Track: Industrial

Unit #8: Primary Metals

An overview of Primary Metals Market Segment

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Presentation Outline

- Market Overview
- Economic Issues and Market Analysis
- Technologies
- Case Studies
- Trade Associations and References

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Primary Metals Overview

- The primary metals industry addresses facilities that melt and refine metals from ores and / or scrap metal.
- The molten metal output is generally poured directly into semi-finished shapes (i.e. continuous casting) or solidified into semi-finished condition (i.e. slabs, billets or other near shape products) before it is further processed (rolled, drawn, extruded, etc.), generally after reheating, to produce plate, sheet, tubing, bar, rod, wire, and other items.
- Primary metals industries include ferrous and non-ferrous metals and provide products both in the form of direct end products or as stock for use by other industries (i.e. billets for reheating and forging).

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Primary Metals Overview

- The processes and technologies included in this presentation involve molten metal production and handling.
- Most other metals processes (i.e. heat treating) that occur after the molten metal solidifies will not be covered.
- For steel, the presentation will include process steps through the reheat furnace (see Processes - Ferrous) and will also include some information on coating, finishing, and annealing.
- For aluminum, only melting, transport, and holding technologies will be covered.
- The metal casting foundry market will be broadly characterized.

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Major Market Segments

- Steel
- Aluminum
- Metal Casting
  - Copper
  - Zinc
  - Lead
  - Magnesium




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Demographics

- Overall, the primary metals industries in the USA produce steel, aluminum and other nonferrous materials, and metal castings. Total receipts for fabricated metal products in USA was ~300 billion dollars*.
- 375,000 persons are employed in these industries according to statistics compiled from Bureau of Labor Statistics (1st Qtr. 2020) Industry profile reports number of establishments – 5500 (approx.)
- The Primary Metals industries consumed 1,618 TBtu/year (8.6% of total) and ~425 Billion Cu.ft. (6.9% of total) natural gas in 2019*. Nearly 10.5% of all the manufacturing energy in the U.S.

- Adjusted using available data from EEA and USGS data

Photo Credits: Steel & Aluminum - National Renewable Energy Laboratory
Other Non-Ferrous - Asarco LLC

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Market Segment - Steel

- The U.S. Steel industry equates to a $90+ billion enterprise with additional downstream processing pushing the value closer to $135 billion.
- Total primary steel production in 2019 is approximately 88 million metric tons/year. This represents about 4.7% of the world steel production.
- Steel industry employs about 140,000 people in the year 2020.
- Steel is produced in 37 states with the highest concentration of mills in the Great Lakes states (Indiana, Ohio, Pennsylvania, Illinois, Michigan, and New York).
- Although many thousands of facilities in the USA process steel products, only around 50 companies produce the bulk of the molten primary metal including about 115 mini mills in USA.
- Steel is the backbone of bridges, large office buildings, railroads, automobiles, and appliances.

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Steel Plants of North America

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Steel Industry Demographic - Overview

- Two major routes for steel making:
  - Use of blast furnace to produce pig iron BOF to produce steel in integrated mills.
  - Use of electric arc furnace (EAF) to produce steel from the steel scrap and other raw materials (i.e. direct reduced iron, hot metal etc.) in mini mills
- Per ton of steel shipped, the mini-mills (EAF process) require about 50% energy used for the BF - BOF (integrated mills) route.
- Overall energy intensity (energy use per unit of production) has been going down due to improvements in processes and steps taken to improve energy use.
- Number of operating blast furnaces have been declining – from 21 to less than 9 between 1991 to 2018. Many are idled and operated as needed.

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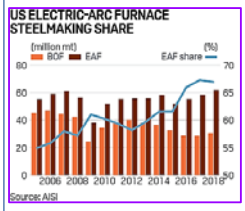
Steel Industry Demographic - Overview



- Integrated mills mostly use coal (in the form of coke) in steel making process while producing a large amount of by product fuels (blast furnace gas and coke oven gas) that is used in the down stream heating process and on-site electricity generation.
- Use by EAF is increasing rapidly due to lower capital cost and energy use per ton of steel produced.
- EAF steel making is used for almost 60% of total steel production in USA.
- EAF steel making uses electricity and other fuels (mostly natural gas in USA). This is a growth market for the gas industry.

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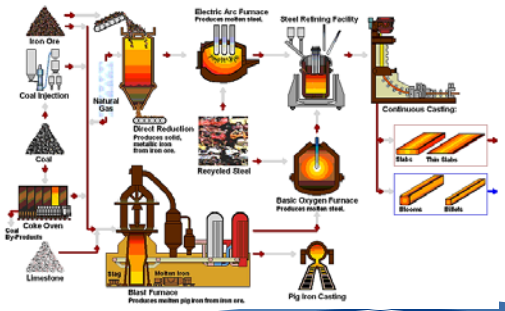
Steel Production and Processing



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Energy Use and Natural Gas in Steel Making

Process	Percentage of total
Sintering/palletizing	1
Cokemaking	3
Ironmaking	38
BOF steelmaking	3
EAF steelmaking	15
Casting	3
Boilers	12
Cogeneration	5
SUBTOTAL	**80**
All other processes (e.g. reheating, rolling, finishing)	20
TOTAL	**100**

Data from American Iron and Steel Institute (1966-1699)

- For steel manufacturing close to 38% of the energy consumed is used in blast furnace iron making.
- EAF steelmaking uses 15% of the total energy.
- Steel making by EAF method uses electricity as primary source of energy with 5 to 15 % gas-oxygen use as supplement fuel.
- Energy costs account for about 11% of the cost of producing steel for Blast furnace – BOF method while it is 8% for the EAF method.
- Second largest energy user in steel plant is reheating furnaces. Due to continuous casting energy use in reheat furnaces is going down

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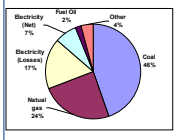
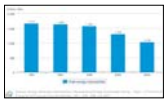
Energy Use in Steel Industry





- Energy use and energy intensity (energy used per ton) has been steadily declining for steel industry for the last few years. Energy use declined by 40% from 1994 to 2014*.
- Nearly half of the industry's energy is derived from coal, most of which is used to produce coke for use in the blast furnace.
- Natural gas and electricity combined account for most of the remainder.
- Two major byproduct fuels – coke oven gas and blast furnace gas – are recovered and used to generate steam, preheat blast furnace air, or supply heat to other plant processes.
- EAF offers increased use of natural gas as supplementary and cost effective energy source for US minimills.

* The most recent data available from EIA - MECS

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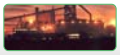
Equipment - Ferrous


Blast Furnace


Electric Arc Furnace (EAF)


Scrap Preheating Systems


Ladles / Ladle Drying


Steel Making / Refining / Tundishes

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Equipment - Ferrous


Reheat Furnaces
- Pusher
- Walking Beam
- Rotary


Coating / Finishing / Annealing


Oxy-Fuel – Ferrous and Non-Ferrous
- Blast Furnace Enrichment
- Oxy-Fuel Ladle Preheating
- Air-Oxy-Fuel Aluminum Reverb
- EAF Oxy-Fuel Assisted Melting
- Oxy-Fuel Aluminum Rotary

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Use of Natural Gas in Steel Making

Natural gas is used in the following processes/equipment in steel making.

Sintering and pelletizing process	Electric Arc Furnaces (EAF)
Blast furnace natural gas injection	Basic oxygen furnace (BOF)
Blast furnace air stoves to preheat blast air	Steel reheating furnaces – rolling
Tundish and molds heating	Annealing furnaces (Batch/continuous)
Ladle heating	Heat treating of semi-finished or finished steel
Coke ovens	Galvanizing/coating lines
Boilers	Other heating processes

Note: In most cases natural gas is used as supplemental or self standing fuel

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Aluminum - Demographic

- Aluminum production in the United States generally takes two routes with very different energy requirements.
  - Primary production involves making aluminum products from raw material (Bauxite – alumina) into ingots, which is highly energy intensive, especially electricity intensive.
  - Secondary production involves recycling aluminum scrap to form new products, a significantly less energy-intensive process
- Primary aluminum production in US has declined considerably (from 23 smelter to only one) from the year 2000 to 2010. However from 2017 to 2019 seven are operating. Mean while several primary aluminum plants have been closed.
- Secondary aluminum production has fluctuated considerably. See figure in a later slide.

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Aluminum - Demographic

- Annual US aluminum production (2018)* :
  - Primary plants produced 891 thousand metric tons with a total value of $2,264 million dollars.
  - Secondary recovery plants produced 3,710 thousand metric tons with a total value of 4,860 thousand metric tons from new and old scrap.
  - Total US aluminum consumption was 4,860 thousand metric tons.
  - Large quantities of aluminum is imported in raw form while finished parts are exported resulting in net import to USA.
  - Total world aluminum production was 63,600 thousand metric tons.
- More than 162,000 workers are directly employed in the aluminum industry.
- Total aluminum sector energy use accounted for over 69 trillion British thermal units in 2014 according to ESA MECS data. Electricity consumption was 37 TBtu. Natural gas consumption was 28 TBtu with 4 TBtu from other fuels.

* Data from USGS 2018 Mineral year book

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Aluminum – Markets

- Aluminum is used to produce automotive parts (including pistons, engine blocks, body parts, and wheels), beverage cans, doors, door and window frames, and other construction materials.
- It is also used as sheet metal siding, aluminum plate and foil, rod, bar, and wire, and aircraft components.
- The leading aluminum users include container and packaging, transportation, and construction industries

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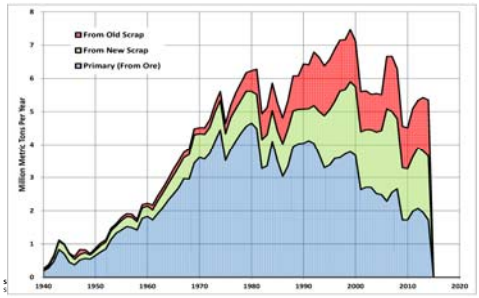
Aluminum Production in USA



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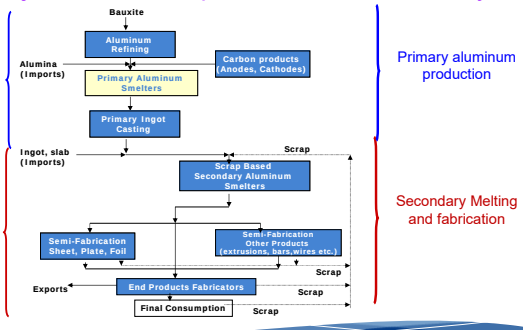
Major Process Steps for Aluminum Industry



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Aluminum Melting Furnaces




Direct heat crucible furnace

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Aluminum Melting Furnaces




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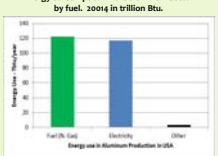
Energy Required for Aluminum Melting



Aluminum sector total

Source: U.S. Energy Information Administration, most recently available data Manufacturing Energy Consumption Survey 2006.

Range of energy consumption (Btu/lb. of metal tapped) and thermal efficiency for different types of aluminum furnaces

Type of Furnace	Range of Btu/pound	Range of metal loss
Gas crucible	2500 - 4000	1 - 3 %
Electric crucible	716 - 887	1 - 1.5 %
Coreless induction	785 - 887	1 - 1.5 %
Dry hearth	1500 - 2000	2 - 4 %
Wet hearth reverb	1500 - 1800	1.5 - 3 %
Barrel melter	1500 - 1800	1.5 - 3 %
Stack melter	1100 1300	1 - 2 %
Regenerative wet bath	1200 - 1400	1.5 - 3 %
Electric reverb	716 - 853	1 - 1.5 %

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Equipment Using Natural Gas

- Primary Aluminum Production
  - Drying
  - Calcining
  - Steam generation (Boilers)
  - Anode baking
  - Misc. heating
- Secondary Melting
  - Scrap dryer, de-oiler and preheater
  - Thermal oxidizer (where required)
  - Melting furnace
  - Ladle or mold heating
  - Homogenizing furnace
  - Annealing furnace
  - Aging oven
  - Coating line oven and thermal oxidizer
  - Misc. heating

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Market Segment – Metal Casting

- The metal casting industry consists of firms that melt and ship both ferrous and non-ferrous materials.
- Concentrations of metal casting companies exist in the Midwest, Southeast and California.
- Leading metal casting states include: Alabama, Indiana, Illinois, Michigan, Ohio, Pennsylvania, Texas, Wisconsin and New York.

Source: DOE

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Market Segment – Metal Casting

- Metal Casting is a broad industry covering both Ferrous and Non-Ferrous materials. A table outlining the breakout of USA castings produced by end-use type is as follows:

Supply	Metal Casting	End Use Markets
Gray iron - 42% Ductile iron - 31% Aluminum - 10% Steel - 10% Copper - 2% Zinc - 1.5% Other - 3.5%		Automotive and light truck - 35% Pipe and Fittings - 15% Construction, Mining, and Oil Field Machinery - 6% Internal Combustion Engines - 5% Railroad - 5% Valves - 5% Farm Equipment - 3% Municipal Castings - 3% Other - 23%

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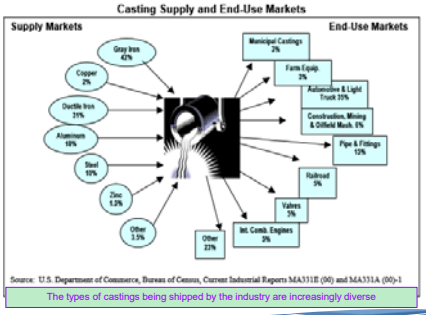
Metal Castings – Supply and End Use



Source: U.S. Department of Commerce, Bureau of Census, Current Industrial Reports MA331E (00) and MA331A (00)-1

The types of castings being shipped by the industry are increasingly diverse

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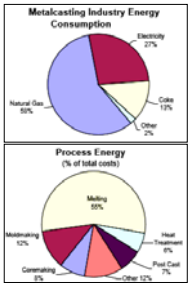
Market Segment – Metal Casting

- Metal casting facilities are one of the most energy-intensive industries in the U.S. with approximately 55% of energy costs consumed in the melting process.
- Overall, total industry energy consumption is estimated to be nearly 31 trillion Btu (MECS 2014) in 2014, which represents about 0.4 % of all U.S. manufacturing energy use.



Note: The data is the best available information as of April 2020

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Market Segment – Metal Casting
Copper

- Domestic mine production in 2018 was 1.11 million metric tons and valued at $3.33 billion.
- The principal mining states in descending order, Arizona, Utah, and New Mexico, accounted for 99% of domestic production.

	2014	2015	2016	2017	2018
Production - Refinery	1050	1090	1180	1040	1100
Production - scrap	46	49	46	40	40
Recovered - old scrap	173	166	149	146	150
Consumption	1780	1820	1880	1870	1850
Price (Cents/lb.)	311.1	249.5	220.6	279.5	300

All production - recovered figures in Thousand metric ton
Price - London Metal Exchange

Source: US Geological Service

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Metal Casting Plant Equipment using Natural Gas

- Ferrous Metals
  - Sand and mold drying
  - Scrap preheaters – deoilers
  - Metal melting
  - Thermal oxidizer (incinerator)
  - Air preheating for cupola/ melter operation
  - Parts heat treating
  - Misc. heating
- Non-ferrous Metals
  - Ore drying equipment
  - Ore roasting equipment
  - Smelters - melters
  - Metal refining equipment
  - Parts heat treating
  - Steam generators (Boilers)
  - Misc. heating

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Equipment – Non-Ferrous

Scrap Preheating

- Roasting
- Delacquering
- Sweating

Reverb Melters

- Rectangular Box Type
- Rectangular Box Type (w/scrap charging well)
- Round Type Furnace (w/removable lid)
- Rotary Drum Furnace

Electric Reverberatory Furnace
Wet Hearth Compared with "Dry" Hearth

Crucible Melters

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Equipment – Non-Ferrous

Other Melters

- Barrel Melters
- Shaft Melters
- Jet and Tower Melters

Vertical Flotation Melter
Electric Induction and Channel Induction

Holders / Launders

- Plate Freezer

Scraped Surface Freezers

Dross Aluminum Recovery

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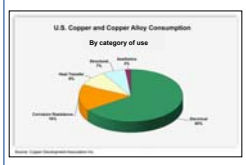
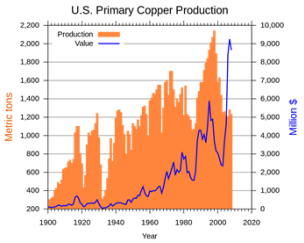
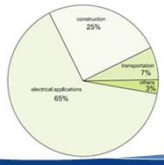
Market Segment – Metal Casting Copper







US Copper consumption ~2.0 million metric tons
Production~ 2.0 million metric tons
The imports fill the gap

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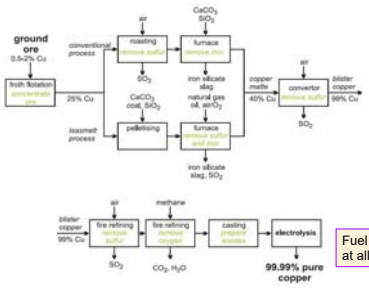
Copper Production Process



Major steps in production of copper

- Mining
- Concentrating
- Smelting
- Refining
- Casting

Fuel (mostly natural gas) is used at all stages of copper production

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Market Segment – Metal Casting - Copper

- All aspects of primary copper production use energy.
- In general, mining uses about 20% of the total energy requirement, mineral processing (grinding, concentration, floatation) another 40%, and smelting, converting, and refining the remaining 40%.
- Energy use will vary by type of production process (pyrometallurgical or hydrometallurgical).
- For the more prevalent pyrometallurgical approach, the smelting, converting and refining (electrolytic or fire) processes will collectively consume 30 to 40 million Btu per ton of copper produced.
- Flash smelters can reduce the overall energy demand to about 20 million Btu per ton.

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Market Segment – Metal Casting - Zinc

- Zinc is the fourth most widely used metal, following iron, aluminum and copper.
- It's produced in 6 states at 19 mines operated by 8 companies.
- Zinc was mined in six States at 15 mines operated by five companies. Two smelter facilities, one primary and one secondary, operated by two companies, produced commercial-grade zinc metal.
- Of the total reported zinc consumed, most was used in galvanizing, followed by brass and bronze, zinc-based alloys, and other uses. Most zinc is used in the galvanizing steel process.
- Other uses include the automotive, construction, electrical and machinery industries.

Year ------>	2016	2017	2018
Production: Mine, zinc in ore*	805	774	790
Production: Refined zinc*	126	132	130
Price, average cents per pound	792	829	880
Employment: Mine and mill, number	2350	2420	2660
Employment: Smelter primary, number	246	240	250

* In thousands metric tons
Ref: USGS Mineral Summaries (February 2019)

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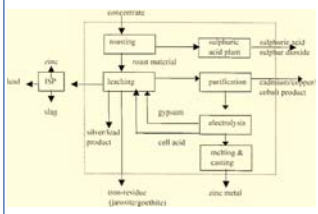
Market Segment – Metal Casting - Zinc



Zinc production process steps

- Zinc smelting requires a large energy input. For electrolytic smelters, the main energy source is electric power.
- All four primary zinc producers in the USA utilize an electrolytic process.
- The second energy commodity utilized is steam, used for heating the solution.
- The steam used is a part (about 40 to 50%) of the steam generated from the roasting step.

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Market Segment – Metal Casting - Lead

- Five lead mines in Missouri, plus five mines in Alaska, Idaho, and Washington that produced lead as a principal product or byproduct, accounted for all domestic lead mine production.
- The U.S. is the world's third largest producer of primary lead, with most originating from Alaska and Missouri.
- Lead is consumed in the manufacture of end-use products, including batteries, ammunition, covering for power and communication cable, building construction materials, and solders for motor vehicles, metal containers, and electrical and electronic components and accessories.

Year ----->	2016	2017	2018
Production: Mine, lead in ore*	346	310	260
Production: Refined lead*	986	1130	1300
Price, average cents per pound	94.4	114.5	115
Employment: Mine and mill, number	1970	1890	1870
Employment: Smelter primary, number	1850	1850	1850

* In thousands metric tons
Ref: USGS Mineral Summaries (February 2019)

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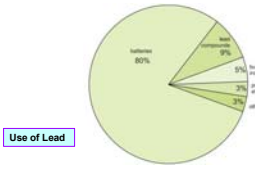
Market Segment – Metal Casting - Lead



Use of Lead

- The Manufacturing Process from Ore
  - Mining the ore
  - Concentrating the ore
  - Flotation
  - Filtering
  - Roasting the ore
  - Blasting
  - Refining
  - Casting
- A large amount (almost 2/3rd) of total production of lead is recycled lead

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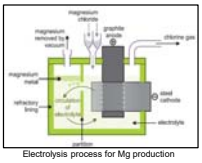
Market Segment – Metal Casting Magnesium

- Magnesium (Mg) is primarily produced by using brine – sea water. U.S. has one plant located near Salt Lake City, UT which is designed to produce magnesium using water from the Salt Lake. This plant was shut down in 2016 leaving US with no operating Mg production facility.
- The process involves two stages:
  i) production of pure magnesium chloride from sea water or brine
  ii) electrolysis of fused magnesium chloride
- Secondary Mg is produced from scrap. The production rate is about 100 thousand metric tons in 2018.

Primary Mg Use	Percentage
Automotive and other castings	45
Aluminum alloys	25
Iron and steel industry	11
Reduction agent for metal production	10
Other uses	9
Secondary Mg use	
Aluminum alloys	65
Structural uses	35



Electrolysis process for Mg production

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General Market Trends

- Steel – Automobile and appliance industries are creating demand for new products that are lighter, stronger, more uniform in their characteristics, and more corrosion resistant.
- Aluminum – Applications continue to expand due to demand in automobiles and light weight, corrosion resistance and recyclability.
- Metal Casting – Demand for the cast products, particularly precision castings will continue to grow in the USA
  - Copper – There are cutbacks in the mining of copper. Increase in imports depresses prices.
  - Zinc – Demand for galvanized steel will continue to stimulate growth in automobile and appliance industries.
  - Lead – Expected increase in demand due to battery replacement, worldwide electric vehicle production and possibility of radiation shielding in food related irradiation technologies
  - Magnesium – Increasing auto industry demand that may spur in investments in new plants.

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Future Roadmaps

Steel, Aluminum and Metal Casting are all considered Industries of the Future by DOE. Each has their own roadmap and vision for achieving energy use reduction and other production related and quality goals by the year 2020.

The broad technology goals of these Industry of the Future roadmaps are outlined below:

- **Steel:**
  - Advance alternate iron making processes
  - Capture lost energy
  - Advance melting for optimum productivity, energy efficiency, and flexibility
- **Aluminum:**
  - Reduce total energy consumption by 25%
  - Reduce overall operating costs by 3% per year
  - Increase use of co-generation and process improvements
- **Metal Casting:**
  - Achieve 15% productivity increase every 5 years
  - Reduce energy use by 20%
  - Reduce manufacturing lead times by 50%

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Supplier Resources

For a comprehensive listing of suppliers, the following links are recommended:

- Steel: www.modernmetals.com , www.amm.com/Magazine.html
- Other Melting / Holding Equipment: www.metalworld.com/equip




Courtesy Thermironix Inc.

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Case Studies

- Steel plants and Weirton Steel Corporation Plant-Wide Energy-Efficiency Improvement Case Study
  - https://www.nrel.gov/docs/fy09osti/45815.pdf
  - https://www.nrel.gov/docs/fy04osti/33993.pdf
- Metal Casting Industry Best Practices
  - https://www.energy.gov/sites/prod/files/2013/11/f4/implementation_final.pdf
- Energy Use Reduction Activities and Results at ALCOA
  - https://www.nrel.gov/docs/fy04osti/36152.pdf

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Trade Association

- Advanced Steel Processing and Products Research Center
  http://www.mines.edu/research/aspprc/
- The Aluminum Association
  http://www.aluminum.org
- American Coal Coke and Chemical Institute
  http://www.accci.org/
- American Institute of Mining, Metallurgical & Petroleum Engineers
  http://www.aimeny.org/
- American Iron & Steel Institute
  http://www.steel.org

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Trade Association

- American Iron Ore Association
  614 West Superior Avenue, Suite 915
  Cleveland, OH 44113-1383
  Phone: 216-241-8261 Fax: 216-241-8262
- American Society of Metals International
  http://www.asminternational.org/
- American Zinc Association
  http://www.zinc.org
- Association of Iron and Steel Engineers (AISE)
  http://www.aist.org/
- Canadian Steel Producers Association
  http://www.canadiansteel.ca/

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Trade Association

- Department of Energy Office of Industrial Technologies:
  http://www.eere.energy.gov/industry/steel
  http://www.eere.energy.gov/industry/aluminum
- Steel Alliance: www.steelalliance.com
- Steel Manufacturers Association:
  http://www.steelnet.org/
- U.S. Department of the Interior U.S. Geological Survey (USGS): http://minerals.usgs.gov/

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Trade Association

- Institute of Scrap Recycling Industries
  http://www.isri.org/
- International Copper Association
  http://www.copper.org/
- The International Copper Study Group
  http://www.icsg.org/
- International Council on Mining and Metals
  http://www.icmm.com/
- International Iron & Steel Institute (IISI)
  http://www.worldsteel.org/
- International Lead Zinc Research Org., Inc.
  http://www.ilzro.org/

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Trade Association

- International Lead & Zinc Study Group
  http://www.ilzsg.org/
- International Magnesium Association
  http://www.intlmag.org/
- International Zinc Association
  http://www.iza.com/
- InterZinc
  http://www.interzinc.org/
- Lead Development Assoc. International
  http://www.ldaint.org/
- Light Gauge Steel Engineers Association
  http://www.lgsea.com/

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Trade Association

- McMaster Steel Research Center McMaster University
  http://mcmasteel.mcmaster.ca/
- Minerals, Metals & Materials Society
  http://www.tms.org/
- National Mining Association
  http://www.nma.org/
- New Steel
  http://newsteel.com/
- SECAT - Research Resource for the Aluminum Industry
  http://www.secat.net/

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