

## Conservation of Energy in Al Cast House – Technology Advancement to Overcome Challenges

Praddyum Pavitrakar<sup>1</sup> and Shibu Mathew<sup>2</sup>

1. Cast House Specialist

2. Smelter Specialist

Bechtel India, New Delhi, India

Corresponding author: ppavitra@bechtel.com and smathew@bechtel.com

<https://doi.org/10.71659/icsoba2024-ch002>

### Abstract

Aluminium smelter cast house (CH), operates at approximately 800°C, generates heat (furnace burners and incoming hot aluminium molten metal from potroom) that have numerous opportunities to conserve and reuse it to support sustainability and carbon footprint. It helps in saving gas/fuels and other consumable materials.

This paper focuses on advanced technology and approaches to overcome challenges to conserve, reduce and reuse energy and materials in cast houses. In normal process this heat energy is exhausted through stacks. Normally, 0.6 million tonnes per annum (Mt/a) capacity smelter cast house wastes around 35 MJ/s of energy (reaches to 135 MJ/s at peak operation) considering 30 % maximum thermal efficiency of the cast house. This energy could be reused for launder preheating and could also be extended further to other preheating opportunity e.g., scrap, casting moulds, tools preheating, etc. Moreover, preventing loss of heat of molten metal flowing through launders not only conserve energy but also help in achieving quality of casting value added products.

Energy potential in aluminium cast house is well known and efforts are underway worldwide to optimize it. Lean technology concepts of conserving and reusing energy should replace the conventional complex system during operation within facilities. It helps optimising quantity and design of equipment and systems in cast houses. This paper put further emphasis on use of technology and continual effort in the direction to commercialize concepts to conserve energy to support sustainability and reduce carbon footprint.

**Keywords:** Cast house, Sustainability, Carbon Footprint, Energy Efficiency, Productivity.

### 1. Introduction

In view of the challenging global sustainability goals, it is pertinent to pursue energy saving initiatives at each stage of the aluminium smelting process value chain. In an aluminium smelter molten metal is produced in the potroom and transported to cast house for converting to solid products. Considerable amount of energy is lost in the process which if addressed properly could open avenues for energy savings. The contribution of cast house in the overall smelter energy scenario is comparatively less but quantum of savings on a yearly basis is significant. Energy saving is possible during each process step of hot metal management by using modern techniques for heat retention and recovery. The areas of interest are metal transport from potroom to cast house, cast house furnace metal holding and scrap management.

This paper focus on energy quantification, opportunities for energy savings through improved operational practices and technological advancements in this field.

## 2. Energy Potential

Cast house (CH) is an integral part of a primary Aluminium smelter where the molten metal is solidified into various shapes.

Heat energy potential of CH is majorly categorised in two divisions:

1. Incoming hot aluminium molten metal from potroom (161 MJ/t of Al)
2. Burning of fuel (natural gas, HFO, etc) (see Table 1).

Heat potential of incoming hot aluminium molten metal (850–900 °C) is from potroom of reduction area until it gets solidified to product. Pure Aluminium metal starts solidifying at 660 °C. Heat is also released from burning of fuel which is required to maintain desired temperature of molten metal in the holding and melting furnaces before start of casting and heating of tools and auxiliary casting equipment. The residual flue gases are exhausted to atmosphere through stack.

Both the above energy potential sources inside CH could be conserved, reduced, and reused by various opportunities which are elaborated further below.

For a typical 0.6 Mt/a capacity smelter having product mix as 50 % billet and 50 % ingots, the fuel energy distribution details for CH are provided in Table 1. Natural gas heating source is used as basis of calculation.

**Table 1. Typical 0.6 Mt/a smelter, CH energy distribution.**

Description	Nominal	Maximum*
Holding/Melting type Furnaces	53 %	6 ×
Continuous Homogenizing	12 %	N/A
Batch Homogenizing Furnace	25 %	N/A
Billet VDC	1 %	N/A
Ingot caster	4 %	1.25 ×
CCF	5 %	1.20 ×
<b>TOTAL</b>	<b>100 %</b>	<b>3.7 ×</b>
Energy released at 39 MJ/m <sup>3</sup> calorific value of fuel - natural gas at Total nominal and maximum gas flow	2 785 MJ/t Al	4 450 MJ/t Al
Energy waste considering 30–35% maximum thermal efficiency of the cast house	1 811 MJ/t Al	2 892 MJ/t Al

\* - Maximum is calculated considering scrap melting in the furnace.

## 3. Areas of Opportunities

The Aluminium smelter CH has numerous opportunities to conserve, reduce and reuse energy and material by optimising processes, increasing efficiencies and adopting advanced techniques. Opportunities for the same including alternate clean energy options with equivalent energy consumption for decarbonisation are listed and discussed below.

- Crucible turnaround
- Furnace heat loss
- Launder heat loss

- Thermal insulation
- Decarbonization opportunities.

### 3.1 Crucible Turnaround

Improved approaches and technologies should prevent heat loss of incoming hot aluminium molten metal to CH which is tapped in crucibles at around 900–950 °C and transported to CH by Metal Transport Vehicles (MTV). This will ensure lower energy consumption in CH to maintain its temperature at the desired level required for casting.

#### 3.1.1 Cast House Location

Locating the CH location near to the potroom plays an important role in energy saving. Continuous movement of molten metal in crucibles occurs between potroom and CH. Locating a CH near to potroom shall minimise heat loss. Normally, for a 0.6 Mt/a capacity smelter, 118 crucibles of around 15 tonnes of capacity travel daily between potroom and CH.

Generally, the metal crucible is having area divided into two parts, wall and bottom area. Wall and bottom area is governed by the following formula:

$$A = (2\pi rh) + (\pi r^2) \quad (1)$$

where:

$r$       Radius, m

$h$       Height, m

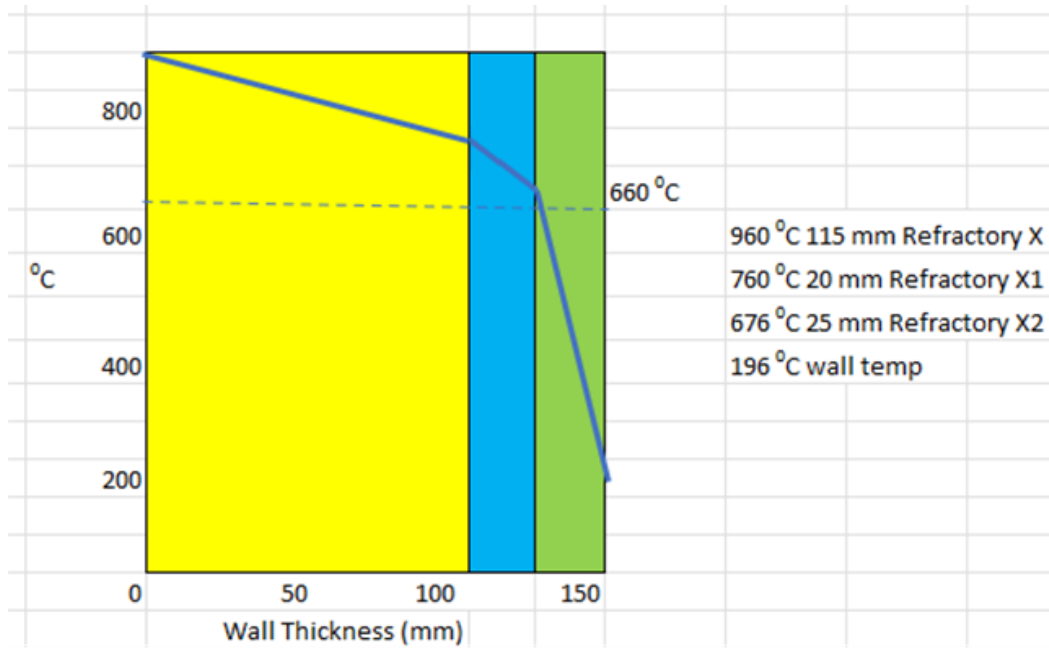
Considering a 2.9 m-diameter and 1.79 m-high crucible, the area A is:

$$A = 16.3 + 6.6 = 22.9 \text{ m}^2 \quad (2)$$

Typical heat loss from crucible wall is 1 916 W/m<sup>2</sup> and bottom is 3 171 W/m<sup>2</sup> [1].  
Total heat loss through crucible area of 22.9 m<sup>2</sup>:

$$\text{heat loss} = 1\,916 \times 16.3 + 3\,171 \times 6.6 = 52 \text{ kW} \quad (3)$$

The heat loss is dependent on the wall thickness and insulating properties of the refractory materials. Refer to Figure 1 below for a typical heat loss diagram for a metal crucible. 55 °C ambient temperature considered for typical heat loss values.

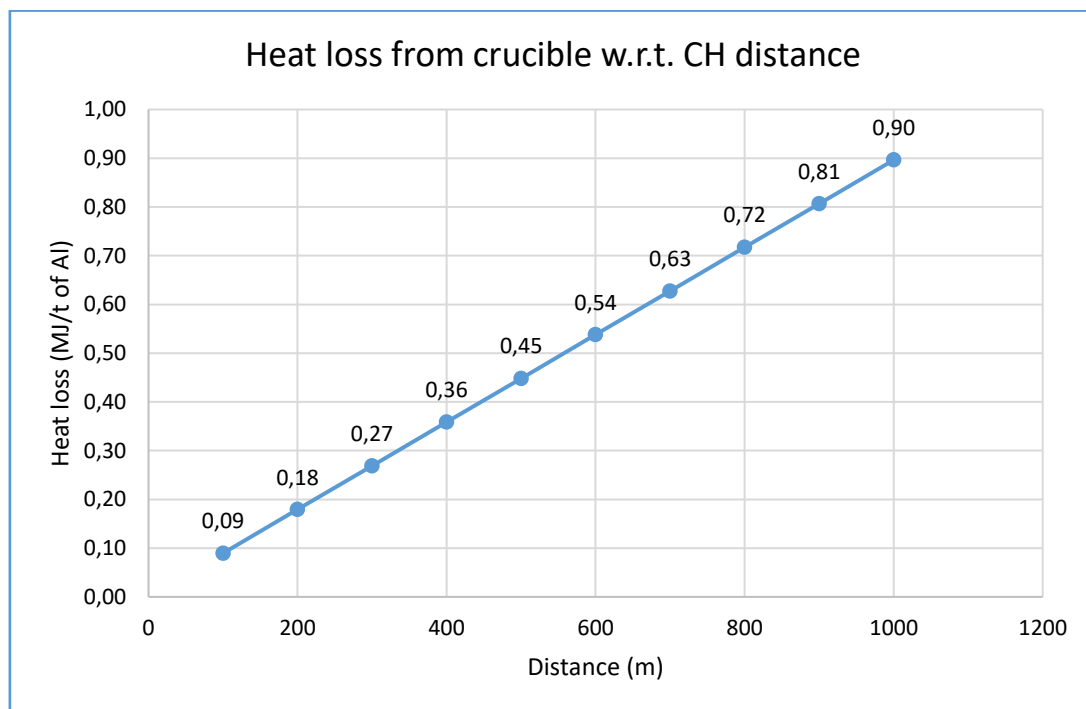


**Figure 1. Typical heat loss diagram for crucible.**

Considering a scenario where CH is located 500 m closer from potroom, energy saving considering 15 km/h MTV speed can be calculated as:

$$\text{heat loss saving} = 52 \text{ kW} \times 120 \text{ s} / \left( \frac{600\,000}{365 \times 118} \text{ t Al} \right) = 0.45 \text{ MJ/t Al} \quad (4)$$

Figure 2 provides an indication of heat loss from crucible with respect to (w.r.t.) CH distance.



**Figure 2. Heat loss from crucible w.r.t. CH distance.**

Above mentioned heat loss signifies the importance of CH distance from potroom. Moreover, distance of CH in relation to potroom is directly proportion to fuel requirement for MTV transport.

Mobile Equipment Personnel Interface (MEPI) studies is an important tool which can be used to mitigate risks and minimum interference with other aluminium smelter vehicles. Simulation software is available to recommend the nearest and preferred route with options from potrooms to CH [2]. Moreover, locating treatment of aluminium in crucible (TAC) exactly in the path of crucible from potroom to CH will help saving time and energy.

### 3.1.2 Optimum MTV Speed

Due to the risks involved in hot metal transport, operational smelter imposes curbs on maximum speed of MTVs. Normally this is in the range of 15–20 km/h. Road gradients, crossings and concurrent traffic along the way impacts the speed of MTV and in turn the travel time.

Energy saving for speed difference from 10 to 20 km/h for covering 1 km distant CH calculated as below:

$$\Delta = 52 \text{ kW} \times (360 - 180) \text{ s} / \left( \frac{600\,000}{365 \times 118} \text{ t Al} \right) = 0,67 \text{ MJ/t Al} \quad (5)$$

Refer below Figure 3 for heat loss from crucible with respect to MTV speed.

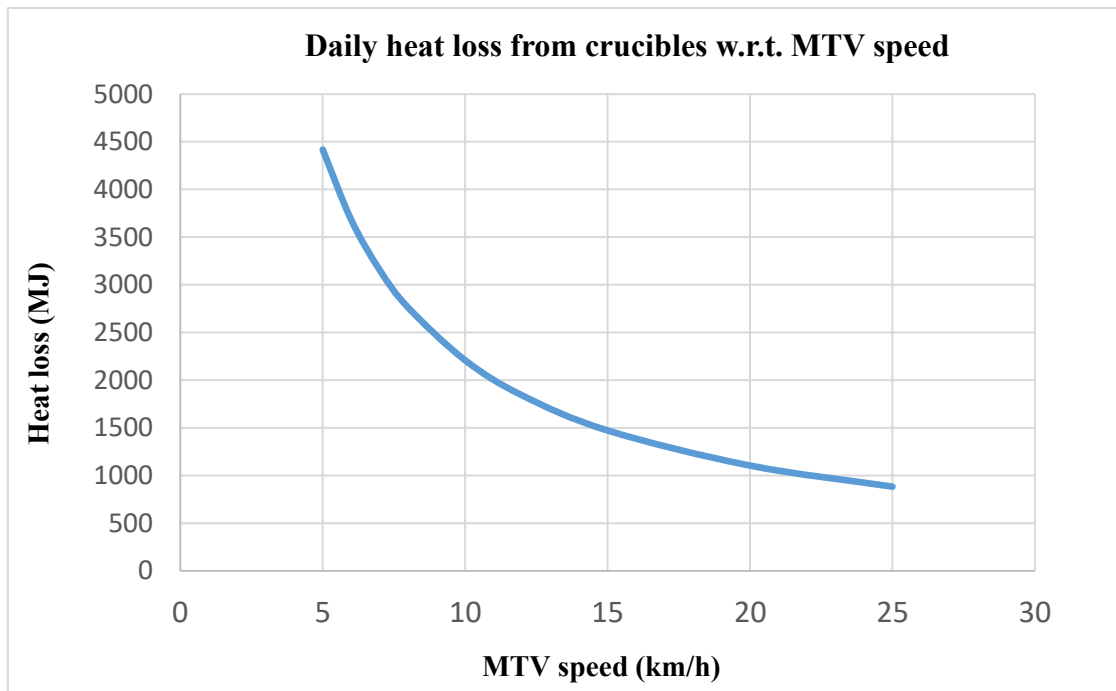


Figure 3. Heat loss from crucible w.r.t. MTV speed.

Engineering design takes care into the aspects of heat loss while determining the plant road network. Geotech and topographic study assessment report shall be used to optimally design the road network with minimum level differential between cast house and potroom. Unless there are constraints due to geographical location and climatic conditions, potroom operating level could be matched with road grade.

### 3.1.3 Unloading of Liquid Metal

To minimise crucible turnaround time, quick and safe unloading of liquid hot metal is necessary. Various methods are available to transfer metal from crucible to furnace and each method has its own benefits and challenges. Few metal transfer methods are specified below:

1. Siphoning
2. Crucible Transport and Tilting Vehicle (CTTV) with portable launder attachment
3. Portable launder with tilter stand
4. Portable launder with crucible tilting using EOT crane
5. Fixed sidewall and launder with crucible tilting using EOT crane
6. Cranes with lifting and tilting beams.

Implementing detachable stand with MTV facilitates quick crucible turnaround time. Below available equipment/method could be adopted to enhance crucible unloading efficiency and safety:

1. Furnace cameras
2. Furnace door with window (with sliding door lid) or minimal opening while unloading.

See below equation (8) and Figure 4 for heat loss savings.

### 3.1.4 Auto Weighing

Auto weighing facilities enables quick turnaround of weighment. Below available technologies could be adopted for auto weighing:

1. Use of RFID
2. Inbuilt weighing feature on equipment.

Based on the above discussions hot metal unloading and auto weighing should minimize the crucible turnaround time. A “one-minute” each saving in time will save energy as calculated below.

$$\text{heat loss saving} = 52 \text{ kW} \times (60 \times 2) \text{ s} / \left( \frac{600\,000}{365 \times 118} \text{ t Al} \right) = 0,45 \text{ MJ/t Al} \quad (6)$$

Figure 4 shows heat loss savings w.r.t. crucible turnaround time saving.

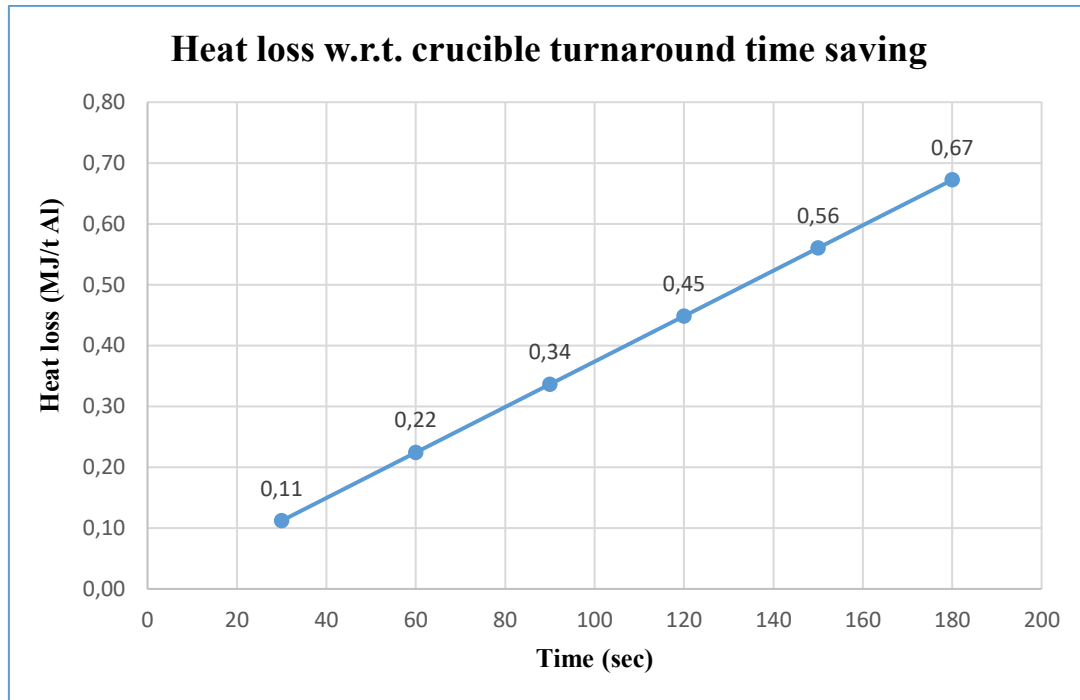


Figure 4. Heat loss vs crucible turnaround time saving.

### 3.2 Furnace Heat Loss

Major portion of the CH energy loss is through furnace exhaust flue gases. In CH, 50 – 80 % of energy consumption is due to furnace heating for holding and maintain temperature of metal and melting of CH generated scrap due to rejection at casting machines.

Hence there is huge scope to conserve and reuse heat generated at furnace by burning of fuel/gas. Scrap (including recovery from dross) percent rate varies in CH depending on product mix selected, however typical scrap or rejection rates are:

- Billet casting products: 5-6 %
- Ingot products: 2 % approximately.
- Average will be: 4 % approximately.

Typical 0.6 Mt/a smelter CH generates 24 000 t/a scrap considering average 4 % rate, reducing the rate from 4 % to 3 % leads to saving high energy saving which is required to melt it. E.g. for a typical 0.6 Mt/a capacity smelter, delta for nominal and maximum energy released at 39 MJ/m<sup>3</sup> calorific value of fuel - natural gas (which is mainly used for scrap melting) is shown below:

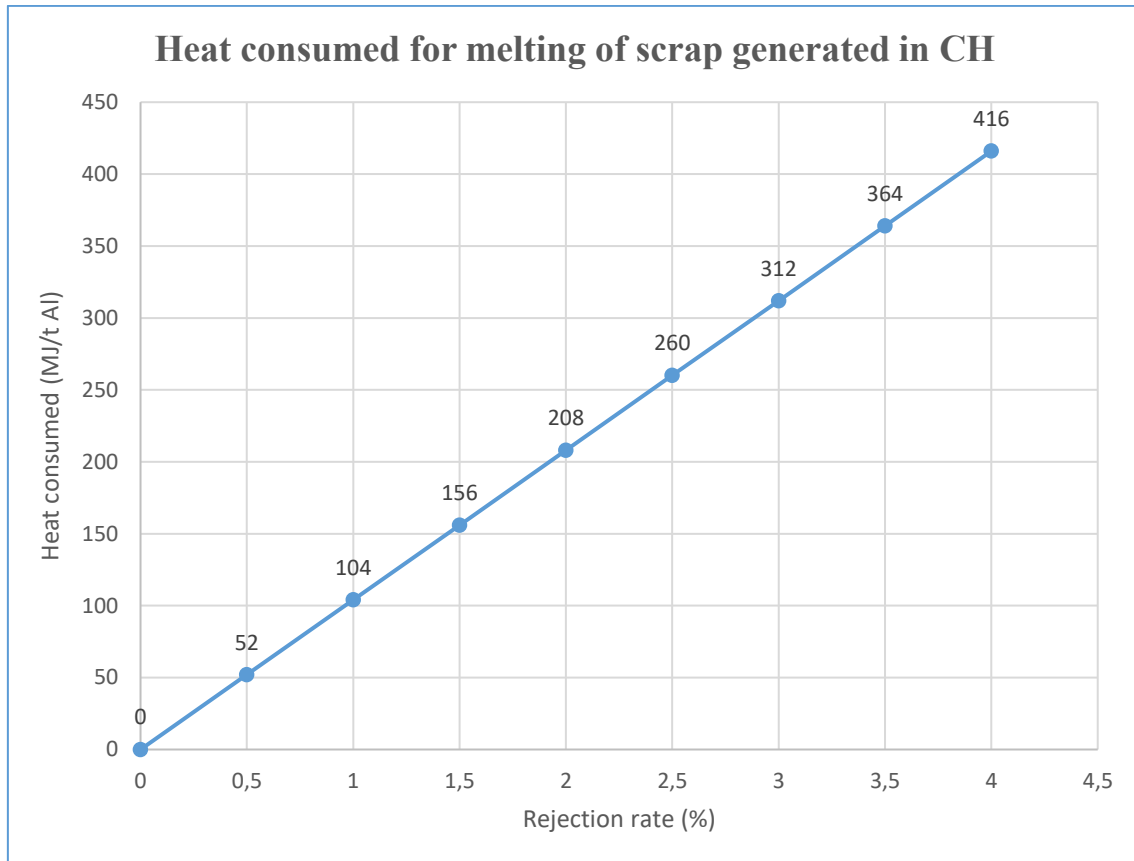
$$\text{Delta heat released} = \text{Maximum} - \text{Nominal} \quad (7)$$

$$\text{Delta heat released} = 4450 - 2785 = 1665 \text{ MJ / t Al} \quad (8)$$

Reducing the rate from 4 % to 3 % leads to saving of:

$$\text{Energy saved} = 1665 \times 0.25 = 416 \text{ MJ / t Al} \quad (9)$$

Refer below Figure 5 for heat consumed for melting of scrap generated in CH for a typical 0.6 Mt/a smelter.



**Figure 5. Heat consumed for melting of scrap generated in CH.**

Reduction of scrap could be achieved by adopting below techniques:

1. Casting flow and level control for consistent size of standard/foundry remelting ingot
2. Relook on rejection parameters – accuracy and relaxation on parameters
3. Temperature control for proper cooling and demoulding of ingots
4. Keeping cylinder stroke length higher than billet/slab length
5. Consistent billet/slab length per cast per table
6. Keeping billet/slab length aligned to cut lengths
7. Adopt and maximise continuous casting
8. Skilled and trained operators
9. Compliance to OEM documents, etc.

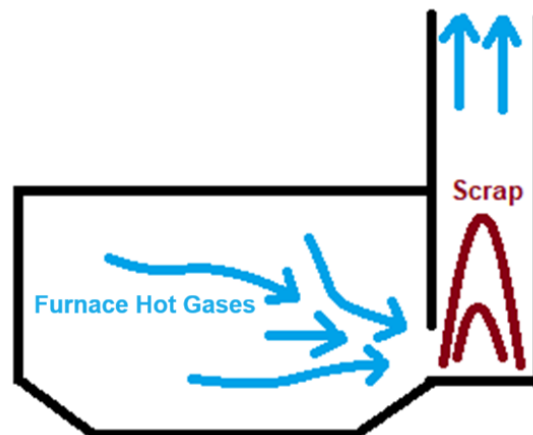
Other heat loss sources from furnace are during tending operations such as skimming and scrap charging which could be minimised by adopting below technologies:

1. Air curtain for furnace door activate while opening
2. Furnace cameras to minimize opening of doors for inspection
3. Advance tending machines.

Possible utilisation of furnace flue gas heat energy is described further below under section 3.2.1 and 3.2.2. These ideas are at conceptual stage but have potential for further development.

### 3.2.1 Scrap/Alloy Preheating

Scrap/alloy preheating is necessary to remove moisture from the CH generated scrap safe operation. Presence of moisture traces in scrap during its melting could lead to molten metal blast. Conceptual sketch for furnace hot gases heat utilization for preheating is shown in Figure 6.



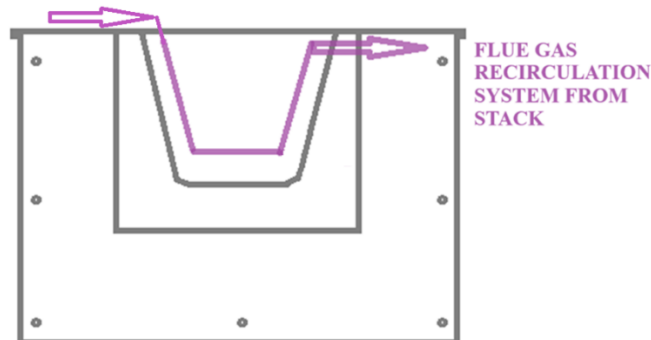
**Figure 6. Conceptual sketch for scrap preheating.**

Scrap/alloy preheating furnace could be eliminated or energy load of the same could be reduced utilising above method. Typical 0.6 Mt/a smelter CH utilises 24 000 t/a scrap and 20 000 t/a alloy. Typical scrap/alloy preheating furnace is of 350 kW at 4-5 t/h capacity.

$$\text{Possible Energy Saving} = \left(1260 \frac{\text{MJ}}{\text{h}} * 11\,000 \text{ h}\right) / 600\,000 = 23 \text{ MJ/t Al} \quad (10)$$

### 3.2.2 Launder Preheating

Launder preheating is also necessary to remove moisture traces before start of casting. Launder is used to transfer hot molten metal from furnace to casting machines. Presence of any traces of moisture in launder could lead to molten metal blast. Conceptual sketch for furnace hot gases heat utilization for launder preheating is shown in Figure 7.



**Figure 7. Conceptual sketch for launder preheating.**

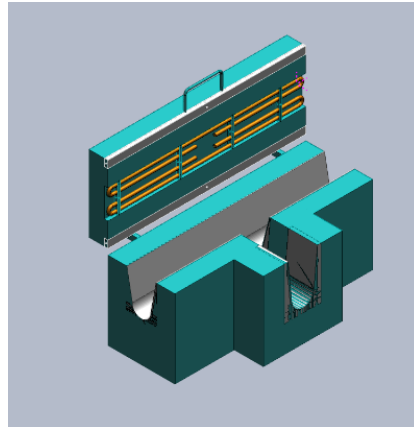
Considering 5% reduction in fuel gas consumption:

$$\text{Possible Energy Saving} = 2\,785 \times 0.05 = 140 \text{ MJ/t Al} \quad (11)$$

### 3.3 Launder Heat Loss

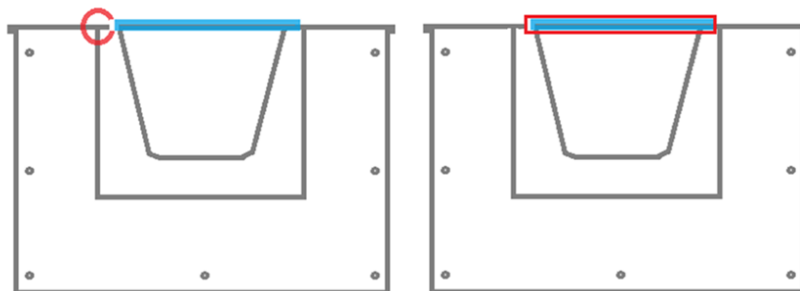
Preventing heat loss from metal flowing through launder is another opportunity to conserve energy. Preventing heat loss of metal flowing through launder not only save energy but also eases operations and maintains product quality. Temperature control of molten metal flowing through launder is crucial in casting value added and other products.

Current system of covering of launder in aluminium smelter CH is cumbersome which could be substituted by lean approach and use of technology. Refer below sample Figure 8 for the system of preheating and covering aluminium smelter CH launders:



**Figure 8. Typical sample of launder heating and covering.**

Prevention of loss of heat of molten metal flowing through launder could be explored by air curtain (act as insulating cover) or double layer cover with insulating media trapped in between. Light material which sustains at high temperature with insulating media like air, cerawool, etc. could be used. Arrangements are possible to implement the concept. Refer Figure 9 for brief overview of lean concept to cover launder to prevent heat loss.



**Figure 9. Conceptual sketch for launder covering. Left: Air curtain, Right: Double layer light material.**

Moreover, optimising the length of launder from furnace spout to casting machine shall help in reducing heat loss.

Preventing launder heat loss shall reduce fuel consumption of furnaces. Fuel consumption in furnace due to heat loss through launder contributes around 6-8 % hence effective covering shall save significant heat loss figures:

$$\text{Heat loss thru launders} = 2785 \times 0.53 \times 0.08 = 118 \text{ MJ/t Al} \quad (12)$$

$$\text{Savings Opportunity} = 0.5 \times 118 = 59 \text{ MJ/t Al} \quad (13)$$

### 3.4 Thermal Insulation

Introducing a new and innovative thermal insulation solution over traditional should help efficient molten metal transfer in the CH via crucibles, furnaces, and launders. Efficient thermal management shall reduce thermal loss, particularly during metal transfer in the cast house.

Effective insulation in overall CH has prominent role in saving thermal loss. Considering 1% savings:

$$\text{Savings Opportunity, Nominal} = 0.01 \times 2785 = 28 \text{ MJ/t Al} \quad (14)$$

$$\text{Savings Opportunity, Max.} = 0.01 \times 4450 = 44.5 \text{ MJ/t Al} \quad (15)$$

$$\text{Avg.} = 36 \text{ MJ / t Al} \quad (16)$$

The high-temperature environments in CH necessitate robust insulation systems to enhance energy efficiency, worker safety, and operational productivity. Selecting advance thermal insulation will further contribute to energy savings in CH [3].

### 3.5 Decarbonisation Opportunities

Supply of clean/green electrical energy and use of recent technology to supply clean thermal energy should replace fossil fuel use in CH for all equipment including:

- Holding/Melting Furnaces and launder system,
- Homogenizing furnaces, and
- Casting machines.

Below are the promising options for decarbonization in CH [4, 5]:

1. Plasma torch technology  
Plasma torch technology is used in a wide range of applications, including metallurgy, In particular the processing of aluminum dross in rotary furnaces and for the melting of titanium alloys in vacuum furnaces. And, now proposed to use this technology in a reverberatory furnaces of aluminum cast house. It is feasible to implement the concept for both retrofit of existing furnaces and for new designs based on recent study and published technical papers. A furnace with plasma torch utilizes a direct-current and operate with nitrogen, air, or argon as plasma working gases. The performance of the furnace depends on varying plasma torch operating conditions (working gas, gas flow rate, power).
2. Hydrogen combustion in burners  
Technology development for blending of hydrogen and natural gas in a range from 0 to 100% hydrogen is underway with long and short flame mode for optimal control of the heating profile.
3. Electrical power (non-conventional source)  
In order to meet the net-zero carbon targets immediate attention to be given to replace fossil fuels with solar energy, bioenergy, hydro and wind energy etc.
4. Oxy-fuel Combustion System  
Modelling and Implementation of an Oxy-fuel Combustion System in an existing regenerative furnace is in progress to reduce CO<sub>2</sub> emissions while improving productivity.

The energy consumption of the above listed decarbonisation options also offers equivalent or better energy consumption than of the traditional fossil fuels facilitating transition to low carbon footprint in CH.

## 4. Conclusions

Looking at current scenarios, conservation of every unit of energy shall be a pivotal step towards sustainability and protect global ecosystems to support health and wellbeing. Energy potential in aluminium cast house is known however conservation of it is not up to the mark and there is scope for improvement. An attempt is made to quantify the energy scenario in the hot metal to finished

products conversion process. The energy potential due to the incoming hot metal and burning of fuel is 4 611MJ/t Al. Around 63 % the heat identified is lost during the operations involved in solidifying the metal. In this process the paper identifies energy savings of 39 % by implementing improved operational practices and utilising modern technologies.

Summary of Energy Potential & Savings as depicted above in this paper is shown in Figure 10:

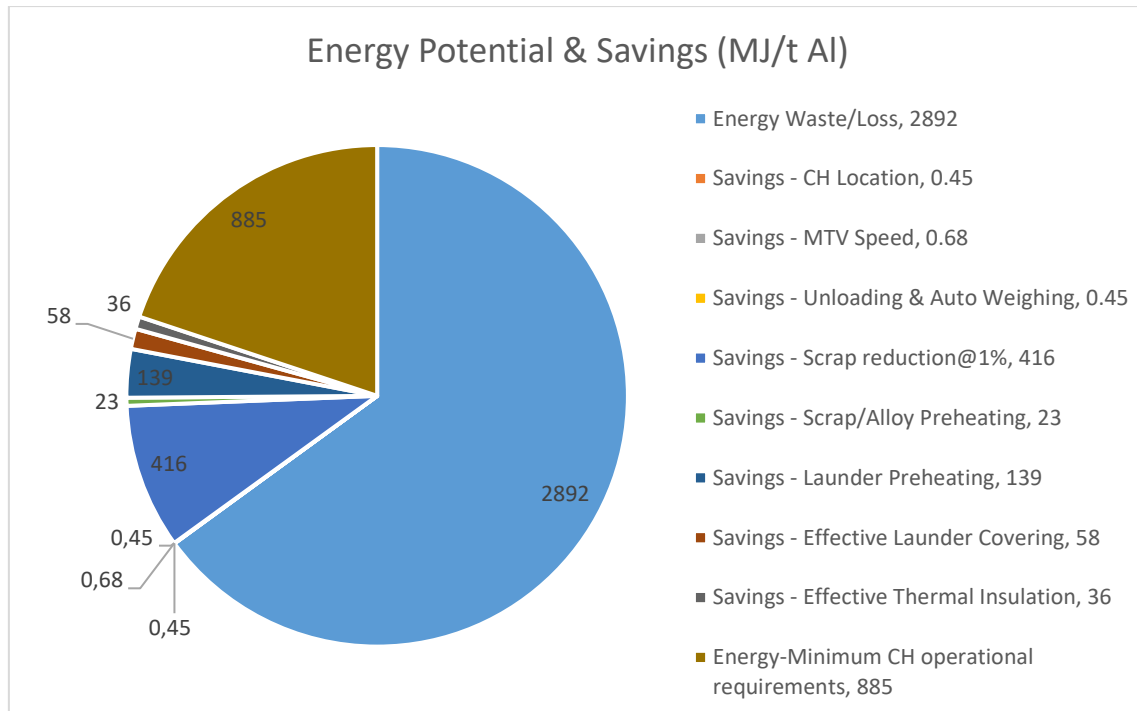


Figure 10. Summary of energy potential & savings.

Although efforts are underway worldwide to optimise energy, further emphasis to use technology and continual improvement in the direction to commercialise energy conserving concepts is need of the hour to reduce carbon footprint.

## 5. References

1. ASTM C680-19, Standard Practice for Determination of Heat Gain or Loss and the Surface Temperatures of Insulated Pipe and Equipment Systems by the Use of a Computer Program Standard by ASTM International, Last updated March 16, 2023, <https://www.astm.org/c0680-19.html>.
2. Laszlo C. Tikasz et al, Safe and efficient traffic flow for aluminium smelters, *Light Metals* 2010, 427-432.
3. Pierre Delvaux, Normand Lesmerises, Daniel Poisson, Marcel Guin, Light weight mineral foam and process for preparing the same, US Patent Number: 5,360,771 Date of Patent: Nov. 1, 1994. Pyrotek backup insulation, Wollite 30 ST (<https://www.pyrotek.com/products/casthouse/show/ProductLine/backup-insulation>)
4. Louis Piquard et al., Reverberatory Furnaces Decarbonization—The Case of Hydrogen Combustion: Proof of Concept and First Experimental Results on Borel Furnace, *Light Metals* 2024, 873-850.
5. Juan E. Salazar et al, Decarbonization of Aluminum Reverberatory Furnaces: The Case of Plasma Melting, *Light Metals* 2024, 881-889.