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To cite this article: R Sen *et al* 2021 *J. Phys.: Conf. Ser.* **2069** 012218

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# Community cooling infrastructure from waste heat among diverse building types in Rourkela Steel Township, India

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**Abstract.** Urban building energy modeling is an important field in the current decade due to the rising rate of urbanization, specifically in developing countries. The UN environment is promoting urban level space cooling approaches in the upcoming smart cities of India. Rourkela is a tier-2 steel township included within the ‘smart city’ mission in India and houses one of the largest Steel Plants of India, classified under Koppen Aw tropical climate zone. However it experiences extreme heat stress in the dry summer season before the onset of monsoons. The given study proposes an alternative cooling scenario utilizing waste heat from the rolling mill with which cooling in the range of 700-900 tons of nearly zero energy cooling can be made available in the surrounding areas, otherwise catered by an energy intensive cooling system reporting a COP of 2.45. This study can be further expanded to provide cooling to the nearby residential communities keeping the steel plant area as center point for community cooling infrastructure provision.

## 1. Introduction

In India, the building sector is the second largest energy consumer ranking after the power sector [1]. About 60% share of this energy consumption is incurred from space cooling and this consumption is projected to grow around 2.2 times till 2027 [2] even though a majority of commercial, institutional and residential buildings operate in temporal mixed mode. Currently cooling is unaffordable in major parts of the country due to the high cost of energy inefficient split air conditioners (AC) dominating the refrigeration market. The current state of cooling deficits compounded by the increasing GDP of the country calls for a paradigm shift from space cooling using unitized ACs to more efficient centralized cooling infrastructure models in community scale to reduce energy and emissions in the building sector. A recent study [3] based upon primary data collection in Indian warm humid climate anticipated that district cooling models can reduce up to 60-65% summer monthly cooling electricity.

Our study is conducted in Rourkela Steel Township, the industrial capital of the state of Orissa in eastern India and a tier-2 city under ‘Smart Cities Mission’ of the country. The city is geographically classified under the Koppen Aw warm humid climate zone; however the peak summer is dry with extreme temperatures. Rourkela is home to the oldest integrated steel plant of India. During peak summer the city experiences power deficits due to steel plant activities. Our study in the given context demonstrates an alternative cooling scenario utilizing recovered waste heat from the new rolling plate mill complex inside the steel plant to surrounding building types with diverse functional uses.

## 2. Study area and methodology

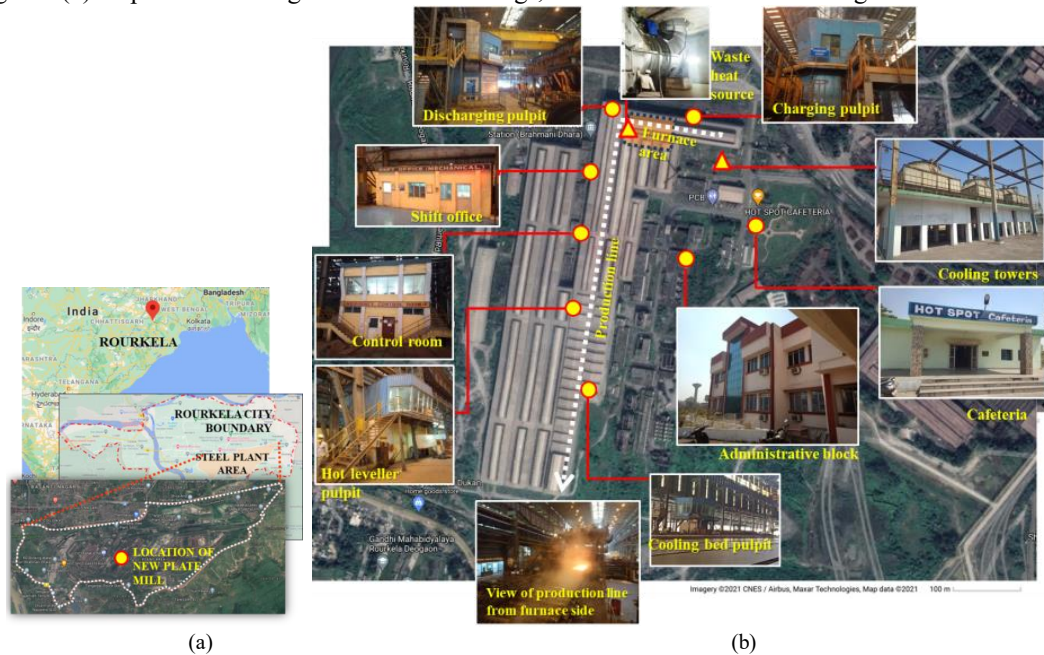
### 2.1 Study area

The Rourkela steel plant was chosen for this alternative cooling problem owing to the opportunity of availing waste heat from the industrial belt and utilizing it in a vapor-absorption refrigeration cycle, a



rarely practiced alternative cooling in the country. A primary survey was carried out in the steel plant for waste heat availability through consultation with experts working in the steel plant. The 'New Plate Mill area' was suggested for the study. The mill is producing a wide range of high strength rolled steel plates to meet stringent international standards. The plate mill is equipped with a state of the art furnace for rolling plate production. The flue gas exiting the furnace has a temperature of 350 degC.

Figure 1(a) gives the location of Rourkela and locates the New Plate Mill inside the steel plant. Figure 1(b) maps the site along with related buildings, waste heat source and cooling tower location.



**Figure 1.** (a) Location of study area (b) Mapping of site with key features

**2.1.1 Existing situation- cooling demand and provision in the New Plate Mill and surrounding premises.** Currently the offices and workshops surrounding the New Plate Mill's production line have a total of 700 tons cooling load. This cooling is provided by a central cooling system operating in a vapor compression refrigeration cycle using R134a refrigerant. The shift offices and elevated control rooms or pulpits surrounding the production line of the plate mill have cooling demand round the clock. The administrative offices outside the mill area are served with unitized split ACs whereas the canteen block is not having cooling. The existing cooling demand surrounding the mill intends the cooling load for this centralized cooling system to further scale up to 1400 tons integrating additional cooling demand from unconditioned spaces and spaces served by split ACs.

**2.1.2. Waste heat source.** The furnace location in the basement of the plate mill area is illustrated in Figure 1(b). The flue gas coming out of this furnace has a temperature of 350°C. It is considered as waste heat in this problem.

**2.1.3. Methodology and proposed alternative scenario**

The coefficient of performance (COP) that defines the energy performance of an AC system is in equation (1) where the amount of heat removed from the system denoted by  $Q_c$ , to the amount of work done  $W$ , to remove this heat from the conditioned space. COP is a function of the evaporation temperature  $T_1$  and condensation temperature  $T_2$  and if  $g$  is the exergetic efficiency of the system.

$$COP = \frac{Q_c}{W} = g \frac{T_1}{T_2 - T_1} \quad (1)$$

COP of existing and alternative cooling scenarios are calculated based on the above formula. The waste heat from the flue gas outlet from the mill's furnace is harnessed such that a chimney safety temperature of 200degC is maintained. This free heat energy is supplied as heat input to the high temperature generator of a double effect vapor absorption refrigeration system through a shell and tube heat exchanger setup, delivering alternative cooling to the site. Figure 2 depicts the alternative process.

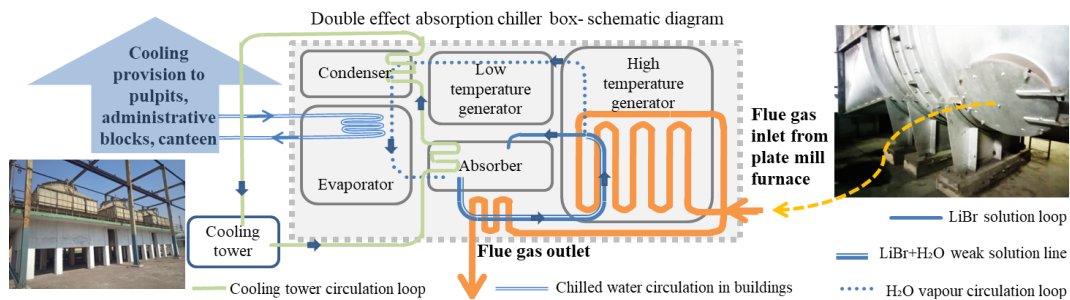


Figure 2. Alternative cooling with waste heat through double effect absorption chiller

### 3. Results and discussion

The total power consumption of the existing cooling system delivering 700 tons of refrigeration is 1 megawatt. Therefore from equation (1), the COP of this system is 2.45, which is surprisingly additionally lower than standard split air conditioners whose COP is assumed to be in a range of 2.7-3.1 depending upon the star rating.

In an alternative proposed scenario, this centralized vapor compression refrigeration system is replaced by a double effect LiBr-H<sub>2</sub>O absorption chiller, where LiBr acts as absorbent and H<sub>2</sub>O as refrigerant. The compressor is replaced by a combination of an absorber and a generator. Heat captured from the flue gas would act as a heat source to separate LiBr and H<sub>2</sub>O in the generator.

The waste heat is easily available at 150°C even after maintaining the chimney safety temperature of 200°C by the heat exchanger while harnessing this heat. The specific heat of the flue gas is 0.3 J/kgK and its mass flow rate is 50000 Nm<sup>3</sup>/hr. Hence the amount of waste heat available is 2250000kcal/hr or 2.6 megawatt.

Now, the work done  $W$  for the system is the sum of this heat energy supplied to the generator and the pumping power, which we calculated to be 3.56 kW. Considering a COP in a range of 0.9-1.3 for a double effect absorption chiller [4][5], a cooling in the range of 700-900 tons can be supplied. Therefore with 2.6 MW of heat available and 700 tons of cooling, the 1MW electric input can be replaced with waste heat for a zero energy cooling scenario.

### 4. Conclusions and future work

The Rourkela steel plant along with the surrounding township area poses a diverse land use plan where community cooling infrastructures can be demonstrated and optimized scenarios can be worked out.

The above problem is a pilot study demonstrating waste heat availability in the power plant that can be leveraged towards cooling infrastructure provisions. In future hybrid cooling scenarios such as combining existing systems with renewable technologies can be worked out for purveying this cooling infrastructure. Scenarios can also be modeled for more diverse land use around the study area with load balancing mechanism between the industrial township and the nearby residential communities considering shifting load intensity in various parts of the day depending upon cooling demand.

### References

- [1] International Energy Agency, 'Understanding Energy Challenges in India'. 2015. [Online]. Available: <https://www.oecd-ilibrary.org/content/publication/9789264247444-en>
- [2] Alliance for an Energy Efficient Economy, 'Demand Analysis for Cooling by Sector in India in 2027', New Delhi, 2018.
- [3] R. Sen, F. Meggers, and S. Chattopadhyay, 'Planning for centralized cooling systems in high density mass housing for tropics - towards smart energy policy in housing communities', presented at the ISOCARP 2017, Portland, Oregon, 2017.
- [4] R. Nikbakhti, X. Wang, A. K. Hussein, and A. Iranmanesh, 'Absorption cooling systems – Review of various techniques for energy performance enhancement', *Alexandria Engineering Journal*, vol. 59, no. 2, pp. 707–738, Apr. 2020, doi: 10.1016/j.aej.2020.01.036.
- [5] G. C. Vliet, X. Wang, M. B. Lawson, and R. A. Lithgow, 'Water-lithium bromide double effect absorption cooling systems', University of Texas Austin and DOE, USA, 1980.