



WYOMING STATE GEOLOGICAL SURVEY

Gary B. Glass, State Geologist

Proceedings of the First International Soda Ash Conference Volume I

edited by

John R. Dyni and Richard W. Jones



Public Information Circular No. 39

1998

Laramie, Wyoming

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Front cover: Trona, also known as sodium sesquicarbonate, is the primary ore to produce natural soda ash. The Green River Basin in southwestern Wyoming contains the world's largest deposit of this important industrial mineral. The photograph shows a sample of the prismatic spar-variety of trona next to some refined white soda ash. (Photograph courtesy of Union Pacific Resources.)

WYOMING STATE GEOLOGICAL SURVEY
Gary B. Glass, State Geologist

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PROCEEDINGS OF THE FIRST INTERNATIONAL SODA ASH CONFERENCE VOLUME I

Utilization of natural resources of
sodium carbonate into the next century

Meeting in Rock Springs, Wyoming, June 10-12, 1997

edited by

John R. Dyni and Richard W. Jones



Laramie, Wyoming

1998



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Foreword for Volume I

Soda ash is an important global commodity with a strong possibility of increasing demand. For this reason, utilization of world sodium carbonate resources into the twenty-first century will be extremely important. The First International Soda Ash Conference (ISAC) was held June 10-12, 1997, in Rock Springs, Wyoming, the largest city in Sweetwater County, the heart of the U.S. soda ash industry. The conference provided a forum for attendees to discuss, as a group, all facets of the industry and the resources.

This historic gathering was sponsored by the U.S. Geological Survey, the U.S. Bureau of Land Management, and the Wyoming State Geological Survey. More than 300 representatives from 15 countries and 30 states attended the meeting. The conference, stressing natural deposits of soda ash, featured 33 formal presentations and poster sessions by some of the world's leading experts in the geology, mining, processing, marketing, and environmental engineering of sodium carbonate resources. The date of the conference also coincided with the 50th anniversary of the beginning of the Wyoming soda ash industry, which will continue to be a major source of soda ash for the world.

The first group of papers included in Volume I of the conference proceedings are those concerned with marketing soda ash and forecasting future trends in the soda ash industry. Because these papers are relatively time-sensitive, it was deemed appropriate that these should be published first. The remaining papers shall be published in Volume II of the conference proceedings.

The conference organizers would like to express their gratitude to everyone who contributed to making this First ISAC a success.

Dennis S. Kostick
U.S. Geological Survey

John R. Dyni
U.S. Geological Survey, Emeritus

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Wyoming State Geological Survey

Editors' preface

The editors of the first ISAC proceedings volume would like to thank all the authors that contributed to this publication. Most of the papers published here were also presented at the meeting, and we would like to thank the authors for preparing not only a presentation for the meeting but also for preparing a preliminary manuscript that served as a basis for their article in this proceedings. We would also like to thank those unnamed people within the authors' organizations that reviewed the manuscripts before they were submitted for this volume. Their comments and suggestions certainly improved the overall quality of the papers and saved us much work.

The papers were reviewed first for technical and scientific content and then edited for style, language, and consistency. In some cases, word slides from the oral presentations were transcribed into text manuscript and headings.

We acknowledge the assistance of Fred H. Porter and Phyllis A. Ranz, cartographers with the Wyoming State Geological Survey (WSGS), for their work in redrafting, revising, or retouching some of the illustrations and photographs. We are especially grateful to Janet A. Van Nuys, Editorial Assistant with the WSGS, for word processing, design and layout of the publication, and proofreading of the manuscripts. Finally, we thank the organizers and committees of the First International Soda Ash Conference for the funding support necessary to produce the proceedings volumes.

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U.S. Geological Survey

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Wyoming State Geological Survey

The role of soda ash in the chloralkali family of chemicals

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Abstract

Soda ash plays a unique role in the chloralkali family of chemicals. Its long-term outlook depends on the outlook for chlorine and caustic soda. Predictions for the growth of the latter two products vary, with the latest thinking increasingly favorable towards a re-invigoration of chlorine growth. A significant imbalance between chlorine and caustic typically creates substitution problems or opportunities for soda ash. This paper will explore the key relationships linking soda ash to chlorine and caustic soda (both electrolytic and "chemical" forms), offer some thoughts on the evolution of the ever-changing chlorine regulatory scene, and conclude with a likely scenario for the resulting impacts on soda ash.

Introduction

If this conference is focused on soda ash, why talk about chlorine and caustic soda? The answer lies in a mysterious compound called sodium oxide, and in the complex context of substitution effects. With the evolution of a growing number of environmental concerns over the past decade—especially those leading to the regulation of chlorine—many analysts had come to believe that the global demand for soda ash would receive a boost as soda ash gradually replaced increasingly scarce and expensive electrolytic caustic soda as the alkali of economic choice for many applications. This was expected to occur because co-

product caustic soda availability would be suppressed along with chlorine production.

The goal of this paper is to increase the reader's understanding of the three major chloralkali chemicals, chlorine, caustic soda, and soda ash, in terms of their interrelationships, their demand patterns, their growth outlooks, and the important factors which affect the overall alkali balance. Finally, I hope to answer once and for all the question of whether soda ash can truly expect to find new, long-term markets as a result of the decline of caustic soda availability in the years to come.

Chloralkali interrelationships

In order to understand the worldwide outlook for soda ash, it helps to understand its place in the chloralkali family. As stated above, the three most important members of the chloralkali family are chlorine, caustic soda, and soda ash; less important members include, among others, hydrochloric acid, sodium bicarbonate, and caustic potash. Supply and demand for the key members of the chloralkali family are linked for the following reasons: 1) chlorine and caustic soda are co-products; 2) chlorine production

generally determines caustic soda supply; and 3) caustic soda and soda ash are, in certain applications, interchangeable on a sodium oxide basis. Sodium oxide is a theoretical "common denominator" to which both caustic soda and soda ash may be reduced, with one short ton of soda ash being equivalent to 0.6 short ton of sodium oxide or 0.8 short ton of caustic soda, and with one short ton of caustic soda being equivalent to 0.8 short ton of sodium oxide or 1.3 short tons of soda ash.

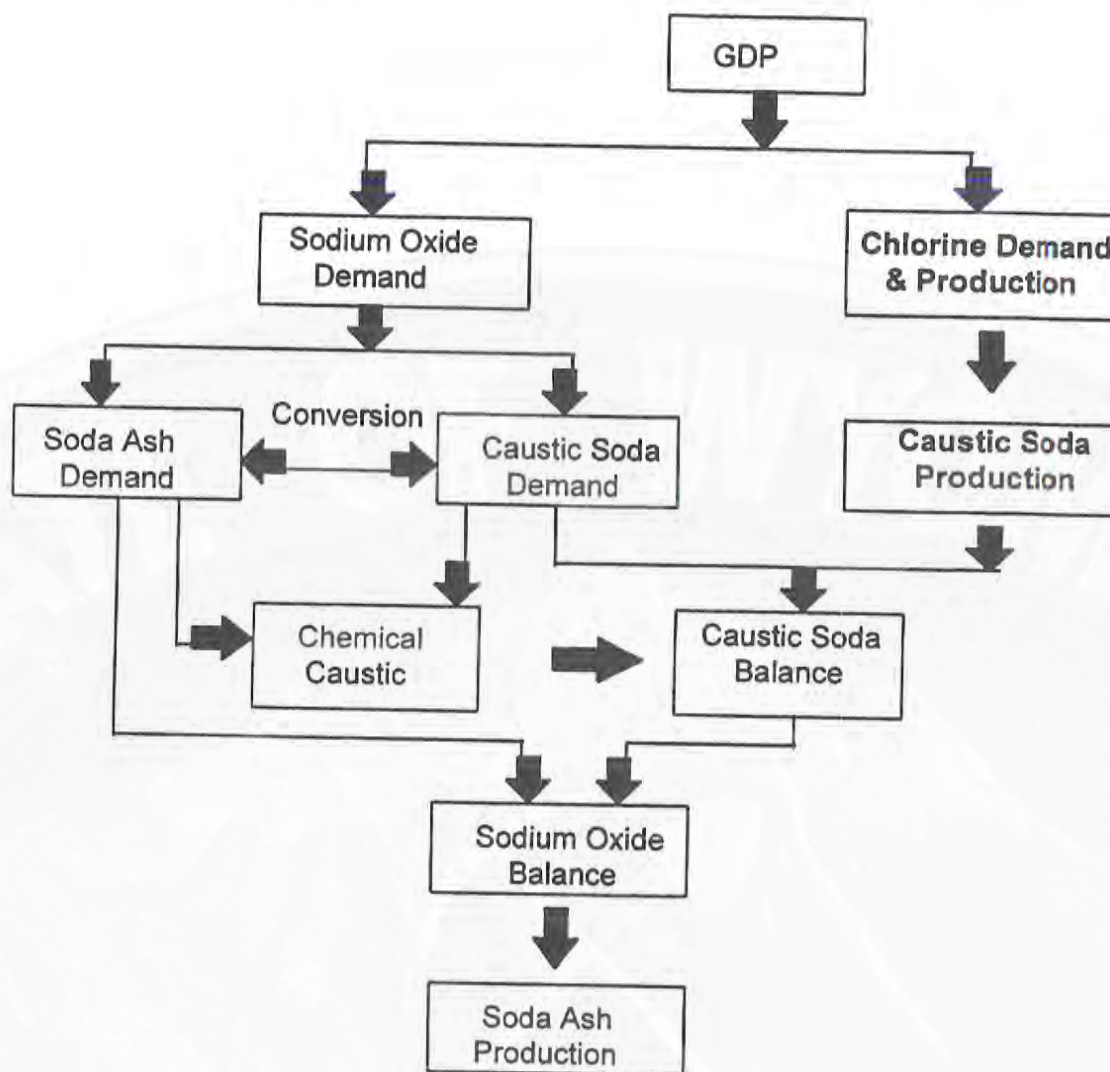


Figure 1. Chloralkali interrelationships.

As **Figure 1** illustrates, a given country's economic activity, represented by gross domestic product (GDP), drives both sodium oxide demand and chlorine demand. Sodium oxide demand can be broken into two components: soda ash demand and caustic soda demand.

To expand on what was mentioned earlier, the principal source of chlorine and caustic soda is the electrolysis of sodium chloride brine, where caustic soda is produced as a co-product of chlorine at a ratio of about 1.1 short tons of caustic soda per short ton of chlorine. In this process, chlorine is produced as a gas which is usually liquefied before being transported, stored, or used. Chlorine is difficult and relatively expensive to liquefy and maintain under pressure, and therefore difficult to transport and store. It is also somewhat toxic and corrosive. Therefore, local chlorine demand typically determines local chlorine pro-

duction. Additionally, chlorine demand is relatively more sensitive to fluctuations in GDP (gross domestic product) than is caustic soda because such a large share of chlorine goes into PVC (polyvinyl chloride) production, as will be discussed later.

Caustic soda produced as a co-product of electrolytic chlorine is generally in a dilute aqueous solution which may be used as is, at the plant site, but more often it is concentrated to the normal commercial strength of about 50%. Compared to chlorine, caustic soda is relatively easy to transport, store, and handle. Additionally, caustic soda has a much wider and more diffuse end-use pattern than chlorine, thus its demand is much less sensitive to the cyclical swings of the economy than is chlorine demand.

This is the heart of the virtually perpetual imbalance between the supply and demand of the two chemicals, chlorine and caustic soda: they are pro-

duced together as co-products, but follow different consumption cycles. Whenever chlorine/caustic production varies significantly from caustic soda demand, there have been large swings in the price of caustic soda. Additionally, whenever the markets impacting chlorine demand are in a state of transition, there is likely to be a short-term relative tightness or looseness in the caustic soda market. Thus, with supply and demand for chlorine and caustic soda almost never in phase, we have an interesting market situation in which producers, distributors, and customers are, like high-wire circus performers, engaged in an endless "balancing act."

The historical cycle has tended to follow a somewhat consistent pattern. As the economy begins to recover from a recession, chlorine demand improves before demand for caustic soda, which picks up later; as the economy reaches a peak, demand for the co-products may become temporarily balanced. When the economy begins to contract, chlorine demand falls faster than caustic soda demand, leading to tight caustic soda supplies, which can provide a special opportunity for both soda ash and for "chemical caustic." The caustic soda market tightens and loosens in a pattern which is out of phase with the overall economy (**Figure 2**). In North America, the vast majority of soda ash production comes from natural deposits: either mined trona here in Wyoming, or from dry lake brines at Searles Lake, California (see **Figure 3** for a map of U.S. soda ash sources). While

some soda ash in other parts of the world is produced synthetically from limestone, coke, and salt, future production increases in North America will come from natural deposits. Soda ash is generally produced and sold as a dry solid, making it relatively easy to transport and store. Although soda ash demand is also driven by GDP, it is generally less sensitive to economic cycles than chlorine, because of its more resilient end use pattern, which is discussed later.

It is important to note that soda ash can be interchanged for caustic soda in certain end uses, such as in the production of sodium phosphates for detergents, in pulp and paper production, and in acid waste stream neutralization. There are times, however, such as now, when chlorine demand growth has temporarily exceeded caustic soda growth and thus caustic soda has become relatively inexpensive compared with soda ash. The difference in product form between caustic soda and soda ash mentioned above, wherein caustic soda is produced and sold as a 50% solution in water while soda ash is sold as a dry white powder, can add a tremendous amount of inertia to a caustic soda user's decision to convert to soda ash. This is because of the added cost of being able to convert between different handling and storage systems. Other mitigating factors slowing conversion may include the need to invest in process changes, uncertainty regarding relative future alkali price and availability levels, and safety concerns.

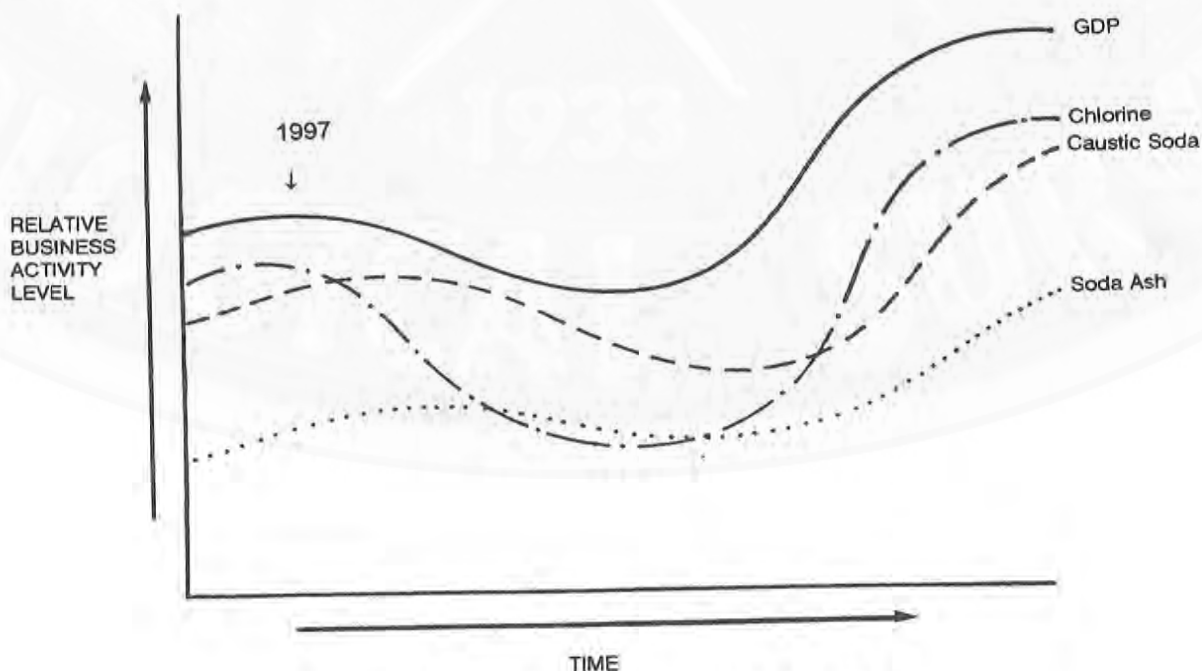
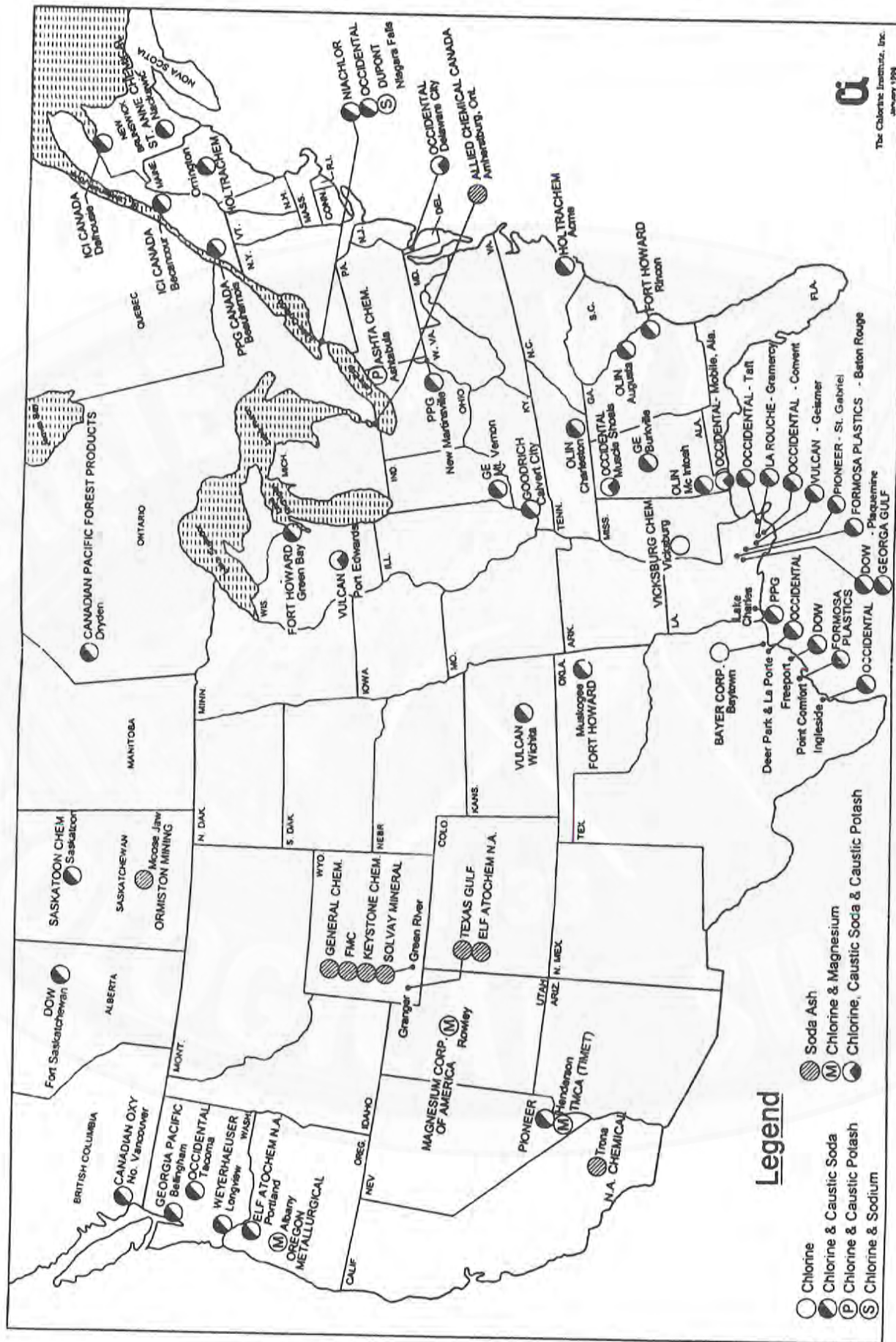


Figure 2. Chloralkali business activity cycles.



Historically, chemical alkali end-use markets which simply require a sodium oxide source have tended to use caustic soda. Aside from glass production, where its dry state is preferred, much of soda ash demand is determined by the sodium oxide demand that remains unsatisfied by caustic soda production. However, during extended periods of tight caustic soda and loose soda ash, as noted above, many of these markets can convert to soda ash, either through direct substitution or through so-called "chemical" caustic

soda production using the lime-soda process, in which caustic soda is produced directly from soda ash. This "conversion market" ensures that sodium oxide demand will be satisfied regardless of chlorine production. It is also this substitutability between caustic soda and soda ash which necessitates an examination of the outlook for chlorine and caustic soda demand before any thorough soda ash demand forecast is complete.

Chloralkali supply/demand and balances

Having covered the essentials of the chloralkali interrelationship, we are now in a position to consider the thesis that regulatory and other influences are likely to continue to suppress chlorine demand in the future, leading to a tight caustic soda market and thereby to the replacement of unavailable and expensive caustic soda with increasingly attractive soda ash. While there are a number of key factors influencing the chloralkali balance, specifically those shown in **Figure 4**, this discussion will focus largely on supply/demand balances.

In order to better understand the differing patterns of demand for the three chloralkali chemicals, and how they affect the shifting chloralkali balance, one can examine their expected 1997 demand levels by end use and geographic region.

For chlorine the production of ethylene dichloride (EDC), which in turn is converted to vinyl chloride monomer (VCM), and then to polyvinyl chloride (PVC), is the major end use, both in the United States and worldwide (**Figure 5**). This is also one of the few chlorine end uses which has so far, quite properly, withstood much of the pressure for environmental regulation. (Not that PVC hasn't had its share of scrutiny.) Organic and inorganic chemicals make up the next largest end uses, and their status with regard to chlorine regulation is somewhat mixed, with the inorganics and propylene oxide generally doing better than the chlorinated organics. As we shall see later, when we examine our projected growth rates for the three chemicals, the chlorine end use which is currently most under attack is its use in pulp and paper bleaching.

Chlorine and other chloralkalis differ in importance to a nation's economy at various stages of economic development, and this difference is reflected in different demand growth rates for each region (**Figure 6**). Chlorine demand is generally growing faster in the developing world (up to, say, 10% per annum), and



SUPPLY/DEMAND BALANCES

COSTS/PRICES

SUBSTITUTION RATIOS/RATES

PUBLIC PERCEPTIONS

REGULATIONS

TECHNOLOGY

Figure 4. Key factors influencing chloralkali balance.

slower in the developed world (at about 1% per annum).

For caustic soda, production of organic chemicals represents the largest end use segment, followed by

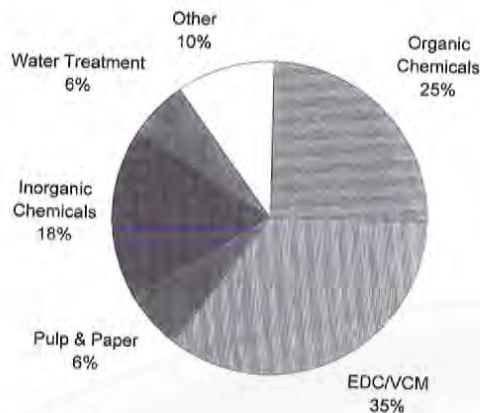


Figure 5. Global chlorine demand by end use, 1997. Total demand is estimated at 43.6 million tons.

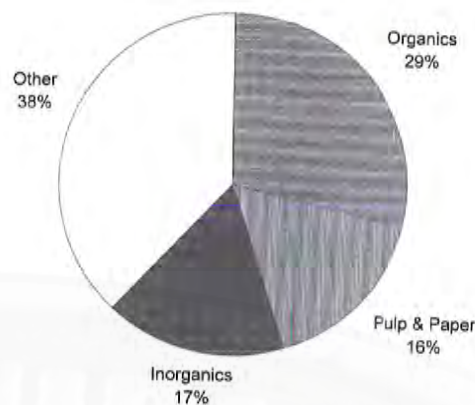


Figure 7. Global caustic soda demand by end use, 1997. Total demand is estimated at 46.1 million tons.

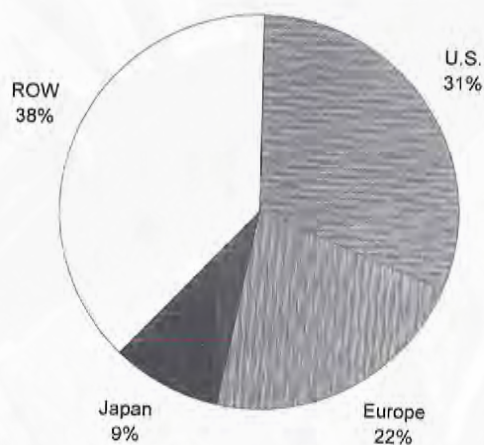


Figure 6. Global chlorine demand by region, 1997. Total demand is estimated at 43.6 million tons. ROW = rest of the world.

inorganic chemicals production and then pulp and paper production (Figure 7). In contrast to the situation with chlorine, few, if any, caustic soda end uses are facing environmental regulations of the type which could suppress chlorine demand. As we shall see later, this has translated to the expectation of a slightly higher demand growth for caustic soda than for chlorine.

As with chlorine, the fastest demand growth for caustic soda (Figure 8) is occurring in developing

countries, at about 10% per annum, with slower growth in developed countries of about 1% per annum.

Finally, for soda ash, the global and U.S. end use patterns are again similar, with glass production accounting for the largest share of soda ash demand, chemical production the second largest single share, and exports and miscellaneous end uses the balance. Soda ash demand for glass containers continues to be restrained by recycling and by some loss of market share to plastic and paperboard containers. However, this situation is often more than offset by the growth of soda ash demand in other domestic uses and in export markets.

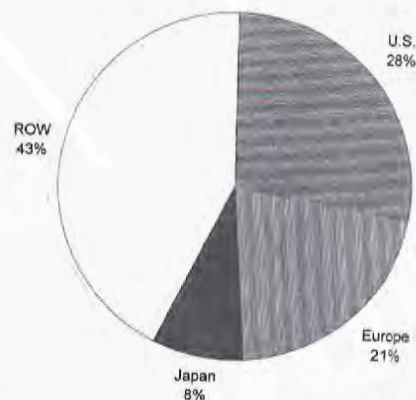


Figure 8. Global caustic soda demand by region, 1997. Total demand is estimated at 46.1 million tons.

The outlook

What does the future hold? Consulting Resources Corporation (CRC) estimates that chlorine has not been as severely impacted by environmental regulation as was expected earlier in the decade. Other than experiencing a downturn related to the recession in the early 1990s, chlorine use has kept growing even

in the face of various environmental and health concerns. The growth has not been across all end-use markets; for example, there has been and will continue to be a declining use of chlorine in pulp and paper applications as papermakers switch to elemental chlorine-free (ECF) bleaching (Table 1). However,

Table 1. Consulting Resources Corporation's chlorine outlook.

Usage category	Outlook
Organic chemicals	Environmental regulations will suppress overall demand
EDC/VCM/PVC	Growing domestic and export demand
Pulp and paper industry	Gradual shift to ECF and TCF processes
Inorganic chemicals	Slow to moderate growth
Water treatment	Environmental concerns will slow growth

the strong expansion of chlorine demand in PVC applications has more than offset the reduced chlorine demand in pulp and paper and other end-use applications. Thirty years ago, EDC/VCM applications accounted for only about 11% of U.S. chlorine demand; today, that sector accounts for more than three times that proportion. Last year (1996), and the first part of 1997 have seen a strong worldwide demand for chlorine use in these applications, particularly in Asia. Barring an unforeseen serious recession, the global PVC market should grow at about 3% per year for the next several years (Figure 9). PVC demand is heavily tied to the construction industry,

which is more vigorous when the economy is strong and consumer confidence is up.

Due to recent chlorine demand growth exceeding the rate of capacity expansion, the chlorine market has been relatively tight for several years, with U.S. chloralkali operating rates close to 100% of capacity in the fall of 1996 and in the first quarter of 1997. The snug supply/demand balance has led to several recent chlorine price increases, with an increase of \$25 per short ton in May 1997, along with a similar \$25 per short ton increase for caustic soda. Several new chloralkali plants and expansions of current plants are in various stages of planning and construction in the United States and around the world. I predict that the current wave of capacity growth will outstrip rates of demand growth, avoiding serious shortages for either co-product.

Given the co-product relationship between chlorine and caustic soda, and the relative stability of demand for caustic soda as the demand for chlorine has increased, it should not be surprising to currently see an adequate supply of caustic soda and a relatively soft caustic market. CRC's outlook for caustic soda is summarized in Table 2 and Figure 10. Earlier predictions of demand for caustic soda increasing at a significantly higher rate than demand for chlorine re-

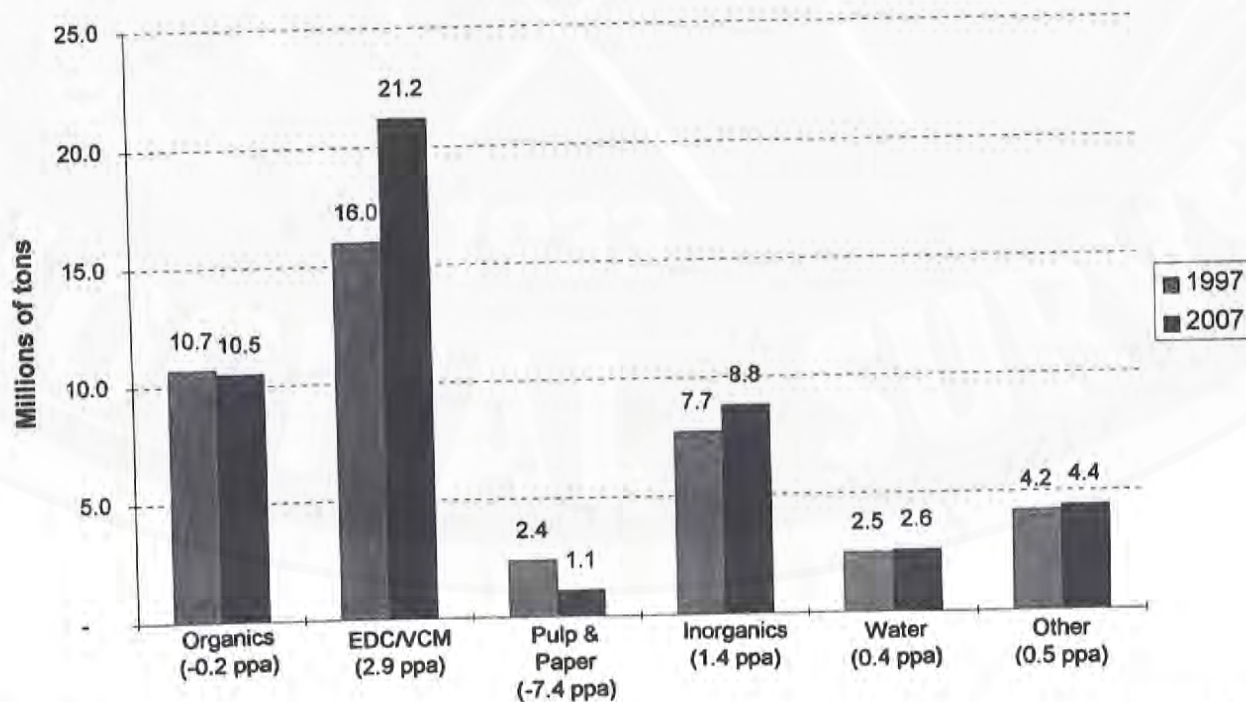


Figure 9. Consulting Resources Corporation's outlook for global chlorine demand by end use. The overall growth rate is 1.1 ppa (percent per annum), from 43.6 million tons in 1997 to 48.6 million tons in 2007. The 1997-2007 growth rate (in ppa) for each end use is shown in parentheses.

Table 2. Consulting Resources Corporation's caustic soda outlook.

Usage category	Outlook
Organic chemicals	Slow growth
Pulp and paper industry	Moderate growth
Inorganic chemicals	Will grow, but susceptible to substitution
Miscellaneous	Modest growth

sulting in severe shortages in caustic soda have not come to pass, particularly due to the robust demand for chlorine in PVC. In fact, as PVC grows, it consumes a larger share of chlorine demand, thus having an ever greater impact on overall chlorine demand.

The relatively loose caustic soda market has sent caustic prices tumbling in the past year (1996), with a U.S. drop from \$225 per short ton during the first quarter of 1996 to as low as about \$75 per short ton currently. This dramatic price decrease has brought caustic soda prices down to the level of soda ash prices, and has led some U.S. and European producers with conversion capacity to switch from soda ash to caustic soda. This latest conversion began in late 1996, and has the potential to impact between

300,000 and 500,000 short tons of soda ash in the U.S. and up to 1 to 1.5 million short tons globally. Most of this conversion potential is in the sodium phosphate and paper industries. As mentioned above, the recent move to increase caustic soda prices by \$25 a short ton suggests a bottoming out of the current cycle.

Domestic soda ash demand remains flat, due mostly to stable demand in the glass industry and, to a much smaller degree, to the caustic soda situation. Recycling and competition from plastics, as noted above, have been problematic for glass containers, but the extent of their impact has leveled off. While U.S. demand is expected to remain flat, exports will continue to play an important role in U.S. soda ash demand growth. CRC's global soda ash demand forecast is shown in **Figure 11**.

Table 3 summarizes CRC's global chloralkali forecasts. CRC expects chlorine and caustic soda to grow at an overall rate of just over 1% per annum, with soda ash expected to grow slightly faster at 1.3% per annum.

It is instructive to consider the historical pricing trends for caustic soda and soda ash over the last 27 years. As shown in **Figure 12**, when viewed in 1996

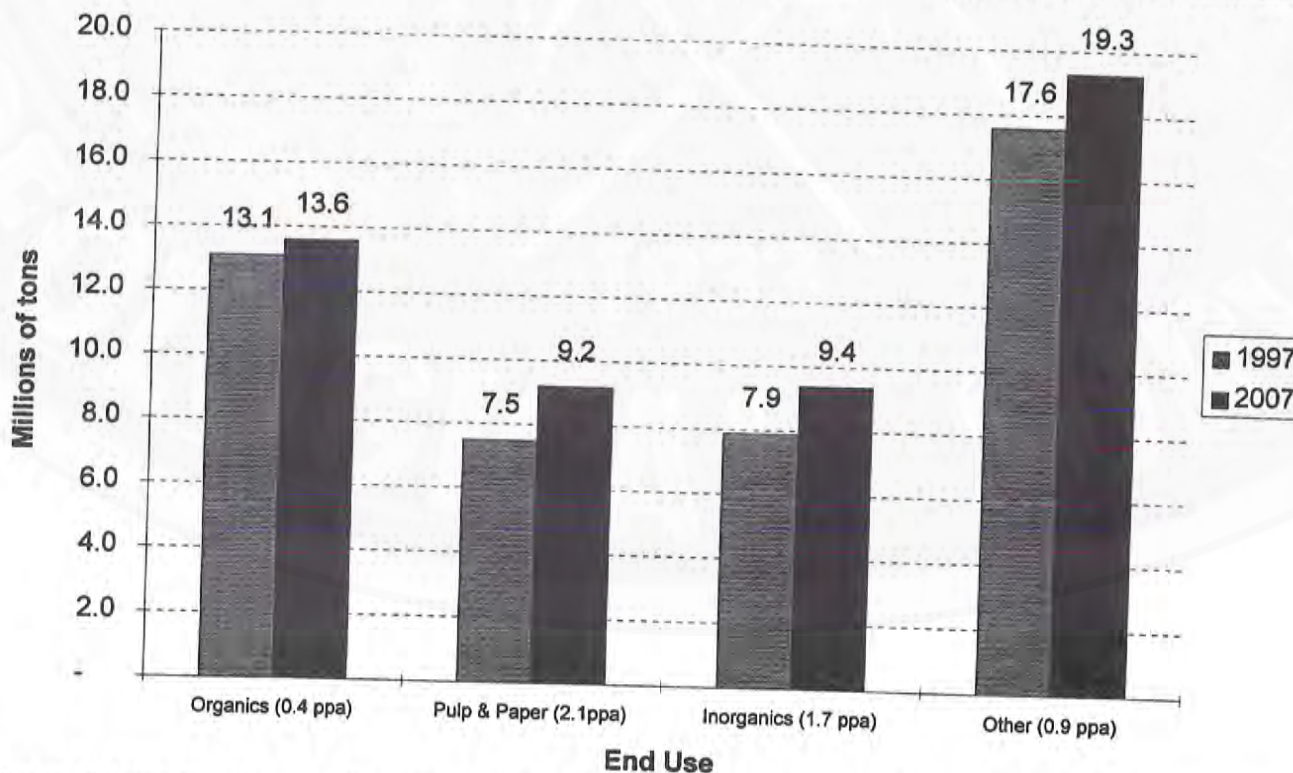


Figure 10. Consulting Resources Corporation's outlook for global caustic soda demand by end use. The overall growth rate is 1.1 ppa (percent per annum), from 46.1 million tons in 1997 to 51.5 million tons in 2007. The 1997-2007 growth rate (in ppa) for each end use is shown in parentheses.

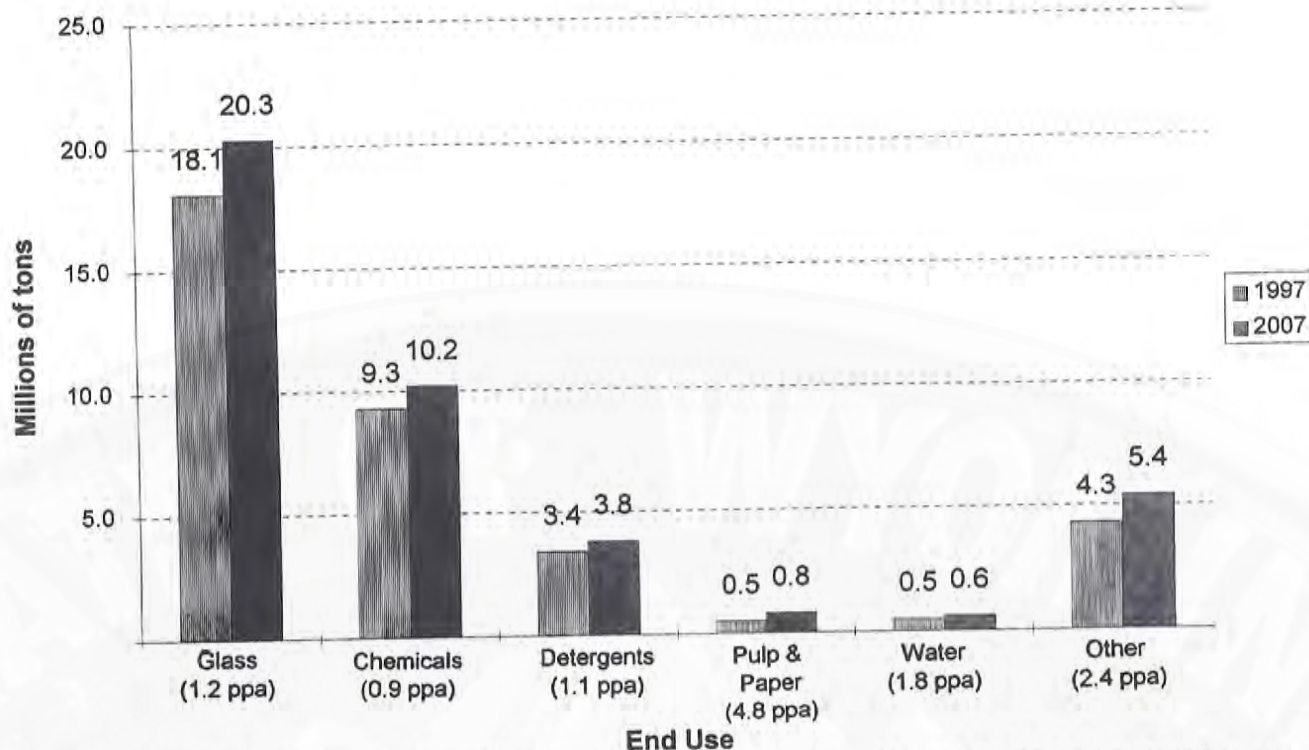


Figure 11. Consulting Resources Corporation's outlook for global soda ash demand by end use. The overall growth rate is 1.3 ppa (percent per annum), from 36.2 million tons in 1997 to 41.2 million tons in 2007. The 1997-2007 growth rate (in ppa) for each end use is shown in parentheses.

Table 3. Summary of global chloralkali demand forecasts made by Consulting Resources Corporation (in millions of tons).

Chemical	Base Year	Average Annual		
		Forecast Years	Growth	
	1997	2002	2007	1997-2007
Chlorine	43.6	46.2	48.6	1.1%
Caustic soda	46.1	48.7	51.5	1.1%
Soda ash	36.2	38.7	41.2	1.3%

constant dollars, both products are not much different in price than they were in 1970. This provides additional evidence that the relationships between the supply, demand, and prices of caustic soda and soda ash have remained approximately the same over the course of the last three decades; neither alkali is getting significantly cheaper or more expensive over time with regard to the other. If anything, it appears that caustic soda prices may be on a slight downward trend, in real terms.

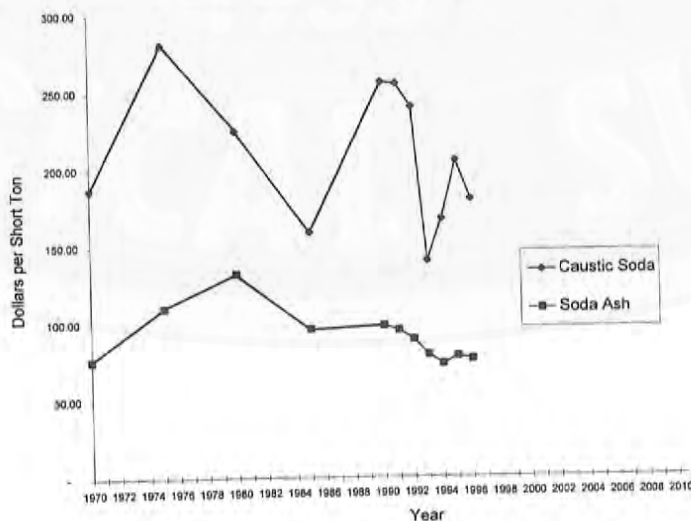


Figure 12. Consulting Resources Corporation's estimated U.S. soda ash and caustic soda historic price trends in dollars per short ton, 1996 constant dollars, trade.

Conclusion

In summary, the regulation of chlorine and subsequent lack of chlorine demand that was expected to slow growth of caustic soda production, and cause a significant increase in soda ash demand, has not occurred. Although CRC expects to continue to see some ebb and flow of caustic soda and soda ash

demand among alkali consumers with easy conversion capabilities, barring a new and unexpected level of chlorine regulation, CRC does not expect to see soda ash develop a whole new set of markets due simply to the longer-term unavailability or high price of caustic soda.

The origin of the U.S. natural and synthetic soda ash industries

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Abstract

The first International Soda Ash Conference (ISAC) which was held in June 1997, celebrated the 50th anniversary of the Wyoming trona industry. In 1947, or more than one-half century ago, the Westvaco Chemical Corporation (now known as FMC Corporation) sunk its first mine shaft into the Green River Basin in Wyoming, and reached the top of Bed 17 for the first time. Since then, more than 200 million short tons of soda ash has been produced from this mine and the four others that followed.

To appreciate the significance of Westvaco's endeavors, we need to recall the achievements and events that helped shape the history of the U.S. soda ash industry. The history begins in the early seventeenth century, when the Jamestown settlers needed a source of alkali to manufacture their glassware, continues through the late nineteenth century, when natural sodium carbonate deposits were being developed in the West and synthetic soda ash plants were being constructed in the East, and endures into the twentieth century. Although most of these older operations have shut down leaving very little physical evidence remaining to show they once existed, their successes and failures built the foundation of the present U.S. soda ash industry.

Because a comprehensive discussion of each company and facility is beyond the bounds of this presentation, four of the more important soda ash ventures in the United States will be discussed. Of the four operations, only FMC Corporation remains.

The U.S. Geological Survey and the U.S. soda ash industry

The relationship between the U.S. Geological Survey and the domestic soda ash industry dates back to the late nineteenth century. Many industry and government geologists, chemists, engineers, and hydrologists have used their technical expertise to develop the soda deposits of the West and to provide the knowledge that we take for granted today. Early geological expeditions prior to the formation of the U.S. Geological Survey evaluated the economic potential of the soda lakes in Nevada and Owens Lake in California. The first statistical data on soda ash production was collected by the U.S. Geological Survey. The responsibility of collecting this data was

transferred to the U.S. Bureau of Mines, and then transferred back to the U.S. Geological Survey in 1996.

Many natural and synthetic soda ash companies have existed in the United States, as shown in **Table 1**. Each company has provided soda ash at a time in U.S. history when the product was in strong demand, such as during the Industrial Revolution of the late nineteenth century, World Wars I and II, and the Korean Conflict. The domestic glass, chemical, and metals industries relied on a continuous and dependable source of soda ash for national needs.

Table 1. History of U.S. natural and synthetic soda ash plants in the United States, 1868 to 1997.

Company	Location	Deposit	Start up date	Closure date	Nameplate capacity (million short tons)				
					1950	1960	1970	1980	1990
Natural soda ash plants									
American Potash and Chemical Corp. ¹	Trona, CA	Searles Lake (south)	1926	1979	.150	.150	.150	—	—
California Alkali Co. ²	Cartago, CA	Owens Lake (south)	1917	1932	—	—	—	—	—
FMC Wyoming Corp.	Green River, WY	Green River trona	1948	—	.300	.500	1,250	2,550	2,850
General Chemical (Soda Ash) Partners ³	Green River, WY	Green River trona	1968	—	—	—	.550	2,200	2,400
Inyo Development Co. ⁴	Keeler, CA	Owens Lake (northeast)	1887	1920	—	—	—	—	—
Natron Soda Co. ⁵	Ragtown, NV	Big Soda Lake	1885	1907	—	—	—	—	—
Natural Soda Products Co. ⁶	Keeler, CA	Owens Lake (northeast)	1912	1952	.020	—	—	—	—
Nevada Soda Co. ⁷	Ragtown, NV	Little Soda Lake	1868	1907	—	—	—	—	—
North American Chemical Co. ⁸	Trona, CA	Searles Lake (northwest)	1978	—	—	—	—	—	—
Occidental Alkali Co.	Schurz, NV	Double Springs Marsh	1886	1917	—	—	—	1,300	1,300
OCI Chemical Co. ⁹	Green River, WY	Green River trona	1962	—	—	—	—	—	—
Pacific Alkali Co. ¹⁰	Bartlett, CA	Owens Lake (northwest)	1926	1968	.009	.070	—	—	—
Permanente Metals Corp. ¹¹	Bartlett, CA	Owens Lake (west)	1947	1950	.022	—	—	—	—
Sodium Products Co. ¹²	Wilson Creek, WA	Mitchell Lake	1936	1941	—	—	—	—	—
Solvay Minerals, Inc. ¹³	Green River, WY	Green River trona	1982	—	—	—	—	—	—
Tg Soda Ash, Inc. ¹⁴	Granger, WY	Green River trona	1976	—	—	—	—	—	1,850
Union Pacific Alkali Works ¹⁵	Laramie, WY	Union Pacific Lakes	1895	NA	—	—	—	1,000	1,300
Washington Sodium Products Co.	Warden, WA	Carbonate Lake	1927	1941	—	—	—	—	—
West End Chemical Co. ¹⁶	Westend, CA	Searles Lake (southwest)	1926	1988	.150	.190	.160	.150	—
Western Alkali Corp.	Green River, WY	Green River brines	1907	1918	—	—	—	—	—
Total natural capacity					.651	.910	2.860	8.720	11.900
Synthetic soda ash plants									
Ammonia-soda process									
Diamond Alkali Co. ¹⁷	Painsville, OH	—	1912	1976	.727	.800	.800	—	—
Mathieson Alkali Works, Inc. ¹⁸	Lake Charles, LA	—	1935	1975	.365	.365	.375	—	—
Mathieson Alkali Works, Inc. ¹⁸	Saltville, VA	—	1893	1971	.200	.410	.400	—	—
Michigan Alkali Co.	Wyandotte, MI ¹⁹	—	1892	1978	.835	.700	.800	—	—
Pittsburgh Plate Glass Co.	Barberton, OH	—	1900	1973	.350	.600	.600	—	—
Solvay Process Co. ²⁰	Hutchinson, KS ²¹	—	1908	1918	—	—	—	—	—
Solvay Process Co. ²⁰	Baton Rouge, LA	—	1935	1975	.750	.750	.785	—	—
Solvay Process Co. ²⁰	Detroit, MI	—	1898	1969	.800	.800	—	—	—
Solvay Process Co. ²⁰	Syracuse, NY	—	1884	1986	.850	.900	1,000	.900	—
Southern Alkali Corp. ²²	Corpus Christi, TX	—	1934	1978	.200	.240	.270	—	—
Caustic carbonation process									
Dow Chemical Co.	Freeport, TX	—	1955	1970	—	.100	—	—	—
Total synthetic capacity					5.077	5.665	5.030	.900	—
Total industry capacity					5.728	6.575	7.890	9.620	11.900

NA = Not available. Note: This table does not include plants that used the electrolytic process or LeBlanc process.

¹Began as California Trona Co. in Feb. 17, 1908, which was acquired by American Trona Corp. on June 13, 1913. American Potash formed in 1926 and soda ash production began in 1931. Bought by Kerr-McGee Chemical Corp. in 1967; ceased production in 1979.

²Owned by Great Western Electro-Chemical Co., a subsidiary of Dow Chemical Co. Bought Inyo Development Co. in 1918 and was acquired in May 1924 by Inyo Chemical Co. Operated until January 1932.

³Formerly part of Allied Corp.; separated in 1985. Joint venture with ACl of Australia (1986-25%) and Tosoh of Japan (1992-24%).

⁴Sold to California Alkali Co. in 1918; property leased to Natural Soda Products Co. in 1922.

⁵Formed by Griswold and Epperson Sept. 22, 1885. Capacity about 1.5ktpy but only about 450 tons produced annually.

⁶Bankrupt in 1927; sold to receivership and kept operating until 1933. Natural Soda Products reorganized as subsidiary of Michigan Alkali Co. (part of Wyandotte Chemical Corp.). Resumed full production by 1942; sold to independent group in 1950; ended in June 1952.

⁷Sold by A. Kenyon in 1868 to Higgins & Duffy, who sold lake to San Francisco group Doe & Dowd. Nevada Soda Co. was probably their company until about 1879 when John Horstmann Co. acquired facility and operated until 1907. Produced about 300 tons annually.

⁸Plant began July 1978. Acquired Argus plant of Kerr-McGee Chemical Corp. Dec. 1, 1990. OCI of South Korea was 27% partner; now about 7%.

⁹Formerly Stauffer Chemical Co.; sold to Rhône-Poulenc of France in 1987, and to OCI in 1996. Joint venture with Union Pacific Resources (49%) and OCI of South Korea (51%).

¹⁰Operated until 1944 when acquired by Columbia Southern Chemical Corp. New plant built and onstream in late-1958. Became subsidiary of Pittsburgh Plate Glass Co. on Jan. 1, 1961. PPG closed plant in 1968.

¹¹Acquired as a division of Kaiser Aluminum and Chemical Corp.

¹²Reorganized into Sodac Chemical Co. in 1941.

¹³Formerly Tenneco Minerals. Joint venture with Asahi Glass of Japan (1990-20%) and Solvay of Belgium (1992-80%).

¹⁴Bought in 1987 by Société Nationale Elf Aquitaine of France (100%).

¹⁵Acquired by American Soda, Glass and Chemical Co. in 1899. The American Development Co. and American Native Soda, Glass and Chemical Co. incorporated in 1898 to develop the soda deposits in Wyoming.

¹⁶Formed as the Westend Chemical Co., subsidiary of Westend Consolidated Mining Co. in 1920. Bought by Stauffer Chemical Co. in 1956, which was sold to Kerr-McGee Chemical Corp. in 1974.

¹⁷Later became Diamond Shamrock Corp.

¹⁸Became Olin-Mathieson in 1954, and later Olin Corp.

¹⁹Facility had two plants: North plant built in 1892 and South plant built in 1895.

²⁰Became part of Allied Chemical and Dye Co. in 1920.

²¹During World War I, the plant was leased from Kansas Chemical Co. and sold to the Solvay Process Co.

²²Production began September 1934. Owned by Pittsburgh Plate Glass Co. and American Cyanamid Co.

Background

To appreciate the significance of the development of the U.S. soda ash industry, it is important to put it into historical perspective. The use of soda ash dates back to about 3500 B.C., when Egyptians used a natural material found along evaporite lakes known as "natron" to make glass ornaments. Natron also was used as a drying agent for preserving the remains of the Pharaohs and as an ingredient to make a silica-aluminate cement mortar. With the limited sources of natron, people discovered that certain vegetation (plants, trees, seaweed, kelp, bamboo, sagebrush, and straw) could be burned, leached with water, and dried in pots to recover a potassium-bearing alkali (called pot ash) that could be used as a substitute for natron in glass making (Bateman, 1919).

Early glassworks were located in the country where there was an abundance of timber. It was not long before there were complaints about the destruction of the forests. In 1641, a bill was introduced in the English Parliament to stop the felling of trees for fueling glass furnaces. After about 1675, glassworks were built nearer to towns where coal could be obtained (Moore, 1943, p. 11).

Various wood types yielded different ashes that had different properties and compositions. The composition of a typical ash was 50 to 80% potassium carbonate, 5 to 20% potassium sulfate, and smaller quantities of sodium carbonate, potassium chloride, and other salts (Martin and others, 1916). The trees also provided a source of energy to fuel the furnaces of the glassworks. Production of potash from the ashes of wood or plants flourished until about 1870, when mining of potassium mineral salts began in Germany (Gale, 1919).

Vegetation from salt-bearing soils (the Middle East), kelp (Scotland), and seaweed (Spanish barilla) was so different from that obtained from timber that it became known as "soda ash" because of the sodium content. This was the origin of the terms potash and soda ash. The use of potash or soda ash depended on the location and supply of natron or potassium-rich or sodium-rich vegetation. Because the demand for soda ash was greater than the supply, the price of soda ash was high. By the end of the eighteenth century, Spanish producers were raising their prices month by month. Lord MacDonald of Scotland, who owned some of the largest kelp beds in that country, made more than £10,000 annually selling soda ash in the 1780s (Froman, 1967).

Soda ash in colonial America

In May 1607, the first colonists arrived in Jamestown, Virginia, to establish what would become the first permanent English settlement. Later that year, they started what was perhaps the first commercial enterprise in the this country—a glassworks that was run by eight Dutch and Polish glass blowers. Silica sand from the James River was melted with wood ashes in furnaces to manufacture various glass articles that were exported to England; the wood ashes were probably the remains of the burned timber used to fuel the furnaces (Moore, 1943, p. 209). An analysis of the Jamestown glass showed the following composition: silica, 57%; lime, 25.8%; potassium, 4.5%; and soda, 1.3%. Reportedly, some soda ash was brought over from England and sparingly used (Harrington, 1972). By 1617, Captain Argall arrived in Jamestown and found that the glassworks had deteriorated. By about 1621, a second glassworks was built primarily for the manufacture of glass beads, which were made by Italian workmen sent by the London Company in England. The beads were traded with the local Native Americans who prized these ornamental decorations. The glassworks operated until about 1625 (McKearin and McKearin, 1989).

Potash alkali was used in glass making for the next 250 years. Sodium alkali made from Spanish barilla and other salt-bearing plants was known to have been imported, but records of quantities and origins are vague. At this time, England, France, and Scotland were known to have been producers of sodium alkali.

Soda ash during the Industrial Revolution

In the late eighteenth century, the Industrial Revolution in Western Europe put a strain on the availability of many raw materials. One of the scarce materials was soda ash. Because of the Seven Years War with England and the Napoleonic wars with other countries in Europe, France could not obtain sufficient quantities of Spanish barilla or other sources of soda ash. The demand for soda ash led the French Academy of Sciences in 1775 to offer a large prize of 2400 livres to anyone who could find an inexpensive method to make soda ash. In September 1791, French chemist Nicolas LeBlanc (1742-1806) developed such a technique at St. Denis that used salt, sulfuric acid, coal, and limestone. Basically, common

salt and sulfuric acid were reacted to produce hydrochloric acid and sodium sulfate, which was roasted with coal and limestone to produce soda ash and calcium sulfide. This finished product consisted of 39 to 45% sodium carbonate, 27 to 31% calcium sulfide, 9 to 11% calcium oxide, 5 to 6% unreacted coal, and minor quantities of sodium sulfate, sodium chloride, and silicates. The soda ash often was called "black ash" because of the dark color of the unreacted coal. During the French Revolution, his patent and factory were confiscated. He only received partial compensation for all his work. Napoleon returned his factory to him, but LeBlanc was unable to raise enough money to reopen it. A dejected and financially ruined man, LeBlanc committed suicide in 1806.

A small and unsuccessful LeBlanc plant was first built in England in 1814. With the repeal of the salt tax, Muspratt built a commercially successful operation in Liverpool. The process was introduced in Germany in 1843 and in Austria in 1851 (Harness and Coons, 1942) and was at its peak around 1880; the process began to decline as the Solvay process (which will be discussed later) became more popular. The LeBlanc process was used to a limited extent during World War I in Europe but had disappeared by World War II.

U.S. soda ash in the late nineteenth century

In the mid-nineteenth century, annual reports written by the U.S. Department of the Treasury and submitted to the Committee on Mines and Mining of the U.S. Congress described the status of mineral-resource activities in the states and territories west of the Rocky Mountains. Some of these reports provided general observations on occurrences of natural salts and alkali incrustations but included little detail.

Prior to the establishment of the U.S. Geological Survey in March 1879, several scientific expeditions mapped and collected information on mineral resources that provided some of the first detailed references to natural soda ash deposits (Table 2). The more important surveys included Clarence King's Geological Exploration of the 40th Parallel, 1867-72; the Lt. George M. Wheeler Survey, 1875; and the U.S. Army's U.S. Geographical Surveys West of the 100th Meridian, 1876. With the creation of the U.S. Geological Survey in 1879, annual reports were prepared for Congress on the status of the domestic mineral resources. This publication was known as Mineral Resources of the United States, the predecessor of the Minerals Yearbook that has been written each year since 1883 (Table 2).

Table 2. Chronology of U.S. Geological Survey and U.S. Bureau of Mines reports¹ on the U.S. soda ash industry.

Dates of chapters	Name of author(s)	Number of chapters written	Name of chapter
1882	(unknown)	—	Carbonate of Soda
1883-85	Joseph D. Weeks	3	Glass Materials
1886	(none)	(none written)	—
1887	William C. Day	1	Sodium Salts
1888-92	(none)	(none written)	—
1893	R. L. Packard	1	Natural Sodium Salts
1894-1911	(none)	(none written)	—
1912	(article on Searles Lake by Hoyt S. Gale)	—	Potash Salts
1913-16	(none)	(none written)	—
1917-20	Roger C. Wells	4	Sodium Salts (1917); Sodium and Sodium Compounds (1918); Sodium Compounds (1919-20)
1921-31	(none) ²	(none written)	—
1932-37	A. T. Coons	6	Natural Sodium Compounds and Boron Minerals
1938-39	Paul M. Tyler and A. T. Coons	2	Magnesium Compounds, Bromine, Calcium Chloride, Iodine, Sodium Sulfate, Borates, and Miscellaneous Salines
1940-41	Alvin Schallis and A. T. Coons (1940); with K. G. Warner (1941)	2	Magnesium Compounds and Miscellaneous Salines (1940-47)
1942-46	Charles L. Harness and Nan C. Jensen (1942-43); with F. M. Barsigian (1944-46)	5	Magnesium Compounds and Miscellaneous Salines
1947	G. W. Josephson and F. M. Barsigian	1	Magnesium Compounds and Miscellaneous Salines
1948-53	Joseph C. Arundale and F.M. Barsigian (Mentch) ³	6	Salines - Miscellaneous (1948-51); Sodium and Sodium Compounds (1952-80)
1954-63	Robert T. MacMillan and Annie L. Marks (Matilla) ³ , (1954-57); with James M. Foley (1958-59); and with Victoria M. Roman (Schreck) ³ , (1960-62)	10	Sodium and Sodium Compounds

Table 2 continued.

Dates of chapters	Name of author(s)	Number of chapters written	Name of chapter
1964-65	William H. Kerns	1	Sodium and Sodium Compounds
1966	(tables only)	(tables only)	Sodium and Sodium Compounds
1967-68	Benjamin Petkof	2	Sodium and Sodium Compounds
1969	Arnold M. Lansche	1	Sodium and Sodium Compounds
1970-75	Charles L. Klingman	6	Sodium and Sodium Compounds
1976-77	Russell J. Foster	2	Sodium and Sodium Compounds
1978-83	Dennis S. Kostick	6	Sodium and Sodium Compounds; Sodium Compounds (1981-87)
1984	James P. Searls	1	Sodium Compounds
1985-present	Dennis S. Kostick	12	Sodium Compounds; Soda Ash and Sodium Sulfate (1988); Soda Ash (1989-present)

¹U.S. Department of the Interior, U.S. Geological Survey 1882-1923; U.S. Department of Commerce, Bureau of Mines 1924-33; U.S. Department of the Interior, Bureau of Mines 1934-1995; U.S. Geological Survey 1996-.

²Beginning in 1923, sodium salts were discussed as by-products of potash production, but there was no data or information.

³Married names in parentheses.

Soda lakes, Nevada

The first natural soda ash deposit to be commercially developed in the United States was a small lake near the present town of Fallon, Churchill County, Nevada. As early as 1854, a small station was known to have existed on the Humboldt Overland Trail that served as a watering stop for westbound travelers who were crossing the desolate plains of the Forty Mile Desert on their way to California, where gold had been discovered in 1849 (Paher, 1970). Although many did not survive the rigors of this region, thousands did brave the long and treacherous journey in wagons, on foot, and on horseback hoping to find their fortunes. This station was the beginning of Ragtown, which got its name from the tattered clothing that the immigrant women washed in the Carson River and hung on the trees to dry. On August 1, 1854, a settler named Asa L. Kenyon (born April 20, 1830 in Rome, New York) and his wife Catherine arrived at Ragtown and set up a trading post to sell provisions and livestock to pioneers continuing their western journey. The settlement had a population of between 300 to 500 people, the majority of whom lived in crude willow houses and tents.

In 1855, Kenyon began acquiring land, including a little oval-shaped soda lake (now known as Little Soda Lake) about 4.02 kilometers (2.5 miles) northeast of Ragtown. At first, he thought the white surface was ice but soon realized the dry material was a soda alkali (Angel, 1958, p. 363). Surrounding the lake were extensive incrustations of white-colored salts that accumulated through the evaporation of the lake water. According to early land records, the name of this lake was Sal Soda Lake; when it was surveyed by the county surveyor, William A. Jackson, on April 29, 1865, it was called Saleratus Lake (Churchill County, 1865). This little lake, which had an area of about 6.5

hectares (16 acres) and occupied a depression that was approximately 23 meters (75 feet) below the local ground level, would be the site of the first natural soda ash deposit to be commercially developed in the United States.

In 1866, a larger lake about 0.8 kilometer (0.5 mile) to the northeast was surveyed. This lake, which was called Oil Lake (now called either Soda Lake or Big Soda Lake), covered an area of 108.7 hectares (268.5 acres), had a diameter of 1.2 kilometers (0.75 mile), and had a depth of 45 meters (147 feet). The lake may have gotten its name because of the soaplike feel of the water, which contained carbonate and bicarbonate; alkaline-water of subterranean origin filled part of the crater. Like Little Soda Lake, this lake occupied a depression in an extinct, nearly circular volcanic crater, which gently rose above the surface of the desert floor. The highest part of the wall that surrounded Big Soda Lake was 25.6 meters (84 feet) above the desert floor and was 50.3 meters (165 feet) higher than the surface of the lake. In the late nineteenth century, the geology and hydrology of the area was thoroughly examined by the U.S. Geological Survey (Russell, 1885). This report stated that the lake contained an estimated 1.8 million tonnes or metric tons (2 million short tons) of salts; 388,000 tonnes (428,000 short tons) of sodium carbonate, 310,000 tonnes (342,000 short tons) of sodium sulfate, and 1.16 million tonnes (1.284 million short tons) of sodium chloride. **Figure 1a** shows an early land survey of the two lakes done on July 17, 1865. **Figure 1b**, a 1951 U.S. Geological Survey topographic map of the area, and **Figure 1c**, a high-altitude photograph taken in 1980, are shown for comparison.



Figure 1a. Survey of the soda lakes near Ragtown, Nevada, July 17, 1865. (Photograph from Churchill County Museum and Archive, Fallon, Nevada.)

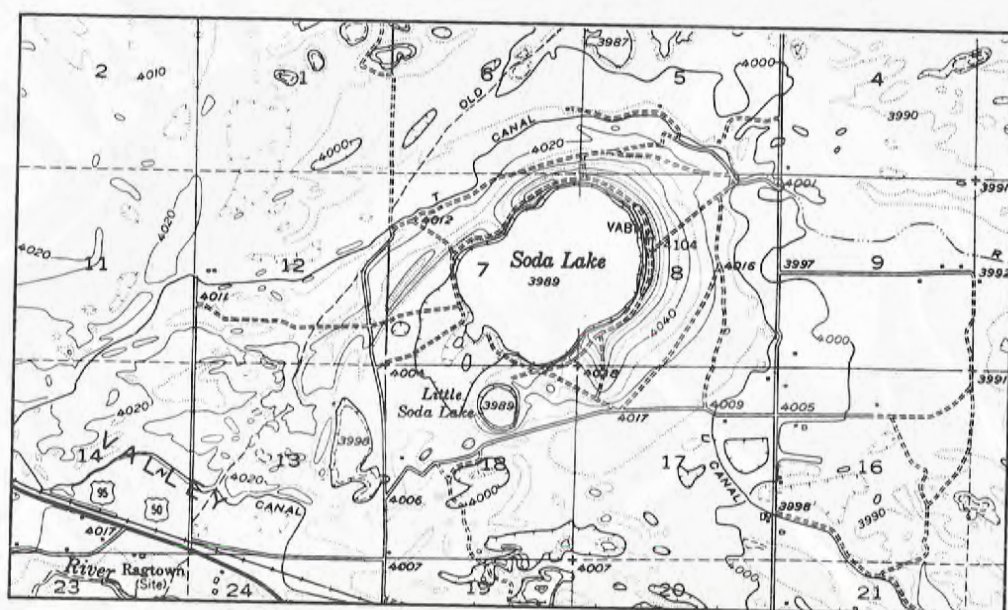


Figure 1b. Topographic map showing Ragtown (lower left) and the irrigation supply canals around both soda lakes, 1951. (From U.S. Geological Survey 1:62,500-scale topographic map.)

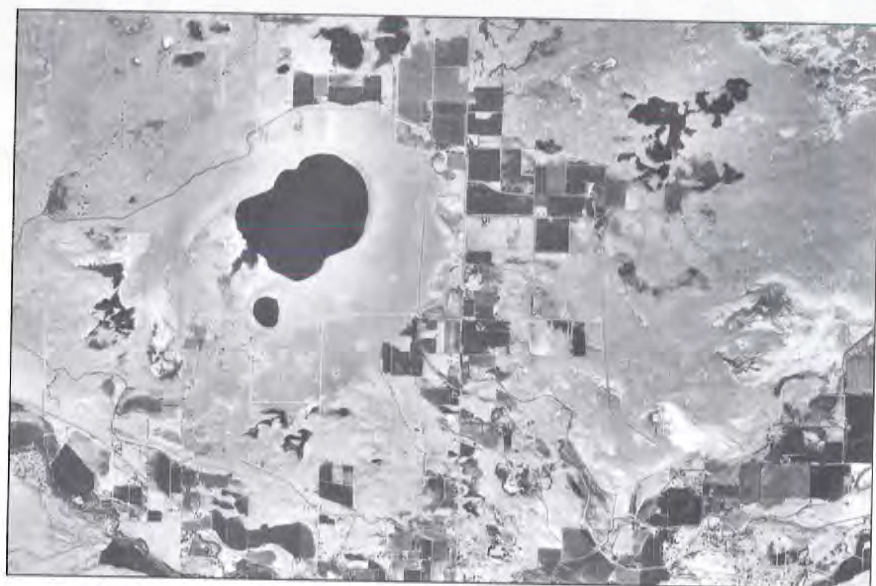


Figure 1c. High-altitude photograph of the soda lakes near Ragtown, Nevada, 1980. (From U.S. Geological Survey.)

In 1868, Kenyon sold the little soda lake to two businessmen, Higgins and Duffy, who in turn sold it to a business group from San Francisco, Doe and Dowd. The Nevada Soda Company (also later referred to as the Nevada and Pacific Soda Company) was formed, and a small plant that was erected along the lake margin annually produced about 272 tonnes (300 short tons) of crude soda dug from the surface of the lake bed during the summer.

Photographs taken sometime between 1867 and 1872 by Timothy O' Sullivan, a noted photographer during the Civil War and a member of the King expedition (Clarence King's Geological Exploration of the 40th Parallel, 1867-72), showed the presence of soda along the lake margins. **Figure 2** shows Little Soda Lake as it appeared during this time. A small wooden structure visible in the background of the photograph was probably a storage shed for the first crude soda collected. By 1872, the company claimed it could produce about 18,100 tonnes (20,000 short tons) of crude soda annually (State of Nevada, 1873). It is doubtful, however, that this level of production was ever achieved. Only five men were required to mine 54 tonnes (60 short tons) per month. At the height of its production, the operation produced between 360 and 450 tonnes (400 to 500 short tons) annually (Russell, 1885).

The mined material was loaded on horse-drawn wagons and taken 40 kilometers (25 miles) to Wadsworth, Nevada, for \$10 per ton and off loaded

for rail shipment for \$9 per ton to San Francisco, where it sold for about \$50 per ton. In San Francisco, the crude soda was refined and made into sal soda (also known as washing soda), sodium bicarbonate, and caustic soda (Virginia City Territorial Enterprise, 1878); many soap manufacturers and wool mills used these chemicals. Some of the Virginia City metal mines consumed from 27 to 36 tonnes (30 to 40 short tons) of soda monthly in metal refining from the Comstock Lode. An 1881 listing of people living in Churchill County showed that B.F. Gray from Illinois was the superintendent of the Nevada Soda Company operation and that A. Merry was the superintendent at the Big Soda Lake facility; G.W. Stone and Smith, both from Maine, were listed as employees at the Big Soda Lake operation (Angel, 1958). In the early 1880s, the Nevada Soda Company was sold to the John Horstmann Company, which operated it until its closure in about 1907.

During the next several years, the production of crude soda ash became more efficient. In the hot weather, or summer soda, process, a solution containing sodium carbonate and sodium bicarbonate was pumped into vats lined with clay bottoms and sides and allowed to evaporate by means of solar heat. The concentrated solution was sent to crystallizing vats where a deposit of sesquicarbonate accumulated by the end of the summer season. The thickness of the material varied from a few centimeters (inches) to as much as 30 centimeters (12 inches). As colder



Figure 2. Little Soda Lake. One of the members of the King Expedition is in the middle-left foreground. The arrow points to a small wooden structure that could have been used to store crude soda. Photograph taken by Timothy O' Sullivan sometime between 1867 and 1872. Compare with 1909 photograph on page 10. (Photograph from the National Archives.)

weather approached, the hard soda was broken up, collected, washed, and air-dried in a stockpile. After drying, the soda was heated in a reverberatory furnace and converted to a pure anhydrous product. In the cold weather, or winter soda, process, sodium carbonate in solution with sodium chloride precipitated out as sodium decahydrate. The salt in solution was drawn off and discarded. The soda was collected and placed on platforms to air dry to a sodium monocarbonate until spring, when the material was ready for shipment (Knapp, 1898). **Figure 3** is a panoramic view of Big Soda Lake in 1905 showing the evaporation ponds on the southern part of the lake.

On September 22, 1885, the Natron Soda Company was incorporated under California law with Eugene Griswold and W.D. Epperson as owners; Griswold had placer claims on Big Soda Lake since October 2, 1875 (*Natron Soda Company v. United States*, 1913). They built a soda ash facility on the shallow southeastern edge of Big Soda Lake. Although its capacity was about 1360 tonnes (1500 short tons) of soda ash per year, the operation only produced about 408 tonnes (450 short tons) per year which yielded an average annual profit of \$3,500. During this time period, natural soda ash was being produced by the Inyo Development Company at the soda deposit in Owens Lake, California and by the Union Pacific Alkali Works near Laramie, Wyoming, which had been formed by the Union Pacific Railroad to produce soda ash at some lakes it discovered in the early 1870s (Brown, 1995); the first synthetic soda ash facility in the United States went into operation near Syracuse, New York.

In 1903, the newly created U.S. Reclamation Service initiated the Newlands Project, which was an effort to take more than 80,940 hectares (200,000 acres) of barren desert land and convert it to useful farmland. The Derby Diversion Dam was constructed on the Truckee River that linked it with the Carson River via a 50.7-kilometer (31.5-mile) canal. Diversion canals were built to distribute the water through the area; two that passed close to the two lakes are shown in **Figure 1b**. During the summers of 1906 and 1907, the soda ash operators noticed that the evaporation of the waters from the lake surface was considerably below normal and that the level of the water was actually rising. They attributed this to seepage from the canals that migrated through the soil and into their lakes. Soon, however, the evaporation ponds began to flood and the levees broke, forcing both producers to terminate soda ash production. According to the correspondence between the Reclamation Service and Eugene Griswold which began in

1908 [letters from the files of the Truckee-Carson Irrigation District (TCID) (1908a, b; 1909)], beginning in 1908 the government determined that the excess water was from the higher-than-normal rainfall carried by the Carson River 4 kilometers (2.5 miles) away and not from their canals; therefore, the government denied any responsibility in the matter. In the 26 years before the canals were built, Griswold noticed there had been a net gain of between 20.3 and 25.4 centimeters (8 and 10 inches) of water in the lakes; however, the net increase had climbed to 61 centimeters (24 inches) since 1906 (TCID, 1908b).

Several years went by with both parties collecting data and exchanging letters. By January 1912, a new project engineer with the Reclamation Service, D.W. Cole, conceded that the canals did have a direct affect on the rise of the lake waters and suggested a settlement with the owners. He cautioned Griswold that he would have a hard time positively proving the extent to which the canal waters contributed to the damage because the farmers also had responsibility of irrigation control in the vicinity and that it would be impossible to determine the influence from either party. Although Griswold stated that his property was worth \$45,000 and generated an annual income of \$3,500, Cole recommended offering only a fraction of the value as settlement citing that Griswold would have a difficult and costly legal fight if the case went to court (TCID, 1909).

In July 1915, at the request of the U.S. Department of Justice, the U.S. Geological Survey began a comprehensive hydrologic investigation of the soda lakes to compare with the study done by Russell (1885). The report concluded that Big Soda Lake rose 4.76 meters (15.62 feet) between January 1, 1908, and December 22, 1915; the rise at Little Soda Lake was about the same. Since 1906, both of the lakes had risen about 5.18 meters (17 feet). Seepage loss was measured from the Carson River, canals, and irrigated lands; the direct source of water supply was from newly irrigated lands during the nonirrigating season and from irrigated lands adjacent to the soda lakes area (Lee and Clark, 1915). **Figure 4** shows Little Soda Lake in 1909.

The Natron Soda Company and the John Horstmann Company sued the U.S. government on June 25, 1917 for a total of \$205,000 in the U.S. Court of Claims in San Francisco. The case was decided on April 7, 1919, when the judge ruled in favor of the government (Court of Claims of the United States, 1919). The decision was appealed to the U.S. Supreme Court, which decided on November 21, 1921, that the government was not liable for the dam



Figure 3. Panorama of Big Soda Lake showing the evaporation ponds along the southern shore, 1905. (Photograph from Churchill County Museum and Archive, Fallon, Nevada.)



Figure 4. Little Soda Lake in 1909 from the same location as Figure 2. (Photograph from Churchill County Museum and Archive, Fallon, Nevada.)

ages. One major determining factor was the right-of-way agreement that Mr. Griswold and Mrs. Hattie Epperson had signed with the U.S. government on December 4, 1904. At the time, the U.S. government needed access onto their property to dig the diversion canals, and it seemed like a logical request. Nobody was aware of the potential water problems that would arise in the next couple of years with these canals. The agreement (TCID, 1908a) contained the following clause:

It is further agreed that in consideration of the premises the first party releases the second party from all claims for damages for entry, survey, or construction of said works.

Solicitor-General Beck issued a statement (Bulletin, 1921) that said the case set a precedent because:

The decision lays down the principle that the government is not liable for all actual damages resulting from public improvements, but only for such damages as inevitable to result and which, with due diligence and expert study, could have been anticipated.

Because the government had no prior knowledge that their canal project would adversely affect the soda lakes, both companies lost their bid to recover damages. It is an interesting note that the first commercial soda ash operation in the United States became involved in a landmark U.S. Supreme Court case.

It has been 90 years since the soda ash facilities were abandoned and flooded, and the level of Big Soda Lake is more than 15.2 meters (50 feet) higher today than it was in 1885 when detailed measurements were first taken. Through the years, the memories have faded about the events and the people associated with Little Soda and Big Soda Lakes and the part they played in the history of the U.S. soda ash industry. In 1978, however, people began telling stories about what was hidden in the murky depths of the lakes. At the request of the Churchill museum, local divers Keith Chesnut, Ed Glaser, and Mike Ansotegui volunteered to examine the remains of Big Soda Lake to see if there was any historical significance (Taylor, 1987). Photographs were taken showing the remains of building machinery boiler (Figure 5a), kilns (Figure 5b), and other structures.

other equipment. In 1982, a detailed underwater archaeological survey mapped these locations. An effort was started in the 1980s to nominate the site to the

National Register of Historic Places; however, the momentum reportedly has waned. The operations may be gone, but they will never be forgotten.



Figure 5a. Diver examining the remains of a boiler at the bottom of Big Soda Lake. Underwater photograph taken at the request of the Churchill County Museum. (Photograph from Churchill County Museum and Archive, Fallon, Nevada.)



Figure 5b. Diver swimming past part of a furnace at the bottom of Big Soda Lake. Underwater photograph taken at the request of the Churchill County Museum. (Photograph from Churchill County Museum and Archive, Fallon, Nevada.)

Owens Lake, California

One of the earliest surveys of Owens Lake in Inyo County was done in 1856 and 1857 by A.W. von Schmidt, who established a meander line around the shore; this line has been used as a base in many subsequent surveys. Despite the dangers and difficulties encountered by the early pioneers in that part of the West, several important mineral locations were found for salt, soda, and borax as early as 1865 (Dub, 1947). Although John Wemple Searles first recognized the economic importance of borax in 1862, it was not until 1873 that he and his brother Dennis formed the San Bernardino Borax Mining Company. In 1908, the California Trona Company was formed to produce soda ash by using the old equipment from the Searles' borax plant. The operation was never successful. The first soda ash produced at Searles Lake in Trona, California was in 1931 by the American Potash and Chemical Corporation (Moulton, 1981).

Dr. Oscar Loew, who was a member of the Wheeler Survey in 1875, was perhaps the first to recognize the importance of finding sodium carbonate present in Owens Lake. He estimated that the deposit contained 20 million tonnes (22 million short tons) of dissolved sodium carbonate, enough to supply the United States for about 100 years (Chatard, 1890). At the time, the lake was 27.4 kilometers long by 14.5 kilometers wide (17 miles long by 9 miles wide) at its greatest width and had a total surface area of 285 square kilometers (110 square miles); its greatest depth was recorded at 15.5 meters (51 feet).

The fortunes made from the gold and silver mines of the Nevada Comstock Lode prompted investors to extend the rail lines to the south into the Owens Valley where prospectors were making discoveries of other minerals. In 1880, the Central Pacific Railroad in Reno connected with the Virginia and Truckee Railroad at Mound House, Nevada, which linked up with the narrow gage Carson and Colorado Railroad to reach Keeler on the eastern shore of Owens Lake in August 1883 (Ver Planck, 1959). The owners of the Carson and Colorado Railroad were D.O. Mills of New York and H.M. Yerington, who saw an opportunity to ship more than precious metals. After hearing about the abundance of sodium carbonate in Owens Lake and the growing demand for soda ash in the West, Mills and Yerington formed the first soda ash company in California—the Inyo Development Company—on April 2, 1885.

The Inyo Development Company constructed a plant north of Keeler that began producing crude soda during the winter of 1885-86 under the direction of L.F.J. Wrinkle, a mathematics professor at the University of Nevada (Dub, 1947). **Figure 6** shows a view of the plant that was taken about 1910. The first results were disappointing because of the lack of experience of the people involved. Dr. Thomas Marean Chatard, who was a noted chemist with the U.S. Geological Survey in Washington, D.C., visited Owens Lake during the summers of 1886 and 1887 and was permitted to collect and analyze samples of the lake water. In July 1886, Wrinkle obtained the services of a man named Browning, who had worked at the Ragtown soda lakes and was experienced in constructing evaporation vats (Wrinkle, 1886). Frank Gray, who also came from Ragtown, was hired to manage the operation when commercial production began in the summer of 1887. This is probably the same Mr. Gray who was referenced earlier as the operation supervisor of the Nevada Soda Company at Big Soda Lake in 1881.

At the beginning of warm weather, the evaporation ponds were filled with lake water. After evaporation, the brine reached a certain density, and trona began to crystallize on the bottom of the ponds. The mother liquor was often replaced with fresh lake water when other salts began to form. The ponds were drained around October 1, and the three-quarter inch layer of trona was harvested. Some of the trona was sold as crude soda, and the remainder was processed into a 95% pure soda ash product by heating it in a reverberatory furnace to drive off the water of crystallization and the excess carbon dioxide present in the sodium bicarbonate. The finished product was ground to produce a more dense material preferred by glass producers.

In November 1887, Chatard wrote to Yerington in response to a job offered to him the preceding summer. Apparently, Chatard had been asked to take charge of the operations because of his technical expertise (Chatard, 1887). He would be paid \$3,000 per year and 1000 shares of stock for his past services (Chatard, 1888b) and was told to keep the matter private. Chatard was prepared to resign from the U.S. Geological Survey in January 1888 and go to Keeler by March 1 but wanted confirmation from Yerington about the job (Chatard, 1888a). Wrinkle was furious that Chatard was being offered a job and implored



Figure 6. The Inyo Development Company plant north of Keeler, California, about 1910. (Photograph from Eastern California Museum, Independence, California.)

Yerington not hire him, stating that Chatard was “a mere laboratory chemist, inexperienced in the manufacture of soda,” that he was “dumb as an oyster” about how to crush the crude soda, and that “if he was any great shakes he would not be in a subordinate position in Government employ at \$120-per month” (Wrinkle, 1888). Wrinkle obviously regarded Chatard as a threat to his own position as superintendent and wanted to discredit him.

Without warning, Chatard was notified by a telegram from Yerington (Yerington, 1888) and told not to resign his job at the U.S. Geological Survey. Apparently an article had been written in a New York newspaper on January 21, 1888 that quoted Chatard as saying he was quitting his government job and going west, which Yerington wanted kept secret. Chatard also allegedly discussed the “drying out of the lake,” which Yerington interpreted as negative publicity about his operation. An appeal was made to D.O. Mills, Yerington’s partner. In a letter sent to Mills, Chatard adamantly denied talking with reporters but conceded that some newspapermen in Washington, D.C. could have found out about his plans to leave the U.S. Geological Survey because it was common knowledge within the organization (Chatard, 1888b). Chatard suspected that Wrinkle was somehow con-

nected to the news story, especially when he found out from Mills that the San Francisco Examiner carried a story about Owens Lake (with the information purportedly furnished by Wrinkle) that was used as the basis of the New York article (Chatard, 1888c). Although his opportunity to join the Inyo Development Company was gone, Chatard remained with the U.S. Geological Survey and published the results of his scientific investigations of Owens Lake in a comprehensive report (Chatard, 1890).

Soda ash on a 48 to 55% alkali basis sold in 1889 for \$15 per ton, f.o.b. Keeler, or \$25 per ton in carload lots in San Francisco. Imported soda ash from England was selling for \$29.75 per ton in San Francisco. Communication between Eugene Griswold, president of the Natron Soda Company at Big Soda Lake at Ragtown, Nevada, and H.W. Yerington suggested that both companies exchanged soda products and information to improve the quality of their respective products (Griswold, 1888). Both were now competing not only with imported soda ash on the West Coast, but synthetic soda ash, which had been first produced at Syracuse, New York in 1884. Because rail rates from Keeler to St. Louis and Chicago were \$10 per ton, no natural soda ash could economically be shipped to the Midwest (Wrinkle, 1890).

L.F.J. Wrinkle remained the superintendent of operations for the Inyo Development Company into 1893. Sometime before 1904, his son Noah Wrinkle assumed the position but resigned in July 1907 citing family responsibilities and a desire to leave the area (Wrinkle, 1907). In 1908, he was succeeded by F.E. Fritsche, who was succeeded by F.L. Young in 1909. Noah Wrinkle did not leave the area but instead formed the Natural Soda Products Company in 1912; it stayed in operation until 1927.

By 1900, the Inyo Development Company had an annual capacity of about 9072 tonnes (10,000 short tons) and employed about 150 workers during harvesting season. **Figure 7** shows some workers using picks and shovels to harvest the crude trona from the ponds and pushing wheelbarrows to haul it to the plant. By 1914, the demand for water in Los Angeles and other cities required the construction of the Los Angeles aqueduct, which diverted water from the eastern side of the Sierra Nevada in the Owens Valley. For the next several years, Owens Lake was drying up, which concentrated the level of sodium carbonate in the lake waters. In 1918, the company was sold to the California Alkali Company, which had constructed a soda ash plant in Cartago, California in 1917. The Inyo Development Company's facility operated until 1920, and the property was leased in 1922 to the Natural Soda Products Company, which never

did anything with the operation (Ver Planck, 1959). In the next few decades, several more soda ash companies built plants along the margins of Owens Lake.

Production of natural soda ash from Owens Lake could not keep up with the increased domestic demand caused by World War II and the Korean Conflict. Beginning about 1950, competition from the new natural soda ash venture in Green River, Wyoming also contributed to the decline in soda ash production in the West. The last plant to produce refined soda ash at Owens Lake was the PPG facility, which closed in 1968 (**Table 1**). Lake Minerals Corporation, which is a joint venture between Cominco American and Vulcan Chemical Company, continues to harvest crude sodium salts from the surface of Owens Lake.

Since Owens Lake became a dry lake bed about 75 years ago, the airborne particulate matter that has blown from the dry lake surface has caused respiratory and air pollution problems that exceed the requirements of the Clean Air Act. The air pollution control managers of Owens Valley and Inyo County have developed a mitigation plan that would force the Los Angeles Department of Water and Power to restore part of the water back to Owens Lake (Booth, 1997). This action would result in the flooding of this deposit, which could affect its economic potential



Figure 7. Workers using picks and shovels to harvest the crude trona from the evaporation ponds at Owens Lake, California. (Photograph from Eastern California Museum, Independence, California.)

because many companies continue to regard Owens Lake as a viable economic resource compared with other deposits in the world.

Water has played an important, if ironic, part in the history of the first natural soda ash operations in Nevada and California. Production from the Ragtown soda lakes ended because a water diversion project

flooded the lakes, and production from Owens Lake declined because a water diversion project dried up the lake. Water irrigation projects also caused the closure of two soda ash plants in Washington in 1941: the Sodium Products Company at Mitchell Lake and the Washington Sodium Products Company at Carbonate Lake.

Syracuse, New York

Origin of synthetic soda ash

Fresnel, the French optician, is credited with discovering the chemical reaction of the ammonia-soda process in 1811 but was unable to implement his idea fully. By this time, the LeBlanc process was in its infancy in Europe. In 1838, two Englishmen, Harrison Gray Dyar and John Hemming, obtained a patent for treating brine with carbonate of ammonia and a subsequent patent was issued to Delaunay in 1839. Dyar and Hemming built plants in Whitechapel, England, but after two years they were unable to commercialize the chemical process successfully and abandoned their project in frustration (Cominoli, 1990). The introduction of carbon dioxide in gaseous form was patented by Canning in 1840. In 1852, Crinus, a Frenchman, succeeded in recovering the gas liberated by the calcination of sodium bicarbonate. That same year, Chisholm patented the distillation of ammonium chloride with lime and the subsequent absorption of the gas in brine (Martin and others, 1916). By 1852, all of the chemical reactions necessary for synthesizing soda ash were known. Ernest and Alfred Solvay, sons of a Belgian salt manufacturer, became the first to incorporate successfully all the concepts and equipment necessary to develop the ammonia-soda process. On April 15, 1861, they received a patent for manufacturing soda ash by using salt, limestone, ammonia, and coal. The secret to their success was the addition of carbonating towers in the process. With the financial backing of Eudore Primez, Ernest formed Solvay and Company in 1863, constructed a plant at Couillet, Belgium in 1864, and began operations in January 1865. By 1866, the plant was producing 1.5 tonnes of synthetic soda ash daily. By 1872, production had increased to 10 tonnes per day. The success of the Couillet facility led to the construction of a second plant in Dombasle, France. This was the beginning of the ultimate displacement of the more expensive LeBlanc soda ash process.

In April 1872, Ernest Solvay was contacted by Ludwig Mond, who wanted to license the Solvay

technology and construct an ammonia-soda plant at Winnington, Cheshire, England. The agreement between the two was signed September 23, 1872. Mond and his friend and financial partner, John Tomlinson Brunner, formed Brunner Mond and Company in 1873, and the first English soda ash plant came onstream in 1874 (Dick, 1973). Synthetic soda ash production using the ammonia-soda process was now firmly established in Europe.

Synthetic soda ash in the United States

In February 1879, William B. Cogswell heard a presentation titled "The Manufacture of Soda by the Ammonia Process," by Oswald J. Heinrich in Baltimore, Maryland, at the American Institute of Mining Engineering. Heinrich cited the following advantages of the ammonia-soda process over the LeBlanc process: fuel economy, low production costs, and smaller investment (only one-tenth of the amount required in the LeBlanc method). The industrial growth after the Civil War in the United States caused the demand for soda ash to increase. Rather than relying on soda ash imports to supply the needs of the East Coast glass, detergent, and chemical manufacturers, Cogswell obtained letters of introduction from Heinrich, and sailed to Europe to meet with the Solvays about using their process in the United States. Unfortunately, the Solvays had an earlier bad experience with a boisterous American promoter who "planted his cowhide boots against Alfred Solvay's walnut desk, tilted back his chair, and proceeded to lay down the terms upon which he would make the Solvays a 'blooming, everlasting fortune'" (Haynes, 1940). Consequently, the brothers refused to see Cogswell. In time, however, Cogswell's knowledge, courtesy, and tact won the respect of the brothers who agreed to provide their technology in exchange for the right to subscribe to one-third of the stock (3000 shares at \$100 per share) and one half of the profits after 10% dividends had been declared to the stockholders (Cominoli, 1990).

In the fall of 1881, the Solvay Process Company was incorporated in New York for the purpose of constructing the first synthetic soda ash plant in the United States. With a capital of \$300,000 (one-third supplied by the Solvays and two-thirds supplied by Hazard, Cogswell, and a few of their friends in Syracuse), Rowland B. Hazard, William B. Cogswell, William A. Sweet, Earl B. Alvord, and George E. Dana began building the plant in September, 1881 on a 20.2-hectare (50-acre) tract in Geddes, which was about 4.8 kilometers (3 miles) west of Syracuse. The site was selected because of the availability of salt, limestone, and coal, which were the essential raw materials. Also, the location provided access to the New York Central Railroad and the Erie Canal to ship the finished product to customers. The first major problems were the lack of qualified workers and blueprints for construction. Because Cogswell and William L. Neill, who was the first employee hired by the new Solvay Process Company, could speak fluent French and German, they traveled to Dombasle, France in the winter of 1881-82 to work as apprentices to learn how to make synthetic soda ash at the Solvay plant. When Cogswell returned in the spring of 1882, he began recruiting chemists and engineers to operate the Syracuse facility; Edward N. Trump became the chief engineer. In April 1883, Neill was joined in France by Henry Cooper, John Bodot, and J. William Smith, who also learned the science of making soda ash from their European masters.

The first attempt to make soda ash at the first synthetic soda ash plant in the United States coincided with the night of the company's first official accident. At 11:00 p.m. on Tuesday, January 8, 1884, several men almost suffocated to death from the carbon dioxide gas contained in the carbonating towers. Cooper and Cogswell were hurt, and one man in the tower died (Cominoli, 1990). The operation officially began on January 10, 1884. Out of a possible 355 days that year, the facility actually ran for 332 days and produced about 11,160 tonnes (12,300 short tons) of 58% alkali. Later in the year, the first officers and staff of the Solvay Process Company posed for a group photograph with several officials from Europe, including Ernest Solvay and John Brunner (Figure 8). The first year of operation was not without its problems. At 4:10 a.m. on January 13, 1885, an improperly vented iron distilling vessel exploded and destroyed the roof of the main building. Of the 50 men who were subjected to falling debris, corrosive fumes, and scalding chemicals, only ten were injured and one died from ammonia inhalation. The accident forced the temporary closure of the plant for 30 days. In early 1885, plans were made to double the output

by expanding the facility. The expansion was completed in February 1886 and raised the annual soda ash capacity to nearly 40,800 tons (45,000 short tons). Figure 9 shows the Syracuse plant and the Erie Canal about 1913.

In 1869, which was before the Syracuse plant was built, the United States imported 59,578 tonnes (65,674 short tons) of soda ash that sold at \$39.55 per tonne (\$35.88 per short ton). The selling price of Syracuse soda ash in 1885 was \$29.30 to \$30.63 per tonne (\$26.58 per short ton to \$27.79 per short ton), with 58% sodium oxide, whereas the price of imported soda ash that year declined to \$25.90 per tonne (\$23.50 per short ton) (Day, 1888). Soda ash production at Syracuse in 1885 was 15,240 tonnes (16,800 short tons) and total imports of soda ash, primarily from England, were 118,357 tonnes (130,466 short tons). In that same year, England produced 266,267 tonnes (293,509 short tons) of soda ash; 187,493 tonnes (206,675 short tons) of soda ash by the LeBlanc process and 78,775 tonnes (86,834 short tons) by the ammonia-soda process. If almost all the U.S. imports were from England, then the United States consumed 44% of England's total output. During the next decade, however, imports steadily declined as domestic soda ash production increased.

By the mid-1880s, natural soda ash production had begun at Owens Lake in California, and was at its peak at the soda lakes in Nevada; however, the output from these operations remained in the West because of the distance to eastern markets. In 1887, U.S. consumption of soda ash, by end use, was estimated at glass, 25%; sodium bicarbonate and sal soda, less than 25%; paper manufacture, 20%; soap and chemicals, nearly 20%; and other uses, 10% (Day, 1888). In 1898, only 39,936 tonnes (44,022 short tons) were imported from England. At its annual meeting on March 17, 1899, the United Alkali Company, Ltd., of Liverpool, England, met to discuss the problem of decreasing exports to the United States (Rothwell, 1899).

The Solvay Process Company constructed three more synthetic soda ash plants in United States during the next several years: Detroit, Michigan (1898), Hutchinson, Kansas (1908), and Baton Rouge, Louisiana (1935). Writing about his 50 years in the alkali industry, Edward Trump in 1933 believed the Solvay Process Company was perhaps the first American company to reduce shift work from 12 hours to 8 hours, and provide accident, health, and old-age pension plans (Trump, 1933).



Figure 8. The first officers and staff of the Solvay Process Company, Syracuse, New York, and European and other American officials, 1884. 1. William B. Cogswell, General Manager; 2. Edward Hannon, Solvay and Cie, Belgium; 3. Edward N. Trump, Chief Engineer; 4. Rowland G. Hazard, Vice President; 5. Ernest Solvay, Solvay and Cie, Belgium; 6. John Brunner, Brunner Mond and Company, Winnington, England; 7. Rowland Hazard, President; 8. John Wing, Wing and Evans, New York; 9. Frederick R. Hazard, Secretary; 10. J. William Smith, Engineer; 11. Henry R. Cooper, Engineer; 12. Baron Vanderstratten, Solvay and Cie, Belgium; 13. Nathaniel T. Bacon; and 14. Edmond Solvay, Solvay and Cie, Belgium. (From Allied Chemical Company, now known as General Chemical Corporation.)

The company expanded into other chemical enterprises and formed sister companies, such as the Semet-Solvay Company, and General Chemical Company, which were consolidated under the name of Allied Chemical and Dye Corporation on December 17, 1920. The General Chemical Company name was resurrected prior to the Syracuse shutdown in 1986 when Allied Chemical divested itself of its soda ash and other chemical businesses. General Chemical continues to operate soda ash plants in Amherstburg, Ontario, Canada (an ammonia-soda operation), Green River, Wyoming (a trona mine and soda ash refinery), and some other chemical plants.

With the demonstrated success of the Solvay process, other companies entered the synthetic soda ash

business, including Diamond Alkali Company (later renamed Diamond Shamrock Corporation), Mathieson Alkali Works, Inc. (renamed Olin-Mathieson; later Olin Corporation), Michigan Alkali Company (renamed BASF Wyandotte Corporation), Pittsburgh Plate Glass Company (later known as PPG), and Southern Alkali Corporation (owned by Pittsburgh Plate Glass Company and American Cyanamid Company). Dow Chemical Company also operated a caustic carbonation plant in Freeport, Texas. By 1939, ten Solvay plants were in operation in six states throughout the nation. Competition from the natural soda ash operations in California and Wyoming, the costs to implement pollution abatement equipment mandated by environmental legislation, and rising energy costs ultimately were responsible for closing



Figure 9. The Solvay Process Company, Syracuse, New York, seen from across the Erie Canal, 1913. (From Allied Chemical Company, now known as General Chemical Corporation.)

nine of the ten synthetic soda ash plants in the United States. On September 12, 1981, Allied Chemical celebrated the Syracuse plant's 100th anniversary. After 100 years of operation, the nation's first synthetic soda ash plant had the distinction of being the last one.

Glass production began decreasing after 1980 because of glass recycling and the growing use of aluminum cans and plastic bottles that displaced glass containers. By 1986, 30 glass plants had closed east of the Mississippi River, thus reducing soda ash con-

sumption. Competition from the natural soda ash plants in California and Wyoming also affected the economic position of the Syracuse facility. As a result, the Syracuse plant was officially closed on January 6, 1986; total shutdown was completed by February 1986. The closing of the 105-year-old plant eliminated 1500 jobs, or about one-third of the residents of the town of Solvay, and an annual payroll of \$46 million. Much of the complex has been demolished but parts still stand today as a tribute to this historic symbol of the U.S. soda ash industry.

Green River, Wyoming

The presence of alkali had been known in the territory that became Wyoming since at least 1835 when the Reverend Samuel Parker crossed the Rocky Mountains and noticed epsom salts on the ground near Independence Rock, Wyoming. Mormon pio-

neers traveled across the territory and found "sweetwater," a term for the taste of the waters and the name of the county that contains the majority of the trona resource. They reportedly used the natural sodium bicarbonate that occurs in the Sweetwater

River for laundry and medicinal purposes as early as 1849. One of the first famous geological expeditions in Wyoming was headed by Major John Wesley Powell, who later became the second director of the U.S. Geological Survey. Powell and nine other geologists, geographers, and scouts set out from Green River at 1:00 p.m., May 24, 1869 to follow the Green and Colorado Rivers and explore the last great unmapped part of the continental United States (Powell, 1895).

Early soda ash production attempts

Attempts to produce soda ash in Wyoming from surface deposits or from underground brine sources were few and short-lived. The Union Pacific Railroad owned some soda deposits that it discovered in the early 1870s about 21 kilometers (13 miles) south of Laramie. They were known as the Union Pacific lakes, five lakes that had a total area of about 809 hectares (2000 acres). Jay Gould, who was a member of the Union Pacific board of directors, sent his chief engineer, T.E. Sickels, to Europe to find out how to make soda ash (Brown, 1995). Although homesteading pioneers around the lakes delayed the development of the deposits, some of the property was leased to Howard Hinckley, who constructed a plant that produced 2 tonnes of caustic soda daily by using the LeBlanc process (Weeks, 1886). Because problems in the design of the plant caused delays and losses of caustic soda, the plant operated only from July 1884 to January 1885. Other soda lakes in the region include the Donney lakes [three lakes with a combined area of 210 hectares (520 acres)] located 29 kilometers (18 miles) southwest of Laramie and the Dupont lakes [four lakes ranging from 2.4 to 809 hectares (6 to 2000 acres) in area and containing these five claims: the Omaha soda, the Wilkes Barre, the Wilmington, the New York, and the Philadelphia] located about 80 kilometers (50 miles) north of Rawlins. The absence of a railway prohibited the development of these deposits.

The Union Pacific Alkali Works built a plant to develop the soda deposits of the Union Pacific lakes in 1895. In 1898, the American Development Company, and the American Native Soda, Glass and Chemical Company were incorporated to also develop the soda deposits in the region. Another company, the American Soda, Glass and Chemical Company, acquired the Union Pacific Alkali Works and reportedly began production in 1899 (Rothwell, 1899).

Discovery of trona

In the late 1890s, the Green River Fuel and Oil Company drilled an exploration well near Green River, Wyoming, and found alkali water at 38 meters (125 feet) (Brown, 1995). In 1902, The Wyoming Chemical Company was formed but was sold four years later to the Western Alkali Company, which invested \$500,000 to improve the property. Soda brines were pumped from three wells and evaporated in large open-air concrete basins. Sal soda crystallized first. Slaked lime was added to the sal soda and heated to produce caustic soda, which was used locally by the Union Pacific Railroad in water softening and by soap manufacturers in nearby states. Because the company defaulted on its mortgage, the operation was sold to F.J. Siegel and Associates of Denver (FMC Corporation, 1961) in 1908. This was incorporated into the Wyoming Soda Products Company, which operated until about 1918.

On October 29, 1937, Mountain Fuel Supply Company began drilling the John Hay Jr. No. 1 exploratory well on Federal land to search for oil or gas. After drilling to a depth of 1622.5 meters (5323 feet), the well was abandoned on January 3, 1938 because no oil or gas was discovered. William T. Nightingale, who was the company's chief geologist, noticed a variety of minerals in the drill cores and sent sections of the cores taken from depths of 485.9 to 487.7 meters (1594 feet to 1600 feet) to Howard I. Smith, who was chief of the mining division of the U.S. Geological Survey in Washington, D.C. Although trona was identified in the cores by Roger C. Wells (who authored the 1917-20 sodium salts chapters in reports published by the U.S. Geological Survey; see table 2), it was the discovery of the new mineral, shortite, by Joseph J. Fahey that initially intrigued the U.S. Geological Survey (Fahey, 1939).

The following two sentences in an obscure paragraph in Fahey's 1939 article caught the attention of Robert D. Pike, a consulting chemical engineer from Pittsburgh (Anonymous, 1953). It stated:

Massive trona is present at depths of 1325 feet and 1587 1/2 feet, but is not found associated with the new mineral. At the lower depth shortite is present in the clay that overlies the massive trona.

Pike caught the significance of this statement and convinced the Union Pacific Railroad to do some more exploration. Joseph Fahey went to Wyoming to pack and ship the remainder of the core back to

Washington, D.C., where he finished logging and identifying the minerals in it. In January 1940, Walter C. Mendenhall, director of the U.S. Geological Survey, officially announced the occurrence of the Green River trona deposit (Mendenhall, 1940). Through the persistence of Pike, who was hired by the railroad at \$500 per month and no expenses, the Union Pacific Railroad cored two more holes, numbers 1 and 2, in 1940 that confirmed the existence of the trona bed discovered in the John Hay Jr. No. 1 well. Hole numbers 3 and 4 drilled in 1942 also confirmed the existence, analysis, thickness, and depth of the trona deposit. Senator Joseph C. O' Mahoney of Wyoming, who chaired the U.S. Senate subcommittee of the Public Lands Committee, heard about the trona find and invited Pike to testify on July 23, 1941 about its importance (Chemical and Metallurgical Engineering, 1941). Pike approached his friend, Dr. Max Y. Seaton, who was Executive Vice President of the Westvaco Chemical Corporation, to discuss the opportunity for developing this deposit despite the fact that Westvaco was not in the soda ash business.

Although Westvaco became interested in the idea, actual work on the operation was suspended until after the end of World War II. Between 1944 and 1946, Westvaco Chemical Corporation drilled three more wells in the region that showed that the main trona bed was at least 78 square kilometers (30 square miles) in area. In the spring of 1946, Westvaco notified the Union Pacific of its intention to sink a mine shaft and to construct a trona processing plant. A concrete-lined vertical shaft 3.7 meters (12 feet) in diameter was sunk during the early months of 1947.

After reaching the 457-meter (1500-foot) level, workers stood for the first time on top of the main trona bed, Bed 17; three companies currently mine this bed. Mining equipment was disassembled on the surface, lowered down the shaft, and reassembled below to begin the development of the honey-combed maze of rooms and pillars. After being deposited more than 52 million years ago, the first skipload of trona was brought to the surface in late 1947. In the fall of 1948, the Westvaco Chemical Corporation was acquired by the Food Machinery Corporation in the fall of 1948.

For the next two years, the company experimented with different mining techniques and equipment. **Figure 10** shows a Goodman 665 ore loader being delivered in 1949. In 1950, 38,896 tonnes (42,875 short tons) of trona was mined and processed into calcined trona, which was the first commercial product sold. In 1952, the Westvaco Chemicals Division of the Food Machinery and Chemical Corporation (later to be known as FMC Corporation) formed the Intermountain Chemical Company (**Figure 11**), which was Wyoming's first trona mining company. The company expanded its operation in April 1953 to begin producing refined soda ash by a sesquicarbonate process. The plant, which cost \$20 million and employed 325 persons, had a total annual nameplate capacity of 272,000 tonnes (300,000 tons).

Several people contributed to the success of the plant during its first year of operation including: C.A. Romano, resident manager; John Jacobucci, plant



Figure 10. Delivery of a Goodman 665 ore loader to Westvaco Chemical Corporation, 1949. (Photograph from Sweetwater County Historical Museum, Green River, Wyoming.)

superintendent; A.P. McCue, assistant plant superintendent; G.B. Gaylord, superintendent of underground operations; Robert F. Love, assistant mine superintendent; N.E. McDougal, superintendent of surface operations; William C. Bauer, superintendent of processing engineering; E.V. Birmingham, maintenance superintendent; and L.K. Marshall, mining engineer.

Figure 11. Construction of FMC's soda ash plant, 1952. (Photograph from Sweetwater County Historical Museum, Green River, Wyoming.)



For the next 50 years, FMC expanded to become the largest producer of natural soda ash in the world. It was followed by four more companies: OCI Chemical Company (formerly Stauffer Chemical Company and Rhône-Poulenc Basic Chemicals Company) in 1962;

General Chemical Corporation (formerly Allied Chemical Company) in 1968; Tg Soda Ash, Inc., in 1976; and Solvay Minerals, Inc. (formerly Tenneco Mineral Company) in 1982.

Summary

The Greek historian Thucydides (ca. 400 B.C.) once stated:

I shall be content if those shall pronounce my history useful who desire to have a clear view both of the events which have happened, and of those which will some day, in all human probability, happen again in a same or similar way.

In some ways, history is repeating itself. Some old company names that have come and gone have been resurrected: the formation of Brunner Mond and Company in 1881, its merger into ICI in January 1927, and the reappearance of the name Brunner

Mond in 1991; the formation of General Chemical Corporation in 1899, its merger into Allied Chemical and Dye Corporation in 1920, and the reappearance of the name "General Chemical" in 1985; and the reporting of soda ash information that began in the U.S. Geological Survey in 1882, its transfer to the U.S. Bureau of Mines in 1924, and its return to the U.S. Geological Survey in 1996. Perhaps Thucydides was right.

An industry is measured by the legacy it leaves to the next generation. The accomplishments and failures of this generation of soda ash producers will be measured by their successors in the twenty-first century.

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Soda ash goes global for growth

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Abstract

The U.S. soda ash industry owes much of its success over the past decade to an increase in its sales to markets outside the U.S. While total soda ash production grew from 8.4 million short tons in 1986 (an average annual growth rate of 2.9%), U.S. exports doubled from 2.1 million short tons to 4.2 million short tons (an average annual growth rate of 7.2%). In contrast, domestic demand grew at a modest 1.0% rate. Exports now account for 38% of all U.S. soda ash sales. This paper reviews some of the reasons behind the success of the U.S. in the world export market, and takes a brief look at what the future may hold for the soda ash industry worldwide.

Exports drive soda ash growth

Production of soda ash in the United States has increased in the last ten years primarily due to increased exports. With relatively flat domestic consumption during this period, the growth in exports continued to drive production up (Figure 1 and Table

1). The average annual growth rates in domestic consumption, production, and exports during this ten-year period were 0.7%, 2.9%, and 7.2%, respectively. This growth in exports, when expressed as a percent of the nation's soda ash production,

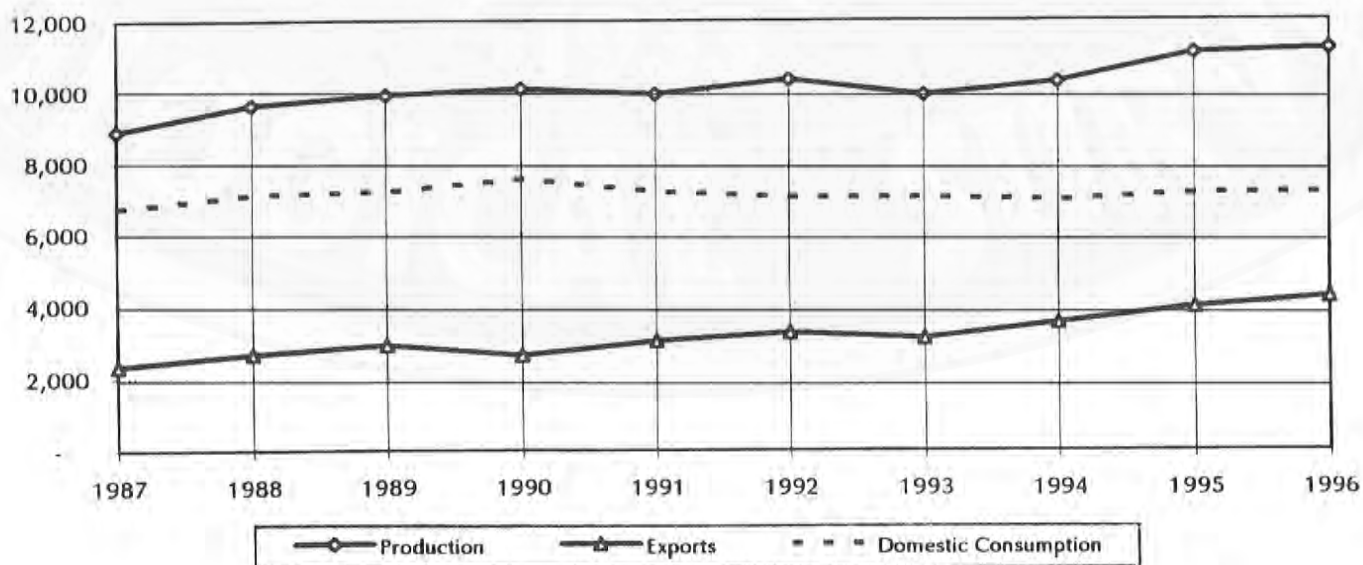


Figure 1. Production, consumption, and exports of U.S. soda ash, 1987 to 1996 (in thousands of short tons).

has steadily increased from 13.2% in 1980 to nearly 38% in 1996 (Table 2 and Figure 2).

Table 1. Production and consumption of U.S. soda ash, 1987 to 1996, in thousands of short tons.

	Production	Exports	Domestic consumption
1987	8890	2342	6734
1988	9632	2662	7104
1989	9915	2915	7186
1990	10,092	2639	7544
1991	9926	3014	7188
1992	10,339	3257	7009
1993	9886	3085	7006
1994	10,254	3511	6930
1995	11,075	3930	7124
1996	11,189	4222	7124

Adjusted for inventory changes and imports.

The growth of the U.S. soda ash export market was spurred by the lower production costs of natural versus synthetic soda ash, the growing Asian market, the formation of American Natural Soda Ash Corporation (ANSAC), closure of foreign plants, and improved shipping and distribution costs. Export of 1.95 million short tons of soda ash to Asian countries in 1996 accounted for almost half the total exports (Table 3). Exports to Latin America and Mexico combined for about 1.31 million short tons or nearly 32% of total exports (Figures 3 and 4).

Table 2. Exports of U.S. soda ash, 1980 to 1996, expressed as a percent of total production.

1980	13.2%
1981	12.7%
1982	15.5%
1983	19.3%
1984	19.4%
1985	23.9%
1986	25.1%
1987	26.3%
1988	27.6%
1989	29.4%
1990	24.1%
1991	30.4%
1992	31.5%
1993	31.2%
1994	34.2%
1995	35.5%
1996	37.7%

Table 3. Major export destinations of U.S. soda ash in 1996, in thousands of short tons.

Destination	Quantity	Percent
Canada	260	6.2
Mexico	403	9.6
Latin America	911	21.6
Europe	224	5.3
Asia	1950	46.2
Middle East	204	4.8
Oceania	82	1.9
Africa	185	4.4
Total	4219	100.0

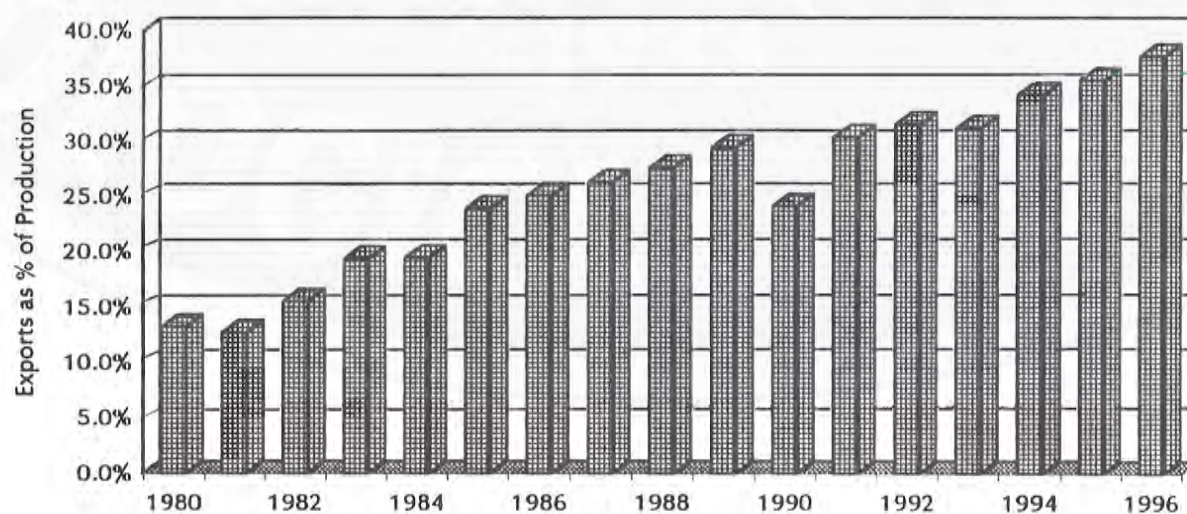


Figure 2. U.S. exports of soda ash as a percent of the total production, 1980 to 1996.

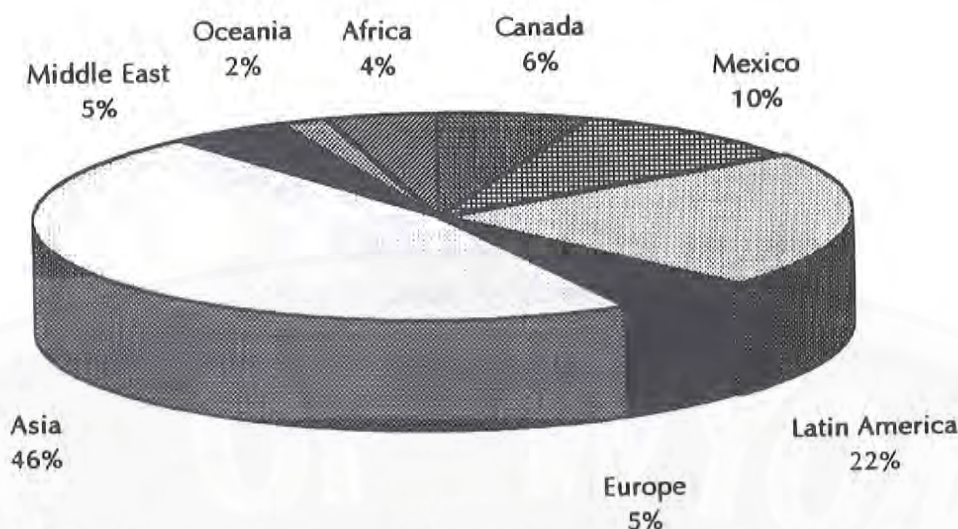


Figure 3. Major export destinations of U.S. soda ash, and percentages of total exports, 1996.

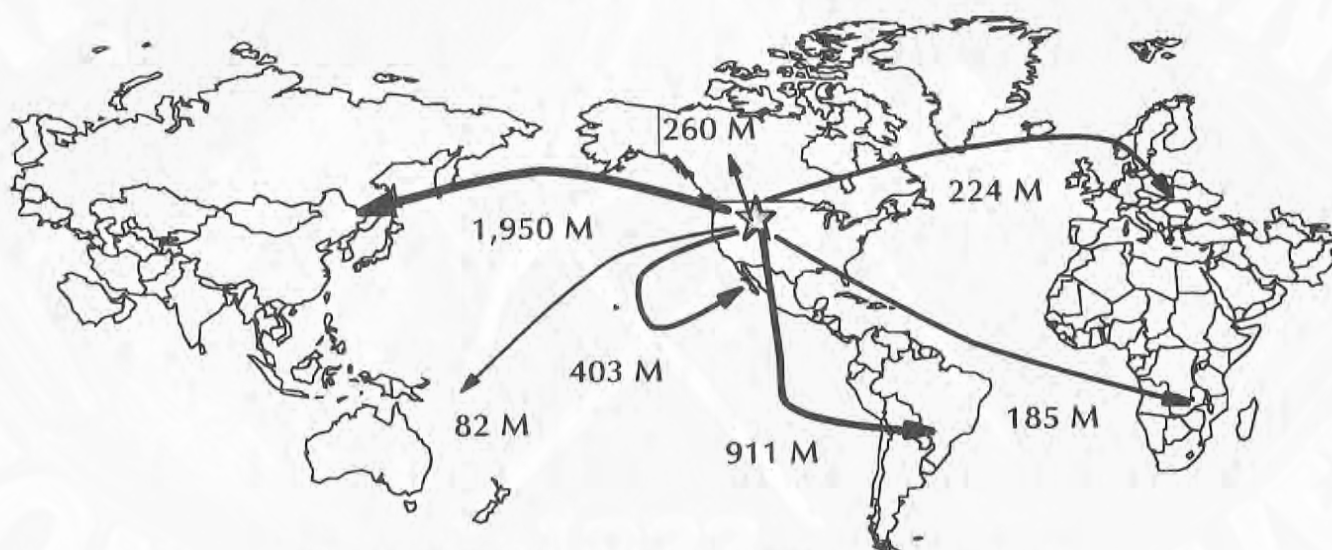


Figure 4. World map of U.S. soda ash trade in 1996, in millions of short tons.

In the last five years, some 2.5 million tonnes of soda ash productive capacity worldwide has been shut down in a number of countries (Table 4) for a variety of reasons. Europe has been especially susceptible to capacity shutdowns, experiencing a loss of about 1.7 million tonnes in the last five years. This has allowed the U.S. soda ash industry to penetrate some previously closed markets; exports to European countries accounted for about 5% of the total exports in 1996.

The formation of ANSAC, the exporting association for American soda ash producers, has been important in increasing U.S. export volumes and has lead to improved shipping and distribution costs. Formation of soda ash unit trains has reduced rail

Table 4. Worldwide shutdowns of soda ash capacity, 1992 to 1997, in thousands of tonnes (metric tons).

Company	Country	Capacity	Closure date
Fab. Soda	Bosnia	225	1992
Fab. Soda	Czech Republic	150	1992
Solvay et Cie	France	300	1992
Fab. Soda	Albania	50	1993
Alcali de Colombia	Colombia	130	1993
Sosa Texcoco	Mexico	180	1993
Solvay et Cie	Belgium	400	1993
Solvay et Cie	Germany	300	1993
Chemische Fabrik Kalk	Germany	300	1993
Tosoh	Japan	320	1996
Asahi Glass	Japan	150	1997
Total capacity shutdown		2505	

transportation costs, especially to the export terminals on the coast. ANSAC and the Union Pacific Railroad now operate a dedicated terminal in Portland, Oregon and ANSAC now has six ships dedicated to soda ash exports.

On the negative side for U.S. export markets is the People's Republic of China's emergence as a soda ash exporter. From 1985 to 1996, China has gone from importing over a million tonnes of soda ash to becoming almost non-dependent on imports while at the same time developing an export market of about one-half million tonnes (Table 5).

Table 5. Soda ash trade for the People's Republic of China, 1985 to 1996, in millions of tonnes (metric tons).

	Imports	Exports
1985	1047	-
1986	1124	-
1987	853	-
1988	823	-
1989	676	-
1990	210	12
1991	54	197
1992	59	376
1993	61	281
1994	101	282
1995	75	515
1996	63	509

Slowdown in domestic soda ash markets

The domestic soda ash market has grown slowly in the last few years because of the loss of the soft drink container market to plastics and because of the increased use of recycled glass. About 27% of the container glass is now recycled to the glass batch. The glass containers sector is no longer the leading domestic market for soda ash, having been displaced by the chemicals sector. In 1996, 26.4% of U.S. domestic soda ash was used by the chemicals industry, compared to 24.3% used by the glass containers industry (Table 6).

Table 6. Domestic soda ash consumption in the U.S. by percent of end use in 1996.

End use	Percent
Glass containers	24.3
Flat glass	15.7
Other glass	7.6
Chemicals	26.4
Detergents	12.3
All others	13.7

Production of container glass in the U.S. has declined every year since 1993 (Table 7). In 1995, glass container production in the U.S. declined by more than 6% from the previous year, and in 1996, glass container production dropped by over 8% from 1995 (Figure 5). Glass produced for soft drink containers, which accounted for nearly 20% of the entire glass container production in 1988, has fallen steadily since then (Table 8 and Figure 6). Production of glass soft drink containers was 750 million pounds in 1996, accounting for only 4% of the total glass container production. Production of glass soft drink containers declined 55% between 1994 and 1995.

Table 7. Production of glass containers in the U.S., 1986 to 1996, in million pounds.

1986	21,949
1987	20,320
1988	21,635
1989	22,172
1990	21,865
1991	21,092
1992	22,128
1993	22,773
1994	22,597
1995	21,160
1996	19,396

Table 8. Production of glass soft drink containers in the U.S., 1986 to 1996, in millions of pounds.

1986	4025
1987	3785
1988	4247
1989	4054
1990	3819
1991	3655
1992	3356
1993	3002
1994	2057
1995	971
1996	750

Flat glass production in the United States accounted for about 15.7% of the domestic soda ash consumed in 1996. After a brief period of decreasing flat glass production from 1988 to 1991, flat glass production has been increasing steadily since then (Table 9 and Figure 7).

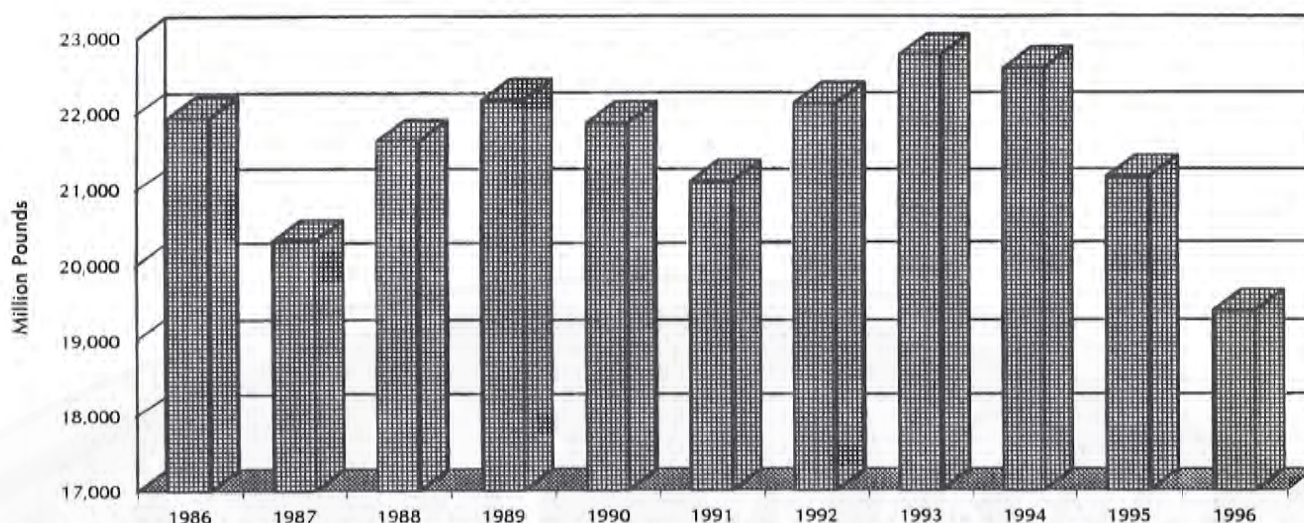


Figure 5. Glass container production in the U.S., 1986 to 1996, in million pounds.

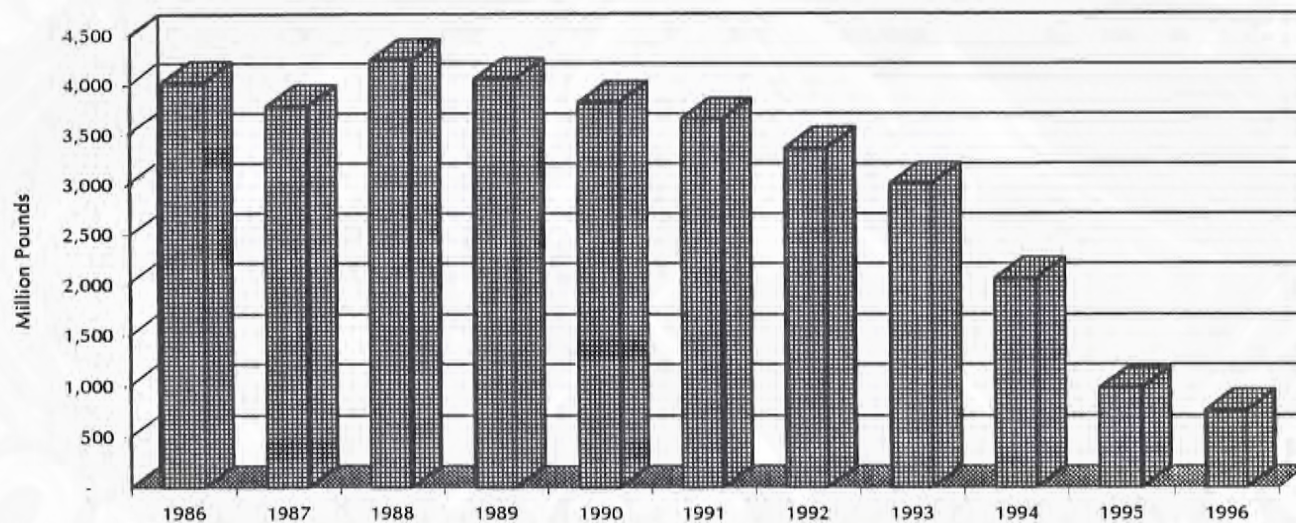


Figure 6. Glass soft drink container production in the U.S., 1986 to 1996, in million pounds.

Table 9. Production of flat glass in the U.S., 1986 to 1996, in thousands of short tons).

1986	3881
1987	4122
1988	4307
1989	4183
1990	4080
1991	3648
1992	3892
1993	4004
1994	4262
1995	4438
1996	4370

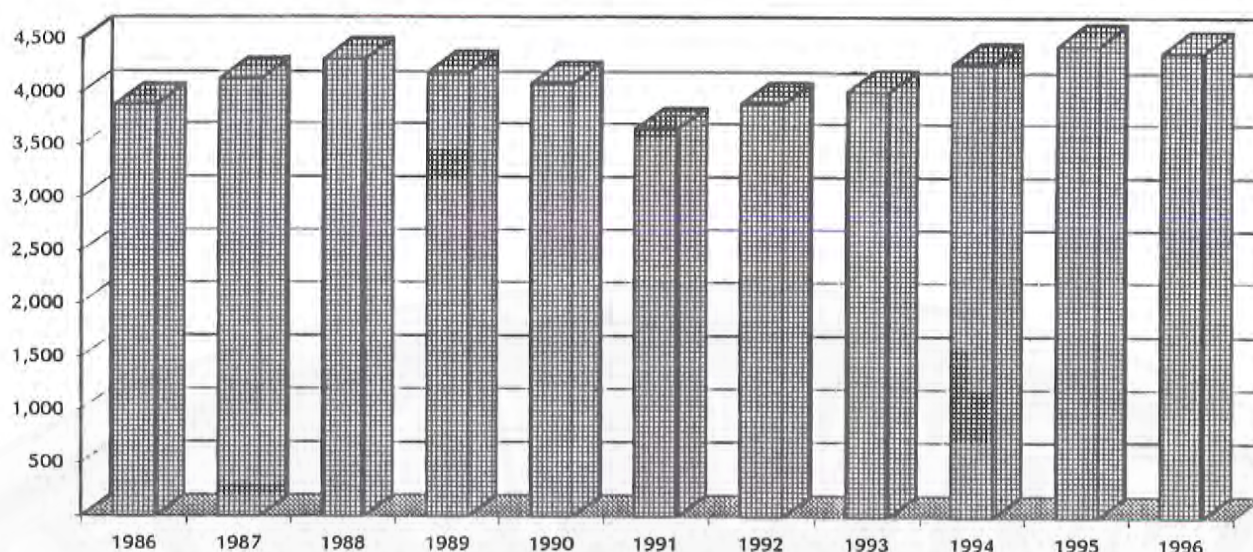


Figure 7. Flat glass production in the U.S., 1986 to 1996, in thousands of short tons.

Industry expansion to meet growing demand

The increased production of U.S. soda ash to meet the growing demand from the export market has driven the industry to continuously increase total nameplate capacity of their plants (**Table 10** and **Figure 8**). In general, as nameplate capacity and effective capacity are increased each year, production lags behind by several years, as also reflected by decreased operating rates (**Table 11** and **Figure 9**). During times of stable or relatively small additions to capacity, the operating rate tends to increase with time as the production catches up to the expansion.

Table 10. Nameplate capacity of U.S. soda ash plants, 1987 to 1999, in thousands of short tons.

1987	10,560
1988	10,560
1989	10,560
1990	10,680
1991	11,000
1992	11,410
1993	12,150
1994	12,150
1995	12,150
1996	12,900
1997	13,150
1998	13,150
1999	13,750

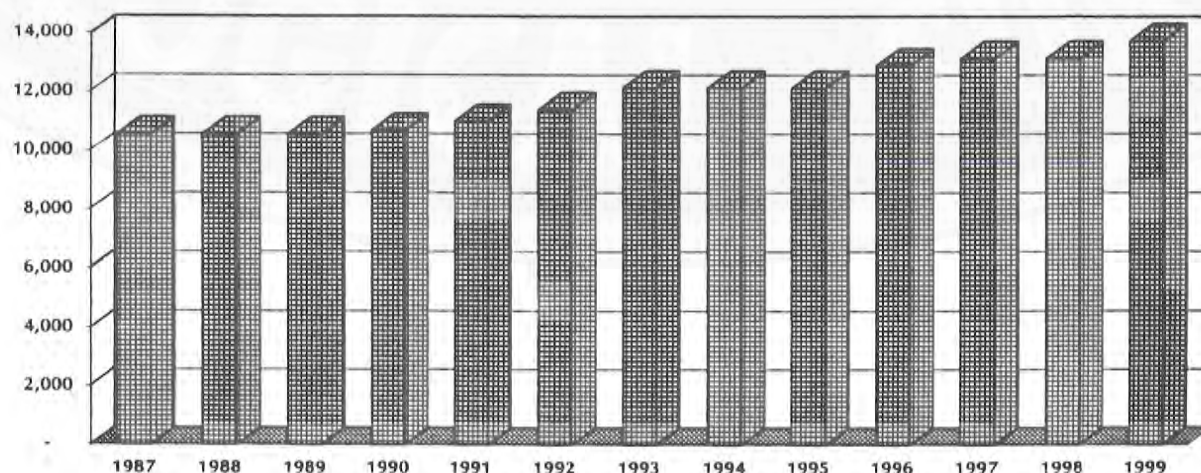


Figure 8. Nameplate capacity of the U.S. soda ash industry, 1987 to 1999, in thousands of short tons.

Table 11. Effective capacity, production, and operating rates of the U.S. soda ash industry, 1987 to 1999. Capacity and production in thousands of short tons.

	Effective capacity	Operating rate	Production
1987	10,000	89.6%	8890
1988	10,100	94.9%	9632
1989	10,100	98.2%	9915
1990	10,500	94.2%	10,092
1991	10,700	93.0%	9926
1992	10,900	92.3%	10,339
1993	10,900	91.0%	9886
1994	10,900	95.4%	10,254
1995	11,100	99.5%	11,075
1996	12,200	92.0%	11,189
1997	12,500	95.0%	11,750
1998	12,700	93.0%	11,800
1999	13,300	92.0%	12,250

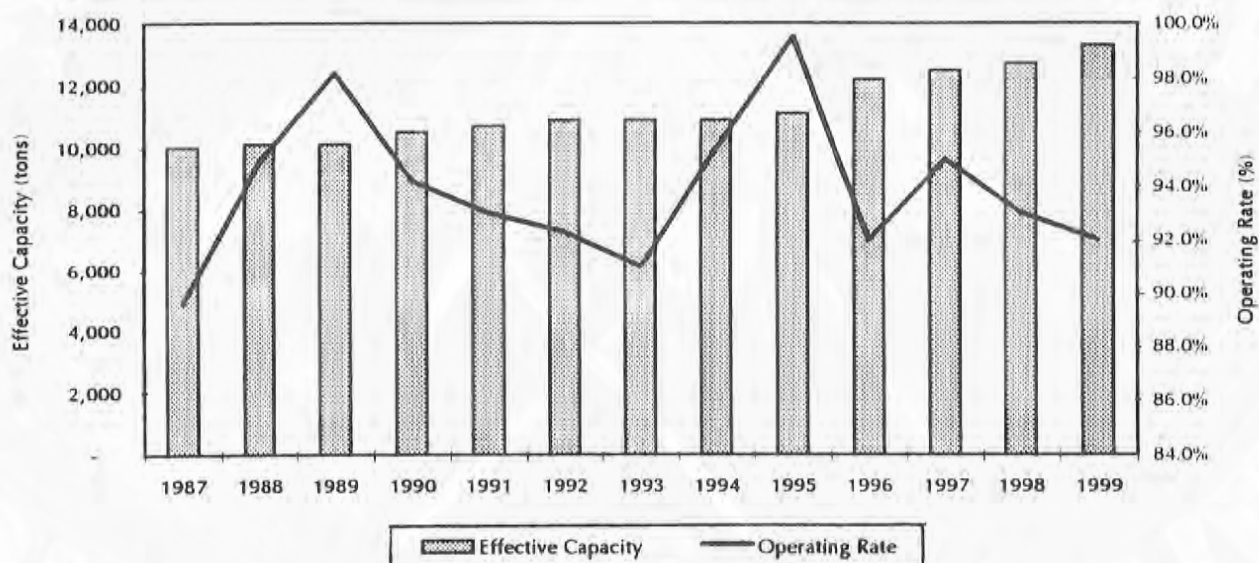


Figure 9. Effective capacity (in thousands of short tons) and operating rates (in percent) of the U.S. soda ash industry, 1987 to 1999.

More expansions in productive capacity are planned for the future. Following the expansions completed by FMC Corporation and Solvay in 1996, OCI and Solvay have announced further expansions in 1999 (Table 12). By 1999, total nameplate capacity is expected to be 13.75 million short tons while production is projected at 12.25 million short tons.

Existing producers have obvious advantages on the costs of expanding their capacity. For example, we estimate that it would cost from \$375 million to \$400 million to construct a new 1.0-million short ton soda ash refinery at Green River, or from \$375 to \$400 per short ton of refined soda ash. OCI's projected 0.8-

million short ton expansion slated for 1999 is expected to cost about \$140 million, or about \$175 per ton of soda ash. FMC's 0.7-million short ton expansion project is estimated at \$125 million, or from \$175 to \$180 per short ton of refined soda ash.

Table 12. Recently completed and announced expansions of the U.S. soda ash industry, in short tons.

Company	Location	Expansion	Completion
FMC	Green River, WY	700,000	April 1996
Solvay	Green River, WY	300,000	January 1996
OCI	Green River, WY	800,000	January 1999
Solvay	Green River, WY	400,000	July 1999

A multinational U.S. soda ash industry

Foreign ownership of all or parts of the soda ash operations in the United States is now the rule rather than the exception. Five different countries besides

the U.S. have interests in the domestic industry, including Japan, Australia, Korea, Belgium, and France (**Table 13**).

Table 13. Ownership of U.S. soda ash operations.

Company	Owners	Country	Percent
FMC Wyoming Corporation	FMC Corporation	USA	80
	Nippon Sheet Glass	Japan	10
	Sumitomo Corporation	Japan	10
General Chemical (Soda Ash) Partners	General Chemical	USA	51
	ACI International	Australia	25
	Tosoh Corporation	Japan	24
Solvay Minerals Inc.	Solvay et Cie	Belgium	80
	Asahi Glass	Japan	20
OCI	Oriental Chemical	Korea	51
North American Chemical Tg Soda Ash	Union Pacific Resources	USA	49
	Harris Chemical Group	USA	100
	Ste. Nationale Elf Aquitaine	France	100

World soda ash demand — now and future

Worldwide demand for soda ash is expected to grow by about 2.1% per year between 1995 and 2000, increasing from 31.4 to 34.7 Mt (**Table 14**). The highest annual growth rates are expected in Asian countries, including Indonesia (7.7%), India (5.6%), and China (5.0%). Growth in soda ash demand in

North America and Western Europe is expected to be modest, with only 0.5% and 0.3% per year, respectively. Much of the increased demand is expected to be satisfied by producers in the United States, and possibly the People's Republic of China.

Table 14. World soda ash demand (in thousands of tonnes) and average annual growth rates by region, 1995 to 2000.

Region	Demand		Average annual growth rate
	1995	2000	
North America	7550	7750	0.5%
Africa	550	580	1.1%
Asia, Total	11,119	13,747	4.3%
China	5304	6765	5.0%
Japan	1330	1250	-1.2%
India	1603	2100	5.6%
Indonesia	500	725	7.7%
Korea	700	825	3.3%
Taiwan and others	1682	2082	4.4%
Eastern Europe	3800	4100	1.5%
Middle East	670	725	1.6%
South and Central America	1225	1290	1.0%
Western Europe	6450	6540	0.3%
Total	31,364	34,732	2.1%

Soda ash – Annual review, 1996

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Abstract

U.S. soda ash production reached a record high 10.2 Mt [million tonnes (metric tons)] in 1996. Based on 12.07 million tonnes of annual nameplate capacity, the industry operated at 85% of total nameplate capacity. Soda ash exports also set another record, rising 8% to 3.84 Mt in 1996 over that of the previous year. U.S. exports to 50 countries, on a regional basis, were: Asia, 46%; South America, 21%; North America, 16%; Europe, 6%; Africa and the Middle East, 4% each; Oceania, 2%; Central America, 1%; and the Caribbean, negligible. Domestic consumption of soda ash declined about 2% in 1996. The distribution of soda ash by end use was glass, 48%; chemicals, 27%; soap and detergents, 12%; distributors, 5%; pulp and paper, 3%; flue gas desulfurization and miscellaneous, 2% each; and water treatment, 1%. The United States accounted for about 34% of total world soda ash production in 1996.

Introduction

Soda ash, also known as sodium carbonate, is an inorganic chemical that is produced from the mineral trona or sodium carbonate-bearing brines, or from a process that uses the chemical reaction of primarily salt and limestone. This commodity is used in many familiar household products, such as glass, soaps and detergents, paper, textiles, and foods. The United States has the world's largest deposit of trona, and represents about one-third of total world soda ash output.

Because soda ash is used in flat glass for automobile manufacture and building construction, which are important economic sectors of the domestic economy, monthly soda ash production data are incorporated into monthly economic indicators for industrial production by the Federal Reserve Board. These indicators monitor the economic condition of the U.S. economy. Soda ash and the various consumer products it is incorporated into, contributes substantially to the gross domestic product of the United States.

Production

Monthly soda ash production and inventory data are collected by the U.S. Geological Survey from monthly, quarterly, and annual voluntary surveys of the U.S. soda ash industry. Of the six soda ash operations to which a survey request was sent, all responded, representing 100% of the total production data shown in this report (**Table 1**).

The U.S. soda ash industry in 1996 was composed of six companies; five in Wyoming produced soda ash from underground trona ore, and one in California produced soda ash from sodium carbonate-rich brines (**Table 2**). Many foreign synthetic soda ash producers have now become advocates of having a presence in the U.S. natural soda ash industry. For-

eign investment in U.S. soda ash operations has risen from 10% of capacity in 1981, when Societe Nationale Elf Aquitaine of France bought Texasgulf Chemical Company, to 51% in 1996. All of the six U.S. companies have either Australian, Belgian, French, South Korean, or Japanese partners. Since the beginning of the European producers' acquisitions of partnerships in some of the U.S. facilities (Societe Nationale Elf Aquitaine of France owning 100% of Tg Soda Ash and Solvay S.A. of Belgium owning 80% of Solvay Minerals Company), the international competitive situation had begun to change. Approximately 24% of the Wyoming soda ash production capacity is European-owned as of 1996 (Tg Soda Ash with 1.18 Mt and Solvay with 1.67 Mt), a

Table 1. Salient soda ash statistics, in thousand tonnes (metric tons) and thousand dollars.

	1992	1993	1994	1995	1996
United States:					
Production ¹	9379	8959	9321	10,097	10,172
Value ¹	\$836,690	\$734,157	\$724,000	\$829,000	\$926,147
Average annual value:					
Per short ton	\$80.93	\$74.34	\$70.44	\$74.50	\$82.60
Per metric ton	\$89.21	\$81.95	\$77.65	\$82.12	\$91.05
Wyoming trona production	14,885	14,491	14,586	16,485	16,304
Exports	2955	2798	3227	3571	3837
Value	\$433,606	\$376,206	\$406,000	\$445,386	\$508,317
Imports for consumption	72	89	79	83	107
Value	\$12,772	\$17,084	\$12,128	\$11,995	\$14,730
Producers' stocks, December 31	371	274	203	306	271
Consumption:					
Apparent	6359	6348	6244	6505	6470
Reported	6323	6280	6260	6500	6390
World:					
Production	30,700	29,500	29,309 ²	30,285 ²	30,396 ³

¹Natural soda ash only; soda liquors and purge liquors converted to soda ash equivalents are as follows: 1992, 121,000 tonnes; 1993, 85,100 tonnes; 1994, 92,000 tonnes; 1995, 105,000 tonnes; and 1996 withheld to avoid disclosing company proprietary data.

²Revised

³Estimated

Table 2. U.S. producers of soda ash in 1996, in million short tons¹, unless otherwise noted.

Company	Plant nameplate capacity	Plant location	Source of sodium carbonate
FMC Wyoming Corporation ²	3.55	Green River, Wyoming	Underground trona
General Chemical (Soda Ash) Partners ³	2.40	Green River, Wyoming	Underground trona
North American Chemical Company ⁴	1.45	Trona, California	Dry lake brine
OCI Chemical Corporation ⁵	2.30	Green River, Wyoming	Underground trona
Solvay Minerals Inc. ⁶	2.30	Green River, Wyoming	Underground trona
Tg Soda Ash Inc. ⁷	1.30	Granger, Wyoming	Underground trona
Total	13.30		
Total million tonnes (metric tons)	12.07		

¹To convert to tonnes (metric tons), multiply by 0.9078.

²Formed joint venture (20%) in February 1996 with Sumitomo Corporation and Nippon Sheet Glass Company, Ltd., both of Japan.

³A joint venture between General Chemical Corporation (51%), Australian Consolidated Industries International (ACI-25%), and TOSOH Wyoming Inc. of Japan (24%), which purchased part of ACI's share in June 1992.

⁴Oriental Chemical Industries Company Ltd. of Korea as a partner had 27% equity share, but was reduced to about 7% in 1993.

⁵Rhône-Poulenc of France sold its 51% share to Oriental Chemical Industries Company Ltd. (OCI) of Korea on February 29, 1996; Union Pacific Resources Company owns 49%.

⁶Solvay Soda Ash Joint Venture is owned by Solvay S.A. of Belgium (80%) and Asahi Glass Company of Japan (20%), which became a partner in February, 1990. Capacity increase of 272,000 tonnes (300,000 short tons) installed December, 1995.

⁷Owned by Texasgulf Inc., subsidiary of Société Nationale Elf Aquitaine of France (100%).

decline from 35% in 1995 when Rhône-Poulenc S.A. of France sold its Wyoming soda ash facility to Oriental Chemical Industries of South Korea.

The capacity expansion project between FMC Corporation and its partners Nippon Sheet Glass

Company, Ltd. and Sumitomo Corporation, both of Japan, came onstream in May. This added 635,000 tonnes (700,000 short tons) of capacity to FMC's existing 2.59 Mt (2.85 million short tons) of capacity (Industrial Minerals, 1996a). The new process takes spent mine tailings in a slurry of soda liquors, which

normally were discharged to surface tailing ponds, and injects them underground where the solutions migrate downslope to a natural depression in the mine that acts as a collection sump. The solution becomes enriched in sodium carbonate as it dissolves trona in the floor and pillars in abandoned sections of the mine. The solution is recovered and pumped to the surface where it becomes feedstock for the soda ash refinery. The process reportedly will reduce production costs by 30 to 40%.

Approximately 210,000 tonnes of soda ash from the new expansion was scheduled to be used in FMC's project with DuPont. Iron chloride and hydrochloric acid waste at DuPont's New Johnsonville, Tennessee, titanium dioxide plant was to be treated with soda ash to produce iron carbonate and about 200,000 tons of food-grade salt, which will be marketed by North American Salt Company. The project was to come onstream in mid-1996; however, the start-up was delayed because of normal start-up issues, according to company officials (Chemical Market Reporter, 1996b).

After Solvay Minerals, Inc., brought its 272,000-tonne expansion onstream in late 1995, it announced a three-phase \$170 million project to add another 1.09 Mt of capacity beginning in 1999 with the third phase to be finished by 2003 (Chemical Marketing Reporter, 1996c). This would increase its present annual nameplate capacity from 2.09 Mt to 3.18 Mt, making Solvay the second-largest soda ash facility in Wyoming after FMC. Part of Solvay's new capacity will replace that lost because of closure of the synthetic soda ash plant in Chiba, Japan by its joint venture partner, Asahi Glass Company. The Chiba facility was scheduled to shut down by September 1997.

In early 1996, Rhône-Poulenc S.A. of France sold its U.S. affiliate, Rhône-Poulenc Basic Chemicals Company, for \$150 million to Oriental Chemical Industries Company, Ltd., (OCI) of South Korea. The sale was for the 51% share of the Wyoming soda ash plant; the remaining 49% owned by Union Pacific Resources Company was unaffected. The sale did not include Rhône-Poulenc's sodium bicarbonate business in Chicago Heights, Illinois. OCI, which also operates a synthetic soda ash plant in Inchon, Korea, and has a reported 7% share in North American Chemical Company's Searles Lake operation, announced plans to raise capacity at its Wyoming facility from 725,000 tonnes to 907,000 tonnes (800,000 short tons to 1 million short tons) per year by 1998 (Chemical Marketing Reporter, 1996e). The cost of

the expansion project was estimated at \$150 million. Although it was not reported, the expansion may be replacement capacity if OCI decides to close its Inchon plant, which has an annual capacity of about 400,000 tons.

On November 21, 1996, Tg Soda Ash, Inc. announced the development of new process technology to produce soda ash from a solution-mined feedstock at its Granger, Wyoming facility. The new technology will utilize dilute solutions from underground mine water and recycled liquors from the soda ash crystallizers. The solutions will collect in an underground mine lake for subsequent processing. The feedstock will be steam-stripped in a new process to convert some of the sodium bicarbonate contained in the solution to sodium carbonate prior to crystallizing sodium carbonate decahydrate crystals. The process does not use any solvents such as caustic soda or other chemical agents to convert the sodium bicarbonate (The Rocket Miner, 1996).

U.S. production of natural soda ash from California and Wyoming in 1996 increased slightly to a record 10.2 Mt. Based on 12.07 Mt of total nameplate capacity, the U.S. soda ash industry operated at 85% of total nameplate capacity. Capacity utilization was lower in 1996 compared with that of 1995 because FMC's 635,000 tonnes of new expansion capacity that came on-stream in May was not fully utilized: start-up problems associated with DuPont's project would have used about one-third of this quantity.

Cominco American Corporation and Vulcan Chemicals decided to sell their Owens Lake Soda Ash Company joint venture at Owens Lake in California. The company terminated plans to construct a 544,000 tonne-per-year (600,000 short tons-per-year) soda ash facility in 1995 because of delays in obtaining an environmental permit. Several companies evaluated the assets of the project but no buyer was found by year end (Industrial Minerals, 1996b).

North American Chemical Company's subsidiary, White River Nahcolite Minerals, announced plans on June 11, 1996 to expand its natural sodium bicarbonate facility near Rifle, Colorado, by 90,700 tonnes (100,000 short tons) (North American Minerals News, 1996). The present capacity is 96,200 tonnes (106,000 short tons). Another nahcolite company, AmerAlia Inc., completed core hole drilling at its Rock School Lease in the Piceance Creek Basin of Colorado. Three nearly horizontal beds of nahcolite were located having an average nahcolite content of 26.5% with a thickness of 510 feet at a depth of 2020 feet.

The company plans to construct a sodium bicarbonate plant by the fall of 1997 with an initial capacity of 45,400 tonnes (50,000 short tons) (Chemical Marketing Reporter, 1996b).

A total of 222,000 tonnes of soda ash equivalent was used to manufacture chemical caustic soda by FMC, Solvay Minerals, and Tg Soda Ash. The total quantity of trona mined in Wyoming in 1996 was 16.3 million tons (Table 3).

Table 3. U.S. production of sodium compounds, by month, in tonnes¹.

	1995			1996		
	Soda ash	Caustic soda ²	Wyoming trona	Soda ash	Caustic soda ²	Wyoming trona
January	840,000	15,947	1,460,858	762,000	13,989	1,479,560
February	698,000	11,398	1,222,014	814,000	17,017	1,361,148
March	867,000	15,559	1,492,812	789,000	18,942	1,358,393
April	837,000	18,161	1,358,969	855,000	16,895	1,315,669
May	843,000	16,583	1,375,754	876,000	17,648	1,368,046
June	816,000	10,051	1,345,338	885,000	20,441	1,249,959
July	860,000	13,495	1,440,649	850,000	19,979	1,432,015
August	840,000	20,328	1,377,247	847,000	17,580	1,323,929
September	845,000	18,528	1,429,978	857,000	21,970	1,353,991
October	870,000	17,026	1,392,020	909,000	20,444	1,458,438
November	876,000	12,826	1,271,262	859,000	18,879	1,272,766
December	907,000	14,480	1,320,000	866,000	18,451	1,329,722
Total	10,099,000	184,382	16,486,901	10,169,000	222,235	16,303,636

¹To convert to short tons, multiply by 1.102.

²As soda ash equivalent.

Legislation and government programs

Soda ash mined on Federal lands is subject to the Mineral Leasing Act of 1920, which provides royalty payments to the United States government. In Wyoming, the trona deposit within the Known Sodium Leasing Area is under the jurisdiction of the U.S. government [administered by the Bureau of Land Management (BLM)], the State of Wyoming, and the Union Pacific Railroad, which was given alternate 0.6-square-kilometer (1-square-mile) sections in a 20-mile band extending both north and south of the railway it constructed in the 1860s. Of the almost 370,000 hectares (915,000 acres) of total sodium mineral estate, the Federal ownership is 55.7%, Union Pacific, 38.1%; and the State of Wyoming, 6.2%. Sixteen lessees hold 53 active and inactive Federal leases having a total of 75,783 acres. In order to prevent a possible land monopoly, no lessee may hold more than 6216 hectares (15,360 acres) of Federal land, but may lease more private or state land. The state royalty rate is tied to the Federal rate, which was 5%; however, the private royalty rate varies. One-half of all Federal royalties collected by the Minerals Management Service is disbursed to the Wyoming government for various state and local programs. A Federal lease is issued for an initial period of 20 years, with 10-year discretionary renewals thereafter.

On February 22, 1996, the Assistant Secretary-Land and Minerals, U.S. Department of the Interior, signed the policy that increased the Federal royalty rate from 5 to 6% for renewed leases and from 5 to 8% for new leases. This resulted in five Federal leases remaining at 5% until they are up for renewal, 49 leases at 6%, and 10 leases at 8%. The Federal royalty is based on the quantity of the output of the sodium compounds and other related products at the point of shipment to market. Each Federal lease also has other costs, such as bonds, acreage rental fees, sodium prospecting permit application fees, and permit bonds.

On May 1, 1996, three Federal tracts totaling 1036 hectares (2560 acres) that had 88.9 Mt (97.9 million short tons) of trona were offered for lease by the BLM. Two bids met or exceeded the presale estimate of fair market value and were accepted; the third was rejected because it failed to meet fair market value. On September 26, 1996 eight more tracts totaling 4522 hectares (11,173.93 acres) containing 460.7 Mt (507.8 million short tons) of trona were offered for lease. Six bids met or exceeded fair market value estimates and were accepted, generating \$10.8 million in bonus bids, of which one-half goes to the State of Wyoming.

Consumption and uses

The U.S. Geological Survey collects reported consumption data by end use quarterly from the marketing and sales departments of each company within the industry. Every effort has been made to categorize company sales with the intended end-use sector. Quarterly reports are often revised in subsequent quarters because of customer reclassifications, or other factors. Because all six U.S. soda ash companies respond to the quarterly survey, the data represents 100% of the total reported consumption data found in this report. Reported consumption data and apparent consumption data do not necessarily correspond because reported consumption data are based on actual sales whereas apparent consumption data are the calculated quantity available for domestic consumption based on balancing supplies (production, imports, and inventory adjustments) with external demand (exports) (Table 4).

U.S. apparent consumption and reported consumption in 1996 varied by only 80,000 tons. The discrepancy between the two forms of consumption was attributed to disagreement between the sources of export data used to derive consumption statistics. The two sources were the Bureau of the Census, which reports exports upon departure from the U.S. ports, and the soda ash producers, which consider a shipment as exported when their export association American Natural Soda Ash Corporation (ANSAC) takes consignment of the product at California or Wyoming plant sites. Transit times between the plant and port, which can take about two to three weeks before the cargo is actually exported, and carry over export inventories contribute to the discrepancy between reported and apparent consumption as well.

Table 4. Reported consumption of soda ash in the United States, by end use, by quarters, in metric tons (tonnes). Totals may be different due to independent rounding.

SIC Code	End use	1995 total	First quarter	Second quarter	1996 Third quarter	Fourth quarter	Total
32	Glass:						
32	Container	1,691,537	372,100	409,165	391,628	378,897	1,551,790
32	Flat	978,917	218,386	251,583	260,701	274,545	1,005,215
32	Fiber	214,260	59,454	58,580	58,581	59,676	236,291
32	Other	248,102	66,143	60,738	60,105	60,303	247,289
	Subtotal	3,132,816	716,083	780,066	771,015	773,422	3,040,586
28	Chemicals	1,649,298	385,171	410,821	443,560	445,880	1,685,432
28	Soaps and detergents	783,463	203,595	189,729	200,787	190,534	784,645
26	Pulp and paper	186,345	49,862	49,999	42,779	40,384	183,024
28	Water treatment ¹	108,277	19,048	21,700	24,124	21,676	86,548
	Fluegas desulfurization	129,669	36,094	35,120	43,997	36,691	151,902
	Distributors	323,143	77,578	79,933	76,527	80,225	314,263
	Other	184,753	35,747	37,128	35,136	37,295	145,306
	Imports ²	82,680	24,993	25,717	27,449	28,816	106,975
	Total domestic consumption	6,497,766	1,523,178	1,604,496	1,637,925	1,626,108	6,391,707
	Exports ³	3,600,505	902,775	986,709	1,039,014	1,001,676	3,930,174
	Canada	180,474	52,517	50,529	57,747	65,506	226,299
	Total industry sales⁴	10,098,271	2,425,953	2,591,205	2,676,939	2,627,783	10,321,880
	Total sales from plants	9,759,321	2,319,769	2,618,513	2,607,587	2,594,891	10,140,760
	Total production	10,096,922	2,365,462	2,617,520	2,554,436	2,634,337	10,171,755

¹Includes soda ash equivalent from soda liquors and purge liquors sold to powerplants for water treatment. Sales of mine water are excluded.

²Data are from the Bureau of the Census and may vary from the quantity reported by the producer/importer. Actual imports are proprietary data but have been distributed into appropriate end-use categories and included in "Total domestic consumption."

³As reported by producers; includes Canada; data may not necessarily agree with that reported by the Bureau of the Census for the same periods.

⁴Represents soda ash from domestic origin (production and inventory changes) and imports and for exports. Includes soda ash sold by coproducers and distributed by purchasers into appropriate end-use categories.

The distribution of soda ash by end use in 1996 was glass, 48%; chemicals, 27%; soap and detergents, 12%; distributors, 5%; pulp and paper, 3%; flue gas desulfurization and miscellaneous, 2% each; and water treatment, 1%.

Glass

Glass manufacture represented about 48% of domestic soda ash consumption, with the container sector comprising 51%; flat, 33%; and specialty and fiber, 8% each. According to Bureau of the Census data, production of glass containers declined from 9.71 Mt (10.70 million short tons) in 1995 to 8.82 Mt (9.72 million short tons) in 1996, primarily because the beverage sector continued to decline; more soft drinks were packaged in plastic containers than glass bottles. Glass containers for the beer industry increased from 38% of total container glass in 1995 to 43% in 1996. Glass for the wine bottling industry rose from 10 to 12% during the same time period.

The glass recycling rate remained the same at about 37%, of which post-consumer cullet was estimated at 24% of this rate with the remainder being in-house scrap. Some municipalities have started to terminate their glass collection programs because the price of clean, sorted cullet has declined, thereby making it less attractive to recyclers. Another reason is that breakage during collection has affected the quality of material sold to glass container manufacturers.

Based on Bureau of the Census data (with between 11 to 19% of the data being estimated) flat glass production decreased about 1.5%, which contradicts the 3% increase noted from the soda ash end use survey. Guardian Industries Corporation brought onstream a new float glass plant at Dewitt, Iowa in 1996 that will increase flat glass production and soda ash consumption in the future. The demand for window glass for automobiles and residential and commercial building construction has been increasing since 1990.

Anchor Glass Container Corporation, which had been the second largest glass container manufacturer in the United States, was offered for sale by Vitro S.A. of Mexico, its parent corporation. Vitro reportedly needed capital because of depressed economic conditions in Mexico and the sagging glass container market within the United States. Vitro filed for bankruptcy protection and was negotiating to sell its assets, which were listed at \$1.2 billion with liabilities of \$951 million, to Ball-Foster Glass Container Company for

\$365 million and the transfer of certain liabilities (Industrial Minerals, 1996c).

Chemicals

Soda ash is used to manufacture many sodium-based inorganic chemicals, including sodium bicarbonate, sodium chromates, sodium phosphates, and sodium silicates. Part of the 2% increase in reported consumption of soda ash in the chemicals sector from 1995 to 1996 was because 222,000 tonnes of soda ash equivalent were consumed to produce liquid chemical caustic soda that was used in various downstream applications. Chemical caustic soda caters to certain Western markets that are fairly distant from electrolytic caustic soda plants. Although low-priced caustic soda has had a negative affect on soda ash sales, chemical caustic soda sales remain strong.

According to data from the Bureau of the Census, production of sodium bicarbonate increased from 418,000 tonnes in 1995 to 432,000 tonnes in 1996. The estimated end use distribution for sodium bicarbonate consumption was household products, 30%; animal feed, 20%; food and beverages, 17%; chemicals, 12%; pharmaceuticals, 8%; fire extinguishers, 3%; and miscellaneous, 10%.

Sodium phosphates are another important sector of the chemical industry that uses soda ash. There are several sodium phosphate-bearing compounds; unfortunately, most of the data that are available are withheld by the Bureau of the Census because the number of respondents required to publish statistics was not met. However, an estimate of the distribution of industrial phosphates by end use is detergent builders and cleaners, 44%; miscellaneous, 26%; food and beverage, 19%; metal treatment, 6%; and water treatment, 5% (Chemical Market Reporter, 1996d). Market conditions for sodium phosphates began to improve by year end and were expected to continue to rebound in 1997 and 1998.

Demand for sodium silicates appeared strong in 1996 as producers ran at about 88% of capacity; however, some plants closed to consolidate and raise individual plant operating rates at other sites. About 1.15 Mt of sodium silicates were produced in 1996.

Sodium chromates, another important use for soda ash, remained flat during 1996 with little optimism for growth in the next few years. The industry has been adversely affected by legislation that re-

stricted the quantity of chrome used in manufacturing industrial enamels, particularly medium chrome yellow that is used in traffic paints.

Soaps and detergents

Detergents is the third largest use of soda ash. Soda ash is used as a builder to emulsify oil stains, reduce the redeposition of dirt during washing and rinsing, provide alkalinity for cleaning, and soften laundry water. In addition, soda ash is a component of sodium tripolyphosphate, another major builder in detergent formulations; soda ash consumption here has been decreasing because phosphatic detergents can contribute to the environmental problems of eutrophication. Many regions of the nation have adopted phosphate limitations or bans. These areas represent about 40% of the U.S. population. In response to the environmental issue, detergent manufacturers began reformulating their detergents to make compact and superconcentrated products. These reformulations require sodium silicates and synthetic zeolites, which are made from soda ash. Liquid detergents, which do not contain any soda ash, compete with powdered detergents and command 40% of the household laundry detergent market, up from only 15% in 1978. With the October 1 price increase announcement by the soda ash producers, detergent formulators threatened to convert back to caustic soda because its price had been declining since the third quarter (European Chemical News, 1996a).

Stocks

Year end stocks of dense soda ash in domestic plant silos, warehouses, terminals, and on teamtracks amounted to 271,000 tonnes. Producers indicate that a potential supply problem could exist when inventories fall below 180,000 tonnes. Most consumers of soda ash do not have storage facilities to accommodate large quantities of soda ash and must rely on suppliers to provide the material on a timely basis.

Foreign trade

U.S. soda ash exports increased 8% in 1996 to 3.84 Mt, which was another record. U.S. exports to 50 countries, on a regional basis, were as follows: Asia, 46%; South America, 21%; North America, 16%; Europe, 6%; Africa and the Middle East, 4% each; Oceania, 2%; Central America, 1%; and the Caribbean, negligible. The average free-alongside-

Prices

About 38% of U.S. soda ash production is exported with the remainder for domestic consumption. In the domestic market, the large volume buyers of soda ash are primarily the major glass container manufacturers, whose purchases are seasonal (more beverage containers are made in the second and third quarters for summertime beverage consumption). Soda ash sales to the flat glass sector are usually dependent on the state of the economy because the largest use of flat glass is in automobile manufacture and residential housing and commercial building construction. These two major industrial sectors are especially sensitive to changing economic conditions. If construction starts and automobile sales are up, soda ash sales will proportionally follow.

The average annual value for bulk, dense natural soda ash, f.o.b. Green River, Wyoming, and Searles Valley, California, was \$91.05 per tonne (\$82.60 per short ton), which was an 11% increase over that of 1995. The value is not a "price;" it is the value of the combined revenue of California and Wyoming bulk dense soda ash sold on an f.o.b. plant basis at list, spot, or discount prices, on long-term contracts, and for export, divided by the quantity of soda ash sold. The list prices quoted in trade journals or by producers differ from the annual average values reported to and by the U.S. Geological Survey. This value may or may not correspond to the posted list prices. The list price for Wyoming bulk, dense soda ash was raised effective July 1, 1995, or as contracts permit, to \$105 per short ton from \$98 per short ton. The California price for the comparable product also increased by \$7 per short ton; from \$123 per short ton to \$130 per short ton (Table 5).

Effective October 1, 1996, Solvay Minerals increased its off-list price for soda ash by \$5 per short ton, not to exceed the list price of \$105 per short ton in bulk and \$153 per short ton in 100-pound bags. Although many of the other producers followed, the price increase attempt was not successful by year end (Chemical Marketing Reporter, 1996d).

ship value was \$132.29 per tonne in 1996 compared with \$124.65 per tonne in 1995. The top ten countries that represented 71% of total U.S. soda ash exports were, in decreasing order, Indonesia, Mexico, Japan, the Republic of Korea, Thailand, Canada, Venezuela, Brazil, Taiwan, and the Republic of South Africa (Tables 6 and 7).

Table 5. Year end prices of soda ash. Sources: *Chemical Marketing Reporter* (1996a) and *Chemical Market Reporter* (1997).

		1995	1996
Sodium carbonate (soda ash):			
Dense, 58%, Na ₂ O 100-pounds, paper bags, carlot, works, f.o.b.	per short ton	\$153.00	\$153.00
Bulk, carlot, same basis tons	per short ton	105.00	105.00
Light, 58%, 100-pounds, paper bags, carlot same basis	per short ton	158.00	158.00
Bulk, carlot, same basis tons	per short ton	110.00	110.00

On July 13, 1997, the European Commission, which is the administrative section of the European Union (EU), was requested by FMC Corporation, General Chemical Corporation, North American Chemical Company, and OCI Chemical Corporation, to conduct an interim review of the antidumping duties imposed on the industry earlier. The four U.S. soda ash companies cited that the enlargement of the EU with the addition of Austria, Finland, and Sweden alters the basis for antidumping allegations (Chemical and Engineering News, 1996). European producers challenged the request stating that the three new countries account for only 5% of EU soda ash consumption. Furthermore, Austria and Finland previously had voted in favor of the antidumping duties. The four U.S. companies presently are subject to antidumping duties ranging from 2.5 to 8.9% as well as an import duty of 7.3%. European soda ash producers proposed raising prices, causing an intensive lobbying effort on behalf of the U.S. soda ash producers by European glass producers. Despite that the price increases were the first in three years, the glass industry petitioned the Commission to eliminate the antidumping duties on U.S. soda ash imports, citing that the European soda ash producers have improved their market position and no longer need import protection (Chemical Market Reporter, 1996e). The

Commission continued its investigation through the end of 1996 and may release its decision in 1997.

Although the United States exported 222,000 tonnes of soda ash to Europe in 1996, the material was not subject to the antidumping duties because there is a provision in the legislation that permits soda ash to enter duty-free as long as that quantity is incorporated into products (such as glass) of total comparable contained weight that are exported by that country. Therefore, there is no effect on the European market and no injury to the European soda ash producers.

Despite a 30% import duty, ANSAC exported about 22,000 tonnes of soda ash in August to India that resulted in a protest by the Indian Monopolies and Restrictive Trade Practices Commission. The complaint was initiated by the Alkali Manufacturers Association of India, which represents all the domestic soda ash producers. The Commission determined that ANSAC violated the provisions of the country's restrictive trade practices laws and passed an order banning ANSAC, but not its individual members, from shipping to India (Industrial Minerals, 1996d). ANSAC also was involved in an antidumping suit by Brazil in September.

World review

The largest consumers of soda ash tend to be the developed nations; however, these countries also usually have lower growth rates compared with developing countries that have greater demands for consumer products. Although the production and consumption quantities vary among the countries, the end-use patterns are basically the same (e.g., glass, chemicals, and detergents are the major sectors). Although the United States is the largest soda ash-producing country in the world, foreign ownership in the U.S. soda ash industry is presently 51% of nameplate capacity (Table 8).

Nine countries have the capacity to produce more than 1 Mt annually. They are, in descending order, the United States, China, Russia, India, Germany, France, Japan, Poland, and the United Kingdom. Bulgaria, Romania, and the Ukraine have production installations that had been rated at about 1 million tons; however, adverse economic conditions have caused these nations to produce below their design capacities. Most of these soda ash-producing countries have large populations that require consumer products made with soda ash. The lesser-developed nations tend to have greater soda ash demand and higher rates of growth as soda ash-consuming industries are developed.

Table 6. Regional distribution of U.S. soda ash exports, by customs districts, in 1996, in tonnes (metric tons). Source: Bureau of the Census as adjusted by the U.S. Geological Survey using trade data and information from the Journal of Commerce. Totals may be different due to independent rounding.

Customs districts	North America	Central America	South America	Caribbean	Europe	Middle East	Africa	Asia	Oceania	Total	Percent of total
Atlantic:											
Baltimore, MD	--	--	--	--	315	--	--	--	--	315	--
Charleston, SC	--	--	--	--	383	--	--	--	--	383	--
Miami, FL	--	--	36	39	--	--	--	--	--	75	--
New York, NY	--	--	--	--	1734	--	16	2086	--	3836	--
Philadelphia, PA	--	--	34	--	--	--	--	--	--	34	--
Savannah, GA	--	7	--	--	--	--	--	--	--	7	--
Wilmington, NC	--	--	--	--	778	--	--	--	--	778	--
Gulf:											
Houston-Galveston, TX	--	21	1893	2929	7	--	--	500	--	5350	--
New Orleans, LA	5	--	--	--	--	--	--	--	--	5	--
Port Arthur, TX	--	--	228,728	12,023	12,282	22,622	32,005	--	--	307,660	8
Pacific:											
Columbia-Snake River	--	20,886	345,943	--	163,818	137,109	74,645	1,527,606	74,365	2,344,372	61
Los Angeles, CA	--	--	--	--	--	--	--	326	319	645	--
San Diego, CA	13,142	4915	211,373	--	42,531	6764	61,965	242,310	--	583,000	15
San Francisco, CA	--	--	--	--	68	--	--	40	242	350	--
Seattle, WA	10,044	--	--	--	--	--	--	608	--	10,652	--
North Central:											
Detroit, MI	136,874	--	--	--	167	--	--	--	--	137,041	4
Duluth, MN	51	--	--	--	--	--	--	--	--	51	--
Great Falls, MT	16,479	--	--	--	--	--	--	--	--	16,479	--
Pembina, ND	10,018	--	--	--	--	--	--	--	--	10,018	--
Northeast:											
Buffalo, NY	41,856	--	--	--	--	--	--	--	--	41,856	1
Ogdensburg, NY	1313	--	--	--	124	--	--	--	--	1437	--
St. Albans, VT	1222	--	--	--	--	--	--	--	--	1222	--
Southwest:											
Laredo, TX	353,815	--	--	--	--	--	--	--	--	353,815	9
Nogales, AZ	89	--	--	--	--	--	--	--	--	89	--
Unknown:	17,942	--	--	--	--	--	--	--	--	17,942	--
Total	602,850	25,829	788,007	14,991	222,207	166,495	168,631	1,773,476	74,926	3,837,412	100
Percent of total	16	1	21	--	6	4	4	46	2	100	--

Table 7. U.S. exports of soda ash, by country, in thousand tonnes (metric tons); value in thousands of dollars. Source: Bureau of the Census, as adjusted by the U.S. Geological Survey, using Journal of Commerce trade data and information.

Country	1995		1996	
	Quantity	Value	Quantity	Value
Argentina	121	\$15,391	92	\$13,045
Australia	31	3565	56	6612
Belgium	23	3911	72	10,152
Belize	6	1005	--	--
Bolivia	4	726	6	1051
Brazil	233	31,366	209	27,270
Canada	187	15,669	236	21,838
Chile	78	10,511	123	16,966
China	50	6262	45	6206
Colombia	86	12,283	98	14,245
Costa Rica	16	2334	4	617
Croatia	27	3654	34	3306
Dominican Republic	3	515	4	710
Ecuador	11	1366	6	816
El Salvador	4	715	3	438
France	5	702	--	--
Germany	1	1	1	104
Guatemala	18	3019	15	2323
India	--	--	23	2059
Indonesia	343	46,586	414	59,699
Iran	25	2225	--	--
Ireland	1	1	2	220
Israel	33	4082	23	2787
Jamaica	2	682	4	693
Japan	339	41,812	327	43,236
Korea, Republic of	277	39,300	311	45,890
Malaysia	78	11,171	76	11,451
Mexico	397	35,908	367	39,577
New Zealand	20	2265	19	2211
Nigeria	--	--	5	500
Panama	4	575	4	580
Peru	19	3014	24	3918
Philippines	103	13,167	94	13,198
Poland	--	--	15	1430
Saudi Arabia	65	5824	134	14,020
Singapore	26	3451	17	2337
South Africa	112	13,850	164	22,216
Spain	97	9351	78	8052
Taiwan	198	26,575	182	26,171
Thailand	263	35,999	285	41,330
Trinidad and Tobago	35	1967	7	1511
Turkey	--	--	19	1971
United Arab Emirates	16	1575	10	1023
Uruguay	5	641	2	344
Venezuela	210	32,198	227	36,009
Other ²	1	174	1	187
Total	3573	\$445,386	3838	\$508,319

¹Less than 1/2 unit, included with "Other."

²Includes The Bahamas (1995), Bahrain (1995), Barbados (1995), Finland (1995), Ghana (1996), Honduras (1996), Hong Kong, Federated States of Micronesia (1995), the Netherlands, Russia, Sweden (1996), the United Kingdom, and Uzbekistan (1996).

Solvay S.A. of Belgium announced plans to expand soda ash production capacity at its plant in Rosignano, Italy, which will be increased to 1 Mt per year by 1998. Solvay recently completed capacity expansion in Torrelavega, Spain from 900,000 to 950,000 tonnes; and in Povoa, Portugal from 180,000 to 230,000 tonnes. These increases raise Solvay's total European capacity to 4.2 Mt (Solvay S.A., 1996).

Australia

On April 1, 1996, D. George Harris and Associates purchased Penrice Soda Products Pty. Ltd., of Osborne. The purchase includes: the synthetic soda ash plant with an annual capacity of 385,000 tonnes of soda ash and 24,000 tonnes of sodium bicarbonate; the solar salt facility of Penrice Saltfields Products at Dry Creek; and the limestone quarry of Penrice Quarry Products in Angaston. Although terms of the agreement were not disclosed by either party, the Australian press estimated the transaction at \$81.5 million. Penrice had sales of \$80 million in 1995 (Industrial Minerals, 1996e).

Bulgaria

In an effort to raise \$1 billion from the sale of some of its chemical, refining, and industrial enterprises, the Bulgarian State-owned company, Sodi Devnya, offered a 60% share of its 1.2 million-tonnes-per-year soda ash operation for sale. Among the interested parties were Solvay S.A., LG Chemicals, Brunner Mond and Company, D. George Harris and Associates, and General Chemical Corporation, Anglovaal Ltd., and several other Nordic and East European firms (Industrial Minerals, 1996f). General Chemical offered \$160 million, which was \$40 million higher than the second highest bid (European Chemical News, 1996b). By year end, General Chemical reversed its decision to acquire the soda ash plant and allowed Solvay to become the apparent winner; however, a final decision was expected by February 28, 1997 (Chemical Market Reporter, 1996c).

Botswana

Severe rains damaged the walls of the evaporation ponds and diluted the brines at the Sua Pan soda ash facility of Botswana Ash, the successor company of the refinanced Soda Ash Botswana. A two-month stockpile of soda ash was available to meet the tem-

Table 8. World production of soda ash, by country, in thousands of tonnes (metric tons).¹

Country	1992	1993	1994	1995	1996 ^e
Albania ^e	²	--	--	--	--
Australia ^e	300	300	300	300	300
Austria ^e	150	150	150	200	200
Belgium ^{e3}	375	300	-- ⁴	-- ⁴	--
Bosnia and Herzegovina ^e	25	20	15	15	15
Botswana	124	126	174	202	100
Brazil ^e	200	200	200	200	200
Bulgaria	517	259	300 ^e	300 ^e	300
Canada ^e	305	305	300	300	300
China ^e	4500	5270	5680	5820	6390
Colombia ^{e4}	121	121	-- ⁴	-- ⁴	--
Czechoslovakia ⁵	100 ^e	N.A.	N.A.	N.A.	N.A.
Egypt ^e	51	51	51	51	51
France	1100	1222	1123 ^r	1120 ^r	1100
Germany	1639 ^r	1586 ^r	1380	1400 ^e	1400
India ^e	1500	1500	1500	1500	1500
Italy ^e	600	500	500	500	500
Japan	1057	1056	1050	1049 ^r	1050
Kenya ⁶	186	145	226 ^r	218 ^r	220
Korea, Republic of ^e	300	310	310	310	320
Mexico ^{e7}	440	440	290 ^r	290 ^r	290
Netherlands ^e	400	400	400	400	400
Pakistan	146 ^e	186	185 ^r	180 ^e	185
Poland	929	815	997	1019 ^r	1000
Portugal ^e	150	150	150	150	150
Romania	452	371	449 ^r	350 ^e	350
Russia	2679 ^r	1992 ^r	1585 ^r	1823 ^r	1460
Spain ^e	500	500	500	500	500
Taiwan	91 ^r	89 ^r	128 ^r	128 ^r	128
Turkey ^e	385	385	385	385	390
Ukraine ^e	1000	800	660	475	425
United Kingdom ^e	1000	1000	1000	1000	1000
United States ⁶	9380	8960	9320	10,100	10,200 ⁸
Total	30,700	29,500	29,300^r	30,300^r	30,400

^e = Estimated. ^r = Revised. N.A. = Not applicable.

¹Table includes data available through April 21, 1997. Synthetic unless otherwise specified.

²Less than 1/2 unit. Plant at Vlora reportedly closed in 1993.

³Plant at Couillet closed by year end 1993.

⁴Plant closed in 1993.

⁵Dissolved on December 31, 1992.

⁶Natural only.

⁷Includes natural and synthetic. Estimated production of natural soda ash, in metric tons, was as follows: 1992–160,000 and 1993–160,000. Natural soda ash operation closed in August 1993.

⁸Reported figure.

porary demand by its customers. Production was reduced to about one-half of what had been produced but was still far below its production capacity. The majority of the output had been marketed in South Africa, which began importing soda ash from ANSAC in the United States (Industrial Minerals, 1996g).

France

Rhône-Poulenc S.A. announced a divestiture program to raise between \$1 billion and \$1.5 billion to

reduce the company's debt through selling their chemical commodity businesses, which included soda ash. As a result, Rhône-Poulenc sold its Wyoming natural soda ash operation to OCI of South Korea and its 600,000 tonne-per-year synthetic soda ash plant in Nancy, France to the Harris Chemical Group. The French plant was managed by a wholly-owned subsidiary of Rhône-Poulenc Chimie, Novacarb. Harris owned a natural soda ash plant in California and synthetic soda ash plants in Australia and Germany. Harris Chemical will market the material while Novacarb will continue to operate the plant through

1998, when Harris will acquire the entire operation (Chemical Market Reporter, 1996a; European Chemical News, 1996c).

Japan

Tosoh Corporation of Japan closed its 320,000-tonne plant in Shinnanyo, Yamaguchi Prefecture in September 1996 and imported soda ash from its U.S. joint-venture operation in Wyoming. Tosoh Wyoming Inc. owns 24% of the General Chemical Corporation facility. Tosoh has about 200,000 tonnes of the total Japanese soda ash market, which is about 1.3 Mt.

Poland

As part of a plan to privatize its State-owned chemical operations, Poland sold a 75% share in Janikosoda S.A. and Soda Matwy S.A., the two synthetic soda ash plants with a combined annual capacity of 1 Mt, to Ciech, the Polish chemical trading company. Ciech agreed to purchase the facilities for \$78 million and invest another \$128.5 million over the next ten years (Industrial Minerals, 1996h).

Saudi Arabia

The Arabian Mining and Manufacturing Company awarded a contract to Hitachi Zosen Corporation and

Marubeni Corporation, both of Japan, to construct a synthetic soda ash facility near Jubail. The plant will have an annual capacity of 264,000 tonnes of light and dense soda ash, 90% of which will be consumed locally with the remainder for export. The \$176 million project is expected to be in operation by mid-1998. Akzo Nobel of the Netherlands will provide the technology. Total cost of the project was estimated at \$267 million, of which \$107 million will come from a loan from the Saudi Industrial Development Fund and the balance from commercial banks (European Chemical News, 1996d).

Turkey

Discussions resumed between Rio Tinto Zinc (RTZ) and FMC Corporation with Etibank, the State mining agency, regarding developing the trona deposit at Beypazari, near Ankara. Negotiations with various U.S. companies have occurred during the past 13 years but talks with these two companies were suspended when the present political coalition came into office in June, 1996. At the time, Etibank announced it would develop the deposit itself. The proposed project would cost about \$400 million for a 1 million tonne-per-year soda ash operation (MEED, 1996).

Outlook

Exports will continue to be the driving force behind increasing U.S. soda ash production capacity, especially to countries that are joint venture partners with the United States. Some of these countries will continue to evaluate the economics of closing certain synthetic soda ash facilities and importing soda ash from their U.S. subsidiaries. Total U.S. exports are forecast to increase an additional 400,000 tonnes in 1997, especially to Asia and South America. Joint venture partnerships with developing nations involving new technology will stimulate economies in those countries and increase soda ash sales. The automotive manufacturing industry in South America is expanding considerably. Chrysler, Peugeot, Renault, Mercedes-Benz, Honda, and Toyota announced they will construct new assembly plants while Ford, General Motors, and Volkswagen will expand existing facilities. This will require a lot of new flat glass for automotive windows for the estimated two million vehicles that are planned to be manufactured by the end of this century.

Owens-Corning Fiberglass Company announced plans to form a partnership with China for fiberglass insulation manufacture. Asahi Glass Company of Japan formed a joint venture to produce flat glass in Song Be, Vietnam. Asahi also invested between \$56 million and \$66 million to expand flat glass production at Teplice in the Czech Republic. Saint-Gobain is scheduled to bring onstream in 1998 a float glass plant in Ravong, Thailand with an annual capacity of 350,000 tonnes of glass. Other flat glass projects are scheduled for construction in Brazil, Germany, and Indonesia that will require soda ash, the majority of which should be supplied from the United States.

Domestic soda ash consumption should rise in 1997 as FMC increases its shipments of soda ash to DuPont's titanium dioxide plant in Tennessee. Reportedly, about 230,000 tonnes of soda ash will be required annually for this use. Domestic apparent consumption for 1997 is forecast at 6.5 Mt.

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Developments in the European soda ash market, 1990 to 1996

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Abstract

The 1990s saw Solvay consolidate its position as the biggest soda ash producer in Europe. Also in this decade, ICI and Rhône-Poulenc sold their operations and the Bulgarians and Poles privatized their industries. The collapse of the Soviet empire had a catastrophic effect on domestic East European soda ash markets at the beginning of the 1990s, from which they are only slowly recovering. Looking ahead to the rest of the decade and into the early part of the next millennium, there will probably be further rationalization and integration in the European soda ash industry. East European soda ash consumption will see some growth as regional economies benefit from a closer relationship with the European Union, but there will very little growth in Western Europe.

Introduction

The European soda ash industry has lived through interesting times in the 1990s, with closures, mergers, and acquisitions figuring strongly in the course of events. This presentation concentrates on the East Bloc nations and Western Europe, and excludes the soda ash markets of Russia and the Ukraine (see article by Watts-Jones in this volume, p. 73-78). One major producer, Solvay, has consolidated its position as the preeminent supplier of soda ash in the region.

With the uniting of the two Germanys in 1990, Solvay took back its old plant at Bernberg and Lars Christensen bought the nearby soda ash plant at Stassfurt. In 1991, ICI sold its UK soda ash operation to Penrice of Australia, who renamed the acquisition Brunner Mond. Another prominent chemical company, Rhône-Poulenc, also disappeared from the soda ash scene, this time in 1996. In the past year (1996) we have also witnessed the first involvement by a U.S. company in the manufacture of soda ash in Europe, with the Harris Chemical Group buying Matthes and Weber of Germany and the Rhone-Poulenc plant in France.

There have also been closures of soda ash plants in Europe. In the west, Solvay has shut down a couple of plants in Belgium and Germany. In 1994, Kalk of Germany was bought by Rhône-Poulenc and closed down. In the east, turmoil followed the breakdown of

the Communist system, but gradually the soda ash industry is reclaiming some of its former importance. However, some old plants have paid the penalty of lack of investment and over-manning and have died; there has been no production in the Czech Republic and Albania for several years now. The Bosnian plant looks unlikely to reopen this decade. The most interesting feature in Eastern Europe in the last two years has been the trend to privatization, launched by Poland and recently followed by Bulgaria. The Polish soda ash industry is now controlled by Ciech, the export agency, and Bulgaria has sold a majority shareholding in its soda ash manufacturing capacity to Solvay.

The main markets for soda ash—glass and detergents—have remained more or less steady. However, demand plunged about 300,000 tpy (metric tons or tonnes per year) in 1994, when STPP (Sodium triphosphosphate) manufacturers switched to caustic soda from soda ash on price grounds. There are indications that falling caustic prices could trigger a similar switch in 1997, but there has been only a muted reaction so far in the first quarter of 1996. The glass industry continues to take around 70% of total ash demand and has remained surprisingly resilient, especially in the container glass sector, in the face of competition from PET (polyethylene terephthalate).

The European soda ash producers

There has been a considerable shake-up in the ownership of European soda ash plants over the last six years, as can be seen in Table 1. The largest changes have been seen in the plants of the former East Bloc; two East European plants have ceased operations altogether, and it is extremely unlikely that the Yugoslavian plant will start up again, at least in this decade. In Western Europe, a major U.S. producer has bought into the market and in 1996, a major West European producer, Rhône-Poulenc, withdrew from the business.

Total East European soda ash capacity (excluding Russia and the Ukraine) is about 3.36 Mtpy (million tonnes or million metric tons per year). The East Bloc soda ash industry faced enormous problems in the early part of the 1990s, following the breakup of the Soviet empire in 1990. Bulgaria and Romania, with plant capacities in excess of 1 Mtpy in each country, were operating at around 30% in the first three to four years of the decade. Only Poland, with capacity from two plants of around 960,000 tpy, managed to perform at a reasonable rate (reaching 75% in 1993), but it is estimated that average operating rates at East Bloc soda ash plants dropped from 87% in the 1980s to 55% and even lower by 1993.

Overall, East Bloc soda ash capacity dropped at the start of the decade with the withdrawal of the DDR from the fold, when it became part of the new unified Germany. There were also many production cutbacks in the early 1990s. Poland closed a 100,000 tpy plant at the end of 1990, with a further 100,000 tpy cut-back in 1995; Czechoslovakia closed its 125,000 tpy plant in September 1991; Albania closed down in 1992/93. Bulgaria closed one line at its Devnya plant for a period and Romania was only operating at about one third of capacity for much of the earlier part of the decade. Finally in late 1996/early 1997, Poland and Bulgaria relinquished state control of their soda ash operations, with Ciech, the export sales operation taking a majority share in the two Polish plants, and Solvay purchasing a controlling interest in the Bulgarian plant. Both companies are seeking partners to help them with the heavy financial burden of improving quality and increasing dense ash production.

In Western Europe, there were also closures during the first half of the 1990s. In 1993, Rhône-Poulenc bought and closed the Kalk plant at Cologne (Germany). In the same year, Solvay closed its Heilbronn (Germany) and Couillet (Belgium) plants. The com-

bined effect was to take almost 900,000 tpy of capacity out of the system. With the combination of the two Germanys, Lars Christensen acquired the Stassfurt plant (500,000 tpy capacity) and Solvay got back its old plant at Bernberg (540,000 tpy). Both companies have invested heavily in improving quality and increasing dense ash production at the expense of light ash output.

In late 1993, Rhône-Poulenc purchased Kalk, the small German soda ash producer, and promptly closed down production; in essence the French producer had acquired a customer list in Germany to supply from its plant at Nancy. During 1994, Rhône-Poulenc had discussions with Akzo with a view to combining their soda ash operations, but these came to nothing. After also failing to make any headway in its attempts to take over the two Polish plants, the French producer decided to get out of the soda ash business completely, first selling its U.S. operation to the Korean producer, OCI, and later, at the end of 1996, selling its European operation, Novacarb, to the Harris Group. Previously, in 1994, Harris had bought the other small German producer, Matthes and Weber and continues to run it as a viable operation. In all, the Harris Group has acquired 820,000 tpy of capacity in Europe to add to its North American Chemical plant in the U.S. (capacity 1.4 Mtpy) and the Penrice plant in Australia (capacity 400,000 tpy), also bought in 1996.

Table 1. European soda ash plant owners and capacities (in thousands of tonnes), 1990 and 1997.

Owner	1990	1997
Albanian State	30	-
Bulgarian State	1200	-
Czechoslovakian State	125	-
DDR State	850	-
Poland/Ciech	960	860
Romanian State	1300	1300
Yugoslavian State	260	-
Solvay	4310	5510
Rhône-Poulenc	550	-
Lars Christensen	-	390
Kalk	280	-
Matthes & Weber	270	-
BASF	35	35
Akzo	370	370
ICI/Brunner Mond	1100	1000
Harris Chemical Group	-	820
Total Europe	11,640	10,285

European soda ash supply and demand

Western Europe

The West European soda ash market is reasonably stable, but there have been some changes in production patterns as can be seen in **Figure 1**. The German

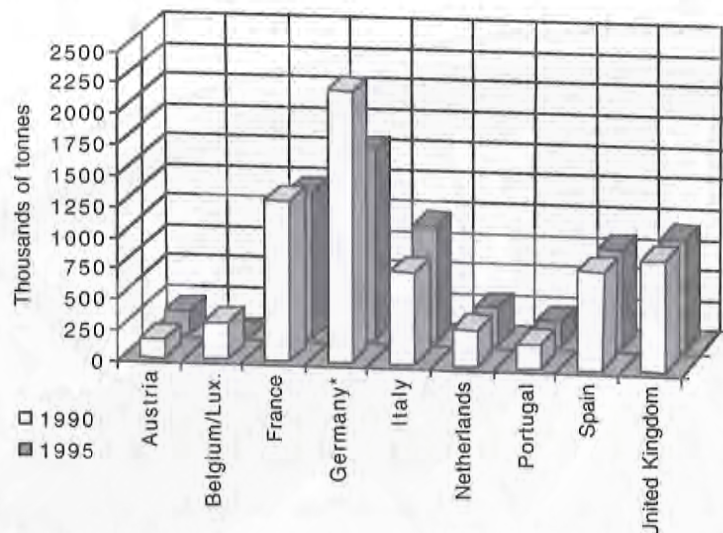


Figure 1. West European soda ash production, 1990 and 1995 (in thousands of tonnes). Total production in 1990 was 6.908 Mt (million tonnes or million metric tons), in 1995 it was 6.095 Mt.

figure includes the DDR in 1990 and the lower level in 1995 reflects how overall capacity has fallen, with Solvay's closure of its Heilbronn plant and the exit of Kalk. Similarly, the closure of Solvay's unit at Couillet has had an effect on the Belgium total capacity in 1995. There was growth in Italy, due to Solvay debottlenecking its Rosignano plant.

Total capacity fell over the five-year period, down by 7% to 6.92 Mt in 1995. Production was also down, by 6% at 6.10 Mt in 1995.

Similarly, soda ash demand varied over the first five years of the decade in each country, as can be seen in **Figure 2**. Germany remained the largest single consumer of soda ash, up 7% over the next biggest market, France, in 1995. The Italian market showed the greatest growth in demand over the five-year period, with the 1995 total up by 25% over 1990.

Only France, Germany, and Italy reported demand in excess of 1 million tpy in 1995. The UK has been consistently around the 820,000-850,000 tpy level.

Eastern Europe

East European soda ash production dropped considerably during the earlier part of the decade and has only recently started to improve. Statistics for 1990/1995 are given in **Figure 3**. The largest producer in 1990 was Bulgaria, but the following five years saw a fall in production of 24%, with first place being surrendered to Poland. Polish production was up 6% and was actually higher than that of Bulgaria and Romania, despite the fact that Poland has a smaller soda ash capacity than either of the other countries.

The first five years of the decade also saw the demise of two soda ash plants, in Albania and Czechoslovakia, respectively, and the virtual closure of the Bosnian plant.

East European soda ash demand also fell over the first half of the 1990s, as shown in **Figure 4**. Total demand in 1995 was 1.481 million tpy, down by 24% from 1990. Domestic consumption remained highest in Poland, where the local glass and detergent industries showed greatest growth over the five-year period. However, there were significant falls in demand in other East Bloc markets between 1990 and 1995: Bulgaria was down 36%, Hungary was down 40%, Romania was down 42%, and the former Yugoslavia was down 47%.

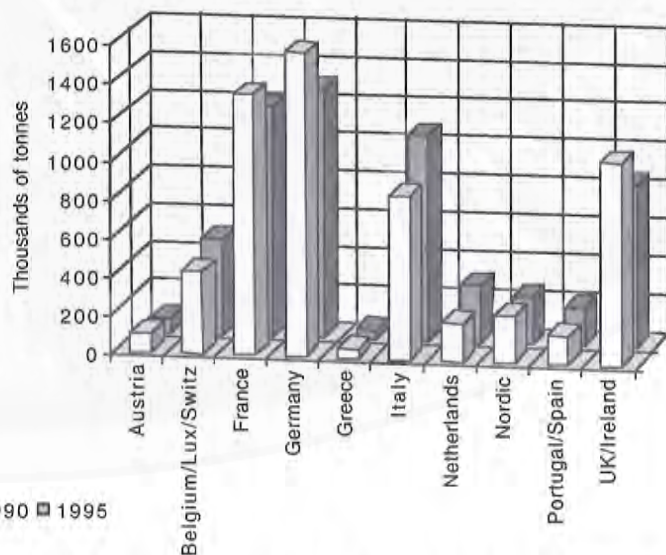


Figure 2. West European soda ash demand, 1990 and 1995 (in thousands of tonnes). Total demand was 6.012 Mt in 1990, in 1995 it was 5.802 Mt.

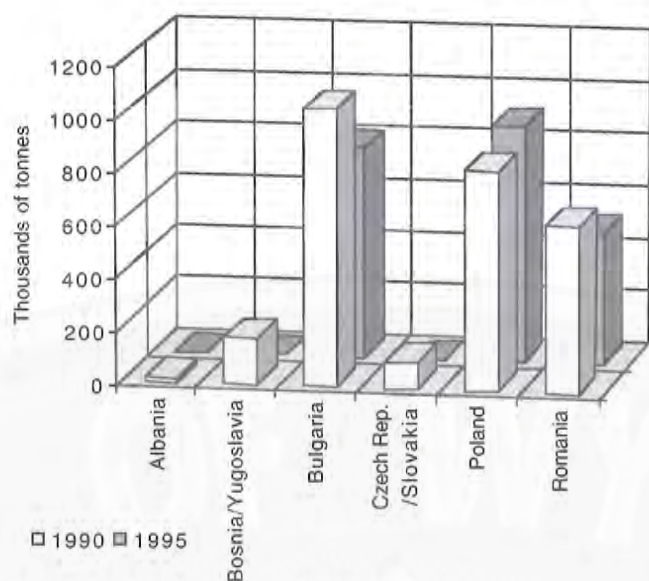


Figure 3. East European soda ash production, 1990 and 1995 (in thousands of tonnes). Total production in 1990 was 2.812 Mt; in 1995 it was 2.166 Mt.

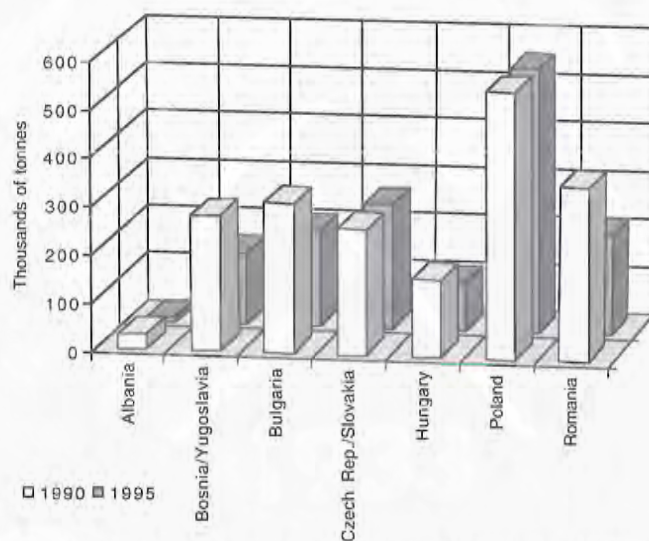


Figure 4. East European soda ash demand (excluding USSR), 1990 and 1995 (in thousands of tonnes). Demand in 1990 was 1.953 Mt, in 1995 it was 1.481 million Mt.

Soda ash consumption in the European glass industry

Western Europe

The major West European glass producers are equal in volume, efficiency, and quality to any in the world, with such famous names as Pilkington, Saint-Gobain, and Glaverbel (see Table 2).

The strength of the continental soda ash market this decade has been largely due to the excellent

performance of its main end-use sector, the glass industry. Glass production in the European Union (EU) has grown steadily in the 1990s, with only one hiccup—in 1993, when production fell by 1.5% only to bounce back by 6.5% the following year (Figure 5). Container glass production in 1995 was up 3.5% over 1994, while flat glass rose only marginally by 0.7%. Flat glass figures showed a slower rate of growth with the total for 1995 up 10% from the level of 1990.

Table 2. Major West European glass producers.

Country	Company	Type of glass
Belgium	Glaverbel (62% Asahi)	Flat
	Guardian Industries	Float
	Glacier de St. Roch	Float
France	Saint-Gobain	Float/Container
	Boussois (PPG)	Float
	BSN	Container
Germany	Flachglas (Pilkington)	Float
	Vegla (St Gobain)	Float
	Gerrheimer Glas	Container
	PLM Glashutte Munder	Container
Italy	Saint Gobain	Float
	SIV	Float
	AVIR	Container
Netherlands	PLM	Container
	Asahi	Container
Portugal	COVINA	Float
	CIVE	Container
Spain	Cristaleria Espanola	Float
	VILCASA	Container
UK	Pilkington	Float
	United Glass Cntrs (Owens)	Container
	Rockware Glass	Container

Without doubt, the glass industry forms the major end use industry for soda ash in West European countries, as elsewhere in the world. The volume of soda ash used by the West European glass industry in 1995 is shown in Figure 6.

Eastern Europe

There are a number of large glass producers in the East Bloc and a considerable amount of western capital and expertise in the form of joint ventures and takeovers have occurred over the past few years (see Table 3).

It is difficult to provide a detailed breakdown by country of soda ash end use, as data does not exist on which to base the assessment. However, as is the case with its western neighbor, the glass industry forms the major end use industry for soda ash in East European countries, as elsewhere in the world. It has been possible to obtain detailed statistics for glass production for some countries, confirming its preeminent position as a consumer of soda ash. The volume of soda ash believed to have been used by the East European glass industry in 1995 is shown in Figure 7.

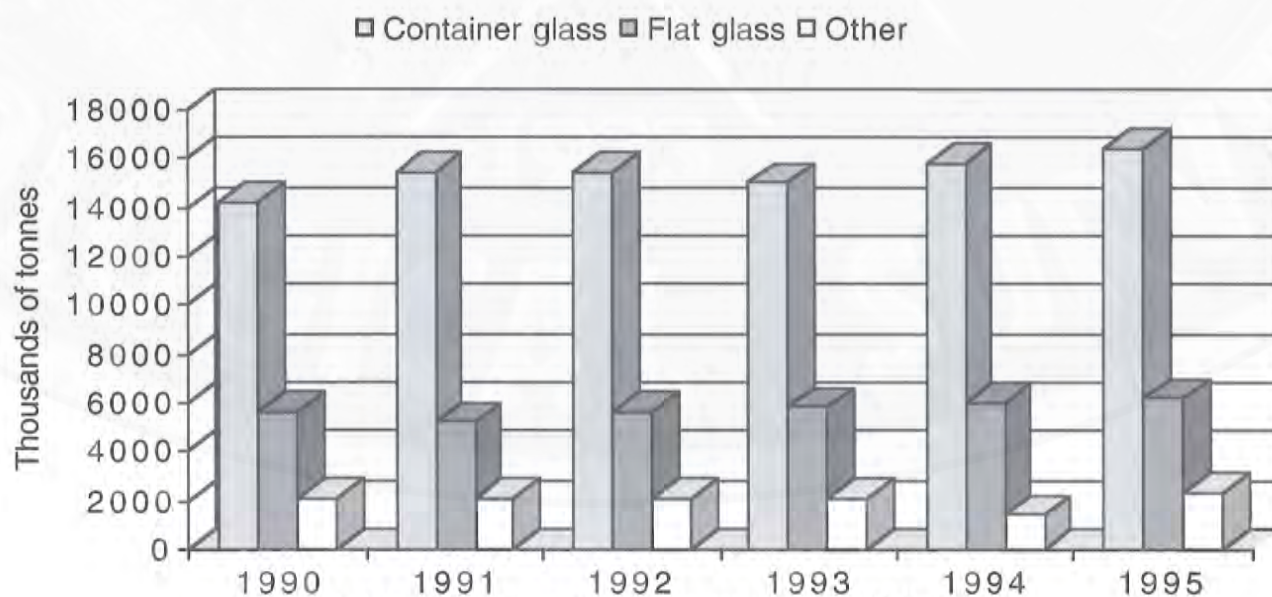


Figure 5. European Union glass production, 1990 to 1995 (in Mtpy).

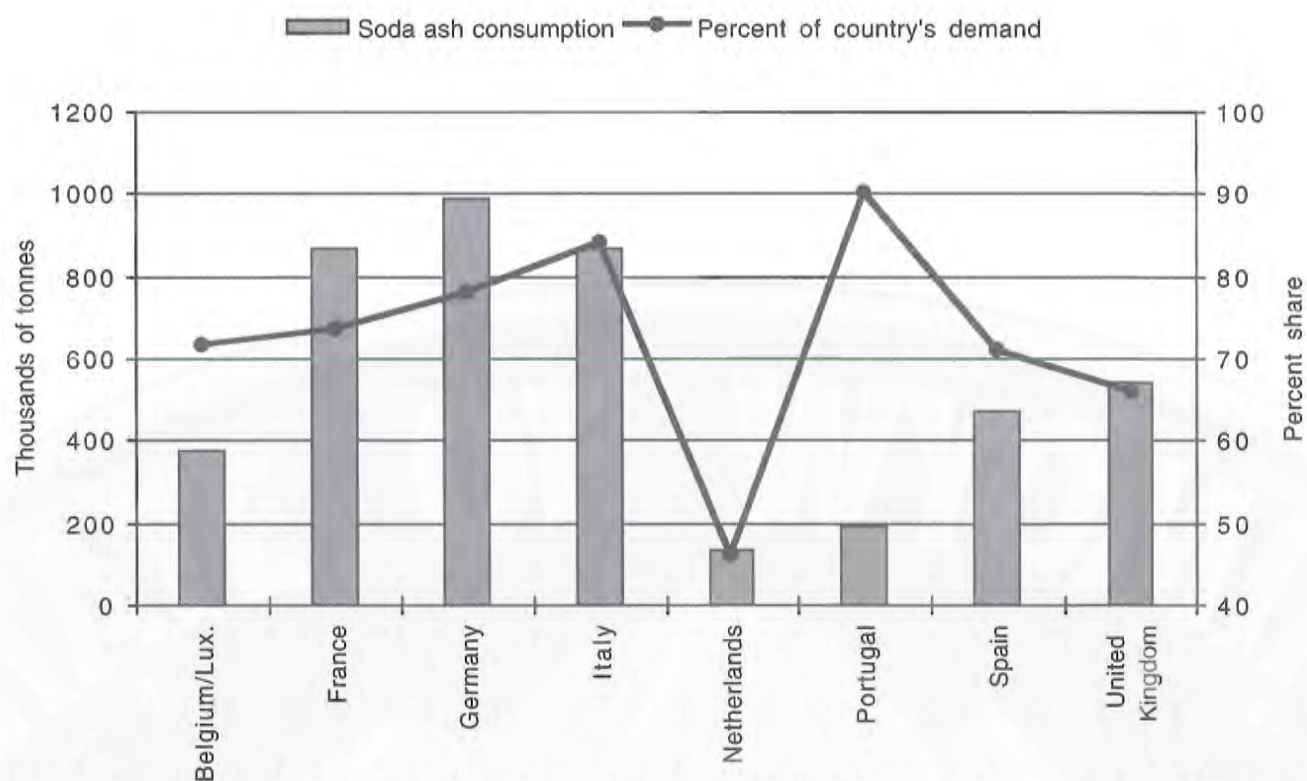


Figure 6. Consumption of soda ash by the Western Europe glass industry in 1995 (in thousands of tonnes) and the percentage of each country's soda ash demand by the glass industry (black line).

Table 3. Major East European glass producers.

Country	Company	Type of glass
Bulgaria	Diamant	Flat
	Belopal	Container
	Drujba	Container
Czech Republic	Sklo Union (67% Glaverbel)	Float/Container
	Kyjov	Container
Hungary	Pannonglas (includes jv with Guardian Industries)	Float/Container
Poland	Pilkington/	Float
	HSO Sandomierz	Float
	Saint-Gobain	Float
	PLM	Container
Romania	S.C. Ges S.A.	Flat
	S.C. Sticla Turda S.A.	Household glass

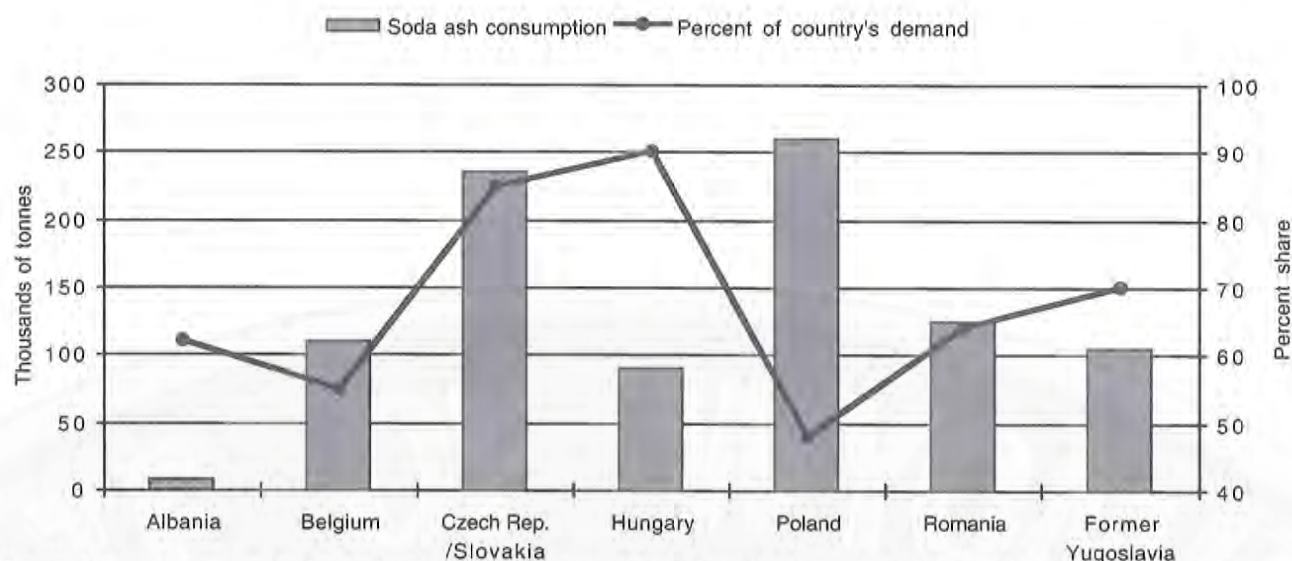


Figure 7. Consumption of soda ash by the Eastern Europe glass industry in 1995 (in thousands of tonnes) and the percentage of each country's soda ash demand by the glass industry (black line).

Soda ash switching in the West European soda ash STPP industry

The biggest market for switching in Western Europe is the sodium tripolyphosphate (STPP) industry. The main West European producers involved and their reported switchable volumes (DMT) are given in Table 4.

Table 4. West European STPP producers and their switchable volumes (DMT) in tonnes.

Producer	DMT
Albright & Wilson (UK)	50,000
Hoechst (Netherlands)	70,000
Prayon (Belgium)	30,000
Rhône-Poulenc (France)	25,000
Rhône-Poulenc (Spain)	50,000
Foret (FMC) (Spain)	50,000
Kemira (Sweden)	30,000
Total	305,000

Switching in the STPP industry has not translated itself into the detergents industry. STPP is a precursor to the detergent industry, and while detergent manufacturers also use caustic soda and soda ash, the two alkalis are largely not switchable in detergent formulation processes, since they serve different functions. Therefore, it can be said that switching does not occur in the detergents industry, but only at the STPP production stage, that is, before the detergents producers buy STPP for their formulation processes.

In the STPP industry, where the two alkalis are interchangeable, switching is strongly influenced by price. When caustic soda prices rise above a certain level, it becomes more economical to use soda ash, and vice-versa. The so-called 'Delta Factor' can be used to calculate the point at which substitution should take place. This factor represents the difference between the NaO equivalent price of soda ash and the caustic soda price and is defined as follows:

$$\text{Delta Factor} = \text{Soda Ash Price} \times 1.325 - \text{Caustic Soda Price}$$

When the factor is positive it is more cost effective to use caustic soda, and when the factor is negative, soda ash is to be preferred. The dominant influence affecting a company's decision whether or not to switch between the alkalis is the price factor, i.e., the relationship between the market prices of soda ash and caustic soda. Because of the different quantities of alkali required in a process, the caustic soda price theoretically is required to be more than 1.325 times that of soda ash before a switch to soda ash from caustic soda can be contemplated as an economic feasibility.

Regarding soda ash producers, the effects of these switches have mainly affected the performance of two major suppliers, Solvay and Brunner Mond, over the years. The third large producer, Rhône-Poulenc (now Harris Chemicals), has not been greatly affected as it has captive STPP production in France and Spain.

The smaller West European soda ash producers, Akzo, Matthes and Weber (now North American), and Lars Christensen, have not been deeply involved in the STPP sector.

Caustic soda and soda ash price movements in a number of West European countries last indicated a move towards the negative in the Delta Factor in the fourth quarter of 1994, triggering a switch from caustic soda to soda ash in that quarter, and moving ahead more strongly in the first quarter of 1995. Previously, the Delta Factor broke through from negative to positive values early in 1993, which triggered a move to caustic soda from soda ash and was responsible for a large part of the decline in soda ash consumption in Western Europe in 1993. A similar effect was observed in the U.S., and as caustic soda prices plunged further there, and then started to rise again, the switch back to soda ash in the U.S. was

further advanced than in Western Europe. About 100,000 DMT was estimated to be in the process of switching back to soda ash in the U.S. in the fourth quarter of 1994, with a further 100,000 DMT in the first quarter of 1995, and the balance in the second quarter of 1995. In Western Europe, around 50,000 DMT was in the process of switching back to soda ash in the fourth quarter of 1994, with the balance moving across in the first half of 1995.

The previous switching period to soda ash was in the second half of 1987 and the first half of 1988 when the Delta Factor curve last moved to negative values. At that time a much smaller volume of caustic soda—probably only around 100,000 DMT—was available for switching in the West European market, due to the lack of equipment at several plants to handle both liquid and solid alkali products.

Conclusions

The European soda ash industry has endured some radical changes in the 1990s in regard to both ownership and total capacity. At the same time, demand has remained centered overwhelmingly on the glass sector, followed a considerable distance behind by the detergent sector. No change in this situation is envisaged.

However, looking ahead to the rest of this decade and into the early part of the next millennium, it is very probable that further rationalization and integration will occur in the European soda ash industry, with more East European plants being taken over by, or forming joint ventures with, West European and/or U.S. companies. The process will be hastened and indeed facilitated by the gradual growth of the European Common Market, as it absorbs more and more states of the former Eastern Bloc.

Soda ash consumption in the 1990s has increased only marginally in Western Europe, punctuated by a short-term drop in 1993, due to the detergent sector switching to caustic soda when prices dropped to a certain level. In Eastern Europe, domestic consumption fell significantly in the first half of this decade, but there should be some acceleration in demand for the alkali later in the 1990s and into the next decade as economies in the region benefit from a closer relationship with their richer Western neighbors. However, there will be very little growth in Western Europe and the next decade may in fact see a decline in consumption in the glass industry with further penetration of the container glass sector by plastics.

Soda ash – A European producer's perspective

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Abstract

This paper considers areas of world consumption and growth of the soda ash market, and suggests that the areas of greatest growth will be those recovering from political turmoil and third world developing economies. The alternative methods of production of soda ash are reviewed and the place of the synthetic producer is considered. There have been significant developments in the technology of the synthetic process in recent years, making it more efficient and cost effective. These trends, plus business re-engineering of the operating companies, means that the cost base of several companies operating the synthetic process has been reduced significantly, making them able to compete easily with ash produced from other sources and delivered into the synthetic producers' home markets.

Soda ash consumption

World consumption of soda ash increased through the 1980s, but the early 1990s saw little or no growth until about 1995; since then it has been increasing at about 1.5% per year. It is now at about 32 Mt (million tonnes or million metric tons) and some analysts predict an average 2.5% per year growth rate for the future. The majority of this growth will occur in the Far East and South America. The areas of highest growth have been in third world countries which are rapidly improving their standard of living; future areas of greatest growth will be in third world economies as

they develop and expand (**Figure 1**). It is also probable that those countries emerging from economic or political upheaval such as Eastern and Central Europe will have a period of high growth as they recover from a period of decline.

The consumption of soda ash in Western Europe in recent years has been relatively flat (**Figure 2**) and we expect this to remain so. Similarly, if one looks at the equivalent consumption curve for the U.S., one sees that this also is remarkably flat.

Supply/demand balance

On a world scale there is ample soda ash capacity to meet current demands, although this capacity is now often far from the consuming market. As a result, the pattern of trade is changing, and this is further influenced as manufacturers in the Far East slowly rationalize, buying into other cheaper capacity in the U.S.

European producers see an industry in Wyoming which is constantly expanding, in a domestic market which is relatively static (see **Table 1** and **Figure 3**). The ever increasing gap between production and domestic consumption is being used to target the growth

markets of the Far East and South America, with occasional attempts to sell soda ash in other less attractive markets when there is a short-term capacity surplus.

In contrast, Europe is quite different, with installed capacity being reduced in 1993/94 and some of the gap between capacity and consumption being filled by a small export presence (**Table 2** and **Figure 4**). Even after the capacity reductions of 1993, there is more than enough productive capacity within Europe to match likely requirements.



Figure 1. World soda ash consumption (in thousands of metric tons) and expected annual growth rates (in percent), 1995.

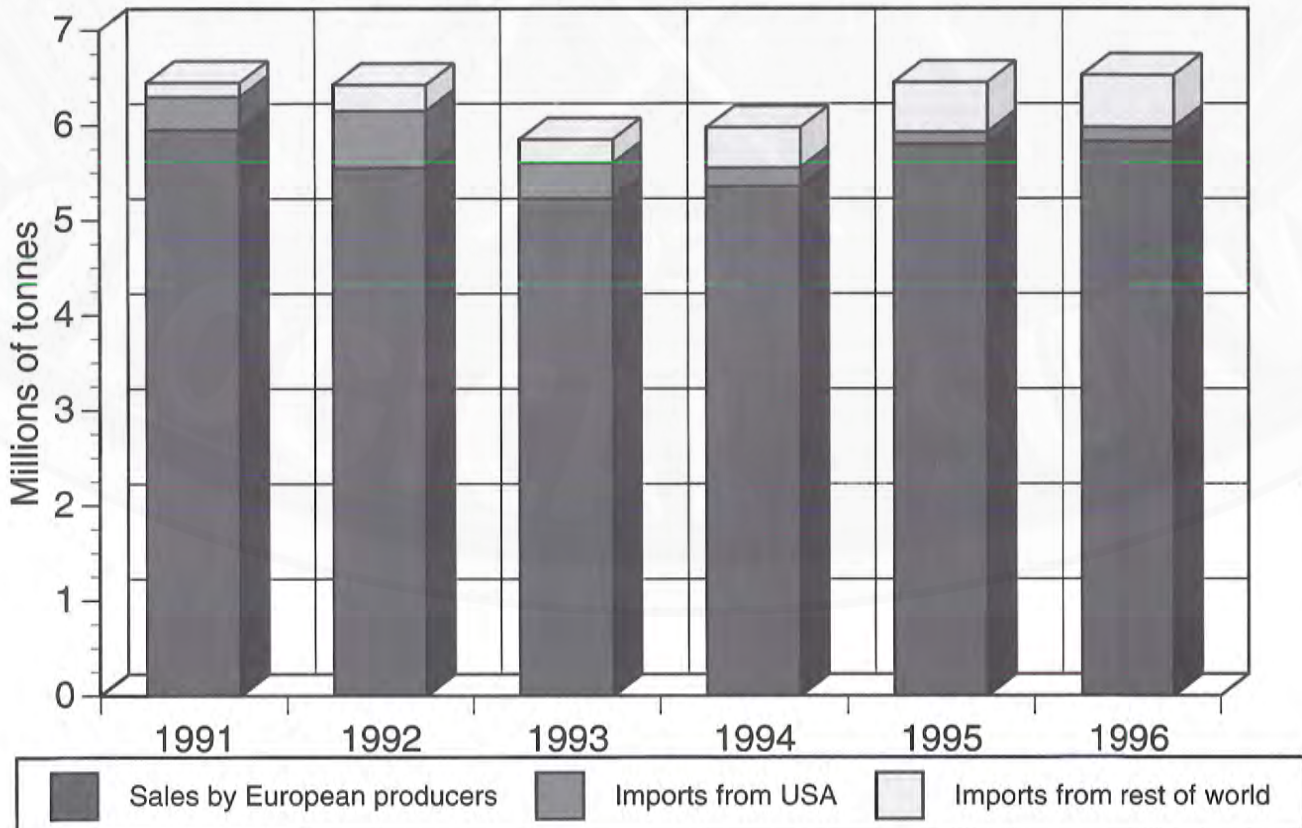


Figure 2. Soda ash consumption in Western Europe, in millions of tonnes. ROW = rest of world.

Table 1. U.S. soda ash capacity, production, and consumption (approximate), 1987 to 1996, with forecasts (F) to 1997 (in tonnes).

Year	Capacity	Production	Approximate consumption
1987	9,441,870	8,066,000	6,214,000
1988	9,509,895	8,736,000	6,594,000
1989	9,577,920	8,995,000	6,516,000
1990	9,577,920	9,156,000	6,843,000
1991	9,577,920	9,005,000	6,458,000
1992	9,939,970	9,379,000	6,360,000
1993	11,020,050	8,959,000	6,350,000
1994	11,020,050	9,321,000	6,240,000
1995	11,292,150	10,100,000	6,510,000
1996	11,292,150	10,200,000	6,470,000
1997	(F) 12,063,100	(F) 11,500,000	

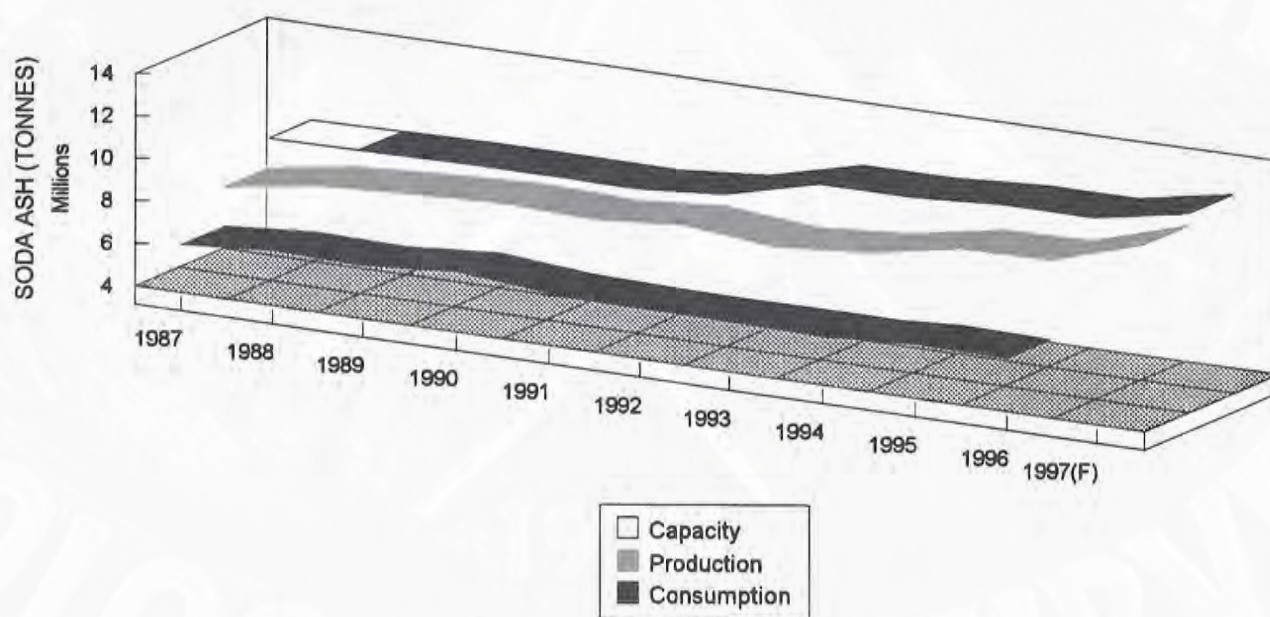


Figure 3. Development of the U.S. soda ash industry, 1987 to 1996, with forecast for 1997.

Table 2. Western European soda ash capacity, production, and consumption, 1991 to 1996 (in tonnes).

Year	Capacity	Production	Consumption
1991	7,685,000	6,478,053	6,447,951
1992	7,685,000	6,175,941	6,459,918
1993	7,085,000	5,808,684	5,853,579
1994	6,805,000	5,815,337	5,997,409
1995	6,814,920	6,289,644	6,468,152
1996	6,916,048	6,264,026	6,529,024

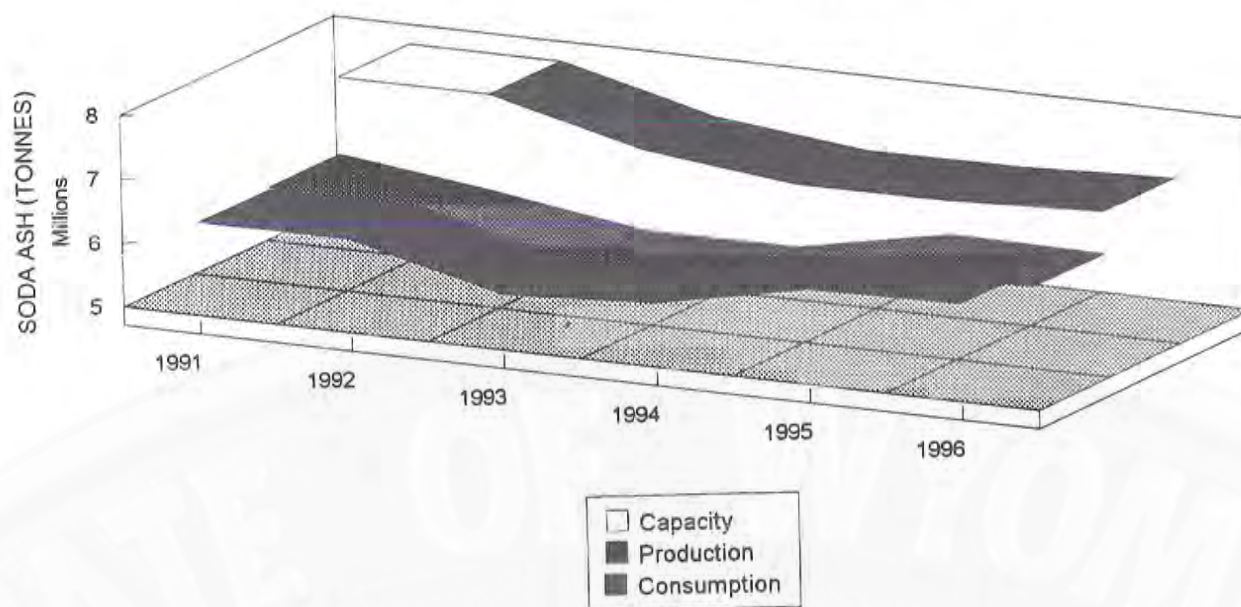


Figure 4. Development of the European soda ash industry, 1991 to 1996.

Sector analysis

Almost 63% of the soda ash consumption in Western Europe goes into the glass industry; this consumption pattern has been remarkably consistent over the last five years. This compares with the U.S. where there has been a definite move away from the glass industry and towards chemicals; only 48% of the soda ash is used in glass (Figure 5). The split in the United Kingdom (UK) falls between these two with 52%

going to glass. This illustrates the relatively high dependence of the European soda ash industry on the glass manufacturers, although certainly in the UK there are indications that this is starting to diminish as the detergents and chemicals sectors show some signs of growth. It might also be argued that these statistics illustrate the relative success of the European glass industry versus other competitive packaging materials.

Review of production processes

At the present time world capacity for soda ash is about 40 Mt. Of this, approximately 27 Mt is based upon the traditional Solvay ammonia-soda process (Roskill). Some of these plants (in Japan and Korea) are scheduled to close as their owners buy into trona-based capacity in Wyoming, but others will continue to operate depending in part upon their geographical location and local economic conditions. The remaining 13 Mt of capacity are based upon alkaline lakes or trona deposits.

Comparing the costs of the various production routes is difficult, but in general one can say that on a "cost per tonne product produced at the site gate" basis, ash from dredged trona or from mined trona costs less than ash from an ammonia-soda plant. However, dredged alkaline lakes and mined trona plants tend to be far from areas of major consump-

tion, and rather isolated with very high distribution costs. This means that in areas where there is no local efficient ammonia-soda producer, the alkaline lake or trona-based plant will be the most cost competitive supplier of soda ash. However where there is an efficient local ammonia-soda producer with cheap energy and raw materials, this local producer may well be the most competitive supplier in his natural market on a "like-for-like" basis.

Many of the poorer, less efficient plants which produce soda ash via the Solvay ammonia-soda process have closed and others are destined to do so, but the more efficient, well-managed plants which are well-placed geographically for cheap raw materials and energy will continue to operate and reduce their cost base further by investment in new technologies and application of modern management methods.

Cost improvements in ammonia-soda operations

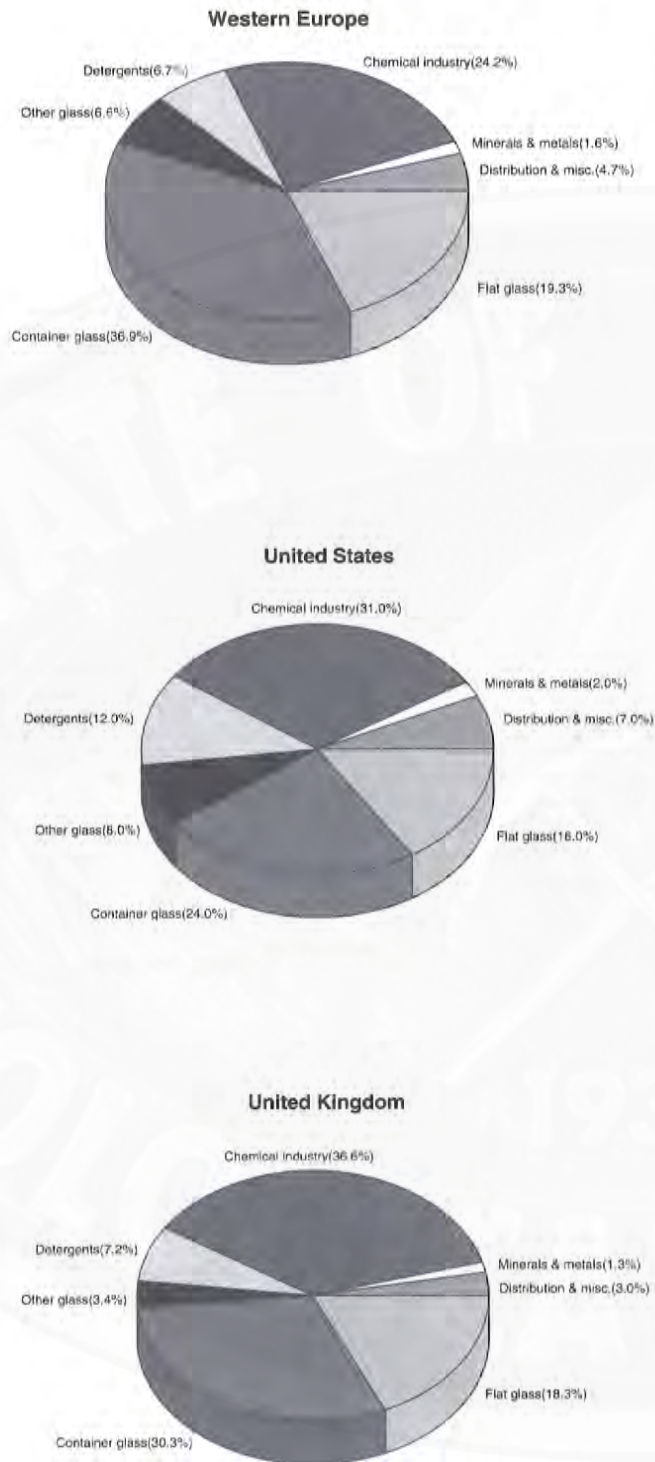


Figure 5. Soda ash consumption by industry sector in 1996 for Western Europe, the United States, and the United Kingdom.

The costs of operating ammonia soda plants have reduced significantly over recent years due to changes in technology, management methods, flexible working, and business re-engineering. Examples of these changes include:

1) The elimination of a number of large and expensive-to-maintain columns within the process, which have been replaced by titanium-plate heat exchangers;

2) New distributed control systems have lead to significantly improved control algorithms, expert systems, and manpower reductions in the operating teams;

3) Improved materials of construction, new types of pumps and valves, and reliability-centered maintenance methods have lead to increased equipment availability and reliability;

4) Modern structural packing for absorption and scrubbing columns have simplified and reduced costs in certain sections of a plant;

5) New working practices enabling operators that are properly trained to repair equipment on shift have helped reduce numbers and increase availability; and

6) ISO 9002 quality registration for all products and environmental registration. ISO 14001 has resulted in much tighter control of losses, better raw material usages, and a cost-effective means of complying with new legislation which is regularly introduced to improve environmental standards.

In addition to these developments, technology continues to advance and further improvements are in the pipeline. Re-engineering of total businesses has also significantly reduced fixed and overhead charges, leading to leaner and more competitive operations.

The overall effect of these changes has been to reduce direct factory costs significantly. Figure 6 illustrates the band of cost savings which we believe European soda ash producers have achieved; this is based upon data from the anti-dumping, non-confidential files of the European Commission. Our company has tackled all aspects of its cost base and unit production costs have been reduced by 15% since 1991 (Table 3).

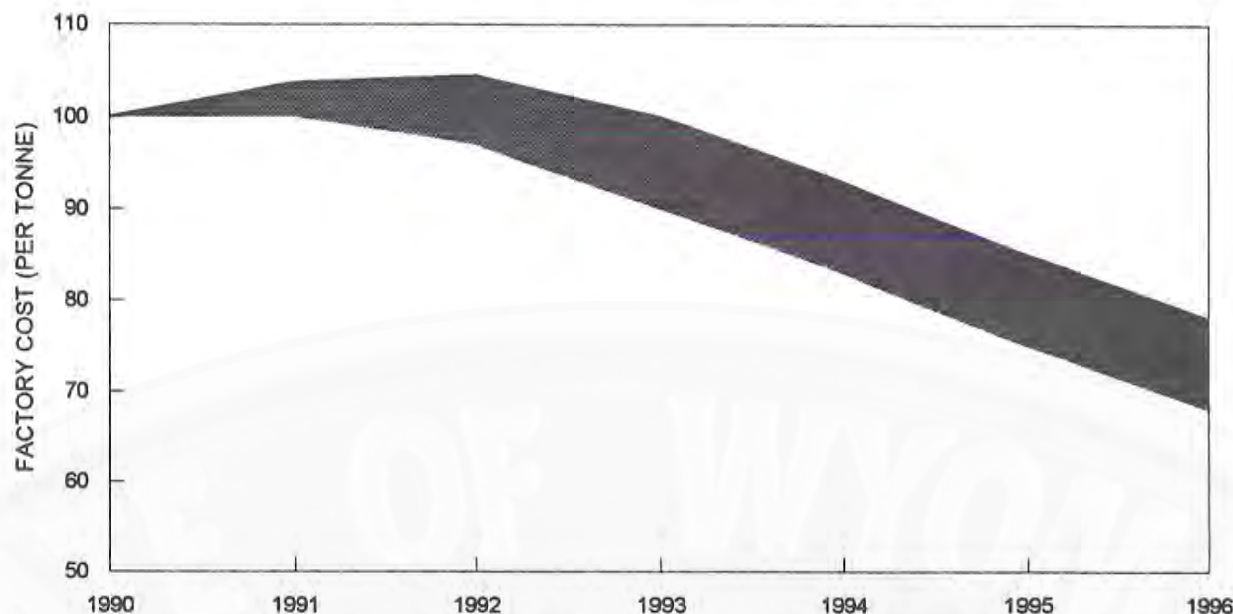


Figure 6. Band of total factory cost reductions for European soda ash producers.

Table 3. Indices of cost elements at standard production levels.

	1991	Current
Manpower	100	73
Variable	100	83
Other fixed	100	92
Total	100	85

These trends will continue because the European producers are determined to remain competitive against imported ash and to give their customers the benefits of efficient operations.

The effect of these cost reductions, Brunner Mond believes, is that on a "like-for-like" basis, trona-derived ash cannot compete with synthetic ash in its

home markets until the exchange rates move beyond \$2/£.

For the future, Brunner Mond has a combined heat and power (CHP) plant planned. Several other European producers have already built or have announced plans for similar plants. For an ammonia-soda plant with an existing conventional power station, a gas-fired CHP installation significantly improves the energy bill, the numbers employed, and increases the reliability of steam supply. In Brunner Mond's case, with the proposed PowerGen installation, energy efficiency which is already high at about 80% will improve to 87% and the company's energy bill will continue to reduce over the next 15 years. In addition, with the plant configuration proposed, available steam supply will be twice that required, guaranteeing a very reliable level of production.

Summary

Soda ash from an ammonia-soda plant is more expensive to produce than trona-based material, even though costs have been reduced significantly in recent years. However, the balance of production and transportation costs does mean that this ash can compete with trona-based ash after it has been transported from Wyoming to the areas of local ammonia-soda production. Brunner Mond's calculations indicate that on a "like-for-like" basis, trona-derived ash cannot compete with synthetic ash until the exchange rates move beyond \$2/£. On the other hand, synthetic ash will never compete on the same basis with trona-based ash which is sold in markets far from its point of production. Therefore, European producers

will never sell in the major growth areas far from their natural markets of Western Europe, although some of the more eastern of these European plants may well be able to sell profitably in some areas of Central Europe.

Similarly, efficient ammonia-soda producers in other countries may be able to compete with trona-based ash; these producers will have well-managed modern and efficient synthetic plants competing within natural home markets. Eastern Europe may well be such an area depending upon how quickly their economy stabilizes and how much investment is available for their soda ash industry.

Therefore, in the long term we see synthetic ash producers being the main low-cost suppliers to the European market, with opportunities for trona-based

ash in third world areas of high growth and possibly in areas of economic and political instability.



The soda ash industries of Russia and Ukraine

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Abstract

The USSR used over 5 million metric tons (tonnes) of soda ash in 1985 when it represented more than 18% of global consumption. Although the country had production capacity nominally capable of supplying its domestic requirements of soda ash, it was in fact a significant importer of ash from other COMECON member states. The region's consumption of soda ash fell in the following years with the decline becoming precipitate following the introduction of economic reforms. By 1996, regional consumption was under 3 million tonnes, less than 10% of global consumption.

Approximately 15% of the Former Soviet Union's (FSU) production capacity is based upon nepheline as its raw material, the remainder uses the conventional ammonia-soda (Solvay) synthetic process. Production from natural sodium carbonates, which was always small, stopped in the mid-1970s.

This paper reviews the operating characteristics of the region's eight soda ash sites and examines historic consumption patterns. In conclusion, it considers the outlook for the industry in the coming years.

Introduction

Soda ash production in the countries of the Former Soviet Union (FSU) is established solely in Russia and Ukraine. While there are sometimes rumors of new plants being established elsewhere in the region, at the time of writing, none is confirmed. Soda ash consumption is spread, albeit unevenly, across the entire area.

This paper considers the production plants, their raw materials and products, and the consumption patterns across the region. It concludes by discussing how the industry may change in the coming years.

Production

Natural soda ash is no longer produced in the countries of the FSU. The last production unit stopped in 1974, reportedly because of low profitability. All the region's natural soda ash was derived from brine sources located in relatively remote parts of Siberia. To date, no large trona deposits have been found, although small deposits have been reported in the Kola Peninsula and in parts of the Urals. None of the deposits, however, have been commercialized.

The Soviet Union is very poor in conventional bauxite reserves, particularly those suitable as raw materials for metallurgical alumina. This provided a driver for the development of some unconventional mineral deposits—alunite $[\text{KAl}_3(\text{OH})_6(\text{SO}_4)_3]$, dawson-

ite $[\text{NaAl}(\text{CO}_3)(\text{OH})_2]$, and nepheline $[(\text{Na}_3\text{K})(\text{AlSiO}_4)_4]$. An alunite processing plant was established at Ghyandja, Azerbaijan; the process is only interesting to the alkali industry in that it required large quantities of caustic potash. The dawsonite projects, which were to be based on deposits found in Belarus and the Kuznetsk coalfields, were never commercialized; the proposed process would have made about 1.4 tonnes of soda ash per tonne of alumina. Three nepheline plants were built in Russia; at the time of writing, they are still operational and account for about 15% of the region's soda ash capacity; the balance of the capacity is provided by five classic ammonia-soda (Solvay) plants (**Table 1**).

Table 1. Soda ash capacity in the FSU (in thousand tonnes per year).

Country	Location	Capacity	Process
Russia	Achinsk	595	Nepheline
	Berezniki	1080	Solvay
	Pikalevo	200	Nepheline
	Sterlitamak	2135	Solvay
	Volkhov	20	Nepheline
Ukraine	Krasnoperekopsk	690	Solvay
	Lisichansk	580	Solvay
Total	Slavyansk	235	Solvay
		5535	

Given that the ammonia-soda process produces quite substantial volumes of effluent (mostly calcium chloride in aqueous solution), some may consider that the nepheline-based process is particularly attractive in that it yields (almost) no effluents; whether it makes economic sense is another matter. What is interesting from the standpoint of soda ash is that the process is a net producer of alkali. This is shown in the typical material balance (Table 2).

Table 2. Nepheline process material balance (in unspecified units).

Material inputs	Quantity	Product outputs	Quantity
Limestone	12.0	Alumina	1.0
Nepheline ore	4.0	Soda ash	0.7
		Potassium carbonate	0.3
		Portland cement	10.0
		Wastes	nil

In practice, these material balances are not always achieved and as a result, wastes are produced. Also, the potassium alkali does not always appear as carbonate but rather as sulfate. When offering the process for license, the Russian licensors have quoted the parameter ranges shown in Table 3.

The driver for the development of this nepheline process was alumina self-sufficiency. Accordingly, it is interesting to compare the unit consumptions in Table 3 with those found in the conventional bauxite process (Table 4).

The comparison confirms the need for the technology to be operated on a full co-product basis if it is to be viable in competition with the stand-alone alternatives. It is equally important in a free market that all its product qualities be acceptable in their respective marketplaces. On this latter point the nepheline process is also challenged for it does not yield high quality soda ash; typical analyses are shown in Table 5.

Table 3. Nepheline process parameters (units per tonne of alumina). Abbreviations are GCal=gigaCalories; kwh=kilowatt hours.

	Low	High
Main products		
Alumina (tonnes)	1.00	1.00
Soda ash (dense - tonnes)	0.62	0.76
Potassium carbonate (anhydrous - tonnes)	0.20	0.32
Portland cement (tonnes)	9.00	11.00
Main consumption		
(For alumina, potassium carbonate, and soda ash production)		
Nepheline concentrate (tonnes)	3.90	4.30
Limestone (tonnes)	6.00	7.80
Fuel (GCal)	10.50	11.20
Steam (GCal)	3.20	3.40
Electrical energy (kwh)	1050	1190
(For Portland cement production)		
Limestone (tonnes)	5.00	6.00
Fuel (GCal)	9.10	11.20
Electrical energy (kwh)	700	800

Table 4. Bayer (conventional bauxite) process parameters (units per tonne of alumina). Abbreviations are GCal=gigaCalories; kwh=kilowatt hours.

Parameter	Low	High
Aluminous ore	2.0	3.5
Residue production	0.4	2.0
Energy (GCal)	2.2	3.2
Electrical energy (kwh)	200	300

Table 5. Soda ash specifications for the nepheline process (in percent). Roman numerals indicate different plants.

Grade/Constituent	I	II	III
Soda ash (Na_2CO_3)	96.5	90.5	87.0
Potassium carbonate (K_2CO_3)	2.0	5.0	6.5
Potassium sulfate (K_2SO_4)	1.5	4.4	6.5
Iron oxides (Fe_2O_3)	0.0005	0.01	0.02
Insolubles	0.1	0.1	0.2
Water (H_2O)	1.0	1.0	1.0

The balance between the grades, which are all dense ash, tends towards II and III. These qualities would not find ready acceptance in the international market although glass-makers could probably accept them in the right circumstances. But the glass industry was not the original target market for this ash. When the plants were built, they were under the control of the Ministry of Non-Ferrous Metallurgy which also had responsibility for the bauxite-based alumina refin-

eries; some of these refineries use soda ash as their principal alkali.

The first nepheline plant constructed was that at Volkhov, near Lake Ladoga east of St. Petersburg. It started up in 1950 and forms part of an integrated aluminum smelter. Pikalevo, about 80 miles away, started up about nine years later. Both plants run on a nepheline co-product of phosphate mining in the Kola Peninsula and both are nil-waste plants in that they co-produce around ten tonnes of cement per tonne of alumina. The Achinsk plant started in 1970 and consumes a nepheline that is extracted nearby. Achinsk is east of the Ural Mountains in the western part of Siberia. The local demand for cement is not substantial, consequently the plant makes only four tonnes of cement per tonne of alumina.

Three of the five ammonia-soda sites were established more than 100 years ago: Berezniki in 1883, Lisichansk in 1892, and Slavyansk in 1897. The plant at Sterlitamak, believed to be the largest synthetic soda ash plant in the world, began production in the mid-1950s while the Krasnoperekopsk unit was started up in 1972. All the plant sites were selected on the basis of proximity to salt and limestone deposits.

Berezniki is about 100 miles north of Perm in the western foothills of the Ural Mountains. Both towns are on the Kama River, a navigable tributary of the Volga River. Perm is on the Trans-Siberian railway from which a spur line runs to Berezniki. Berezniki is the center of the Russian potash industry and today the salt solution for the soda ash plant is obtained from the potash mines. The plant has its own limestone reserves about 50 miles away.

Lisichansk is in the Donbas coalfield area of eastern Ukraine. Both salt and limestone are taken from local deposits as is also the case at Slavyansk, some 50 miles west of Lisichansk.

Sterlitamak is in the Republic of Bashkortan. In addition to having the country's largest soda ash plant, it also has its largest chloralkali unit. Both these alkali factories use salt-in-brine from large local salt

deposits. Limestone comes from a quarry about three miles from the plant.

Krasnoperekopsk is on the western side of the isthmus that joins the Crimean peninsula to mainland Ukraine. Limestone comes from the Crimea, salt is obtained from a company-owned solar saltfield.

All these synthetic soda ash plants have large settling ponds, known locally as "white seas," in which the solid effluents are settled. The inland plants discharge the supernatant to the rivers that pass their sites; the Crimean plant sends its liquid effluents directly to the Black Sea.

All the plants make most of their output as light ash. Certain plants have the ability to densify their output by the conventional monohydrate route. Densification capacity is limited and frequently underutilized. Normally three product qualities are offered; typical specifications are shown in **Table 6**.

Table 6. Typical FSU soda ash specifications (in percent).

Product/Characteristic	Extra	Superior	First
Soda ash (Na_2CO_3)	99.0	98.5	98.0
Sodium chloride (NaCl)	0.6	1.0	1.5
Iron oxides (Fe_2O_3 maximum)	0.003	0.006	0.015
Water insolubles (maximum)	0.12	0.12	0.15

Product is shipped in bulk and bags. The railway systems in the region require substantial investment and rail deliveries can take weeks to complete while bulk rail-wagons are sometimes lost for months.

In common with many chemical plants in the FSU, these units have not been the subject of continuous process improvement over the years nor have they received the regular maintenance that is usual in, say, Western Europe. They are aware of their shortcomings and are working hard to modernize both operating efficiencies and product qualities and delivery systems.

Consumption

In 1985 the Soviet Union consumed about 5.3 million tonnes of soda ash. By 1990 consumption had fallen to around 4.9 million tonnes and five years later it was around 2.9 million tonnes in the countries of the FSU.

Precise figures for the breakdown of consumption by industry and by country are not available for the

most recent years. It is therefore necessary to base this analysis on the older data and assume that the historic patterns have not changed radically since.

Russia has always been the largest ash consumer with an average of 58% of total use. The two other large consumer nations are Ukraine (19%) and Kazakhstan (11%). The consumption of the balance is

spread fairly evenly across the other republics. The breakdown of consumption by industry for the three principal consuming nations is shown in **Table 7**.

Table 7. End-use breakdown for the principal FSU soda ash markets (in percent).

Industry	Kazakhstan	Russia	Ukraine
Chemicals	40	38	42
Glass	5	28	33
Metals	38	22	10
Others	17	12	15

Before considering the rationale for this distribution of end-uses, it may be helpful to recall the balances found in other parts of the world (**Table 8**).

Table 8. End-use breakdown, other selected markets (in percent) for soda ash.

Industry	China	USA	Western Europe
Chemicals	18	22	18
Glass	42	50	65
Soaps/detergents	6	13	4
Others	34	14	13

The most immediate difference between **Table 7** and **8** is the lack of separate figures for soaps and detergents in the three republics of the FSU and the relative importance of the chemicals and metals sectors in those countries. The reason for the first difference lies in the way that the numbers are reported rather than a lack of use in the sector in the FSU republics.

Soda ash has always been the "favored" sodium alkali in the FSU. Expressed in sodium oxide terms, the ratio of caustic soda to soda ash consumption found, for example in Western Europe, is approximately 2:1. For the FSU the ratio is of the order of 0.8:1. The primary explanation for this unusual ratio is that the chloralkali industry of the FSU is comparatively underdeveloped. Regional nameplate capacity for soda ash production is 3.4 million tonnes, of which 70% is in Russia and about 15% in Ukraine.

Among the other causes for this low ratio of caustic soda to soda ash are the poor transport systems, the huge distances between manufacturers and their customers, and the severe climatic conditions. This led the authorities to establish a pricing policy which favored soda ash use. Some typical prices are shown in

Table 9; the difference between "high" and "low" is due to specification differences—it does not reflect market fluctuations.

Table 9. Official sodium alkali prices in the Union of Soviet Socialist Republics, mid-1980s (in roubles per dry tonne).

		As Is	Sodium Oxide
Caustic soda	High	189	146
	Low	126	98
Soda ash	High	85	50
	Low	60	35

A result of this pricing strategy limited the use of caustic soda in the chemical industry to those applications in which soda ash could not be used. This means that most users of sodium alkali are set up to use soda ash and, as they already have ash at their works, it is the alkali of choice in routine neutralizations.

Consumption of soda ash within the metals sector is found principally in the production of alumina; it arises also in nickel/cobalt processing and in the iron and steel industries. The region's bauxites are generally fairly high in silica and therefore not suitable for working up by the conventional Bayer process. Accordingly, the Soviet Union turned to sinter processes that are refinements of the high temperature sinter technology which was employed on Arkansas bauxites in two U.S. plants during World War II. In essence, they depend upon a high temperature calcining of the ore with limestone and soda ash to yield insoluble calcium silicates and soluble sodium aluminate. The latter is separated and worked up to yield alumina.

Three variants of the sinter route are used—sinter and two variants of the so-called Combination Bayer-Sinter process, parallel and series. The parallel combined sinter process is intended for use where both low- and high-silica bauxites are available. The series combined sinter process is for application in the case that only high-silica bauxites are available. According to the exact nature of the ore and processing conditions, caustic soda was required as well as soda ash. **Table 10** compares the performance parameters of these processes.

Comparison of these parameters with those of the conventional Bayer process (**Table 4**) confirms the substantial energy advantage of the classic Bayer process. These sinter processes are not demanding in terms of the quality of the soda ash that they can use.

They are indeed quite able to use the qualities made in the nepheline co-product process.

Table 10. Technical performance of three sinter processes used in the FSU (units per tonne of alumina). Abbreviations are kg=kilograms, GCal=gigaCalories, kwh=kilowatt hours.

	Sinter	Bayer-Sinter Parallel	Series
Aluminous ore	3.25	2.80	2.90
Na ₂ O Consumption (kg)	124	62	75
Energy (GCal)	11.0	5.9	7.6
Electrical energy (kwh)	915	310	465

Outlook

The economic prospects for countries of the FSU are difficult to project in the short term. For the medium/long term there is confidence that the economic health of the region will improve. The rate of recovery will not be uniform and not all sectors of the economy will recover to the same degree.

Although the chloralkali industry is relatively underdeveloped, global challenges to the use of chlorine make it difficult to foresee a significant expansion of this sector. This will moderate the growth in the production of caustic soda while the huge distances from the frontiers to the users will discourage its import. Soda ash may therefore be expected to remain the (sodium) alkali of choice although it will probably lose some markets to calcium alkali (lime) as that sector expands.

Rising energy and raw material costs will drive the region's glass factories to improve operating efficiencies; this will lead to a greater use of dense ash and the requirement for soda ash qualities with reduced chloride levels. Post-consumer glass recycling is practically unknown in the region. It will develop but seems unlikely to impact soda ash demand to any large degree during the next decade. Thus soda ash demand will track glass output which is itself driven by the needs of the construction and automotive industries.

Changes in the alumina/aluminum industry will affect both the consumption and production of soda ash. Several alumina refineries are located at a considerable distance from ports. Domestic freight rates are broadly in line with those found elsewhere in the world, consequently the import of bauxite to supplant the domestic supplies appears unlikely. Direct supply of imported alumina to the smelters might make better economic sense and, if this were to happen across the aluminum industry, it would result in an important net loss of soda ash production.

The use of soda ash in the remaining applications such as glass manufacture is unremarkable. It is however noteworthy that many glass makers are accustomed to using light ash. The reason for this practice is probably the fact that dense ash was not available reliably during the time of the command economy. This practice is likely to die away in the future. There are already signs that the soda ash plants are preparing to reduce chloride levels and increase densification capacity in anticipation of the emerging market economy's needs.

Drawing these and other considerations together, the base-case forecast for regional demand for soda ash is for a total of 4.7 million tonnes, divided between the countries as shown in **Table 11**.

Table 11. Soda ash demand forecast for FSU countries in 2010 (in million tonnes).

Country	Volume
Kazakhstan	0.4
Russia	3.0
Ukraine	0.9
Others	0.4
Total	4.7

Nameplate capacity for soda ash is currently 5.5 million tonnes. Of this total some 0.8 million tonnes is provided by the nepheline-process plants. Closure of those alumina co-product plants would reduce available nameplate capacity to 4.7 million tonnes.

At first sight it would appear that the region should be able to satisfy its internal needs from domestic production. That result requires that a number of criteria be satisfied, including:

- 1) effective capacity equal to nameplate capacity;
- 2) a satisfactory domestic quality, consistency, and reliability of supply; and
- 3) delivered cost from domestic suppliers competitive with those of imports.

Today the first two criteria are not met. To meet them would require very substantial capital investment, sums that are probably not available from the cash flows of the producers themselves. To meet the third requirement would also demand investment in

delivery systems. On balance it may be easier to justify the latter logistic investment than it would the former. If this proves correct, the soda ash industry of

Russia and Ukraine will be smaller in 2010 than it appears today and overseas suppliers could be shipping more than half a million tonnes a year into that market.



The Asian soda ash market – A regional analysis

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Abstract

Attention has been concentrated on the Asian market for soda ash because of high growth rates in some countries and because of its attraction as an export destination for U.S. suppliers seeking alternative markets following European Union anti-dumping action. Export opportunities for producers of natural soda ash have been further improved by the high cost of local synthetic soda ash production in Asian countries.

Expansion in the production of float glass in the region has led to increased demand for low salt, dense soda ash—specifications easily met by the U.S. natural soda ash companies. Chinese suppliers have also responded to increased demand for this grade of soda ash by expanding and upgrading many of their plants.

The movement offshore of Japanese manufacturing facilities, particularly automotive assembly plants, has resulted in changes in the pattern of local float glass production with expansions in Indonesia and Thailand, for example, while output in Japan has declined. In Taiwan, another country with rising labor and land costs, manufacturers of both float and container glass are seeking to invest in plants in mainland China. Thus, the markets for soda ash move within the region and growth in one country may be partially offset by decline elsewhere. It is important, therefore, to consider the supply and demand pattern for the region as a whole.

In this overview, I calculate the regional demand for soda ash, show how this is met by regional production and intra-regional trade, and review the main markets for soda ash with particular reference to Indonesia.

Introduction

The area covered by this review consists of the countries of southeastern and eastern Asia (**Figure 1**). We have estimated that in 1995 regional demand for soda ash in southeastern and eastern Asia was nearly 9.2 Mt (million tonnes or million metric tons) (**Table 1**). This compares with apparent consumption in the U.S. of around 6.5 Mt in the same year. China is now both the second largest producer and second largest consumer of soda ash in the world, but consumption has also shown rapid growth in some other countries in the region.

Around 80% of the soda ash consumed in the region is also produced within the region. However, this is mainly due to China's virtual self-sufficiency in soda ash (except in terms of low salt, dense grades). Other countries in the region are much more import-

dependent and even those that were self-sufficient in the past, such as South Korea and Japan, are now significant importers.

Table 1. Roskill's estimates of soda ash consumption in Asia 1995 (in thousands of tonnes).

Nation	Consumption
China	5500
Japan	1300
South Korea	655
Indonesia	433
Taiwan	321
Thailand	284
Others	<u>677</u>
Total S.E. & E. Asia	9170



Figure 1. Location map of nations in southeastern and eastern Asia.

Supply of soda ash

There are four countries producing soda ash in the region (**Table 2**), of which China is by far the most important, and the only country where soda ash production is increasing significantly.

Table 2. Production of soda ash in Asia (in thousands of tonnes). Numbers in parentheses are estimates.

	1990	1995
China	3750	5799
Japan	1130	1070
South Korea	(280)	(300)
Taiwan	(120)	(100)

Japanese production will have fallen to around 870,000 tonnes in 1996 and there are many rumors about the viability of the Oriental Chemical plant in South Korea and that of South East Soda in Taiwan. Producers of soda ash by the synthetic route in these countries are dependent on imported salt—unlike most European synthetic soda ash producers who frequently are also major producers of salt.

In southeastern Asia, where there has been strong growth in demand for soda ash in the 1990s, there are currently no local production facilities.

China

There has been a doubling of soda ash production in China over the last ten years. Reported output in 1995 was 5.9 Mt but early reports suggest that output may have fallen slightly to 5.7 MT in 1996. In February 1997, the China Chemical Reporter predicted production of 5.9 MT in 1997 with exports rising to 600,000 tonnes. Around 2 Mt of capacity were added during the Seventh five-year plan; during the Ninth five-year plan investment will be concentrated on changing the product mix to produce more low-salt, dense ash. A total of 2 Mt of new and upgraded capacity is expected to come on stream by 2000.

There are over 60 enterprises producing soda ash in China; some of them are very small but others have capacities exceeding 600,000 tonnes with some scheduled to reach 900,000 tonnes within the next two years. The leading producers are listed in **Table 3** together with details of those reported capacity expansions.

In addition to the expansions listed in **Table 3**, there are a number of new projects scheduled to

Table 3. Capacity and planned expansions of leading Chinese soda ash producers, in tonnes per year (tpy). Source: China Chemical Reporter and other press reports.

Producer	Capacity	Projected expansions
Weifang Marine Chemical Industrial	800,000	
Tianjin Alkali plant	600,000	150% increase in capacity by 1999
Tangshan Soda Ash	625,000 ¹	
Dalian Soda Ash	750,000	Capacity expansions planned
Yuanddu Chemical Industry Group	651,200 ¹	
Qingdao Soda Ash Company	432,800 ¹	
Lianyngang Soda Ash, Nanjing	414,500 ¹	
Delingha Soda Plant (Quinhai province)	400,000	Plans to double announced
capacity		
Zigong Honghe General Chemical	255,100 ¹	
Hubei Shuanghuan Chemical	244,600 ¹	
Jintan Salt, Jiangsu		New 180,000 tpy plant planned

¹Output in 1994

come on stream in the near future. These include a 200,000-tpy (tonnes per year) plant at Nanfang in Guangdong province; 200,000-tpy at Jartai in Inner Mongolia; and a 600,000-tpy unit planned for Hebei province.

In the autumn of 1996 it was announced that China will bar foreign companies from holding controlling stakes in joint ventures with large state enterprises producing strategic materials such as soda ash.

There has been some interest over the years in the natural soda ash deposits in Henan and Inner Mongolia. The Wucheng trona deposit in Henan has 40 Mt of proven reserves but total reserves are likely to be much larger. Current production is restricted to a 30,000-tpy plant operated by Henan Nanyang Wucheng Salt and Soda Mine.

Reserves in Inner Mongolia have been estimated to be in the region of 100 Mt. While the Inner Mongolia Chagannuoer Trona Chemical works has a reported capacity to produce 0.5 Mtpy (million metric tons or million tonnes per year) of trona, it is unlikely that it operates at anything like this rate. The distance

of these deposits from the main markets in China are a disincentive to the further exploitation of these deposits.

Japan

Following the closure of Tosoh's operations in early 1995, there are now three producers of soda ash in Japan (Table 4). Production in 1995 was 1.07 Mt but is likely to fall below 900,000 tonnes in 1996 as Tosoh Corporation was producing over 200,000 tpy. Asahi Glass plans to close their Chiba plant in 1997 although the capacity loss will be partially offset by debottlenecking at the Kitakyushu plant.

Asahi and Tosoh have invested in U.S. natural ash producers as has one of the major consumers of glass, Nippon Sheet Glass, in cooperation with their parent, Sumitomo.

South Korea

Oriental Chemical Industries operates a 1200-tpd (tonnes per day) capacity plant at Inchon. Current

Table 4. Production of soda ash (in tonnes) in Japan, 1994 to 1995 (a "year" runs from April 1994 to March 1995). Source: Asahi Glass.

Company	Plant	Production	Shipments for captive use	Shipments as sales	Total	Stock
Asahi Glass	Chiba	125,487	101,647	116,276	217,924	8259
	Kitakyushu	318,659	73,625	235,574	309,199	29,125
	Total	444,146	175,273	351,850	527,123	37,384
Tokuyama Soda	Tokuyama	195,934	19,119	176,635	195,754	11,366
Central Glass	Ube	212,587	95,571	124,362	219,933	11,756
Tosoh Corp.	Nanyo	218,167	8933	203,284	212,217	13,884
Total		1,070,834	298,896	856,131	1,155,027	74,390

operating rates are probably less than 75%. The soda ash is of a quality suitable for the burgeoning Korean float glass industry, but is also sold to container glass companies and chemical companies. In 1995, soda ash and hydrogen peroxide accounted for 43% of unconsolidated revenues.

In response to liberalization of soda ash imports and growing competition from U.S. natural soda ash, the Korean producers first invested in North American Chemical Corporation (NACC) in California, and then (having substantially reduced their stake in NACC) the company purchased 51% of Big Island (formerly Stauffer) trona operations in Wyoming.

It is worth noting that the LG Group in Korea has started discussions with NACC. LG has in the past (and may still) acted as agents for Bulgaria soda ash.

Import restrictions for Chinese soda ash are scheduled to be lifted in 1997.

Taiwan

South East Soda Manufacturing produces about 100,000 tpy of soda ash from a 140,000-tpy plant at

Tong Shan Soda. They are dependent on both imported salt and coal. Their soda ash is used in the manufacture of container glass and chemicals.

Potential plant

For many years there have been plans mooted for the construction of a 150,000-tpy plant in Kalimantan (Borneo, Indonesia). It is now reported that P.T. Kaltim Sahid Baritosodakimia has started to construct a soda ash/ammonium chloride plant at Bontung, East Kalimantan. Technology for the plant has been supplied by the China National Technical Import and Export Corporation and Chengdu Chemical Engineering Corporation. The construction is scheduled for completion by August 1997. It is worth noting, however, that banks were still seeking finance for this project earlier in 1996.

Questions have been raised about the likely quality of the soda ash from this plant; it seems likely that the main markets will be chemicals and pulp and paper. Output from the plant is likely to replace current imports from China rather than imports from the U.S.

Trade

Around 20% of the soda ash consumed in the region is supplied by producers in other regions. The main source by far is natural soda ash from the U.S. (Table 5).

Kenyan exports to the region appear to have declined in 1995 and 1996 whereas Bulgarian exports

Table 5. Estimated imports of soda ash from outside the region, 1995 (in thousands of tonnes).

U.S.	1572
Kenya	120
Bulgaria	66
Australia	23
Russia	12
Poland	10
Romania	4
Total	1807

are increasing. The natural soda ash from Magadi is used mainly in the manufacture of container glass by companies in the ACI Group.

There is also some inter-regional trade with China exporting 450,000 tonnes in 1995 and exports from Japan, South Korea, and Taiwan totalling 6000 tonnes.

Figure 2 shows the main destination of U.S. exports of soda ash to Asia and the change since 1992. Figure 3 shows the importance of the Asian market to U.S. exporters, accounting for 40 to 50% of exports between 1992 and 1996. The impact of the EU (European Union) anti-dumping measure on U.S. exports from 1993 onwards has underlined the importance of the Asian market.

Markets

Soda ash consumption has been characterized by strong growth in most Asian countries in the 1990s. The one exception is Japan where consumption has declined, partly as a result of a slowdown in the economy, but mainly because of a shift to offshore manufacture of both glass and the motor vehicles in

which it is used. Growth is slowing in Taiwan, where limited land availability and rising labor costs are encouraging companies such as Taiwan Glass and some of the container glass manufacturers to invest in manufacturing capacity in mainland China.

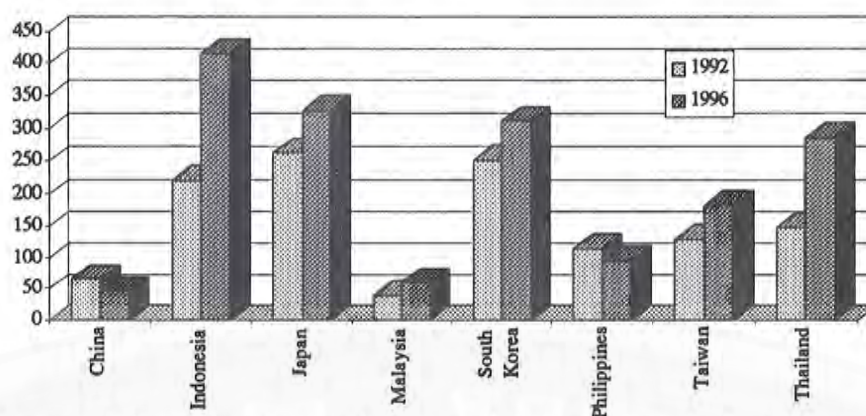


Figure 2. U.S. exports of soda ash to selected Asian countries, 1992 and 1996, in thousands of tonnes.

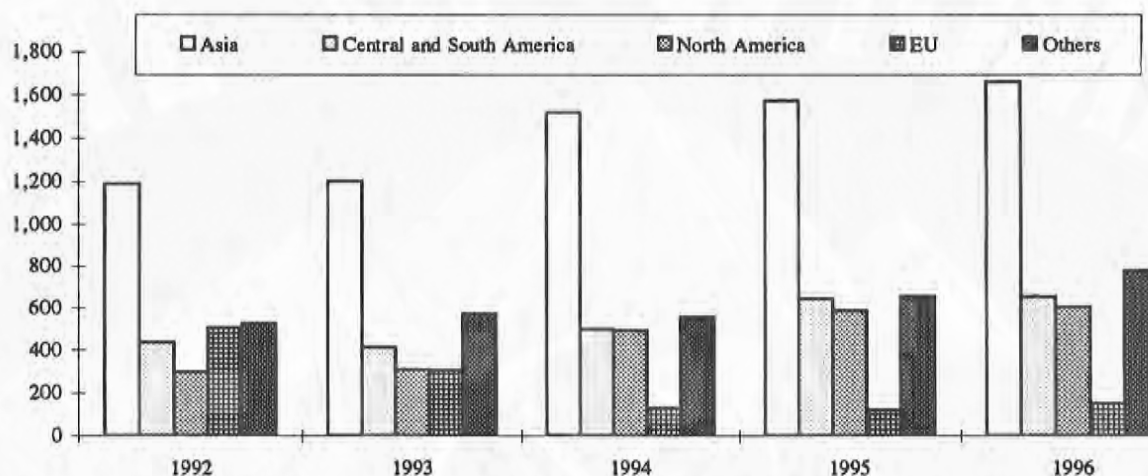


Figure 3. Exports of U.S. soda ash by world region, in thousands of tonnes.

China

Consumption of soda ash in China has risen from just over 3 Mt in 1985 to 5.5 Mt in 1995, a growth rate of over 6% per year. Over the same period, output of flat glass has grown by nearly 10% per year, and that of container and table glass by nearly 7% per year. There is also an increasing demand for soda ash from the dyestuffs and textiles industries as well as in detergents for automatic washing machines. Consumption in 1996 is shown on Table 6.

Table 6. Consumption of soda ash in China by end-use, 1996 (in millions of tonnes). Compiled from press reports.

End use	Consumption
Flat glass	1.5
Light industry (mainly other forms of glass)	1.5
Chemical industry	1.2
Metallurgical/non-ferrous	0.8
Pharmaceutical and other	0.6
Total	5.6

Chinese sources have predicted that demand in 1997 will be around 5.6 Mt and that just over a quarter of this total will be used in the manufacture of flat glass.

Indonesia

Of those countries that are import dependent, Indonesia has shown one of the most rapid rates of growth in demand for soda ash. Soda ash consumption in Indonesia is shown in Table 7. The local building boom, together with a growing number of motor vehicle assembly plants, has led to a rapid increase in demand for flat glass. The availability of good quality silica sand and relatively low labor costs have also stimulated growth in the glass industry. Dolomite is also available in Java.

A recent report on the soda ash sector by Bank Bira suggests that the fast growing markets are now pulp and paper and ceramics. They have also projected that total Indonesian demand for soda ash will be nearly 600,000 tonnes in 1997 and exceed

700,000 tonnes by 1999. Roskill considers these projections may be over-optimistic.

Table 7. Estimated pattern of soda ash consumption in Indonesia (in percent).

End use	Percent
Glass (all types)	55
Pulp and paper	25
Detergents	10
Others (including ceramics and textiles)	10

Currently Indonesia imports all the soda ash that it uses; the main sources of supply are the U.S., China, and Japan (Figure 4). Indonesia is one of the few countries in the region where a significant proportion of supply is derived from China. Thailand also derives a significant supply of soda ash from China.

Growth in the Indonesian glass industry

Output of sheet glass in Indonesia increased from 361,000 tonnes in 1990 to 646,000 tonnes in 1994 and is continuing to grow. There are two main producers of flat glass by the float method: P.T. Asahimas and Mulia Glass.

P.T. Asahimas is a subsidiary of Asahi Glass in a joint venture with Rodamas. The company operates plants in Jakarta and Surabaya. By the end of 1997 planned capacity is 570,000 tpy. Mulia Glass produces float, container, and tableware glass. Capacity at the end of 1997 was scheduled to be 330,000 tpy.

A third company, Tensindo, has a smaller float glass plant in Central Java. Its subsidiary company, PT Tossa Shakti, is planning to build a 130,000 tpy float glass plant in Central Java for completion by the beginning of 1998.

In Japan, South Korea, and Taiwan, container glass faces strong competition from cans and waxed paper cartons and this is becoming increasingly true in other Asian countries. The growth in output of container glass in Indonesia may be constrained by increasing competition from aluminium cans. The four main producers of container glass are P.T. Iglas, KCI Glass Packaging, Mulia Glass, and Kedaung.

The Indonesian tableware industry is very well established and very export-oriented. PT Kedaung is one of the largest glass tableware manufacturers in the world and operates four plants in Indonesia, one in China and one in Malaysia. (Since one of the main markets for the tableware produced by Kedaung is the U.S., this raises the intriguing prospect that glasses used here today could contain soda ash from Green River that has been shipped to Surabaya or Jakarta and then been shipped back in the form of a tumbler or wine glass.) First National Glass (part of the Mulia Group) is also a major exporter of glass tableware from Indonesia.

Future demand growth in Indonesia for low salt, dense soda ash of the type imported from the U.S. is likely to be contingent on further growth in the float glass sector which, in turn, will depend on growing export markets. Indonesian flat glass competes in the Asian market with glass from China (which is generally perceived as rather poorer quality) and with flat glass from Thailand. Since it is likely the Thai glass companies will be using U.S. soda ash as will some of the Chinese manufacturers, it is clear that the demand for soda ash for use in glass will only continue to grow if the total size of the flat glass market increases.

Pulp and paper

In 1995, the Indonesian pulp and paper industry comprised 70 companies with a capacity to produce 2.6 Mtpy of pulp. There are 23 potential new pulp

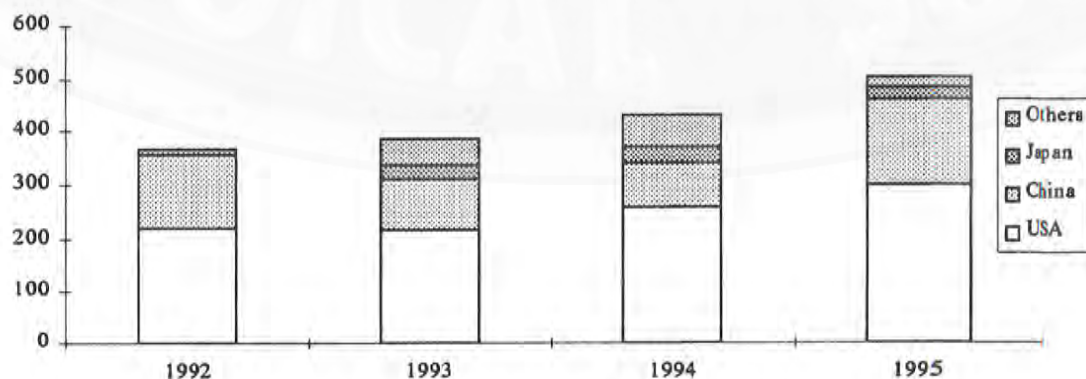


Figure 4. Imports of soda ash to Indonesia, 1992 to 1995, in thousands of tonnes.

and paper projects and pulp output is likely to grow by 16% per year between 1996 and 2000 (Figure 5).

As with glass current growth in pulp and paper production is partially dependent on maintaining

growth in exports. Both of the main producers Asian Pulp and Paper and Asia Pacific Resources International, have embarked on major capacity expansions and output will be targeted at markets such as Australia.

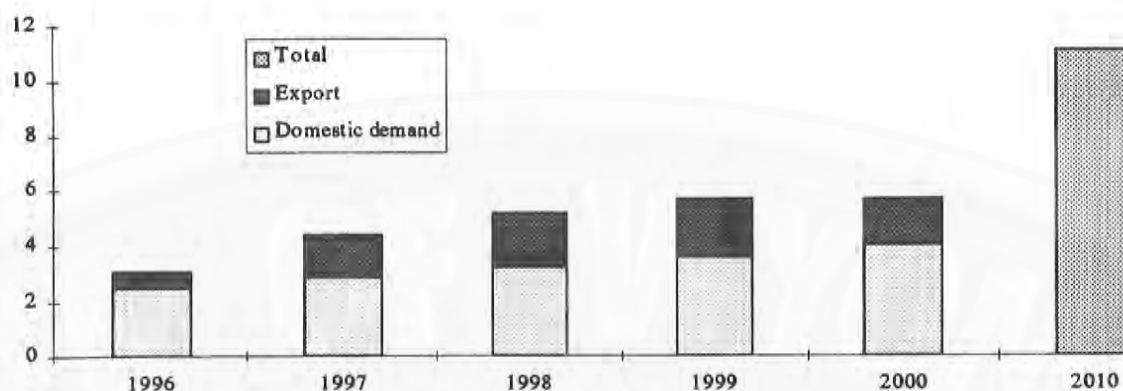


Figure 5. Projected output of Indonesian pulp for domestic use and for export, 1996 to 2010, in millions of tonnes.

Outlook

Most economic commentators agree that growth rates in the tiger economies of southeastern Asia will slow in the next few years. This will affect glass consumption which is closely tied to the level of construction activity and motor vehicle manufacture. In southeastern Asia, container glass will face increased competition from alternative packaging materials. Additionally, there will be moves to increase the amount of cullet used in the batch. Container glass manufacturers in Japan, Taiwan, and South Korea have already felt the effect of these trends.

The Chinese market for soda ash is likely to continue to grow fairly strongly, but is likely to be increasingly self-sufficient as more capacity for low salt, dense soda ash comes on stream.

Local production in the other countries of eastern Asia is likely to continue to decline. Manufacturers of soda ash, traders, and consumers in these countries are seeking to secure supplies of U.S. soda ash by investing in producers in both the Green River Basin and in California.



Appendix A – List of participants

FIRST INTERNATIONAL SODA ASH CONFERENCE June 10-12, 1997

A

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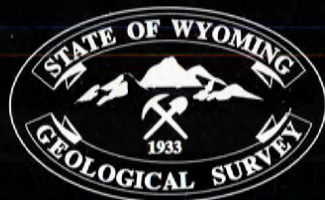
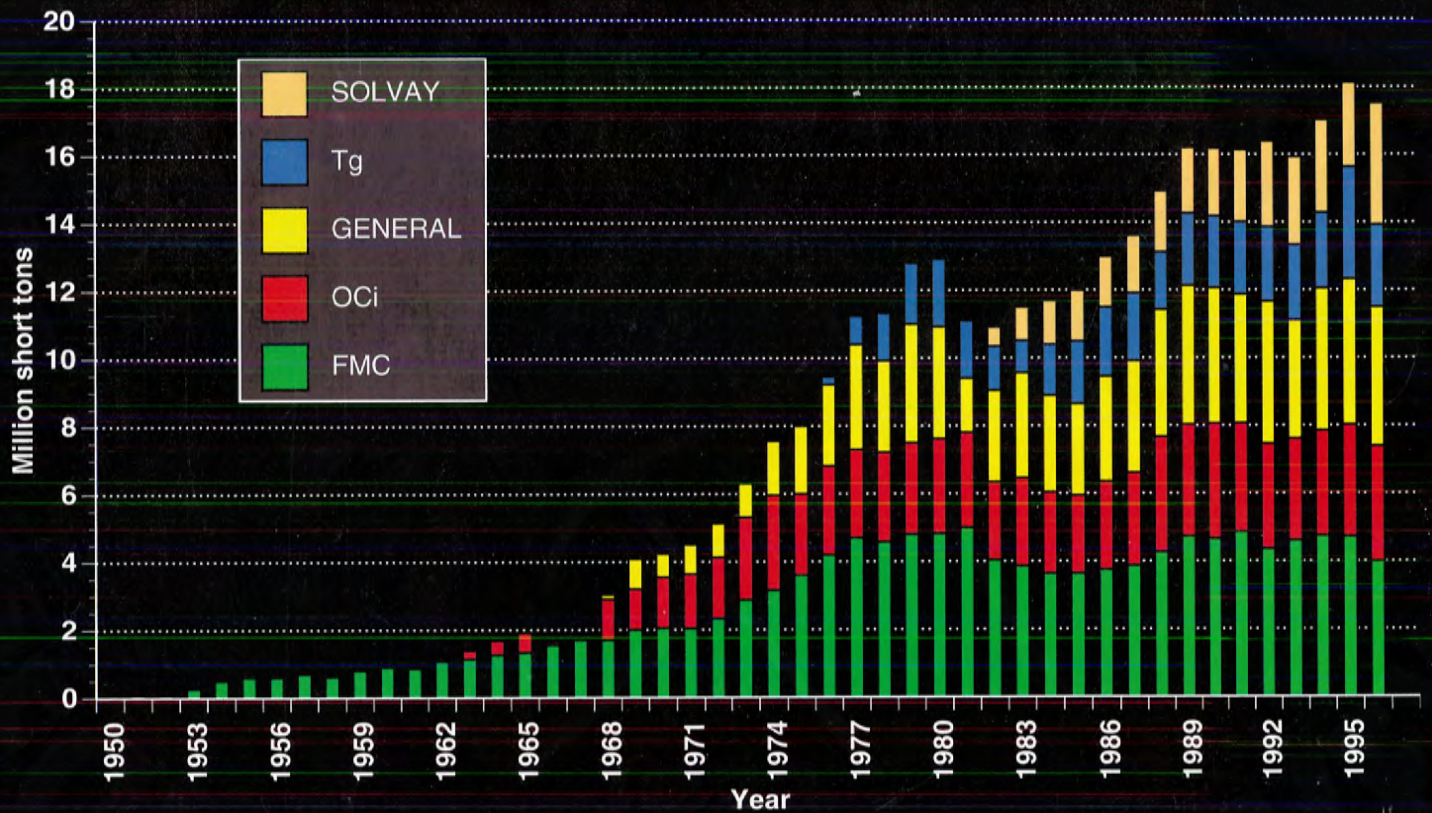


Selected conversion factors*

TO CONVERT	MULTIPLY BY	TO OBTAIN	TO CONVERT	MULTIPLY BY	TO OBTAIN
Length			Pressure stress		
inches, in	2540	centimeters, cm	lb in ⁻² (=lb/in ²), psi	7.03×10^{-2}	kg cm ⁻² (=kg/cm ²)
feet, ft	3.048×10^{-1}	meters, m	lb in ⁻²	6.804×10^{-2}	atmospheres, atm
yards, yds	9.144×10^{-1}	m	lb in ⁻²	6.895×10^{-1}	newtons (N)/m ² , N m ⁻²
statute miles, mi	1.609	kilometers, km	atm	1.0333	kg cm ⁻²
fathoms	1.829	m	atm	7.6×10^{-2}	mm of Hg (at 0°C)
angstroms, Å	1.0×10^{-8}	cm	inches of Hg (at 0°C)	3.453×10^{-2}	kg cm ⁻²
Å	1.0×10^{-4}	micrometers, µm	bars, b	1.020	kg cm ⁻²
Area			b	1.0×10^6	dynes cm ⁻²
in ²	6.452	cm ²	b	9.869×10^{-1}	atm
ft ²	9.29×10^{-2}	m ²	b	1.0×10^{-1}	megapascals, MPa
yds ²	8.361×10^{-1}	m ²	Density		
mi ²	2.590	km ²	lb in ⁻³ (=lb/in ³)	2.768×10^{-1}	gr cm ⁻³ (=gr/cm ³)
acres	4.047×10^3	m ²	Viscosity		
acres	4.047×10^{-1}	hectares, ha	poises	1.0	gr cm ⁻¹ sec ⁻¹ or dynes cm ⁻²
Volume (wet and dry)			Discharge		
in ³	1.639×10^{-1}	cm ³	U.S. gal min ⁻¹ , gpm	6.308×10^{-2}	l sec ⁻¹
ft ³	2.832×10^{-2}	m ³	gpm	6.308×10^{-5}	m ³ sec ⁻¹
yds ³	7.646×10^{-1}	m ³	ft ³ sec ⁻¹	2.832×10^{-2}	m ³ sec ⁻¹
fluid ounces	2.957×10^{-2}	liters, l or L	Hydraulic conductivity		
quarts	9.463×10^{-1}	l	U.S. gal day ⁻¹ ft ⁻²	4.720×10^{-7}	m sec ⁻¹
U.S. gallons, gal	3.785	l	Permeability		
U.S. gal	3.785×10^{-1}	m ³	darcies	9.870×10^{-13}	m ²
acre-ft	1.234×10^3	m ³	Transmissivity		
barrels (oil), bbl	1.589×10^{-1}	m ³	U.S. gal day ⁻¹ ft ¹	1.438×10^{-2}	m ² sec ⁻¹
Weight, mass			U.S. gal min ⁻¹ ft ¹	2.072×10^{-1}	l sec ⁻¹ m ¹
ounces avoirdupois, avdp	2.8349×10^{-1}	grams, gr	Magnetic field intensity		
troy ounces, oz	3.1103×10^{-1}	gr	gausses	1.0×10^{-5}	gammas
pounds, lb	4.536×10^{-1}	kilograms, kg	Energy, heat		
long tons	1.016	metric tons, mt	British thermal units,	2.52×10^{-1}	calories, cal
short tons	9.078×10^{-1}	mt	BTU	1.0758×10^{-2}	kilogram-meters, kgm
oz mt ⁻¹	3.43×10^{-1}	parts per million, ppm	BTU lb ⁻¹	5.56×10^{-1}	cal kg ⁻¹
Velocity			Temperature		
ft sec ⁻¹ (=ft/sec)	3.048×10^{-1}	m sec ⁻¹ (=m/sec)	°C + 273	1.0	°K (Kelvin)
mi hr ⁻¹	1.6093	km hr ⁻¹	°C + 17.78	1.8	°F (Fahrenheit)
mi hr ⁻¹	4.470×10^{-1}	m sec ⁻¹	°F - 32	5/9	°C (Celsius)

*Divide by the factor number to reverse conversions.

Exponents: for example 4.047×10^3 (see acres) = 4,047; 9.29×10^{-2} (see ft²) = 0.0929.



Geology -- Interpreting the past to provide for the future

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