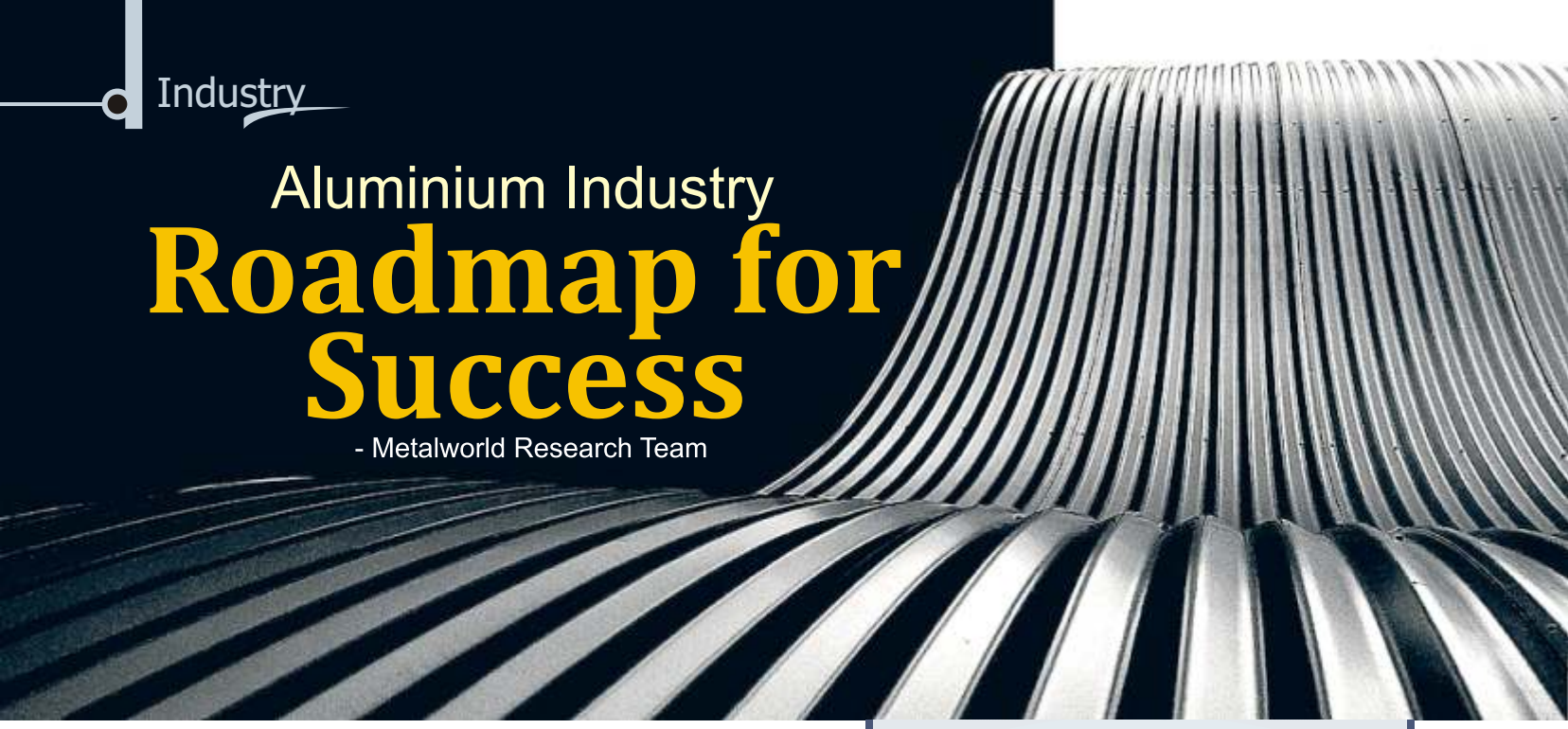

Aluminium Industry
Roadmap for Success

- Metalworld Research Team

The Aluminium Association of India has prepared a draft plan of a 67 pages report on Indian aluminium industry .The report is titled as "ROADMAP FOR INDIAN ALUMINIUM INDUSTRY", based on the comments/views and inputs on the general information, future needs, market trends and essential technological needs etc., which is received from various industries and available reports from International Aluminium Institute, the American Aluminium Association, European Aluminium Association, UK Aluminium Federation, Aluminium Association of Canada and various other Aluminium Associations.

The basic Objective behind drafting a Technology Road map for Indian Aluminum industry is re-evaluating at regular intervals, to incorporate new market and technical information and to ensure that the research priorities remain relevant to customer needs. The draft is about goal-based research and development agenda. Technology path to achieve that vision which generally, is pre-competitive collaborative partnerships between companies, research organisations, government agencies and where applicable, suppliers. It focuses primarily on the three goal areas that require technical solutions like Products and Markets, Sustainability, Energy and Resources.

Prof Murthy feels this draft will help the industry as Indian aluminum industry has now defined a set of performance targets for assessing progress toward and achievement of each of the strategic long-term goals involving technical solutions: Products and Markets, Sustainability, and Energy and Resources. To achieve these targets, the industry must pursue an organized, strategic technology agenda.

The Roadmap outlines that agenda, organized according to the major aluminium processes. It presents detailed, sector-specific performance targets, technical barriers, research and development needs, and R&D priorities for each of these process-based sectors:

- Primary Production
- Melting, Solidification, and Recycling
- Fabrication – Castings, Extrusions, Rolled Products, Foils etc.
- Alloy Development and Finished Products
- Waste Management

Aluminum is a truly versatile, most sustainable and industrially appealing metal. Aluminium's unique properties – light-weightiness, high strength and resistance to corrosion make it an ideal material for use in conventional and novel application and a strong potential candidate to replace steel. Indian Aluminium industry is forging ahead with rapid expansion in both primary metal and downstream sectors. With the continuing trend of economic growth, the demand and consumption of Aluminium is expected to increase rapidly. Indian aluminium industries focus on research and development and have ample opportunities for growth in various application sectors. Aluminium demand in India is anticipated to grow more than 5 times by 2030. Besides the growth in domestic consumption, India can attain a viable position in the global market through export of value added products thereby benefiting the country by providing the avenues to fulfill much desired foreign exchange. New products are developed bearing in mind the unique properties of aluminum. The new markets for aluminum are found - consumer durables, Railway wagons & Rail Coaches, Aviation, Solar panels, Electronics, and new types of material for Construction (roofing, window panels etc) to maintain sustainable development in the future.

- Advances and Execution
- High on Agenda

While TRM has been created in order define the specific research and development priorities, performance targets and milestones to achieve a vision which is set for the Aluminium Industry in India. It guides to prepare R & D plan for implementation by the respective aluminium industries. It lays out a strategic R & D plan which is designed to build on the inherent benefits of aluminium, favorably utilize the resources that are available within the country and attain the visions strategic goals. By pursuing the ambitious agenda laid out in this Roadmap, the Indian Aluminium Industry should secure its place as a world leader in providing innovative, material based solutions that deliver superior value to the users

The Aluminum Production is basically divided into 4 different stages like:

Primary Metal Production

Primary aluminium production is an energy intensive activity. The theoretical minimum energy requirement for producing aluminium from alumina is 9.03 kWh/kg (2Al 2O3 _ 4Al + 3O2). The world aluminium industry has selected a goal of 11 kWh/kg of aluminium as its smelting current practice value for the year 2020 and considers it as obtainable and practical minimum smelting energy goal.

Secondary Metal Production (Recyclability)

Aluminium is a highly recyclable metal and is a forward-looking technology. Secondary aluminium is produced from recycled aluminium scrap requires less than 6 percent of the energy to produce aluminium from mined bauxite and emits only 5% of green house gases (GHG - a key environmental and sustainability issue for the world in the twenty-first century). A special melting technique is needed and which must satisfy strict ecological and economical requirements.

Semi-finished Aluminium Products

These correspond to transformation of pre-fabricated aluminium ingot into a semi-product, i.e. profile, sheet or foil ready for delivery to the user and include secondary aluminium generated via recycling of the scrap, chips generated during this semi-fabrication stage as well as the recycling of the dross. For example, semi products of wrought aluminium alloys may be sheets, strips and plates, which are fabricated from ingots by hot working (mainly a rolling or an extrusion process) which is normally followed by cold working and /or finishing operations. Aluminium castings are manufactured by the solidification of molten metal, followed by finishing operations.

Waste Management

Several types of waste products are generated by decomposition of carbon electrodes during the smelting operation. The largest waste product generated in bauxite refining is the tailings (ore refuse) called "red mud" and several thousand tons of spent pot-lining (SPL) material is removed from aluminium reduction pots each year - wastes usually disposed of in a landfill. The electrolysis of alumina to produce aluminum involves the use of aluminum fluoride, carbon anodes, and large amounts of electricity and significant waste products are air emissions including perfluorocarbon (compounds of carbon and fluorine) gases and carbon dioxide. The wastes must be managed both via reducing their production and disposal (value added products).

Production and Consumption Statistics

World and Indian Market Size of Aluminium

Market	World 57.6 million tons (includes the 29% recycled)	India 2.1 million tons (includes the 19% recycled)
Castings and Forgings	23%	24%
Extrusions	31% *(58% of this is attributed to China)*	11%
Flat Rolled products	33%	18%
Wire and Cable	12%	39%
Powder and others	1%	8%

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Consumption of Aluminium (India and the World)

The Indian aluminium consumption in 2010 by the end users is given below

- **Electrical :** Main-stay of Indian market; reforms and investment in electricity sector key to growth - 41 %(11%)
- **Construction :** To benefit from urbanization- 14 %(25%)
- **Transport :** Tremendous potential due to auto growth and deepening of usage- 17 %(28%)
- **Packaging :** Currently at Low base with scope to grow-5 %(18%)
- **Consumer Durables :** Consumption story augurs well- 7 %(7%)
- **Machinery :** Manufacturing policy positive- 8 %(11%)

Worldwide aluminium ranks second, next only to steel, in terms of volumes used, primarily due to its versatility, which stems from its excellent properties. The utilization of the abundantly available material on the earth's crust though, is far from being exploited.

Why is steel so much more popular than aluminium? The answer simply lies in the following - (i) Technological limitations (ii) lack of awareness (iii) non-availability and (iv) higher initial cost. While China has surged ahead of other countries in the production and consumption of aluminium, the world in general, faces several issues pertaining to the growth of aluminium industry and naturally Indian Aluminium Industry faces all of those and additional issues. With abundant

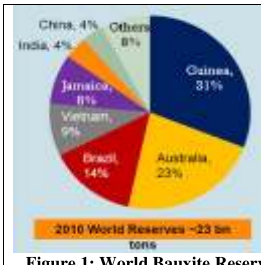


Figure 1: World Bauxite Reserves

Worldwide Production Pattern
Total for 2012: 45,207 thousand metric tonnes of aluminium

Period	Africa	Asia (excluding China)	China	North America	South America	West Europe	East & Central Europe	Oceania	GCC*	Est. Un-reported	Daily Avg.	Total
2012	1,639	2,535	9,754	4,851	2,052	3,605	4,323	2,186	3,662	600	123.5	45,207

* Gulf Cooperation Council

PROF. K. S. S. MURTHY
Gen. Secretary
Aluminium Association of India

said "the draft TRM is now being revised based on the valuable comments / inputs received from the participants, which will enable AAI to prepare an enriched final document for the Indian Aluminium Industry". He further added that "emerged final document will act as a guideline document assisting planning authorities, industries, R&D organizations and academic institutions in ensuring sustenance of demand and filling up of competence gap, enabling various Ministries to fund the projects along with industries and R&D organizations. It will be the guide to the future development of an industry".

resources, capacities and capabilities and guidance in the right direction, Indian industries are poised for a great leap to totally change the production and consumption pattern. Higher consumption levels are expected in packaging, building, automotive and consumer durable sectors, besides normal consumption in electrical, transport and other industrial sectors. On the global scenario, while a definite eastward shift appears in the business trend in aluminium, the shifting trend offers tremendous business opportunities nonetheless integrated with newer challenges.

Trends, Drivers and the Challenges faced by the Indian Aluminium Industry

1. Energy Costs And Availability : Energy is a major component of the total cost of producing aluminium. Worldwide smelter expansions and new plant construction have focused on nations with low cost energy and labor resources.

2. Low Per Capita Consumption of Aluminium Products : strong competition with the most used metal i.e. steel. Increase in the market for aluminium by enhancing world-wide awareness of its unique and valuable qualities.

3. Technology Barriers : There are a number of barriers that prevent greater energy efficiency, productivity, metal quality and environmental performance of primary and secondary aluminium production. Before aluminium producers can achieve their performance targets, the industry must develop solutions to several technological and institutional barriers.

4. Identification of Issues of Relevance to the Production Products and their Usage : Appropriate research including advancements in energy efficiency, materials substitution developments, promotion and other concerns.

5. Lack of Wider Understanding of All Key Sustainability Issues Related with Aluminium : Environmentally sound production of aluminium, health, safety and recycling.

6. Waste Management : Addressing the waste disposal and management issues.

Current Technological Scenario

Primary production of aluminium is highly energy intensive. 125 years ago Hall-Heroult cell technology emerged as a method to create aluminium by separating it from bauxite ore through electrolysis. Nearly 75 percent of the aluminium produced since then is still in use today—a testament to the material's durability and recyclability. No other metal can match aluminium's sustainability advantage or its combination of useful physical properties. However, significant also is the fact that this energy intensive method is still the only technology available to produce aluminium from bauxite ore – 50% smelting capacity depends upon non-hydro energy. Now with the global centers of production and consumption shifting emphasis towards East – including India – we must nurture the opportunities by breaking the upward shift in the cost curve of smelting. The technology continues to be overshadowed with major issues: beyond the control of the aluminium industry pertaining to electricity supply, reliability and cost. Only the best cells in the world operate at lower than 13kWh/kg– the industry average continues to be 15kWh/kg and the long-range research efforts focus on advanced electrode systems that promise to reduce anode-cathode distance.

While The Indian aluminium industry faces several technological barriers like Lack of TRMs for any of the aluminium based industries/sector then major problem is the Large gap in terms of energy consumption per Ton of aluminium metal produced in India – Aluminium is produced by more than 100 year old Electrolytic route technology – Hall-Heroult process. Old smelting plants use 15-16000 kWh/T while the newer plants use power equivalent to 13,000 kWh/T aluminium, Low amperage cells, Large gap between theoretical and actual energy efficiency, and high associated power costs, limiting primary aluminium smelting which includes all the four main categories.

- **Electrolytic Reduction Processes :** technical limitations in existing reduction cells constrain improvements in their energy and production efficiencies, metal quality, and environmental performance.
- **Alternative Reduction Processes :** Lack of commercially viable alternative to the Bayer and Hall Heroult process hinders primary aluminium producers in their efforts to achieve revolutionary advances in cost and efficiency.
- **Enabling Technologies :** Such as sensors, controls, models, and materials can help overcome these barriers.
- **Institutional Barriers :** Less coordination among industry, government, academic institutions limits the rate of technology development

Research and Development Needs

The Indian aluminium industry can overcome the technical barriers to achieve improved primary production through research, development, demonstration and pro-active actions aimed at improving smelting technologies and processes. The Key Technical Areas that need R&D efforts are like reduce cost, dramatically lower energy consumption, improve product yield, Improve product quality, Initiate alternative aluminium

production techniques, Initiate enabling technologies such as sensors, controls and models to better understand and operate reduction processes at optimal efficiency, explore ways to recycle process wastes generated during primary production, initiate and pursue innovative, and longer-term advances to achieve the goals.

The roadmap also has made a time frame for aluminium primary production sector which is planned for long term as well as short term and medium term also.

- 24 barrels of crude oil equivalent of energy
- Over 15 tons of fresh or sea water usage
- More than 9 tons of CO2 equivalent of greenhouse gas emissions
- 2.5 tons of solid waste (including recyclable solid waste)

In 1990 total aluminium production was around 28 million tonnes (with over 8 million tonnes recycled from scrap) and during 2009 the total was close to 56 million tonnes (with close to 18 million tonnes recycled from scrap).

Aluminium Primary Production Sector - Priorities and Time Frame

During the Next 3 years	Within 10 years	By 2025 (top priorities)
• Assess and prepare industry wide sustainability report & roadmap on manufacture, extraction and refining • Conduct technology audit of current smelters • Develop sustainability initiative roadmap for zero waste of aluminium • Initiate and establish collaborative programs to promote education on aluminium technologies and usage • Initiate aluminium recycling in India in a large way • Conduct statistical analysis of waste streams from smelters by region and technology • Initiate effective environmental management system • Prepare work plan to increase per capita consumption of aluminium & its products • Initiate research in lightweight automobiles • Initiate R & D in alloys with higher strength and heat resistant diesel engines • Alternative pre-treatment technologies for scrap • Initiate R & D of high formability, low cost, high strength aluminium alloys	• High capacity furnace design – safe & environment friendly, low melting loss, fuel efficient, cost effective • Mass reduction of 30-50% via light weighting automobiles • Production of industry specific alloys • Capability and practice of secondary recovery of aluminium from all sources • Minimize dross & salt cake formation / landfill • Effective mathematical models – understanding structure (micro / macro) – property relationships • Long term elimination of PFC emissions • Reduce total fluoride emission by >35% per ton of primary metal production • Produce high quality downstream products – wires/ billets/ingots etc. • Promote and be self sufficient to provide to the needs (including special alloys, composites, and downstream products) for following sectors buildings and construction ➢ Indian Defense (Aviation) ➢ Packaging ➢ Electrical Power ➢ Transportation (Especially Auto/Rly.) ➢ Consumer Durables • Aluminium life cycle – a green metal • Technology to eliminate dross from aluminium metal casting • Develop viable methods to separate scrap by alloy • Improve methods for molten metal handling • Processing techniques to improve productivity, cost reduction, product quality and design improvements	• Energy efficiency of Hall-Héroultcell– attain 11 kWh/kg • Self sustained research on anode and cathode technology • Non-consumable anode to reduce CO2 emission • Long term R&D on refining bauxite ore & alternate reduction processes of alumina • Reduce cost of primary metal production by 25% • All aluminium waste to be turned into usable feedstock • Offer integrated aluminium solutions to OEM's/manufacturers • Develop multi-material solutions • Effective mathematical models • Design cell capable of handling power modulation

Aluminium Recycling / Secondary Production / Melting / Solidification

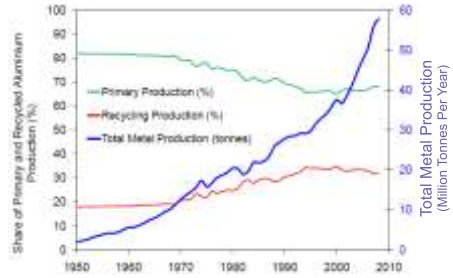
Aluminium can be recycled over and over again without loss of properties. The high value of aluminium scrap is s key incentive and major economic impetus for recycling. Recycled (secondary) aluminium production offers Obvious/enormous energy and environmental benefits as it requires only five percent of the energy use and emission associated with primary production. Aluminium is always being more efficient as each ton of aluminium recycled saves

By 2020 metal demand is projected to have increased to around 97 million tonnes.

Caption Global Share Of Primary & Recycled Metal Production

In India, the trend of aluminium recycling has somewhat increased to about 25% of total aluminium consumption in 2008 and moreover remained the same till now. This lull may possibly be attributable to the global economic scenario which is not expected to last long. However, recycling is a fairly well organized business in India and several corporate houses are engaged in recycling of aluminium scrap to manufacture aluminium alloy for the automobile sector. India has imported 339,000 kt of aluminium scrap in 2011-12 besides

Global Share of Primary and Recycled Metal Production



sourcing of substantial quantity from domestic source for making aluminium alloy for the automobile sector. The objective for 2025 or beyond is for the Indian aluminium industry to help in avoiding greenhouse gas emissions than it creates directly/indirectly through its production by replacing traditional energy inefficient materials not just with aluminium, but with recycled aluminium, especially in transport applications.

Major Issues in Recycling / Melting / Solidification / Secondary production in India

Undoubtedly aluminium is an invaluable resource which we have in the country. However the potential is not tapped to its fullest extent. Synergistic approach to the development and maintenance of the Indian Aluminium Industry is crucial. Education and training are the ever present needs and must be part of future development strategies. In order to improve the Indian Aluminium Industry's overall energy efficiency, it is essential to :

- **Spread the Word :** Aluminium recycling is a forward looking technology.
- Increase the shift towards secondary rather than primary aluminium production
- Develop the special melting technique for recovering aluminium from recycling material, which must satisfy strict ecological and economical requirements
- Create newer alloys compatible with recycling.

Fabrication / Downstream Aluminium

Driven by the wide applications and growing demand, downstream aluminium fabrication activities are

increasingly potential global focus. Aluminum from primary industry is processed in downstream for further value – addition to produce semi-finished end-product like extrusions rolled, fabrications and finished items especially for automobile & transportation, construction, packaging, power and consumer products industries. Downstream activities transform primary and secondary aluminium into products to be used by the manufacturing Industry's end users. A significant part of the broad range of downstream activities is pursued by the aluminium producers, while the remainder is developed by independent fabricators and processors or by the manufacturing industry itself, particularly the original equipment manufacturers (OEMs). Fabrication can be broken down into the making of ingots, stocks, semi-fabricated products.

Technical Barriers : Fabrication/ Downstream

- Lack of methods to produce larger castings with thinner walls.
- Aluminium composites – production and application technology.
- Manufacturing Process for aluminium sheets with high reflectivity for solar applications
- Technology for manufacture of aluminium multi-material flat panels
- Lack of information on surface and metal chemistry
- Insufficient and inefficient tooling
- Inconsistency in in-coming raw materials

Extract of the Research and Technological Needs In Aluminium Fabrication Industry

- New manufacturing concepts that include fabricating from all sources including scraps from different sources
- Deeper understanding of physical metallurgical properties, structure property relationships in primary and secondary alloys/composites, extension of the understanding to fabrication processes and materials used
- Non-invasive techniques of analysis – develop non-contact sensors

- Understanding of process fundamentals
- Advanced Sensors and precision tools
- Health and Safety consciousness
- Improved productivity and quality to meet existing and novel/additional market demands
- Improved joining technologies and Cost cutting and energy savings
- Advanced research on newer and novel technologies – retention of only the critical processing steps
- Education and training at all levels
- Advanced sheet and extrusion technologies – understanding customer requirements under specific and stringent Conditions. Extrusion modeling – computer tools to improve extrusion process.

Utilization Sectors, Alloys and Finished Products

Aluminium metal has grown 12.7 times while steel has grown only 4 times. No other engineering metal among tin, lead, zinc, nickel, copper and steel have shown such a phenomenal growth prospects such as aluminium. The world aluminium consumption rate has quickened in the past 10 years and the projected consumption growth is 41 million tons to 61 million tons in a span of just 6 years (2010 – 2016). Finished aluminium products are important in several key markets. Major current and emerging markets for aluminium include packaging, transportation, building and construction, and national infrastructure. The building and construction market includes residential, industrial, commercial, farming and highway applications. Representative products in the containers and packaging industry include metal cans, semi-rigid food containers and household and institutional foils.

Waste Management

In aluminium industry, several wastes are generated during the conversion of bauxite to alumina and subsequently from alumina to aluminium and its alloys. Some of the major solid wastes generated are red mud, dross and spend pot lining (SPL). India produces around 1.2 lakh tons dross per annum, about 5 million tons to Red mud and 35,000 tons SPL. Some contain certain toxic materials among which cyanide in SPL is concerning to the industry and therefore needs to be stored especially in a covered manner to avoid direct contact with soil. Considerable R&D work has been carried out throughout the world for effective utilization of the above mentioned wastes. However, every limited applications so far have been commercialized is outside India. In case of India, commercialization of the above wastes is yet to be proved.

Suggestions as Per Roadmap

In order to arrive at a strategic approach to strengthen the Indian Aluminium Industry, following key elements are needed to be provided as inputs. They are (i) Technology Roadmaps, (ii) Collaborative Partnerships, (iii) Corporate R&D, (iv) Communication and outreach efforts, (v) Rapid Technology Deployment and (vi) Education and workforce efforts.

A well-planned, organized and efficient methodology and collaboration among the Indian government, Aluminium industries and

Academic institutions is vital to work on and promote aluminium in India. For initiation, in addition to information gathered via presentations made by eminent people from various aluminium related organizations, AAI was able to gather considerable information on the current status and futuristic needs of the Indian aluminium industry by communicating with organizations functioning under different industrial backgrounds and segments. The findings are summarized as the following. They include an overview of current and futuristic areas in research, production, application, usage, technological gaps and requirements to be addressed and fulfilled as well etc. Notable expectations from the Indian Government are as the following.

- Continuous electrical power
- Support by making large R&D investments
- Standardize alloys and products, include in purchase specifications of utilities, give excise refund, and prioritize funding model.
- Protection, encouragement, support, safeguard & incentives for growth and for new applications, increasing per capita consumption.
- Prepare a long term vision for the Aluminium industry in India, addressing possibilities such as: which section (s) of the Al industry should India focus on, e.g. Bauxite mining, alumina refining, aluminium smelting, downstream product development. The choice should fit into the context of the specific requirements to be successful in each of these areas (e.g. availability of first class bauxite deposits, existing infrastructure close to these deposits, availability of sustainable low-cost power, etc) and India's current strengths in these areas. Based on these choices, develop long term (e.g 30 – year) goals (e.g. in 2040 India should have developed 3-4 of its major Eastern Ghats bauxite deposits, etc).
- Develop a plan of action for the next 5 and 10 years to achieve the long term goals. This plan should specify actions required by the Indian & State Governments (e.g. by 2020 the railway system in Orissa will be extended into the identified hills to enable development of the identified bauxite deposits).
- Address regulations especially in the transport sector to promote aluminium

Recommendations and Scope Including Industry Needs

- Increase use of aluminium in furniture industry, transport sector, extruded sections for truck body building and rail wagon manufacturing.
- R&D Departments to take up projects related to Aluminium usage
- Plant layouts improvement for better material handling.
- Latest Technology adoption and Manpower training

- Adoption of better & easily available methods for Scrap recycling.
- Development of economical and easy ways for hazardous material disposal.
- Improvements in Automation of the machines & process s control sensors.
- Address need for economical & environment friendly methods for metal melting
- Improved molten material handling process required along with better impurity removal methods.
- Develop alternative dross treatment.
- Develop easy methods / machines to separate the scrap by alloy.
- Efficiency loss due to inefficient furnaces for the scrap heating and waste heat recovery to be addressed.
- Human resource management: Training the Human resources for the better productivity & efficiency improvement
- Upgrade and improve plant and machinery suitable to adopt latest process techniques
- Processing techniques to improve productivity cost reduction, product quality and design improvements advantage of aluminium products to help increasing consumption.
- Continuous efforts to be taken by Indian industries to fill the gap mostly by own R&D.
- Range of Applications can be widened in the areas of building & construction, electrical and transportation sectors.
- Aluminium should replace steel used in auto components and civil structures
- Aluminium to be promoted as a sustainable green metal

Talking about how roadmap has previous was useful in different cases for improvement and development of industry Prof Murthy said " 'Similar efforts have been undertaken by The Aluminium Association of America, USA, Canadian Aluminium Industry, Canada, Aluminium Federation Ltd, UK and have implemented many of the suggestions/recommendations arising out of such reports. TECHNOLOGY ROADMAP FOR INDIAN ALUMINIUM INDUSTRY is first of its kind.

He further added "in order to develop India-specific products to promote the use of Aluminium for which the industry, government, academia and R&D sector should join hands and the living document is meant for implementation. Government as well as industries of The Aluminium Association of America, USA, Canadian Aluminium Industry, Canada, Aluminium Federation Ltd, and UK have funded Research Projects based on these reports.

The purpose of this study in our country too is to identify Technologies and enable various Ministries to fund the projects along with industries and R&D organizations.

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