Canadian Aluminium Industry Technology Roadmap

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FOREWORD

The Canadian aluminium industry is now entering a period of growth which will provide substantial economic benefits to firms, research centres, and institutions that demonstrate the capability of defining their future markets and of taking up the technological challenges they present.

The Canadian aluminium industry is now very well poised at the international level. Within the context of globalization, it is faced with ever-increasing competitiveness and must select its technological strategy wisely to adequately respond to market challenges.

A series of recent events have spurred the Canadian aluminium industry to improve and consolidate its position in the global matrix. In light of this future goal, the National Research Council of Canada, Canada Economic Development, Industry Canada, and the Réseau Trans-Al inc. joined efforts, in cooperation with the consulting firm of Samson Bélair/Deloitte & Touche, to produce the very first technology roadmap of the Canadian aluminium industry.

The technology roadmap, **a joint endeavour undertaken in cooperation with major industry stakeholders**, such as aluminium producers, primary and secondary aluminium transformers, equipment manufacturers, as well as Canadian universities and research centres, is the first step of an overall approach aimed at securing the future of the aluminium industry in Canada. It is a leading-edge tool for encouraging new technology development and innovative product design and enabling Canadian firms and institutions to position themselves in the most promising markets.

The technology roadmap will benefit all industry stakeholders: it will provide firms with a strategic planning tool to seek out and bridge the gaps between their current technological resources and their future requirements, it will serve as a guide for program design within research organizations and teaching establishments, and it will afford governments a strategic guidance framework for industrial research and development programs.

It is with much eagerness that we present the first edition of the technology roadmap, developed following **a stringent process of in-depth consultation that lasted nearly a year**. We are extremely thankful for the outstanding cooperation of all those who took part in the workshops and for the work of the technology roadmap steering committee members who made this project possible.

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MEMBERS OF THE TECHNOLOGY ROADMAP STEERING COMMITTEE:

Beauchamp, Émile	Industry Canada
Champagne, Blaise	Industrial Materials Institute of the NRC
D'Anjou, Yvon	Alcan Primary Metal
Dieter, Rupp	Homet-Cercast Canada inc.
Éthier, Charles	Industry Canada
Frenette, Jean-Guy	Fonds de solidarité des travailleurs
Gendron, Lucien	Centre québécois de recherche et de développement de l'aluminium
Hudon, Donald	Canada Economic Development
Lavoie, Robert	Canada Economic Development
Lipman, Richard	Canadian Window and Door Manufacturers Association
Manseau, André	National Research Council of Canada (NRC) - Planning
Niquet, Alain	Industrie Spectal inc.
Paré, Jean	Réseau Trans-Al inc. and Spectube inc.
Sokolowski, Jerry	Windsor Industrial Research Chair in light metal casting technology
Tremblay, Aline	Réseau Trans-Al inc.
Tremblay, D-André	Alcan Primary Metal
Van Houtte, Christian L.	Aluminum Association of Canada
Young, Tim	Magna symatec

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Allaire, Claude	École polytechnique de Montréal
Allard, Christian	Almaho inc.
Barter, John	SNC-Lavalin Group inc.
Bauer, Dominic Bernard	École de technologie supérieure
Beaulieu, Denis	Laval University
Bérubé, Hugo	Sport Rack international inc.
Blyth, Robert	Spec-Structure design
Bouchard, Pierre	Société des technologies de l'aluminium STAS ltée
Bui, Rung Tien	Chaire CRSNG-ALCAN-UQAC en ingénierie des procédès
Caron, Madeleine	Ministère de l'Industrie et du Commerce du Québec
Champagne, Robert	Centre intégré des fonderies et métallurgie
Cloutier, Benoît	CIF Métal
Couture, Ghislain	Bombardier Transportation (Recreational Products)
Di Lénardo, Bruno	National Research Council of Canada (NRC)
Doutre, Don	Kinston Research and Development Center-Alcan International Inc.
Dubé, Ghyslain	Centre de recherche et de développement Arvida—Alcan International inc.
Dubuc, Réjean	Fonderie Saguenay ltée
Dufour, Gilles	Alcoa, Aluminerie Lauralco inc.
Dupont, Gilles G.	National Research Council of Canada (NRC)
Dupuis, Marc	GéniSim inc.
Fillion, Gaëtan	Comact Chicoutimi inc.

Fournier, Claude	Industries Lyster
Fournier, Serge	Les Industries Fournier inc.
Fradet, Claude	Centre de recherche et de développement Arvida—Alcan International inc.
Gauthier, Sylvain	Montupet ltée
Glavicic-Théberge, Tanya	McGill University
Gravel, Marc	Lar Machinerie inc.
Gruzleski, John E.	McGill University
Hamel, François	Industrial Materials Institute of the NRC
Hayes, Carmy	Association québécoise de l'aérospatiale
Hodson, Michael	Aisco Systems
Hornibrook, Arthur	Exal Aluminum inc.
Horton, Ray	Industry Canada
Houde, André	Ministère de l'Industrie et du Commerce du Québec
Huni, Jean-Paul	Centre de recherche et de développement Arvida—Alcan International inc.
Jackman, Jennifer	Canmet
Jennings, Cy	Saskatchewan Economic and Co-operative Development
Lapointe, Pierre	Alcoa, Aluminerie Lauralco inc.
Legault, Rock	Signotech
Masounave, Jacques	École de technologie supérieure
McLean, Glen	H&G Powder Coating
Melhem, Nafez	Industrial Materials Institute
Moselhi, Oshama	Concordia University
Pasini, Ciro	Implo-Technologies
Pagé, Gisèle	Centre québécois de recherche et de développement de l'aluminium
Pekguleryuz, Mihriban	Noranda Inc., Centre de Technologie
Renaud, Jean	Technologie Intermag
Samsom, Richard	Canmec Industriel inc.
Samuel, Fawsy Hosny	Chaire industrielle de recherche GM-CRSNG-UQAC sur la technologie avancée des métaux légers pour les applications automobiles
Santiago, Rui	Hatch Associés
Schliep, Rainer	Ronal Canada inc.
Spiller, Adrian	National Research Council of Canada (NRC)
Simard, Alain	ABB, Bomem inc.
Taillon, Carol	Acralum Paint inc.
Taylor, Martin	Société des technologies de l'aluminium STAS ltée
Thomas, Bruce	Canadair
Tremblay, Marc	Précicast
Tremblay, Robert	AMT Die Casting inc.
Venne, Jean-Pierre	Altex Extrusion
Walsh, Bruse	Advanced Dynamic Corp.
Yelle, Jean-Marc	Alumico Métal & Oxydation inc.
Zmuda, Mathias	Montupet ltée

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Summary

INTRODUCTION

The Canadian Aluminium Industry is entering a period of growth that will have significant economic impacts for companies, research centers and universities capable of participating in future markets and seizing technological opportunities.

Despite the successes gained by aluminium during the last decade, numerous challenges still remain. For example, steel intends on regaining the ground it has lost in such growth sectors as the automobile industry. Moreover, many materials like magnesium and polymers compete with aluminium. Polymers, in particular, have gained relative market share in sectors involving containers, packaging, doors and windows.

Canada must innovate

To ensure growth while remaining competitive, the Canadian Aluminium Industry must coordinate its efforts and successfully meet the technological challenges to come. It is this view that has united all major parties, including the National Research Council of Canada, Canada Economic Development, Industry Canada and Réseau Trans-Al Inc., in drafting the first edition of the Technology Roadmap in collaboration with the consulting firm of Samson Bélair/Deloitte & Touche.

In this context, the present Technology Roadmap constitutes an invaluable tool in helping us understand future market trends, technological innovation, research and development and technology transfer. It will allow the Canadian Aluminium Industry to make technological forecasts as well as better and more informed strategic choices.

THE OBJECTIVE OF THE TECHNOLOGY ROADMAP

To help the overall Canadian Aluminium industry, from primary aluminium suppliers to value-added secondary product manufacturers, as well as equipment suppliers, become global leaders while allowing them to adequately fulfil the growing requirements of their respective clients.

CANADIAN REFERENCE DOCUMENT

Strategic planning tool

Created by and for the parties of the Canadian Aluminium Industry, and written to reach a broad audience, the Technology Roadmap speaks to organizations, sectorial specialists, leaders, researchers, equipment suppliers, decision makers in the public and private sectors and to educators. The Technology Roadmap makes it possible to understand the principal opportunities/challenges of the Canadian Aluminium Industry, and constitutes a tool of choice for all parties to plan their activities, clarify their priorities and establish their strategic orientations.

A completely new angle

Although a good number of the technological challenges drawn up by the American Technology Roadmap are also valid for Canada, it is clear that the Canadian Aluminium Industry has **intrinsic characteristics** that must be taken into account when considering technological priorities. The Canadian Technology Roadmap places particular emphasis on the equipment industry, the transportation industry and the construction and electricity sectors, which gives it a completely new angle.

A RIGOROUS PROCEDURE

The first edition of the Canadian Aluminium Industry Technology Roadmap is the result of a process which lasted nearly one year. To ensure the validity of the roadmap, a rigorous procedure was followed: exhaustive bibliographical review, questionnaires, market surveys, workshops and intensive consultations with close to 100 Canadian sectorial experts.

STEP 1 : **Industry portrait** based on the review of many sources of information: American technological roadmaps on aluminium; specialized magazines; market surveys; world data banks; annual company reports; internet sites; documentation from Industry Canada, Natural Resources Canada, research centers and various universities. Moreover, many internationally recognized experts were consulted.

More than one hundred participants

STEP 2 : **Surveys of industry specialists:** questionnaire in both of Canada's official languages, sent to more than 150 experts, with three distinct sections: 1) general information; 2) future needs and market tendencies; 3) essential technological needs.

STEP 3 : **Workshops pertaining to:** 1) aluminium production and equipment suppliers; 2) the transportation industry; and 3) the construction industry and electricity. In all, about **60 specialists** took part in the creation of the Technology Roadmap through the formulation of projects and participation in workshops. Overall, **47 projects were adopted** from the 116 submitted and analyzed by the experts.

47 projects were adopted

GENERAL PORTRAIT OF THE INDUSTRY

In 1999 global aluminium production reached 23.5 million tons. The aluminium industry is characterized, however, by greater world production than consumption. According to forecasts, aluminium consumption should exceed world production around 2003, when production reaches 27 million tons. Based on this data, the aluminium industry should continue to flourish on the global scene. If the Canadian Aluminium Industry positions itself advantageously on the world market, it will be able to profit from this anticipated growth.

Since 1994 Canada has lost 1.3% of relative market share to countries having significantly greater relative growth (South Africa, China, Australia). On the other hand, the addition of a new Alcan aluminium smelter in Alma (Québec) in 2002 will make it possible for the Canadian Aluminium Industry to increase production relative to world averages and preserve its **fourth place ranking.**

Canada represents 10.5% of world production

To preserve a competitive position as a leader in aluminium production, Canada must develop technology to lower the cost of producing aluminium. Unfortunately, during the last ten years, the average level of **R&D activities** in the production and non-ferrous metal transformation sectors **was only about half that** (0.75%) **of Canadian manufacturing companies** (1.13%).

Lacking R & D on aluminium in Canada

In light of these statistics, it is urgent to put forth the most relevant and promising technological projects, with the aim of allowing the industry to preserve and even increase its ranking among the more significant aluminium producing countries. The Canadian Aluminium Industry does not conduct enough research and development, particularly on ways to reduce production costs. This is a important venture for Canada, because new production factories are being located in countries where production costs are more advantageous.

PARTICULAR : CANADIAN EQUIPMENT SUPPLIERS

The last fifty years has seen the emergence of equipment suppliers capable of providing specialized equipment to the global aluminium industry. Good examples of this type of equipment are electrolytic cells, semi-continuous casting tables and anode changers.

The growth potential of Canadian **equipment suppliers** is enormous. Canadian expertise could be better exploited on the world market. For example in countries like China or South Africa where smelting facilities are developing. However, although the potential is great, many challenges still remain, such as:

- Establishing closer links with Canadian producers of primary aluminium;
- Obtaining or maintaining world class status in the fields of scientific and technological knowledge;
- Developing innovative technologies;
- Marketing and promoting Canadian equipment throughout the world

ISSUE

In 1999 Canada produced 2.38 million tons of aluminium, 90% of which came from Québec. Close to 85% of Canadian production is exported to the United States, Europe and Asia. With 15% of world aluminium exports, Canada is the second largest exporter of primary aluminium behind the C.I.S. (Russia) (22%). More than 80% of the aluminium exported is in the form of ingots.

Canada, the second largest exporter of aluminium

Although Canada is one of the largest producers of aluminium, it annually imports 0.55 million tons of aluminium, and 75% of these imports are semi-finished products (extruded, rolled and moulded products) manufactured in the United States and Europe. According to the experts, compared with national primary aluminium consumption, the proportion of imports is very high.

This poses an essential question: **Could Canadian companies manufacture semi-finished products here, instead of elsewhere, from Canadian primary aluminium?** This question is complex and requires a thorough costs/benefit analysis. Canadian institutions can, however, begin contemplating this matter.

FIRST ALUMINIUM TRANSFORMATION

The world production of semi-finished products experienced a sustained growth of about 6% over the last five years, rising to more than **30.5 million tons** in 1997. Production is divided into three large sectors: rolled products (41%), extruded products (35%) and cast products (24%).

Sustained growth of semi-finished products

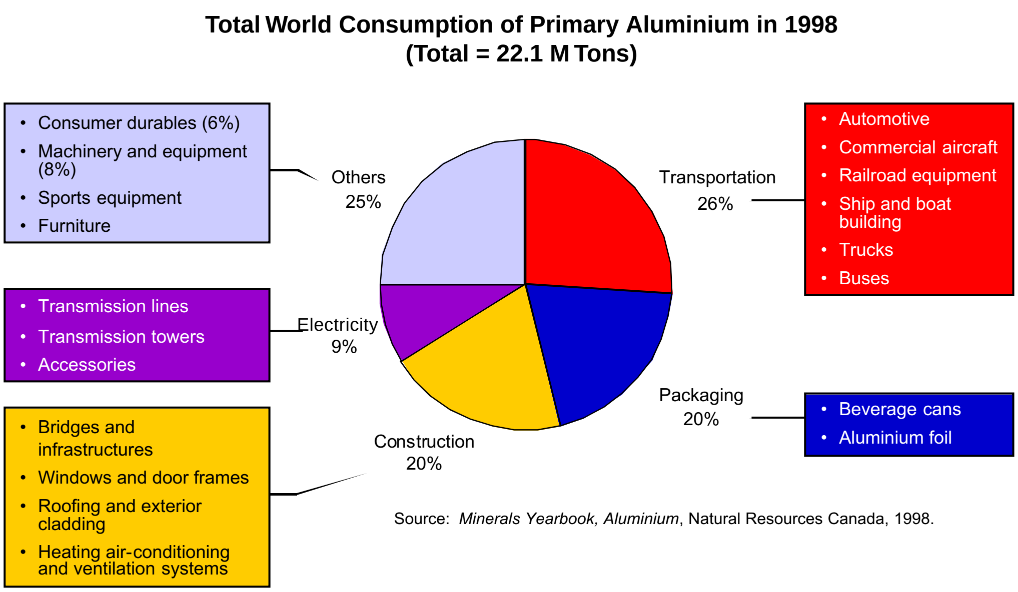
Although extruded and rolled products represent the applications of greatest demand by aluminium users, casting is experiencing substantial growth due to its importance to the transportation industry, particularly the automobile sector. World wide, Canada has experienced the greatest annual growth in all three products. In 1997 Canadian production of:

- Rolled products rose 290 000 tons (8% increase since 1993);
- Extruded products rose 190 000 tons (10% increase since 1993);
- cast products rose 185 000 tons (9.5% increase since1993).

SECOND ALUMINIUM TRANSFORMATION

World consumption of aluminium is concentrated in four large industrial sectors that account for 75% of the aluminium consumed in 1998 (see Figure 1)**: transportation, packaging, construction and electricity.** It is forecast that for the period from 1995 to 2015, the transportation sector will experience the largest annual growth (3.5%).

Figure 1

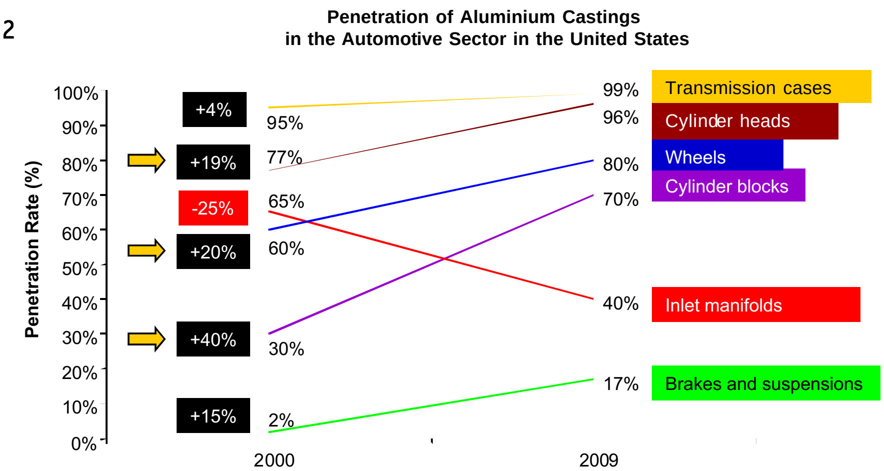


Source: *Minerals Yearbook, Aluminium*, Natural Resources Canada, 1998.

Important breakthroughs in the automobile sector

Over the years, aluminium has become increasingly popular in the automobile sector. From 1991 to 1999, the quantity of aluminium used in vehicle production in North America, Japan and Western Europe rose 5% annually. It is anticipated that aluminium use in North American vehicle production will exceed 58 million tons in 2001; and this trend should have a considerable impact on the industry. According to industry specialists, cylinder blocks (+40%), wheels (+20%) and cylinder heads (+19%) are the automobile components that will show the greatest increase in aluminium usage between 2000 and 2009.

Figure 2



Source*: Modern Casting,* "Total U.S. Casting Demand Forecast in 2000", January 2000

MARKET NEEDS : PRINCIPAL VENTURES

The Technology Roadmap presents common ventures for all sectors of the aluminium industry and the new challenges that the industry must address. For a strong and competitive industry that also supports job creation, it is essential to fully understand the impact of the ventures of each sector and to find long-term solutions.

As illustrated in Table 1, the relative importance of identified ventures varies from one sector of the industry to another. It goes without saying that a better perception of their relative importance facilitates the choice of technological projects and focuses expert recommendations.

Tableau 1

Principal Venture	Aluminium Production and Equipment Suppliers	Primary Transformation (rolling, casting, extruding)	Secondary Transformation: Construction and Electricity	Secondary Transformation: Transportation
Reduce Costs	✪✪✪✪✪	✪✪✪✪✪	✪✪✪	✪✪✪✪✪
Respect Regulations	✪	✪	✪	✪✪
Decrease Energy Consumption	✪✪	✪	✪	✪✪✪
Respect the Environment	✪✪✪	✪	✪	✪✪✪
Increase Level of Quality	✪✪	✪✪✪	✪✪	✪✪
Develop and Diffuse Knowledge	✪	✪✪	✪✪✪✪✪	✪
Develop Markets	✪✪	✪✪✪	✪✪✪✪	✪
Develop Alloys/Materials	✪	✪✪	✪	✪✪

Legend: ✪✪✪✪✪ = strong priority
✪ = weak priority

1 Ducker Research Company, Passenger Car and Light Truck Aluminum Content Report, 1999.

At the present time, the three most significant needs for the Canadian Aluminium Industry are to:

1. Reduce costs and increase productivity

The construction of new and more efficient aluminium smelters throughout the world increases the need to reduce aluminium production costs. Cost reduction is also necessary for manufacturing aluminium products, including the design stage.

2. Develop and diffuse knowledge

In an increasingly knowledge-based economy, intellectual capital replaces natural resources as one of the leading determinants of a country's economic strength and competitiveness. In the construction industry, for example, there exists a lack of knowledge of available aluminium technologies, and there is little relevant research in the field. Companies need to increase their understanding of the intrinsic characteristics and various applications of aluminium.

3. Develop markets

In addition to improving characteristics of aluminium products, the development of new applications and new markets constitute significant steps in ensuring the future growth of the industry.

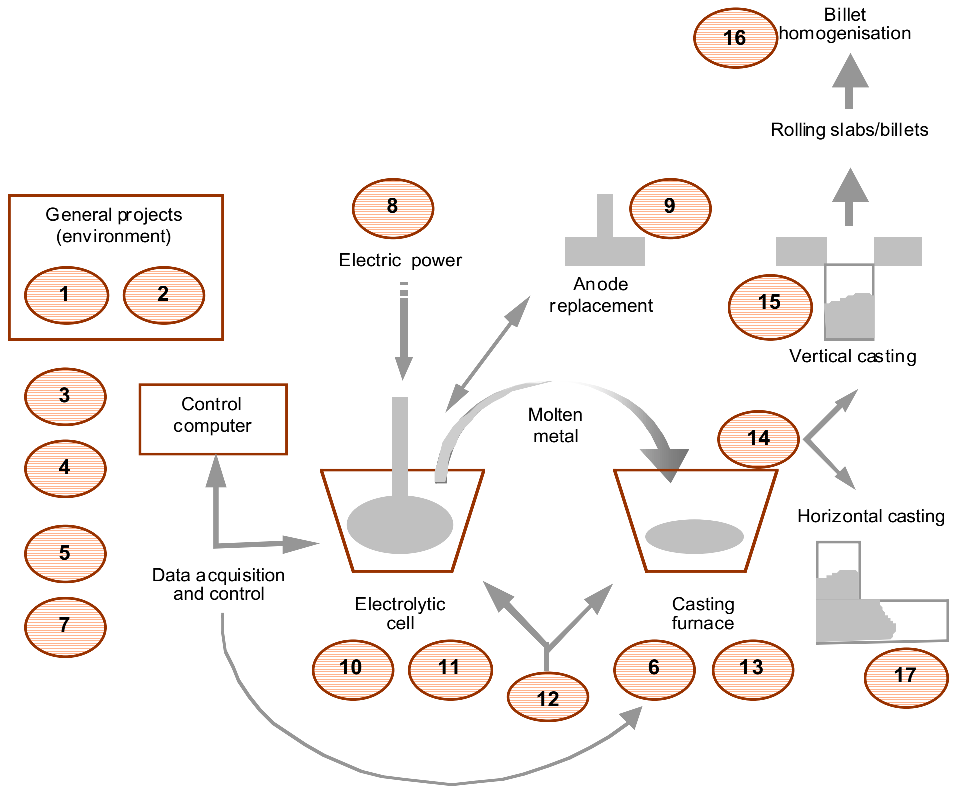
TECHNOLOGICAL PROJECTS

After having identified the key sectors and examined their principal ventures, the experts at the workshops and the steering committee determined the technologies judged to be essential in allowing the industry to meet market needs for the next 10 years.

On the whole, 47 technological projects were adopted and analyzed. The first 17 technological projects are related to aluminium production, whereas the others are associated with first and second aluminium transformation. **These project lists are reproduced in Figures 3 and 4, which illustrate the interrelationships of the projects.**

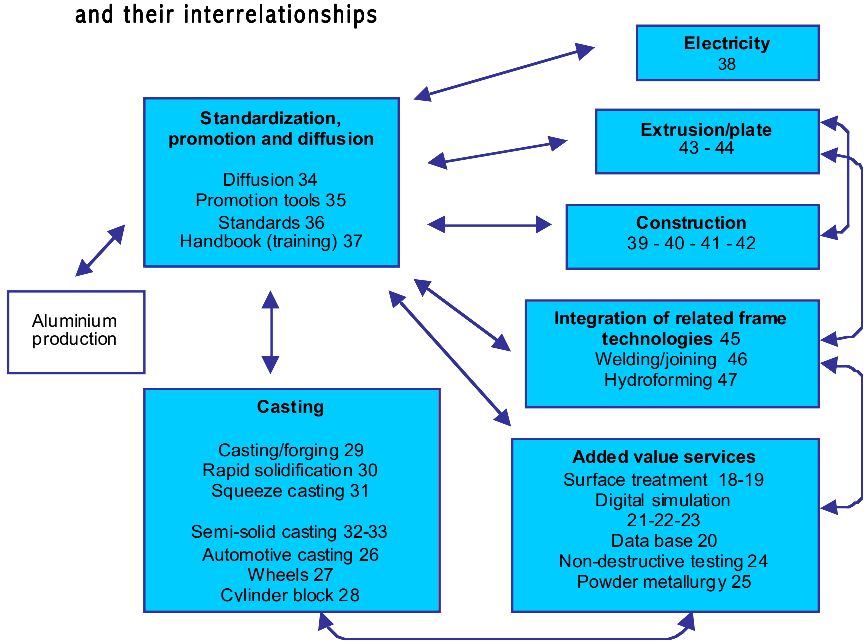
These are real and relevant projects because they precisely meet the market needs and take into account current Canadian priorities. Other technological projects can be added to this list since the Technology Roadmap is continuously being updated so as to take into account market trends.

Figure 3 List of technological projects for aluminium production and their interrelations



1. Environmental technological programs to reduce solid and liquid waste and gas emissions.
2. Recycling technologies for products with high aluminium content
3. Specialized heuristic control systems (creation of algorithms)
4. Dynamic model for the control and operation of cells (process model)
5. Specialized sensor pot signals (continuous recording parameters)
6. Continuous reading/monitoring of the metal quality
7. Thermocouples and probes resistant to liquid bath (new materials)
8. Technologies to lower the energy consumption of electrolytic cells (without increasing production costs)
9. Automation technologies to replace anodes in the electrolytic cell
10. Unified model to design (or modify) electrolytic cells
11. New materials (cathode) to contain electrolyte and molten metal
12. Technico-economic analysis tools for research and development projects in electrolysis and D.C. casting
13. Liquid-aluminium-resistant materials (e.g. refractory concrete in the casting furnace/transport containers of molten aluminium)
14. Modelling solidification phenomena to reduce waste and improve recovery and quality of the casting
15. Vertical casting technologies for ingots and rods
16. Technologies allowing billet homogeneity produced in D.C. casting
17. Technologies allowing improvement of continuous horizontal casting

Figure 4 List of technological projects of the primary and secondary aluminium transformation sectors and their interrelationships



18. Ion Implantation technologies (or PVD) for surface treatments
19. Aluminium-based coating
20. Data base on the alloy composition according to the form
21. Digital simulation of mould filling and solidification
22. Process simulation (rolling, extrusion, casting, forging)
23. Improved modelling tools for die design
24. Improved techniques for non-destructive testing of parts (automation)
25. Powder metallurgy
26. Manufacture of aluminium castings for the transportation industry
27. Casting technologies of aluminium wheels for trucks (to ensure technology transfer)
28. Develop SHLP process (Sand Hybrid Low Pressure) for cylinder block production
29. New casting and forging techniques
30. Rapid solidification technologies for casting parts
31. New casting and forging techniques (squeeze casting)
32. Semi-solid casting technology
33. Semi-solid forming technology (SSF-feedstock preparation)
34. Creation and dissemination of standards and knowledge
35. Strategy and mechanisms to increase awareness of aluminium
36. Calculation standards (aluminium uses)
37. Handbook and computation software adapted to the design of aluminium
38. High-temperature conductors for transmission lines
39. Life Cycle Cost Model
40. Effective project delivery systems (modular design)
41. Mechanical assembly joints (field connections) to assemble structural elements
42. Bridge construction (and restoration of bridge decks) using aluminium
43. Transfer of extrusion technologies using specific alloys (at competitive costs)
44. Improved range of structural products available (extrusion, plates) on the Canadian market
45. Technologies relating to manufacture of vehicle frame
46. Innovative welding/joining techniques
47. Hydroforming technology

RECOMMENDATIONS

At the present time, the greatest challenge facing the Canadian Aluminium Industry is to remain at the forefront in the race among countries that produce and transform aluminium.

With this in mind, the experts made the following recommendations taking into account. Not only the technical and technological issues but also the broader social and environmental issues as well.

1. Create a Canadian aluminium research and development institute;
2. Ensure the follow-up of the Technology Roadmap on an annual basis;
3. Coordinate research and development activities;
4. Encourage the development of equipment for the aluminium production sector and develop software for all sectors of the industry;
5. Support development related to value-added products;
6. Reinforce linkages among industries, universities and research centres;
7. Create specialized aluminium teaching/training programmes;
8. Conduct market surveys on various aluminium manufacturing sectors and disseminate the findings.

CONCLUSION

The first objective of the Canadian Aluminium Industry Technology Roadmap was to start discussion and to create constructive exchanges between members of the industry and their many partners: equipment suppliers, research organizations, universities and governments.

The publication of this document is not an end in itself, but the beginning of a long process of collaboration with all partners. It identifies technological projects aimed at making the Canadian Aluminium Industry even more competitive in international markets.

The expert consultations made it possible to clarify several industry needs; the three principal ones being: reduce costs and increase productivity, develop and disseminate knowledge, and develop markets. To date, 47 technological projects have been adopted and analyzed according to these criteria and by taking into account current Canadian priorities.

The future of the Canadian Aluminium Industry and its leadership in the international scene does not, however, depend solely on its technological successes. Other global and related mechanisms must be considered and addressed to ensure the realisation of the potential benefits of technological innovation. Developed by and for the Canadian Aluminium Industry and therefore tailored specifically for its needs, this report can be used as a starting point for discussions and an instrument to develop and implement future integrative projects, such as the establishment of a Canadian aluminium research and development institute.

TABLE OF CONTENTS

FIGURES

TABLES

INTRODUCTION

The aluminium industry—one of the nation's leading employers—is a cornerstone of the Canadian economy. The aluminium production and primary and secondary transformation sectors employ approximately **20,000 workers** and generate economic benefits in the order of **$8.3 billion per year.** Close to 80% of production is exported.

In Canada as in other countries **aluminium has been produced on an industrial scale for slightly over a century**, while iron and copper have been in use for thousands of years. However, its properties, namely, its light weight, mechanical strength, thermal conductivity, and resistance to corrosion, have spurred its phenomenal growth over the past decades.

Aluminium, whether in pure or alloy form, is used in a wide variety of semi-finished (rolled products, rods and wires, extrusions, and castings) and finished products for the consumer durable goods market (automobiles, aircraft, containers, ships, bicycles, machinery, building materials, etc.). Given its remarkably short history, aluminium's performance and rate of growth have been impressive. Its future seems bright, although the steel industry, ever a direct competitor, has yet to throw in the towel. For example, the steel industry is intent on regaining lost ground in growth areas such as the automobile industry. Furthermore, many substitutes, such as magnesium and polymers, are also giving aluminium a run for its money. Polymers especially are gaining market shares in areas such as containers, packaging, and doors and windows.

The aluminium industry generates benefits of $8.3 billion per year

Despite aluminium's success over the past decade, many challenges remain. For the Canadian aluminium industry to continue to grow while remaining competitive, it must coordinate its efforts and successfully meet the technological challenges to come.

In this context, **the technology roadmap is an invaluable tool** in helping us understand future market trends, technological innovation, research and development, and technology transfer. It will allow the Canadian aluminium industry to make technological forecasts as well as better and more informed strategic choices.

Intensive consultations

In light of new market trends, the Canadian Aluminium Industry Technology Roadmap may seem ambitious, but it is realistic and practicable thanks to the firm resolve demonstrated at various levels of the industry. The roadmap was developed following intensive consultations with all public and private sector stakeholders, who can be expected to cooperate fully in its implementation. This is a fine example of cooperation between government and industry!

WHAT IS A TECHNOLOGY ROADMAP?

A technology roadmap is a practical forecasting tool whereby aluminium production and transformation industries identify their future technological needs and define the strategic directions required to meet them.

A strategic planning tool

A technology roadmap is a chronological representation of various technological projects under way to create products. It is both a statement of market needs and an analysis framework enabling the industry to take a systematic approach to meeting such needs.

Development of a technology roadmap requires forecasting:

1. market needs (major challenges); and
2. their effects on technologies and products (semi-finished and finished).

Once the technology roadmap is complete, the industry must conceive and implement the technological projects it identifies. Throughout the process government officials will act as facilitators and catalysts.

It must be emphasized that the process is iterative in nature, meaning that the Canadian Aluminium Industry Technology Roadmap will be updated on a regular basis to account for changes in market requirements and to allow firms to adjust to scientific and technological developments.

THE PURPOSE OF THE TECHNOLOGY ROADMAP

To help the Canadian aluminium production and primary and secondary transformation industries as well as equipment suppliers become global leaders while allowing them to adequately fulfil the growing requirements of their respective clients.

Canada must innovate

Growth of the Canadian aluminium industry has always been driven by technological innovation. Following consolidation and globalization of trade and the construction of plants using ever more efficient production techniques, the challenge we now face is to maintain our current pace and make the proper choices pertaining to technological innovation. These choices must be congruent with market change and consumer requirements, while ensuring the prosperity of the industry.

The aluminium technology roadmap is meant to be a practical guide to assist the industry in meeting multiple technological challenges by:

- Underscoring the importance of innovation in the major aluminium production and transformation sectors;
- Identifying emerging and promising technologies;
- Making recommendations with respect to infrastructure and marshalling the potential to assist the various industry sectors in moving into the fast lane; and
- Suggesting future priorities.

Created BY and FOR the stakeholders of the Canadian aluminium industry and aimed at a broad audience, the technology roadmap speaks to organizations, sectorial specialists, leaders, researchers, equipment suppliers, decision makers in the public and private sectors, and educators. It is a tool of choice for all parties to plan their activities, clarify their priorities, and establish their strategic orientations.

It is our wish that this first Canadian Aluminium Industry Technology Roadmap will stimulate discussion and debate, facilitate decision making related to investment, training, and policy, and give direction to new research programs within the industry.

THE BENEFITS OF THE TECHNOLOGY ROADMAP

The technology roadmap provides numerous benefits to decision makers within the aluminium industry who wish to set their new research programs on a proper course:

- Clearer definition of roles and responsibilities of the various industry players;
- Diminished technological risks due to a multitude of approaches;
- Increased networking possibilities, leading to joint development projects involving the private and public sectors;
- Ability to develop and maintain leading-edge technologies and seize business opportunities in line with recent market trends; and
- Increased competitiveness of the various aluminium production and transformation sectors through cooperation and knowledge sharing.

Regular update

In brief, the exchange of information and the ongoing dialogue among private and public sector organizations make the technology roadmap a reference document in support of policy development and objective setting for the aluminium industry and the governments of Canada. It is essential that discussions and dynamic exchanges be pursued among all stakeholders with a view to maintaining roadmap currency.

CONTEXT

Many countries have already availed themselves of technology roadmaps in all areas of burgeoning economic activity. In most cases there have been substantive benefits in terms of new technology development.

In 1997, for example, the Aluminium Association Inc., in cooperation with the U.S. Department of Energy, produced a technology roadmap of the American aluminium industry. Two years later, in May 1999, a new aluminium technology roadmap for the automobile market was finalized. These initiatives and their outcomes led the United States to launch several R&D projects.

This document highlights the drivers of technology development within the Canadian aluminium industry.

A totally new approach

The first Canadian Aluminium Industry Technology Roadmap suggests various avenues for ensuring technological advancement within the industry and related sectors based on the development of efficient and durable products. While a good many technological challenges set out in the American technology roadmaps also apply to Canada, it is clear that the Canadian aluminium industry has intrinsic features to be considered in setting technological priorities. The Canadian roadmap places particular emphasis on the capital equipment industry, the transportation industry, as well as on construction and electricity, thus taking an entirely new approach.

METHODOLOGY

The first edition of the Canadian Aluminium Industry Technology Roadmap is the result of **a process which lasted nearly one year**. To ensure the validity of the roadmap, a rigorous procedure was followed including an extensive literature review and intensive consultations with many Canadian sectorial experts.

STEP 1: INDUSTRY PORTRAIT

In order to draw up a portrait of the Canadian aluminium industry, we reviewed all available literature and collected relevant data on the production and primary and secondary transformation sectors. To this end we consulted many sources of information: American technology roadmaps on aluminium; industry journals; market surveys; world databanks; annual company reports; Internet sites; as well as documentation from Industry Canada, Natural Resources Canada, research centres, and various universities. Moreover, we sought the views of many internationally recognized experts.

The overall portrait of the aluminium industry brings to the fore the strengths and weaknesses of each sector under study, market trends, and Canada's position in the global matrix. An initial report was tabled with the members of the technology roadmap steering committee. Specifically, the report provides:

- A profile of the Canadian aluminium production and primary and secondary transformation sectors;
- A listing of the most promising consumer goods sectors;
- A portrait of goods and service providers to firms within the aluminium production and transformation sectors; and
- An overview of current Canadian research and technologies.

Over 100 participants

This step provided an opportunity for in-depth analysis of the major challenges which the Canadian aluminium industry will have to meet in the coming years. For ease of reference, the roadmap only deals with the aluminium industry's main features. (Please refer to the section titled "The Canadian Aluminium Industry.")

STEP 2: SURVEYS OF INDUSTRY SPECIALISTS

We next distributed a questionnaire, in both of Canada's official languages, to **over 150 experts** in all industry segments across Canada. The questionnaire was developed by market survey specialists and approved by the project steering committee.

The questionnaire contained three distinct sections: 1) general information; 2) future needs and market trends; and 3) essential technological needs.

STEP 3: WORKSHOPS

The questionnaire led to no less than 116 projects being submitted by experts, who then took an active part in workshops pertaining to: 1) aluminium production and equipment suppliers; 2) the transportation industry; and 3) the construction industry and electricity.

All told, **approximately 60 specialists took part in the roadmap design process** through project development and attendance at workshops. This number does not include members of the steering committee, who were present throughout the process.

Among workshop outcomes were the validation of questionnaire content, the achievement of a consensus among experts and the identification of eight major challenges related to market trends.

47 projects were selected

The primary purpose of a technology roadmap is to foster the emergence of technical projects that are viable in all industry segments; **47 projects were selected among the 116 submissions and analyzed by experts.**

Experts based their selection on the following criteria:

- Relevance and relative importance of submissions;
- Project timelines;
- Challenges and technological risks associated with the projects; and
- Their impact on the various market requirements.

The steering committee and the specialists from various sectors joined efforts to analyze, validate, organize and enhance information collected pertaining to market trends and the various technological projects. The consultation process proved to be extremely satisfactory and brought to light the current position of the aluminium industry.

STEP 4: TECHNOLOGY ROADMAP REPORT PREPARATION

After we reviewed all available literature on the aluminium industry, compiled questionnaire responses and brought our experts together in workshops to select those technological projects which would determine industry direction in future years, we established an editorial and review committee whose task it was to prepare the Canadian Aluminium Industry Technology Roadmap report, of which this is the final version.

THE CANADIAN ALUMINIUM INDUSTRY

World production will exceed 27 million tons in 2003

The purpose of this section is to briefly describe the aluminium industry in Canada. The aluminium production sector and the equipment supplier branch are dealt with in the first instance, followed by the primary transformation sector and, finally, the secondary transformation sector.

The many aluminium industry stakeholders view transformation in various ways. It is therefore essential to define our terminology to avoid any confusion in the use of the technology roadmap.

As suggested by the Aluminum Association of Canada, production, and primary and secondary transformation are defined as follows:

Aluminium production (primary aluminium)

Aluminium produced from raw materials (bauxite, alumina).

Primary transformation

Transformation of metal made from crude aluminium. Generally speaking, primary transformation results in the production of semi-finished goods (sheets, extrusions, drawing stock, etc.) used in manufacturing more complex products or intended for further transformation. However, these operations may also result in the production of finished goods (aluminium foil, cables, etc.). Rolling, wire drawing, and extrusion are the main primary transformation techniques.

Secondary transformation

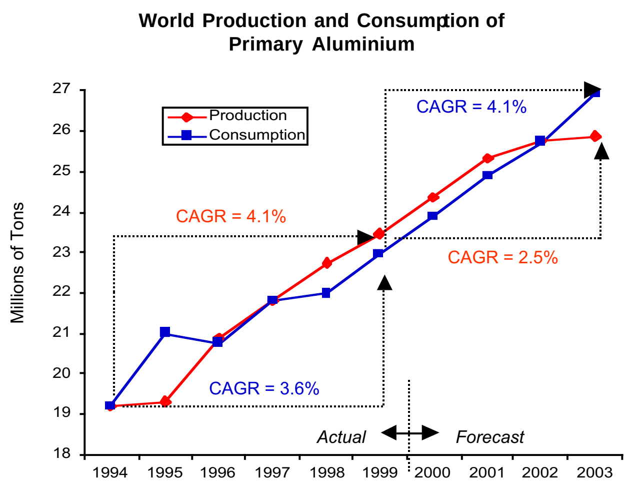
Transformation of aluminium having undergone primary transformation. The product thus transformed is generally at the end of the production process and is considered a finished product (doors, windows, cans, automobile parts, etc.).

CANADIAN ALUMINIUM PRODUCTION

The industrial process known as aluminium electrolysis was discovered in 1886 by Paul-Louis Toussaint Héroult and Charles Martin Hall. The process, which has been continuously refined, is based on the use of a powerful electric current to decompose alumina. The reaction takes place within large pots through which a continuous electrical discharge is directed. The bottom of each receptacle serves as a cathode, while suspended carbon blocks serve as anodes. Alumina is dissolved within the pots in a cryolite and aluminium fluoride electrolyte. When an electrical current is run through the mixture, from the anode to the cathode, the desired effect is obtained. Modern processes require a current in excess of 300,000 amperes. They consume large quantities of electrical power varying from 13 to 17 kilowatt-hours per kilogram of metal. Aluminium is drawn into a melting pot at regular intervals and transferred to a holding furnace where alloys are prepared. Once its composition has been analyzed, aluminium is normally made into ingots whose shape depends on the transformation process for which they are intended.

World production and consumption of primary aluminium are constantly on the rise. From 1944 to 1999 world primary aluminium production grew unfailingly at a compound annual growth rate (CAGR) of 4.1% (see figure 1). **In 1999, 23.5 million tons of aluminium were produced**[2]. That said, the aluminium industry is nonetheless characterized by world production levels in excess of consumption. According to forecasts, aluminium consumption should exceed world production around 2003, when production reaches 27 million tons.

Figure 1

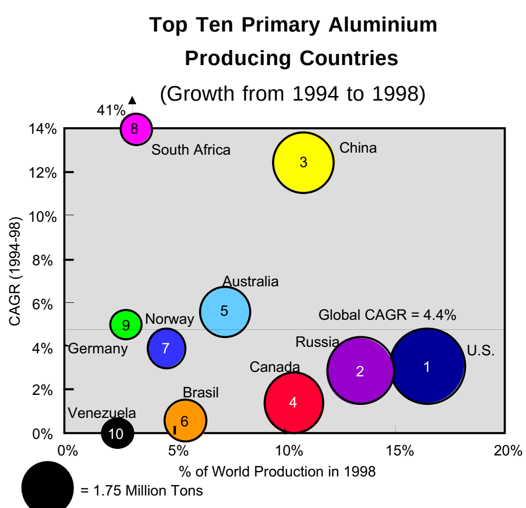


Source: *World Capacity and Market Report for Primary Aluminium*, James King, January 2000

Based on the above data, and assuming that no recession will upset our scenario, the aluminium industry should retain its overall positive trend. Should the Canadian aluminium industry position itself favourably in world markets, it could benefit from projected growth.

Canada accounts for 10.5% of world production

Figure 2



Source: *World Capacity and Market Report for Primary Aluminium*, James King, August 1999.

For years readily available electrical energy at competitive prices and a positive social and economic environment enabled Canada to rank third among aluminium producing countries. In 1998, however, China was able to overtake Canada, having recorded a CAGR of 12% over the four previous years (see figure 2). Canada now ranks fourth with 10.5% of world primary aluminium production, behind the United States (17%), the Commonwealth of Independent States (13.5%), and China (12%).

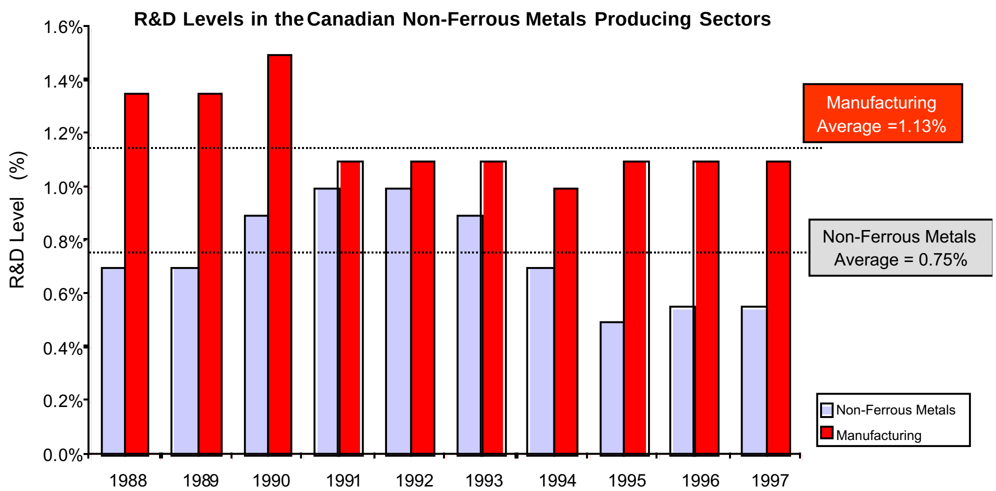
[2] Nearly 40% of total world aluminium demand is met by recycled, or secondary, aluminium

Since 1994 Canada has lost 1.3% of relative market share to countries enjoying significantly greater relative growth (South Africa, China, Australia). On the other hand, the addition of a new Alcan aluminium smelter in Alma (Québec) in 2002 will make it possible for the Canadian aluminium industry to increase production to world averages and preserve its fourth place ranking.

Insufficient aluminium R&D in Canada

To preserve a competitive position as a leader in aluminium production, Canada must develop technology to lower the cost of producing aluminium. Unfortunately, over the last ten years the average level of **R&D activities** in the non-ferrous metals production and transformation sector **was only about half that of Canadian manufacturing companies** (0.75% in comparison of 1.13%)[3], as shown in the following figure.

Figure 3



Source: *Minerals Yearbook, Aluminium*, Natural Resouces Canada, 1998.
Note: R&D Level = R&D Expenditures/Total Shipments.

In light of these statistics, it is essential to put forth the most relevant and promising technological projects, with the aim of allowing the industry to preserve and even increase its ranking among the most significant aluminium producing countries. The Canadian aluminium industry does not conduct enough research and development, particularly on ways to reduce production costs. This is an important challenge for Canada, because new production plants are being located in countries where product costs are lowest.

THE CAPITAL EQUIPMENT INDUSTRY AND ALUMINIUM PRODUCTION

Relatively little data is available on Canadian equipment suppliers, especially with regard to internal operations. Moreover, the size of the equipment market is difficult to quantify, inasmuch as equipment suppliers' sales figures are distributed among several domestic accounting systems and are not recorded as such by any international organization. Despite the dearth of data, certain trends may be observed among Canadian equipment suppliers.

[3] Source: Mineral Yearbook, "Aluminium," Natural Resources Canada, 1998.

EMERGENCE OF THE CAPITAL EQUIPMENT INDUSTRY

The aluminium industry is approximately a century old. Over its first 50 years the market was shared by a small number of major producers whose research facilities and production workshops were capable of developing and sometimes even producing required equipment. Over the past 50 years a global capital equipment industry has emerged, with the ability to provide specialized equipment to the aluminium industry around the world. Good examples of this type of equipment are electrolytic cells, semi-continuous casting tables and anode changers.

A number of major aluminium producers, such as Péchiney, Alcoa, Alusuisse and Alcan, remain major equipment suppliers with varying levels of operations. It may be stated, however, that primary aluminium producers now concentrate to a greater extent on deriving the utmost benefit from their considerable investments, by virtue of the fact that equipment development is conducted in cooperation with equipment suppliers. Briefly stated, equipment suppliers now possess substantial holdings of aluminium production technology and several, such as Wagstaff (semi-continuous casting moulds), ECL (anode changers), and KHD (anode manufacturing), are leaders in their field.

High performance standards

Client requirements and the general population hold the aluminium industry to stringent performance standards. These requirements pertain, for example, to product quality, costing, delivery reliability, industrial relations and plant safety, as well as environmental protection. The resulting constraints are being passed on to equipment suppliers, whose responsibilities are essentially the same. Furthermore, the industry has matured: its operations are now grounded on a substantial scientific and technical knowledge base, the essentials of which must be shared with equipment suppliers, as dictated by their field of operations. Finally, given that several aluminium producers are global firms, their equipment suppliers must conduct their activity at the international level.

CHALLENGES FACING CANADIAN EQUIPMENT SUPPLIERS

The considerable size of Canadian aluminium production must not obscure the fact that 90% of primary aluminium production is foreign-based. Additionally, the service life of equipment is high (between 10 and 50 years or more) and the flow of new investments can only be considered on a global level.

Conquering international markets

It follows that Canadian firms within the sector are part of an export market, in which they must vie with competitors who operate in similar conditions. Within this market major promising technologies originate in Western Europe and the United States. Furthermore, companies within these countries have traditionally supplied the primary aluminium industry exclusively. They therefore enjoy a significant competitive edge.

Canada has a dozen or so major suppliers specialized in various types of equipment. Three of them are of world class. The other, smaller, firms were able to gain expertise in the local market through Canadian aluminium plant building projects carried out over the past decades.

Tremendous growth potential

The growth potential of Canadian equipment suppliers is enormous. Canadian expertise could be better exploited on the world market in countries like China or South Africa , for example, where building projects are under way. However, although the potential is great, many challenges still remain, such as:

- Establishing closer links with Canadian producers of primary aluminium, who make use of the majority of technologies applied throughout the world, to identify business opportunities, gather privileged information and potentially demonstrate new improved technologies. In this regard, more formal co-operative arrangements are required;
- Emulating Canadian producers of primary aluminium by obtaining or maintaining world class status in the fields of scientific and technological knowledge. To do so will require partnering with universities, government R&D centres and other companies;
- Developing innovative technologies. Canadian equipment suppliers market several products under license; and
- Marketing and promoting Canadian equipment throughout the world.

IS CANADA CAPABLE OF REDUCING ITS RELIANCE ON SEMI-FINISHED PRODUCT IMPORTS?

Canada is the second largest exporter of aluminium

In 1999 Canada produced 2.38 million tons of aluminium, 90% of which came from Québec.[4] Close to 85% of Canadian production is exported to the United States, Europe and Asia.[5] With 15% of world aluminium exports, Canada is the second largest exporter of primary aluminium behind the CIS-Russia (22%).[6] More than 80% of the aluminium exported is in the form of ingots.[7]

According to the *Aluminium Statistical Review* (1997), although Canada ranks among the largest producers of aluminium, it annually imports 0.55 million tons of aluminium, 75% of which are semi-finished products (extrusions, rolled products, and castings) manufactured in the United States and Europe. According to the experts, compared with national primary aluminium consumption, the proportion of imports is very high.

According to the latest statistics from Industry Canada, **imports are largely made up of sheets**, and these products are therefore a major cause of the **negative Canadian trade balance**, with an annual deficit of **$466 million** (see figure 4). In Canada as in other countries the aeronautics industry is a major user of sheet aluminium. Canadair, for example, imports large quantities of these products from the American markets.

Castings also contribute to the negative Canadian trade balance, with a deficit of $67 million.

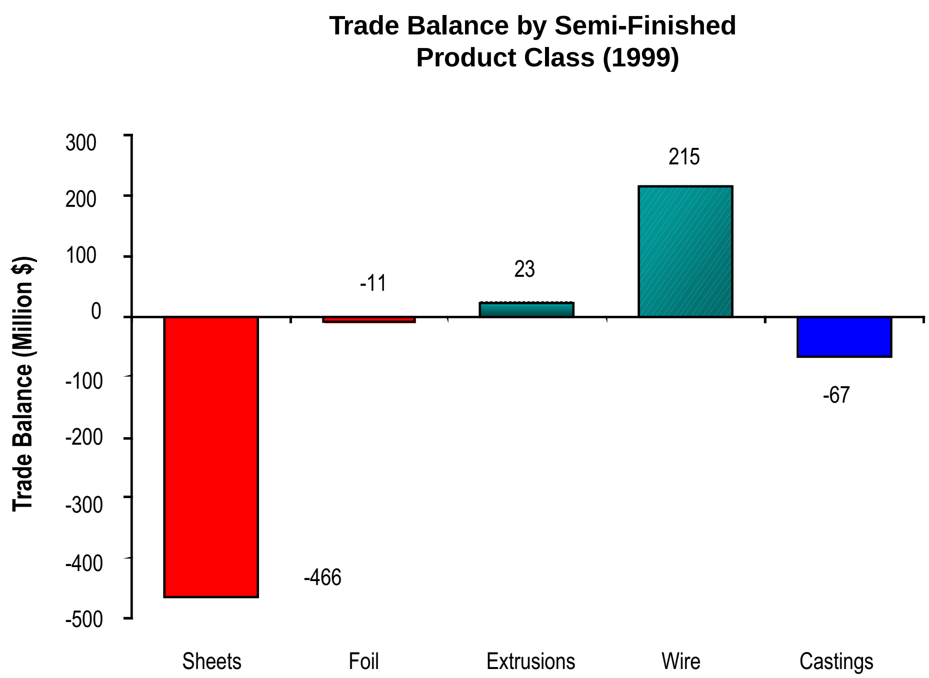
4 Source: Minerals Yearbook, "Aluminium," Natural Resources Canada, 1998.

5 Source: Aluminium Association of Canada.

6 Source: World Capacity and Market Report for Primary Aluminium, James King, August 1999.

7 Source: The Aluminium Statistical Review, 1997.

Figure 4



Source: *The Aluminium Semi-fabricating Industry*, Industry Canada, 1999.

Canada's particular situation as both a major producer and a major exporter of aluminium is mainly due to the nature of the Canadian aluminium industry. The availability of hydroelectric facilities and a qualified workforce facilitate aluminium production, particularly in Québec. However, the transformation of ingots into semi-finished products often occurs close to major consumer markets such as the United States. Plant location and supply logistics are key variables that determine the profitability of primary and secondary transformation operations. This explains in part Canada's prominent roles as both an exporter and an importer of aluminium.

This begs an essential question: **Could Canadian companies manufacture semi-finished products domestically from Canadian primary aluminium?** The question is complex and requires a thorough cost/benefit analysis. Canadian institutions can, however, begin contemplating the matter.

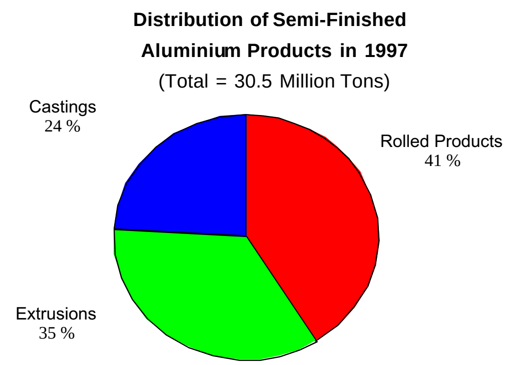
THE PRIMARY ALUMINIUM TRANSFORMATION SECTORS

World production of aluminium semi-finished products grew steadily at a rate of approximately 6% over the past five years. It exceeded **30.5 million tons** in 1997 and is concentrated in three major sectors, as shown in the accompanying figure: rolled products (41%), extrusions (35%), and castings (24%). While extrusions and rolled products are in strong demand by users of the metal, the demand for castings is growing substantially due to its significance in the transportation industry, especially in the automobile sector.

Steady growth in semi-finished products

Thus, over the period 1993-1997, rolled products accounted for 41% of the market, with an annual growth rate of 5%, whereas castings rose by 7% annually, despite the fact that they made up only 24% of world tonnage. Extrusions (35%) were up 6.5% per annum from 1993 to 1997.

Figure 5

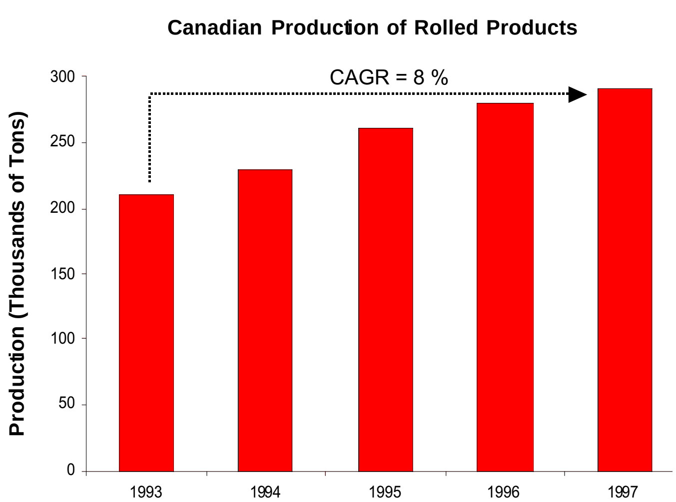


Source: *World Capacity and Production Report*, James King, June 1998

ROLLED PRODUCTS

The first step of the aluminium rolling process normally consists in thinning a thick slab of primary aluminium. The slab is softened through preheating, a process which also ensures homogeneity, and is then rolled repeatedly between pressure cylinders which are tightened after each rolling pass. The slab is thus laminated and lengthened, though its width is unchanged. Cold rolling is generally performed, and the slab is gradually transformed into plates of varying thickness.

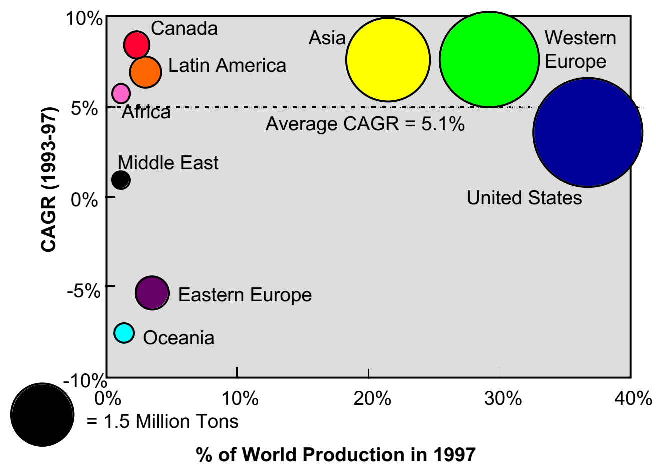
Figure 6



Source: *World Capacity and Production Report*, James King, June 1998

In 1997, Canada produced 290,000 tons of rolled products, as shown in Figure 6. Though it accounts for a mere 2.3% of world production, **Canada had the highest annual growth rate**, with a rise in production of 8% since 1993, as shown in the figure on the right. Major world producers of rolled products are the United States (37%), Western Europe (28%), and Asia (22%).

Figure 7



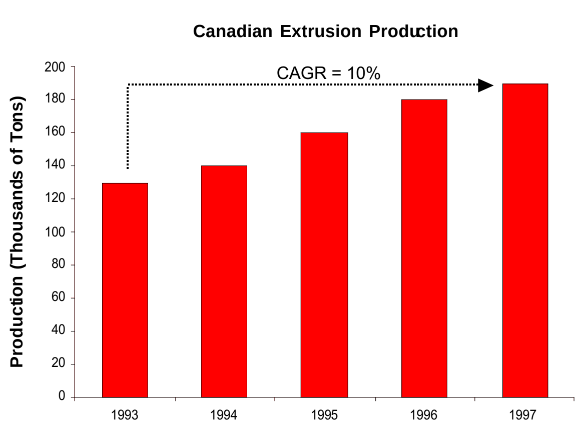
Source: *World Capacity and Production Report*, James King, June 1998.

EXTRUSIONS

Extrusion is the process of pushing a pre-heated billet through a steel die. The metal is thus shaped along its entire length according to the die profile, similar to icing forced through a pastry tube. To produce extruded tubing and hollow profiles, a mandrel is added to the exit of the die. The aluminium is pressed between the mandrel and the die so as to take on the shape of the mandrel on its inner surface and that of the die on its outer surface. Profiles are generally used in the production of doors, window frames and exterior cladding, streetlamps, and garden furniture. They may also be used in the manufacture of automobiles, freight cars, trailers, aircraft, and ship superstructures.

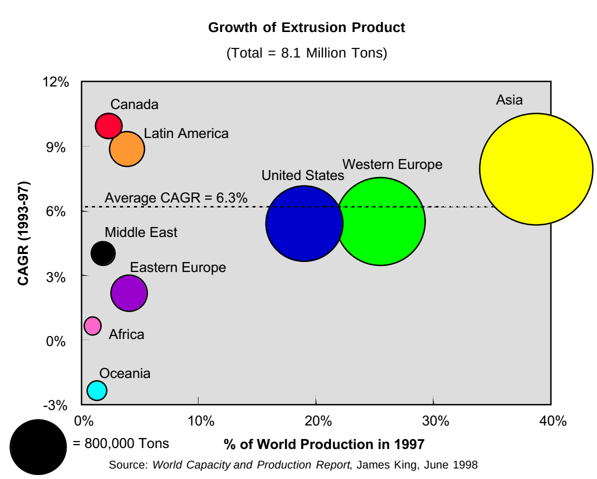
Canadian extrusion production was 190,000 tons in 1997 (see Figure 8). Since 1993 **Canada has ranked first in annual extrusion production growth,** with a rate of 10% (see Figure 9). Other major producers are Asia (38%), Western Europe (26%), and the United States (19%). Despite a strong compound annual growth rate (CAGR), Canadian extrusion production only accounts for 2.3% of world production.

Figure 8



Source: *World Capacity and Production Report*, James King, June 1998

Figure 9

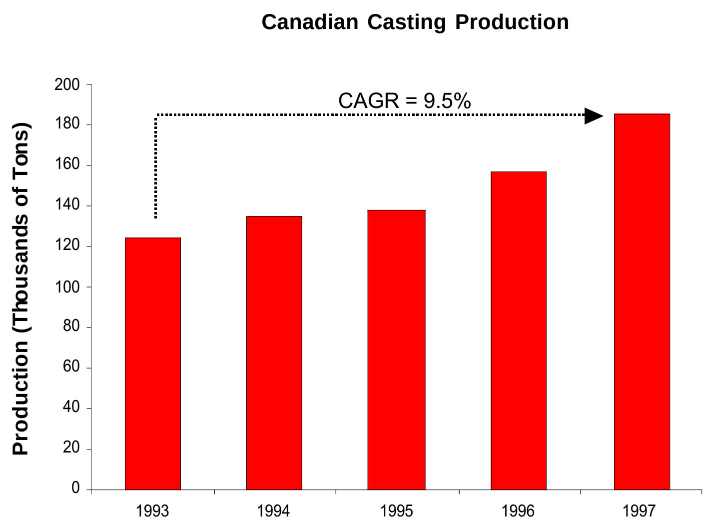


Source: *World Capacity and Production Report*, James King, June 1998

CASTINGS Casting involves pouring molten aluminium into moulds to obtain products of various shapes. The main techniques currently in use include pressure die casting, permanent mould casting and sand casting.

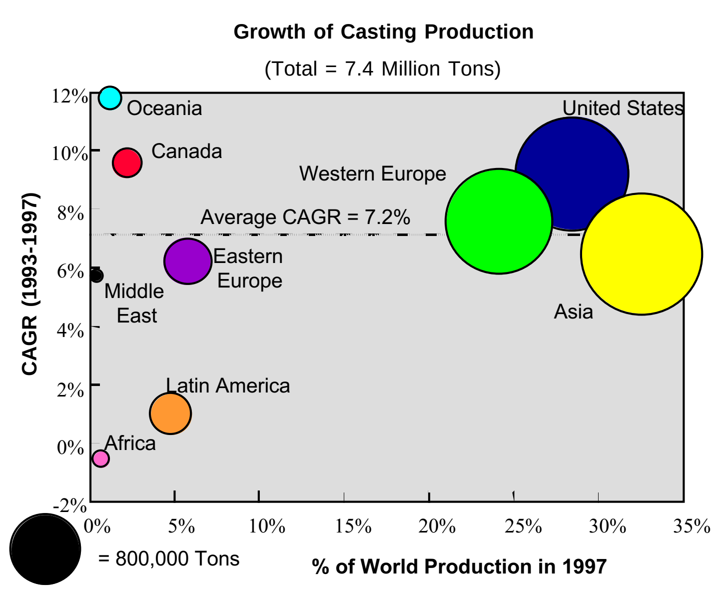
As shown in the following figures, Canada produced 185,000 tons of castings in 1997, accounting for 2.5% of world production, which was 7.4 million tons. **Canada is ranked among countries enjoying the highest annual growth rates** since 1993, having achieved a CAGR of 9.5%. Once again, Asia, the United States, and Western Europe are the largest producers of castings.

Figure 10



Source: *World Capacity and Production Report*, James King, June 1998

Figure 11



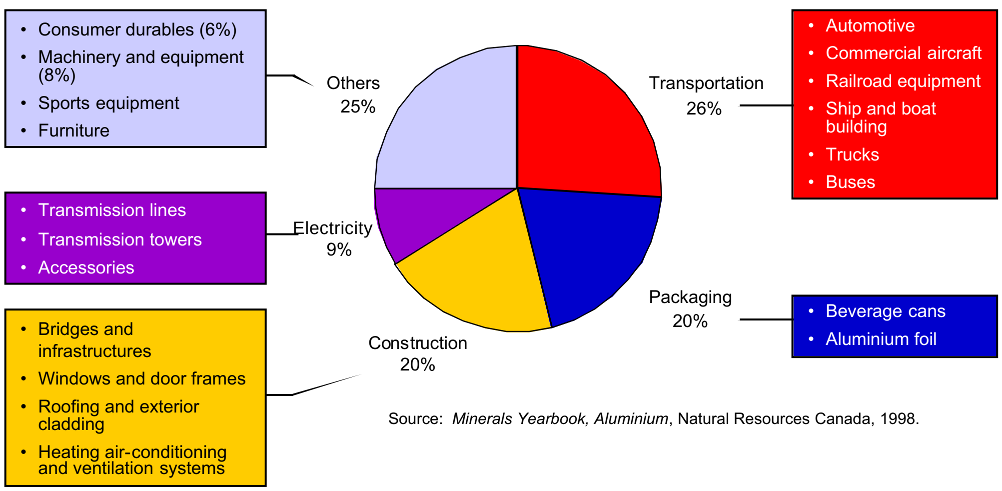
Source: *World Capacity and Production Report*, James King, June 1998

THE SECONDARY ALUMINIUM TRANSFORMATION SECTORS

World aluminium consumption is currently concentrated in four major industries: **transportation, packaging, construction, and electricity, which accounted for 75% of aluminium consumption in 1998** (see figure 12). It is predicted that the strongest rates of annual growth will occur in the transportation and packaging and container sectors from 1995 to 2015 (see figure 13). The following figures illustrate the situation described above and related forecasts.

Figure 12

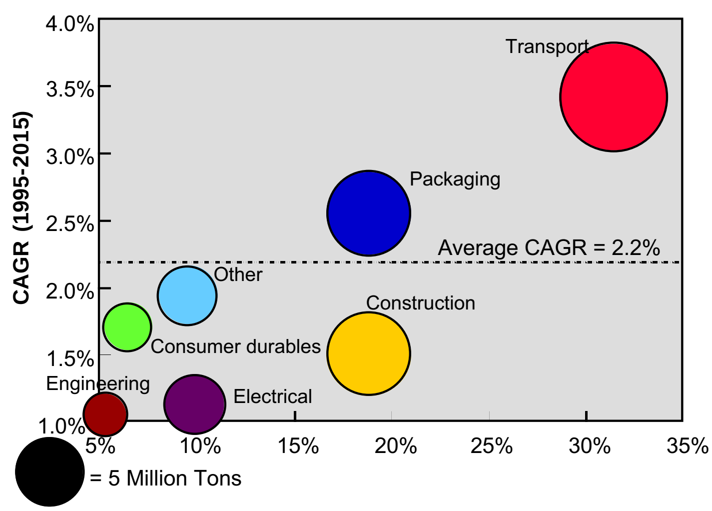
Total World Consumption of Primary Aluminium in 1998
(Total = 22.1 M Tons)



Source: *Minerals Yearbook, Aluminium*, Natural Resources Canada, 1998.

Figure 13

North American Consumption of Semi-Finished Aluminium by End-Use
(1995-2015)



% of Semi-Finished Aluminium Consumption by End-Use in 2015

Source: *The Economist Intelligence Unit, Aluminium to 2015*, November 1997.

FINISHED PRODUCTS FOR THE TRANSPORTATION INDUSTRY

The transportation industry is the primary user of aluminium, **with a market share in excess** of 26%. The industry includes automobiles and utility vehicles, trucks, buses, commercial aircraft, rolling stock (trains), and all types of ships and boats (including recreational products).

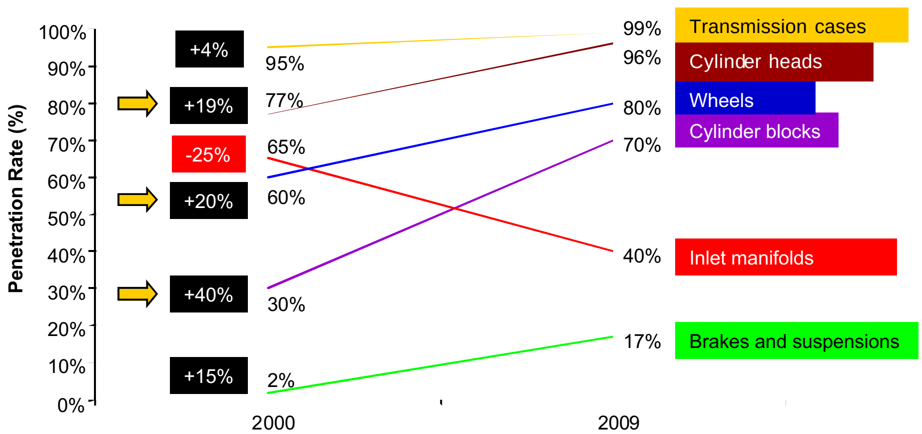
As a point of reference, approximately 90% of tractor-trailers and buses have aluminium bodies. The use of aluminium components can result in a 1,800 kg weight saving in a tractor-trailer; with the ensuing fuel economies greatly exceeding aluminium production energy requirements.

Small aluminium utility vehicles are 45% lighter than steel ones and are thus capable of carrying heavier loads with smaller frames. As well, purchase prices and maintenance costs are lower. Aluminium is also used in railway cars: a 100-ton capacity boxcar in aluminium can weigh up to 10 tons less than a steel one. The use of aluminium in shipbuilding also results in weight savings. The overall mass of passenger liners may be reduced by 8,000 tons with the use of structures containing 2,000 tons of aluminium. Aluminium remains the material of choice in the aircraft industry, where weight and fuel consumption are critical. An average-size aircraft is 80% aluminium.

Major breakthroughs in the automobile industry

Over time aluminium's popularity has grown in the automobile industry. From 1991 to 1999 the amount of aluminium used in producing vehicles in North American, Japan, and Western Europe 8 grew by 5% per annum. Given that North American vehicle production is forecast to exceed 58 million units in 2001,9 this trend should have a considerable impact on the industry. According to industry specialists, cylinder blocks (+40%), wheels (+20%), and cylinder heads (+19%) are the automotive components that will show the greatest increase in aluminium usage between 2000 and 2009 (see figure 14).

Figure 14



Source*: Modern Casting,* "Total U.S. Casting Demand Forecast in 2000", January 2000

8 Ducker Research Company, Passenger Car and Light Truck Aluminum Content Report, 1999.

9 Ward's Automotive Yearbook, 1987-1996, DRI-McGrawHill.

FINISHED PRODUCTS FOR THE PACKAGING INDUSTRY

The food packaging sector makes extensive use of aluminium foil, both as a packaging material and as a protective liner. It is versatile, resistant to cold and to heat, and easily sterilized. It also serves as an effective protective barrier against liquids, fumes, and light. Foil is also used to package various pharmaceuticals and cosmetics. Containers and packaging account for **20% of overall consumption of secondary aluminium**.

FINISHED PRODUCTS FOR THE CONSTRUCTION INDUSTRY

Aluminium is commonly used in the construction industry. It is made into doors and windows, exterior cladding, heating, ventilation, and air-conditioning systems, as well as various building materials. Its use is on the rise in the construction and renovation of large structures such as bridges and buildings. In Europe especially, such practices are well entrenched. The construction sector accounts for **20% of consumption of secondary transformation finished products**.

FINISHED PRODUCTS FOR THE ELECTRICITY INDUSTRY

Since the Second World War aluminium has replaced copper as the material used most extensively in the production of high-voltage transmission lines, and it remains the preferred material to this day. Aluminium provides the most economical means of electricity transmission: its capacity is twice that of an amount of copper of equal weight. It is used for transmission line installation, transmission tower construction, and various ancillary components. The electricity sector **accounts for 9% of aluminium consumption**.

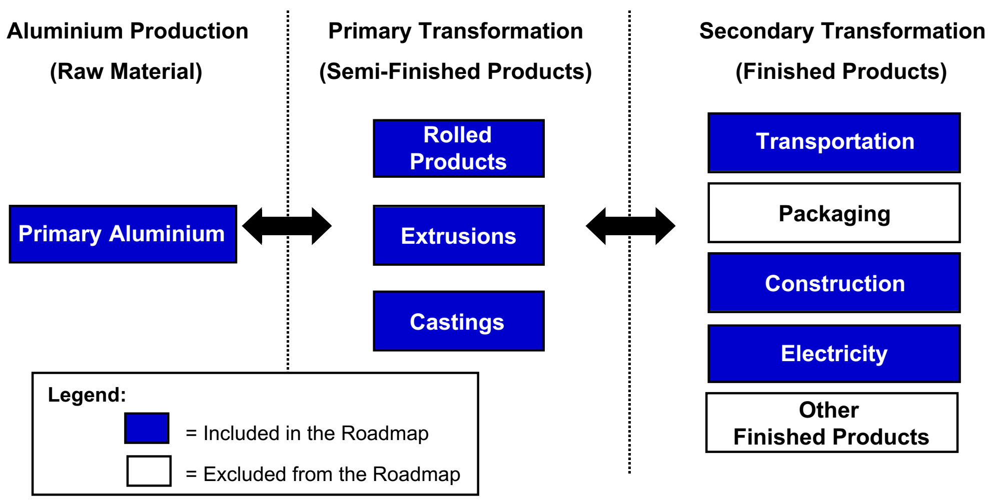
OTHER FINISHED PRODUCTS

Aluminium is used in a host of other sectors such as consumer durables (6%), machinery and heavy equipment (8%), sports equipment, furniture, industrial design, innovative products, etc. Overall, these market niches represent 25% of world aluminium consumption. Aluminium is widely used in Europe, in the development of designer products (innovative products), for example. In North America design using aluminium components is just beginning to break through and holds great potential for market development.

The following sections of the technology roadmap (see Figure 15) are focused on the transportation, construction and electricity sectors. Despite its magnitude, the packaging industry was omitted for several reasons. First, the North American sector (and its technology) has achieved maturity. Growth occurs in South America and Asia, where consumption of beer and carbonated drinks is on the rise. Secondly, technological benefits derived from R&D efforts will be less significant than in other sectors due to recent technological developments aimed at reducing the weight of the aluminium beverage can. Finally, there are important substitutes available to the bottling industry, such as glass (a transparent material) for beer and plastic (flexible and easy to shape) for carbonated beverages.

Figure 15

Sectors Included in the Technology Roadmap



MARKET NEEDS: MAJOR CHALLENGES FACING THE INDUSTRY

This section sets out the major challenges facing the aluminium industry, the relative importance of each by sector, as well as recommended action to adequately respond to market needs.

MAJOR CHALLENGES

The technology roadmap describes the challenges shared by all sectors of the aluminium industry as well as new issues to be addressed. To achieve a strong and competitive industry that also supports job creation, it is essential to fully understand the impact of the challenges on each sector and to find long-term solutions.

Workshops attended by some 60 experts brought to light several challenges linked to aluminium production (actual production and equipment suppliers) and transformation (extrusion, rolling, casting, transportation, construction and electricity).

Based on information provided by sector experts and following lively discussions at the three workshops, eight major challenges were identified. They are listed in Table 1. These challenges are, in some respects, the **drivers of technology development or modification within the Canadian aluminium industry.**

Table 1
Major Challenges Facing the Aluminium Industry

1. Reduce costs and increase productivity
2. Respect regulations and meet the requirements of the PNGV (Partnership for a New Generation of Vehicles)
3. Decrease energy consumption
4. Respect the environment
5. Increase the level of quality of raw aluminium and semi-finished and finished products
6. Develop and diffuse knowledge
7. Develop markets
8. Develop alloys/materials

A PREREQUISITE: PROTECTING THE HEALTH AND SAFETY OF WORKERS AND OF THE POPULATION AT LARGE

Health and safety are constant concerns within the workplace and among the population at large, and the Canadian aluminium industry is keenly aware that proactive behaviour in this area must accompany all efforts to respond to the other needs identified. In the automobile industry, for example, no aluminium vehicle should be allowed on the road unless it is as safe (or safer than) vehicles produced using other technologies available in the marketplace.

Thus, health and safety are a sine qua non of satisfactory industry operations and a token of our competitiveness on world markets. Safeguarding health and safety is a major social and financial investment for the industry.

PRIORITIES BY INDUSTRY SECTOR

As shown in table 2, the relative significance of the challenges we identified varies among industry sectors. Needless to say, a clearer perception of their relative importance facilitates priority ranking of the technological projects selected and determines the direction taken by experts in framing their recommendations.

At the present time, the three most significant needs for the Canadian aluminium industry are to:

1. Reduce costs and increase productivity;
2. Develop and diffuse knowledge; and
3. Develop markets.

Table 2 **Challenge Priorities by Industry Branch**

Principal Venture	Aluminium Production and Equipment Suppliers	Primary Transformation (rolling, casting, extruding)	Secondary Transformation	
			Construction and Electricity	Transportation
Reduce Costs	✪✪✪✪✪	✪✪✪✪✪	✪✪✪	✪✪✪✪✪
Respect Regulations	✪	✪	✪	✪✪
Decrease Energy Consumption	✪✪	✪	✪	✪✪✪
Respect the Environment	✪✪✪	✪	✪	✪✪✪
Increase Level of Quality	✪✪	✪✪✪	✪✪	✪✪
Develop and Diffuse Knowledge	✪	✪✪	✪✪✪✪✪	✪
Develop Markets	✪✪	✪✪✪	✪✪✪✪	✪
Develop Alloys/Materials	✪	✪✪	✪	✪✪

Legend: ✪✪✪✪✪ = strong priority
✪ = weak priority

PRIORITY 1: REDUCE COSTS AND INCREASE PRODUCTIVITY

The construction of new and more efficient aluminium plants throughout the world increases the need to reduce aluminium production costs. In response to the threat posed by substitutes such as steel and polymers, the major Canadian aluminium manufacturers have in the past taken important **steps to reduce their production costs.**

Competing with substitutes

Cost reductions and productivity improvements are essential for all sectors of the aluminium transformation industry to remain competitive in world markets. Insofar as the production levels of extrusions, rolled products, and castings of Canadian firms are lower than those of their American competitors, they must make up for their shortcomings through much greater effectiveness in the aluminium transformation process.

Moreover, in the transportation sector, for example, aluminium parts transformation costs must be reduced to compete with steel as the material of choice in the design of certain components (such as cylinder blocks).

Priority 2: Develop and diffuse knowledge

In an increasingly knowledge-based economy, intellectual capital replaces natural resources as one of the leading determinants of a country's economic strength and competitiveness. Even traditional sectors such as construction are subject to this principle, and construction sector experts attending the workshops were unanimous in this regard: there is a serious need for aluminium transformation knowledge creation and diffusion within the construction industry.

Misconceptions regarding aluminium

It is also noted that there is little awareness of available technologies as well as insufficient relevant research. Firms in the construction industry will have to foster skill development in designing and using aluminium structures. They should also increase their knowledge of the various applications and the intrinsic characteristics of aluminium.

It is apparent that the designers of major structures, such as bridges and buildings, could make greater use of aluminium. Its benefits (resistance to corrosion, light weight and recyclability) should lead to the use of aluminium on a larger scale, but we are forced to recognize that, in Canada, contrary to the situation in Europe, aluminium structures are rarely considered viable alternatives.

The workshops clearly demonstrated that:

- Our civil engineers do not have the tools required to perform calculations related to aluminium frames the way they do for steel; and
- Our engineers must learn to consider the overall cost—the life-cycle costs—of a structure rather than the construction cost alone.

It would be advisable to introduce the use of aluminium in the training of our engineers in order to encourage them to assess the life-cycle costs of a project rather than seeking the lowest initial cost. They would thus be in a position to better appreciate the many advantages of aluminium. The use of steel does not always offer such competitive features.

Priority 3: Develop markets

Finding new applications and developing new markets are important means of supporting future industry growth in addition to improving aluminium product characteristics.

Margin insert: Capitalizing on new opportunities

In this regard, construction is an area that holds great promise given that aluminium may be used in bridge and building structures, such as exterior cladding, etc. The industry would be well advised to take firm strategic steps to derive the greatest possible benefits from new opportunities in the construction field. These are distributed among three following sub-sectors:

- Home construction: aluminium structures and components used in residential construction, from single-family homes to large apartment buildings;
- Institutional, commercial and industrial construction: all non-residential buildings, such as teaching and medical establishments, offices, stores, hotels, plants, and warehouses; and
- Civil engineering projects: major projects such as highways (signage), bridges, dams, port facilities, airports, petroleum facilities and acquisition plans.

Primary transformation of aluminium also offers strong potential for new market development, especially with regard to exports. Furthermore, given the regular breakthroughs in the use of aluminium in the transportation sector, castings are currently enjoying rapid growth.

PREFERRED RESPONSES—BY SECTOR—TO EACH MAJOR CHALLENGE

Once major challenges were ranked according to priority, sector experts identified and validated a series of responses designed to meet them. In the majority of cases, the measures put forth are specific to the activity area under study. Responses may be linked, either individually or collectively, to the various aluminium production and transformation sectors.

Following are the responses identified—by sector—for each major challenge in the course of developing the technology roadmap:

1. Reduce costs and increase productivity

Both cost reduction and productivity improvement have always been major concerns of the aluminium industry. Furthermore, given the globalization of trade and the recent move towards consolidation, this trend could very well intensify over the next few years. Aluminium must be produced at a lesser cost if it is to adequately compete with substitute materials such as steel, glass, and polymers.

There are several ways of reducing the cost of producing aluminium, and semi-finished and finished products. According to experts, specific measures to reduce costs or increase productivity may be grouped around four domains: 1) equipment improvement; 2) alloy improvement; 3) production process improvement; and 4) structure deployment improvement (within the construction industry). Several actions have been identified for each domain and in some cases are specific to the activity areas under study (see table 3).

Table 3 Measures Aimed at Reducing Costs and Increasing Productivity

Measures Recommended to Meet Market Needs	Aluminium Production and Equipment Suppliers	Primary Transformation	Secondary Transformation	
			Construction and Electricity	Transportation
Equipment Improvement				
Achieve optimum durability of (molten) aluminium working/handling/transformation equipment	✓	✓		✓
Optimize the service life of production equipment	✓	✓		✓
Increase equipment reliability	✓	✓		✓
Optimize procedure design	✓	✓		✓
Develop less costly equipment/moulds	✓	✓	✓	✓
Improve Alloys				
Reduce the cost of alloys to make aluminium more competitive with substitute materials	✓	✓	✓	✓
Increase alloys mecanical properties (ductility and yield strength)	✓	✓		✓
Optimize the number of alloys per process		✓		✓
Improve Production Processes				
Reduce primary metal/aluminium transformation costs	✓	✓		✓
Increase productivity	✓	✓	✓	✓
Reduce cycle time and timelines	✓	✓		✓
Increase automation levels	✓	✓	✓	✓
Optimize production plans and operations management	✓	✓		✓
Develop more efficient production techniques	✓	✓		✓
Improve Structure Deployment/Assessment				
Consider the overall life-cycle costs of a structure (including recycling)			✓	
Develop a more effective project delivery system (modular construction)			✓	

2. Respect Regulations and Meet the Requirements of the PNGV

Regulatory compliance is essential. One cannot compete in a particular market without abiding by the rules and requirements of the country where consumer goods are produced or sold.

It may be noted that, in the past, equipment was frequently developed to meet the specific requirements of the North American market. Designers did not necessarily take into account European and international requirements, and technologies must thus be adjusted to increase market potential.

Insofar as regulation evolves at the same pace as technological and socio-political change, it must be constantly kept in mind when determining the direction of technological developments (see table 4).

In the automobile industry, for example, when Ford, GM, and Chrysler joined ranks in 1994 under the Partnership for a New Generation of Vehicles (PNGV), their objective was to achieve a 40% reduction in the average weight of a sedan by 2004, with a view to reducing average fuel consumption per vehicle. Although this goal is not a regulation as such, the objective pursued by the PNGV enabled the partners to directly meet certain requirements of the Clean Air Act and the Kyoto Protocol.

Table 4 Responses Related to Compliance with Regulations and the Requirements of the PNGV

Measures Recommended to Meet Market Needs	Aluminium Production and Equipment Suppliers	Primary Transformation	Secondary Transformation	
			Construction and Electricity	Transportation
Develop equipment that meets international requirements	✓	✓	✓	✓
Meet the requirements of the PNGV (Partnership for a New Generation of Vehicles)				✓

3. Reduce Energy Consumption

Reducing energy consumption is a constant concern, closely tied to reducing aluminium production and transformation costs.

Aluminium producing companies continue their efforts to reduce energy consumption. To this end experts specifically identified refinement of the "Hall-Héroult" process as one of the preferred responses which would allow for reduced energy consumption in the production of aluminium.

Experts also identified the aluminium primary transformation branches (extrusion, rolling, casting) as important consumers of hydroelectric power. The use of more effective equipment or processes could contribute to decreased energy consumption.

In this regard the transportation industry is also a major energy user. For several years now we have been aware that highway vehicles (automobiles, trucks, buses) must reduce their fuel consumption in order to limit their emissions of greenhouse gases and other air pollutants (see table 5).

Table 5 Responses Related to Reducing Energy Consumption

Responses Recommended to Meet Market Needs	Aluminium Production and Equipment Suppliers	Primary Transformation	Secondary Transformation	
			Construction and Electricity	Transportation
Reduce energy costs per ton of aluminium produced	✓	✓		
Reduce energy consumption in peak periods	✓	✓		
Increase effectiveness of the "Hall-Héroult" process	✓			
Reduce vehicle fuel consumption				✓

4. Respect the Environment

The population is much concerned at present with the environmental consequences of industrial, commercial, and economic activity. Among the major concerns, there are CO_2 and greenhouse gas emissions, as well as global warming.

Numerous environmental protection groups are urging that we move to "greener" energy forms. The buying public is exerting ever-increasing influence over the selection of materials used in the production process, as well as environmental groups are bringing pressure to bear on production and the market. The environment is henceforth at the heart of our energy policies.

Regulatory instruments, such as the Kyoto Protocol, the Montréal Protocol and the Clean Air Act, have a considerable impact on air pollution reduction and climate change, and companies are generally aware of the need to decrease the amount of waste they produce and their emission levels (see table 6).

Regarding aluminium production, the industry is faced with several environmental challenges, including the treatment of spent pot-lining and the use of certain raw materials such as chlorine.

For its part, the secondary branch, including transportation, must find effective ways of curtailing CO_2 emissions.

Table 6 Responses Related to Environmental Protection

Responses Recommended to Meet Market Needs	Aluminium Production and Equipment Suppliers	Primary Transformation	Secondary Transformation	
			Construction and Electricity	Transportation
Meet the requirements of the Kyoto Protocol, the *Clean Air Act*, etc.	✓	✓	✓	✓
Reduce waste production and the rate of environmental pollution	✓	✓		✓
Reduce residue emissions, including landfill disposal	✓	✓		✓
Eliminate toxic raw materials (e.g., chlorine)	✓	✓	✓	
Increase aluminium recycling	✓	✓		✓
Develop new uses for crop losses and by-products of aluminium transformation processes	✓			
Improve brasque treatment	✓			
Reduce or eliminate PFCs	✓			
Reduce or eliminate CO2 emissions	✓	✓		✓

5. Increase the Level of Quality of Raw Aluminium, and Semi-Finished and Finished Products

Given the highly specialized nature of semi-finished and finished product offerings, clients are stepping up their requirements for product quality and physical, mechanical, and chemical properties of alloys. Such properties depend on a multitude of factors such as production methods and their dynamic application. For example, aluminium alloy properties must be strictly characterized during and following the production process.

To develop customer loyalty companies must maintain and even improve the quality level of products, reduce rejection rates, diminish the level of impurities contained in aluminium, improve quality control and decrease galvanic corrosion through better methods (see table 7).

Table 7 Responses Related to Increasing Quality Levels

Measures Recommended to Meet Market Needs	Aluminium Production and Equipment Suppliers	Primary Transformation	Secondary Transformation	
			Construction and Electricity	Transportation
Maintain a consistent and constant quality level	✓	✓	✓	✓
Reduce rejection rates and losses	✓	✓	✓	✓
Decrease aluminium impurity levels	✓	✓		
Improve the quality of ingots and castings	✓	✓		
Improve quality control	✓	✓	✓	✓
Meet increasing client demands in terms of quality and physical, mechanical, and chemical properties of alloys	✓	✓	✓	✓
Decrease or eliminate galvanic corrosion through improved methods			✓	✓
Prolong the service life of products/components and vehicles				✓

6. Develop and diffuse knowledge

As the aluminium industry is relatively young, knowledge of aluminium properties and the many uses of aluminium are still limited. To increase aluminium's market prevalence, manufacturers, research centres, and universities must be able to develop and disseminate knowledge more effectively.

Generally speaking, principal contractors and designers do not give enough thought to using aluminium. This is odd inasmuch as its advantages (corrosion resistance, light weight and recyclability) should result in its use on a larger scale. Aluminium parts and structures are rarely considered a viable alternative in Canada, contrary to the situation in Europe. Our engineers do not possess the required tools to perform calculations on aluminium and, strange as it may seem, no Canadian universities now teach computation methods for aluminium structures as they do for steel.

Our engineers must learn to consider total costs—over a product's life cycle (including recycling)—rather than manufacturing costs alone. They would thus recognize that aluminium has economic advantages with which steel, for example, cannot compete. Generally speaking, available technologies are not well known and little relevant research is conducted on the subject (see table 8).

Table 8 Responses Related to Knowledge Development and Diffusion

Measures Recommended to Meet Market Needs	Aluminium Production and Equipment Suppliers	Primary Transformation	Secondary Transformation	
			Construction and Electricity	Transportation
Increase the level of (university, college, technical, and professional) training and knowledge pertaining to aluminium within the workforce	✓	✓	✓	✓
Step up training on emerging technologies	✓	✓	✓	✓
Develop more efficient construction techniques adapted to aluminium			✓	

7. Develop markets

Greater use could be made of aluminium in all branches. We must, therefore, increase our efforts to crack the most promising markets. Moreover, we must increasingly strive to position Canada as a leader in more mature markets.

The cost of aluminium may hamper its use in the construction industry, although aluminium may prove to be more economical than steel, for example, when long-term, overall costs are considered. In this perspective, promotional and commercial development efforts are required. To this end, aluminium manufacturers could set an example by including more aluminium in the design of their own structures.

Moreover, secondary transformation branches, such as transportation and construction, also hold strong growth potential. It is, therefore, in the interest of equipment suppliers to develop equipment and infrastructures for use by the construction and electricity sectors.

With respect to primary aluminium transformation, efforts must be stepped up to introduce extrusions, rolled products and castings in the construction and transportation sectors. Due to the limited presence of Canadian companies, the finished-product industry is sometimes required to seek suppliers in the United States and Europe (see table 9).

The Canadian balance of trade for aluminium primary transformation is negative: more semi-finished products are imported than are produced (e.g., sheets). This situation demonstrates the extent to which the Canadian primary transformation market is underexploited in certain areas.

There are also important challenges and opportunities in the casting sector. As barriers to international trade fall away, automobile manufacturers increase production outside North America and local assembly plants meet their supply needs on world markets. Consequently, a growing number of Canadian suppliers (e.g., in the castings sector) must necessarily become world suppliers.

Table 9 Responses Related to Market Development

Measures Recommended to Meet Market Needs	Aluminium Production and Equipment Suppliers	Primary Transformation	Secondary Transformation	
			Construction and Electricity	Transportation
Increase the use of aluminium in the automobile market and the transportation industry	✓	✓		✓
Increase the use of aluminium in the construction and electricity industries	✓	✓	✓	
Increase the use of aluminium in aluminium plant construction projects	✓	✓		
Develop markets to foster primary sector equipment design	✓			
Develop new structural (and non-structural) components for the construction industry			✓	
Launch rolling, extrusion and casting technologies (as they are not currently available)		✓	✓	
Develop equipment in support of electricity and construction industry growth			✓	

8. Develop new alloys/materials

In order to produce aluminium at competitive costs aluminium plants must increase the service life of aluminium electrolytic cells, among other equipment. Improving ingot quality means reducing refractory material deterioration caused by concurrent mechanical impacts, thermal shocks and wear (abrasion and erosion). It is therefore necessary to implement technological projects for the purpose of developing more efficient materials and tools for use in the production and handling of molten primary aluminium (see Table 10).

Table 10 Responses Related to the Development of New Alloys/Materials

Measures Recommended to Meet Market Needs	Aluminium Production and Equipment Suppliers	Primary Transformation	Secondary Transformation	
			Construction and Electricity	Transportation
Develop more efficient materials for primary aluminium production	✓			
Develop more efficient materials for aluminium handling	✓			
Develop more efficient materials for use in the course of aluminium transformation	✓	✓		✓
Provide access to a wider range of alloys		✓ (extrusion)		✓
Develop more efficient alloys for a wide assortment of applications, to replace several existing alloys (universal alloys, to reduce the number currently in use)		✓ (casting)		✓

Some primary transformation sectors are facing different challenges. Canadian extruders, for example, are limited to two or three common alloys and have not developed technology to make use of specific ones (series 2000, 5000, 7000) employed in the aeronautics, aircraft, sports equipment, military equipment, and transportation industries. Users must rely on American or European imports. As well, some domestically made products are at the low end of the quality scale, and available profiles are inefficient and poorly suited to intended uses. Extrusion experts have expressed the wish that a wider range of alloys be made available.

The situation is different in the casting and transportation branches. Experts state that companies must develop more efficient alloys suited to a wider range of applications and capable of replacing alloys in current use (universal alloys). In other words, the time is right to reduce the number of available alloys in order to lower production costs and provide additional economies of scale by consolidating the range of alloys in use.

TECHNOLOGICAL PROJECTS

After having identified the key sectors and examined their major challenges, experts at the workshops and the steering committee determined those technologies deemed essential to enable the industry to meet market needs over the next 10 years.

47 technological projects

On the whole, 47 technological projects were selected and analyzed (see appendix A). These are real and relevant projects because they are attuned to market needs and take into account current Canadian priorities. It must be remembered, however, that a technology roadmap is evolutionary in nature and is continuously being updated and, furthermore, that new technology projects may be added to take into account market trends.

Technological projects currently being conducted by research centres, universities, and Canadian companies are also listed at the end of this report (see appendix B). Such projects are an excellent starting point, although research institutes and universities have only recently undertaken R&D research efforts in Canada. In fact, technological projects submitted while the first edition of the roadmap was being prepared were aimed at strengthening and complementing their efforts rather than duplicating them.

Technological projects selected are closely linked to the aluminium transformation process. Some are specific and highly specialized, while others offer a **strong integrative potential** and are aimed at achieving a greater cohesiveness of more specialized projects.

In order to accurately define the actual reach of proposed technological projects, some are shown as being "exclusive" to specific transformation sectors. In this regard, the first 17 projects submitted are linked to aluminium production (see figure 16), more specifically, to key process activities such as those related to the electrolytic cell and the casting furnace.

Some projects offer a strong integrative potential

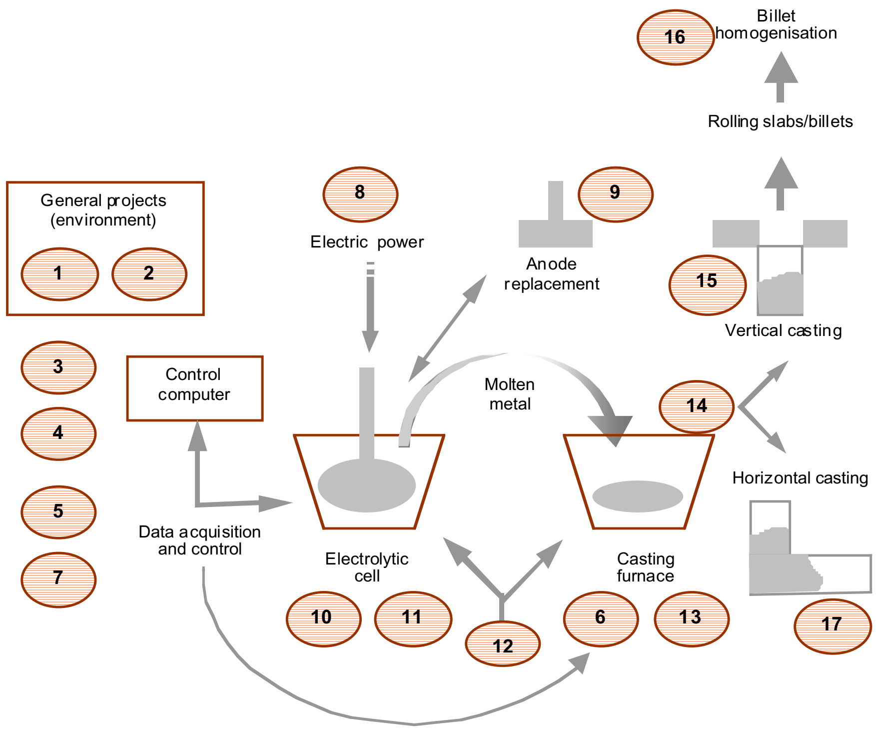
The schematic in Figure 17 fills out the picture by bringing together all of the other technological projects. Indeed, given that the primary and secondary aluminium transformation sectors are closely linked, it seems only natural that these projects be an integral part of the same chart. This graphic assembly of projects is a fine illustration of the potential integration of the primary and secondary aluminium transformation sectors held by Canadian experts, a move which offers the added advantage of bringing the sectors out of isolation. It is apparent that each project may be linked to either the first or the second transformation. Others, on the other hand, have numerous ramifications and go beyond both transformation sectors.

Project relevance was assessed by means of a technology analysis sheet. As the sheets themselves demonstrate (see project descriptions), the experts described the technologies, rated their significance, and identified global challenges related to their development. Analysis sheets also provide links to and impacts on market needs. Experts also sought to determine project timeframes and the perceived level of risk linked to technology development (see Tables 11 and 12). Technological risk was evaluated on a perception scale of 1 to 10. Although preliminary in nature, these evaluations allow us to assess the technological efforts required for achieving concrete results. The technological projects are set out in detail in the following pages.

THE ALUMINIUM PRODUCTION SECTOR

This section sets out the 17 technological projects related to the aluminium production sector. Figure 16 is a schematic representation of the various links among projects, while Table 11, on the following page, provides project timeframes and the level of risk perceived to be associated with the selected technological projects.

Figure 16 List of Technological Projects for the Aluminium Production Sector and Their Interrelations



1. Environmental technological programs to reduce solid and liquid waste and gas emissions.
2. Recycling technologies for products with high aluminium content
3. Specialized heuristic control systems (creation of algorithms)
4. Dynamic model for the control and operation of cells (process model)
5. Specialized cell signal sensors (continuous parameter recording)
6. Continuous reading/monitoring of metal quality
7. Thermocouples and probes resistant to liquid bath (new materials)
8. Technologies to lower the energy consumption of electrolytic cells (without increasing production costs)
9. Automation technologies to replace anodes in the electrolytic cell
10. Unified model to design (or modify) electrolytic cells
11. New materials (cathode) to contain electrolyte and molten metal
12. Technico-economic analysis tools for research and development projects in electrolysis and D.C. casting
13. Liquid aluminium-resistant materials
    (e.g., refractory concrete in the casting furnace/transport containers of molten aluminium)
14. Modelling solidification phenomena to reduce waste and improve recovery and casting quality
15. Vertical casting technologies for ingots and billets
16. Technologies allowing homogeneity of billets produced in D.C. casting
17. Technologies allowing improvement of continuous horizontal casting

Table 11 Technological Projects Related to Aluminium Production (Technological Risk Vs. Project Timeframe)

Project Timeframe →

Technological Risk ↓

	0-3 years	3-10 years	+10 years
4		Automation technologies to replace anodes in the electrolytic cell	
5	Technico-economic analysis tools for research and development projects in electrolysis and D.C. casting	Environmental technological programs to reduce solid and liquid waste and gas emissions Recycling technologies for products with high aluminium content Vertical casting technologies for ingots and billets Specialized heuristic control systems (creation of algorithms) Dynamic model for the control and operation of cells (process model)	
6		Technologies allowing improvement of continuous horizontal casting	
7	Thermocouples and probes resistant to liquid bath (new materials)	Modelling solidification phenomenon to reduce waste and improve recovery and casting Liquid aluminium-resistant materials	
8	Unified model to design (or modify) electrolytic cells	Technologies to lower the energy consumption of electrolytic cells Technologies allowing homogeneity of billets produced in D.C. casting	New materials (cathode) to contain electrolyte and molten metal.
9		Specialized cell signal sensors (continuous parameter recording) Continuous reading/monitoring of metal quality	

Project 1	Environmental technological programs to reduce solid and liquid waste and gas emissions	Timeframe: 3-10 years

Description:

- A wide range of technologies must be developed to reduce the environmental impact of solid, liquid, and gaseous residues and put them to good use. For example, cell brasques should be treated to recycle the elements they contain. Furthermore, techniques and technologies should be refined to reduce chlorine use in aluminium processing and PFC and CO2 emissions (in primary aluminium production).

Significance:

- Environmental awareness is increasing among the population at large and no doubt remains that consumers will be selecting materials used in the products they consume. Those with little impact on the environment will have a competitive advantage. The aim is to reduce air pollution emissions and landfill disposal of material.

Challenges:

- Several crude technologies are now available (especially for brasque recycling). However, most residues are still disposed of at landfill sites. Implementing such an environmental program (e.g., a treatment plant) entails risks, the most important one being that regulations in effect around the world continue to allow landfill disposal at little cost. Furthermore, the establishment of a treatment plant offering optimal efficiency requires servicing widely distributed aluminium plants, resulting in transportation and site location problems.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
	☆☆☆	☆	☆☆☆			☆☆☆	

Project 2	Recycling technologies for products with high aluminium content	Timeframe: 3-10 years

Description :

- Technologies for separating aluminium alloys from other materials to obtain homogeneous recyclables. Recycling techniques now applied to simple materials should be refined to accommodate a wide range of manufactured products of increasing complexity.

Significance:

- Recycling is a crucial means of reducing aluminium product costs and minimizing environmental impacts. Technologies must be highly selective of aluminium alloys and their application must be flexible. Recycled aluminium production is much more energy-efficient than production of primary aluminium.

Challenges:

- The major challenge is ensuring that the cost of recycled metal does not exceed that of primary metal. As well, current regulations do not support technology implementation.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
☆	☆☆☆	☆☆☆	☆☆☆	☆		☆☆	

Project 3	Specialized heuristic control systems (creation of algorithms)	**Timeframe:** 3-10 years

Description :

- Heuristic predictive systems using fuzzy logic and neuronal networks for data collection and electrolytic process control. Artificial intelligence technologies are applied to process control (knowledge bases, expert systems, neuronal networks, fuzzy logic, genetic algorithms).

Significance:

- Much progress has been made in the heuristic (intelligent) systems sector. Despite this, no applications are available to control the electrolysis process. As little information is currently gathered during electrolysis, implementing such technologies could provide the means of controlling this critical stage of aluminium transformation. The technologies involved would lead to increased productivity (energy consumption, carbon specific, fluorinated emissions).

Challenges:

- Challenges are basically economic in nature: return on investment must be adequate. All costs must be taken into account, from development costs to those of implementation and training on-site teams.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★		★★	★	★		★	

Project 4	Dynamic model for the control and operation of cells (process model)	**Timeframe:** 3-10 years

Description :

- Including a dynamic simulator in the cell controller (feed forward).

Significance:

- Increased productivity measured by a combination of criteria, including Faraday performance levels, specific fluorine emissions, specific consumption of carbon and electrical energy. This model allows for increased control and thus reduces greenhouse gas emissions and offers greater flexibility (amperage modulation).

Challenges:

- Lost production due to prototype implementation. There is also a risk that very expensive prototypes will be lost during testing.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★		★★	★	★		★	

Project 5	Specialized cell signal sensors (continuous parameter recording)	Timeframe: 3-10 years

Description :

- Develop sensors for ongoing measurement of temperature, chemical bath composition, and liquid level of an electrolytic cell.

Significance:

- The ongoing measurement of important parameters supports the use of more advanced control algorithms. Production effectiveness is increased by reducing process variations.

Challenges:

- Sensor service life must be equal to that of the cell (over 2,000 days) and sensors must provide accurate measures (to be defined according to the specific parameter being measured). Research was conducted in the past with rather little success. Although research is difficult, it is essential in this area.

Impacts on market needs							
Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
☆☆☆		☆☆☆	☆☆☆		☆	☆	☆☆☆

Project 6	Continuous reading/monitoring of metal quality	Timeframe: 3-10 years

Description :

- Develop a device for direct analysis of molten metal composition.

Significance:

- This technology will lead to reductions in alloy preparation time and the rejection rate both at the casting plant and downstream.

Challenges:

- It will be necessary to demonstrate project and technological development viability at the outset, on the basis of fundamental concepts.

Impacts on market needs							
Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
☆☆☆		☆		☆☆☆	☆	☆	☆

Project 7	Thermocouples and probes resistant to liquid bath (new materials)	Timeframe: 0-3 years

Description :

- Improve electrolytic cell energy efficiency (kilowatt hours/kg) while avoiding a corresponding increase in production costs.

Significance:

- Aluminium electrolysis consumes on average, on a world wide basis, 2.5 times the amount of electricity theoretically required. It is therefore necessary to reduce consumption to approximately 1.5 times the theoretical minimum. Canada would thus realize energy efficiencies of 6,000,000 MWh, a value of some $200 million.

Challenges:

- Technological advances in this area are slow and it may take several years to establish scientific proof. The aim is to reduce energy consumption (kilowatt hours/ton) to 1.5 times the theoretical minimum.

Impacts on market needs							
Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
☆☆			☆	☆☆	☆☆	☆	☆☆☆

Project 8	Technologies to lower the energy consumption of electrolytic cells (without increasing production costs)	Timeframe: 3-10 years

Description :
- Improve electrolytic cell energy efficiency (kilowatt hours/kg) while avoiding a corresponding increase in production costs.

Significance:
- Aluminium electrolysis consumes on average, on a world wide basis, 2.5 times the amount of electricity theoretically required. It is therefore necessary to reduce consumption to approximately 1.5 times the theoretical minimum. Canada would thus realize energy efficiencies of 6,000,000 MWh, a value of some $200 million.

Challenges:
- Technological advances in this area are slow and it may take several years to establish scientific proof. The aim is to reduce energy consumption (kilowatt hours/ton) to 1.5 times the theoretical minimum.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
		★★★	★★		★	★★	★★

Project 9	Automation technologies to replace anodes in the electrolytic cell	Timeframe: 0-3 years

Description :
- Work largely continues to be performed manually in the electrolysis room, where 30 to 40% of the overall plant workforce is concentrated. Anode replacement should be automated using robotics.

Significance:
- Process automation in this area will lead to reduced production costs, better working conditions, lower energy consumption and lower levels of toxic emissions. Anode replacement automation would have a significant impact on all of these factors.

Challenges:
- Capital and operating costs must justify implementation and quality of work must be equal to or greater than that of operations performed manually.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★		★★	★★			★★	

Project 10	Unified model to design (or modify) electrolytic cells	Timeframe: 0-3 years

Description :
- A unified model of an electrolytic cell incorporating mechanical, thermal, electrical, and magneto-hydrodynamic features.

Significance:
- This tool is essential for redesign studies aimed at lowering production costs. Current procedures and methods are slow and hazardous in the course of in-plant prototyping. This model allows for amperage modulation during production.

Challenges:
- Model validation complexity and difficulty: the overall model should include all interactions (through an approach similar to that in use in the aeronautics industry) and be validated on the major types of cells, namely, P-155, F180, AP30.

Impacts on market needs							
Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★		★★★	★		★	★	

Project 11	New materials (cathode) to contain electrolyte and molten metal	Timeframe: + 10 years

Description :
- Develop and use new electrolyte- and molten aluminium-resistant materials, according to electrolysis conditions, for use as cathodes lining the sides and bottoms of pots

Significance:
- These new inert materials provide greater flexibility in cathode design and operation, allowing for substantial productivity and efficiency gains. They may also reduce the production of hazardous materials.

Challenges:
- Materials selected must be compatible with the electrolyte. The cathode bottom must be highly conductive (ideally, more so than graphite) and be compatible with molten metal at 1000°C. The high cost of such (inert) materials must be justified and offset by an increase in process performance.

Impacts on market needs							
Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★		★★★	★			★★	★★★

Project 12	Techno-economic analysis tools for research and development projects in electrolysis and semi-continuous D.C. casting	Timeframe: 0-3 years

Description :

- Techno-economic models of aluminium electrolysis and semi-continuous direct chill casting of semi-finished products.

Significance:

- Equipment and service suppliers to the primary aluminium industry must be capable of analyzing development project impacts to the same extent as their clients, the major producers. Other than the latter, few companies have the resources required to avail themselves of such tools. These enable companies to target the most relevant R&D investments.

Challenges:

- Gain access to company information, frequently of a confidential nature.

Impacts on market needs							
Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
☆					☆☆☆	☆☆	

Project 13	Liquid aluminium-resistant materials (e.g., refractory concrete in the casting furnace/transport containers of molten aluminium)	Timeframe: 3-10 years

Description :

- These are newly formulated materials resistant to molten aluminium, as well as new approaches to designing containers for producing and transporting molten aluminium alloys. These materials must resist concurrent mechanical impacts, thermal shocks, wear, as well as corrosion caused by aluminium alloys at temperatures up to 1400°C. Concrete is one of the materials which need to be explored, though others must also be analyzed.

Significance:

- Contamination due to deterioration of refractory materials is increasingly affecting the metallurgical quality of alloys and products. It is therefore necessary to improve the performance of materials used in this area. Ways must be sought to prevent refractory material deterioration to increase the service life of molten aluminium confinement units and the quality of ingots produced.

Challenges:

- Materials must comply with requirements for high-temperature mechanical strength, resistance to cracking, resistance to corrosion during total immersion testing, corindon testing, etc. Furthermore, materials should offer a good cost/benefit ratio.

Impacts on market needs							
Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
☆☆				☆☆☆		☆☆	☆☆☆

Project 14	Modelling solidification phenomenon to reduce waste and improve recovery and casting quality	Timeframe: 3-10 years

Description :

- Solid 3D modelling, including analysis of constraints/strain caused by finished units, of solidification during casting.

Significance:

- Generic models are already available. However, they must be adjusted to account for conditions specific to aluminium and validated. Casting solidification must be better understood and modelled to substantially increase product quality levels.

Challenges:

- The model must accurately demonstrate solidification-related phenomena and become an essential tool for optimal control of semi-continuous direct chill casting. Challenges stem from the large number of variables and parameters needed to accurately represent process conditions and from the difficulty involved in identifying relevant parameters, in conjunction with service failure behaviours and conditions.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
☆☆☆		☆		☆☆☆	☆☆	☆	

Project 15	Vertical casting technologies for ingots and billets	Timeframe: 3-10 years

Description :

- The project involves integrating the expertise of aluminium producers and that of Canadian equipment suppliers for the semi-continuous direct chill casting of semi-finished products.

Significance:

- This type of casting is used in the extrusion and rolling industries, where it is a prerequisite to manufacturing quality products. Horizontal continuous casting does not meet the quality standards of the extrusion and rolling branches of the industry.

Challenges:

- The technology must exceed established standards of homogeneity, surface quality, ingot microstructure, cracking and transformation rates. Challenges consist in developing a Canadian technological cluster in the area of semi-continuous direct chill casting based on product quality (surface, composition, microstructure), as well as achieving specific production capacity and process automation.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
☆☆				☆☆☆	☆☆	☆☆☆	☆

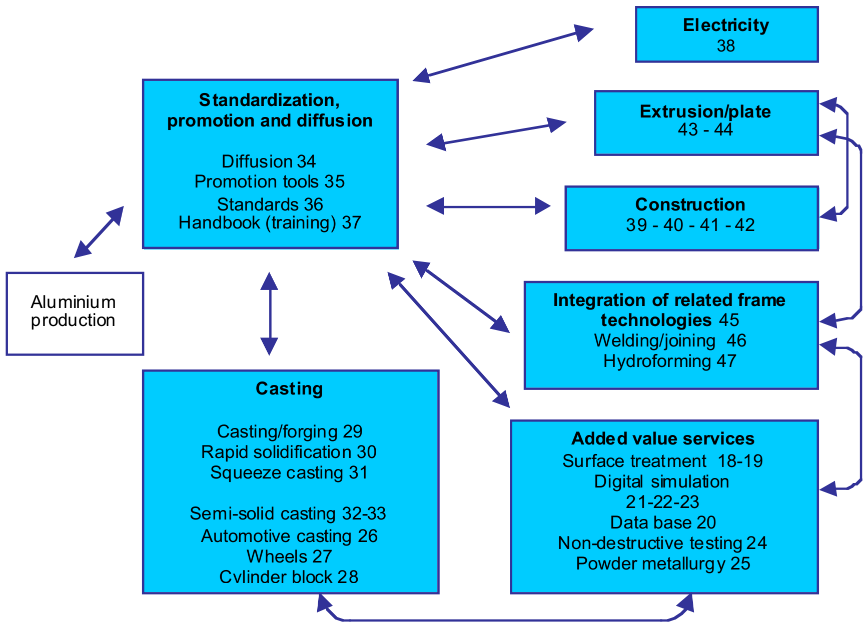
<table>
<tr><td>Project 16</td><td colspan="6">Technologies allowing homogeneity of billets produced in semi-continuous direct chill casting</td><td>Timeframe:
3-10 years</td></tr>
<tr><td colspan="8">Description :
• Develop a new generation of equipment to integrate continuous homogenization into the semi-continuous direct chill casting process.</td></tr>
<tr><td colspan="8">Significance:
• This technology would lead to diminished production costs and increased product quality. It would also reduce homogenization time through quicker handling, eliminate strains due to storage and result in true billets.</td></tr>
<tr><td colspan="8">Challenges:
• This project requires a change in current business practices and implementation of a rigorous control process. Changes in culture and expertise sometimes pose major challenges.</td></tr>
<tr><td colspan="8">Impacts on market needs</td></tr>
<tr><td>Reduce costs</td><td>Respect regulations</td><td>Decrease energy consumption</td><td>Respect the environment</td><td>Increase the level of quality</td><td>Diffuse knowledge</td><td>Develop markets</td><td>Develop materials</td></tr>
<tr><td>★★</td><td></td><td>★</td><td></td><td>★★</td><td></td><td>★★</td><td></td></tr>
</table>

<table>
<tr><td>Project 17</td><td colspan="6">Technologies allowing improvement of continuous horizontal casting</td><td>Timeframe:
3-10 years</td></tr>
<tr><td colspan="8">Description :
• Improve continuous horizontal casting of aluminium billets (bars, slabs) to increase product quality.</td></tr>
<tr><td colspan="8">Significance:
• Continuous horizontal casting supports higher production rates compared to semi-continuous vertical casting. On the downside, the product obtained is of lesser quality.</td></tr>
<tr><td colspan="8">Challenges:
• Achieving quality levels comparable to those of semi-continuous vertical casting. Furthermore, Canadian companies wishing to take up the challenge will compete with established European and American market players.</td></tr>
<tr><td colspan="8">Impacts on market needs</td></tr>
<tr><td>Reduce costs</td><td>Respect regulations</td><td>Decrease energy consumption</td><td>Respect the environment</td><td>Increase the level of quality</td><td>Diffuse knowledge</td><td>Develop markets</td><td>Develop materials</td></tr>
<tr><td>★</td><td></td><td></td><td></td><td>★★</td><td></td><td>★</td><td></td></tr>
</table>

THE PRIMARY AND SECONDARY ALUMINIUM TRANSFORMATION SECTORS

The following section sets out 30 projects related to the primary and secondary aluminium transformation sectors. Figure 17 demonstrates the various links among the projects. Moreover, Table 12 identifies timeframes for project implementation and the level of perceived risk for each of the various technological projects.

Figure 17 List of Technological Projects of the Primary and Secondary Aluminium Transformation Sectors and Their Interrelations



18. Ion implantation technologies (or PVD) for surface treatments
19. Aluminium-based coating
20. Database on alloy composition according to form
21. Digital simulation of mould filling and solidification
22. Process simulation (rolling, extrusion, casting, forging)
23. Improved modelling tools for die design
24. Improved techniques for non-destructive testing of parts (automation)
25. Powder metallurgy
26. Manufacture of aluminium castings for the transportation industry
27. Aluminium truck wheel-casting technologies (to ensure technology transfer)
28. Develop SHLP process (Sand Hybrid Low Pressure) for cylinder block production
29. New casting and forging techniques
30. Rapid solidification technologies for casting parts
31. New casting and forging techniques (squeeze casting)
32. Semi-solid casting technology
33. Semi-solid forming technology (SSF-feedstock preparation)
34. Creation and dissemination of standards and knowledge
35. Strategy and mechanisms to increase awareness of aluminium
36. Calculation standards (aluminium uses)
37. Handbook and computation software adapted to the design of aluminium
38. High-temperature conductors for transmission lines
39. Life cycle cost model
40. Effective project delivery systems (modular design)
41. Mechanical assembly joints (field connections) to assemble structural elements
42. Bridge construction (and restoration of bridge decks) using aluminium
43. Transfer of extrusion technologies using specific alloys (at competitive costs)
44. Improved range of structural products available (extrusions, plates) on the Canadian market
45. Related vehicle frame-manufacture technologies
46. Innovative welding/joining techniques
47. Hydroforming technology

Table 12 Technological Projects Related to Primary and Secondary Aluminium Transformation (Technological Risk Vs. Project Timeframe)

Project Timeframe →

Technological Risk ↓

Technological Risk	0-3 years	3-10 years	+10 years
1	Creation and dissemination of standards and knowledge Life cycle cost model of a structure/project	Calculation standards (aluminium uses)	
2	Handbook and computation software adapted to the design of aluminium Strategy and mechanisms to increase awareness of aluminium		
3		Manufacture of aluminium castings for the transportation industry	Improved range of structural products available on the Canadian market
4	Improved techniques for non-destructive testing of parts Transfer of extrusion technologies using specific alloys		
5	Develop SHLP process (Sand Hybrid Low Pressure) for cylinder block production Aluminium truck wheel-casting technologies High-temperature conductors for transmission lines Effective project delivery systems (modular design) Mechanical assembly joints (field connections) to assemble structural elements Powder metallurgy Database on alloy composition according to form Hydroforming technology		
6		Aluminium-based coating Process simulation (rolling, extrusion, casting, forging)	
7	New casting and forging techniques Squeeze casting Rapid solidification technologies for casting parts	Innovative welding/joining techniques Semi-solid training technologies (SSF-feedstock preparation)	
8	Semi-solid casting technology Digital simulation of mould filling and solidification Ion implantation technologies (or PVD) for surface treatments	New casting/forging technologies Related vehicle frame-manufacture technologies Bridge construction (and restoration of bridge decks) using aluminium	
9	Improved modelling tools for die design		

Project 18	Ion implantation technologies (or PVD) for surface treatments	Timeframe: 0-3 years

Description :

- Applying surface-hardening treatments to parts requiring high resistance to wear. There are two possible approaches: ion implantation and PVD (Physical Vapour Deposition).

Significance:

- These surface treatments lead to new uses for aluminium. With a penetration depth in excess of 30 microns, performance levels obtained are high, and the service life of tools and equipment is significantly extended.

Challenges:

- Technologies are not yet well known. There may be resistance to change. In addition, current use and manufacturing standards are inadequate. Further research is therefore required to document the issue.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★	★		★	★★	★	★★	

Project 19	Aluminium-based coatings	Timeframe: 3-10 years

Description :

- Surface treatments for protection against corrosion.

Significance:

- Aluminium coatings reduce wear, increase resistance to impacts and abrasion, and improve product appearance.

Challenges:

- There are processes already available, such as the AlumiPlate (USA) electrodeposition process, as well as the IVAdizing (Bombardier-Canadair) PVD process for replacing cadmium. The aim is to improve existing methods.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★			★	★★★		★	

Project 20	Database on alloy composition according to form	Timeframe: 0-3 years

Description :
- Create a database on alloy composition (according to form). List the characteristics (structural properties, performance levels, etc.) of available alloys and provide property tables according to the various forms.

Significance:
- Promote industry use of aluminium. Given aluminium's short history, alloys are not as well documented as they are within the steel industry. This database is an integral part of the aluminium industry's promotional efforts. It represents promotion through education.

Challenges:
- Assemble all available information at little cost and make it available to aluminium product engineers/designers. The challenge also involves reducing the number of available alloys (in the transportation sector) to facilitate data gathering (and reduce the cost of inventory management).

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★				★★★	★★★	★★★	

Project 21	Digital simulation of mould filling and solidification (to identify residual heat stress)	Timeframe: 0-3 years

Description :
- Digitally simulate mould filling and molten aluminium solidification. Identify stress status throughout a part's production cycle.

Significance:
- Digitally simulate the filling of moulds and molten aluminium solidification. Identify stress status throughout a part's production cycle.

Challenges:
- The process could be stepped up if foundries were willing to share existing underlying databases.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★				★★★	★★★	★	

Project 22	Process simulation (rolling, extrusion, casting, forging)	Timeframe: 3-10 years

Description :

- Link knowledge bases (alloy properties, performance levels, service characteristics) to existing design systems (CAD) to design production-ready parts (DFM – Design for Manufacturability).

Significance:

- Reduce errors as of the design stage and greatly assist in reducing the tremendous costs associated with iterative design processes. Cut down on design-to-production time. No current software is capable of optimizing manufacturing processes (design and optimal process control) and predicting material microstructure and, hence, the ultimate mechanical properties of manufactured parts. This modelling technique would support optimal process design and moving into production at minimal cost while ensuring that production occurs in ideal operating conditions.

Challenges:

- Modify existing resources for steel-based design. Modify and flesh out existing simulation models to include the properties of aluminium. Develop more comprehensive models, capable of simulating more parameters (wide range of material descriptors).

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★				★★★	★★★	★★	

Project 23	Improved modelling tools for die design	Timeframe: 0-3 years

Description :

- Simulation tools to assist in die design.

Significance:

- Current methods are highly reliant on tests and errors. Improved tools would lead to reduced costs and a greater sharing of knowledge among less experienced designers.

Challenges:

- Gather and formalize undocumented knowledge of experienced die designers. Knowledge is difficult to codify as it is sometimes subjective and empirical.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★				★★★	★★★	★	

Project 24	Improved techniques for non-destructive testing of parts (automation)	Timeframe: 0-3 years

Description :

- As a general rule, aluminium parts are X-rayed or immersed in penetrating liquid to detect cracking. These techniques require interpretation of results by operators and are therefore costly. Other techniques may be considered.

Significance:

- A crack in a structural component may have disastrous consequences. New techniques would allow for greater diagnostic reliability and reduce costs by eliminating human involvement.

Challenges:

- Client acceptance; automation may entail accountability issues.

Impacts on market needs							
Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★	★	★	★★	★★★		★	

Project 25	Powder metallurgy	Timeframe: 0-3 years

Description :

- Production of steel parts using powder metallurgy technology is quite common, though aluminium parts are rarely manufactured in this way because aluminium powder is difficult to sinter due to the presence of an oxide layer. A technology capable of sintering aluminium powder parts could open a new major market for aluminium.

Significance:

- Produce large runs of small parts at affordable cost. Powder metallurgy is well suited to the manufacture of large runs of small parts as a means of amortizing the high cost of matrices and moulds. Such parts are widely used in the automobile industry.

Challenges:

- Obstacles are mostly of a technological nature. Binders and lubricants may cause pollution. Handling large amounts of aluminium powder is a delicate operation due to flammability.

Impacts on market needs							
Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★		★		★		★★	

Project 26	Manufacture of aluminium castings for the transportation industry	Timeframe: 3-10 years

Description :

- According to expert forecasts, aluminium castings will enjoy strong growth in the transportation sectors over the next ten years. It will be necessary to target growth sectors where little use is made of aluminium. The center will not perform parts design but will rather seek out competitive manufacturing processes.

Significance:

- Aluminium is increasingly replacing heavy metals such as cast iron and steel as a means of reducing the weight of transport vehicles and thereby achieving fuel efficiencies and reductions in air pollution. New environmental and energy legislation as well as workforce training requirements will apply gradually as the industry meets new market needs.

Challenges:

- The ability to integrate and coordinate future research in light of clear and precise objectives. In Canada and abroad research is highly fragmented and coordination is rather limited.

Impacts on market needs							
Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
☆☆☆	☆	☆		☆☆☆	☆☆☆	☆☆☆	

Project 27	Aluminium truck wheel-casting technologies (to ensure technology transfer)	Timeframe: 0-3 years

Description :

- Though the technology is already available, steps must be taken for its transfer to Canada in order to optimize the production process and compete with manufacturers across North America.

Significance:

- The trucking industry must remain competitive while complying with environmental and energy legislation. As is the case with cars, reducing vehicle weight becomes essential. It will be important to adapt production technologies to market needs.

Challenges:

- Produce truck wheels at competitive prices. Source qualified workers for high-volume Canadian production.

Impacts on market needs							
Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
	☆☆	☆☆☆	☆☆		☆☆	☆☆☆	

Project 28	Develop SHLP process (Sand Hybrid Low Pressure) for cylinder block production	Timeframe: 0-3 years

Description :

- Develop the SHLP process for medium and large production runs of cylinder blocks to compete with the Ford Cosworth process (firmly established at present). This process is currently under development for the manufacture of a V8, 6.8 L engine prototype.

Significance:

- Considerably reduce cylinder block weight. As well, there are currently few efficient manufacturing processes for large runs of cylinder blocks.

Challenges:

- Achieve a competitive cost/quality ratio within the industry.

Impacts on market needs							
Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★	★★	★★★	★	★	★	★	

Project 29	New casting and forging techniques	Timeframe: 3-10 years

Description :

- These techniques combine intermediate form aluminium casting with forging (or other complementary techniques) to give a part its ultimate shape.

Significance:

- Developing these techniques would increase aluminium consumption for applications requiring specific mechanical properties that current methods cannot economically deliver.

Challenges:

- Maintain competitive production costs. New techniques must be innovative as many patents have already been granted.

Impacts on market needs							
Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★		★		★★★	★	★	

Project 30	Rapid solidification technologies for casting parts	Timeframe: 0-3 years

Description :

- Technology for producing geometrically accurate parts with improved properties through a rapid solidification process.

Significance:

- Typical casting processes (gravity, high- and low-pressure) produce parts with a relatively weak mechanical strength in limited runs due to the solidification rate. Reduced solidification time increases production rates and diminishes production costs.

Challenges:

- Part production rates must exceed those of current techniques (high- or low-pressure casting) while resulting in parts with superior mechanical properties requiring only minimal finishing operations (machining, etc.). The market could also favour other technologies whose cost/benefit ratios are more attuned to requirements.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
☆☆		☆				☆☆☆	

Project 31	New casting and forging techniques (squeeze casting)	Timeframe: 0-3 years

Description :

- This technology is applied to a high-pressure casting unit allowing for aluminium injection into a die and application of a controlled forging cycle following the part casting operation.

Significance:

- Production of less porous parts suited to thermal treatments intended to improve mechanical and physical properties. This technology could be used to produce aluminium automobile suspension parts to replace forged steel components.

Challenges:

- From a cost perspective, this technology must be capable of competing with that used to produce forged aluminium parts.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
☆☆		☆		☆☆	☆	☆☆	

Project 32	Semi-solid casting technology	Timeframe: 0-3 years

Description :

- This technology is derived from pressure casting (die casting), although molten (liquid) alloys are replaced by reheated billets in a semi-solid state (at a temperature just below melting point). Billets are cast using a method involving vigorous stirring during solidification intended to produce a globular structure resulting in very low resistance of the material in a semi-solid state.

Significance:

- This technology reduces costs and improves resistance of castings. Parts are cast at a lower temperature, thus reducing energy costs and mould deterioration, as well as limiting the shrinkage effect responsible for cavity formation in castings.

Challenges:

- Challenges are mostly of a technico-economic nature. Facility acquisition costs are higher than they are for conventional die casting plants.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
✯✯✯		✯✯		✯✯	✯	✯	

Project 33	Semi-solid forming technology (SSF – feedstock preparation)	Timeframe: 3-10 years

Description :

- Metal in a semi-solid state is injected under high pressure into steel moulds to produce castings.

Significance:

- This is an emerging technology providing many of the benefits unique to pressure casting with improved mechanical properties. It allows for productivity gains, energy efficiencies and quality improvement (by reducing part porosity).

Challenges:

- The challenge is economic in nature. As well, certain techniques have been patented.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
✯✯✯		✯		✯✯✯	✯	✯✯✯	

Project 34	Creation and dissemination of standards and knowledge	**Timeframe:** 0-3 years

Description :
- Foster the development of standards and knowledge to promote the overall industry.

Significance:
- The steel industry can rely on the Canadian Institute of Steel Construction to promote steel use and develop national standards. The Canadian aluminium industry has yet to benefit from a similar body. The development of design standards will stimulate aluminium use. It has long been held that lack of knowledge is a major obstacle to aluminium's entry into the tertiary transformation sectors.

Challenges:
- Challenges are not technological in nature. They consist in uniting all key industry stakeholders around a global, shared vision to improve the overall Canadian aluminium industry.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★				★★	★★★	★★★	

Project 35	Strategy and mechanisms to increase awareness of aluminium	**Timeframe:** 0-3 years

Description :
- Develop a strategy and mechanisms (Internet, directories of manufacturers, databanks, handbooks) to increase awareness of aluminium and its characteristics.

Significance:
- One of the primary reasons for which aluminium is not more prevalent in our society is the lack of information on its properties/characteristics and applications. The Internet is an essential tool for increasing aluminium awareness among a large audience at little cost.

Challenges:
- Gather available knowledge within a coherent and intuitive structure for the benefit of designers who require information on aluminium.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★				★★★	★★★	★★★	

Project 36	Calculation standards (aluminium uses)	**Timeframe:** 3-10 years

Description :
- Develop calculation standards in various sectors (e.g., mechanics, building, bridges, transmitters).

Significance:
- Disseminate and standardize best calculation practices at the national level.

Challenges:
- Bring together key players and achieve agreement on recognized standards.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★				★★★	★★★		

Project 37	Handbook and computation software adapted to the design of aluminium	Timeframe: 0-3 years

Description :

- A handbook setting out theory, standards' provisions and examples of calculations for each structural component; a continuing education course and software for aluminium analysis and design.

Significance:

- Aluminium structures will never be considered viable alternatives in Canada if engineers do not have access to at least minimal resources to assist them in their calculations and if no universities teach aluminium framework calculation techniques, as is currently the case.

Challenges:

- Gather knowledge available throughout the world.

Impacts on market needs							
Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★				★★★	★★★	★★★	

Project 38	High-temperature conductors for transmission lines	Timeframe: 0-3 years

Description :

- Identify an aluminium alloy capable of withstanding continuous high temperatures.

Significance:

- Transmission lines could carry higher currents if conductors were capable of withstanding higher temperatures.

Challenges:

- The challenge is technological in nature (research).

Impacts on market needs							
Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★				★	★	★	★★

Project 39	Structure/project life cycle cost model	Timeframe: 0-3 years

Description :

- Demonstrate the competitiveness of aluminium versus steel and wood. Assess not only a structure's building cost, but also the cost of maintenance, recycling, etc.

Significance:

- When overall costs are estimated, aluminium often wins out over steel. However, it is not common practice to take into account overall costs; quite often only initial construction costs are considered. The proposed cost model would support the promotion of aluminium in the market place.

Challenges:

- Design cost models taking into account all essential variables.

Impacts on market needs							
Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★			★	★★	★★	★	

Project 40	Effective project delivery systems (modular design)	**Timeframe:** 0-3 years

Description :
- Identify opportunities for prefabrication of generic modules to be shipped to the building site.

Significance:
- The system will promote development of modular construction, reduce acquisition and construction costs, and foster shorter delivery and production lead times.

Challenges:
- Sharing of knowledge among stakeholders who master modular construction techniques. Such knowledge is sometimes proprietary and confidential in many companies.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★		★	★	★★	★	★★	

Project 41	Mechanical assembly joints (field connections) to assemble structural elements	**Timeframe:** 0-3 years

Description :
- Develop mechanical assembly joints for use between aluminium structures and wood or plastic structures. As well, make use of innovative adhesives.

Significance:
- Assembly may occur directly on site. This method entails cost reductions and allows for delivery of more compact structures.

Challenges:
- The challenge is technological in nature.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★		★	★	★★	★	★	

Project 42	Bridge construction (and restoration of bridge decks) using aluminium	**Timeframe:** 3-10 years

Description :
- Propose aluminium-based designs for the construction and renovation of bridges. All structures involving weight restrictions (decks, pillars) should be explored.

Significance:
- Given equivalent strength levels, a decrease in structural weight results in an increase in the bridge's load limit. Furthermore, if overall costs are considered the aluminium solution is less costly (than the steel solution).

Challenges:
- Examine existing patents and suggest innovative solutions. Sweden and the United States have already patented some technologies.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★				★★★	★	★★	

Project 43	Transfer of extrusion technologies using specific alloys (at competitive costs)	Timeframe: 0-3 years

Description :

- Canadian industry imports various alloy extrusions not available locally. Canadian extruders are restricted to two or three commonly used alloys and have not developed technology which would enable them to take advantage of other specific ones (series 2000, 5000, 7000) in use in the aeronautics, aircraft construction, sports equipment, military equipment, and transportation sectors). This project therefore involves extrusion technology transfer to supply various extrusions of specific alloys.

Significance:

- Users have put an end to their research and ceased bringing pressure to bear on Canadian extruders. Furthermore, certain local products are at the low end of the quality scale and profiles are inefficient and poorly suited to requirements. Canadian production would supply the Canadian marketplace.

Challenges:

- Technology will have to be acquired from European companies such as Péchiney or Alu Suisse, or from Italian companies. The supply of alloy billets may prove difficult. The extruder may be required to integrate the billet casting operation.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
☆☆☆					☆☆☆	☆	

Project 44	Improved range of structural products available (extrusions, plates) on the Canadian market	Timeframe: + 10 years

Description :

- Several structural components are on offer. However, extrusions and plates are difficult to come by in Canada.

Significance:

- If the aluminium and steel industries are compared, it is observed that the availability of aluminium is less than that of steel. It is recognized that an aluminium plant cannot supply a complete range of products, but producers should develop specialties nonetheless.

Challenges:

- Extrusion and plate production technologies are available. What remains to be done is to urge companies to set up operations in Canada. The challenge is economic in nature, given the small size of the Canadian market.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
☆☆		☆			☆	☆☆	

Project 45	Related vehicle frame-manufacture technologies	**Timeframe:** 3-10 years

Description :
- Integrate related extrusion, drawing, casting, welding, hydroforming (and other forming techniques), stamping, and bonding technologies to produce vehicle frames. Furthermore, further research is required on the drawing of light aluminium sheets to replace steel sheets in automobile frames. Aluminium alloys made into drawn aluminium sheets are extremely malleable and can be shaped using existing equipment. Sheet gauges and parts design must be adjusted to accommodate conversion to aluminium.

Significance:
- Many technologies are now available. However, few efforts have been made to integrate existing extrusion, drawing, casting, welding, and bonding technologies to economically and competitively produce aluminium automobile frames.

Challenges:
- The ability to assemble and master a complex group of key competencies to ensure competitive frame production.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★★	★	★★★	★★	★★★	★★★	★★★	★

Project 46	Innovative welding/joining techniques	**Timeframe:** 3-10 years

Description :
- The use of drawn sheets joined with extrusions and castings requires innovative welding techniques. High-strength bonding of parts is another assembly technique which could be combined with welding.

Significance:
- This technique is complementary to drawing and assembly of vehicle frames. The success of frame assembly operations is contingent on applicable standards and process reliability.

Challenges:
- The main challenge is to automate these techniques to make the process as economical as possible. In addition, techniques implemented must be cost-effective and in compliance with environmental standards (especially as regards pre-welding metal preparation). In the case of a vehicle frame, replicating the complete welding cycle outside the plant may prove to be costly.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
★★	★		★	★★	★	★	

Project 47	Hydroforming technology	Timeframe: 0-3 years

Description :

- Hydroforming involves injecting a fluid (water or oil) into a tube or an extrusion (under strong hydraulic pressure) to impart a given shape.

Significance:

- This technology is especially useful for producing long parts with many sectional variations. This application is used particularly in the automobile industry to produce frames, bumpers and seats.

Challenges:

- Current technologies are not suited to high-volume production. Since hydroforming cycle time is relatively lengthy, production costs remain fairly high.

Impacts on market needs

Reduce costs	Respect regulations	Decrease energy consumption	Respect the environment	Increase the level of quality	Diffuse knowledge	Develop markets	Develop materials
✯✯	✯	✯	✯	✯✯✯	✯	✯✯	

OBSERVATIONS AND RECOMMENDATIONS

Canada enjoys exceptional social, economic, and technological infrastructures that enable its companies to compete on a world scale. It should be mentioned, as well, that some of these companies serve as models at the international level.

At the present time, the greatest challenge facing the Canadian aluminium industry is to remain at the forefront in the race among countries that produce and transform aluminium.

With this in mind, the experts made their recommendations, taking into account social and environmental considerations extending well beyond technical and technological fields. Indeed, to remain competitive Canadian companies must establish ecosystem and structural conditions which could potentially foster technological breakthroughs as well as accelerate and sustain development.

In the interest of effectiveness, a clearly defined, holistic approach must be taken towards the technological challenges addressed in this first edition of the *Canadian Aluminium Industry Technology Roadmap*. Stakeholders were adamant that an organization must be established to coordinate the projects selected and ensure that they are centred on an enlightened, overall vision if projects are to meet industry expectations.

RECOMMENDATIONS

Intent upon maximizing the technology roadmap's impact on the Canadian aluminium industry, the experts who designed the document put forth eight major recommendations which must be taken into account to attain the goals of market consolidation and expansion:

1. Create a Canadian aluminium research and development institute;
2. Ensure the follow-up of the technology roadmap on an annual basis;
3. Coordinate research and development activities;
4. Encourage the development of equipment for the aluminium production sector and develop software for all sectors of the industry;
5. Support development related to value-added products;
6. Reinforce linkages among industries, universities, and research centres;
7. Create specialized aluminium teaching/training curricula;
8. Conduct market surveys on various aluminium manufacturing sectors and disseminate the findings.

RECOMMENDATION 1

Create a Canadian aluminium research and development institute

The Canadian aluminium industry must meet many challenges to continue to grow. More specifically, it must find ways of reducing its production costs, disseminating knowledge and developing new markets. Furthermore, the industry must significantly increase its R&D investments.

The creation of a Canadian aluminium institute would result in the proposal and implementation of projects, promotion of the industry, and the establishment of linkages among the various stakeholders having an interest in aluminium.

One of the institute's most prominent roles would be to carry out R&D projects put forth by the technology roadmap, either as a research leader or in partnership with other organizations.

Such institute would also develop standards governing the use of aluminium (mechanical, construction, structures, transmitters, transportation, etc.). Such standards, adopted through consensus, would allow all industry actors to coordinate their efforts while sharing valuable information. In addition to promoting aluminium and its properties, institute members would be responsible for advising engineers, technicians, trainees, industrial and other designers, architects, researchers, and related decision makers on industry standards requiring compliance.

A Canadian aluminium institute, in addition to distributing education material, would also set standards, playing a role similar to that of the Canadian Institute of Steel Construction.

RECOMMENDATION 2

Ensure the follow-up of the technology roadmap on an annual basis

Because the *Canadian Aluminium Industry Technology Roadmap* is intended to be an iterative tool, it will require yearly updates to include the latest developments in science and technology (in the interest of maximum efficiency and credibility). A technology roadmap updated on a yearly basis could be used by industry stakeholders to assess progress to date and remain abreast of the latest technological breakthroughs.

The technological watch procedure described above will also improve upon the first edition of the technology roadmap through the addition of leading-edge information and further technologies, as the case may be. We recommend implementing mechanisms which would allow partners, companies, institutes, universities, and associations throughout Canada to express their views on the roadmap's technological priorities.

Ideally, the industry will take specific action to ensure that companies make an informed and systematic use of the data and information contained in the aluminium technology roadmap. The institute which is the subject of recommendation 1 will be responsible for follow-up and for ensuring that projects put forth in the document are indeed carried through to completion. The Réseau Trans-Al inc. could provide roadmap follow-up in the interim.

RECOMMENDATION 3

Coordinate research and development activities

In Canada as in other countries aluminium R&D activities are highly fragmented and would benefit from better coordination. Current research projects are too few, and it would seem that few institutions and individuals are aware of those projects being conducted throughout Canada. As a result of this dearth of information, some research activities are duplicated, while other programs could profit from additional synergy.

To remedy these shortcomings, the industry must foster new centres of excellence. Such networks, set up in close cooperation with government, would provide an ideal setting for industry/institute/university interaction. Whether virtual or otherwise, these centres of excellence would coordinate new research programs while ensuring that they dovetail with existing (and future) programs, thus avoiding any duplication and waste in research efforts.

RECOMMENDATION 4

Encourage the development of equipment for the aluminium production sector and develop software for all sectors of the industry

Many experts have expressed a desire to further develop the equipment supply branch serving the aluminium production industry. Canada already possesses great expertise in the equipment field, though development potential remains extremely high and Canadian equipment suppliers would profit by the design of equipment for export on expanding international markets.

Moreover, simulation and automation are of interest to all industries wishing to increase the quality of their products. Aluminium is not impervious to this trend. Given that efficient software development requires very specific key competencies, it is obvious that the industry must foster the emergence of software suppliers of international stature.

RECOMMENDATION 5

Support development related to value-added products

As was previously demonstrated, Canada has a negative balance of trade in the aluminium transformation field due to aluminium exports to the United States that are subsequently repurchased in the form of semi-finished products such as extrusions, plates, castings, etc.

It should be noted, by way of example, that certain types of alloys/forms for the construction industry are difficult, if not impossible, to come by. Companies are therefore required to purchase cast, rolled, or extruded semi-finished products on international markets. It is quite apparent that any investment decision in this regard must be meticulously analyzed, from both a financial and a market perspective, though our experts agree that domestic primary aluminium transformation sectors must be encouraged.

Efforts must be stepped up to develop a burgeoning primary transformation sector with an increased demand for Canadian aluminium production and to create favourable conditions for primary transformation of high value-added semi-finished products.

New primary transformation companies could potentially support the development of the secondary transformation sector through access to an improved network of reliable suppliers in Canada.

RECOMMENDATION 6

Reinforce linkages among industries, universities, and research centres

Industry representatives must take an active part, along with universities and research centres, in the debate over research priorities to ensure that the objectives of current programs are met as diligently and as effectively as possible.

Development of this first edition of the *Canadian Aluminium Industry Technology Roadmap* has demonstrated that such cooperation is both possible and essential. Experts unanimously recognized the need to continue efforts in this direction and to strengthen the linkages among stakeholders so that the industry might benefit from complementary expertise and greater synergy.

RECOMMENDATION 7

Create specialized aluminium teaching/training curricula

Research institutes, universities, colleges, vocational training establishments, and private firms must join efforts to provide young engineers, designers, technicians, and trainees with the latest knowledge on aluminium design and applications.

To this day aluminium does not come automatically to mind when specialists design a new application. Until they become aware of the many advantages of aluminium they will continue to choose steel and other materials that they know better and that are more firmly established in the marketplace. This is why we must urgently create new training programs and promote the use of aluminium in our institutions.

The Canadian industry would be well advised to draw on training programs designed in Europe where universities and vocational training establishments traditionally offer specialised curricula in response to highly specific workforce and knowledge requirements. In France, for example, engineers are specialized in mould design. Canadian programs providing such specialization have yet to see the light of day. Much remains to be done, therefore, to remedy these shortcomings.

RECOMMENDATION 8

Conduct market surveys on various aluminium manufacturing sectors and disseminate the findings

Markets evolve at a rapid pace and Canadian companies wishing to remain competitive must be able to rely on the latest information on recent market trends.

To obtain a clear grasp of all challenges at a global level, industry, in cooperation with government and various consulting firms, would do well to gather and share information on rapidly expanding markets. As regards aluminium production and primary and secondary transformation, it would be beneficial to conduct or update several market studies and provide their findings to research groups, universities, governments, associations, and companies across Canada.

Needless to say, in order to implement the various recommendations set out above, the proposed Canadian aluminium institute could act as a catalyst and a unifying agent in order to give a common focus to the various industry, university, and research centre resources. It could also play an essential role in respect of technology roadmap follow-up and promotion.

CONCLUSION

The primary objective of the *Canadian Aluminium Industry Technology Roadmap* was to trigger discussion and constructive dialogue among members of the industry and their many partners: equipment suppliers, research organizations, associations, universities, and governments.

The publication of this document is not an end in itself, but the beginning of a long process of collaboration at all levels and identification of technological projects aimed at making the Canadian aluminium industry even more competitive on international markets.

Over the coming years the roadmap will increase stakeholder awareness of issues of vital importance to the Canadian aluminium industry's future, market needs, and an unending succession of underlying technological challenges. The expert consultations identified 8 market needs, the three principal ones being: reduce costs and increase productivity, develop and disseminate knowledge, and develop markets. To date, 47 technological projects have been selected and analyzed according to these criteria and in light of current Canadian priorities.

That said, it must be kept in mind that the development of a technology roadmap is an ongoing process requiring continuous update and that other technological projects may be added as the market evolves.

This roadmap, once it has been published and distributed, will serve as a basic tool for developing a joint action plan and pursuing discussions among all branches of the Canadian aluminium industry.

The future of the Canadian aluminium industry on the international level is not contingent solely on individual technological successes. Co-ordinated efforts and mechanisms must be considered and implemented to reap the potential benefits of technological innovation. From this perspective, this document, which is perfectly attuned to the Canadian aluminium industry (having been developed by and for its stakeholders), can serve as the basis for discussions on potential mobilising projects and co-ordinated strategy, such as the establishment of a Canadian aluminium research and development institute.

The main activities of the Canadian aluminium institute could include research and development, the design of standards governing aluminium use, industry promotion, dissemination of knowledge, and linking various stakeholders in the aluminium sector. Furthermore, the institute could ensure follow-up of the roadmap.

The technology roadmap development process provided an opportunity to establish durable links, trigger dialogue at all levels, and define promising technological projects for the Canadian aluminium industry.

APPENDIX A – LIST OF TECHNOLOGICAL PROJECTS

1. Environmental technological programs to reduce solid and liquid waste and gas emissions.
2. Recycling technologies for products with high aluminium content
3. Specialized heuristic control systems (creation of algorithms)
4. Dynamic model for the control and operation of cells (process model)
5. Specialized cell signal sensors (continuous parameter recording)
6. Continuous reading/monitoring of metal quality
7. Thermocouples and probes resistant to liquid bath (new materials)
8. Technologies to lower the energy consumption of electrolytic cells (without increasing production costs)
9. Automation technologies to replace anodes in the electrolytic cell
10. Unified model to design (or modify) electrolytic cells
11. New materials (cathode) to contain electrolyte and molten metal
12. Techno-economic analysis tools for research and development projects in electrolysis and D.C. casting
13. Liquid aluminium-resistant materials
    (e.g., refractory concrete in the casting furnace/transport containers of molten aluminium)
14. Modelling solidification phenomena to reduce waste and improve recovery and casting quality
15. Vertical casting technologies for ingots and billets
16. Technologies allowing homogeneity of billets produced in D.C. casting
17. Technologies allowing improvement of continuous horizontal casting
18. Ion implantation technologies (or PVD) for surface treatments
19. Aluminium-based coating
20. Database on alloy composition according to form
21. Digital simulation of mould filling and solidification
22. Process simulation (rolling, extrusion, casting, forging)
23. Improved modelling tools for die design
24. Improved techniques for non-destructive testing of parts (automation)
25. Powder metallurgy
26. Manufacture of aluminium castings for the transportation industry

27. Aluminium truck wheel-casting technologies (to ensure technology transfer)
28. Develop SHLP process (Sand Hybrid Low Pressure) for cylinder block production
29. New casting and forging techniques
30. Rapid solidification technologies for casting parts
31. New casting and forging techniques (squeeze casting)
32. Semi-solid casting technology
33. Semi-solid forming technology (SSF-feedstock preparation)
34. Creation and dissemination of standards and knowledge
35. Strategy and mechanisms to increase awareness of aluminium
36. Calculation standards (aluminium uses)
37. Handbook and computation software adapted to the design of aluminium
38. High-temperature conductors for transmission lines
39. Life cycle cost model
40. Effective project delivery systems (modular design)
41. Mechanical assembly joints (field connections) to assemble structural elements
42. Bridge construction (and restoration of bridge decks) using aluminium
43. Transfer of extrusion technologies using specific alloys (at competitive costs)
44. Improved range of structural products available (extrusions, plates) on the Canadian market
45. Related vehicle frame-manufacture technologies
46. Innovative welding/joining techniques
47. Hydroforming technology

APPENDIX B – TECHNOLOGICAL PROJECTS UNDER WAY IN CANADA

Certain technological projects already under way were identified over the course of developing the Canadian Aluminium Industry Technology Roadmap. The following list is by no means all-inclusive, though it does offer readers a glimpse of recent Canadian research by transformation sector.

Aluminium Production

- Development of a technique for ultrasonic particle detection in molten aluminium.
- Analysis of metallic composition by laser excitation.
- A study of the effects of mould surface conditions on crack formation in semi-continuous casting.
- Mathematical modelling of various semi-continuous casting systems for the study of thermal cracking.
- Aluminium alloy solidification and resistance to thermal cracking.

Primary Aluminium Transformation

Rolling

- A study of malleability factors of 5000 and 6000 series alloy sheets for the automobile and beverage can industries.
- Development of direct chill continuous casting techniques for light-gauge sheets.

Casting

- Development of durability criteria to improve next generation engine components.
- Development of new techniques for real time control of the characteristics of the casting load and forecasting casting properties.
- Study and improvement of aluminium-resistance of refractory concretes and mortars.
- Technique development and optimization for high-quality light-metal castings for the automobile industry.
- Aluminium part manufacturing by powder metallurgy.
- Development of ultrasonic techniques for controlling semi-solid casting.
- Pore formation in aluminium casting; mathematical modelling and experimental analysis of nucleation and pore expansion during solidification.
- Evaluation of various mathematical functions for predicting porosity of four common casting alloys.
- Basic study of the precipitation process during thermal treatment of AL-Si-Mg castings.
- Characterization of production and casting conditions of aluminium-composite alloys reinforced with SiC or nickel-coated graphite (developed by INCO); study of optimal conditions.
- Use of alloy 201 in castings for the aerospace industry (NASA).
- Microstructure refinement of aluminium alloy 356.
- Thermal treatment optimization of alloys 319 and 356.2 (high temperature ductility).
- Production and property optimization of composite alloys for semi-solid state casting of automobile parts.

Secondary Aluminium Transformation

Transportation

- Development of aluminium-composite product prototypes.
- Semi-solid casting of aluminium or magnesium parts for the transportation industry.
- Development of methods for evaluating the malleability of welded slabs (body work, automobile industry).
- Optimization of rapid aluminium machining, particularly drilling and trimming.
- Design and manufacture of machine tools for Ford USA.
- Design and manufacture of new machine tools for rapid machining of aluminium.
- Design of flexible automobile parts.
- Development of a portable artificial vision system for measuring surface defects.
- Development of an apparatus for measuring force and stress developed during stamping.
- Prevention of stress-induced corrosion and its effects on the CP 140 aircraft.
- Detection of minor defects through analysis using laser-generated ultrasound.
- Detection of corrosion in riveted seams of aeronautical structures through analysis using laser-generated ultrasound.

Construction

- Use of aluminium in civil engineering structures, particularly bridges and buildings.