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Chemical Investments in Iceland

Extracts from a report on Iceland
as a location for chlorine and derivatives industry

Prochemics Ltd.

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Executive Summary

- Iceland provides a very competitive supply of energy in the form of electricity and steam. This competitive advantage should be attractive to a number of industries which have a high consumption of energy, particularly electricity.
- An industry which has a high electricity consumption is the electrolysis of salt to produce chlorine and caustic soda (the chlor-alkali industry). In this case the electricity costs account for 40-50% of the production cost of chlorine and caustic.
- The overall objective of this project is to identify companies producing chlorine derivatives, which could be interested in investing in production facilities in Iceland.
- Since the chlorine and derivatives industry includes many thousands of individual products, the first objective of the project has been to identify the products (or family of products) which meet a set of criteria based on the conditions in Iceland, the attractiveness of producing these products in Iceland, including an estimate of the potential cost advantages which may be realized, and the competitive situation and industry structure which may influence the decision to invest.

Executive Summary

- On this basis, the following chlorine downstream products appear to follow the criteria necessary to attract companies to Iceland.
    - Water treatment
    - Silicon/silicon tetrachloride
    - Chlorinating Agents
    - Aluminum chlorides
- This report has identified a number of industry players which can be approached to determine if they have an interest in investing in Iceland, based on its obvious advantage in energy costs compared to Europe and North America.
- In the following stage of this study, these companies will be approached to gauge their interest and if positive to arrange meetings between them and Invest in Iceland/Prochemics.

Introduction

- Iceland provides a very competitive supply of energy in the form of electricity and steam. This competitive advantage should be attractive to a number of industries which have a high consumption of energy, particularly electricity. An example is provided by the establishment of a large aluminum industry in the country.
- Another industry which has a high electricity consumption is the electrolysis of salt to produce chlorine and caustic soda (the chlor-alkali industry). In this case the electricity costs account for 40-50% of the production cost of chlorine and caustic.
- Since in Iceland the costs of electricity for an industrial user (20-25 €/MW) is approximately half of the price prevailing in the rest of Europe, chlorine can be made available at approximately 30-40% lower cost than in the rest of Europe.
- Therefore, in principle, the production in Iceland of downstream products having a high content of chlorine could be quite attractive, if other costs such as logistics, other raw materials, etc, do not offset the lower cost of chlorine.

Selection Criteria

- The basic premises for this project are as follows:
  - The Invest in Iceland Agency would be in charge of providing the infrastructure of a chemical industry park. One of the elements of the infrastructure will be the supply of chlorine, which as suggested would be supplied by a mini chlor-alkali plant licensed by one of the major players in the chlor-alkali industry.
  - It is assumed at this point that the by-product sodium hydroxide will be sold at world market prices in Iceland.
- In order to maximize the potential to attract investors for production facilities in Iceland, it is necessary to identify products which can best benefit from the competitive advantage of Iceland, namely, the low electricity and energy prices, and, as far as possible, the use of other locally available raw materials.
- Since there is no local market for most products, the costs of transporting raw materials and the end products must also be considered. This implies that the target products should have an adequate value added in Iceland.

Selection Criteria

- Accordingly, the basic selection criteria have been set as follows;

  - The cost component of imported hydrocarbons and other raw materials would be a minimum, as Iceland has no competitive advantage in these materials.
  - Other raw materials should preferentially be materials already largely available in Iceland, such as aluminum and derivatives, ferrosilicon, and sulfur, as well as the purified salt required for the electrolysis.
  - The chosen products should have a reasonable value-added, and their competitiveness in the world markets should not be affected by transport costs.
  - In addition, the volumes produced should require at least one third of the production of chlorine in the mini plant, i.e. ca. 5'000 tons per year.

Selection Criteria

- In the selection of products which may be suitable for production in Iceland, it is also necessary to take into consideration the structure of the industry behind these products. For example the trends and supply and demand, and the key markets. These structural issues will have a substantial impact in the willingness of companies to invest in new plants.
- In selecting the products, the potential advantage of producing in Iceland will also be considered. The higher the content of chlorine in the final product, the greater the advantage of producing in Iceland.
- Since electricity accounts for ca 40-50% of the cost of producing chlorine, products where the chlorine costs account for less than 20% of their production cost, may not justify building a new plant in Iceland as the advantage of low cost electricity on the final cost will be less than 10-15%.
- This cost advantage may not compensate for the costs of logistics, the new investment, and the establishment and operation of a small site, and it is unlikely to be of interest to an investor.

The Chlorine Chain

- Chlorine is a basic chemical building block and its derivatives have a wide range of applications as can be seen in Exhibit 4.1.
- Given the sensitivity of the potentially attractive products to their chlorine content, the main opportunities will be in the first derivatives of chlorine, both organic and inorganic.
- As one moves to the products further downstream in the chlorine chain, the chlorine content will be diluted and the cost advantage becomes less relevant.
- For these downstream derivatives, the advantage obtained from cheaper chlorine will not justify the investment of new production sites at a location where there is a limited local market, and where the product must be shipped.

Specific Product Opportunities

- The following chlorine downstream products appear to follow the criteria necessary to attract companies to Iceland.

  - Water treatment,
  - Silicon/silicon tetrachloride,
  - Chlorinating Agents
  - Aluminum chlorides

Specific Product Opportunities

- The extent to which the criteria are met are shown qualitatively in the following:

Opportunity	Icelandic raw materials	Value added	Cl2 Content	Expected Volumes
Water Treatment	+	+	+++	++
Silicon/Silicon Tetrachloride	+++	++	+	++
Chlorinating Agents	+	+	+	+
Aluminum Chlorides	+++	++	++	++

Specific Product Opportunities

Water Treatment

- Elemental chlorine is added to water at the waterworks to make it safe for household use. The world market is in the order of 200-250 kton.
- Use of chlorine in water treatment is decreasing in Northern Europe but may still be used extensively in other regions, e.g. around the Mediterranean and is growing in regions outside Europe and North America.
- As a result of this drop in consumption in Europe, some existing suppliers may be exiting this business allowing a competitive new supplier to take market share.
- Generally chlorine cannot be transported in bulk, but it may well be able to be transported in cylinders.

Specific Product Opportunities

Water Treatment (continued)

- Under these conditions, a very low cost chlorine may provide a base to provide cylinders to the markets. In this case, the cost of a filling plant and the cost of transport of cylinders back and forth from the market, must be attractively less than the price differential between chlorine produced in Europe and in Iceland, which should be about 30-40% in Iceland's favor. The relative cost advantage of an Iceland-based chlorine filling operation compared with other European locations is influenced by several industry specific factors such as the logistics / cost of transporting the filled cylinders to the destination where the chlorine is used, and transporting back the empty cylinders to the filling plant, and should therefore be best evaluated in the discussion with industry.
- An additional advantage of chlorine for water treatment would be that the initial investment should be low and therefore may be easier to attract fairly quickly an investor which would provide a baseload for the plant.

Specific Product Opportunities

Silicon/Silicon Tetrachloride

- The basic concept of this opportunity would be to produce methyl chlorosilanes which are the building blocks for the extensive silicon chemistry. These products find applications is special products such as high performance fluids, elastomers, etc.
- The underlying manufacturing process is as follows:
    - Quartz (SiO_2) is mixed with coke and reduced to silicon metal by heating in an electric arc furnace.
    - The silicon is then reacted with methyl chloride to form a mixture of methyl chlorosilanes, principally dimethyldichlorosilane (approximately 90% yield), methyltrichlorosilane, trimethylchlorosilane and methyldichlorosilane.
    - These products are then separated by distillation.
- The production of silanes can be attractive due to the relatively high content of chlorine in the mixed silanes (about 55% by weight in dimethyldichlorosilane).

Specific Product Opportunities

Silicon/Silicon Tetrachloride (continued)

- However, the value of chlorine in the cost structure of producing the methyl chlorosilanes will be substantially diluted.
- In addition, the reduction of quartz to elemental silicon is also an electro-intensive process which would benefit from low cost electricity in Iceland (*), and if this cost benefit is transferred to a potential investor in downstream products.
- The final step in the production of the silane building blocks is a separation of the different methyl chlorosilanes by distillation, which also requires thermal energy, where Iceland also has a cost advantage.
- The interaction of all above factors to determine the actual cost advantage of Iceland can only be determined by the interested investor. However, taking all these together, an investment in Iceland may well be feasible.

(*) Remark: There is already a plant for Ferroalloys / Ferro silicium operating in Iceland (Icelandic Alloys Elkem A.S. with a capacity of 60'000 tons per year, as well as two silicium smelter productions under development (one of these is Timminco Ltd., which plans a new silicon metal plant in Iceland with a capacity of 50,000 tons per year).

Specific Product Opportunities

Silicon/Silicon tetrachloride (continued)

- In principle, the individual methychlorosilanes could be exported for further processing in other plants, as there may not be further advantage in large investments in Iceland for downstream products.
- The viability of the preceding concept must be discussed with potential investors.
- Methyl chlorides are mostly produced from methanol, which would have to be made available in Iceland. However, an older process is the high temperature chlorination of methane which would again play to the advantage of the low cost energy in Iceland. The interest in reviving this technology could be evaluated if the methyl chlorosilanes project appears viable.

Specific Product Opportunities

Chlorinating Agents

- Final products containing chlorine or requiring chlorine at certain intermediate steps in the production chain, number in the thousands and find applications in most industries, particularly pharmaceutical, polymers, etc.
- However, the chlorination step in the production of the chlorine containing intermediates can often not be accomplished by using chlorine directly due to the aggressiveness of the molecule.
- As a result, certain chlorine containing agents are used commercially for the chlorination of organic compounds. Industry refers to these products as chlorinating agents.
- The most used chlorinating agents are shown in Exhibit 5.1

Specific Product Opportunities

Chlorinating Agents (continued)

EXHIBIT 5.1

	$SOCl_2$	SO_2Cl_2	PCl_3	$POCl_3$	$COCl_2$
Chlorination Power	mild (selective)	mild (selective)	strong	mild	mild (selective)
Chlorine Efficiency	only one Cl used	one or two Cl used	up to three Cl used		one or two Cl used
Separation Product/Educt	easy (SO_2 +HCl)	easy (SO_2 +HCl)	more difficult (H_3PO_3)		very easy (CO_2 +HCl)
Chemistry	aliphatic OH, CO_2H, SO_2H	acidic C-H, OH, CO_2H	PCl_3 also used for aromatic OH $POCl_3$ less reactive		aliphatic and aromatic OH, chloroformate
Boiling Point	76 ºC (liquid)	69 ºC (liquid)	76 ºC (liquid)	104 ºC (liquid)	8 ºC (gas)
Handling and Safety	easy to handle SO_2-scrubber	more corrosive SO_2-scrubber	more corrosive, by-product recycled		difficult to handle very toxic
Overall economics	Moderate product cost	Moderate product cost	high product cost due to increasing phosphorous price		Lowest product cost, but high investment

Specific Product Opportunities

Chlorinating Agents (continued)

- Among the chlorinating agents, the main interest is in the sulfur-derived agents thionyl chloride and sulfuryl chloride. The latter on is a minor product and therefore not of interest.
- Production of phosphorus trichloride and oxychloride require elemental phosphorus which is supplied in Europe by one dominant supplier.
- Phosgene has been ruled out because the phosgene plant has to be located at the site of the industrial user for safety reasons.
- In principle, these products could be attractive, however the few producers are backward integrated and it is unlikely that they will become interested in the concept.
- Although products based on competitive chlorine may have an advantage of up to 15% over European continental products, their impact on the final product will be very small. Furthermore, these are relatively low cost products.

Specific Product Opportunities

Aluminum Chlorides

- Anhydrous aluminum chloride ($AlCl_3$) is produced primarily by the gaseous chlorination of molten aluminum. The resulting $AlCl_3$ vapor is collected and condensed. Aluminum chloride is sold in technical and reagent grades.
- Commercial hydrous aluminum chloride is produced by dissolving either aluminum hydroxide or metallic aluminum in hydrochloric acid.
- Aluminum chlorides are consumed in three major market segments:
    - The anhydrous material is used largely as a raw material for aluminum alkyl catalysts and co-catalysts. Spent aluminum chloride from some catalyst applications is reused in water treatment.
    - Aqueous and polymerized aluminum chlorides are used in water treatment. Both virgin production and product recycled from the catalyst sector are used.
    - Hydrous aluminum chloride is used in antiperspirants and pharmaceuticals

Specific Product Opportunities

Aluminum Chlorides (continued)

- The global market for aluminum chloride is in the order of 45 kton.
- In principle, aluminum chlorides would be an ideal product for Iceland due to the availability of both aluminum and chlorine produced with low cost energy.
- It is expected that the cost advantage for aluminum produced in Iceland may be the determining factor in the attractiveness of this opportunity and therefore should be evaluated together with aluminum suppliers and the possibility of purchasing the aluminum at preferential prices and not at world market prices.
- The disadvantage would be the relatively low value of these products, which may not make it worthwhile for an investor.
- In the end markets, access to lower cost aluminum chlorides could be significant in PAC, marginal in consumer applications, and of limited relevance in catalyst applications.

Conclusions and Recommendations

- In Iceland the costs of electricity for an industrial user (20-25 €/MW) is approximately half of the price prevailing in the rest of Europe. Since electricity accounts for approximately half of the costs of producing chlorine, this material can be made available at approximately 30-40% lower cost than in the rest of Europe.
- However, this advantage in the cost of chlorine is offset by the investment costs of new dowstream chlorine consumers, and the costs of transporting the products, and if needed raw materials, from Iceland to the markets.
- Therefore, potential production opportunities for industries consuming cost-competitive chlorine in Iceland, must use other local raw materials, and be energy intensive, as well as having a reasonable value added to overcome logistics costs.
- Furthermore, the products must obviously have established markets which can absorb the product from Iceland.

Conclusions and Recommendations

- On this basis, the following chlorine downstream products appear to follow the criteria necessary to attract companies to Iceland.
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- This report has identified a number of industry players which can be approached to determine if they have an interest in investing in Iceland, based on its obvious advantage in energy costs compared to Europe and North America.
- In the following stage of this study, these companies will be approached to gauge their interest and if positive to arrange meetings between them and Invest in Iceland/Prochemics.
- The list of identified companies is provided in Exhibits 6.1a and 6.1b.