states. Himachal Pradesh showed lesser share of emissions from electricity in comparison to Jammu and Kashmir and Uttarakhand. This was primarily because a large percentage of rural population in Himachal Pradesh is situated at higher altitudes in comparison to the other two states. Therefore, the percentage of fuelwood usage is more than electricity usage. The overall emissions reported in Jammu and Kashmir were higher than the rest because the population resides at higher altitudes and the overall temperature in the region is much lower when compared to the others throughout the year. In the Northeast, the overall population is considerably less when compared to that of the northern states, hence those states record lower emissions.

SPACE HEATING TECHNOLOGIES



3.1 TYPES OF FUEL AND TECHNOLOGIES FOR HEATING IN THE IHR

In India, almost 40–50 per cent of the final energy is consumed by the residential sector, where the final demand for heating (36 per cent) is higher than for lighting (31 per cent)[6] (EIA 2014). The importance of space heating varies for states and regions depending on climatic conditions and income strength. There are significant criteria that must be taken into account while choosing heating technologies, including annual heat profile space heating, relative timing of thermal and electric loads, space constraint, emissions regulations, utility prices for electricity, availability and prices of other fuels, initial cost and the cost of financing, seasonal efficiency of equipment, complexity of installation and operation, reputation of the manufacturer, and architect/engineer/builder/installer's knowledge of available technologies and models among others. This section focuses on the space heating technologies used in the IHR.

In rural areas, fuelwood and LPG are the two main sources of fuel. In the IHR, the per capita consumption of wood for space heating during winters is as high as 1.6–1.9kg per person. The consumption of LPG is reported to be 0.7 kgoe per person[7] (CEEW 2014). However, use of LPG is not popular because of its high cost. The houses in rural areas are prone to outdoor air infiltration because of the use of construction techniques. Additionally, the fire provides the inhabitants with localised comfort. These houses are normally lit in the evening hours. Most of the villages do have access to electricity but the voltage drops drastically with increasing electrical load on grid. Hence, electricity cannot be used for heating purposes in such villages.

In urban areas, most houses use electrical appliances, the most prominent ones being coil heaters and convective blowers. Other common appliance types that are prevalent includes oil-filled radiators but these are costlier than the other two previously mentioned. This equipment is useful only if the air infiltration is less in the building. These kinds of systems are found mostly in hotels, offices with airtight construction and residences of a higher economic strata.

Apart from these, there are unitary systems for heating called heat pumps. There are indoor units and outdoor units as well, which can function in both cooling and heating modes and only heating mode too. These systems are more expensive than standalone oil-filled radiators, and therefore, not affordable to a larger section of the IHR's population. In the lower Himalayas, there is a requirement of appliances for both heating and cooling purposes. However, on higher altitudes, only heating equipment is needed. Centralised heating systems equipped with boilers are a handful and they

[6] Details available at http://www.eia.gov/analysis/studies/international/consumption/pdf/issues_itl_energyconsumptionanalysis.pdf

[7] Details available at http://admin.indiaenvironmentportal.org.in/files/file/CEEW-Energy-Access-in-IndiaToday-and-Tomorrow.pdf

are used only in a few hospitals and hotels. Moreover, there are a few demonstration projects showcasing sustainable heating solutions such as ground source heat pumps (GSHP), and GSHP integrated with solar PV.

3.2 CLASSIFICATION OF SPACE HEATING TECHNOLOGIES IN THE IHR

The cost benefit analysis of existing and innovative space heating technologies for rural and urban areas with their strengths and limitations are described in Tables 6 and 7.

Table 6: Existing space heating technologies

Technology solution	S. No.	Technology	Fuel type	Cost of technology (in INR)	Energy/fuel consumption (kg/h) or (L/h)	Total emissions (kg CO2/h)	Strength	Limitation
Existing space heating technologies (rural areas)	1	Saggar	Wood	1,000–3,000	2–3	4.5[8]	• Container provides easy mobility • Cost of product is low	• Used in small habitats only • Leads to indoor air pollution
	2	Bukhari	Wood	2,000–8,000	3–4	6.4[9]	• Less expensive in areas where wood is abundantly and freely available • Can be deployed for cooking as well as in space heating	• Leads to both outdoor air pollution and indoor air pollution
	3	Army kerosene heater*	Kerosene	3,000–20,000	0.64	1.6[10]	• Less expensive to use in contrast with other space-warming innovation techniques, for example, Bukhari, Saggar • Provides instant heat, thereby eliminating the waiting time to warm up • Capable to heat larger rooms	• Not recommended for use in airtight spaces as this leads to poor indoor air quality • Sleeping with a kerosene heater 'on' is not recommended

[8] Details available at https://www.researchgate.net/publication/223040081_Emission_factors_of_wood_and_charcoal-fired_cookstoves
[9] Burning of 1kg fuelwood emits 1.83kg CO_2e per hour
[10] Details available at https://energypedia.info/wiki/The_Reduction_of_Kerosene_Lamp_Emissions_through_Solar_Lighting

Table 6: Existing space heating technologies

Technology solution	S. No.	Technology	Fuel type	Cost of technology (in INR)	Energy/fuel consumption (kg/h) or (L/h)	Total emissions (kg CO_2/h)	Strength	Limitation
Existing space heating technologies (rural areas)	4	Traditional fireplace	Wood	72,000–250,000	3–4.5	8.1[11]	• Oldest and most traditional fireplace option, valued for its aesthetics • Easily converted to gas-burning fireplaces	• Likely to lose heat through the chimney • Requires a chimney that can be very expensive and difficult to retrofit • Sparks popping into the room may lead to accidental fire
	5	Kangri	Charcoal	190–1,500	0.5-0.6	1.3[12]	• Cheap and plentiful availability of charcoal • Long power cuts in hilly terrain • Provides good heating even in chilly winters • Wide acceptance among local people since ages	• Regular use is hazardous for health and may lead to skin cancer

[11] Details available at http://www.stoveindia.com/wood-burning-fireplace.html
[12] Details available at https://www.researchgate.net/publication/223040081_Emission_factors_of_wood_and_charcoal-fired_cookstoves

Table 6: Existing space heating technologies

Technology solution	S. No.	Technology	Fuel type	Cost of technology (in INR)	Energy/fuel consumption (kg/h) or (L/h)	Total emissions (kg CO_2/h)	Strength	Limitation
Existing space heating technologies (rural areas)	6	Biomass briquettes space heater	Sugarcane bagasse, leaf	2,000–15,000	Sugarcane bagasse (19.87 or 0.11kWh/kg) Sugarcane leaf (32.01 or 0.07 kWh/kg)	Sugarcane bagasse (5.4)[13]	• High heating value per unit volume • Easy to transport • Easy to store and reduces store area • Biofuels are as effective as fossil fuels, but a lot less polluting	• Chipping, compacting, cutting and shredding massive volumes of biomass are frequently required. However, such cleaning technology is often not economically feasible for smaller manufacturing units
	7	Gas heater	LPG	3,500–8,500	0.125	0.4	• May cost up to 50% less to operate than a conventional electric heater • Easier to move around because it doesn't have to be plugged in, the fuel comes in a can and can be mounted to the device • Can quickly achieve its maximum temperature	• Not recommended to operate while sleeping at night • Initial purchase price is generally high • Maintenance is difficult as compared to a conventional heater

[13] Details available at https://www.researchgate.net/publication/331885593_Carbon_footprint_of_the_generation_of_bioelectricity_from_sugarcane_bagasse_in_a_sugar_and_ethanol_industry

Table 6: Existing space heating technologies

Technology solution	S. No.	Technology	Fuel type	Cost of technology (in INR)	Energy/fuel consumption (kg/h) or (L/h)	Total emissions (kg CO_2/h)	Strength	Limitation
Existing space heating technologies (rural areas)	8	Mini Bukhari – portable space heater	Wood	5,000–10,000	1	3.2 [14]	• Requires less fuel in comparison to traditional bukhari • Portable and user-friendly	• Outreach in market is limited • Still requires wood burning
	9	Sawdust Bukhari	Sawdust	2,000–15,000	2–4	2.6[15]	• Cost-effective • Scalable to low- and medium-altitude areas	• Application is limited to areas where wood-based industries are located
	10	Himtapak	Kerosene	> 8,000	0.5-0.7	1.5[16]	• Requires less fuel than army kerosene heater • Portable and user-friendly	• Outreach in market is limited • Kerosene smell could pose a problem

[14] Details available at http://nif.org.in/innovation/portable-room-heater/1102
[15] Details available at https://www.sciencedirect.com/science/article/abs/pii/S0960852497000643
[16] Details available at https://drdo.gov.in/space-heating-device-bukhari-himtapak

Table 6: Existing space heating technologies

Technology solution	S. No.	Technology	Fuel type	Cost of technology (in INR)	Energy/fuel consumption (W/h)	Total emissions (kg CO_2/h)	Strength	Limitation
Existing space heating technologies (urban areas)	11	Coil heater	Electricity	250–2,500	1000–2000	1.7[17]	• Silent since it does not have any moving equipment • Cost-effective • Minimal maintenance required	• • Not safe for use around children • Flammable materials such as paper, wood, fabric can catch fire if placed too close to the equipment coil
	12	Infrared heater	Grid electricity	1,500–5,000	1800	1.5	• Unlike convective heaters, it can emit a specific beam of heat that warms the space directly by throwing out a steady stream of heat elements • Works silently since it does not consist of any moving equipment	• Not safe for use around children • May cause indirect thermal stress when the heater is positioned too close to the body surface or object • Needs a constant voltage electrical supply • Effective in less cold places, but not so effective during very cold climatic conditions

[17] Details available at http://www.cea.nic.in/reports/others/thermal/tpece/cdm_co2/user_guide_ver13.pdf

Table 6: Existing space heating technologies

Technology solution	S. No.	Technology	Fuel type	Cost of technology (in INR)	Energy/fuel consumption (W/h)	Total emissions (kg CO_2/h)	Strength	Limitation
Existing space heating technologies (urban areas)	13	Convection heater	Grid electricity	900–3,000	1800–2000	1.6[18]	• Good for small and medium-sized rooms • Adjustable heating ranges • Compact and portable	• Poor acoustic comfort • Poor health and indoor environment quality • Not suitable for large spaces and spaces with a high infiltration rate of cold outdoor air
	14	Ceramic heater	Grid electricity	560–2,000	1000–2000	1.6	• High conversion efficiency (85-90%), converts most of the supplied electricity units to heating • Provides heat for some time even after the heater is switched off • Safer operation since the device does not get overheated • Does not produce any hazardous fumes, chemicals or emit burning smell during operation	• Costlier than gas or coil heaters • Not adequate for heating large areas/ spaces

[18] One kWh of electricity through coal emits 0.83kg CO_2e

Table 6: Existing space heating technologies

Technology solution	S. No.	Technology	Fuel type	Cost of technology (in INR)	Energy/fuel consumption (W/h)	Total emissions (kg CO_2/h)	Strength	Limitation
Existing space heating technologies (urban areas)	15	Oil-filled radiator heater	Grid electricity	> 8,000	700–2900	1.2	• More energy-efficient than conventional electric heaters • Provides greater operational flexibility to user (thermostat controlled) and thus better control for occupant-centric thermal comfort • Mostly comes with wheels, making it easier to move within the building • Better acoustic comfort	• Does not perform well in light construction buildings • Coverage of large spaces is difficult • Sometimes, releases a burning smell to negatively impact the overall comfort level of the user • Unit cost is highest among available options, including infrared heaters and fan coil heaters

Table 7: Innovative space heating technologies

Technology solution	S. No.	Technology	Cost of technology (INR/ft²)	Energy/fuel savings (kWh/year)	Total emissions reduction (kg/day/ft²)	Strength	Limitation
Innovative space heating technologies	1	Integration of ground source heat pump (GSHP) systems with solar photovoltaic (PV)	5,000 (approx.)	45,000	0.18	• Applicable for dual purposes, i.e. space cooling and heating • Can be installed in any climatic profile • Better payback • Displaces non-renewable, polluting heating fuels such as electricity	• Lack of expertise and skill set for installation and design of the equipment • Installation cost is high • Periodic maintenance is required • Cost can vary based on the supply chain, material and technology availability
	2	Liquid-based active solar heating	1,475 (approx.)	15,000 (for a single-family dwelling)	0.03	• Heating the space with a liquid-based solar heating system benefitted commercially • It also reduces carbon emissions	• Lack of awareness about possible solar energy applications • Limited number of suppliers • Higher installation cost • Skilled labour required for installation

Table 7: Innovative space heating technologies

Technology solution	S. No.	Technology	Cost of technology (INR/ft^2)	Energy/fuel savings (kWh/year)	Total emissions reduction (kg/day/ft^2)	Strength	Limitation
Innovative space heating technologies	3	District heating system (DHS)	1,204	465,013.4 (approx.)	0.05	• Energy-efficient and has better pollution control than individual heating units • Flexible integration with renewable energy systems or waste heat recovery enables further scope for a greener and cleaner future • Better operational control if designed efficiently	• High capital investment and poor short-term returns on investment • High spatial concerns (topography, soil quality, etc.) regarding the designing of distribution network • Not profitable for low population density areas and single/small buildings • Monopoly issues may arise due to fewer market players available in this sector

Table 7: Innovative space heating technologies

Technology solution	S. No.	Technology	Cost of technology (INR/ft²)	Energy/fuel savings (kWh/year)	Total emissions reduction (kg/day/ft²)	Strength	Limitation
Innovative space heating technologies	4	Integration of evacuated tube heat pipe (ETHP) with fan-coil unit (FCU)	850 (domestic) 800 (Commercial)	2,53,800[19]	0.02	• Capable of delivering high energy savings • Environment-friendly and produces low GHG emissions • Maintains good indoor air quality inside the building as no burning of oxygen occurs (unlike conventional heaters • Requires negligible maintenance if properly designed	• Availability of component suppliers, manufacturers, and service personnel could be a challenge • Poor system performance on days having low solar insolation
	5	Cloud-based smart heating	35.5 (approx.)	Depends on different starting points, building's varying usages and other building systems	0.03	• Significant energy savings and reduced GHG emissions • Improved comfort levels through occupant thermal response • Continuous monitoring of indoor environment • Easy to implement with trained manpower	• Immature technology, hence chances of errors are high • Availability of skilled manpower for technical guidance during designing and installation could be difficult • Awareness of the system functioning and integration with conventional space heating system

[19] WWF-India and CEEW Renewables Beyond Electricity report (2013)

Table 7: Innovative space heating technologies

Technology solution	S. No.	Technology	Cost of technology (INR/ft²)	Energy/fuel savings (kWh/year)	Total emissions reduction (kg/day/ft²)	Strength	Limitation
Innovative space heating technologies	6	StratiFlex	1,230	Annual average energy savings by 15–25% over a conventional boiler-based heating system	0.01[20]	• Superior level of stratification • Easy installation • Extensive durability	• High shipping charges as it is manufactured only in Denmark across the world • No technical record of its performance in Indian climatic conditions
	7	Himalayan rocket stove	>185	15,000	0.08	• Clean burning, thus not hazardous to health • Easy to use and requires little maintenance	• Social acceptance among people • Relatively costlier than traditional cook stoves • Outreach at higher altitudes is difficult • Confidence in new technology is less

[20] Details available at http://eyecular.com/wp-content/uploads/2013/06/2.-Heat-pump-systems-Quantification-of-Energy-Savings-by-StratiFlex.pdf

Table 7: Innovative space heating technologies

Technology solution	S. No.	Technology	Cost of technology (INR/ft²)	Energy/fuel savings (kWh/year)	Total emissions reduction (kg/day/ft²)	Strength	Limitation
Innovative space heating technologies	8	Solar hybrid heat pump system	1,400	10,800	0.03	• Simple to install • No batteries needed • No power is exported and no net metering agreement or special meter is needed • Can be used with all-DC, all-AC, or AC-DC	• Cost of purchasing components and installation is too high • High operational cost • Outreach and availability issues in India • Lack of certification system for S+HP combinations
	9	SolarSheat	249.2[21]	36,000 (on clear sunny days)	0.03	• Simple to install • Provides solutions for all sizes of rooms and homes • Temperatures up to 60°C • Self-powered, no electrical hook up required • Thermostatically controlled • Saves on high costs of oil and gas	• Lack of outreach and research

[21] Details available at http://www.yoursolarhome.com/solarsheat-products/solarsheat-1500gs-pv-fan

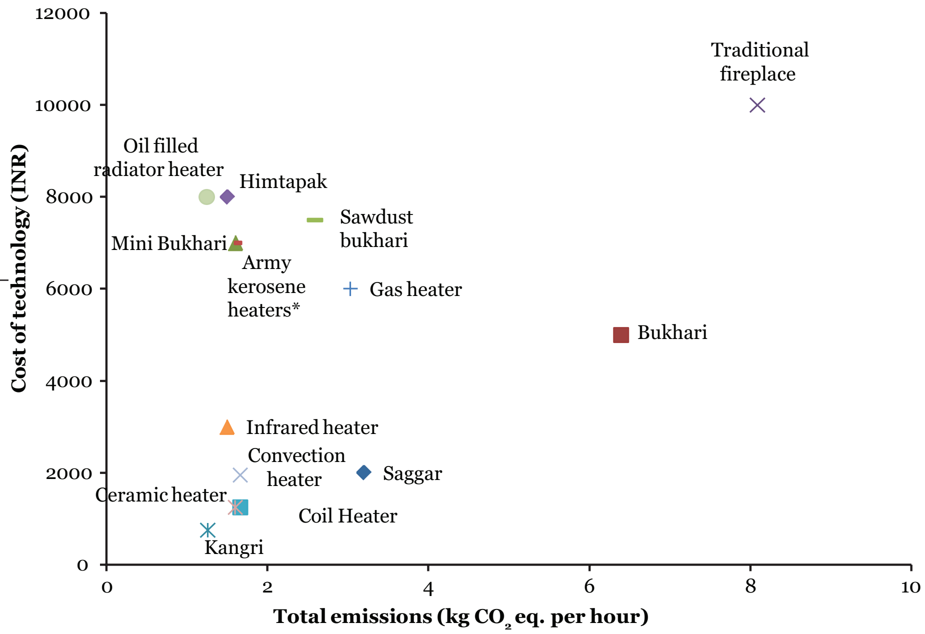
Table 7: Innovative space heating technologies

Technology solution	S. No.	Technology	Cost of technology (INR/ft²)	Energy/fuel savings (kWh/year)	Total emissions reduction (kg/day/ft²)	Strength	Limitation
Innovative space heating technologies	10	Building integrated photovoltaic (BIPV) solar seating	1,260[22]	Reduction of 34% on an average as compared to a building's average use with full consumption from the grid	0.04	• Saves on material and electricity costs • Reduces use of fossil fuels • Reduced emissions of ozone-depleting gases • Lends architectural esthetics to the building	• High operational and maintenance cost • Solar insolation-dependent technology • Lack of consumer outreach and awareness
	11	Parabolic solar dish collector coupled with finned-tube heat exchanger	1,540[23]	Varies largely (dependent on generation)	0.04	• Easy maintenance • Silent operation and high reliability • Temperatures up to 800°C • Does not produce any GHG emissions during operation	• Dependent on the altitude and solar radiation potential

[22] Details available at https://www.brikbase.org/sites/default/files/best3_bagatelos.pdf

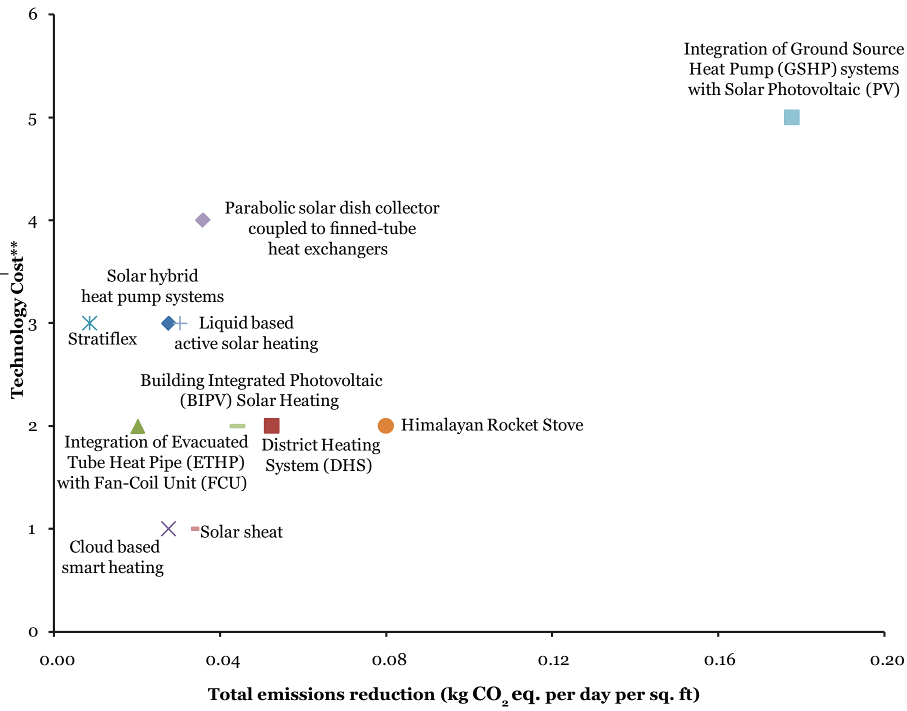
[23] Details available at https://www.indiamart.com/proddetail/parabolic-solar-concentrators-11640393312.html

Figure 14: Cost v/s total emissions relation to existing space heating technologies



Note The segregation of existing space heating technologies for rural and urban areas considers the average cost of each technology.

Figure 15: Innovative technologies: cost vs emissions reduction



***Technology cost distributed in the range of 1-5 i.e. (1-Low, 2-Medium low, 3-Medium, 4-Medium high, 5-High)*

In Figure 14, the existing space heating technologies are plotted on the basis of their average cost and emissions generated. Figure 15 shows innovative technologies that are segregated based on the cost and total emissions reduction. During extensive desktop research and review of case studies, it was found that most of these innovative technologies were assisted with renewable energy sources. Hence, the emissions reduction was calculated based on the average operation. The cost of the innovative technologies varies from INR 250 to 5000 per sq. ft. The costs given in the scatter plot are distributed in the categories of 1 to 5, while the actual per square feet cost of these technologies is mentioned in Table 7.

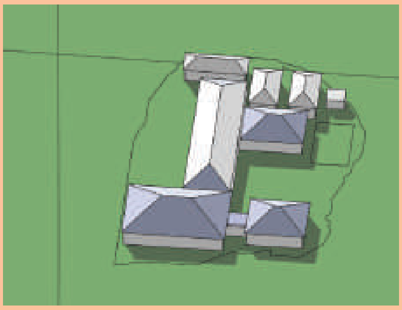
The technologies being used in the IHR can be broadly classified in three groups for the purpose of developing relevant policies for the promotion of more sustainable solutions for space heating. Those technologies, which are standalone systems and portable, and can be moved around between various spaces, form the first category. The examples of such systems are saggar, kangri, kerosene heater, gas heater and other electrical appliances that can be easily moved around. These systems provide localised comfort. The second set of equipment include those which are restricted to the place where they are installed; examples of these are various kinds of stoves, bukharis and fireplaces. The location of these is fixed, but the heating output is linked to the consumption of fuel. The third and last category include those sets of equipment which are sized as per the heating demand and can interact with the building/space to create a comfortable environment. Examples of such systems are oil-filled radiators, heat pumps and several other innovative technologies that must be sized appropriately as per the heating demand. Normally, these are expensive systems because of engineering requirement and therefore, cater to a select segment of population that can afford them. These also entail adequate designing of the buildings and choice of construction materials to keep the heating demand low, thereby controlling the overall cost of the equipment. All these equipment sets can be used in the IHR. The description of each technology mentioned in this section is given in detail in Annexure 7.

CASE STUDY 1

DESIGN AND IMPLEMENTATION OF GEOTHERMAL HEAT PUMP WITH SOLAR PV SYSTEM AT COMMUNITY HEALTH CENTER , KIMIN

Proposed site: Location available for installation

TERI has designed and commissioned a geothermal-based heat pump system for space cooling and heating in Arunachal Pradesh. The project is a technological demonstration for the entire Northeast region where there is tremendous potential for geothermal energy utilisation. This can be used for both cooling and heating in many parts of the region. Apart from conservation of energy through high efficiency variable refrigerant volume (VRV) heat pump, this system also addresses issues of conservation of water, which is a crucial resource. An analysis showed that in cooling mode, geothermal-based heat pumps are 29 per cent more efficient than conventional water-based heat pumps. In heating mode, geothermal-based heat pumps are 31 per cent more efficient than conventional electrical heaters. The compressor in a heat pump requires electrical energy for its operation. This electrical energy was proposed to be offset through renewable sources of energy.



Software model of Community Health Center, Kimin & Slinky used for heat exchange during installation

The configuration of the system at CHC Kimin is given as follows:

Total installation cost: INR 28 lakh (approx.)

Geo exchange loop 8 to 10 TR (estimated)

Number of loops: 10 + 3 (additional as standby)

Material: High density polyethylene pipes for underground water circulation, unplasticized polyvinyl chloride (UPVC) pipes for headers and inter-connection

Circulation pump: 0.75 HP 3 Phase

Heat pump machine (configuration)

Capacity: 10 HP

Make: Daikin

Indoor units: 4x 1TR and 2 x 1.5TR (total 6 nos)

Solar PV system capacity: 10kWp

Panel make: Vikram Solar (330Wp panels 30 nos)

Inverter make: Solis (10kW rating)

Inverter type: Grid connected

CASE STUDY 2

SOLDRY

Details of SolDry technology demonstrated in Ladakh was collected from National Institute of Solar Technology (NISE). The SolDry technology (patented) can be used for a variety of agricultural and industrial process applications. In addition to its substantial usage for poultry and livestock ventilation and space heating, it is also ideal for other agricultural applications, such as crop and process drying.

Agricultural and agri-food operators consume tremendous quantities of energy, which represent a sizable proportion of their total input costs. An alarming rise in energy prices has been exerting downward pressure on agricultural incomes in countries around the world, which is why, solar energy represents a tremendous opportunity for the agricultural sector.

SolDry systems supplied to farmers in Ladakh for apricot drying and space heating

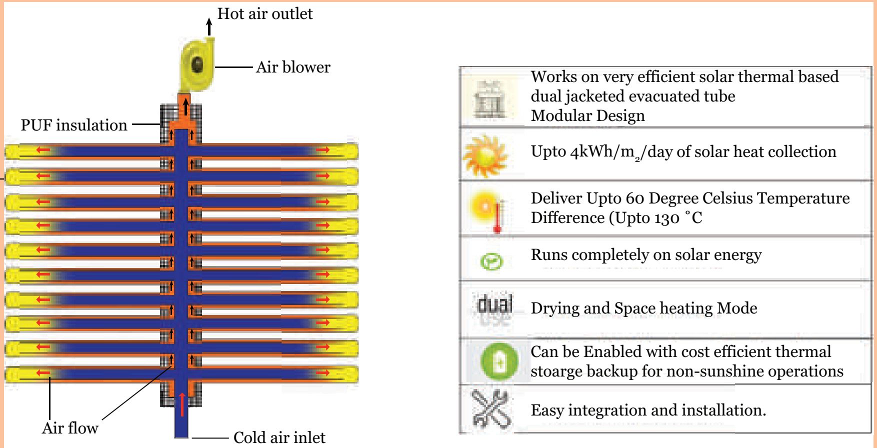
The SolDry technology can heat large volumes of incoming air up to 60°C above ambient, making it ideal for many agricultural and horticulture-drying applications. The solar air heating system may provide all of the heat during a sunny day or be a catalyst for pre-heat during cloudy conditions. It can either act in a standalone capacity via a modular system, or as a pre-heat system to traditional mechanical operations as well as space heating.

In both these cases, it substantially reduces the dependency on traditional fuels. This has myriad positive effects, including:

- lower operating costs;
- decreased reliance on fuels that need to be transported to remote sites;

- counteracting deforestation by reducing the quantity of trees that are harvested for fuel;
- lower humidity in the incoming air (because it is heated before entering the building or drying chamber), which means that the air has been preconditioned to absorb more moisture;
- GHG emissions reduction; and
- producing a high-quality finished product that is eco-friendly and was processed using "clean and green" energy resources.

SolDry System Process



Each square metre of SolDry system produces the same amount of heat generated by a 500-watt heater. By installing a solar air heating system, burners not only get turned down, they often get turned off completely for extended periods of time.

As a result, the SolDry technology has tremendous potential to lead the way in using solar for drying agricultural and horticultural produce, along with solar process heating standards for both agricultural and commercial applications across the world.

Table 8: Saving calculations

Cost of SolDry per m² of collector area	**Rs 15,000**	
	Electricity	**Diesel**
Saving per day per m² collector area (SolDry running for 8 hours a day)	4 units (kWh)	0.35 L
Savings per day	Rs 36 (electricity cost @ 9 Rs/kWh)	Rs 21 (diesel cost @ 60 Rs/L)
Rate of return (@ 300 sunny days)	**1.3 years**	**2.3 years**

SolDry system installation for industries for drying/process heat applications

CASE STUDY 3

SOLCER HOUSE, BRIDGEND

Solcer House's wall incorporates a transpired solar collector [24]

Cardiff University created a prototype low-cost energy smart house, capable of exporting more energy to the national electricity grid than it uses. The Solcer House in Bridgend follows the "buildings as power stations" concept, using renewable energy systems as building elements. Its upper, first-floor wall incorporates a transpired solar collector (TSC) and a 4.3kWp photovoltaic (PV) panel system on the south-facing roof.

The glazed solar photovoltaic panels are fully integrated into the design of the building, allowing the roof space below it to be naturally lit. This was done to reduce the installation cost. The energy systems combine solar generation and battery storage to power up the combined heating, ventilation, hot-water and electrical power systems.

Heating is supplied by passing external air through the solar collector and a mechanical ventilation heat recovery (MVHR) unit. The exhaust air is passed through the MVHR and then an exhaust air heat pump heats up the thermal water store, further heating up domestic water. The heat pump is powered by the PV and battery-storage systems. The three-bedroom house, which combines the best off-the-shelf technologies in a unique way, uses grid electricity supply only when the PV-battery system is exhausted. The predicted energy performance is 70 per cent (autonomous), with a 1.75 grid export-to-input energy ratio.

[24] Details available at http://www.yoursolarhome.com/

BARRIERS IN IMPLEMENTATION OF SUSTAINABLE HEATING TECHNOLOGIES IN THE IHR

On studying the estimation of emissions from space heating, it was found that 75 per cent of the emissions from space heating are linked to burning fuelwood. In the IHR, fuelwood burning devices, such as saggars, stoves, bukhari and fireplaces, are used for space heating. In order to address the issue of emissions from space heating, a push should be made towards switching to cleaner technologies that are efficient, have better efficiency of combustion and use cleaner fuels (e.g. renewables, electricity and LPG). The prevalent cultural norms, traditional system and social structure have important roles in the existing technologies being chosen in the region for space heating. In rural areas, heating and cooking are interlinked activities. Fuelwood is used not only for space heating but also for cooking, water heating, crop protection, cooking food for livestock festivals and cultural events. Being widely and locally available, it is the cheapest available source of heating. In rural area, the switch to sustainable fuel or technology will be only possible when the solution encompasses all the benefits that fuelwood provides to the locals.

In urban areas, LPG is the preferred mode for cooking. For space heating, mostly mature heating technologies that run on electricity are opted. Financial affluence has an important bearing when a better technology-based product for heating is opted in urban areas. Innovative technologies use renewable energy and ground source heat pumps (GSHPs), which, though promising solutions for sustainability, are expensive, technologically complex and require retrofitting of building for capital cost management. In recent times, the government has been pushing towards renewable energy through policies such as accelerated depreciation in taxes, but the overall impact of the same is very less.

In Chapter 3, we discussed the challenges associated with technology; this chapter covers the policy landscape with focus on MSMEs and start-ups, and the associated barriers in implementing space heating technologies in the IHR.

In the commercial sector, emissions from space heating are significantly small in comparison to the overall emissions. Figure 16 shows the emissions by space heating from electricity and wood in the residential and commercial sectors.

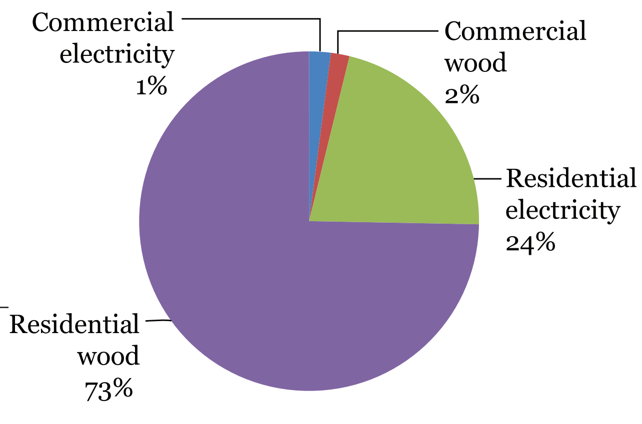


Figure 16: Percentage of space heating emissions in commercial and residential sector by electricity and wood

4.1 CLEAN FUEL USAGE, ELECTRICITY ACCESS AND DISTRIBUTION INFRASTRUCTURE

As mentioned earlier, cooking and heating are related activities in the rural households of the IHR (Anon. 1996). Clean cooking and provisions of off-grid electrification solutions, including the use of solar photovoltaic (PV) technologies, are being promoted in the country today. By pushing policies that promote modern and clean use of bioenergy (energy produced by burning **biomass** or **biomass** fuels) in households, the Government of India has made significant progress towards replacing traditional use of biomass. The alternative cooking and heating fuels can be both renewable (solar cooking) and non-renewable (such as LPG) (International Energy Agency 2020). The government is pushing towards implementation of such policies in the IHR as well.

The government has also been supporting the expansion of distribution grid infrastructure across India to foster electricity access in villages. It provides budgetary support (grants) to the state government DISCOMs under the **Deendayal Upadhyaya Gram Jyoti Yojana** (in rural areas), the **Saubhagya scheme** (last-mile connectivity to households) and the **Integrated Power Development Scheme** (IPDS) (in urban areas) (International Energy Agency 2020). These coordinated cross-government schemes focus on strengthening distribution networks and increasing village and household connections by co-funding network upgrades and extensions by the DISCOMs. As per the latest Energy Statistics 2020 as of 31 March 2019, 100 percentage of villages have been electrified in the IHR (MoSPI 2020).

To promote clean cooking and reduce exposure to indoor air pollution as a result of burning of wood and biomass, the Government of India has been subsidizing LPG. Several major initiatives have been introduced to better target the subsidies and avoid commercial use of LPG, notably through the **Pratyaksh Hanstantrit Labh (PAHAL), Pradhan Mantri Ujjwala Yojana (PMUY)** and **"#GiveItUp"** schemes. PAHAL, also known as the Direct Benefit Transfer of LPG scheme, sends the subsidy for the LPG purchased directly to a citizen's bank account. Under the PMUY, women and below poverty line families receive a subsidy. The 2020–21 budget also extended the PAHAL and PMUY to provide every single rural family with electricity and a clean cooking facility.

4.1.1 Related barriers

4.1.1.1 Distribution infrastructure

- In villages that have been electrified, the distribution infrastructure requires maintenance and upgradation; otherwise, it will be unfit for large loads. The households in these villages that have access to only single-phase power supported by older infrastructure will not be able to use heating appliances.

- Off-grid communities and poor households are provided with low-capacity connections, because of their limited capacity to pay; they are, therefore, unable to use electricity for heating (World Health Organization 2018).

4.1.1.2 Financial capacity of rural households

- While it is expected that the consumption subsidies will increase as the percentage of people accessing electricity will steadily rise, it will not be the same case for financial capacity (Soman, Gerasimchuk, Beaton, et al. 2018). Although most the IHR areas have access to electricity, however its usage for space heating is limited largely to the urban areas.

4.1.1.3 Consumer behaviour and response to government schemes

- Since its launch in September 2016, the PMUY enabled 32 million poor women to access subsidized LPG within 20 months. However, initial reports on programme performance indicate that on average there are only four refills per household in a year.
- The Oil Marketing Companies (OMCs) have reported that till May 2019, 1.67 crore people who purchased LPG connection and 1.45 crore PMUY beneficiaries have purchased the refills four and five times respectively, and nearly 86 per cent of the PMUY beneficiaries who have been part of the scheme for at least a year have returned for the second refill (Press Information Bureau 2019). This is true in rural areas of the IHR as well where a single cylinder of LPG gas is used for four to six months.

4.1.1.4 Lack of awareness on benefits of transition to cleaner fuels

- In rural areas, only those households with good socio-economic status use electricity for heating purposes. Even though electricity is the primary source of lighting in all the areas, biomass is the primary source of heating as it is freely available. Most cash-poor rural households, especially the mountain community, use biomass (available at zero cash outlay) instead of commercial cooking fuels, even when these commercial fuels are subsidized.
- The conventional methods for heating and cooking still remain prevalent in households owing to lack of awareness on the benefits associated with the use of clean fuels for cooking and partly because the time saved by using the commercial cookstoves does not necessarily result in increased income-generating time for the rural populations.
- In commercial and institutional establishments, heating is done partially using electricity; however, in the hotel industry electricity is more prevalent for space heating.

4.1.1.5 Adaptability, versatility and ease associated with conventional methods

- Though most households have access to clean energy for cooking, its usage is limited. For instance, in a survey conducted by TERI in the IHR, it was found that cooking gas is generally used in emergency situations when wood is not available, cooking is to be completed in limited time or the need of urgency outweighs the efforts needed to build the fire by fuelwood. Fuelwood also has a dual purpose; it can be used for both cooking and heating till the fuelwood burns out.
- Even households that are marginally better economically, use fuelwood as subsidies on LPG have been reduced (Dutta 2018).
- As fuelwood can be used for a multitude of applications, alternative fuels have been unable to replace it. In the rural areas of the IHR states, apart from space heating and cooking, fuelwood is also used for water heating, heating and preparation of food for livestock, community heating during gatherings and festivals, and protection of crops.

4.1.2 Summary of barriers

- Limited access to reliable electricity and lack of proper distribution infrastructure
- Limited financial capacity of cash-poor rural households
- Consumer behaviour leading to limited usage of clean technologies
- Lack of awareness on benefits associated with clean technology use
- Limited subsidies leads to limited uptake or switching back to conventional practices

4.2 START-UP ECOSYSTEM AND THE MSME SECTOR

Over the last 2–3 years, policy initiatives including **Start-up India** has placed the ecosystem as the third largest for successful start-ups in the world (Ministry of Finance 2020). India has also improved its ranking considerably in the World Bank listing of **Ease of Doing Business**. However, as per the industry-wise distribution of recognized start-ups, IT Services stood at 13.9 per cent, whereas Green Technology (3 per cent), Technology Hardware (2.9 per cent) and Renewable Energy (2.8 per cent) accounted for the lowest (Ministry of Finance 2020).

The Micro, Small and Medium Enterprises (MSMEs) contribute significantly in the economic and social development of the country by fostering entrepreneurship and generating large employment opportunities at comparatively lower capital cost. The Government of India is committed to supporting this sector through initiatives and policies for its growth.

To ease access to finance, the Ministry of MSME, Government of India and SIDBI set up the **Credit Guarantee Trust Fund for Micro & Small Enterprises (CGT SME)** to provide collateral-free loan up to a limit of ₹ 100 lakh for individual micro and small enterprises (MSE) on payment of guarantee fee to the bank by the MSE. To support the "Make in India" initiative, **Zero Defect and Zero Effect (ZED)** scheme ensures the provision of subsidy by the Government of India for MSMEs at 80 per cent, 60 per cent and 50 per cent respectively, for assessment and rating/re-rating/gap analysis/hand-holding.

The **ASPIRE scheme** aims to incubate new/existing technologies for their commercialization through technical/research institutes. The policy is coordinated by the Aspire Scheme Steering Committee of the Ministry of MSME. Small and medium-sized enterprise (SME) with innovative ideas ready for commercialization get early-stage funding support for setting up **"Business Incubators"** by applying for support to the listed host institutions such as IITs, NITs, technical colleges, research institutes, etc. (Ministry of Micro, Small and Medium Enterprises 2019).

It is imperative to take success stories for mass consumption which requires bridging the gap between potential technologies, and start-ups and their impacts. There are 52 schemes by the government and departments operating in the IHR, which target self-employment generation for creating "necessity entrepreneurs" and "opportunity entrepreneurs".

One of the prominent schemes, **AGNIi (Accelerating Growth for New India innovation)** will help successful technologies with business and development advice in order to become national and global successes with a focus on rural areas. The Himalayan Research Group designed and fabricated solar water and space heating panels developed for the IHR region and supported by the Department of Science and Technology are the only technologies listed as part of AGNIi database for space heating in the IHR.

To understand the current state of play concerning the above initiatives, interviews were conducted of various stakeholders such as manufacturers, technology providers, standardization institutes, government, etc. involved in the deployment of space heating technologies in the IHR. This helped to gather insights on the issues limiting their operations, implementation and day-to-day functioning. These are summarized here.

Innovator, Social Enterprise

Himalayan Research Group (HRG), Shimla, a core supported group (CSG) of the Science for Equity Empowerment and Development (SEED) division of the Department of Science and Technology, Government of India, designed and fabricated **Mountain Solar Water and Space-Heating Systems** for domestic needs in mountains of locally available material through training of rural artisan (carpenter). A total of 173 space heating and 933 water heating systems have been installed with the support of different international, national and state agencies till now in Himachal Pradesh and Ladakh. HRG Shimla and Dr Lal Singh were awarded H.P. State innovation Award for 2016–17 by the H.P. State Innovation Council for developing the Mountain Solar Water Heating System.

Dr Lal Singh in his discussions with TERI informed that they are operating as a social enterprise and are currently in the process of ***setting up their own MSME*** *largely due to the* ***ease and benefits associated with this expansion****. They have experience of over 25 years and innovation on their side and are* ***aware of all the instruments in the market to access finance****.*

It was mentioned that ***technology validation and certification from the accredited agencies were major constraints*** *in the commercialization of the innovation.*

MSME Representative, Manufacturer of Solar-based Drying and Heating Systems

The following challenges were faced:

- *The industry is aware of the implementation-based challenges better and the R&D institutes that hit a major roadblock due to this reason collaborated to mutually benefit from the partnership.*
- *The support of R&D institutes would provide credibility to MSMEs along with enabling access to funding for joint R&D and setting up incubators or pilots for effective implementation.*
- *The MSMEs in India lack internal capacity and potential to carry out productions at scale in comparison with international markets.*
- *There is also a lack of skill availability and forward looking market in the IHR to implement innovative technologies.*
- *For the MSMEs to get access to subsidies provided by local and state governments for implementation, validation and certification from*

accredited agencies are required. Sometimes, the standardization process is not established for a new or upcoming technology leading to delays in its adoption, commercialization and further losses.

- *The MSMEs generally do not get the market buy-in easily unless there is an association of a credible institute which is also a challenge.*
- *The banks offering credit to the MSMEs often lack the technical know-how of the energy sector for effective decision-making to process the application.*
- *The manufacturers of green or renewable technologies could get a separate inclusion or identification under the MSME sector.*

National Institute of Solar Energy, an Autonomous Institution of the Ministry of New and Renewable Energy

NISE is looking at technology transfer of three technologies: Solar Dryer with Space Heating implemented in Ladakh is one of them. NISE is in the process of inviting interested MSMEs to a platform where they would be looking to transfer the technology.

The transfer process is intended to be transparent in nature and it is backed by a ***selection criteria*** *to shortlist the interested players. The players would be expected to provide their* ***capacity to invest capital, technical know-how of solar thermal technologies, experience of operating in hilly regions of the country****, etc. Knowledge of working with solar dryers would be considered as an advantage and is likely to be prioritized.*

NISE is not facing challenges in transferring technology to the manufacturers because of their ***credibility leading to higher market confidence****. The technology has also* ***successfully demonstrated benefits*** *such as high efficiency and has proven market potential as it is being used for decades.*

NISE is in the process of determining if it could generate revenues though technology transfer in the form of a royalty as a percentage of the cost of units sold, which could contribute to the organization's sustainable operation.

MSME Representative, Manufacturer of Rocket Stove

The technology was transferred from Russell Collins, Australia to Indian partners. So far Russell Collins has the majority of shareholding in the venture. For carrying out its operations till date, the Indian partners have reached out to international corporates.

The manufacturers of the Rocket Stove technology were also the winner of the Social Alpha Energy Challenge. They received customized lab-to-market incubation support at Clean Energy International Incubation Centre (CEIIC), including access to world-class lab infrastructure and test beds, technical advisory, R&D support, piloting opportunities with industry leaders, access to grant funding, hands-on operational support, business planning, go-to-market strategic advisory, international exposure and collaboration opportunities, opportunity to access seed support from Social Alpha, a connect with a larger investor and donor network, access to shared office space with amenities and shared support services.

The following challenges were highlighted:

- *The product and the manufacturing are profitable; however, there is a* ***need for credit or funding support to scale-up the manufacturing for expansion****. The process is going on to explore the schemes provided by the Government of India and finding academic institutions to partner to get access to finance.*
- *They are also looking at restructuring their organization as the majority shareholding of the company with an international partner does not align with the "Make in India" policy promoted by the Government of India.*

4.2.1 Related barriers

4.2.1.1 Complicated legislative and statutory compliance process

- Although the Government of India is committed to supporting the MSME sector for better credit flow, technology up-gradation, ease of doing business and market access; documentation and declaration procedures under several regulatory statutes are rather cumbersome, extensive and protracted.
- As per the Economic Survey of India, 2019–20, India continues to trail in parameters such as Ease of Starting Business which has limited the overall growth of this ecosystem.

4.2.1.2 Access to finance

- Lack of access to finance in MSMEs has held back the establishment of small units, and their overall growth and development. Local banks have limited capacity and tend to prefer the larger transaction sizes associated with utility-scale projects.
- There is a limitation associated with higher transaction costs involved in the IHR in comparison to the plains.
- Moreover, there is a **lack of frameworks for evaluating the credit worthiness** of smaller companies and consumers. **Financing decentralized projects**, such as solar irrigation pumps and rooftop solar and mini-grids, are often more difficult than funding utility-scale projects despite the large markets for these products.
- The operatives of the banking institutions are not capacitated with adequate technical knowledge required for effective decision-making to grant loans.

4.2.1.3 Capacities of MSMEs

- There is an issue of scale that gets into the business efficiency as majority of the manufacturing units have low capacities.
- In order to cater to the large markets demanding deployment of innovative space heating technologies in the IHR, their manufacturers require necessary capital, skilled workforce and technology up-gradation for manufacturing and competing with international manufacturers.

4.2.1.4 Credibility and trustworthiness

- RD&D execution is limited to government laboratories, PSUs or certified academic institutions (International Energy Agency 2020). In some cases, private-sector organizations are invited to apply for government funding, but require eligibility certification. Few awards or grants seek SME participation.
- Some public programmes in India do not allow private-sector companies to bid as lead applicant (International Energy Agency 2020), or require specific certifications that hinder and slow down private-led technology innovation processes, especially for SMEs. For instance, the MNRE's Research, Development, and Demonstration (RD&D) in solar energy provides start-ups, entrepreneurs and manufacturing units financial support of up to 50 per cent of the project cost in comparison to academic institutions, universities, research institutes, government/non-profit research organizations, etc. that are awarded up to 100 per cent support.
- Sometimes, the certification/standardization process is not established for a new or upcoming technology leading to delays in its adoption, commercialization and further losses.

- There is also a gap in support for the scale-up of emerging energy technologies, where capital costs and risks are high.

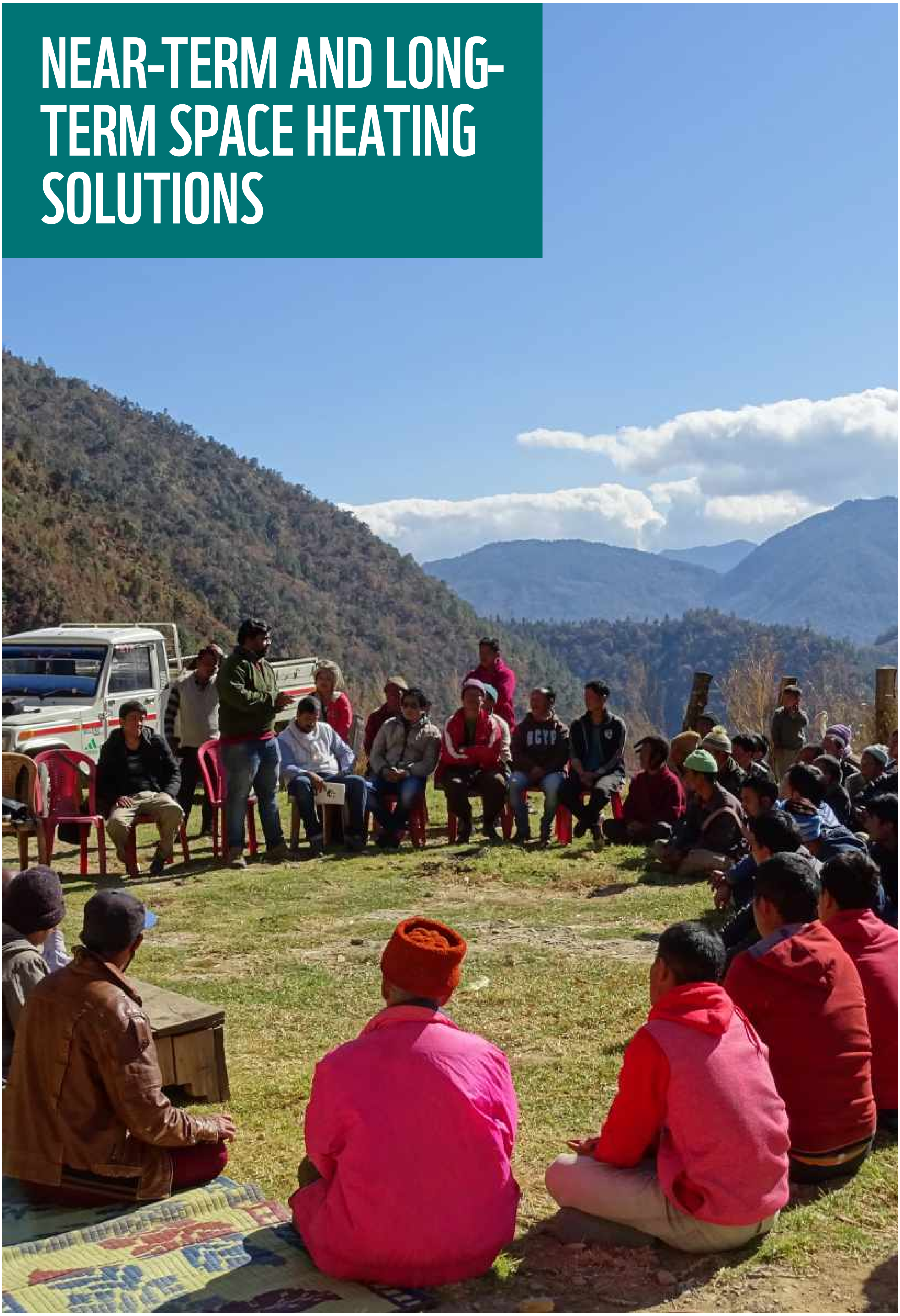
4.2.1.5 Market and skilled workforce in the IHR

- A small number of projects have been implemented though there has been limited adoption of efficient technologies and replication of best practices, due to the existence of numerous barriers and market failures leading to a low market confidence.
- There is a lack of information and collation of success stories of the IHR available in the public domain that has limited the availability of information on health benefits associated with the use of clean fuels for the users.
- Incentive mechanisms and investments in skill and entrepreneurship development focusing on sustainable technologies lack effective implementation, which can utilize the existing workforce of the IHR for employment generation.

4.2.2 Summary of barriers

- Limited institutional frameworks to strengthen implementation
- Limited skill availability of the rural population in the IHR
- Challenges associated with technology deployment due to geography
- Limited access to finance
- Low market confidence due to market faliures and implementation-based challenges
- Lack of transparency in credit disbursement by banks and limited knowledge of the energy sector
- Limited R&D support and lack of mandates for industrial collaboration

NEAR-TERM AND LONG-TERM SPACE HEATING SOLUTIONS



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5.1 POTENTIAL EMISSIONS REDUCTION

The study on current emissions and the technologies for space heating provides us perspective on the current scenario of emissions due to space heating. Presently, almost 97 per cent of emissions due to space heating in the IHR are from residential buildings. Out of this, 19 per cent are from urban residential buildings and 78 per cent are from rural residential buildings. The share of commercial and institutional buildings is only 3 per cent. Out of the total emissions, 75 per cent of the total emissions in the IHR are linked to the use of wood. Therefore, finding technological solutions for residential buildings are very important for reduction of emissions from space heating. Greater focus should be given to rural areas as majority of emissions are from rural residential buildings.

The SDG 7 Targets – to ensure access to affordable reliable and modern energy, increasing the share of renewable energy and improving energy efficiency by 2030 – are used as guiding factors in calculating the potential of emissions reduction. Based on the comparative study of existing technology used conventionally and the mature innovative technology available, the projection of reduction in emissions is done. The study of the policy landscape in Chapter 4 provided insights into government policies towards cleaner fuels and the barriers that prevent widespread adoption of the same.

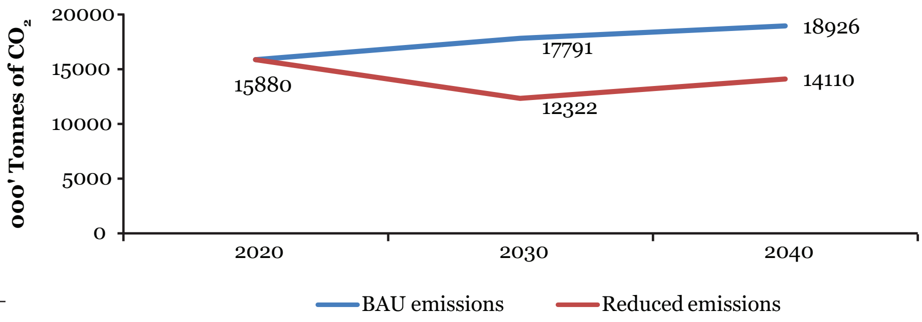
The following assumptions are made for calculating potential for reduced emissions:

- 75 per cent of total emissions are linked to wood, hence improvement of efficiency of the heating systems using wood is targeted by 2030.
- The emissions reduction for 2040 is calculated considering that all the space heating shall be done through clean energy, i.e. electricity.

Electricity-based heating can be used in the rural areas, which will reduce emissions from the existing fuelwood-based heating. The government is working towards making electricity available to the entire region with better infrastructure. However, presently electricity-based heating technologies are not being used due to affordability and reliability issues. Traditional fuelwood-based technologies are inefficient and also pose health issues due to bad indoor air quality. If emissions can be reduced by using cleaner fuel, then it will result in improved health, reduced drudgery linked to collection of fuelwood and reduced energy poverty. This will also improve the affordability of the clean energy in the region as more time can be used for productive work.

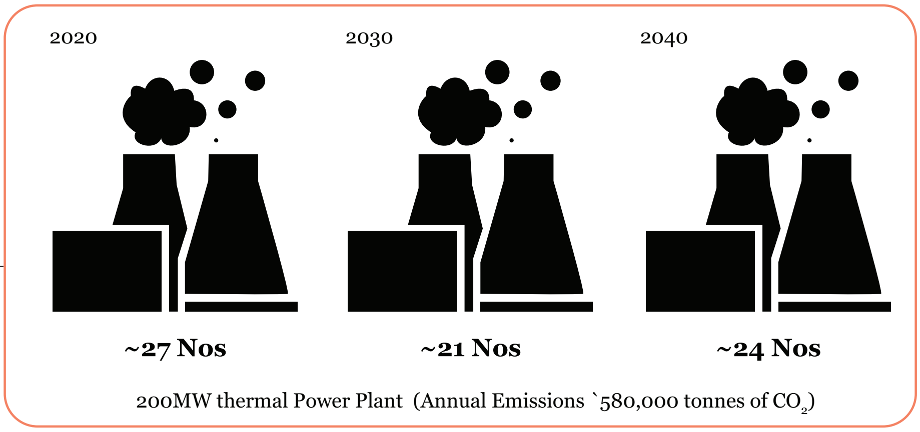
There is a big gap in the present use of inefficient technologies for space heating and in the usage of new improved efficiency technologies. By bridging the gap, emissions can be reduced. Based on the above assumption, calculation of potential reduction of emissions is done. These are presented in Figure 17.

Figure 17: Potential of emissions reduction through innovative space heating technologies and clean energy penetration



The reduction potential of annual emissions by opting for efficient fuelwood-using technologies and clean energy for space heating is projected to be 22 per cent less than emissions of the base year 2020 and 11 per cent less in year 2040 from emissions of the base year 2020 (refer to Figure 18).

Figure 18: Emission in space heating through efficient technologies and clean energy



5.2 SUSTAINABLE SPACE HEATING SOLUTIONS IN THE IHR

In Chapter 3, the study had identified 21 space heating solution technologies for the IHR. In this chapter, we will further explore the near-term and long-term sustainable space heating solutions that are based on the three pillars of sustainability: environmental, social and economics. In recent years, many innovative space heating solutions were introduced in the IHR, which offer the advantages of greater safety, lower fuel consumption and reduced emissions. However, some of these innovative space heating solutions such as Himtapak (army kerosene heater) cannot be placed under sustainable heating solution category as they run on non-renewable fuel sources (kerosene or coal) which are identified as potential emitters of greenhouse gas and other hazardous fumes. Amongst the different Bukhari-based technologies, Sawdust Bukhari has the lowest efficiency and demands a higher degree of handling efforts which makes it a non-sustainable heating solution. Under this background, the present study does not recommend these innovative space heating technologies as the near-term or long-term sustainable heating solutions. Under the near-term solution category, eight space heating technologies have been identified that are market-ready, mature and have a green impact. These technologies do not require much research and development, but need a push from the government so as to increase their uptake among the local masses. This can be achieved by increasing their outreach, subsidy support, awareness, etc. We have identified nine long-term space heating solutions based on viability, innovation and the overall impact. Near-term and long-term space heating solutions are further discussed in the subsequent sections.

5.2.1 Near-term technology solutions for space heating

- **SolDry** is a patented technology, developed by the National Institute of Solar Energy (NISE), used for drying agri-based food through solar thermal technology. In addition to utilizing solar heat for drying purposes, this system can also be used to meet the in-house space heating needs of agri-based food processing establishments. The payback period of this technology is approximately 1.3 years which can be further reduced by availing subsidy from the MNRE. Drying of agri-foods and horticulture produce improves the shelf life of these products and, thus, it is very advantageous to local farmers and related enterprises. Uttarakhand, Himachal Pradesh, Jammu and Kashmir, Sikkim and some parts of Assam produce significant amount of flowers and fruits including Indian olives and figs, apricots, pears, apples, raisins, etc. SolDry can find great applicability in these states as the technology provides emissions-free drying and simultaneously supplements the space heating requirements to create thermally comfortable conditions for its users.

- **Integration of Evacuated Tube Heat Pipe (ETHP) with Fan-Coil Unit (FCU)** for space heating application can be easily deployed in the urban areas that have good electricity supply. The components of this integrated system are mature and widely used in the solar and HVAC industry of India. This system is capable of achieving huge savings on electricity bills owing to the continuous operation of the heaters. FCU is the only power-consuming unit that is not energy intensive and the ETHP system drives through solar thermal. These evacuated tubes perform well under indirect as well as diffuse solar radiation. Thus, this whole system is capable of providing thermal heat on sunny and partially cloudy days. On days with very low solar radiation, auxiliary electric heating can also be integrated with solar ETHP. A similar space heating system has been installed at the Secretariat in Kohima, the hilly capital city of Nagaland. Enfragy Solutions India Pvt. Ltd. designed and installed this system as a pilot project. Kohima lies at an elevation of 1382 m above sea level and experiences the subtropical highland climate (Köppen: Cwb). The initial installation cost of the system is INR 5.9 million and it can produce 3500 litres of hot water per day and collect 23.34kW of solar thermal energy per hour. In consideration of the annual energy savings, water and maintenance costs of the system, the total payback period is calculated to be 4.3 years. The installed system was conceptualized mainly for institutional purposes catering to large heating requirements and can be deployed in other regions of India with good solar insulation/irradiance, especially Uttarakhand, Himachal Pradesh, Jammu and Kashmir, Leh and Ladakh. However, the higher upfront cost and large space requirement for system installation need to be addressed. Additionally, a supply-side push is required, especially for the efficient ETHP manufacturing in the Indian market. As per Enfragy Solutions India Pvt. Ltd., the system penetration in the Indian market can be increased by increasing the outreach and creating awareness on availing subsidies from the MNRE. This will further reduce the calculated payback period of the system.

- **SolarSheat** is one of the commercially available **solar air heaters integrated with a DC fan and PV panel**. It is ready to install space heating solution for all areas including remote or off-grid locations having intermittent or no electricity supply and good solar availability. SolarSheat was designed and developed by Solar Furnace Pvt. Ltd., a North American space heating solution provider. More than 1500 SolarSheat have been sold in various parts of the world. One SolarSheat panel is effective for heating a 500 sq. ft area. SolarSheat can cut down electricity bills by up to 40 per cent and return on investment between three and six years, depending on the solar resource availability and heating costs. For heating a family home for five months in central Massachusetts, where this technology has been implemented, at the current price of fuel, and based on a modest 15 per cent projected offset in heating costs on a 712-liter consumption rate per month, a SolarSheat has a payback period of fewer than six years without producing greenhouse gases (Solar Energy Financial Corporation 2011). This innovative air heater has components that are technology-wise mature and easily available in the Indian solar market. If manufacturing units are set up in the country that use components from the Indian solar market, then the costs can be easily lowered and adoption escalated in the IHR. As India witnesses a significantly higher number of sunny days than the cold Western countries including Canada and America (where this product is based upon), the return on investment can be expected to be much higher.

- **Himalayan Rocket Stove** is a commercially available heating and cooking stove which claims to address three key issues of the Himalayas: air pollution, deforestation and health of women through advanced burning of fuelwood in a smokeless manner. This technology has fairly good outreach in Kullu, Manali, Shimla and other parts of Himachal Pradesh and some parts of Leh and Ladakh due to its manufacturing units located in Chandigarh (Himachal Pradesh) and Leh. However, penetration of this technology needs to be strengthened in other parts of the IHR, including Uttaranchal, Jammu and Kashmir and Northeast India. Higher handling charges and delivery costs as a result of far located manufacturing units must be the foremost action point for the government and the MSME sector. Rocket stove can be used at all altitudes; designs can be modified to cater to cooking and heating as per need and priority. The technology can be made popular in middle to higher income group households in the region. This technology can also be adapted to use biomass briquettes as fuel. The product has won many accolades and awards, including the ASME ISHOW award (Collins 2019).

- **Biomass briquettes** are considered as renewable sources of energy fuel which provide stable flame, low hazardous emissions and maintain a steady indoor temperature for longer times. These biomass briquettes are composed of crop residue of straw, sugarcane (bagasse), sunflower husks, rice husks, buckwheat, sawdust, etc. and hence can be widely adopted in low- and mid-altitude hilly regions having a large green cover. They can be directly used as burning fuel instead of charcoal in cooking or heating applications. The calorific value of biomass briquettes is almost 2.5 times the calorific value of hard fuelwood (Food and Agriculture Organization 2014). This also implies that for catering the heating requirement of a single-family unit at mid-altitudes (500–1500m) during the winter season will require approximately 900 kg of biomass briquettes against 2200kg of hard fuelwood for meeting the same heating needs. Low- and medium-income groups in rural areas can immediately switch to biomass briquettes along with improved cookstoves and bukhari. The government should identify the key locations and industries for the adoption of briquettes and then MSME may set up manufacturing units. Biomass briquettes can find great applicability in the Northeast India, including Meghalaya, Mizoram, Nagaland, Arunachal Pradesh, Manipur and Tripura. The livelihood of tribal populations in these states depends largely on the forests. Even though the climate of these states is less harsh compared to settlements located in higher altitudes in Northern states, considerable amount of biomass is used for cooking and space heating. These tribes follow Jhum (shifting) cultivation. It is a primitive practice of cultivation with a conventional cycle of shifting as 10–15 years. In recent times, this has decreased to 5–10 years because of reduced fertility of the soil (Bhatt, Rathore, Lemtur, et al. 2016). The government can look into providing alternative fuel like briquettes in these areas which can be sourced from regularly cultivated areas in the plains.

- In 2019, the National Innovation Foundation-India 2019, an autonomous body of Department of Science (DST), presented the 10th National Grassroots Innovation Award (Consolation) to **"Mini Bukhari – Portable Space Heater"** which is a technologically advanced version of a traditional wood bukhari. After complete combustion of fuelwood, the mini Bukhari can retain heat for about 3–4 hours, in comparison to just half an hour in conventional alternatives. Fuelwood consumption in this advanced Bukhari is less than 2kg per hour compared to 3 to 4kg per hour in the traditional Bukhari. This space heating solution has been tested and validated at the National Institute of Technology, Srinagar. Wood bukharis are most effective and conveniently used in low to medium altitude hilly areas of Jammu and Kashmir and some parts of Himachal Pradesh having abundant forest covers. In mid-altitudes where fuelwood is easily available, the **m**ini Bukharis can be widely promoted as it consumes far less wood than a traditional wood Bukhari.

- **Infrared/ceramic/oil-filled radiator heaters** can be a better solution in urban areas of the IHR compared to coil heaters or convective blowers. Urban areas have a continuous and stable connection to electricity grid. The upfront cost of an oil-filled radiator heater is the highest followed by a gas heater, ceramic heater and electric blower heater. Ceramic and oil-filled heaters provide better indoor environmental quality compared to coil or convective heaters. By improving the transmission and distribution networks for good electrical connectivity, the outreach of electrical appliance-based heating solutions in the rural areas of the IHR will significantly increase. These solutions can be linked to renewable energy, but its high cost prevents it from being a suitable replacement in the rural and remote areas.

- Gas heaters can be a clean space heating solution for rural areas. They do not require electricity, wood or kerosene. The availability of LPG has improved in the IHR, but the usage of gas heaters is still limited due to higher upfront cost and poor market readiness. CO_2 emissions from an LPG room heater are approximately five times lower than an electric room heater for meeting the same space heating requirements on a typical winter day.

Table 8: Near-term sustainable heating solutions

Technology	Key observations
SolDry	• Space heating requirements can be met at much lower system capacities as compared to agri-based food drying applications which require very high temperatures. This can further lower the current payback of 1.3 years.
	• The outreach of the system to be improved to establish it as a space heating solution in the IHR.
Integration of Evacuated Tube Heat Pipe (ETHP) with Fan-Coil Unit (FCU)	• Solar thermal-based renewable energy system has a payback period of 4.9 years that can further be lowered by availing the MNRE subsidy.
	• New technology, hence government intervention is required to develop an in-built service mechanism, ensuring the supply of highly efficient ETHP manufacturers and improve awareness among the masses for this ready to install technological solution.

Table 8: Near-term sustainable heating solutions

Technology	Key observations
SolarSheat	• SolarSheat is a commercially available renewable energy-based heating solution claiming a payback period between three and six years. All the components of this solution are readily available in the Indian market. It is a good opportunity for the MSME to start the local assembly and supply of this solution under the Government of India umbrella. This will lower the payback time, create more employment and increase income generation across the IHR.
Himalayan Rocket Stove (HRS)	• HRS can significantly bring down fuelwood consumption. It can find vast applicability in the low- to mid-altitude IHR, especially Uttarakhand, Jammu and Kashmir, and Northeast India.
Biomass briquettes	• Biomass briquettes made from local crop residue, sawdust, etc. can reduce wood consumption by up to three times.
	• Tapping the industrial application of briquettes and consequently upscaling its availability for residential use can be the key enabler.
Mini Bukhari	• Mini Bukharis can reduce wood consumption by half in comparison to conventional bukharis.
Oil filled radiator heater	• Maintain good indoor air quality inside the space. However, higher upfront cost still limits their adoption to higher income groups.
Gas heater	• Higher first cost but lower emissions compared to electric heaters. • Government support is required to strengthen the supply and distribution network, which will ensure gas availability in the IHR.
Ceramic heater	• The safest option among all the available heater choices. • Cost is comparable to the electric blower heater in the market.

5.2.2 Long-term solutions for space heating

- **Solar hybrid heat pump systems** can be adapted for space heating applications in all the regions supporting good solar exposure as it is a self-sufficient system integrating solar photovoltaics, thermal and refrigeration technology. The system components are mature; however, the integration of solar hybrid (photovoltaic plus thermal) system and heat pump units is still a challenge and thus this technology needs exhaustive research and development work to recognize the optimal configurations under various criteria including technical, financial, outreach, etc. Solar and heat pump system can be designed for small residential units as well as large spaces including the commercial building sector as there is no restriction on the size. Higher altitudes require heating for more than eight months on an annual basis. Northern states including Uttarakhand, Himachal Pradesh, some parts of Jammu, Leh and Ladakh can potentially have a high return on investment for solar hybrid heat pumps, having a relatively greater number of sunny days than the Northeast states, which usually have cold and cloudy winter season. Incorporating auxiliary electric heating with this system can make it more convenient and accessible for the user.

- **Stratiflex** has been a recently developed innovative water storage tank component based on the thermal stratification phenomenon to improve the thermal performance of various components of a centralized heating system including gas condensing units, heat pumps, solar thermal systems, etc. Performance testing of this component in the Indian context is required. Since this is a very new product in the international market, its outreach is limited and the cost is high. Thus, its penetration in the Indian market is challenging. In this regard, academicians, government and industry players can come together to understand, replicate and later deploy this technology in the Indian market through MSME.

- The concept of **smart space heating** through Wi-Fi-enabled smart thermostats in place of conventional water radiator thermostats of central heating systems is novel and unique. This recent technology is mainly used with centralized heating systems to improve thermal comfort and reduce energy consumption by incorporating machine learning, local weather forecasting, occupant feedback and demand-side management. This smart technology is also capable of readjusting the heating requirements with changes in the indoor environment due to a window opening, occupancy change, etc. Along with DHS, this technological solution can meet all the space heating needs, and thus pilot testing needs to be done in the future.

- **Integration of ground source heat pump (GSHP) systems with solar photovoltaic (PV) systems** can be effectively used to provide space heating as well as cooling in areas receiving a good number of clear and bright sunny days annually, such as Uttarakhand, Himachal Pradesh, some parts of Jammu and Ladakh. The designing, procurement, installation and commissioning of the system requires technical, financial and logistic support. Although it has been successfully demonstrated at a site in Kimin by TERI, the main challenge is its higher upfront cost and system complexity. With financial and technical support, it can be upscaled in the urban areas because these areas are better equipped to meet the system requirements as compared to rural areas.

- **Building integrated photovoltaic (BIPV) solar heating** involves the integration of solar photovoltaic panels in the building envelope design in the form of walls, facades, etc. for meeting its heating demand. In addition to providing solar passive heating, mostly through the building envelope, this technology also produces electricity to operate electric air heaters. It is a very innovative concept and still in the development stage. This technology can be very effective for space heating applications in areas with high solar irradiation.
- **Liquid-based active solar heating** involves the distribution of solar heat by introducing a liquid-to-air heat exchanger or heating coil in the indoor space. Flat plate solar collectors are found to be best suited for space heating applications. This system works well for small and large spaces, depending on the space heating demand. However, the installation cost is high and requires skilled manpower to design, install and commission.
- **Solar air heaters made by the coupling of a parabolic solar dish collector to finned-tube heat exchangers** for hot air production appears to be a very innovative solution for space heating applications in the Himalayan regions receiving clear and bright sky. The upfront cost of the system is high and it needs research interventions for cost reductions to ensure its deployment in the IHR as per user needs, geographic features and infrastructure. This system is capable of providing stable space heating in large spaces for long durations.
- **Piped natural gas** can be a great space heating solution in the IHR as natural gas heat is comfortable, convenient, reliable and efficient. The natural gas heating system requires a good supply and distribution network for its distribution. However, the upfront costs are high but the operating costs are generally very less as compared to electric heat pump systems.
- Centralized heating through **district heating system (DHS)** is a well-established technology in western countries and is capable of handling space heating needs of a large number of residential and commercial units simultaneously in a more energy-efficient manner. The concept of DHS is new in India and it is yet to develop a robust and effective centralized heating system. DHS can find applicability in areas which require heating across the year and have anchor loads as these are critical to making a network economically viable. For this purpose, it needs to identify the exact heating requirements and accordingly plan the system configuration. Since huge investments are required in DHS installation, the involvement of government and private players is required in overcoming the first-cost barriers, high spatial concerns, development of distribution and transmission heat networks, etc. to establish a robust business plan. R&D initiatives must be undertaken to explore the possibilities of further improving the efficiency of DHS in India, through its integration with renewable, combined heat and power, etc.

Table 9: Long-term sustainable space heating solutions

Technology	Commercial availability in market		Degree of R&D interventions required	Ease of implementation
	National	International		
Solar Hybrid Heat Pumps	✓	✓	High	Easy
Stratiflex	✗	✓	Low	Easy
Cloud-based smart heating	✗	✓	Low	Easy
Integration of ground source heat pump (GSHP) systems with solar photovoltaic (PV)	✓	✓	Low	Difficult
Building integrated photovoltaic (BIPV) solar heating	✗	✓	High	Easy
Liquid-based active solar heating	✗	✗	High	Difficult
Solar air heater: Integration of parabolic solar dish collector with finned-tube heat exchangers	✗	✓	Low	Difficult
District heating system (DHS)	✗	✓	High	Most Difficult

In the current scenario, more than 90 per cent of the space heating requirements in the rural settlements of the IHR are met by freely available local biomass and the remaining 10 per cent are met by electricity and other fuel sources including coal, kerosene, gas, etc. Traditional fireplaces lit through coal and wood produce hazardous emissions and deteriorate the indoor air quality. Saggar, Bukhari, Kangri and kerosene heaters are widely adopted space heating solutions in the rural IHR. These existing space heating solutions are very popular among the masses despite producing large emissions from burning fuels such as coal, kerosene, sawdust, etc. However, in the urban settlements lighting and space heating requirements are majorly met by electricity. Owing to reduced fuel consumption, enhanced ease to the user and lower hazardous emissions, innovative space heating solutions need to be promoted in the rural and urban areas of the IHR. Locations at 2500m above the sea level do not exhibit rich biomass during various times of the year and, thus, the high space heating requirements are substantiated through the burning of kerosene, charcoal and coal in different means and instruments.

Renewable-based space heating technologies have limitations in the application where the payback cannot be achieved faster due to intermittent nature of renewable energy sources and higher upfront costs. These technologies are suitable for locations where heating is required for most of the year, renewable energy (mostly solar) is available and in higher altitudes. Hotels, hostels, hospitals and other large building setups can be potential sectors where these technologies can be deployed. In addition to this, solar-based heating solutions can serve the day-time operated buildings in a better way. Adding the option of auxiliary electric heating can further increase the outreach and accessibility among the users. Northern states especially Himachal Pradesh, Uttarakhand, some parts of Jammu and Kashmir and Leh and Ladakh can provide good opportunities for the application of solar photovoltaic-based technologies, due to a decent number of sunny days and lower ambient temperatures, which are the best combination for reaching highest efficiency of solar photovoltaic systems.

Electrical appliances are being widely used in urban areas where the quality of the electricity supply is good. The current popular systems for heating are the coil-based heater and convective heaters. There are more effective technologies available such as a ceramic heater and oil-based radiator heater. These systems are capable of meeting similar or more connected loads, but they have thermal mass and thermostat settings available, which makes them more efficient. In the IHR, 29 per cent of the population are urban. The rest 71 per cent of the population in the region are rural and rely on fuelwood for heating purposes. Mainstreaming the use of electrical appliances in place of fuelwood-based methods of heating in these rural areas can significantly reduce emissions through space heating. Achieving this goal requires a lot of other interventions, such as improving the income levels to develop affordability, along with delinking cooking and heating and improving the quality of electricity supply in the IHR. The largest share of the market for such technologies lies in Jammu and Kashmir, Himachal Pradesh, Uttarakhand and, to some extent, Sikkim and Arunachal Pradesh. Rocket stove can be used in all altitudes; designs can be modified to cater to cooking and heating as per need and priority. These technologies can be made popular in middle to higher income group households in the region. These technologies can also be adapted to use biomass briquettes as fuel. In Meghalaya, Mizoram and Nagaland, more than 85 per cent of the population are tribes. In Arunachal Pradesh, tribal population comprise 65 per cent and in Manipur and Tripura it is 30–35 per cent (Encyclopedia.com). The livelihood of the tribal population depends largely on forests. Even though the climate of these states is a less harsh, considerable amount of biomass is used. The government can look into providing alternative fuel like briquettes in these areas.

The choices of sustainable heating methods are mapped in table 3 with the potential of application in different states and at an altitude range of up to 1500m and greater than 1500m.

Table 10: Prioritization of near-term and long-term technologies for states in IHR and different altitude ranges

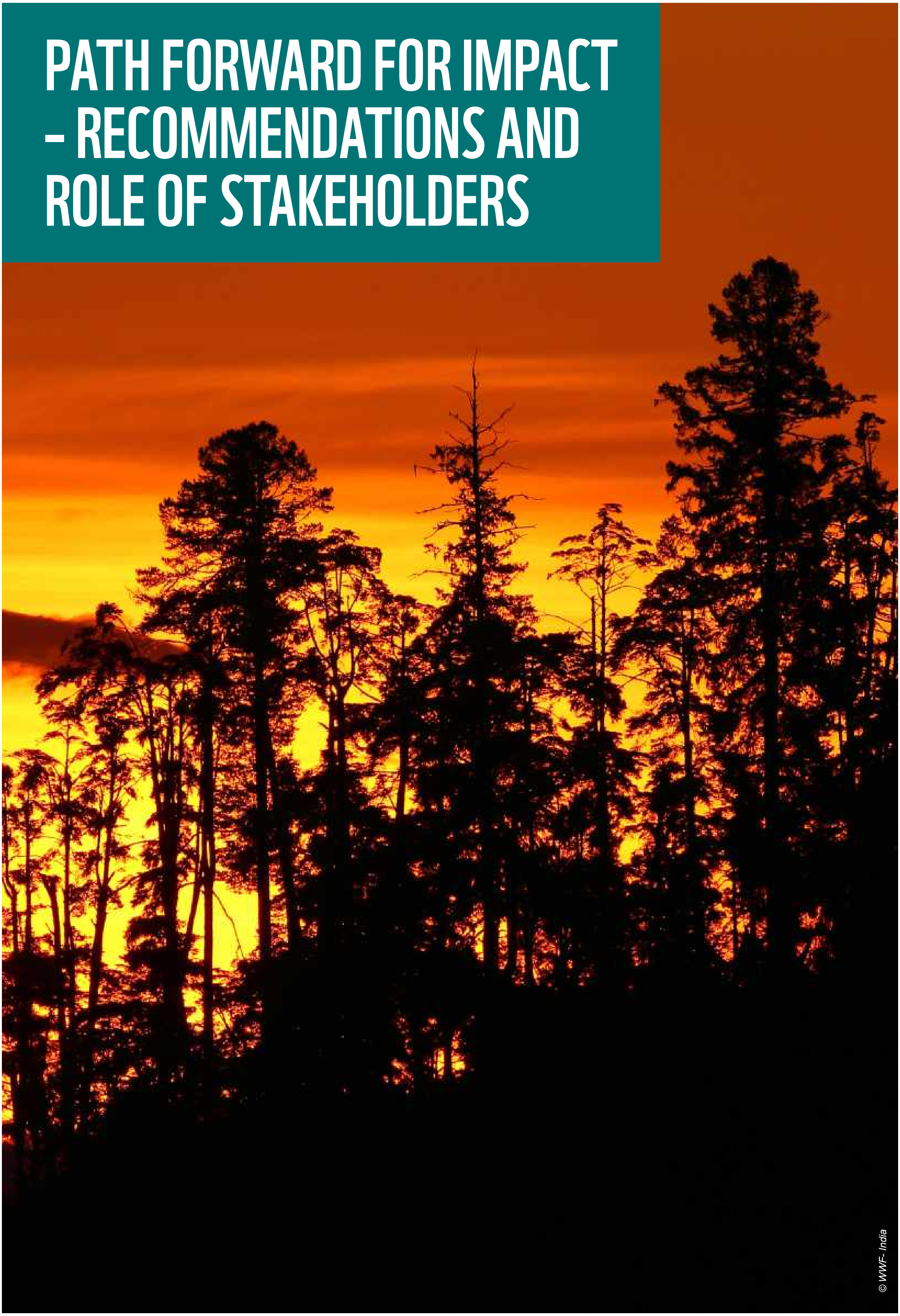
Technology solution	Technology	JK		HP		UK		SK		AP		NG		MN		MZ		TR		MG		AS		WB	
		<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m
Near-term solutions	Mini Bukhari – Portable Space Heater	✓	✓		✓		✓		✓		✓		✓												✓
	Himalayan Rocket Stove	✓	✓		✓		✓				✓														✓
	Himtapak	✓	✓																						
	Army Kerosene Heaters*	✓		✓		✓		✓		✓		✓		✓		✓				✓				✓	
	Saw dust Bukhari	✓			✓		✓							✓		✓									
	Biomass briquettes	✓		✓	✓	✓	✓											✓		✓		✓		✓	✓
	Ceramic heater	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Oil filled radiator heater	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
	Gas heater	✓	✓	✓	✓	✓	✓																		✓
	Integration of ground source heat pump (GSHP) systems with solar photovoltaic (PV)	✓	✓		✓		✓		✓		✓										✓				✓
	SolarSheat			✓		✓																			
	Integration of evacuated tube heat pipe (ETHP) with fan-coil unit (FCU)	✓	✓		✓		✓		✓		✓														

Table 10: Prioritization of near-term and long-term technologies for states in IHR and different altitude ranges

Technology solution	Technology	JK		HP		UK		SK		AP		NG		MN		MZ		TR		MG		AS		WB	
		<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m	<1500m	>1500m
Long-term solution	Solar hybrid heat pump systems		✓		✓		✓																		✓
	Parabolic solar dish collector coupled to finned-tube heat exchangers		✓		✓		✓																		✓
	Building integrated photovoltaic (BIPV) solar heating	✓	✓	✓	✓	✓	✓																		
	Liquid based active solar heating		✓		✓		✓																		✓
	District Heating System (DHS)	✓	✓	✓	✓	✓	✓																		✓
	Cloud based smart heating	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Stratiflex	✓	✓		✓		✓		✓		✓		✓		✓		✓		✓		✓		✓		✓

AR - Arunachal Pradesh, AS - Assam, HP - Himachal Pradesh, JK - Jammu and Kashmir, MN - Manipur, MZ - Mizoram, MG - Meghalaya, NG - Nagaland, SK – Sikkim, TR - Tripura, UT - Uttrakhand, WB - West Bengal

PATH FORWARD FOR IMPACT – RECOMMENDATIONS AND ROLE OF STAKEHOLDERS



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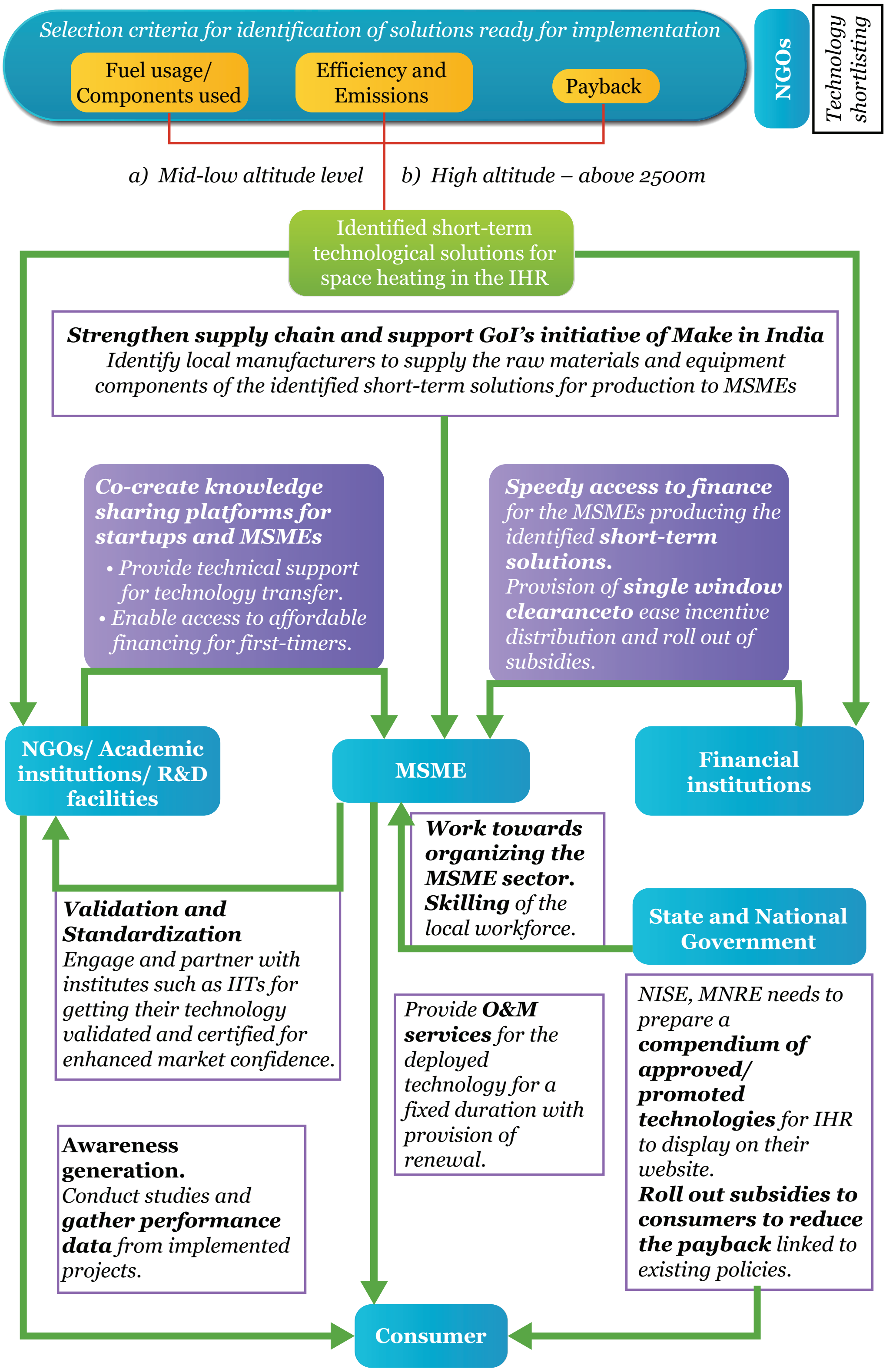
This study gives recommendations on how the Indian ecosystem actors (innovators, investors, end user companies, nongovernment organizations and policymakers) can successfully support in the deployment and scale-up of sustainable space heating solutions in buildings in the IHR.

The IHR does not have the necessary supportive policies, legal and institutional frameworks, innovations specific to the region and its financing, enhanced multi-stakeholder capacity building for scaling-up successful energy programmes. Reliable electricity access (through a rational combination of grid-connected and off-grid power) and elimination of inefficient traditional sources for cooking and heating (through a sustainable supply of clean, affordable and demand-responsive energy and technology options) should be the priority of the national energy agenda.

Additional technical and financial support needs to be given to RD&D programmes for developing energy-efficient and low/zero-carbon heating and cooling technologies. The Government of India could consider measures to incentivize other actors with better access to MSMEs, such as the state and local governments and industry associations and work with them on energy efficiency. Another option could be to leverage ongoing initiatives such as “Make in India” and ensure that energy efficiency is prioritized. Financial institutions can provide incentives to MSMEs and innovators through institutional and policy frameworks that will scale-up production of energy-efficient technologies and thus reduce the capital costs (depreciation rules, investment incentives, etc.).

The nongovernmental organizations and research institutes are encouraged to conduct studies and document success stories, in the public domain, pertaining to energy-efficient space heating technologies and evaluate the benefits and impacts associated with its use to enhance the uptake and market confidence.

We had defined broad strategies for implementation of the identified short-term and long-term technological solutions in Chapter 5. Notably, the engagement of the stakeholders would vary significantly and so will the focus on methods. For instance, in the case of the short-term technologies there is a need to largely focus on the supply chain, outreach and consumer awareness, whereas in the case of long-term technologies, it is imperative to focus on financial mechanisms and RD&D support.


Selection criteria for identification of solutions ready for implementation
Fuel usage/ Components used
Efficiency and Emissions
Payback
NGOs
Technology shortlisting
a) Mid-low altitude level
b) High altitude – above 2500m
Identified short-term technological solutions for space heating in the IHR
Strengthen supply chain and support GoI's initiative of Make in India
Identify local manufacturers to supply the raw materials and equipment components of the identified short-term solutions for production to MSMEs
Co-create knowledge sharing platforms for startups and MSMEs
• Provide technical support for technology transfer.
• Enable access to affordable financing for first-timers.
Speedy access to finance for the MSMEs producing the identified short-term solutions.
Provision of single window clearanceto ease incentive distribution and roll out of subsidies.
NGOs/ Academic institutions/ R&D facilities
MSME
Financial institutions
Work towards organizing the MSME sector. Skilling of the local workforce.
State and National Government
Validation and Standardization
Engage and partner with institutes such as IITs for getting their technology validated and certified for enhanced market confidence.
Provide O&M services for the deployed technology for a fixed duration with provision of renewal.
NISE, MNRE needs to prepare a compendium of approved/ promoted technologies for IHR to display on their website.
Roll out subsidies to consumers to reduce the payback linked to existing policies.
Awareness generation.
Conduct studies and gather performance data from implemented projects.
Consumer

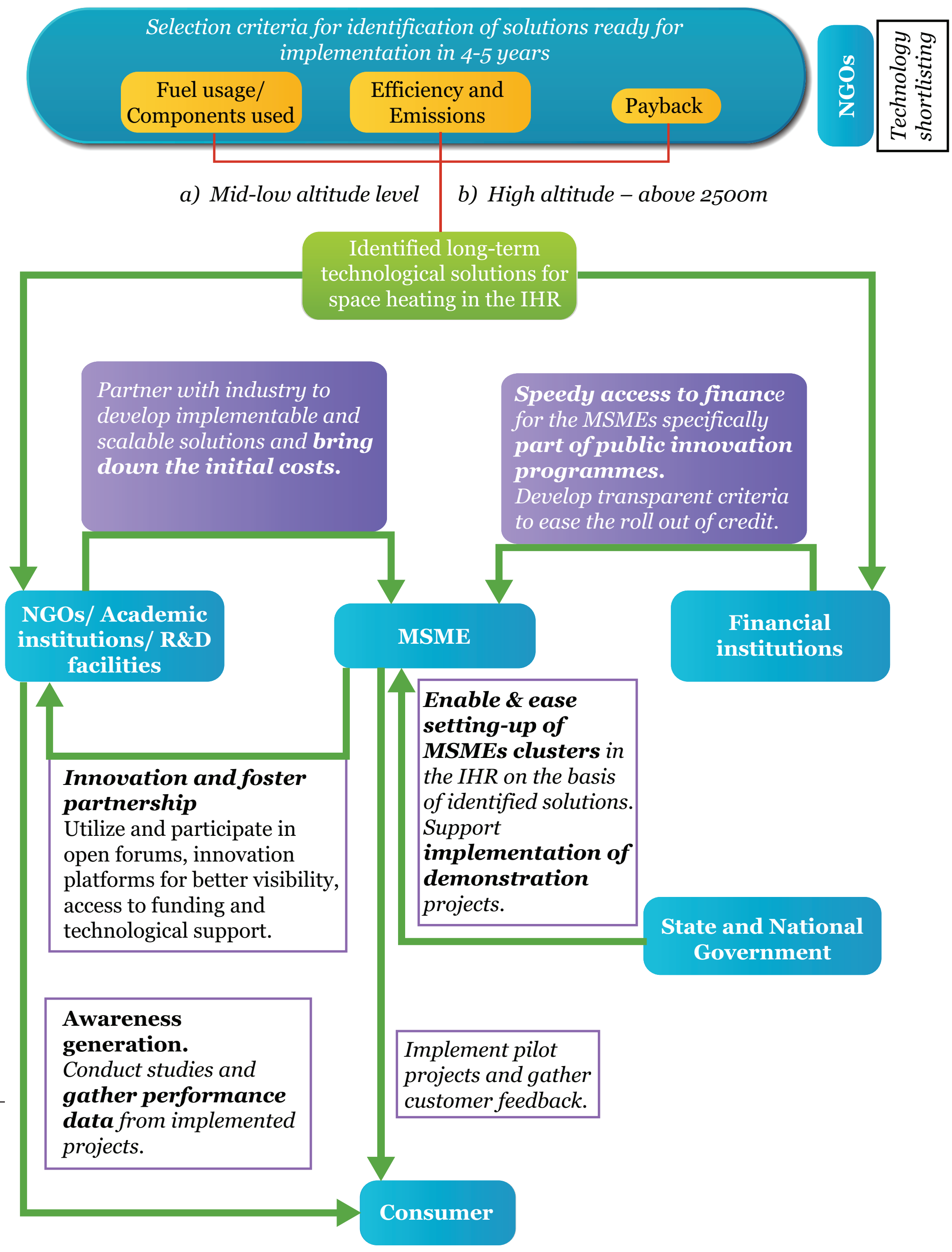


Figure 19: Broad strategies for implementation of the identified short-term and long-term technological solutions

Table 11 details out the specific recommendations for the path forward and the role of stakeholders in the IHR.

Table 11: Specific recommendations for the path forward and the role of stakeholders in IHR

Stakeholder	Targeted recommendations based on identified short-term and long-term solutions	General recommendations
National and State Governments and Policy makers	1 Develop a compendium of approved technologies on the basis of the identified short-term solutions for use in the IHR.	1 Reliable electricity access in the IHR (through a rational combination of grid-connected and off-grid power) and elimination of inefficient use of traditional sources for cooking and heating (through a sustainable supply of clean, affordable and demand-responsive energy and technology options) should be highlighted as a priority in the national energy agenda.
	2 All the IHR states to develop state policy on skill and entrepreneurship building on uniqueness of the mountain states which would lead to creation of jobs locally and avoid migration.	2 Establish and implement codes and standards for residential and commercial buildings that lay out the Minimum Energy Performance Standards for space heating in the country for cold climates.
	3 For instance in the higher altitudes where apricot harvests are predominant, the local and seasonal labourers could be trained to install, operate and service technologies such as SolDry and ETHP with fan-coil unit. The hot water used as a heat exchange medium in these technologies may also be utilized for industrial and commercial applications.	3 Provide more robust support to the MSMEs, including those in the rural areas of the IHR; require enhanced infrastructure provision for better connectivity (along the lines of the Pradhan Mantri Gram Sadak Yojana), a deepening of financial inclusion and access to credit, a data-driven reorientation of National Rural Livelihood Mission (NRLM) and urban skilling programmes (Centre for Policy Research 2019).

Table 11: Specific recommendations for the path forward and the role of stakeholders in IHR

Stakeholder	Targeted recommendations based on identified short-term and long-term solutions	General recommendations
National and State Governments and Policy makers	4 The state governments should promote MSMEs in the renewable energy-based fixed installations for commercial establishments in the IHR.	
	5 For residential applications, specifically in the Northeast region, MSMEs manufacturing portable space heating solutions should be promoted as majority of the population is tribal in nature.	
Financial Institutions	1 Speedy access to finance with additional tax rebates specifically for the MSMEs part of public innovation programmes.	1 There is a need to develop innovative financing structures to inject new financing and access on affordable terms. Develop innovative financial models and programmes to address cost barriers (i.e. repaying additional investment through utility bills, make low/zero-carbon heating and cooling technology installation costs deductible from the local rateable value, not additive).
	2 The financial institutions need to ensure the development and implementation of frameworks to evaluate the creditworthiness of the IHR-based manufacturers to ease incentive distribution and roll out subsidies.	2 Speedy sanction of loans at the branch level by using the knowledge of local conditions and the credit history of the customers to provide hassle free loans.
		3 Simple measures such as extending loan tenures specifically to the providers of innovative solutions in the IHR states would enable an easy re-payment of the manufacturers.

Table 11: Specific recommendations for the path forward and the role of stakeholders in IHR

Stakeholder	Targeted recommendations based on identified short-term and long-term solutions	General recommendations
NGOs, Academic and R&D Institutes	1 Prepare a repository of commercially viable international technologies for adoption in the context of IHR and promote indigenous solutions.	1 There is a need to revamp corporate social responsibility towards leveraging corporate comparative advantage in favour of supporting business enterprises instead of government programmes.
	2 Conduct continuous monitoring and performance evaluation of implemented technologies in the IHR to understand operational barriers and requirement for further improvements.	2 Strengthen cooperation among various stakeholders with an emphasis on public–private partnerships for research and development of skills and entrepreneurship, with particular consideration for the priority sectors identified for the IHR and the needs of women, youth and marginalized populations.
	3 Conduct perception surveys to understand behavioural trends of the IHR population through field investigations.	3 Institutes and think tanks bring in credibility to the manufacturers of nascent and innovative technologies and also act as a nexus between the industry and the government.
	4 Similar to IIT Mandi, there is a need to develop course curriculum where students get exposure to problems of the IHR local community to develop technological solutions to address the issues.	4 Increasing awareness on the commercial viability and loan repayment performance of space heating technologies will encourage more investment and scale in the sector, and help the rural IHR entrepreneurs access affordable financing even if they are first time entrepreneurs without collateral or credit histories.
	5 Explore possibility of creating an institutional platform for exchange of learning on skill building and entrepreneurship between the IHR states.	

Table 11: Specific recommendations for the path forward and the role of stakeholders in IHR

Stakeholder	Targeted recommendations based on identified short-term and long-term solutions		General recommendations	
NGOs, Academic and R&D Institutes	6	Initiatives such as Himalayan Start-up Trek, a two-day annual event of IIT Mandi Catalyst, attract investors, start-up experts, government officials, and budding start-ups. This also provides early stage start-ups an opportunity to learn about fundamental aspects of running a business and operational start-ups get a chance to meet investors to raise funding, could be organized in the IHR to boost the start-up ecosystem.		
	7	Likewise, initiatives focused on innovation by the SMEs such as Climate Solver that provide recognition, outreach and business development support should be scaled up.		
MSMEs and Start-ups	1	Inline with the Government of India's initiative "Make in India", the MSMEs could set-up assembly-lines and manufacturing units through technology transfer of international innovations to bring down the upfront costs and employ local IHR labour at cheaper rates.	1	Promoting "Make in India" for the technologies. The start-ups could benefit from examining the benefits of MSME registrations while considering their expansion plans and benefit equal participation with established companies to enable mutual growth.
	2	MSMEs need to come up with location specific solutions to enhance the operational performance and payback linked to technology use.	2	The MSMEs for their growth need to scale up by reaching out to wider customer base through digital marketing and provide wider services such as operation and maintenance post-technology deployment. They can also help to identify sub-markets that can serve as early adopters/examples for large-scale deployment and focus on collaborative R&D.

Table 11: Specific recommendations for the path forward and the role of stakeholders in IHR

Stakeholder	Targeted recommendations based on identified short-term and long-term solutions		General recommendations	
MSMEs and Start-ups	3	For instance, the technologies based on solar would not be as effective in the Northeast region as compared to the Northern states such as Himachal Pradesh, Uttarakhand as the Northeast region exhibits cold and cloudy weather conditions for most part of the year.	3	Engage and collaborate with academic institutes in the IHR share barriers and challenges to come up with innovative solutions associated with technology deployment. The collaboration would also provide credibility to the MSMEs and help overcome the barriers related to finance and technology standardization.
	4	The MSMEs based out of the IHR should co-create platforms and associations for formalization, better representation and internal connectivity amongst themselves. This would help them to stay abreast on the deployed technologies and gather user feedback to overcome challenges. This would enable them to also leverage on network of local labourers for technology installation and maintenance.	4	The MSMEs play an important role to save energy by adoption of Energy Efficient Technologies (EETs), Renewable Energy Technologies (RETs) and Best Operating Practices (BOPs).
	5	Since the market places are usually placed at a distance from the residential areas, creation of network would help in better connectivity and maintenance services to the users to avoid falling back to conventional practices.	5	Develop innovative financial models/ programmes for the technologies with high first costs.
	6	Leveraging on promising programmes such as AGNIi, ASPIRE scheme and other existing public innovation programmes to get access to funding for technology development, market, potential buyers, technical knowledge, etc.		
	7	There is a need to build capacities of the IHR population, specifically the youth, to compete for employment and entrepreneurship opportunities that require higher-order skill training.		

Above all, there is a pressing need for developing strategies around enhanced **outreach, digitization and formalization in the IHR**. This could be done by the creation of associations of MSMEs through online tools such as GlobalLinker, a B-to-B global networking and transaction platform that helps the MSMEs do business efficiently by creating company websites and digital product catalogues, connecting them with suppliers and customers globally and offering a range of services from insurance to logistics. Solutions like these would help aggregate demand and bring scale and efficiencies to space heating technologies.

Recognizing the uniqueness of the Himalayas and the challenges for sustainable development, NITI Aayog had set up five working groups (WGs) in June 2017 to prepare a road map for actions in the five thematic areas. The themes include: Inventory and Revival of Springs in Himalayas for Water Security, Sustainable Tourism in Indian Himalayan Region, Transformative Approach to Shifting Cultivation, Strengthening Skill and Entrepreneurship Landscape in Himalayas and Data/Information for Informed Decision Making. In November 2018, NITI Aayog constituted the Himalayan State Regional Council to ensure sustainable development of the IHR.

The Himalayan States Regional Council is the nodal agency for sustainable development in the IHR. This council is chaired by the Member of NITI Aayog and consists of the Chief Secretaries of the Himalayan States as well as the Secretaries of the key central ministries, senior officers of NITI Aayog as well as special invitees. The council will develop, implement and monitor tourism sector standards as well as bring policy coherence, strengthen skill and entrepreneurship with focus on identified priority sectors, among different action points. The first-ever Himalayan States Conclave was hosted by Uttarakhand on July 28, 2019 at Mussoorie with the main focus on sustainable development of the IHR.

The findings of the study can provide recommendation and road map for reducing emissions from space heating. Recommendation of the study can be provided to the Himalayan Region States Council as a priority sector for action towards sustainability in the region. Switching to sustainable technologies can provide reduction in emissions in the sensitive landscape of the IHR as well as address socio-economic challenges in the mountain by providing opportunities of skilling of the workforce, providing livelihood and reducing youth migration. Development of mountain-specific heating technologies can become one of the priority sectors for strengthening skill and entrepreneurship with the help of industry partnership. MSMEs in the Himalayan region can provide much required support for this activity. The findings of the study provide the intensity of emissions in the different states for residential and commercial/institutional buildings. This information can be useful in determining the markets of the various technologies that can be implemented in the specific states.

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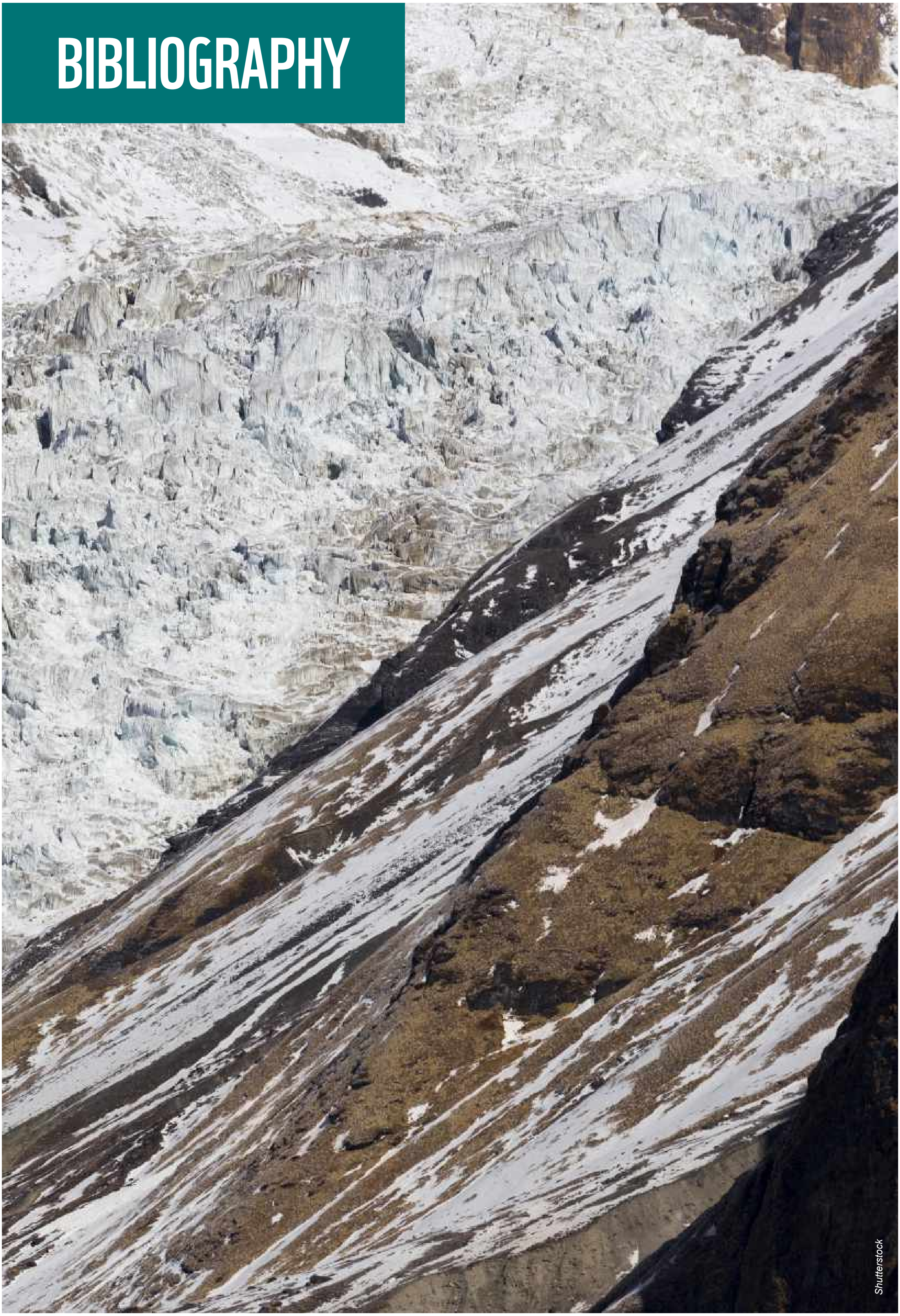

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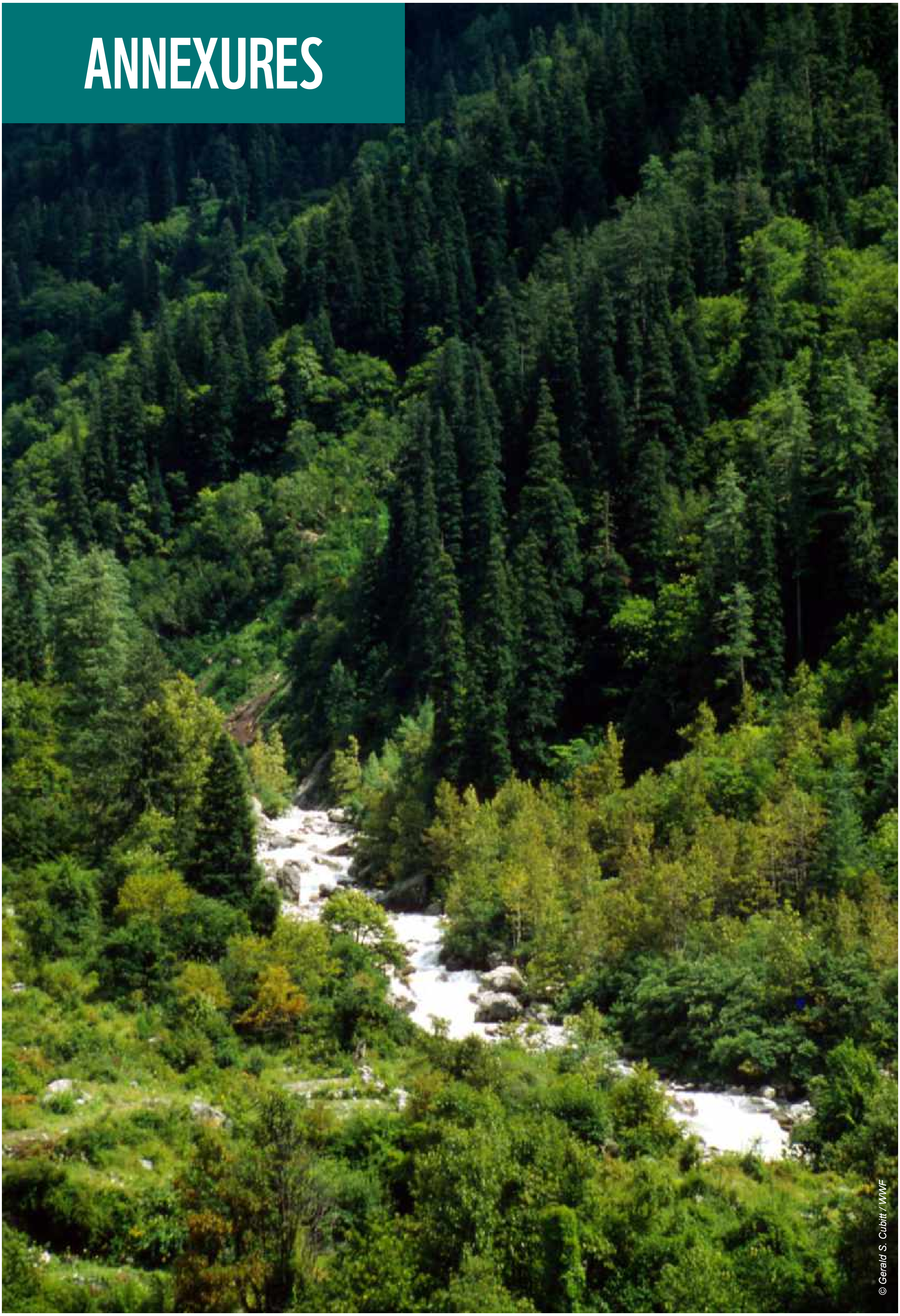
ANNEXURES



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ANNEXURE 1: POPULATION PROJECTIONS FOR YEARS 2020, 2030 AND 2040 FOR THE IHR STATES

Projected population of IHR states ('000)

		2011	2020	2030	2040**
Urban	India*	3,77,106	4,60,507	5,49,981	6,39,272
	J&K	3,433	4,046	4,728	5,406
	HM	689	752	805	859
	UT	3,049	3,887	4,864	5,827
	SK	154	287	462	629
	AR	317	379	451	520
	NG	571	901	1323	1730
	MN	834	991	1172	1348
	MZ	572	654	744	831
	TR	961	1446	2070	2674
	MG	595	668	745	820
	WB***	22	25.9	30.3	34.7
	AS***	12	14.4	16.7	19.3
Rural	India*	8,33,749	8,86,614	9,15,121	9,46,379
	J&K	9,108	9,554	9,850	10,155
	HM	6,176	6,595	6,880	7,178
	UT	7,037	7,383	7,554	7,732
	SK	457	383	269	160
	AR	1,067	1,140	1,205	1,268
	NG	1,408	1,270	1,044	826
	MN	2,022	2,143	2,245	2,343
	MZ	525	550	569	587
	TR	2,713	2,586	2,326	2,074
	MG	2,372	2,588	2,805	3,015
	WB***	105.1	106.2	103.7	101.5
	AS***	136.1	149.3	160.8	172.4

**Population total for entire India*

***Population projections for 2020 and 2030 are provided in the report titled – "Population projections for India and states (2011-2036)". Since this study is projecting till 2040, the projection of population for 2040 is done beyond the year 2036 using statistical methods.*

****Population projections for the hill districts of West Bengal and Assam are done for the same decadal growth rate, as reported for the respective states.*

Source *National Commission on Population (2019)*

ANNEXURE 2: CALCULATION OF FUELWOOD CONSUMPTION AT DIFFERENT ALTITUDES IN THE IHR

In India, percentage of energy required for heating/cooling (36 per cent) is higher than that for lighting purposes (31 per cent). Energy demand for space heating can be even higher in the Himalayan regions, where winters are longer and harsher, and characterised by low ambient temperatures for most part of the year. It is essential to use heat to keep the temperature of indoor spaces at acceptable levels to carry out normal household chores. The use of energy for heating, especially space heating, becomes not only a necessity but also a requirement for survival (Pragya, Environ 2014).

The results of various researches are given in the subsequent table (Kumar and Kumar 2015). It indicates that the fuelwood consumption varies with every site in correspondence to variation in altitudinal gradients. The higher consumption of fuelwood is reported in the Northeast regions, which could be due to higher consumption of meat that in turn requires more fuelwood for cooking, including other daily routine chores.

Similarly, in the Himalayan region, the consumption of heat increases with higher attitudes, where villagers consume more energy for space heating due to severe cold conditions, particularly during winters. They need more time for cooking because of low temperature, which further leads to more consumption of fuelwood. For mountain-folk, especially women, the priority is to meet household energy needs for cooking and space heating. The endless cycle of gathering and burning biomass in homes causes acute damage to the environment, triggers human health risks, and results in serious social deprivation (Wester, Mishra, Mukherji, et al. 2019).

A detailed fuelwood consumption (kg/capita/year) pattern in the Himalayan and other adjacent regions is provided in the table, as given below.

Author(s)	Name of the region	Tribe/sub-region	(kg/capita/ year)		Per capita per day consumption of fuelwood (kg/capita/day)	
			Low	High	Altitude < 1500m	Altitude > 1500m
Maikhuri (1991)	Arunachal Pradesh	Nishis, Karbi, Kacharis, Chakma	949	5,512	5.0	6.0
Maikhuri and Gangwar (1991)	Meghalaya	Garos, Khasis, Mikirs, Nepalese	146	913	0.8	1.0
Bhatt and Sachan (2004b)		Jaintia, Khasi, Garos	880	2,621	2.7	3.3
Sundriyal, et al. (1994)	Sikkim	Sikkim Himalayas	1,278		1.0	1.2
Bhatt and Sachan (2004a)	Uttarakhand	Garhwal Himalayas	391	1,022	1.1	1.3
Bhatt, et al. (1994)		Garhwal	409	891	1.0	1.2
		Himalayas, Tehri				
Bartwal (1987)		Garhwal Himalayas	560		0.9	1.0
Dhanai, et al. (2014)		Garhwal Himalayas	646	1,091	1.3	1.6
Kumar and Sharma (2009)		Garhwal Himalayas	1,215	1,803	2.3	2.8
Sagar, et al. (1985)		Dehradun	540		0.8	1.0
Srivastava (1981)		National average	600		0.9	1.1
Rajwar and Kumar (2009)		Nanda Devi Biosphere Reserve	1,033	2,157	2.5	3.0
Awasthi, et al. (2003)		Garhwal Himalayas	1,095		1.7	2.0

Author(s)	Name of the region	Tribe/sub-region	(kg/capita/ year)		Per capita per day consumption of fuelwood (kg/capita/day)	
			Low	High	Altitude < 1500m	Altitude > 1500m
Vishvakarma, et al. (1998)	Himachal Pradesh	Kullu Valley	1,570		2.4	2.9
Rai and Chakrabarti (2001)		Hill forest urban areas, hill forest urban areas, plane forest areas, hill non-forest rural areas	442	5,515	4.6	5.5
Rawat, et al. (2009)		Khoksar, Jahlma, Hinsa, Kuthar	332	1,095	1.1	1.3
Kumar and Kumar (2015)	Garhwal Himalayas (Uttarakhand)	Takoli Gad (Tehri Garhwal): 500–800	431	644	0.8	1.0
Kumar and Kumar (2015)		Takoli Gad (Tehri Garhwal): 800–1100	487	690	0.9	1.1
Kumar and Kumar (2015)		Takoli Gad (Tehri Garhwal): 1100–1500	407	675	0.8	1.0
Average values of fuelwood consumption					1.6	1.9

Source: *Kumar and Kumar (2015)*

Based on the data collected in various regions at different altitudes, the average fuelwood consumption for space heating, calculated for settlements in the altitude range lesser than 1500m, is 1.6kg/capita/day, and for more than 1500m is 1.9kg/capita/day.

ANNEXURE 3: EMISSIONS CALCULATION FROM SPACE HEATING FOR THE IHR STATES

This annexure provides a detailed calculation of emissions from space heating for the states of Himachal Pradesh, Jammu and Kashmir, and Uttarakhand. Additionally, tables with details of emissions for all the IHR states are also given in this annexure.

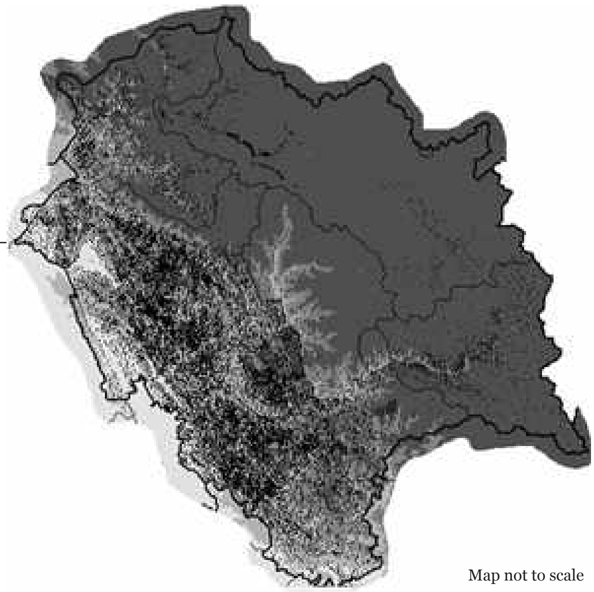
STEPS FOLLOWED FOR CALCULATION OF EMISSIONS – HIMACHAL PRADESH

Step 1: The projections of population for base year (2020) and for 2030 and 2040, respectively, have been done based on the study titled – "Population projections for India and states 2011–2036, report of the technical group on population projections". Since the study projects the population till 2036, projections for 2040 has been calculated using statistical methods. The population projections for years 2020, 2030 and 2040 for Himachal Pradesh are shared in the table, as given below.

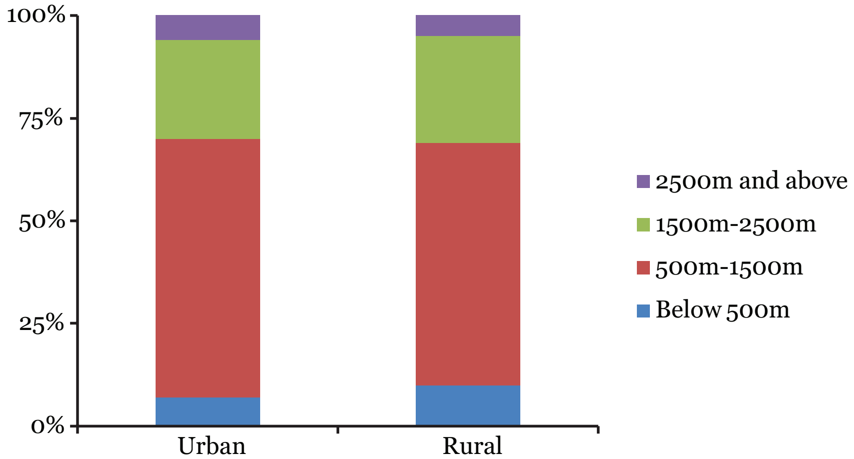
Year	2020	2030	2040
Total population ('000)	7,347	7,685	8,037
Urban population ('000)	752	805	859
Rural population ('000)	6,595	6,880	7,178

Step 2: For the analysis of the distribution of population at different altitudes, the digital elevation model was used to classify the settlements in various altitude ranges. The shape files of settlements showed the demarcation of boundaries of the studied settlements at the village level as per 2001 census data. The shape files were then converted to points to determine the value of elevation of these settlements. The elevation data of settlements were tabulated and classified in the range of up to 500m, 500–1500m, 1500–2500m and, 2500m and above. The analysis was done for both urban and rural settlements. The percentages of population at different altitudes in rural and urban areas were used with the projected population for years 2020, 2030 and 2040, as derived with the help of Step 1.

Spatial distribution of settlements in Himachal Pradesh



Population % by altitude range (m)	Urban (%)	Rural (%)
Below 500	7	10
500–1500	63	59
1500–2500	24	26
2500 and above	6	5



Step 3: Information on fuel usage, heating requirement and duration of winter months (hours of the day) was gathered after consultation with research institutes working in the IHR through telephonic interviews with experts and government officials. The following were the inferences of these interactions.

- 90 per cent of rural population uses fuelwood as potential source of heating;
- 100 per cent of urban population uses electricity for heating purposes;
- Duration of use of electrical heater per day is 12 hours (appliance wattage is 1kW) in residential buildings;
- Duration of heating below 1500m altitude range is 3 months;
- Duration of heating above 1500m altitude range is 6 months;
- Per capita per day fuelwood use below 1500m altitude range is 1.6kg, and above 1500m is 1.9kg.

The amount of per capita fuelwood consumption at different altitudes was calculated based on published research papers on fuelwood consumption in the IHR. The references of the papers are given in Annexure 2.

Step 4: Calculation of fuel and energy consumption in rural and urban areas for different altitude ranges

4.**1** Calculation of amount of fuelwood (in kg) for different altitudes in rural areas (90 per cent population)

$$f = b \times c \times d \times e$$

Altitude range (m)	%	Rural population ('000)	Duration (days)	Per capita fuelwood consumption (kg/capita/day)	tonnes of fuelwood
(a)	(b)	(c)	(d)	(e)	(f)
Up to 500	9	6595	90	1.6	82,250
500–1500	53	6595	90	1.6	5,04,624
1500–2500	23	6595	180	1.9	5,25,143
2500 and above	5	6595	180	1.9	1,10,972
Total					**12,22,989**

4.2 Calculation of kWh of electricity for different altitudes in rural areas (10 per cent population)

g = b x c x e / (d x 1000)

Altitude range (m)	%	Rural population ('000)	Person/ household	Duration (days)	Usage hours	Energy consumed (MWh)
(a)	(b)	(c)	(d)	(e)	(f)	(g)
Up to 500	1	6,595	4.7	90	12	14,544
500–1500	6	6,595	4.7	90	12	89,234
1500–2500	3	6,595	4.7	180	12	78,200
2500 and above	1	6,595	4.7	180	12	16,525
Total						1,98,503

4.3 Calculation of electrical energy consumed for different altitudes (100 per cent of urban population)

g = b x c x e / (d x 1000)

Altitude range (m)	%	Urban population ('000)	Person/ household	Duration (days)	Usage hours	Energy consumed (MWh)
(a)	(b)	(c)	(d)	(e)	(f)	(g)
Up to 500	7	752	4.7	90	12	11,484
500–1500	63	752	4.7	90	12	1,09,089
1500–2500	24	752	4.7	180	12	82,596
2500 and above	6	752	4.7	180	12	20,936
Total						**2,24,105**

Step 5: Calculation of emissions is done based on the emissions factor of fuelwood and electricity

- Emissions factor of fuelwood is taken as 1.83 of CO_2 emissions per kg of wood
- Emissions factor of electricity is taken as 0.83kg of CO_2 emissions per kWh of electricity

Fuel	Quantity	Unit	Emissions factor	Emissions ('000 tonnes of CO_2)
Fuelwood total (from 4.1)	12,22,989	tonnes	1.83	2,238.07
Electricity total (from 4.2 and 4.3)	4,22,608	MWh	0.83	350.76

Step 6: Calculation of emissions for years 2030 and 2040 is done through steps 4 and 5 for the projected population of Himachal Pradesh as per Step 1

Emissions ('000 tonnes of CO_2)	2020	2030	2040
Fuelwood	2,238.07	2335	2436
Electricity	350.76	447	472

Step 7: For the calculation of emissions for commercial/institutional buildings, these buildings are classified in four categories, namely – hotels, hospitals, educational institutions and establishments

7.1 Hotels' consumption

7.1.1 Total number of hotels in Himachal Pradesh as per data based on their tourism websites is

Category of hotels	No. of hotels	No. of rooms
Luxury (heritage and 5-star)	59	9,272
Non-luxury (4-star and below)	3,323	35,280

7.1.2 Duration of winter months and appliance wattage were established as per Step 3

- Diversity of 0.8 for luxury hotels and 0.6 for non-luxury hotels were considered (diversity factor is considered to account for non-continuous use of equipment);
- Distribution of hotels with respect to altitude ranges below 1500m and above 1500m corresponds to the ratio of population living in these altitude ranges.

Number of hotel rooms as per altitude ranges

Altitude range (m)	Luxury	Non-luxury
Above 1500	6,490	24,696
Below 1500	2,782	10,584

7.1.3 Calculation of consumption

j = (b x c x d x e x f x g x h) / 1000

Luxury hotels

Altitude range (m)	Total no. of rooms	No. of heaters per room	Usage hours	Electrical load of each heater (kW)	Usage days in a month	No. of heating months	Diversity	kWh	MWh
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Up to 1500	6,490	1	6	1	30	3	0.8	28,03,853	2,804
1500 – and above	2,782	1	6	1	30	6	0.8	24,03,302	2,403

Non-luxury hotels

Altitude range (m)	Total no. of rooms	No. of heaters per room	Usage hours	Electrical load of each heater (kW)	Usage days in a month	No. of heating months	Diversity	kWh	MWh
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Up to 1500	24,696	1	6	1	30	3	0.6	80,01,504	8,002
1500 and above	10,584	1	6	1	30	6	0.6	68,58,432	6,858

7.1.4 Emissions from hotels

Category	Consumption (MWh)	Emissions factor	Emissions (tonnes of CO_2)	Emissions ('000 tonnes of CO_2)
Hotels	20,067	0.83	16,656	16.66

7.2 Hospitals' consumption

7.2.1 Total number of hospitals based on various categories

Category	Himachal Pradesh
Hospitals	55
Community health centres	77
Dispensaries	11
Private hospitals	31
Public health centres (PHCs)	475
Health centres (HCs)/sub-health centres (SHCs)	1,108
Ayurvedic pharmacies	3
Research institutions	1
Unani dispensaries	3
Homoeopathy dispensaries	14

7.2.2 Duration of winter months and appliance wattage were established as per Step 3 (diversity factor is considered to account for non-continuous use of equipment)

- Private hospitals: 1 heater for every 2 beds with a diversity of 0.8;
- Dispensaries: 1 heater with a diversity of 0.8;
- Ayurvedic and Unani dispensaries: 2 heaters with a diversity of 0.8;
- Public health centres, sub health centres: 2 heaters with a diversity of 0.8;
- Ayurvedic pharmacies, research institutions, Unani dispensaries, homeopathy dispensaries: 2 heaters with a diversity of 0.8.

7.2.3 Calculation of consumption

$$j = (b \times c \times d \times e \times f \times g \times h) / 1000$$

Category of hotels	Altitude range (m)	Total no. of rooms	No. of heaters per room	Usage hours	Electrical load of each heater (kW)	Usage days in a month	No. of heating months	Diversity	kWh	MWh
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Community health centres/RH	Up to 1500	54	2	6	1	30	3	0.8	46,656	46.7
	1500 and above	23	2	6	1	30	6	0.8	39,744	39.7
Dispensaries	Up to 1500	8	1	3	1	30	3	0.8	1,728	1.7
	1500 and above	3	1	3	1	30	6	0.8	1,296	1.3
Private hospitals	Up to 1500	22	5	3	1	30	3	0.8	23,760	23.8
	1500 and above	9	5	3	1	30	6	0.8	19,440	19.4
Ayurvedic and Unani institutions /hospitals	Up to 1500	0	2	3	1	30	3	0.8	0	0.0
	1500 and above	0	2	3	1	30	6	0.8	0	0.0
PHCs, HCs, SHCs	Up to 1500	1108	2	3	1	30	3	0.8	478,656	478.7
	1500 and above	475	2	3	1	30	6	0.8	410,400	410.4
Ayurvedic pharmacies, research institutions, Unani and homeopathy dispensaries	Up to 1500	15	2	3	1	30	3	0.8	6,480	6.5
	1500 and above	6	2	3	1	30	6	0.8	5,184	5.2

7.2.4 Emissions from hospitals

Category	Consumption (MWh)	Emissions factor	Emissions (tonnes of CO_2)	Emissions ('000 tonnes of CO_2)
Hospitals	1,033	0.83	857	0.85

7.3 Educational institutions' consumption

7.3.1 Total number of educational institutions based on various categories

Category	Himachal Pradesh
Primary	10,739
Middle	2,317
Secondary and senior	2,126
Total number of schools	15,182
Colleges	72
Technical universities	326
Total number of colleges and universities	398

7.3.2 Duration of winter months and appliance wattage were established as per Step 3 (diversity is considered to account for non-continuous use of equipment)

- Diversity of 0.6 for schools (primary, middle and secondary and senior)
- Diversity of 0.8 colleges and technical universities considered

7.3.3 Calculation of consumption

j = (b x c x d x e x f x g x h) / 1000

Category of educational institutions	Altitude range (m)	Total no. of rooms	No. of heaters per room	Usage hours	Electrical load of each heater (kW)	Usage days in a month	No. of heating months	Diversity	kWh	MWh
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Schools	Up to 1500	10,627	1	4	1	24	3	0.6	18,36,345.6	1,836.3
	1500 and above	4,555	1	4	1	24	6	0.6	15,74,208	1,574.2
Universities	Up to 1500	279	1	4	1	24	3	0.8	64,189.44	64.2
	1500 and above	119	1	4	1	24	6	0.8	55,019.52	55.0

7.3.4 Emissions from educational institutions

Category	Consumption (MWh)	Emissions factor	Emissions (tonnes of CO_2)	Emissions ('000 tonnes of CO_2)
Educational institutions	3,530	0.83	2,930	2.93

7.4 Establishments' consumption

7.4.1 Total number of establishments in Himachal Pradesh as per data based on MSME report is

State	Rural	Urban
Establishments	1,15,158	47,039

7.4.2 Duration of winter months and appliance wattage were established as per Step 3.

- Electricity is used for heating for a duration of 4 hours in a day (appliance wattage being 1kW);
- Distribution of establishments with respect to altitude ranges below 1500m and above 1500m corresponds to the ratio of population living in these altitude ranges;
- In rural areas, 90 per cent establishments use fuelwood for heating purposes; a community fire is lit between 8–10 establishments;
- About 10 per cent establishments in rural areas use electrical equipment for space heating;
- Number of establishments as per altitude ranges is derived in a ratio of population distribution over different altitude ranges.

Category of institutions	Altitude range (m)	Total no. of establishments
	(a)	(b)
Rural – electric (10%)	Up to 1500	8,061
	1500 and above	3,455
Urban – electric (100%)	Up to 1500	32,927
	1500 and above	14,112

7.4.3 Calculation of electrical energy consumption

i = (b x c x d x e x f x g x h) / 1000

Category of establishments	Altitude range (m)	Total no. of rooms	No. of heaters per room	Usage hours	Electrical load of each heater (kW)	Usage days in a month	No. of heating months	kWh	MWh
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
Rural – (10% electric)	Up to 1500	8,061	1	4	1	30	3	29,01,960	2,902.0
	1500 and above	3,455	1	4	1	30	6	24,87,600	2,487.6
Urban	Up to 1500	32,927	1	4	1	30	3	118,53,828	11,853.8
	1500 and above	14,112	1	4	1	30	6	101,60,424	10,160.4

7.4.4 Calculation of wood usage in establishments

h = c x d x e x f x g x h

Category of establishments	Altitude range (m)	No. of people using fuelwood	No. of saggars	Usage hours	Fuelwood for saggars (tonnes)	Usage days in a month	No. of heating months	Daily fuel usage (tonnes)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Rural (90% fuelwood)	Up to 1500	1,03,142	12,893	1	0.02	30	3	23,207
	1500 and above	44,204	5,525	1	0.02	30	6	19,892

7.4.5 Emissions from establishments

Category	Consumption	Unit	Emissions factor	Emissions (tonnes of CO_2)	Emissions ('000 tonnes of CO_2)
Electric	27,404	MWh	0.83	22,745	22.75
Fuelwood	43,099	Tonne (t)	1.83	78,871	78.87

7.5 Total emissions from commercial and institutional buildings

Typology	**Consumption**	**Unit**	**Emissions factor**	**Emissions (tonnes of CO_2**
Hotel	20,067	MWh	0.83	16,656
Hospital	1,033	MWh	0.83	857
Educational institution	3,530	MWh	0.83	2,930
Establishment – Electric	27,404	MWh	0.83	22,745
Establishment – Fuelwood	43,099	Tonne (t)	1.83	78,871

Typology	**CO_2 emissions '000 tonnes of CO_2**
Hotels	16.66
Hospitals	0.86
Educational institutions	2.93
Establishment – electric	(22.75 + 78.87) 101.64

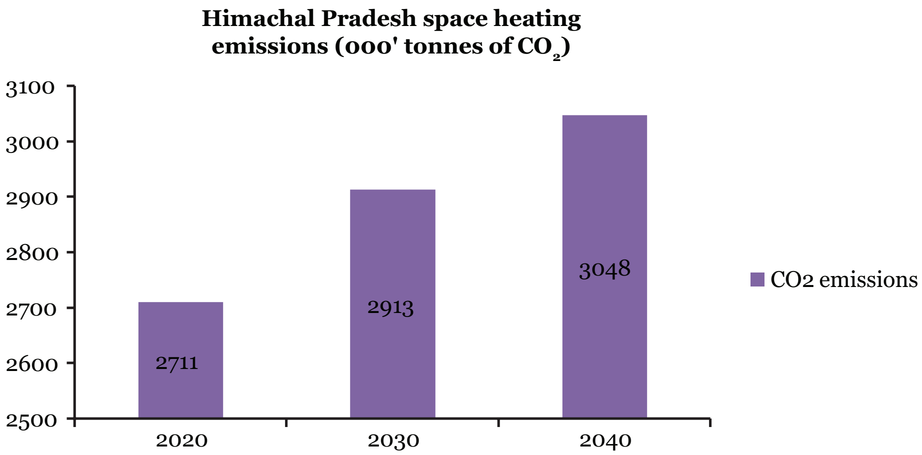
7.6 Total space heating emissions from commercial and institutional buildings (122 '000 tonnes of CO_2 emissions)

7.7 Projection of emissions for 2030 and 2040 for commercial/institutional buildings is done based on the growth rate of population

	2020	**2030**	**2040**
Emissions ('000 tonnes of CO_2)	122	127	135

Step 8: Overall, the emissions rates of Himachal Pradesh for 2020 and projected years 2030 and 2040 are calculated as per steps 6 and 7.7, as given below.

Emissions ('000 tonnes of CO_2)	**2020**	**2030**	**2040**
Residential (fuelwood)	2,238	2,335	2,436
Residential (electricity)	351	447	472
Commercial	122	127	135
Total	**2,711**	**2,909**	**3,043**

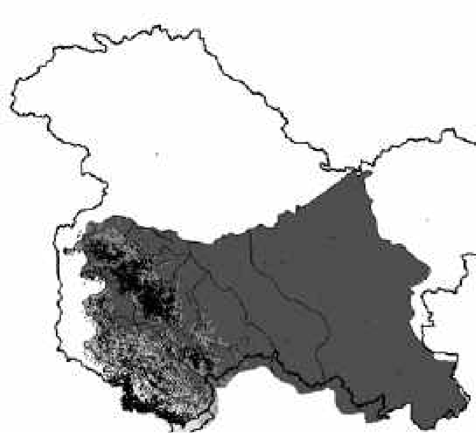


STEPS FOLLOWED FOR CALCULATION OF EMISSIONS – JAMMU AND KASHMIR

Step 1: The projections of population for base year (2020) and for 2030 and 2040 were done based on the study titled, “Population projections for India and states 2011–2036, report of the technical group on population projections”. The report provides year-wise state projections for urban and rural populations till 2036. The population of 2040 is derived through statistical projection methods. The population for years 2020, 2030 and 2040 for Jammu and Kashmir is presented in the following table.

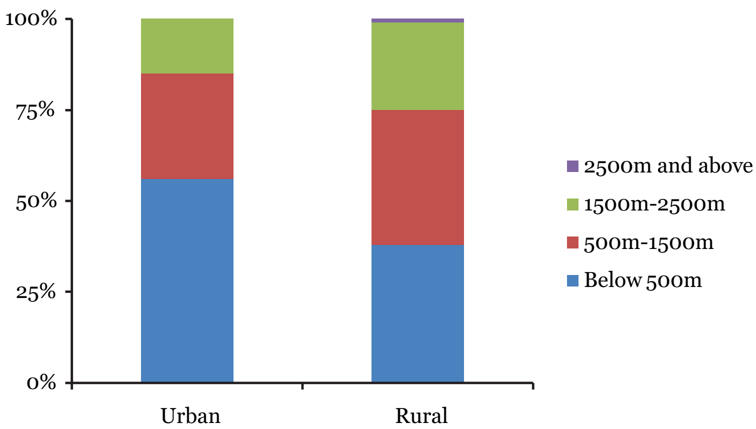
Year	2020	2030	2040
Total population (‘000)	13,600	14,578	15,561
Urban population (‘000)	4,046	4,728	5,406
Rural population (‘000)	9,554	9,850	10,155

Step 2: The analysis of the distribution of population at different altitudes was done using a digital elevation model to classify the settlements in different altitude ranges. The shape files of settlements showed the demarcation of boundaries of the studied settlements at the village level as per 2001 census data. The shape files were then converted to points to determine the value of elevation of the settlements. The elevation data of settlements were tabulated and classified in the range of up to 500m, 500–1500m, 1500–2500m, and 2500m and above. The analysis was done for both urban and rural settlements. The percentages of population at different altitudes in rural and urban areas were used with the projected population for years 2020, 2030 and 2040, as derived earlier in Step 1.



Map not to scale

Population % by altitude range (m)	Urban (%)	Rural (%)
Below 500	24	24
500–1500	17	24
1500–2500	56	47
2500 and above	3	5



Step 3: Details of fuel usage, heating requirement as per the duration of winter months and hours of the day were established in consultation with research institutes working in the IHR through telephonic interviews with experts and government officials. The following are the inferences of the interactions.

- 90 per cent of rural population uses fuelwood as a source of heating;
- 100 per cent of urban population uses electricity to meet heating demands;
- Duration of use of electrical heater per day is 12 hours (appliance wattage being 1000kW) in residential buildings;
- Duration of heating below 1500m altitude range is 3 months;
- Duration of heating above 1500m altitude range is 6 months.

The amount of per capita fuelwood consumption at different altitude ranges was calculated based on published research papers on fuelwood consumption in the IHR. The references of these papers are given in Annexure 2.

- Per capita per day fuelwood use below 1500m altitude range is 1.6kg, and above 1500m altitude range is 1.9kg

Step 4: Calculation of fuel and energy consumption in rural and urban areas for different altitude ranges

4.1 Calculation of fuelwood consumption for different altitude ranges in rural areas (90 per cent population)

f = b x c x d x e

Altitude range (m)	%	Rural population '000	Duration (days)	Per capita fuelwood consumption (kg/capita/ day)	Tonnes of fuelwood
(a)	(b)	(c)	(d)	(e)	(f)
Up to 500	21.5	9,554	90	1.6	2,95,589
500–1500	22.0	9,554	90	1.6	3,02,249
1500–2500	41.9	9,554	180	1.9	13,68,628
2500 and above	4.7	9,554	180	1.9	1,52,227
Total					21,18,694

4.2 Calculation of electricity usage for space heating for different altitude ranges in rural areas (10 per cent population)

g = b x c x e / (d x 1000)

Altitude range (m)	%	Rural population '000	Person/ household	Duration (days)	Usage hours	Energy consumed (MWh)
(a)	(b)	(c)	(d)	(e)	(f)	(g)
Up to 500	2.4	9,554	6.08	90	12	40,511
500–1500	2.4	9,554	6.08	90	12	41,424
15002500	4.7	9,554	6.08	180	12	1,57,956
2500 and above	0.5	9,554	6.08	180	12	17,569
Total						2,57,460

4.3 Calculation of electrical energy consumed for different altitude ranges by urban population (100 per cent)

g = b x c x e / (d x 1000)

Altitude range (m)	%	Urban Population '000	Person/ household	Duration (days)	Usage hours	Energy consumed (MWh)
(a)	(b)	(c)	(d)	(e)	(f)	(g)
Up to 500	24	4,046	6.08	90	12	1,69,530
500–1500	17	4,046	6.08	90	12	1,22,089
1500–2500	56	4,046	6.08	180	12	8,09,012
2500 and above	3	4,046	6.08	180	12	45,043
Total						11,45,674

Step 5: Calculation of emissions is done based on the emissions factor of fuelwood and electricity

- Emissions factor of fuelwood is taken as 1.83kg of CO_2 per kg of fuelwood
- Emissions factor of electricity is taken as 0.83tonnes of CO_2 per MWh of electricity

Fuel	Quantity	Unit	Emissions factor	Emissions ('000 tonnes of CO2)
Fuelwood total (from 4.1)	21,18,694	Tonnes	1.83	3,877
Electricity total (from 4.2 and 4.3)	14,03,133	MWh	0.83	1,165

Step 6: Calculation of emissions for years 2030 and 2040 is done through steps 4 and 5 for the projected population of Jammu and Kashmir, as derived from Step 1

Emissions	2020	2030	2040
Fuelwood	3,877	3,997	4,121
Electricity	1,165	1,604	1,804

Step 7: For the calculation of emissions for commercial/institutional buildings, these buildings are classified in four categories, namely – hotels, hospitals, educational institutions and establishments

7.1 Hotels' consumption

7.1.1 Total number of hotels in Jammu and Kashmir as per data collected from official tourism website is

Category of hotels	No. of hotels	No. of rooms
Luxury (heritage and 5-star)	8	889
Non-luxury (4-star and below)	76	2,373

7.1.2 Duration of winter months and appliance wattage were established as per Step 3

- » Duration of heating below 1500m altitude range is 3 months;
- » Duration of heating above 1500m altitude range is 6 months;
- » Electricity is used for heating purposes for a duration of 6 hours in a day (appliance wattage being 1000kW) per room;
- » Diversity of 0.8 for luxury hotels and 0.6 for non-luxury hotels are considered (diversity is considered to account for non-continuous use of equipment);

- Distribution of hotels with respect to altitude ranges below 1500m and above 1500m

corresponds to the ratio of total population living in these altitude ranges.

Number of hotel rooms as per altitude ranges

Altitude range (m)	Luxury	Non-luxury
Above 1500	364	973
Below 1500	525	1,400

7.1.3 Calculation of electricity consumption for space heating

j = (b x c x d x e x f x g x h) / 1000

Luxury hotels

Altitude range (m)	Total no. of rooms	No. of heaters per room	Usage hours	Electrical load of each heater (kW)	Usage days in a month	No. of heating months	Diversity	kWh	MWh
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Up to 1500	364	1	6	1	30	3	0.8	1,57,460	157
1500 and above	525	1	6	1	30	6	0.8	4,53,177	453

Non-luxury hotels

Altitude range (m)	Total no. of rooms	No. of heaters per room	Usage hours	Electrical load of each heater (kW)	Usage days in a month	No. of heating months	Diversity	kWh	MWh
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Up to 1500	973	1	6	1	30	3	0.6	3,15,229.3	315
1500 and above	1,400	1	6	1	30	6	0.6	9,07,245.4	907

7.1.4 Emissions from hotels

Category	Consumption (MWh)	Emissions factor	Emissions (tonnes of CO_2)	Emissions ('000 tonnes of CO_2)
Hotels	1,833	0.83	1521	1.5

7.2 Hospitals' consumption

7.2.1 Total number of hospitals based on various categories

Category	Jammu and Kashmir
Hospitals	249
Community health centres	374
Dispensaries	394
Ayurvedic and Unani institutions/hospitals	245
Private hospitals	83
Public health centres (PHCs), health centres (HCs), sub-health centres (SHCs)	1,662

7.2.2 Duration of winter months and appliance wattage were established as per Step 3

- Duration of heating below 1500m altitude range is 3 months;
- Duration of heating above 1500m altitude range is 6 months;
- Appliance wattage is 1000kW per room;
- Hospitals: 1 heater for every 2 beds with a diversity of 0.8;
- Community health centres: 1 heater for every 2 beds with a diversity of 0.8;
- Private hospitals: 5 heaters with a diversity of 0.8;

» Dispensaries: 1 heater with a diversity of 0.8;

» Ayurvedic and Unani institutions: 2 heaters with a diversity of 0.8;

» PHCs, SHCs: 2 heaters with a diversity of 0.8.

7.2.3 Calculation of consumption

j = (b x c x d x e x f x g x h) / 1000

Category of hotels	Altitude range (m)	Total no. of beds	No. of heaters per room	Usage hours	Electrical load of each heater (kW)	Usage days in a month	No. of heating months	Diversity	kWh	MWh
	(a)	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**	**(h)**	**(i)**	**(j)**
Hospitals	Up to 1500	444	1	6	1	30	3	0.8	1,91,644	191.6
	1500 and above	638	1	6	1	30	6	0.8	5,51,560	551.6
Community health centres	Up to 1500	153	2	6	1	30	3	0.8	1,32,485.76	132.5
	1500 and above	221	2	6	1	30	6	0.8	3,81,300.48	381.3
Dispensaries	Up to 1500	162	1	3	1	30	3	0.8	34,892.64	34.9
	1500 and above	232	1	3	1	30	6	0.8	1,00,422.72	100.4
Ayurvedic and Unani institutions / hospitals	Up to 1500	100	2	3	1	30	3	0.8	43,394.4	43.4
	1500 and above	145	2	3	1	30	6	0.8	1,24,891.2	124.9
Private hospitals	Up to 1500	34	5	3	1	30	3	0.8	36,752.4	36.8
	1500 and above	49	5	3	1	30	6	0.8	1,05,775.2	105.8
Public health centres (PHCs), health centres (HCs), sub-health centres (SHCs)	Up to 1500	681	2	3	1	30	3	0.8	2,94,373.44	294.4
	1500 and above	981	2	3	1	30	6	0.8	8,47,221.12	847.2

7.2.4 Emissions from hospitals

Category	Consumption (MWh)	Emissions factor	Emissions (tonnes of CO_2)	Emissions ('000 tonnes of CO_2)
Hospitals	2,844.7	0.83	2,361	2.4

7.3 Educational institutions' consumption

7.3.1 Total number of educational institutions based on various categories

Category	Jammu and Kashmir
Primary	13,360
Middle	13,361
Secondary and senior	2,771
Total number of schools	29,492
Colleges	76
Technical universities	4
Total number of colleges and universities	80

7.3.2 Duration of winter months and appliance wattage were established as per Step 3

- Duration of heating below 1500m altitude range is 3 months;
- Duration of heating above 1500m altitude range is 6 months;
- Appliance wattage is 1000kW per room;
- Diversity of 0.6 for schools (primary, middle and, secondary and senior) and 0.8 diversity in colleges and technical universities are considered.

7.3.3 Calculation of consumption

$$j = (b \times c \times d \times e \times f \times g \times h) / 1000$$

Category of educational institutions	Altitude range (m)	Total no. of rooms	No. of heaters per room	Usage hours	Electrical load of each heater (kW)	Usage days in a month	No. of heating months	Diversity	kWh	MWh
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Schools	Up to 1500	12,092	1	4	1	24	3	0.6	20,89,449.2	2089.4
	1500 and above	17,400	1	4	1	24	6	0.6	60,13,536.8	6013.5
University	Up to 1500	33	1	4	1	24	3	0.8	7,557.12	7.6
	1500 and above	47	1	4	1	24	6	0.8	21,749.76	21.7

7.3.4 Emissions from educational institutions

Category	Consumption (MWh)	Emissions factor	Emissions (tonnes of CO_2)	Emissions ('000 tonnes of CO_2)
Educational institutions	8,132.3	0.83	6,750	6.7

7.4 Establishments' consumption

7.4.1 Total number of establishments in Jammu and Kashmir as per data based on the MSME (2014-15) report is

State	No. of rural establishments	No. of urban establishments
Jammu and Kashmir	1,09,524	1,15,391

7.4.2 Duration of winter months and appliance wattage were established as per Step 3

- » Duration of heating below 1500m altitude range is 3 months;
- » Duration of heating above 1500m altitude range is 6 months;
- » Electricity is used for heating purposes for a duration of 4 hours in a day (appliance wattage being 1000kW);

- Distribution of establishments with respect to altitude ranges below 1500m and above 1500m corresponds to the ratio of population living in these altitude ranges.

Number of establishments as per altitude ranges

Category of institutions	Altitude range (m)	Total no. of establishments
	(a)	**(b)**
Rural – electric (10%)	Up to 1500	4,490
	1500 and above	6,462
Urban – electric (100%)	Up to 1500	47,310
	1500 and above	68,081

7.4.3 Calculation of consumption

i = (b x c x d x e x f x g x h) / 1000

Category of establishments	Altitude range (m)	Total no. of rooms	No. of heaters per room	Usage hours	Electrical load of each heater (kW)	Usage days in a month	No. of heating months	kWh	MWh
	(a)	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**	**(h)**	**(i)**
Rural – (10% electric)	Up to 1500	4,490	1	4	1	30	3	16,16,574.2	1,616.6
	1500 and above	6,462	1	4	1	30	6	46,52,579.5	4,652.6
Urban (100%)	Up to 1500	47,310	1	4	1	30	3	1,70,31,712	17,031.7
	1500 and above	68,081	1	4	1	30	6	4,90,18,097	49,018.1

h = c x d x e x f x g x h

Category of establishments	Altitude range (m)	No. of people using fuelwood	No. of saggars	Usage hours	Fuelwood for saggars (tonnes)	Usage days in a month	No. of heating months	Daily fuel usage (tonnes)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Rural (90% fuelwood)	Up to 1500	53,760	6,720	1	0.02	30	3	12,096
	1500 and above	77,361	9,670	1	0.02	30	6	34,813

7.4.4 Emissions from establishments

Category	Consumption	Unit	Emissions factor	Emissions (tonnes of CO_2)	Emissions ('000 tonnes of CO_2)
Electric	72,319.0	MWh	0.83	60,025	60.0
Fuelwood	46,909	tonnes	1.83	85,843	86

7.5 Total emissions

Total emissions by different typologies

Typology	Consumption	Unit	Emissions factor	Emissions (tonnes of CO_2)
Hotels	1,833	MWh	0.83	1,521
Hospitals	2,845	MWh	0.83	2,361
Educational institutions	8,132.3	MWh	0.83	6,750
Establishments – electric	72,319.0	MWh	0.83	60,025
Establishments – fuelwood	46,909	tonne	1.83	85,843

Typology	Emissions ('000 tonnes of CO_2)	
Hotels	1.5	
Hospitals	2.4	
Educational institutions	6.7	
Establishment – (electricity + fuelwood)	146.0	

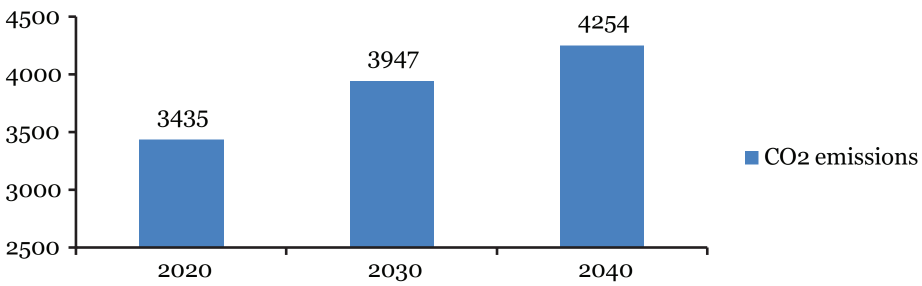
7.6 Projection of emissions for 2030 and 2040 for commercial/institutional buildings is done based on the growth rate of population

	2020	2030	2040
Emissions ('000 tonnes of CO_2)	156.9	168.2	179.5

Step 8: Overall, the emissions rates from Jammu and Kashmir for 2020 and projected years 2030 and 2040 are calculated using steps 6 and 7.7, as given below.

Emissions ('000 tonnes of CO_2)	2020	2030	2040
Residential (fuelwood)	3,877	3,997	4,121
Residential (electricity)	1,165	1,604	1,804
Commercial	156.9	168.2	179.5
Total	**5,199**	**5,770**	**6,105**

J&K space heating emissions 000' (tonnes of CO_2)

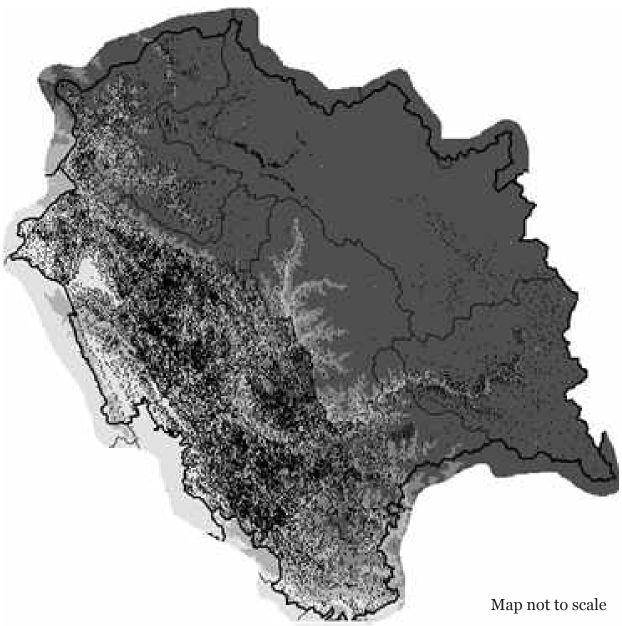


STEPS FOLLOWED FOR CALCULATION OF EMISSIONS – UTTARAKHAND

Step 1: The projections of population for base year (2020) and for 2030 and 2040 were done based on the study titled, "Population projections for India and states 2011–2036, report of the technical group on population projections". The report provides year-wise state projections for urban and rural populations till 2036. The population of 2040 is derived through statistical projection methods. The population for years 2020, 2030 and 2040 for Uttarakhand is presented in the following table.

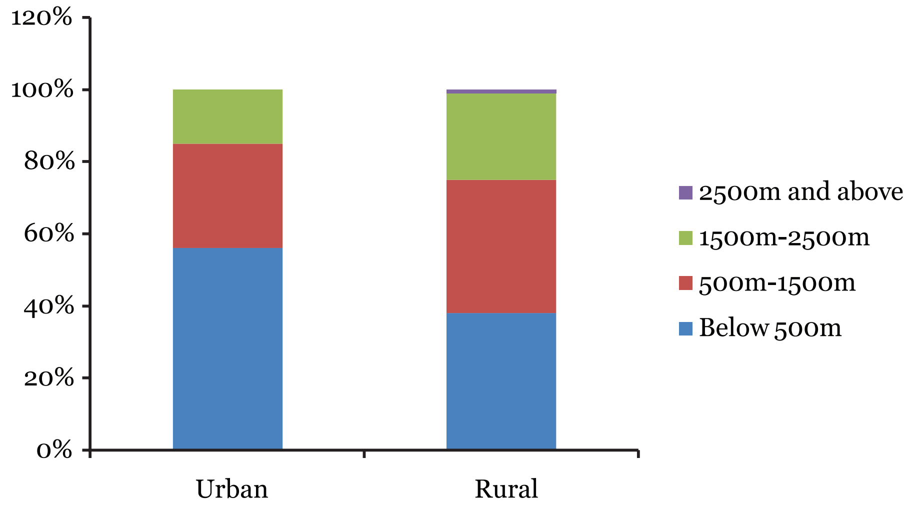
Year	2020	2030	2040
Total population ('000)	11,270	12,418	13,559
Urban population ('000)	3,887	4,864	5,827
Rural population ('000	7,383	7,554	7,732

Step 2: The analysis of the distribution of population at different altitudes was done using a digital elevation model to classify the settlements in different altitude ranges. The shape files of settlements showed the demarcation of boundaries of the studied settlements at the village level as per 2001 census data. The shape files were then converted to points to determine the value of elevation of the settlements. The elevation data of settlements were tabulated and classified in the range of up to 500m, 500–1500m, 1500–2500m, and 2500m and above. The analysis was done for both urban and rural settlements. The percentages of population at different altitudes in rural and urban areas were used with the projected population for years 2020, 2030 and 2040, as derived earlier in Step 1.



Map not to scale

Population % by altitude range (m)	Urban (%)	Rural (%)
Below 500	56	38
500–1500	29	37
1500–2500	15	24
2500 and above	0	1



Step 3: Details of fuel usage, heating requirement as per the duration of winter months and hours of the day were established in consultation with research institutes working in the IHR through telephonic interviews with experts and government officials. The following are the inferences of the interactions.

» 90 per cent of rural population uses fuelwood as a source of heating;

» 100 per cent of urban population uses electricity for heating purposes;

» Duration of use of electrical heaters per day is 12 hours (appliance wattage being 1000kW) in residential buildings;

» Duration of heating below 1500m altitude range is 3 months;

» Duration of heating above 1500m altitude range is 6 months.

The amount of per capita fuelwood consumption at different altitude ranges was calculated based on published research papers on fuelwood consumption in the IHR. The references of the study are given in Annexure 2.

- Per capita per day fuelwood use below 1500m altitude range is 1.6kg, and above 1500m is 1.9kg

Step 4: Calculation of fuel and energy consumption in rural and urban areas for different altitude ranges

4.1 Calculation of fuelwood consumption for different altitudes in rural areas (90 per cent population)

$$f = b \times c \times d \times e$$

Altitude range (m)	%	Rural population ('000)	Duration (days)	Per capita wood consumption (kg/capita/day)	Tonnes of fuelwood
(a)	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**
Up to 500	33.9	7,383	90	1.6	3,60,650
500–1500	33.7	7,383	90	1.6	3,58,691
1500–2500	21.6	7,383	180	1.9	5,46,277
2500 and above	0.7	7,383	180	1.9	17,774
Total					12,83,393

4.2 Calculation of electricity usage for space heating for different altitude ranges in rural areas (10 per cent population)

$$g = b \times c \times e / (d \times 1000)$$

Altitude range (m)	%	Rural population ('000)	Person/ household	Duration (days)	Usage hours	Energy consumed (MWh)
(a)	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**
Up to 500	3.8	7,383	5.01	90	12	59,999
500–1500	3.7	7,383	5.01	90	12	59,673
1500–2500	2.4	7,383	5.01	180	12	76,531
2500 and above	0.1	7,383	5.01	180	12	2,490
Total						1,98,694

4.3 Calculation of electrical energy consumption for different altitude ranges by the urban population (100 per cent)

$$g = b \times c \times e / (d \times 1000)$$

Altitude range (m)	%	Urban population ('000)	Person/ household	Duration (days)	Usage hours	Energy consumed (MWh)
(a)	(b)	(c)	(d)	(e)	(f)	(g)
Up to 500	56	3,887	5.00	90	12	4,67,557
500–1500	29	3,887	5.00	90	12	2,42,566
1500–2500	15	3,887	5.00	180	12	2,50,044
2500 and above	0	3,887	5.00	180	12	5,847
Total						**9,66,013**

Step 5: Calculation of emissions is done based on the emissions factor of fuelwood and electricity

- Emissions factor of fuelwood is taken as 1.83kg of CO_2 per of fuelwood
- Emissions factor of electricity is taken as 0.83t CO_2 per MWh of electricity

Fuel	Quantity	Unit	Emissions factor	Emissions ('000 tonnes of CO_2)
Fuelwood total (from 4.1)	12,83,393	Tonnes	1.83	2,349
Electricity total (from 4.2 and 4.3)	11,64,707	MWh	0.83	967

Step 6: Calculation of emissions for 2030 and 2040 is done using steps 4 and 5 for the projected population of Uttarakhand, as per Step 1

Emissions	2020	2030	2040
Fuelwood	2,349	2,403	2,460
Electricity	967	1,412	1,656

Step 7: For the calculation of emissions for commercial/institutional buildings, these buildings are classified in four categories, namely – hotels, hospitals, educational institutions and establishments.

7.1 Hotels' consumption

7.1.1 Total number of hotels in Uttarakhand as per data collected from official tourism website is given in the subsequent table

Category of hotels	No. of hotels	No. of rooms
Luxury (heritage and 5-star)	39	24,814
Non-luxury (4-star and below)	3,639	50,786

7.1.2 Duration of winter months and appliance wattage were established as per Step 3

- Duration of heating below 1500m altitude range is 3 months;
- Duration of heating above 1500m altitude range is 6 months;
- Electricity is used for heating purposes for a duration of 6 hours in a day (appliance wattage being 1000kW) per room;
- Diversity of 0.8 for luxury hotels and 0.6 for non-luxury hotels are considered;
- Distribution of hotels with respect to altitude ranges below 1500m and above 1500m corresponds to the ratio of population living in these altitude ranges.

Number of hotel rooms as per altitude ranges

Altitude range (m)	Luxury	Non-luxury
Above 1500	19,355	39,613
Below 1500	5,459	11,173

7.1.3 Calculation of consumption

j = (b x c x d x e x f x g x h) / 1000

Luxury hotels

Altitude range (m)	Total no. of rooms	No. of heaters per room	Usage hours	Electrical load of each heater (kW)	Usage days in a month	No. of heating months	Diversity	kWh	MWh
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Up to 1500	19,355	1	6	1	30	3	0.8	83,61,325	8,361
1500 and above	5,459	1	6	1	30	6	0.8	47,16,645	4,716

Non-luxury hotels

Altitude range (m)	Total no. of rooms	No. of heaters per room	Usage hours	Electrical load of each heater (kW)	Usage days in a month	No. of heating months	Diversity	kWh	MWh
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Up to 1500	39,613	1	6	1	30	3	0.6	1,28,34,638	12,835
1500 and above	11,173	1	6	1	30	6	0.6	72,40,052	7,240

7.1.4 Emissions from hotels

Category	Consumption (MWh)	Emissions factor	Emissions (tonnes of CO_2)	Emissions ('000 tonnes of CO_2)
Hotels	33,153	0.83	27,517	27.52

7.2 Hospitals' consumption

7.2.1 Total number of hospitals based on various categories

Category	Uttarakhand
Hospitals	385
Community health centres/RH	59
Dispensaries	7
Ayurvedic and Unani institutions/hospitals	547
Private hospitals	21

7.2.2 Duration of winter months and appliance wattage were established as per Step 3

- Duration of heating below 1500m altitude range is 3 months;
- Duration of heating above 1500m altitude range is 6 months (appliance wattage being 1000kW per room);
- Hospitals: 1 heater for every 2 beds with a diversity of 0.8;
- Community health centres: 1 heater for every 2 beds with a diversity of 0.8;
- Private hospitals: 1 heater for every 2 beds with a diversity of 0.8;
- Dispensaries: 1 heater with a diversity of 0.8;
- Ayurvedic and Unani institutions: 2 heaters with a diversity of 0.8.

7.2.3 Calculation of consumption

$$j = (b \times c \times d \times e \times f \times g \times h) / 1000$$

Category of hotels	Altitude range (m)	Total no. of beds	No. of heaters per room	Usage hours	Electrical load of each heater (kW)	Usage days in a month	No. of heating months	Diversity	kWh	MWh
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Hospitals	Up to 1500	351	1	6	1	30	3	0.8	1,51,632	151.6
	1500 and above	99	1	6	1	30	6	0.8	85,536	85.5
Community health centres/RH	Up to 1500	46	2	6	1	30	3	0.8	39,761.28	39.8
	1500 and above	13	2	6	1	30	6	0.8	22,429.44	22.4
Dispensaries	Up to 1500	5	1	3	1	30	3	0.8	1,179.36	1.2
	1500 and above	2	1	3	1	30	6	0.8	665.28	0.7
Ayurvedic and Unani institutions/ hospitals	Up to 1500	427	2	3	1	30	3	0.8	1,84,317.12	184.3
	1500 and above	120	2	3	1	30	6	0.8	1,03,973.76	104.0
Private hospitals	Up to 1500	16	5	3	1	30	3	0.8	17,690.4	17.7
	1500 and above	5	5	3	1	30	6	0.8	9,979.2	10.0

7.2.4 Emissions from hospitals

Category	Consumption (MWh)	Emissions factor	Emissions (tonnes of CO_2)	Emissions ('000 tonnes of CO_2)
Hospitals	617.2	0.83	512	0.51

7.3 Educational institutions' consumption

7.3.1 Total number of educational institutions based on various categories

Category	Uttarakhand
Primary	15,945
Middle	4,546
Secondary and senior	3,222
Total number of schools	23,713
Colleges	22
Technical universities	107
Total number of colleges and universities	129

7.3.2 Duration of winter months and appliance wattage were established as per Step 3

- Duration of heating below 1500m altitude range is 3 months;
- Duration of heating above 1500m altitude range is 6 months (appliance wattage being 1000kW per room);
- Diversity of 0.6 for schools (primary, middle and secondary and senior) and 0.8 diversity in colleges and technical universities are considered.

7.3.3 Calculation of consumption

j = (b x c x d x e x f x g x h) / 1000

Category of educational institutions	Altitude range (m)	Total no. of rooms	No. of heaters per room	Usage hours	Electrical load of each heater (kW)	Usage days in a month	No. of heating months	Diversity	kWh	MWh
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Schools	Up to 1500	18,496	1	4	1	24	3	0.6	31,96,132.9	3196.1
	1500 and above	5,217	1	4	1	24	6	0.6	18,02,946.8	1802.9
Universities	Up to 1500	101	1	4	1	24	3	0.8	23,182.8	23.2
	1500 and above	28	1	4	1	24	6	0.8	13,077.5	13.1

7.3.4 Emissions from educational institutions

Category	Consumption (MWh)	Emissions factor	Emissions (tonnes of CO_2)	Emissions ('000 tonnes of CO_2)
Educational institutions	5,035.3	0.83	4,179	4.1

7.4 Establishments' consumption

7.4.1 Total number of establishments in Uttarakhand as per data based on the MSME (2014-15) report is

State	No. of rural establishments	No. of urban establishments
Uttarakhand	78,397	87,669

7.4.2 Duration of winter months and appliance wattage were established as per Step 3

- » Duration of heating below 1500m altitude range is 3 months;
- » Duration of heating above 1500m altitude range is 6 months;
- » Electricity is used for heating purposes for a duration of 4 hours in a day (appliance wattage being 1000kW);
- » Distribution of establishments with respect to altitude ranges below 1500m and above 1500m corresponds to the ratio of population living in these altitude ranges.

Number of establishments as per altitude ranges

Category of institutions	Altitude range (m)	Total no. of establishments
	(a)	(b)
Rural – (10% electric)	Up to 1500	6,115
	1500 and above	1,725
Urban (electric)	Up to 1500	68,382
	1500 and above	19,287

7.4.3 Calculation of consumption

$$i = (b \times c \times d \times e \times f \times g \times h) / 1000$$

Category of establishments	Altitude range (m)	Total no. of rooms	No. of heaters per room	Usage hours	Electrical load of each heater (kW)	Usage days in a month	No. of heating months	kWh	MWh
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
Rural – (10% electric)	Up to 1500	6,115	1	4	1	30	3	22,01,387.8	2,201.4
	1500 and above	1,725	1	4	1	30	6	12,41,808.5	1,241.8
Urban (100%)	Up to 1500	68,382	1	4	1	30	3	2,46,17,455	24,617.5
	1500 and above	19,287	1	4	1	30	6	1,38,86,770	13,886.8

h = c x d x e x f x g x h

Category of establishments	Altitude range (m)	No. of people using fuelwood	No. of saggars	Usage hours	Fuelwood for saggars (tonnes)	Usage days in a month	No. of heating months	Daily fuel usage (tonnes)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Rural (90% fuelwood)	Up to 1500	81,723	10,215	1	0.02	30	3	18,388
	1500 and above	23,050	2,881	1	0.02	30	6	10,372

7.4.4 Emissions from establishments

Category	Consumption	Unit	Emissions factor	Emissions (tonnes of CO_2)	Emissions ('000 tonnes of CO_2)
Electric	41,947.4	MWh	0.83	34,816	34.8
Fuelwood	28,760	tonnes	1.83	52,631	52.6

7.5 Total emissions

Total emissions by different typologies

Typology	Consumption	Unit	Emissions factor	Emissions (tonnes of CO_2)
Hotels	33,153	MWh	0.83	27,517
Hospitals	617.2	MWh	0.83	512
Educational institutions	5,035.3	MWh	0.83	4,179
Establishment (electric)	41,947.4	MWh	0.83	34,816
Establishment (fuelwood)	28,760	tonnes	1.83	52,631

Typology	CO_2 emissions (‘000 tonnes of CO_2)	
Hotels	27.5	
Hospitals	0.5	
Educational institutions	4.2	
Establishments – (electricity + fuelwood)	87.4	

7.6 Projection of emissions for years 2030 and 2040 for commercial/institutional buildings is done based on the growth rate of population

	2020	2030	2040
Emissions (‘000 tonnes of CO_2)	119.6	132.0	137.4

Step 8: Overall, the emissions rates of Uttarakhand for 2020 and projected years 2030 and 2040 are calculated from steps 6 and 7.7, as given below

Emissions (‘000 tonnes of CO_2)	2020	2030	2040
Residential (fuelwood)	2,349	2,403	2,460
Residential (electricity)	967	1,412	1,656
Commercial	119.6	132.0	137.4
Total	**3,435**	**3,947**	**4,254**

SPACE HEATING EMISSIONS: TABLE FOR 2020, 2030 AND 2040

Emissions by space heating in '000 tonnes of CO_2 (2020)

		Residential buildings		Commercial/institutional buildings				Year
		Electrical	Fuelwood	Hotels	Hospitals	Educational institutions	Establishments	2020
1	J&K	1,165	3,877	1.53	2.37	6.77	146.3	5,199
2	HP	351	2,238	16.66	0.86	2.93	101.6	2,711
3	UT	967	2,349	27.56	0.51	4.19	87.6	3,435
4	SK	80	134	0.10	0.39	0.16	9.9	224
5	AR	100	359	0.02	0.36	0.67	12.9	473
6	NG	223	383	0.00	0.90	1.04	18.1	626
7	MN	192	556	0.24	0.66	0.51	31.2	780
8	MZ	128	131	0.01	0.38	0.58	8.3	268
9	TR	352	613	0.12	1.00	0.58	40.4	1,007
10	ML	175	767	0.02	0.25	1.28	30.7	974
11	WB*	14	60	-	-	-	-	74
12	AS*	24	84	-	-	-	-	108
Total								15,880

** Commercial emissions for the hill districts of West Bengal and Assam are not included since state-level reports have been used for analysis in the present study.*

Emissions by space heating in '000 tonnes of CO_2 (2030)

		Residential buildings		Commercial/institutional buildings				Total
		Electrical	Fuelwood	Hotels	Hospitals	Educational institutions	Establishments	2030
1	J&K	1,604	3,997	1.64	2.54	7.25	156.77	5,770
2	HP	447	2,335	17.43	0.90	3.07	106.32	2,909
3	UT	1,412	2,403	30.37	0.57	4.61	96.50	3,947
4	SK	144	94	0.11	0.43	0.17	10.76	250
5	AR	140	379	0.03	0.39	0.73	14.04	534
6	NG	373	315	0.00	0.98	1.14	19.70	710
7	MN	268	582	0.26	0.72	0.56	34.01	886
8	MZ	174	136	0.01	0.41	0.64	9.05	320
9	TR	572	552	0.13	1.09	0.63	44.05	1,170
10	ML	233	831	0.02	0.27	1.39	33.52	1,099
11	WB*	19	58	0.00	0.00	0.00	0.00	77
12	AS*	31	91	0.00	0.00	0.00	0.00	122
Total								17,794

** Commercial emissions for the hill districts of West Bengal and Assam are not included since state-level reports have been used for analysis in the present study.*

Emissions by space heating in '000 tonnes of CO_2 (2040)

		Residential buildings		Commercial/institutional buildings				Year
		Electrical	Fuelwood	Hotels	Hospitals	Educational institutions	Establishments	2040
1	J&K	1,804	4,121	1.75	2.71	7.74	167.34	6,105
2	HP	472	2,436	17.78	0.92	3.13	113.49	3,043
3	UT	1,656	2,460	29.42	0.55	4.47	103.01	4,254
4	SK	190	56	0.10	0.42	0.17	11.48	258
5	AR	159	399	0.02	0.39	0.71	14.99	573
6	NG	474	249	0.00	0.96	1.11	21.03	747
7	MN	303	608	0.25	0.71	0.54	36.31	949
8	MZ	193	140	0.01	0.40	0.62	9.66	344
9	TR	716	492	0.12	1.07	0.62	47.02	1,257
10	ML	255	893	0.02	0.26	1.36	35.78	1,185
11	WB*	21	57	0.00	0.00	0.00	0.00	78
12	AS*	33	97	0.00	0.00	0.00	0.00	130
Total								18,924

** Commercial emissions for the hill districts of West Bengal and Assam are not included since state-level reports have been used for analysis in the present study.*

ANNEXURE 4: LIST OF RESOURCE PERSONS FOR THE PROJECT

List of officials/institutions contacted

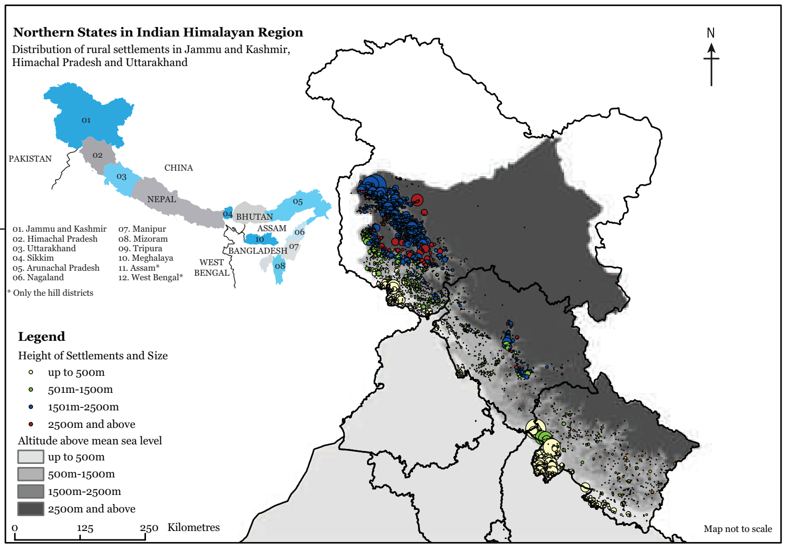
Name	Organization	Designation
Dr Mahua Mukherjee	Indian Institute of Technology (IIT) Roorkee	Professor
Mr S K Negi	Central Building Research Institute, Roorkee	Principal Scientist
Mr Vikram Negi	G B Pant National Institute of Himalayan Environment and Sustainable Development, Uttarakhand	Scientist
Mr Shashi Mohan Srivastava	Town and Country Planning Department, Government of Uttarakhand	Associate Planner
Dr Girish Joshi	Disaster Mitigation and Management Centre, Uttarakhand	Disaster Management Specialist
Dr S S Randhawa	Department of Science & Technology-Himachal	Principal Scientific Officer
Dr Lal Singh	Himalayan Research Group (HRG) Umesh Bhavan, Chota Shimla Himachal Pradesh	Director
Dr Arpan Gupta	School of Engineering, IIT-Mandi	Associate Professor
Mr Chau Dhanya Mungyak	Department of IT and Science and Technology Government of Arunachal Pradesh	Scientist 'B'
Dr Pradeep Bhanot	HIMURJA	Senior Project Officer
Mr Saifuddin Abid	Energy Conservation Building Code (ECBC) Cell, Himachal Pradesh	Consultant
Mr Senthil Kumar	National Institute of Solar Energy (NISE)	Junior Research Scientist
Mr Naveen Gahlawat	Neocholorus Energy Solutions Private Limited	Managing Director
Mr Acho Chozang	Rocket Stove	Sales and Support
Dr Rameshwar Sorokhaibam	National Centre for Disease Control (NCDC)	Assistant Director, Centre for Environmental and Occupational Health, Climate Change and Health

ANNEXURE 5: DISTRIBUTION OF SETTLEMENTS IN THE IHR

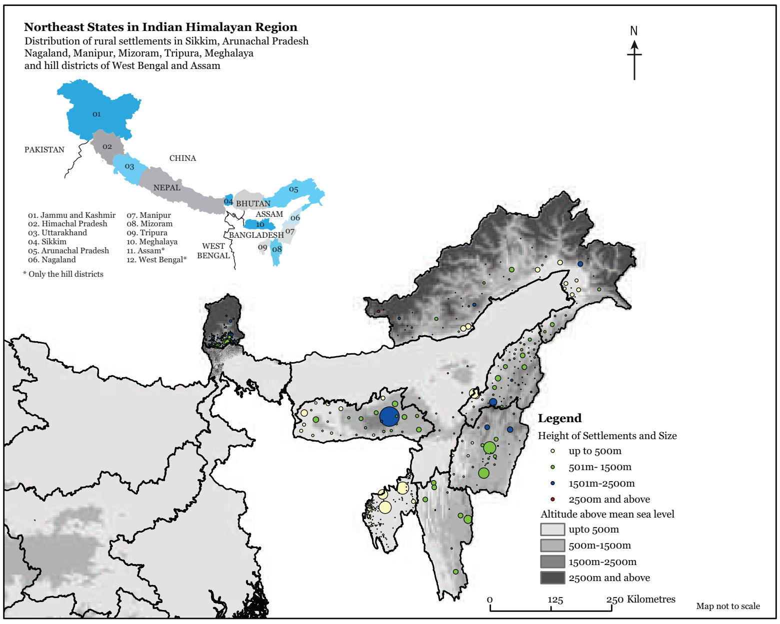
Maps given in this annexure show the distribution of settlement, aided with colour coding to facilitate understanding of the height of the settlements. Altitude data of the settlement is used in the study to determine the duration of the heating period for the settlement.

Note: Size of the settlement population is proportional to the size of the circle. The size of the settlement in Northeast states is proportionally increased by a factor of 10, compared to the settlements of northern states to have an effective graphical representation.

Map 1: Spatial distribution of settlements in Jammu and Kashmir, Himachal Pradesh and Uttarakhand and their altitude range



Map 2: Spatial distribution of settlements in Sikkim, Arunachal Pradesh, Nagaland, Manipur Tripura Meghalaya and hill districts of West Bengal and Assam and their altitude range



ANNEXURE 6: DISTRIBUTION OF URBAN AND RURAL POPULATION AT DIFFERENT ALTITUDES FOR 2020

Altitude-wise distribution of urban and rural population, based on GIS analysis of altitude of settlements								
Population ('000)								
	Urban				**Rural**			
	Altitude range				**Altitude range**			
	0–500m	500–1500m	1500–2500m	Above 2500m	0–500m	500–1500m	1500–2500m	Above 2500m
J&K	954	687	2,277	127	2,281	2,332	4,446	495
HP	50	476	180	46	635	3,894	1,706	361
UT	2,169	1,125	580	14	2,783	2,768	1,775	58
SK	4	182	96	4	6	243	128	6
AR	138	151	69	20	414	455	209	61
NG	237	487	178	0	334	686	251	0
MN	87	836	68	0	188	1,808	146	0
MZ	80	570	4	0	67	480	3	0
TR	1,444	2	0	0	2,582	4	0	0
ML	247	299	121	0	959	1,160	469	0
WB*	7	19	0	0	5	4	1	0
AS*	0	14	0	0	0	15	0	0
*Only hill districts								

J&K – Jammu &Kashmir, HP – Himachal Pradesh, UT – Uttarakhand, SK – Sikkim, AR –Arunachal Pradesh, NG – Nagaland, MN – Manipur, MZ – Mizoram, TR – Tripura, ML – Meghalaya, WB – West Bengal, AS – Assam

Source: National Commission on Population (2019)

ANNEXURE 7: EXISTING SPACE HEATING TECHNOLOGIES (RURAL AND URBAN AREAS) AND INNOVATIVE TECHNOLOGIES

Existing space heating technologies

1. Saggar

Saggar being used by a group of shopkeepers

Description	Saggar is a metal container, often in square shape with handles for manoeuvring the location from outdoor to indoors when required. It is used in both residential and commercial habitats in rural settlements and small towns. In residences, once the cooking is over, the fire is transferred from the stove to the Saggar and is taken to one or more living spaces of the households for heating during critical winters. The fire is doused at the time of sleeping. In commercial establishments, in rural areas and towns, the Saggar is used by shopkeepers in the winter season to keep warm during the daytime. Generally, one fire is lit between seven and eight establishments where people gather to keep themselves warm. Small grouping ensures that the shopkeepers also keep track of their shops.
Application and size of project	Rural households and commercial establishments in rural and smaller towns of the Indian Himalayan region (IHR)

2. Bukhari

Dedicated room for Bukhari in Kashmir household

Source: Dutta (2018)

Description	During winter months, the use of metal stoves, in which the wood is burnt for space heating, locally known as Bukhari, is very common, in both urban and rural areas. Although these stoves are equipped with chimneys, during initial lighting, the door of the combustion chamber is left open to allow sufficient air to flow in so that the wood can catch fire. Generally, a small amount of kerosene is used for the initial lighting of the wood. This normally generates a lot of smoke, which spreads within the indoor space. Strong winds outside can also force smoke back through the chimney into the indoor environment. Construction of a Bukhari typically requires a tin/iron/brass cylinder, fitted with an exhaust system. However, moreover with the same basic design, it can be modified on the basis of the different fuel types. For instance, the basic model, once widely used, by the society including government was fuelwood based. The essential model, generally utilized for indoor purpose by the general public including the government, largely depended on kindling. Later, two more variants were added—one with sawdust as raw material and another coal based. Besides, a few typologies use charcoal as raw material in the Bukhari. As compared to wood and sawdust Bukharis, the coal Bukhari is less popular because of accompanied with poisonous fume emissions. It is usually advised to turn off the Bukharis while sleeping to avoid any accidents. In high altitude of the IHR during winters, all the household activities are held in the room where the Bukhari heating system is installed. A room is dedicated for the Bukhari to be installed for the winters.
Size of project	Vary from small residential to large halls

3. Army Kerosene Heater

Army kerosene heater

Source: Hindustan Army Store (2014)

Description	The basic principle of a kerosene heater is that the kerosene is poured into the fuel tank and the primary combustion process occurs after absorption of kerosene. The ignition plug design makes the kerosene vaporize to create flames and burn through a wick made of either cotton or fibreglass. The kerosene heater can warm up items that are nearby by either radiation or convection heating methods (Hindustan Army Store 2014).
Size of project	Large spaces (380 sq. ft–3100 sq. ft) (homeair 2014)

4. Traditional Fireplace

Wood-burning fireplace and traditional Himalayan tandoor

A gas-powered fireplace and fireplace vents

Description	A fireplace or hearth is a structure made of brick, stone or metal, designed to contain a fire. Fireplaces are used for the relaxing ambiance they create and for heating a room. Modern fireplaces vary in heat efficiency, depending on the design.
Size of project	Limited to living area such as dens, family rooms and living rooms

5. Kangri or Kanger

Kangris

Description	Kangri is a traditional accessory of providing localized space heating to the human body in Kashmir. Kangri consists of a small clay pot filled with embers. This hot earthenware is placed inside hand-woven wicker basket. Kangri is very common among rural masses of Kashmir who carry it as a mobile heater inside their pherans (a local term for flowing wollen gowns) and poots. The pheran and poots consist of two gowns, one over the other, and the kangri is held by hand or hung around the neck inside the gown to keep warm during severe winters.

6. Biomass Briquettes

Biomass briquettes

Description	Briquetting is the "process of densification of biomass to produce homogeneous, uniformly sized solid pieces of high bulk density which can be conveniently used as a fuel." Biomass briquettes are usually used as a fuel substitute to coal and charcoal-based heating or cooking applications. Densifying waste crop residues can provide a better household fuel, especially in remote mountain regions. Briquettes can also be manufactured using a simple hand-process, thereby making them feasible for poor communities. There are several technologies for briquetting and the most conventional and viable is beehive briquetting that carbonizes the biomass waste partially by mixing char with binder, followed by the densification process. This form of briquette is circular with a diameter of 150mm and a length of 85 mm, having circular holes.
Size of project	Residential/commercial

7. Gas Heater

A gas heater
Source: Travel the Himalayas (2018)

Description	A gas heater consists of three parts. The first part is composed of venting, draft inducers, heat exchanges, and burners. Controls and safety devices make up the second part and the final part consists of blowers. All these parts of a gas heater work in unison to provide optimal levels of heat to any house or building.
Size of project	Residential

8. Portable Room Heaters (Mini Bukhari)

Mini Bukhari

Description	The design of a traditional Bukharis can be modified to increase its efficiency and ease of use to form mini Bukhari. A mini Bukhari is typically constructed using a hollow cylindrical sheet metal for burning the wood to heat the indoor space. A sheet metal cylindrical duct is used to exhaust the smoke generated in the Bukhari combustion chamber. Thermal performance of a mini Bukhari can be further improved by increasing the heat retention time. This is done by using logs made from gypsum and baked clay (powder of bricks) during their construction.
Size of project	Residential

9. Himtapak

Himtapak technology

Description	Himtapak is an improved version of a traditional Bukhari, designed and developed by Defence Institute of Physiology and Allied Sciences (Defence Research and Development Organisation). Space heating through Himtapak works on the principle of burning kerosene safely and efficiently. It consists of two chambers, one for hot air and the other for flue gases. A solar-powered DC fan with a battery backup is integrated with Himtapak to recirculate the hot air inside the building. Himtapak provides a controllable blue flame. Negligible soot is formed as it extracts maximum heat and minimum heat is wasted in the exhaust gases. A single unit of Himtapak prevents about 1 tonne of carbon dioxide and 0.3 tonne of black carbon per year from being released into the environment
Size of project	Small residential

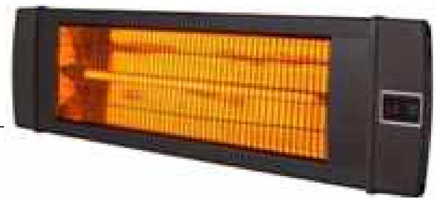
10. Coil Heaters

Coil heaters [25]

Description	Coil electric heaters works on the principle of conducting electricity through metal coils and radiate the heat produced through the room.
Size of project	Small residential

11. Infrared Heater

Infrared heaters



Infrared heater[26]

Ceramic infrared heater[27]

Far-infrared heater[28]

Carbon heater[29]

[25] Details available at https://electrostores.com/

[26] Details available at https://www.ubuy.hk/en/search/index/view/product/B077JM5PB9/s/dr-infrared-heater-1500w-carbon-infrared-heater-indoor-outdoor-patio-garage-wall-or-ceiling-mount-with-remote-black/store/store

[27] Details available at https://superbheater.en.made-in-china.com/product/hbnJzLHlOOtD/China-Curved-240-110mm-Ceramic-Infrared-Heater-Build-in-K-Type-Thermocouple.html

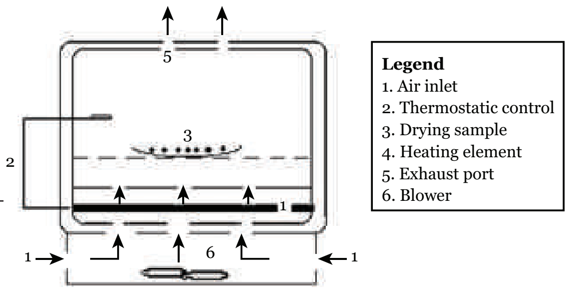
[28] Details available at https://www.hktdc.com/suppliers-products/Far-Infrared-Heater/en/1X00L31Q/1565881/

[29] Details available at https://www.flipkart.com/skyline-vtl5051-carbon-room-heater/p/itmedz2dghvehu9z

Description	Infrared heater or radiant heater works on the basis of infrared radiation. It passes electricity through a conductive wire. This causes the wire to heat up. Infrared heaters use infrared technology to produce heat and spread it on the solid surface (people or objects) rather than to the air. The heat disappears as soon as the heater is turned off. Various types of these heaters are available in the market. For instance, metal wire element such as heat lamps; ceramic infrared heat systems; far-infrared; quartz heat lamps; quartz tungsten; carbon heater; and gas fired. The working principle is same for all infrared heaters.
Size of project	Commercial and residential

12. Convection Heaters or Blowers

Convection heaters/ blowers[30, 31, 32]



Description	The working of convection heaters or blowers is based on the principle of convection heating. In this, cold air from the surrounding is absorbed by the heater. This air is made to flow across the heating element before finally being blown out to warm up the room. This type of room heater encloses a small fan inside to circulate the warm air in the environment. As there is a fan inside, it is known as blower heater.
Size of project	Small residential and commercial

30 Clicked during survey in Uttarakhand
31 Details available at https://www.amazon.in/Amikan-Laurel-Heater-Noiseless-Warranty/dp/B07JB3V5WH
32 Details available at https://www.amazon.in/Electric-Heaters/b?ie=UTF8&node=864122103

13. Ceramic Heater

Ceramic heaters[33]

Source: Wikipedia

Description	Ceramic heaters are basically space heaters which use ceramic in the heating element. The electric resistance heating is the underlying principle of the ceramic heaters. Heating element is made of positive temperature coefficient (PTC) ceramic, which is semi-conductive in nature. It produces heat as electric current flows through it. Ceramic in the heating element increases resistance sharply at the Curie temperatures of the crystalline components, typically 120°C, and remains below 200°C, providing a significant safety advantage. Ceramic heaters consist of multiple ceramic plates which get heated up as a result of resistance offered to electricity flow. Once heated up, these plates start dissipating heat to the surroundings through convective heat transfer process. Fans inside the heaters blow the hot air into the room, and also avoid overheating of ceramic plates by cooling them simultaneously (Wikipedia 2010).
Size of project	Small offices or residences

[33] Details available at https://en.wikipedia.org/wiki/Ceramic_heater

14. Oil-filled Radiator Heater

Oil-filled radiator heater[34]

Description	Oil-filled radiator heaters are gaining noticeable popularity for space heating. Heat transfer in these heaters takes place through convection and radiation modes. An oil-filled radiator heater consists of multiple hollow metal fins (or radiators) inside through which diathermic oil is circulated. These fins are attached to a heating element placed at the bottom of the heater unit. The working of an oil-filled heater is briefed in the following steps: • Electricity is supplied to the heating element which heats the diathermic oil. • The heated oil is circulated through the radiator fins to transfer by the movement of the oil into the heater's metal fins, creating even surface temperatures. • Once the metal fins heat up, they start radiating heat through their surface. • The heat transfer inside the space happens through natural convection mode.
Size of project	Large commercial and residential

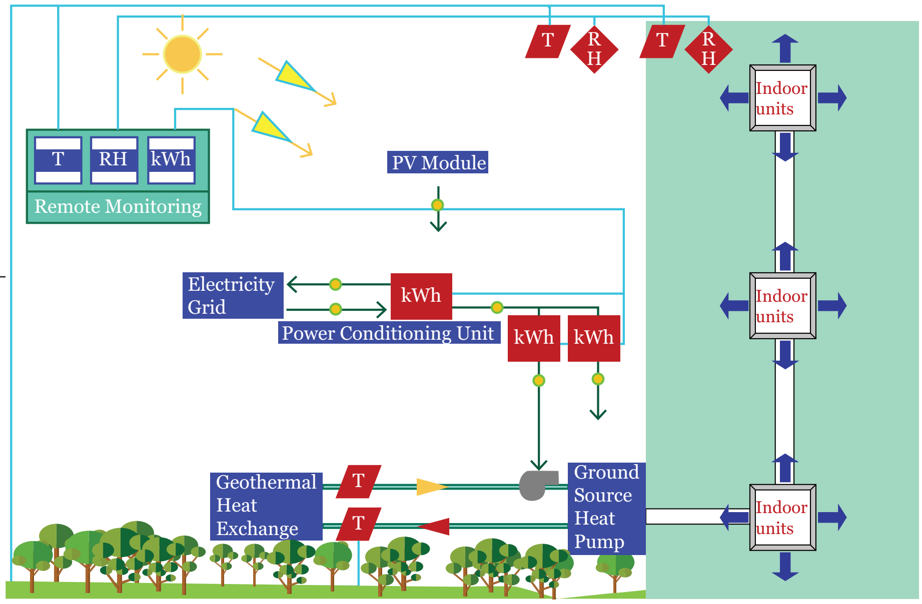
[34] Clicked during stay at hotel for survey in the IHR

Space Heating Innovative Technologies

1. Ground source heat pump with solar photovoltaic (PV) system

GSHP assisted with solar PV system schematic[35]

Source: The schematic taken from the TERI's Project demonstration of GSHP at Kimin



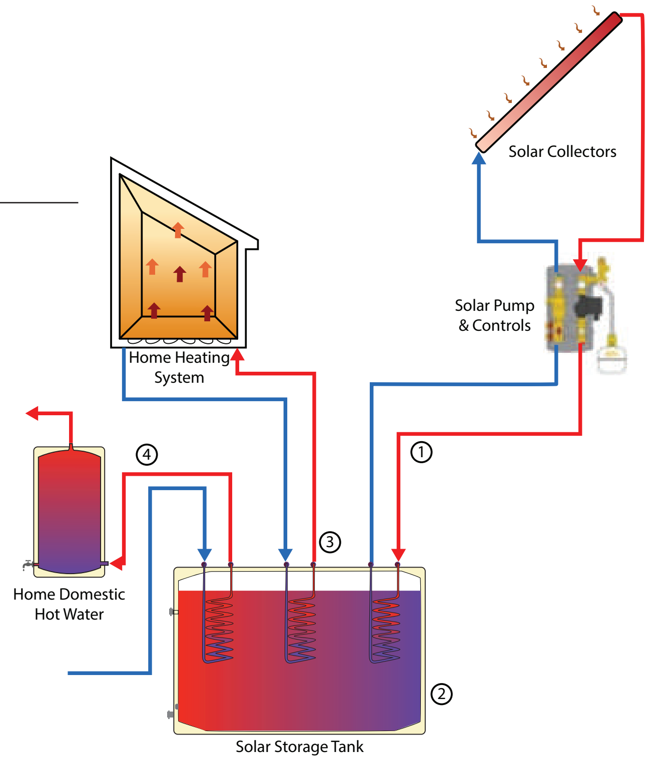
Description	Ground source heat pump (GSHP) systems, also referred to as geothermal heat pump or geo-exchange systems, are electrically powered space heating and cooling technologies that take advantage of the earth's (or surface water's) relatively constant temperature, below certain depths, to provide building space conditioning. It is worth mentioning the subsurface is a source of heat in the winter and an efficient heat-rejection medium in the summer. The GSHP systems work optimally in climate regimes where heating and cooling are relatively balanced. However, they are versatile and, with minor system adaptation, modification, or hybridization, the GSHP systems can be deployed effectively in heating-dominated or cooling-dominated climates. The GSHP system is an outcome of the integration of three technologies : • Geo-exchange system: to utilize earth as heat source/sink • Geo-exchange heat pump machine: to provide space cooling and heating • Solar PV system: to power heat pump and system auxiliaries
Size of project	Commercial

[35] The schematic taken from the TERI's Project demonstration of GSHP at Kimin

2. Liquid-based active solar heating

Liquid-based active solar heating system

Source: Pragya, Environ (2014)

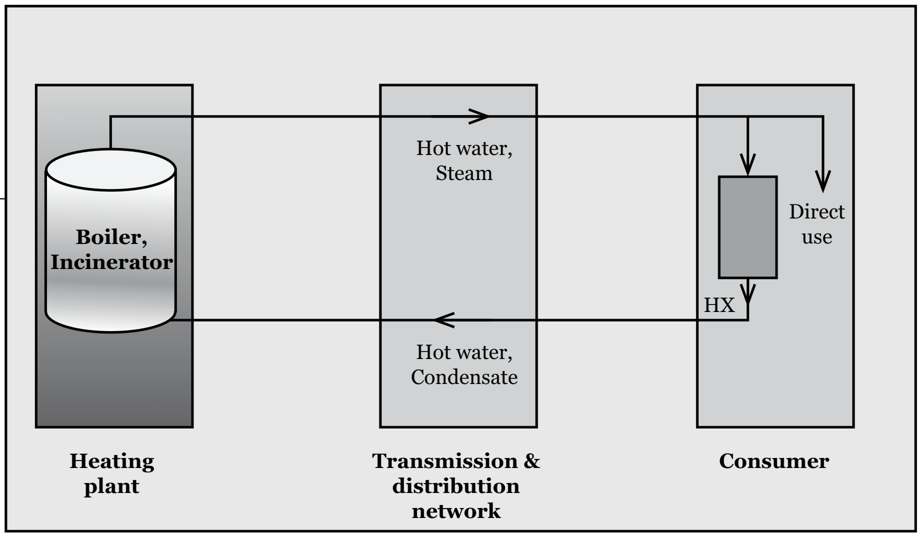


Description	Liquid-based active solar heating is most suitable for centralized heating; this technology enclosed of flat-plate collectors mainly consists of an insulated metal box with a glazing or plastic cover and black-coloured absorber plate. The plate absorbs the solar radiations and transmits the heat to liquid flowing in the heat exchanger connected to the plate. Flat-plate collectors heat the circulating fluid to a temperature ranging between 54.4 and 79.4°C (130–175°F). Solar heat is distributed by introducing a liquid-to-air heat exchanger or heating the coil in the main room. Air returning from the living space is heated as it passes over the solar heated liquid in the heat exchanger. Flat collectors are best suited to applications where the requirement for temperature is 30–70°C (86–158°F) and where heat is needed during the winter months (Pragya, Environ 2014).
Size of project	Large commercial and residential

3. District heating system

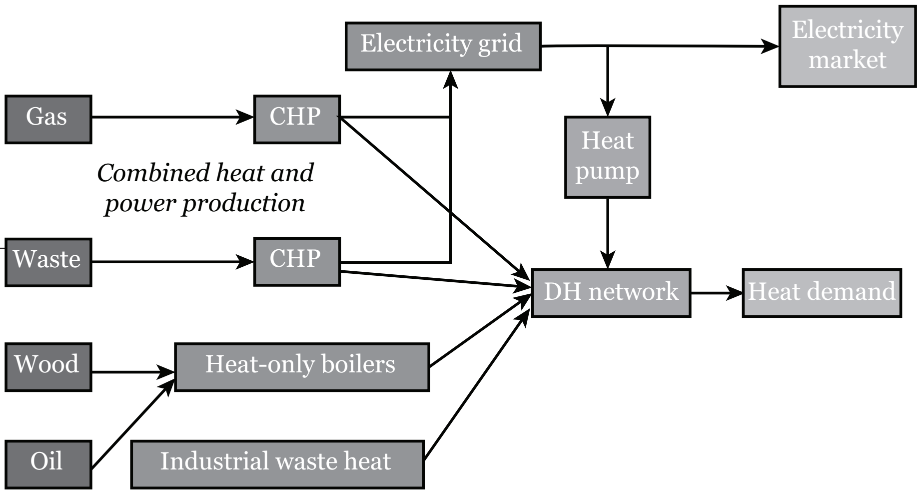
Components of a DHS

Source: Sabru and Sebarchievici (2017)



Common plant types and energy flows for district-heating supply

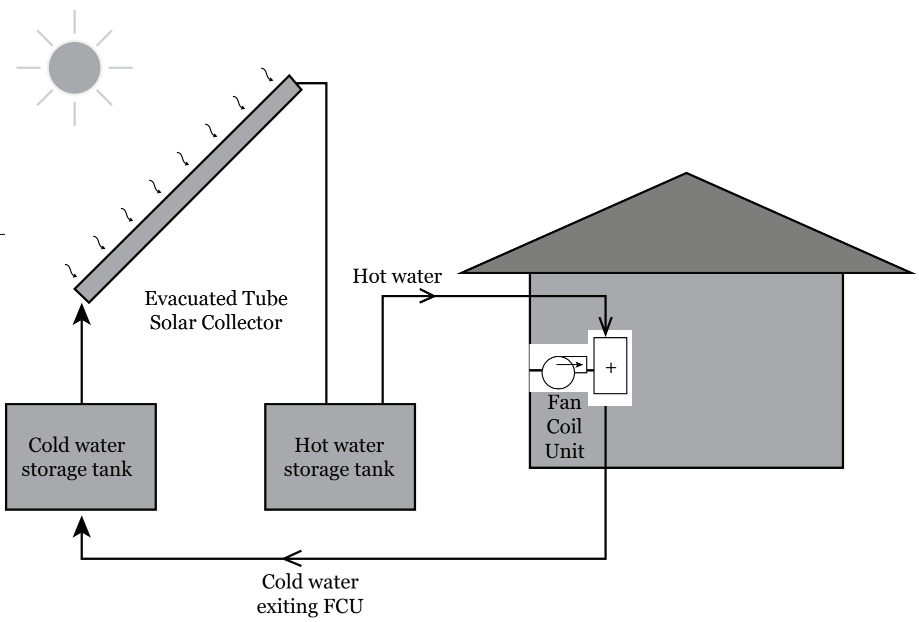
Source: Henning and Gebremedhin (2012)



Description	District heating system (DHS) is a centralized heating system where working fluid, mostly water, is heated at a central plant and later supplied to various households or commercial units through insulated pipes, usually embedded a few metres inside the ground. It has mainly three components: a centralized heating plant, transmission and distribution network and consumer. The most common source of a DHS is a combined heat and power (CHP) generation system. Other sources include a boiler powered by a fossil fuel, natural gas, solar energy, geothermal or waste heat of an industrial plant. DHS is very popular in European countries. In a study conducted on heating systems in South Korea, it was found that DHS integrated with a CHP system achieved a total system efficiency of 67.9 per cent, compared to 54.1 per cent for individual heating (IH) system. In addition, it was observed that DHS was able to reduce emissions by 381,311 tonnes of CO2 (4.1%) in comparison to IH system (Jung, Park, Ahn, et al. 2017).
Size of project	Large scale: commercial and residential

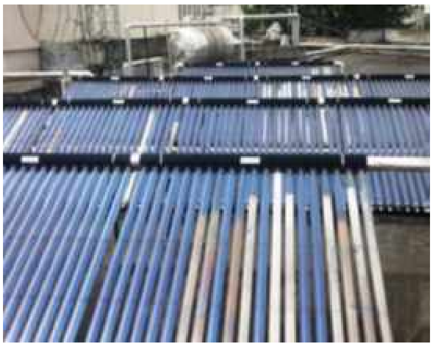
4. Integration of evacuated tube heat pipe with fan–coil unit for space heating application

Block diagram presenting integrated space heating technology of ETHP and fan–coil unit



Demonstration of ETHP being used for space heating at Kohima Civil Secretariat, Nagaland

Source: WWF-India and CEEW (2013)

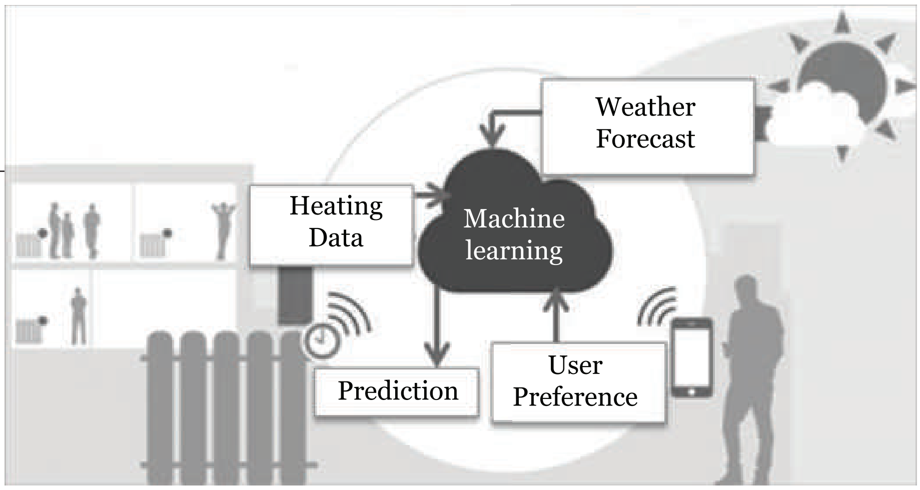


Description	This system integrates ETHP solar collectors with fan–coil unit to produce indoor thermal comfort through forced convection mechanism inside a building. ETHP is a solar thermal system consisting of a series of glass tubes filled with conductive copper material in vacuum. While passing through ETHP water temperature rises and is stored to a hot water storage tank. As and when required, this hot water is circulated via insulated pipes inside the dwelling space where a fan–coil unit is placed. When heat transfer between hot water and air stream occurs, the air temperature increases. This warm air stream is then circulated inside the building via fan. Water exiting insulated pipes is continuously returned to cold water tank and then recirculated through solar collector to provide uninterrupted space heating. To ensure space heating on rainy or low-radiation days, electric heaters can also be integrated with this system.
Size of project	Commercial and large residential

5. Cloud-based smart heating

Cloud-based smart heating

Source: Flexens Oy Ab.



Description	This recent technology is principally used with centralized heating systems to improve thermal comfort and effectively reduce energy consumption by incorporating machine learning, local weather forecasting, occupant feedback and demand-side management. Conventional water radiator thermostats in each occupancy area are replaced with Wi-Fi-enabled and Internet of Things (IoT)-enhanced smart thermostats. These smart thermostats are then connected to the cloud service via the Internet. Based on the thermal response of the building occupant, this technology is capable of delivering space heating at their location as and when required. In addition, this system also forecasts local weather conditions and operates heating system accordingly, ignoring the constant set point concept. Cloud server monitors when the energy cost is the highest and accordingly operates heating system enabling demand-side management, resulting in substantial energy savings. This smart technology is also capable of readjusting the heating requirements with changes in indoor environment, mainly occurring due to window opening, occupancy change, among others.
Size of project	Residential and commercial

CASE STUDY

Microsoft's Smart Campus, United States (King and Perry 2017)

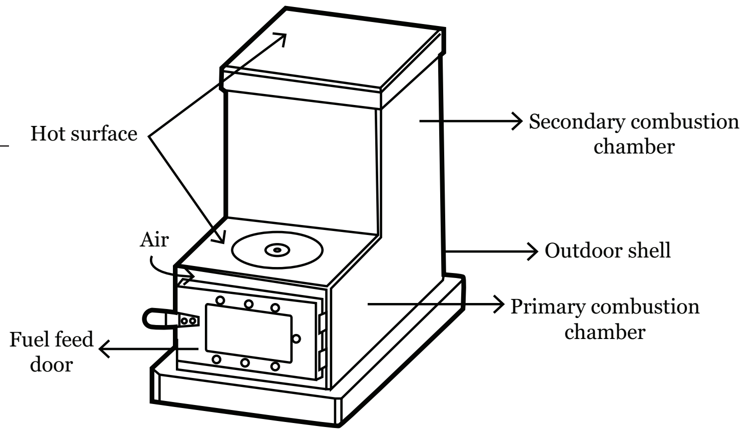
Microsoft smart campus

Source: Microsoft/Life

Microsoft's 88-acres project has become one of the well-publicized examples of a large-scale smart building implementation. The company was uniquely positioned to create one of the smartest office campuses in the United States at its 500-acre headquarters in Redmond, Washington. Like most corporate campuses, the Redmond campus was built in phases, which resulted in buildings that contained sensors, heating, ventilation and air conditioning (HVAC) equipment and building automation system (BAS) from different eras and different manufacturers. As might be expected, each piece of equipment essentially spoke its own language; the challenge was to find a way for all equipment to communicate so that a central system could manage it. To develop its headquarters into a smart campus, Microsoft experts hired real-time automation software firm ICONICS to create a naming convention for each installed device, storing it in a library so that they could easily connect any additional equipment of the same type. As more equipment began communicating, the team began to receive more data points. Microsoft building engineers used the data to improve operations—from staging building start-up based on usage patterns to resolving previously undetectable simultaneous HVAC heating and cooling issues. Microsoft eventually migrated its data to a cloud server, and it planned to develop its platform so that other functions—such as HVAC and data analytics—can use and enhance it. Microsoft estimated that it achieved as much as 10 per cent energy savings from its smart building initiative, saving approximately $0.25 million each year.

6. Rocket Stove

Rocket stove technology

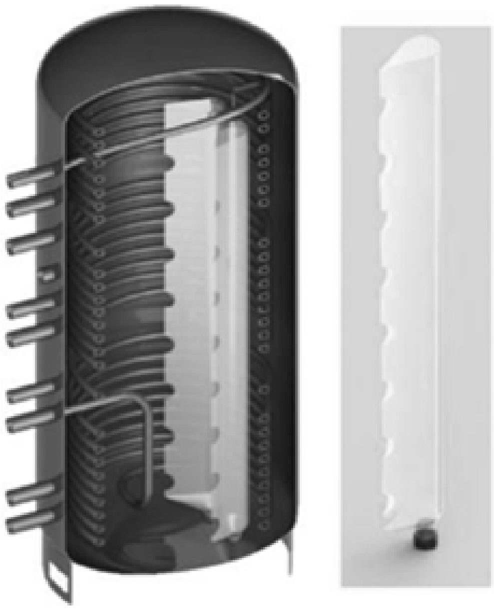


Description	Rocket stove is an innovative technology for energy-efficient burning of fuel (mostly wood) with very small amount of emissions as compared to traditional cook stoves. It consists of dual combustion chamber with an insulated chimney. The design of a rocket stove is such that it ensures complete burning of fuel in the combustion chamber and availability of insulated chimney exhausts the smoke even before it reaches the cooking surface. Smoke is a form of those hydrocarbons which could not be completely combusted inside the stove. Rocket stove design finds its basis in a dual combustion process which draws wood gas and smoke into a secondary combustion chamber, burning the smoke and releasing abundance of additional heat. Temperature inside the rocket cook stove reaches as high as 800°C and the complete combustion of fuel takes place. These stoves are usually tailor-designed for rural areas and are found in two variants: standard rocket stove and water box rocket stove. The standard rocket stove is slightly smaller in size than water box rocket stove and is used for room heating and also provides cooking facility at one of its surfaces. Apart from space heating and cooking facility, water box rocket stove integrates a water heating system for providing domestic hot water to the user. Top surface of a rocket cook stove becomes hot during the fuel burning process and, thus, radiates heat to improve the indoor thermal comfort of the occupants. It has been estimated that rocket stoves consume 18 per cent to 35 per cent less fuel as compared to traditional wood-burning *'chulha'*.
Size of project	Residential

7. Stratiflex

Stratiflex

Source: Anon (n.d.)

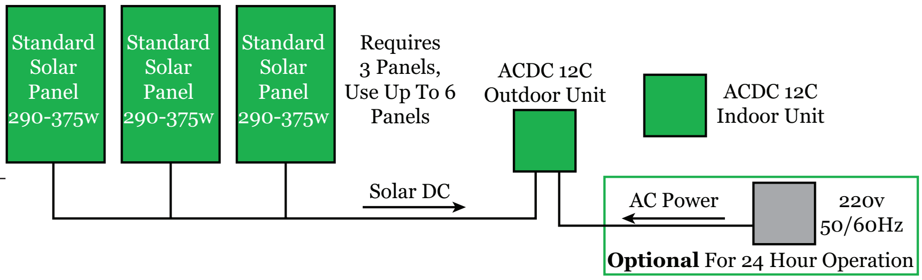


Description	Stratification level inside the water storage tank significantly affects the performance of energy systems including gas condensing units, heat pumps, solar thermal system, among others. Stratiflex is a water storage tank component which follows basic physics behind stratification process to improve the efficiency of various energy systems. It can be easily mounted inside a hot water tank to regulate the thermal layers by not mixing the hot inlet water with the cold water. It can also adjust the inlet water flow rate to quickly bring it to the apt thermal layer. Integration of Stratiflex with heat pump can reduce energy consumption by 10 per cent to 15 per cent while 30 per cent and 6 per cent with solar energy systems and gas condensing units, respectively. It has been envisaged that with 30 per cent market share, installation of Stratiflex could save annual emissions of 26 million tonnes of CO_2 by 2026 (Anon. *n.d.*).
Size of project	Commercial

8. Solar hybrid heat pump

Solar hybrid heat pump[36]

Solar hybrid heat pump working[37]



Description	The purpose of integrating solar and heat pumps is primarily to minimize the electricity needs and maximize the local renewable fraction. In recent low-energy houses, the heating load is often the same as the domestic hot water (DHW) load and even tends to be lower. This favours solar during the sunny season and warmer temperature from solar for heat pump during the heating season. The solar air conditioning unit works on a hybrid principle. It absorbs solar energy to heat the inside medium by utilizing a vacuum solar collector. The refrigerant from the compressor goes through a copper coil inside the collector and undertakes a heat exchange. The heated refrigerant then goes through a cycle inside the system not only for heating but also for cooling. Energy from the sun is fully utilized, therefore less power is required from the mains in this process. This, in turn, allows for smaller compressors to be installed that offer even better savings on power consumption. This system adopts a four-fold type heat exchanger as one of the core components of this air-conditioner. Its heat effective area is increased by 20 per cent to 30 per cent versus the usual V-type and flat plate heat exchanger, which greatly increases the cooling efficiency.

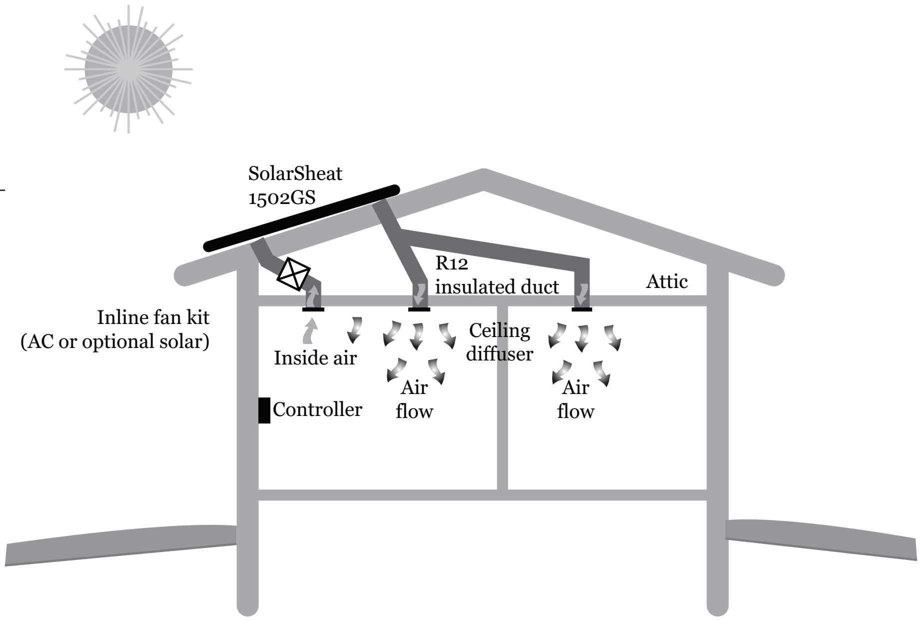
[36] Details available at https://www.hotspotenergy.com/solar-air-conditioner/
[37] Details available at https://practicalpreppers.com/product-category/air-conditioning/ac-dc-air-conditioner-system-hybrid/

Technical specification	Heating COP (3.42); heating capacity (12,000BTU/h)
Size of project	Home/Office Cool or heat up to 750 sq. ft (69m²)

9. SolarSheat solar air collectors

SolarSheat solar air collectors[38]

SolarSheat solar air collectors' working



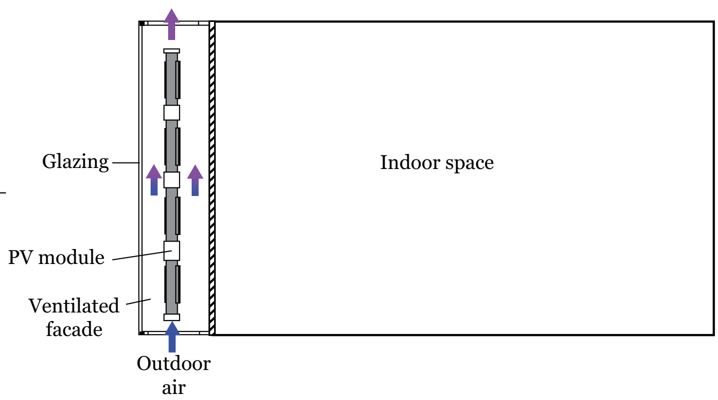
[38] Details available at https://static1.squarespace.com/static/5272dc2ce4b0793e8f87f40d/t/5a5e0776e2c-483c8081785fd/1516111737387/SOLARSHEAT+INSTALLATION+MANUAL+2.0.pdf

Description	This air collector is a self-contained unit with no moving parts. The collector has one air intake port and one air output port. Two small 5" diameter holes are drilled into the exterior wall. The two holes are aligned with the air collector's intake/output ports. The fan assembly sits flush in the wall and mounts in front of the output port. When the sun hits the solar panel it activates the fan. The fan pulls air from a cool room through the intake port and passes it over the collector interior and pushes the heated air back into the room through the air output port.
Technical specification	Rated power (1000W); heating capacity (3450BTU/h), one panel per 1000sq. ft space
Size of project	Home/Office Heat up to 1000sq. ft (100m²)

10. Building integrated solar PV (BIPV) space heating

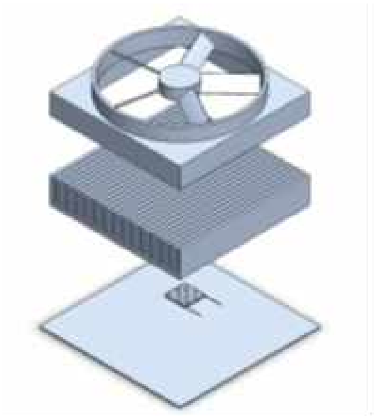
BIPV space heating

BIPV space heating working

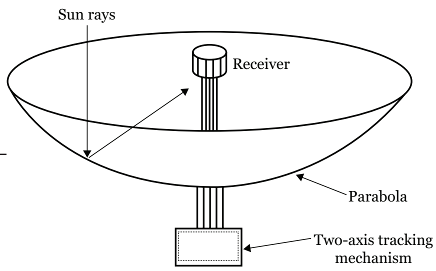


11. Parabolic thermoelectric (TE) generator

Solar parabolic concentrator coupled to TE module and Fan Orientation[39]



Parabolic reflector[40]



Description	Concentrating solar power (CSP) systems can be used effectively to convert solar energy into electrical energy. The CSP systems, namely, parabolic through, liner Fresnel reflector, power tower and parabolic dish are capable of producing power. Amongst the CSP technologies, the parabolic dish collector is recognized as the most efficient system for energy conversion. The TE generator is a solid-state direct energy converter which uses the principle of Seebeck effect. The receiver absorbs the radiant solar energy, converting it into thermal energy in a circulating fluid. The thermal energy can then be either converted into electricity using an engine–generator coupled directly to the receiver or transported through pipes to a central power conversion system.
Size of project	Large offices

[39] Details available at http://solareis.anl.gov/guide/solar/csp/
[40] Details available at http://solareis.anl.gov/guide/solar/csp/

ABOUT WWF INDIA

WWF-India is one of the leading conservation organizations in the country. It is a science-based organization which addresses issues such as the conservation of species and its habitats, climate change, water and environmental education, among many others. Over the years, its perspective has broadened to reflect a more holistic understanding of the various conservation issues facing the country and seeks to proactively encourage environmental conservation by working with different stakeholders.

The Climate Change and Energy Programme of WWF-India is working towards climate resilient future for people, places and species that support pathways for sustainable and equitable economic growth. WWF-India is engaged in promoting renewable energy uptake, enabling clean energy access, demonstrating renewable energy projects in critical landscapes, and overall promoting sustainable clean energy solutions. Climate innovations, low carbon development and renewable energy at scale are the thrust areas of the programme.

ABOUT TERI

TERI is an independent, multi-dimensional organization, with capabilities in research, policy, consultancy and implementation. TERI has innovators and agents of change in the energy, environment, climate change and sustainability space, having pioneered conversations and action in these areas for over four decades.

TERI believes that resource efficiency and waste management are the keys to smart, sustainable and inclusive development. TERI's work across sectors is focused on

- Promoting efficient use of resources
- Increasing access and uptake of sustainable inputs and practices
- Reducing the impact on environment and climate

TERI's research, and research-based solutions have had a transformative impact on industry as well as communities. TERI has fostered international collaboration on sustainability action by creating a number of platforms and forums. TERI does this by translating their research into technology products, technical services, as well as policy advisory and outreach.

Headquartered in New Delhi, TERI has regional centres and campuses in Gurugram, Bengaluru, Guwahati, Mumbai, Panaji, and Nainital. TERI's 1200-plus team of scientists, sociologists, economists and engineers delivers insightful, high quality action-oriented research and transformative solutions supported by state-of-the-art infrastructure.

WWF

SUSTAINABLE SPACE HEATING SOLUTIONS IN THE HIMALAYAN REGION

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