Study on Economic Partnership Projects in Developing Countries in FY2016

Study on the Feasibility of the Business Opportunity for Advanced Production Technology in Chlor-Alkali Industry in Islamic Republic of Iran

Final Report

February 2017

Prepared for:
Ministry of Economy, Trade and Industry

Prepared by:
Kanematsu Corporation
Asahi Glass Co., Ltd.
Japan Oil Engineering Co., Ltd.
Preface

The report summarizes outcomes of study on economic partnership projects in developing countries in FY2016 commissioned by the Ministry of Economy, Investment and Trade to Kanematsu Corporation, Asahi Glass Co., Ltd. and Japan Oil Engineering Co., Ltd.

The survey entitled “the Study on the Feasibility of the Business Opportunity for Advanced Production Technology in Chlor-Alkali Industry in Iran” is a feasibility study of a project for converting the mercury method applied in the process of manufacturing caustic soda and chlorine to the ion-exchange membrane method, which features a low environmental load and a high energy-saving effect.

We hope that the report will contribute to realization of the project and be utilized as reference by concerned parties in Japan.

February 2017
Kanematsu Corporation
Asahi Glass Co., Ltd.
Japan Oil Engineering Co., Ltd.
Executive Summary

In the Islamic Republic of Iran (Iran), the strain of electric power demand and the need to reduce greenhouse gas emissions have become increasingly urgent issues. Petrochemical, one of the key national industries, consumes vast amounts of energy and given the excessive volume of electric power needed to manufacture caustic soda and chlorine using electrolysis cells in particular, there is a need to introduce an ion-exchange membrane method to save energy and reduce the environmental load. Iran has also signed the “Minamata Convention on Mercury (Minamata Convention), Article 5 of which specifies a ban on the use of mercury in the manufacturing process of caustic soda chlorine is by 2025. The Minamata Convention is expected to take effect by the end of 2018 and will prohibit the manufacture of caustic soda chlorine using the mercury method.

Under such circumstances, this survey was conducted as a study on economic partnership projects in developing countries in FY2016 aiming to examine the feasibility of introducing the high-efficiency ion-exchange membrane electrolysis system of a Japanese manufacturer (including supplying ion-exchange membranes of the Japanese manufacturer linked with the introduction of an electrolysis system) to Iranian caustic soda and chlorine manufacturers seeking to convert their manufacturing method from the mercury method.

This survey is a feasibility study of the project, mainly involving a needs survey, selecting applicable companies and investigating the potential for funding via Japanese public finance. In addition to the survey in Japan, two field surveys were also conducted. The first aimed to select an applicable company, engaging in discussion with companies operating a caustic soda chlorine manufacturing plant which applies the mercury method, the National Petrochemical Company (NPC) and other local entities. With the result of this survey and analysis, the Abadan Petrochemical Company and the Kimiya Bandar Imam Company were selected as a target company for the project. (The project scope of the former company involves newly constructing a manufacturing plant, including the supply of the ion-exchange membranes while that of the latter company involves supplying ion-exchange membranes as the survey revealed that the company has already placed an order for an electrolyzer with a German company.) The survey team visited the Department of Environment of Iran during the first field survey and confirmed the following: i) the Department of Environment of Iran had instructed chlorine and alkali manufacturers using the mercury method to halt its use by 2020, ii) the state of mercury waste management discharged from caustic soda and chlorine plants using the mercury method in Iran, iii) the plant construction during the project is subject to an Environmental Impact Assessment (EIA), and iv) there is currently no governmental schemes in Iran supporting the conversion of manufacturing from the mercury method to the
ion-exchange membrane method while Iran is a party state to the Minamata Convention.

During the second field survey, the survey team explained the energy-saving effect of the ion-exchange membrane made in Japan to the Abadan Petrochemical Company, the estimated costs of converting the manufacturing method and the potential for funding via Japanese public finance. The survey team also engaged in discussions concerning the conceptual design and reaffirmed their strong demand for financial support to introduce a high-efficiency ion-exchange membrane electrolysis system as well as their trust and expectation in Japan’s technology. Regarding the potential for funding via Japanese public finance, since the Abadan Petrochemical Company is a private company and given the public nature of the project to convert the manufacturing method of caustic soda and chlorine plant based on private demand, the project is assumed to utilize the financial instruments of JBIC’s export loan or GREEN (Global action for Reconciling Economic growth and Environmental preservation), or Trade insurance covered by Nippon Export and Investment Insurance (NEXI) rather than schemes of Yen Loans or JICA Overseas Loans. Other than these fundraising schemes, the following are also considered: i) international financing mechanisms to support global environment conservation and climate change measures, ii) utilization of the Joint Credit Mechanism (JCM), and iii) enhancing the fundraising capacity by high-value-addition of the project.
Table of Contents

Chapter 1  Overview of the Host Country and Sector ......................................................... 1
  1.1 Economic and financial situations of Iran ................................................................. 1
  1.2 Overview of the target sector ................................................................................... 3
  1.3 Situations of the target area ...................................................................................... 11
Chapter 2  Survey Methodology ......................................................................................... 14
  2.1 Survey contents ........................................................................................................ 14
  2.2 Survey method and structure ................................................................................... 14
  2.3 Schedule .................................................................................................................. 17
Chapter 3  Considerations of Component and Technical Aspects of the Project ............... 21
  3.1 Background and necessity of the project ................................................................... 21
  3.2 Basic policy, decisions, etc. regarding the project components ................................. 26
  3.3 Overview of the project ............................................................................................ 27
  3.4 Required examination items ..................................................................................... 29
  3.5 Effects of implementing the project on Japan’s stable energy supply ...................... 30
Chapter 4  Consideration of Environmental and Social Aspects ........................................ 32
  4.1 Analysis on the present status of environmental and social aspects ....................... 32
  4.2 Effects of the projects to improve the environment .................................................. 34
  4.3 Environmental and social Impacts of the project ..................................................... 35
  4.4 Overview of laws related to environmental and social considerations and measures necessary to comply with the Laws ................................................................. 40
  4.5 Matters to be borne by the recipient country (Implementing and other organizations) .............. 41
Chapter 5  Financial and Economic Feasibility ................................................................... 42
  5.1 Estimation of the project cost .................................................................................... 42
  5.2 Overview of the preliminary financial and economic analysis ................................ 42
Chapter 6  Project Implementation Schedule ...................................................................... 44
Chapter 7  Implementation Capacity of the Iranian Executing Agency/ Company ............. 45
  7.1a Overview of the Iranian executing company (Abadan Petrochemical Company) .......... 45
  7.2a Iranian organizational framework for project implementation (Abadan Petrochemical Company) ................................................................................................................. 46
  7.3a Capacity assessment and countermeasures of the Iranian executing company (Abadan Petrochemical Company) ................................................................. 47
  7.1b Overview of the Iranian executing company (Kimiya Bandar Imam Company) .......... 48
  7.1c Overview of the Iranian executing agency (Department of Environment) ................. 49
  7.2c Iranian organizational framework for project implementation (Department of Environment)
Table of Contents

7.3c  Capacity assessment and countermeasures of the Iranian executing agency (Department of Environment) ........................................................................................................... 49

Chapter 8  Technological Superiority of Japanese Companies ............................................... 51
8.1  Assumed scheme of participation by the Japanese private sector ..................................... 51
8.2  Superiority of Japanese companies in the project implementation (technical and economic aspects) ............................................................................................................. 51
8.3  Necessary measures to encourage orders from Japanese companies .............................. 52

Chapter 9  Prospect of Fundraising ......................................................................................... 53
9.1  Consideration of financing sources and fundraising plan ................................................ 53
9.2  Feasibility of fundraising ................................................................................................ 57
9.3  Cash-flow analysis .......................................................................................................... 60

Chapter 10  Issues for the Project Implementation and Future Measures to be Taken ............ 61
10.1  Current efforts made by Japanese enterprises to implement the project ......................... 61
10.2  Efforts made by Iranian governments and executing agencies to implement the project .... 63
10.3  Legal and financial limitations in Iran ............................................................................. 64
10.4  Items to be analyzed in further detail ............................................................................. 64

Attachments

1.  Explanatory Material about Ion-Exchange Membrane Technology for Iranian Executing Agency/Company
2.  Explanatory Material about Mercury Waste Management for Department of Environment of Iran
<table>
<thead>
<tr>
<th>Abbreviations</th>
<th>Official Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADB</td>
<td>Asian Development Bank</td>
</tr>
<tr>
<td>APC</td>
<td>Abadan Petrochemical Company</td>
</tr>
<tr>
<td>BIPC</td>
<td>Bandar Imam Petrochemical Company</td>
</tr>
<tr>
<td>BIS</td>
<td>Bureau of Industry and Security</td>
</tr>
<tr>
<td>BM</td>
<td>Build Margin</td>
</tr>
<tr>
<td>CTCN</td>
<td>Climate Technology Centre and Network</td>
</tr>
<tr>
<td>DDB</td>
<td>Dodecylbenzene</td>
</tr>
<tr>
<td>DOE</td>
<td>Department of Environment of Iran</td>
</tr>
<tr>
<td>EAR</td>
<td>Export Administration Regulations</td>
</tr>
<tr>
<td>EGM</td>
<td>Expert Group Meeting</td>
</tr>
<tr>
<td>EHS</td>
<td>Environment, Health and Safety</td>
</tr>
<tr>
<td>EIA</td>
<td>Environmental Impact Assessment</td>
</tr>
<tr>
<td>EMP</td>
<td>Environmental Management Plan</td>
</tr>
<tr>
<td>ESIA</td>
<td>Environmental and Social Impact Assessment</td>
</tr>
<tr>
<td>FS</td>
<td>Feasibility Study</td>
</tr>
<tr>
<td>GCF</td>
<td>Green Climate Fund</td>
</tr>
<tr>
<td>GEF</td>
<td>Global Environment Facility</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>GREEN</td>
<td>Global action for Reconciling Economic growth and Environmental preservation</td>
</tr>
<tr>
<td>HSE</td>
<td>Health, Safety and Environment</td>
</tr>
<tr>
<td>ICDC</td>
<td>Iran Chemical Development Company</td>
</tr>
<tr>
<td>IEA</td>
<td>International Energy Agency</td>
</tr>
<tr>
<td>IJPC</td>
<td>Iran-Japan Petrochemical Company</td>
</tr>
<tr>
<td>IMF</td>
<td>International Monetary Fund</td>
</tr>
<tr>
<td>JBIC</td>
<td>Japan Bank for International Cooperation</td>
</tr>
<tr>
<td>JCM</td>
<td>Joint Crediting Mechanism</td>
</tr>
<tr>
<td>JICA</td>
<td>Japan International Cooperation Agency</td>
</tr>
<tr>
<td>LNG</td>
<td>Liquefied Natural Gas</td>
</tr>
<tr>
<td>MCTI</td>
<td>Ministry of Science, Technology and Innovation</td>
</tr>
<tr>
<td>MOP</td>
<td>Ministry of Petroleum</td>
</tr>
<tr>
<td>MRV</td>
<td>Measurement, Reporting and Verification</td>
</tr>
<tr>
<td>NEDO</td>
<td>New Energy and Industrial Technology Development Organization</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>NEXI</td>
<td>Nippon Export and Investment Insurance</td>
</tr>
<tr>
<td>NIGC</td>
<td>National Iranian Gas Company</td>
</tr>
<tr>
<td>NIOC</td>
<td>National Iranian Oil Company</td>
</tr>
<tr>
<td>NIORDC</td>
<td>National Iranian Oil Refining and Distribution Company</td>
</tr>
<tr>
<td>NPC</td>
<td>National Petrochemical Company</td>
</tr>
<tr>
<td>ODA</td>
<td>Official Development Aid</td>
</tr>
<tr>
<td>OM</td>
<td>Operating Margin</td>
</tr>
<tr>
<td>POPs</td>
<td>Persistent Organic Pollutants</td>
</tr>
<tr>
<td>PSEZ</td>
<td>Petrochemical Special Economic Zone</td>
</tr>
<tr>
<td>PVC</td>
<td>Polyvinyl chloride</td>
</tr>
<tr>
<td>SDGs</td>
<td>Sustainable Development Goals</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
</tr>
<tr>
<td>UNEP</td>
<td>United Nations Environment Programme</td>
</tr>
<tr>
<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
</tr>
<tr>
<td>UNIDO</td>
<td>United Nations Industrial Development Organization</td>
</tr>
<tr>
<td>WB</td>
<td>World Bank</td>
</tr>
</tbody>
</table>
Chapter 1 Overview of the Host Country and Sector

1.1 Economic and financial situations of Iran

(1) Basic information

Iran is an Islamic republic country situated in Western Asia (in the eastern part of the Middle East). It comprises a land area of 1,648,000 km², about 4.4 times that of Japan. With a population of 79.11 million people (2015), Iran is the second-most populous country in the Middle East and North Africa region, next to Egypt and the population is expected to increase further. Aryan Persians account for 60% of the people, followed by Turkish Azerbaijanis, Kurds and other minority ethnic groups.

![Location of Iran](image)

**Figure 1.1-1 Location of Iran**

**Table 1.1-1 Basic information about Iran**

<table>
<thead>
<tr>
<th>Capital</th>
<th>Tehran (Population of 8.43 million, 2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>1,648,000 km²</td>
</tr>
<tr>
<td>Population</td>
<td>79.11 million (2015), average annual growth rate of 1.3% from 2011 to 2015</td>
</tr>
<tr>
<td>Ethnical groups</td>
<td>61% Persians; 16% Azerbaijanis; 10% Kurds; other ethnic minorities (Turkmens, Arabs, Baluchi) (2015)</td>
</tr>
<tr>
<td>Religion</td>
<td>99.4% Islam: (90%-95% Shia; 5%-10% Sunni) (2011)</td>
</tr>
<tr>
<td>Languages</td>
<td>53% Persian (official); 18% Azerbaijani; 10% Kurdish; other languages (Arabic, English) (2015)</td>
</tr>
<tr>
<td>Currency</td>
<td>Iranian rial (IRR) USD=32,379 IRR (as of January 4, 2017)*</td>
</tr>
<tr>
<td>Accounting year</td>
<td>March 21 to March 20</td>
</tr>
</tbody>
</table>

Source: Japan Center for International Finance
Economic and financial situations

Iran’s economy is the second largest in the Middle East and North Africa region, after Saudi Arabia. In 2015, however, the GDP growth rate was almost zero (0.03%) because of the economic sanctions imposed due to the nuclear development issue and sluggish crude oil prices since 2014 and the fiscal balance was in deficit from 2012 to 2015. Iran’s economic situation and trends in terms of GDP and fiscal balance are shown in Table 1.1-2 and Figures 1.1-2 and 1.1-3, respectively.

Table 1.1-2 Economic situation

<table>
<thead>
<tr>
<th></th>
<th>Nominal GDP</th>
<th>Nominal GDP per capita</th>
<th>Components of nominal GDP</th>
<th>Components of exports</th>
<th>Major export destinations</th>
<th>Components of imports</th>
<th>Major import origins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal GDP</td>
<td>387.6 billion USD (2015)</td>
<td>4,877 USD (2015, estimated by the IMF)</td>
<td>53.8% services, 15.3% oil and gas sector, 14.3% mining and manufacturing, 8.7% construction and 9.3% agriculture, forestry and fisheries (2014)</td>
<td>64.0% crude oil and natural gas, 36.0% items other than crude oil and natural gas (Breakdown of items other than crude oil and natural gas: 79.7% industrial products, 16.7% agricultural and craft products) (2014)</td>
<td>39.0% China, 16.0% India, 14.0% Turkey, 8.8% Japan, 6.5% ROK, 2.6% Pakistan, 2.2% EU (2014)</td>
<td>37.2% transportation equipment and machinery, 18.8% food and animals, 13.2% chemical products, 7.9% steel (2014)</td>
<td>33.9% UAE, 28.2% China, 5.1% India, 4.8% ROK, 4.5% Turkey, 3.6% Germany, 9.7% EU (2014)</td>
</tr>
</tbody>
</table>

Sources: IMF World Economic Outlook Database, October 2016; Annual Review 1393 (2014/2015) of Central Bank of the Islamic Republic of Iran; and the Japan Center for International Finance

Figure 1.1-2 Trends in nominal GDP and GDP growth rate (2006-2015)
As for economic and financial aspects, following the easing of economic sanctions against Iran in January 2016, the country will see economic growth in future. In fact, in October 2016, the International Monetary Fund (IMF) reported that Iran’s GDP for FY2016 would grow at 4.5%. As for crude oil, which accounts for a substantial portion of the earning of foreign exchange reserves, the International Energy Agency (IEA) reported daily oil production of 2.86 million barrels in 2015, which rose further to 3.64 million barrels in May 2016, (of which more than two million were exported as a major foreign currency earner). Present circumstances thus appear favorable to Iran’s economy and government finance.

1.2 Overview of the target sector

This survey will target the petrochemical sector in a wider sense or, in a narrow sense, the chlor-alkali sector.

(1) Petrochemical sector

In Iran, the National Petrochemical Company (NPC) is responsible for managing and operating the entire petrochemical sector. As illustrated in Figure 1.2-1, NPC is one of four principal government-owned companies comprising the petroleum sector and headed by the Ministry of Petroleum. Table 1.2-1 outlines the four subsidiaries to the Ministry of Petroleum.
Table 1.2-1 Responsibility of the four principal government-owned companies

<table>
<thead>
<tr>
<th>Company</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Iranian Oil Company (NIOC)</td>
<td>NIOC is responsible for formulating policies and instructing on the exploration, drilling, production, research and development and export of crude oil and natural gas.</td>
</tr>
<tr>
<td>National Iranian Gas Company (NIGC)</td>
<td>NIGC is responsible for handling natural gas and transport and for sales of natural gas to domestic, industrial and commercial sectors and power plants.</td>
</tr>
<tr>
<td>National Petrochemical Company (NPC)</td>
<td>NPC is responsible for developing, operating and managing petrochemical facilities. It is also responsible for introducing and supervising policy formulation, planning and activities of subsidiaries.</td>
</tr>
<tr>
<td>National Iranian Oil Refining and Distribution Company (NIORDC)</td>
<td>NIORDC undertakes projects to expand, upgrade and optimize existing refineries and construct new refineries.</td>
</tr>
</tbody>
</table>

The petrochemical industry is a leading industry of Iran, which serves as an important revenue source. Since 1989, NPC has enhanced petrochemical facilities under governmental five-year plans, steadily boosting the production capacity of petrochemical products. While promoting privatization of its subsidiary petrochemical companies and the introduction of foreign investment, NPC itself is undertaking a range of projects; targeting production capacity of 180 million tons by 2025. Figure 1.2-2 shows the trend in terms of its production capacity of chemical products.
Figure 1.2-3 shows the chlorine manufacturing capacity under the mercury method, while Table 1.2-2 shows the number and production capacity of plants using the mercury method by country. According to Table 1.2-2, Iran ranks seventh in terms of chlorine production capacity using the mercury method and has four plants using this approach.
Figure 1.2-3  Chlorine production capacity using the mercury method

Table 1.2-2  Number of plants using the mercury method and production capacity, by country

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of mercury-cell facilities</th>
<th>2014 mercury-cell production</th>
<th>Planned capacity reductions 2010-2015</th>
<th>Known capacity reductions since 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>2</td>
<td>14</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Angola</td>
<td>1</td>
<td>10</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Argentina</td>
<td>2</td>
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<td>-</td>
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<tr>
<td>Azerbaijan</td>
<td>1</td>
<td>145</td>
<td>145</td>
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<td>Belgium*</td>
<td>2</td>
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<td>420</td>
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</tr>
<tr>
<td>Bosnia &amp; Herz.</td>
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<td>3</td>
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<td>-</td>
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<td>Brazil</td>
<td>4</td>
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<td>Canada</td>
<td>-</td>
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<td>China</td>
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<td>-</td>
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<td>Columbia</td>
<td>1</td>
<td>22</td>
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<td>-</td>
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<tr>
<td>Cuba</td>
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<td>Czech Republic*</td>
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<td>Egypt</td>
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<td>Finland*</td>
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<td>France*</td>
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<td>Germany*</td>
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<td>Greece*</td>
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<td>Hungary*</td>
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<td>Israel</td>
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<table>
<thead>
<tr>
<th>Country</th>
<th>Number of mercury-cell facilities</th>
<th>2014 mercury-cell production</th>
<th>Planned capacity reductions 2010-2015</th>
<th>Known capacity reductions since 2005</th>
</tr>
</thead>
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<tr>
<td>Italy*</td>
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<td>42</td>
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<tr>
<td>North Korea</td>
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<td>Myanmar</td>
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<td>Pakistan</td>
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<td>Philippines</td>
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<td>Poland*</td>
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<td>Romania*</td>
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<td>Russia*</td>
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<td>Serbia &amp; Mont.</td>
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</tr>
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<td>Slovakia*</td>
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<td>Spain*</td>
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<td>Sweden*</td>
<td>1</td>
<td>120</td>
<td>120</td>
<td>95</td>
</tr>
<tr>
<td>Switzerland*</td>
<td>1</td>
<td>27</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Syria</td>
<td>1</td>
<td>14</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Turkmenistan</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>U.A.E</td>
<td>2</td>
<td>9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>United Kingdom*</td>
<td>1</td>
<td>277</td>
<td>-</td>
<td>21</td>
</tr>
<tr>
<td>United States*</td>
<td>4</td>
<td>437</td>
<td>338</td>
<td>694</td>
</tr>
<tr>
<td>Uruguay*</td>
<td>1</td>
<td>14</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Units are thousands of metric tons of chlorine capacity
*Indonesia is reported to have phased out mercury-cell production in 2011
*Countries whose facilities are members of the World Chlorine Council


b) Changes in the production process in Iran

According to documents of the Iran-Japan Technical Cooperation Mercury Workshop held in Tehran on February 15-16 in 2016 (Organizer: Department of Environment of Iran), caustic soda and chlorine are mainly manufactured by mercury and ion-exchange membrane methods in Iran. In recent years however, there have been fewer plants using the mercury method and the ion-exchange membrane method has become increasingly common. This trend seems to reflect (1) the introduction of an energy-saving process (ion-exchange membrane method); (2) consideration of the impact of mercury on health and the environment; and (3) reaction to regulations laid down by the Minamata
Convention on Mercury. Figure 1.2-4 shows trends in terms of the numbers of manufacturing plants using the mercury and ion-exchange membrane methods respectively from 2006 to 2012. According to the figure, a total of five plants used the mercury method as of 2012.

![Bar chart showing trends in the numbers of manufacturing plants using mercury and ion-exchange membrane methods (2006-2012)](chart)

Source: Mercury Environmental Contamination in Iran by Dr. Ghazban, University of Tehran at the Iran-Japan Technical Cooperation Mercury Workshop (Tehran, Feb. 15-16, 2016)

**Figure 1.2-4** Trends in terms of the numbers of plants using mercury and ion-exchange membrane methods (2006-2012)

c) **Caustic soda and chlorine manufacturers**

Table 1.2-3 lists major caustic soda and chlorine manufacturers in Iran, as revealed by this survey. Plants using the mercury method are owned by Kimiya Bandar Imam Company, Abadan Petrochemical Company and Shiraz Petrochemical Company, with caustic soda production capacities of 250,000, 30,000 and 30,000 tons/year, respectively. The Arvand Petrochemical Company also owns a plant using the ion-exchange membrane method, with leading global caustic soda production capacity of 660,000 tons/year.
Table 1.2-3  Major caustic soda and chlorine manufacturers

<table>
<thead>
<tr>
<th>Company name</th>
<th>Capital</th>
<th>Plant location</th>
<th>Production capacity* (10,000 tons/year)</th>
<th>Method of electrolyzer (Licensor)</th>
<th>Production start</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kimiya Bandar Imam Company</td>
<td>Bandar Imam Petrochemical Company (100%)</td>
<td>Mahshahr</td>
<td>25</td>
<td>Mercury method (De Nora)</td>
<td>1995</td>
</tr>
<tr>
<td>Abadan Petrochemical Company</td>
<td>Tamin Petroleum &amp; Petrochemical Investment Company (56.6%)</td>
<td>Abadan</td>
<td>3</td>
<td>Mercury method (De Nora)</td>
<td>1993</td>
</tr>
<tr>
<td>Shiraz Petrochemical Company</td>
<td>Parsian Oil and Gas Development Group Company (54.8%)</td>
<td>Shiraz</td>
<td>3</td>
<td>Mercury method (De Nora)</td>
<td>1988</td>
</tr>
<tr>
<td>Arvand Petrochemical Company</td>
<td>Persian Gulf Petrochemical Company (79%)</td>
<td>Mahshahr</td>
<td>66</td>
<td>Ion-exchange membrane method (Uhde)</td>
<td>2010</td>
</tr>
</tbody>
</table>

*a1 Caustic soda production capacity (including previous capacity)


![Locations of major caustic soda and chlorine manufacturing plants](source: Google Map)

Figure 1.2-5  Locations of major caustic soda and chlorine manufacturing plants

d)  Future plan

Table 1.2-4 summarizes the future plans of Kimiya Bandar Imam Company, Abadan Petrochemical Company and Shiraz Petrochemical Company as confirmed by the survey team. The survey revealed that the Kimiya Bandar Imam Company and Abadan Petrochemical Company plan...
to convert their manufacturing approach from the mercury method to the ion-exchange membrane method and continue their caustic soda and chlorine manufacturing business. The former company has already commenced the process of converting to the ion-exchange membrane method and ordered an electrolyzer from a German company. The Abadan Petrochemical Company is formulating its conversion plan to the ion-exchange membrane method and plans to double its production capacity. The Shiraz Petrochemical Company has already halted their plant operation using the mercury method and has no plan to convert the manufacturing method to the ion-exchange membrane method.

Note: Target company of the project to convert the manufacturing method to the ion-exchange membrane method

Based on the first field survey result, the Abadan Petrochemical and Kimiya Bandar Imam companies, which plan to convert their manufacturing approach from the mercury method to the ion-exchange membrane method, were selected as target companies for the project. The contents of their projects are described in Chapter 3.1 (2).

<table>
<thead>
<tr>
<th>Company name</th>
<th>Status</th>
</tr>
</thead>
</table>
| Kimiya Bandar Imam Company    | • The company has already halted the operation of plants using the mercury method.  
                                 | • It is implementing a project to convert the manufacturing method to the ion-exchange membrane method. (It has placed an order of electrolyzers with a German company. The manufacturer of the ion-exchange membrane is unknown.) |
| Abadan Petrochemical Company  | • Plants using the mercury method remain in operation  
                                 | • The company is developing a plan to convert to the ion-exchange membrane method (production capacity of 77,000 tons/year). |
| Shiraz Petrochemical Company  | • The company halted the operation of plants using the mercury method in 2009 on environmental grounds.  
                                 | • It has no plans to convert to the ion-exchange membrane method. |

* Figures in brackets show the caustic soda production capacity.

According to NPC, it has a plan to construct a new PVC plant with the production capacity of 600,000 tons/year, which will require a caustic soda and chlorine manufacturing plant with a capacity to manufacture 500,000 tons of caustic soda per year. However, details, including the period and location of the manufacturing plant to be built, remain unknown.
1.3 Situations of the target area

(1) Abadan area

The city of Abadan, where the Abadan Petrochemical Company has a petrochemical complex, lies in the southwestern part near the Iran-Iraqi border, 53km from the Persian Gulf. There are many oil fields situated in its surrounding areas and Abadan has been an important industrial city in Iran since the Abadan Refinery was built in 1911. The Abadan Port is where Nisshomaru of Idemitsu Kosan, which was dispatched in 1953 when Iran nationalized petroleum and therefore engaged in conflict with the United Kingdom, loaded petroleum products. While the city suffered damage during the Iran-Iraq War in the 1980s, it has since been reconstructed and now plays an important role in the national petroleum industry. Abadan has a population of 213,000 (2011\(^1\)).

The following are major facilities in Abadan:

- Refinery (Abadan Oil Refining Company, the company with the country’s largest refining capacity)
- Petrochemical complex (Abadan Petrochemical Company)
- Tank yard (for crude oil and petroleum products, owned by Abadan Oil Refining Company)
- Abadan International Airport
- Port of Abadan
- Petroleum University of Technology

Currently, Western part of Khuzestan Province, where the city of Abadan is situated, is classified as Level 3 “Avoid All Travel” out of the four levels of the travel advice and warning issued by the Ministry of Foreign Affairs of Japan.
(2) **Mahshahr area**

The city of Mahshahr is located 90 km east of Abadan city and its population is 154,000 (as of 2011²). The Persian Gulf Coast outside Mahshahr city accommodates the Petrochemical Special Economic Zone (PSEZ), which was established to target development by attracting the petrochemical industry and its downstream industries. PSEZ has become one of the important petrochemical industry bases of Iran, where the Kimiya Bandar Imam Company, Arvand Petrochemical Company and other petrochemical complexes are located. Petroleum shipping facilities are located in the area 8 km east of PSEZ; owned by the Abadan Oil Refining Company, a subsidiary of the National Iranian Oil Refining and Distribution Company (NIORDC).

Source: Google Earth

**Figure 1.3-2** Surroundings of the city of Mahshahr

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Chapter 2  Survey Methodology

2.1 Survey contents

With the introduction of the ion-exchange membrane electrolyzers at caustic soda and chlorine manufacturing plants in Iran in mind, the survey was performed, including a needs survey, a technical proposal, calculation of the project cost and considerations of financing plans, etc. Moreover, issues and measures associated with introducing the ion-exchange membrane electrolyzers were sorted by reviewing environmental laws and regulations and measures and engaging in discussions with related organizations.

2.2 Survey method and structure

(1) Activity items

The survey was performed in Japan and Iran. Table 2.2-1 shows the major activity items of the survey.

The first field survey mainly focused on selecting a target of the project to convert the manufacturing method to ion-exchange membrane method and included data collection and analysis of caustic soda chlorine manufacturers and an interview with them.

The second field survey included discussions with Abadan Petrochemical Company, the candidate company for applying the project to convert the manufacturing method, in Tehran city, on the theme of estimated costs of converting the manufacturing method to ion-exchange membrane method, the energy-saving effect, financing sources and the conceptual design.

In relation to the Department of Environment of Iran, the survey result was reported, information on the Minamata Convention and the treatment of mercury waste was exchanged, and their demand for Japan’s support was confirmed.
Table 2.2-1  Major activity items of the survey

<table>
<thead>
<tr>
<th>Survey in Japan</th>
<th>Survey in Iran</th>
<th>Reporting session with Iranian stakeholder organizations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First survey</strong></td>
<td><strong>First survey</strong></td>
<td><strong>First survey</strong></td>
</tr>
<tr>
<td>Survey in Japan</td>
<td>Survey in Iran</td>
<td>Reporting session with Iranian stakeholder organizations</td>
</tr>
<tr>
<td><strong>Second survey</strong></td>
<td><strong>Second survey</strong></td>
<td><strong>Second survey</strong></td>
</tr>
<tr>
<td>Survey in Japan</td>
<td>Survey in Iran</td>
<td>Reporting session with Iranian stakeholder organizations</td>
</tr>
<tr>
<td><strong>Third survey</strong></td>
<td><strong>Third survey</strong></td>
<td><strong>Third survey</strong></td>
</tr>
<tr>
<td>Survey in Japan</td>
<td>Survey in Iran</td>
<td>Reporting session with Iranian stakeholder organizations</td>
</tr>
<tr>
<td><strong>Activity items</strong></td>
<td><strong>Activity items</strong></td>
<td><strong>Activity items</strong></td>
</tr>
<tr>
<td>Survey in Japan</td>
<td>Survey in Iran</td>
<td>Reporting session with Iranian stakeholder organizations</td>
</tr>
<tr>
<td>Selection of local venues to visit</td>
<td>Needs survey on introducing the ion-exchange membrane method</td>
<td>Report of the survey result</td>
</tr>
<tr>
<td>Collection and analysis of data on caustic soda chlorine manufacturers</td>
<td>Future plan of the caustic soda chlorine manufacturing project</td>
<td>Information exchange (status of introducing the Minamata Convention, treatment of mercury waste, international financial mechanism, bilateral credit scheme (Japan Credit Mechanism: JCM))</td>
</tr>
<tr>
<td>Summary of proposed technology</td>
<td>Explanatory overview of the ion-exchange membrane method</td>
<td>Confirmation on demands for Japan’s environmental support</td>
</tr>
<tr>
<td>Decision of the target company</td>
<td>Collection of data on environmental and social aspects (mainly on mercury)</td>
<td></td>
</tr>
<tr>
<td>Consideration of equipment to be introduced</td>
<td>Opinion exchange regarding the conversion to electrolysis method to elect</td>
<td></td>
</tr>
<tr>
<td>Consideration of financing sources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data collection on the treatment of mercury waste generated by applying the mercury method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collection and analysis of additional data</td>
<td>Discussions on technology and the energy-saving effects of the ion-exchange membrane method</td>
<td></td>
</tr>
<tr>
<td>Prospects of financial sources and cash flow analysis</td>
<td>Discussions on conceptual design and estimated costs of introducing equipment</td>
<td></td>
</tr>
<tr>
<td>Summary of the survey (Sorting of issues and measures)</td>
<td>Explanation and discussions of financing sources and various subsidies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Introduction of a method to treat mercury waste generated by applying the mercury method</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(2) Survey implementation system

The survey was conducted by Kanematsu Co., Ltd., which represents the joint implementation companies and was commissioned by the Ministry of Economy, Trade and Industry, Asahi Glass Co., Ltd. and Japan Oil Engineering Co., Ltd., the members of the joint implementation corporations. The system for implementing the survey and the main responsibilities of each company are shown in Figure 2.2-1 and Table 2.2-2.

![Implementation system diagram]

**Figure 2.2-1 Implementation system**

**Table 2.2-2 Main responsibilities of each company**

<table>
<thead>
<tr>
<th>Kanematsu</th>
<th>Asahi Glass</th>
<th>Japan Oil Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team management</td>
<td>Technical considerations</td>
<td>Coordination with local stakeholders</td>
</tr>
<tr>
<td>Collection of local information</td>
<td>Estimation of energy-saving effects</td>
<td>Investigation and consideration of the</td>
</tr>
<tr>
<td>Coordination with local stakeholders</td>
<td>Calculation of project cost</td>
<td>environmental and social aspects</td>
</tr>
<tr>
<td>Consideration of finance</td>
<td>Consideration of project schedule</td>
<td>Investigation of the Iranian petrochemical</td>
</tr>
<tr>
<td>Investigation of the Iranian executing agency/company</td>
<td></td>
<td>industry</td>
</tr>
<tr>
<td>Assessment of project feasibility</td>
<td></td>
<td>Investigation of the Iranian executing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>agency/company</td>
</tr>
</tbody>
</table>

Kanematsu Co., Ltd.
(Representing company)

Kanematsu Iran Ltd
(Supporting field activities)

Asahi Glass Co., Ltd.
(Joint implementation company)

Japan Oil Engineering Co., Ltd.
(Joint implementation company)

Kanematsu Iran Ltd (Supporting field activities)

Kanematsu Co., Ltd. (Representing company)
2.3 Schedule

The schedule is shown in Table 2.3-1 as follows:

<table>
<thead>
<tr>
<th>September 2016</th>
<th>First survey in Japan</th>
</tr>
</thead>
</table>
| September 25 to October 3, 2016 | The first field survey (sites: Tehran, Mahshahr and Shiraz)  
  <Interviews with>  
  • Abadan Petrochemical Company  
  • National Petrochemical Company (NPC)  
  • Kimiya Bandar Imam Company / Bandar Imam Petrochemical Company  
  • Petrochemical Special Economic Zone Company (PSEZ)  
  • Arvand Petrochemical Company  
  • Shiraz Petrochemical Company  
  • Persian Oil and Gas Development Group Company  
  • Department of Environment of Iran (Water and Soil Bureau)  
  • JICA Iran Office  
  • Embassy of Japan in Iran |
| October to December, 2016 | The second survey in Japan  
  <Interviewed with>  
  • Global Environment Partnership Office, Ministry of Economy, Trade and Industry  
  • Japan Bank for International Cooperation (JBIC)  
  • Nippon Export and Investment Insurance (NEXI)  
  • Japan International Cooperation Agency (JICA)  
  • Environmental Health and Safety Division, Ministry of the Environment, Japan  
  • Nomura Kohsan Co., Ltd.³ |
| December 3-5, 2016 | The second field survey (place: Tehran)  
  <Interviewed with>  
  • Abadan Petrochemical Company  
  • JICA Iran Office  
  • Embassy of Japan in Iran |
| December 2016 to January 2017 | The third survey in Japan |
| February 4, 2017 | Reporting session with Iranian stakeholder organizations (place: Tehran)  
  <Interviewed with>  
  • Department of Environment of Iran (Water and Soil Bureau, National Center for Air and Climate Change) |

The following photos show the interview scenes with the Iranian stakeholders:

³ The only mercury recycling treatment company in Japan
Photo 2.3-1  Visit to Abadan Petrochemical Company (Tehran)

Photo 2.3-2  Visit to NPC (Tehran)

Photo 2.3-3  Visit to Kimiya Bandar Imam Company (Mahshahr)
Photo 2.3-4  Visit to PSEZ (Mahshahr)

Photo 2.3-5  Visit to Arvand Petrochemical Company (Mahshahr)

Photo 2.3-6  Visit to Shiraz Petrochemical Company (Shiraz)
Photo 2.3-7  Visit to DOE (Tehran)

Photo 2.3-8  Reporting session with Iranian stakeholder organizations / Visit to DOE (Tehran)
Chapter 3  Considerations of Component and Technical Aspects of the Project

3.1  Background and necessity of the project

(1)  Background and necessity of the project

In Iran, the strain of electric power demand and the need to reduce greenhouse gas emissions have become increasingly urgent issues. Petrochemical, one of the key national industries, consumes much amount of energy and given the excessive volume of electric power needed to manufacture caustic soda and chlorine using electrolysis cells in particular, there is a need to introduce an ion-exchange membrane method to save energy and reduce the environmental load. Iran has also signed the “Minamata Convention on Mercury (Minamata Convention), Article 5 of which specifies a ban on the use of mercury in the manufacturing process of caustic soda chlorine is by 2025. The Minamata Convention is expected to take effect by the end of 2018 and will prohibit the manufacture of caustic soda chlorine using the mercury method.

Under such circumstances, the feasibility of introducing the high-efficiency ion-exchange membrane electrolysis system of a Japanese manufacturer (including supplying ion-exchange membranes of the Japanese manufacturer linked to the introduction of an electrolysis system) to Iranian caustic soda and chlorine manufacturers seeking to convert their manufacturing method from the mercury method was examined.

(2)  Target company of the project

Once the survey got underway, multiple candidates were targeted in the project; hence the first field survey was conducted to narrow down the scope. The survey result is indicated in Section 1.2 (2) c) and d).

Accordingly, the survey confirmed that the Abadan Petrochemical Company and Kimiya Petrochemical Company were companies owning a caustic soda and chlorine plant which applies the mercury method and consider and plan to convert their manufacturing method to the ion-exchange membrane method in future. Therefore, these two companies were recognized as target companies of the project.

Since the latter company has already concluded their order with a German company, the contents of the project vary between the two companies, as outlined in Table 3.1-1.
Table 3.1-1 Contents of the Project

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Contents of the project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abadan Petrochemical</td>
<td>Construction of a new caustic soda and chlorine plant applying the ion-exchange membrane method</td>
</tr>
<tr>
<td>Kimiya Petrochemical</td>
<td>Supply of ion-exchange membranes from a Japanese manufacturer to the electrolyzer of the German contactor.</td>
</tr>
</tbody>
</table>

(3) Ion-exchange membrane method

The background to the development of the ion-exchange membrane method and its technological overview are described as follows.

a) Types and characteristics of the brine electrolysis method

Three methods can be applied to the manufacturing process used to produce caustic soda and chlorine by brine electrolysis: the mercury method, which is old-fashioned and low energy efficiency, the diaphragm method and the ion-exchange membrane method, which improves energy efficiency. The former two methods were practically applied in the late 1800s, while the ion-exchange method is a new technology industrialized in the 1970s. In Japan, the conversion from mercury method to non-mercury method was carried out actively against the background of the Minamata issue and increasing awareness of the need to save energy in response to oil shocks, the development of ion-exchange membrane technology and conversion to the method were actively promoted. In around 1991, the conversion from the mercury method to the ion-exchange membrane method was completed. Accordingly, Japan has been leading the ion-exchange membrane technology worldwide and is one of the few countries supplying (fluoropolymer) ion-exchange membranes that is the core element of the technology. Table 3.1-2 shows the characteristics of the brine electrolysis method.

Table 3.1-2 Characteristics of the brine electrolysis method

<table>
<thead>
<tr>
<th></th>
<th>Ion-exchange membrane method</th>
<th>Mercury method</th>
<th>Diaphragm method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric power</td>
<td>2,100</td>
<td>3,300</td>
<td>2,750</td>
</tr>
<tr>
<td>consumption rate (kWh/t-100%NaOH)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caustic soda quality</td>
<td>○</td>
<td>○</td>
<td>× (mixed with sodium salts)</td>
</tr>
</tbody>
</table>

For the ion-exchange membrane method, the power consumption (consumption rate) per production volume of caustic soda or chlorine is generally 24% to 36% less than the mercury and diaphragm methods and the caustic soda produced by this method features higher quality. To

---

produce fluoropolymer ion-exchange membranes, the core of the ion-exchange membrane method, a special fluoride-containing monomer containing a functional group required for ion-exchange must first be synthesized. Subsequently, a special fluoropolymer is produced by copolymerizing the monomer with another fluoride-containing monomer, then film forming, hydrophilic surface treatment and assembly for maintaining strength are performed. This means that the very high technology is required. Hence, ion-exchange membranes are only supplied by three companies; two from Japan and one from the US. The basic technology behind the ion-exchange membrane was established in Japan in the 1970s and has been developed and improved to date. It is durable against impurities contained in brine and adaptable to load fluctuations in production, which are technologies that Japan boasts to the world (see Attachment-1).

Figures 3.1-1 to 3.1-3 illustrate the brine electrolysis method respectively.

![Brine Electrolysis Method](http://www.eurochlor.org/media/7815/mercury_cell_process.pdf)

**Figure 3.1-1** Brine electrolysis method (mercury method)

\[ \text{NaCl} + \text{Hg} \rightarrow \text{NaHg} + \frac{1}{2} \text{Cl}_2 \]

\[ \text{NaHg} + \text{H}_2\text{O} \rightarrow \text{NaOH} + \frac{1}{2} \text{H}_2 + \text{Hg} \]
NaCl + H₂O → NaOH + 1/2 Cl₂ + 1/2H₂

Figure 3.1-2 Brine electrolysis method (diaphragm method)\(^6\)

NaCl + H₂O → NaOH + 1/2 Cl₂ + 1/2H₂

Figure 3.1-3 Brine electrolysis method (ion-exchange membrane method)\(^7\)

\(^6\) http://www.eurochlor.org/media/7818/diaphragm_cell_process.pdf
\(^7\) http://www.eurochlor.org/media/7812/membrane_cell_process.pdf
b) Ion-exchange membrane method

An ion-exchange membrane is a membrane used for separating anode and cathode chambers, and a fluorine-based cation-exchange membrane is generally used. In brine electrolysis, an oxidation reaction occurs in the anode chamber and reduction reaction occurs in the cathode chamber, which means the mixture and isolation of substances generated in both chambers must be controlled. The ion-exchange membrane used here is the cation-exchange membrane. Na\(^+\) (the sodium ion) in the anode chamber migrates to the cathode chamber through the membrane while Cl\(^-\) (chlorine ion) generated in the anode chamber remains, as it cannot pass the membrane. On the other hand, water molecules are reduced to hydrogen and OH\(^-\) (hydroxide ion) in the cathode chamber but most of the OH\(^-\) cannot pass the membrane, which means NaOH (caustic soda) is generated in the cathode chamber by Na\(^+\) migrating from the anode chamber and OH\(^-\). At this time, the anode chamber becomes strongly oxidized due to chlorine ions while the cathode chamber is strongly alkaline. In addition, liquid temperature increases during the brine electrolysis, both the chemical durability and the separation are required for the ion-exchange membrane. This is why a fluoro-based ion-exchange membrane composed of a polymer equipped with a perfluorocarbon backbone and a cation-exchange ability is applied.

Fluoro-based ion-exchange membranes used more recently have enabled to reduce resistance and to increase current by placing perfluoropolymer containing the sulfonic acid group with significant ion-exchange capacity as a base polymer layer (Figure 3.1-4) on the anode side while placing perfluoropolymer containing the carboxylic acid group, which has a high reversed diffusion preventing effect of OH\(^-\) (Figure 3.1-5) as a barrier layer on the cathode side. Moreover, providing a physical form (uneven condition) on the membrane surface and controlling the surface hydrophilicity and hydrophobicity with a specified chemical coating helps improve permeability and ensure low resistance by reducing gas adhesion. Besides, with the optimization of a core material in the membrane, both durability and dimensional stability have been improved which increased operational stability and helped save more energy.

Figure 3.1-6 shows an example of the fluoro-based ion-exchange membrane.

3.2 Basic policy, decisions, etc. regarding the project components

It’s a given fact that the conversion from mercury method to ion-exchange method for the technical policy of the project. Since the ion-exchange membranes used in the project have been developed year after year as described in Section 8.2, appropriate ion-exchange membranes will be chosen by determining their economic effect, stability and operational conditions, etc.

(1) Abadan Petrochemical Company

The Abadan Petrochemical Company has already possessed specifications at the conceptual design level, including the project size, annual operating hours, utility required and so on. Accordingly, project components except for the ion-exchange membrane are based on the specifications of the Abadan Petrochemical Company. Taking the result of additional field surveys into consideration, the basic design is conducted to implement the project. (the project implementation schedule is described in Chapter 6) Sections 3.3 and 3.4 describe an overview of the project and the required examination items, respectively.

(2) Kimiya Bandar Imam Company

The survey confirmed that the Kimiya Bandar Imam Company has already ordered an electrolyzer from a German company. To realize the supply of Japanese ion-exchange membranes, Japanese

\[
\begin{align*}
\left( \text{CF}_2\text{CF}_2 \right)_x & \left( \text{CF}_2\text{CF} \right)_y \\
\text{O} \left( \text{CF}_2\text{CF} \right)_m & \text{O} \left( \text{CF}_2 \right)_n \text{C} \text{OH} \\
\text{CF}_3 & \\
\end{align*}
\]

Figure 3.1-5 Perfluoropolymer containing carboxylic acid group

Figure 3.1-6 An example of a fluoro-based ion-exchange membrane

manufacturers must collect information from the German company and engage in sales activities with the company.

3.3 Overview of the project

Regarding the construction of a caustic soda and chlorine plant associated with the conversion from mercury method to ion-exchange membrane method, the Abadan Petrochemical Company has already prepared specifications\(^\text{11}\) at a conceptual design level. Based on the prepared specifications, we summarize the project outlines in this section. The project schedule is described in Chapter 6 and the method in which the Japanese companies participate in the project is described in Section 8.1.

(1) Production capacity of the plant

The project will conduct not only the manufacturing method conversion but also the production capacity expansion. The caustic soda-based production capacity will be expanded from the current 30,000 tons/year to 77,000 tons/year. The production items of the new plant are summarized in Table 3.3-1.

<table>
<thead>
<tr>
<th>Production item</th>
<th>Concentration/purity</th>
<th>Production capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caustic soda (aqueous solution)</td>
<td>50 (wt. %)</td>
<td>77,000 (tons/year, 100% conversion)</td>
</tr>
<tr>
<td>Caustic soda (flake)</td>
<td>98.5 (wt. %)</td>
<td>30,000 (tons/year)</td>
</tr>
<tr>
<td>Caustic soda (granule)</td>
<td>—</td>
<td>5,000 (tons/year)</td>
</tr>
<tr>
<td>Chlorine gas (pressure: 4.5 barg.)</td>
<td>99.42 (wt. %)</td>
<td>70,572 (tons/year)</td>
</tr>
<tr>
<td>Hydrogen gas (pressure: 2 to 3 barg)</td>
<td>According to the technology applied</td>
<td>According to the technology applied</td>
</tr>
<tr>
<td>Sodium hypochlorite (aqueous solution)</td>
<td>150 – 160 (g/L)</td>
<td>Normally not produced</td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>32 (wt. %)</td>
<td>—</td>
</tr>
</tbody>
</table>

Table 3.3-1 Production items and capacity of the new plant

Note: Caustic soda is sold as a commercial product. Chlorine gas is used as a raw material of ethylene dichloride (EDC) while hydrogen is used as a raw material of hydrogen peroxide

(2) Annual operation hours

The operation hours are 8,000 hours (333 days) annually.

---

\(^{11}\) General Data on Expansion of Chlor-alkari Plant (Abadan Petrochemical Company)
(3) **Plant area**

The new plant is newly constructed within the site of Abadan Petrochemical Company’s complex (50 ha), rather than the site of the existing mercury plant. The site area of the new plant is 2 ha.

(4) **Equipment**

The main equipments that the Abadan Petrochemical Company plans the installation are the checked items listed in Table 3.3-2. Red-lined items indicate electrolyzers. The installation of equipments is expected to be requested to the EPC (Engineering, Procurement, Construction) contractor. For the next step, the potential to divert existing equipment has to be surveyed and considerations for deciding on the method, capacity and volume of equipment to be installed are necessary.

Table 3.3-2  Main equipment to be installed

<table>
<thead>
<tr>
<th>Process Unit</th>
<th>ISBL Suppl.</th>
<th>ISBL Eng.</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 Salt storage and handling</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>02 Brine saturation</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>03 Brine precipitation</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>04 Brine clarification</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>05 Brine filtration, first stage</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>05 Brine filtration, second stage</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>06 Secondary brine purific., ion exchange</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>07 Anolyte dechlorination</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>08 Chlorate decomposition</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>09 Sulfate removal</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>11 <strong>Cell room for NaCl / KCl Electrolysis</strong></td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>11b Cell room for NaCl <strong>ODC Electrolysis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 Cell workshop</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>13 Transformer / rectifier</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>21 Chlorine treatment</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>22 Chlorine compression</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>23 Chlorine liquefaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 Chlorine storage and filling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 Chlorine evaporation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26 Waste gas dechlorination</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>27 Bleaching lye production, storage &amp; filling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31 Catholyte circulation</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>31b Oxygen recycle (NaCl <strong>ODC Electrolysis</strong>)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 3.3-2  Main equipment to be installed (continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>Equipment Description</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>Caustic concentration</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>33</td>
<td>Caustic storage and filling</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>41</td>
<td>Hydrogen treatment</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>42</td>
<td>Hydrogen compression</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>51</td>
<td>Hydrochloric acid synthesis</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>52</td>
<td>Hydrochloric acid storage and filling</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>71</td>
<td>Raw Water System</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>72</td>
<td>Potable Water System</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>73</td>
<td>Demineralised water plant</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>74</td>
<td>Chilled water plant</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>75</td>
<td>Cooling water plant</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>76</td>
<td>Steam system, boiler plant</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>77</td>
<td>Nitrogen system</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>78</td>
<td>Plant air system</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>79</td>
<td>Instrument air system</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>81</td>
<td>Waste water system</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>82</td>
<td>Safety equipment, e.g. safety showers</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>83</td>
<td>Firefighting system</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>84</td>
<td>Air conditioning</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>85</td>
<td>Laboratory equipment</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>86</td>
<td>Work shop, general mechanical</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>87</td>
<td>Electrical syst. (substation, emerge. power)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>100</td>
<td>Control room</td>
<td>☒</td>
<td>☐</td>
</tr>
<tr>
<td>101</td>
<td>MCC room</td>
<td>☒</td>
<td>☐</td>
</tr>
</tbody>
</table>

Note: Non-numbered items on the list are understood to refer to deleted equipment which is unrelated to the project.

### 3.4 Required examination items

In order to convert an existing chlor-alkali plant from mercury method to ion-exchange membrane method at the Abadan Petrochemical Company, at a minimum, the following modification have to be

---

(5) **Utility and others**

The scales of utilities such as water, cooling water, steam, vapor, nitrogen gas, electric power and fuel used at the new plant, pipes, standard of instruments, composition of brine (raw material), types and consumption amount of chemicals under operation, climate condition of the site are roughly decided.
made\textsuperscript{12}:

At this moment, there is no detailed information about these items, they have to be taken into account before starting the basic design:

- Replace the mercury cells with membrane electrolysis cells and adapt the building
- Replace or adapt electricity transformers/rectifiers
- Add secondary brine purification and filtration units since membrane technology requires higher purity brine
- Add a caustic soda concentration unit since the caustic concentration from membrane cells needs to be increased to the commercial standard of 50\% in most of the cases.

3.5 Effects of implementing the project on Japan’s stable energy supply

Background information on energy resources in Iran and Japan (oil and natural gas) is shown as follows:

<table>
<thead>
<tr>
<th>Iran</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Iran is one of the major counties rich in petroleum and natural gas (with the world’s fourth and top quantity of respective reserves\textsuperscript{13}) and an important oil producing country as a potential energy supplier.</td>
</tr>
<tr>
<td>• The petroleum industry in Iran has encouraged foreign investment by opening up gas field drilling sites field and establishing special economic zones such as petrochemical complexes, etc. It requires plants to be constructed by proactively pursuing foreign investment, attracting foreign enterprises and using high-quality technologies. In particular, after over 30 years of US economic sanctions, the time has come to update aging equipment with new technologies. Accordingly, sufficient opportunities exist to invest in infrastructure using Japan’s high-quality technology.</td>
</tr>
<tr>
<td>• Besides petroleum, exporting abundant natural gas resources could be an important means for Iran to acquire foreign currency. Since not all US economic sanctions have been removed, however, large-scale business negotiations, such as opening up drilling sites of petroleum and gas fields, constructing LNG plants and installing international pipelines, may not yet be proceeding unhindered. Under the circumstances, some European countries (Germany, France, Italy, etc.) are outperforming the rest in terms of progress in business negotiation.</td>
</tr>
<tr>
<td>• The petroleum industry in Iran currently lacks funds for foreign investment and updating new equipment due to past economic sanctions, the subsequent stagnation of crude oil prices and the fact that petrochemical products using abundant natural gas and petroleum gas have not been effectively utilized as a means of acquiring foreign currency.</td>
</tr>
<tr>
<td>• The lack of funds and investment means plant construction projects in the Iranian petroleum industry are requesting the introduction of a buyback method using crude oil or products or loans taken out from each government as a means of compensation or repayment for investment and loans.</td>
</tr>
</tbody>
</table>

\textsuperscript{12} Conversion from Mercury to Alternative Technology in the Chlor-Alkali Industry (UNEP Global Mercury Partnership Chlor-Alkali Area, June 2012)  
\textsuperscript{13} Source: BP, Static Review of World Energy, June 2016
Japan

- Since Japan lacks petroleum and natural gas resources, a long-term and stable oil producer needs to be secured.
- To ensure a stable energy supply, the key is to secure affordable, long-term and stable energy resources as well as diversifying energy resources and their importing countries.
- The petroleum refining industry in Japan diverted heavy crude oil to valuable petroleum products following past market price mechanisms; targeting sound and stable business management. Specifically, heavy crude oil is converted to lighter components by adopting thermal and catalytic cracking treatment. Moreover, the Notification\textsuperscript{14} of the Ministry of Economy, Trade and Industry imposes the obligation to increase the equipment ratio\textsuperscript{15} of heavy oil cracking units based on the Sophisticated Methods of Energy Supply Structures.
- Japan’s installation capacity of heavy oil cracking units is expected to be gradually enhanced. As about 80% of Iranian crude oil comprises heavy crude oil, Japan’s petroleum refining industry can effectively operate a heavy oil cracking unit.
- Public organizations and the private sector in Japan have adequate potential to provide financial and technical support to petroleum and natural gas producers. The Government of Japan signed the Japan-Iran Investment Agreement in February 2016.

Among oil producing countries, Iran has a good relationship with Japan. Given the above-mentioned background information, sufficient room remains to complement and cooperate with each other in the energy area. Accordingly, implementing the project is expected to expand the business of Japanese enterprises with advanced technology (manufacturers, engineering companies, etc.) to the Iranian market, boost the economy via financial assistance of Japan’s loan agencies and enhance bilateral relations between both countries through economic activities, with the import and export of energy resources. In particular, as mentioned above, Japan’s crude oil refining companies have advantages in terms of utilizing Iranian crude oil efficiently. Accordingly, it is preferable to import heavy crude oil affordably for a stable energy supply in Japan, taking the long-term import into consideration as well as diversifying the type of crude oil imported and the quantitative stable supply. The ability to import both crude oil and natural gas from Iran will help diversify natural gas importing countries, paving the way for an even more stable energy supply.

Accordingly, while the direct effect of implementing the project on Japan’s stable energy supply remains very limited, it will open up opportunities for the Japanese private sector to expand its business with Iran and help enhance bilateral relations between both countries through economic activities; thus boosting the long-term and stable energy supply, one of the national policies, in future.

\textsuperscript{14} The first Notification of the Sophisticated Methods of Energy Supply Structures: July 2010, the second Notification: July 2014

\textsuperscript{15} The equipment rate refers to the ratio of crude oil atmospheric pressure distillation unit (denominator) and heavy oil cracking unit (fraction). The second Notification of the Sophisticated Methods of Energy Supply Structures targets efforts to raise Japan’s equipment ratio to around 50% by the end of March 2017.
Chapter 4  Consideration of Environmental and Social Aspects

4.1  Analysis on the present status of environmental and social aspects

(1)  Energy efficiency

The Abadan Petrochemical Company and the Kimiya Bandar Imam Company have caustic soda chloride manufacturing plants using the mercury method, with energy consumption per unit of production some 36% greater than that of the most advanced ion-exchange membrane plant (as of December 2016). With energy saving in mind therefore, it is desirable to convert the present mercury method plant into an ion-exchange membrane method plant.

(2)  Mercury emissions to the environment

At a caustic soda and chlorine plant using the mercury method, as well as generating mercury waste (such as sludge containing mercury), mercury is emitted through diffusion of mercury vapor and discharge of wastewater containing mercury while it is in operation.

The Abadan Petrochemical Company regularly replenishes mercury used at the plant by importing it from overseas (Japan is not included). The quantity of mercury imported between 2014 and 2015 was approximately 5,400 kg. Though the amount of mercury emitted to the environment through diffusion of mercury vapor and discharge of wastewater containing mercury is not confirmed, the quantity of mercury wastes generated from the plant between 2014 and 2015 was approximately 4,000 kg.

As for the Kimiya Bandar Imam Company, some calculation shows that 700 kg of mercury is discharged into the sea each year from their caustic soda and chlorine plant using the mercury method16.

The survey team has obtained no particular report that mercury emissions are harming human health or the living environment at the moment. If the company has suffered any incident of mercury leakage due to human error, aging facilities or for other reasons, it might have caused soil and/or groundwater contamination. At the moment, however, no such contamination has been found.

(3)  Mercury exposure in work environment

According to a report in the Iran Journal of Public Health17, mercury concentrations in the air in a caustic soda chlorine manufacturing plant using the mercury method (0.042± 0.003 mg/m³) exceeded the standard level for work environments (0.025 mg/m³) set forth by the American Conference of Governmental Industrial Hygienists and mercury concentrations in the blood and urine samples of workers at the plant considerably exceeded those of all survey samples. The report concludes in

16 JICA Report: The Project for Strengthening Environmental Management in Petroleum Industry in Parsian Gulf and its Coastal Area (February 2014)
general terms that the work environment of plants using mercury includes the risk of exposure to mercury.

(4) **Mercury waste Management**

Mercury wastes generated at the Abadan Petrochemical Company’s caustic soda and chlorine plant using the mercury method are properly at a controlled disposal site, which is approved by the Department of Environment of Iran.

The Kimiya Bandar Imam Company put mercury wastes generated from the caustic soda and chlorine plant using mercury method into drum cans and temporarily stores them at a controlled disposal site (landfill). The temporary storage period is until the time when the mercury waste recycling technology is established\(^\text{18}\).

(5) **Minamata Convention on Mercury**

Iran signed the Minamata Convention on Mercury, an international treaty to ban the manufacture, import and export of mercury and mercury-added products in October 2013. Article 5 of the Convention stipulates that the use of mercury in the caustic soda chlorine manufacturing process shall be phased out by 2025. The Minamata Convention is expected to come into effect in 2018. Accordingly, the Abadan Petrochemical Company and the Kimiya Bandar Imam Company are considering a means of converting the manufacturing process of its plant using mercury method to a mercury-free manufacturing process.

Table 4.1-1 outlines the Minamata Convention.

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\(^{18}\) JICA Report: The Project for Strengthening Environmental Management in Petroleum Industry in Parsian Gulf and its Coastal Area (February 2014)
Table 4.1-1  Outline of the Minamata Convention

<table>
<thead>
<tr>
<th>Item</th>
<th>Outlines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preamble</td>
<td>• Hazards of mercury, criteria on lessons from Minamata disease</td>
</tr>
<tr>
<td>Introduction</td>
<td>• Purpose and definitions</td>
</tr>
</tbody>
</table>
| Supply and trade                          | • Closure of mercury mines within 15 years of the Convention entering into force  
• Regulation of the import and export of mercury |
| Product and production process            | • Prohibition of manufacturing and import/export of mercury compounds  
• Prohibition of chlor-alkali production and acetaldehyde production, for which mercury is used as a catalyst  
• Exclusion when requested by party states |
| Small-scale gold mining by manpower       | • Reduced use of mercury and mercury compounds and releases into the environment (elimination of use, where possible)  
• Eliminating the diversion of mercury and mercury compounds for use in small-scale gold mining |
| Emissions and releases                    | • Reducing emissions by applying the best technology available / best practice for the environment |
| Interim storage                           | • Environmentally sound management of mercury in accordance with the guidelines, etc. prepared at the Conference of the Parties |
| Storage, disposal, etc.                   | • Sound management taking the guidelines of the Basel Convention into consideration |
| Financial and technical support           | • Creation of a funding mechanism which supports capacity development and capital investment, etc. of developing countries |
| Dissemination, awareness, research, etc.  | • Information sharing, information for the public, awareness and education, research, development, monitoring, an implementation plan, report and assessment of effectiveness |

Source: Provisions of the Minamata Convention and materials of the Ministry of the Environment of Japan

4.2  Effects of the projects to improve the environment

Converting from the mercury method to the ion-exchange membrane method will completely eliminate mercury emissions into the environment and the generation of mercury waste as a result of operations of the caustic soda chlorine manufacturing plant. In other words, the company will achieve zero mercury emissions. The conversion will also improve the environment from perspectives of energy-saving and reductions in global warming gas emissions.

The Abadan Petrochemical Company plans to build a new caustic soda chlorine manufacturing plant with an annual production capacity of 77,000 tons and on a caustic soda basis. Table 4.2-1 shows a comparison of plants of this size to be introduced, using mercury and ion-exchange membrane methods. The ion-exchange membrane method will be able to reduce electricity

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consumption by some 92GWh and CO₂ emissions by some 61,000 tons each year, compared to the mercury method.

<table>
<thead>
<tr>
<th>Table 4.2-1</th>
<th>Comparison of the ion-exchange membrane and mercury methods from environmental perspectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>(in the case of a caustic soda manufacturing plant with production capacity of 77,000 tons)</td>
<td></td>
</tr>
<tr>
<td>Electric power consumption rate (kWh/t-100% Caustic soda)</td>
<td>Mercury method</td>
</tr>
<tr>
<td></td>
<td>3,300</td>
</tr>
<tr>
<td>Annual electric power consumption of caustic soda production (GWh/year)</td>
<td>254.1</td>
</tr>
<tr>
<td>Reduction in annual electric power consumption compared to mercury method (GWh/year)</td>
<td>—</td>
</tr>
<tr>
<td>Reduction in annual CO₂ emissions compared to mercury method (Ton/year)</td>
<td>—</td>
</tr>
<tr>
<td>Use of hazardous material</td>
<td>Yes (mercury)</td>
</tr>
</tbody>
</table>

The CO₂ emission coefficient is set at 0.665 t-CO₂/MWh, which is an average of the OM and BM emission factors in 2016 published by the Ministry of Science, Technology and Innovation (MCTI). Steam for concentration of caustic soda has been converted to electric power and added to electrolysis power, whereby steam of 1 ton is converted at the rate of 200AChkWh.

4.3 Environmental and social impacts of the project

(1) Beneficial environmental and social impacts of converting the manufacturing method

As shown in Section 4.2, converting the manufacturing method is expected to help efforts to avoid using mercury, save energy and reduce CO₂ emissions. It will also solve industrial health problems derived from the use of mercury. The beneficial social impacts of the conversion can be summarized as follows:

a) Energy-saving

Electricity demand in Iran is soaring and the power generation plant capacity and electric power generation doubled and increased 1.7 fold respectively over the decade from 2004 to 2014 (see Figure 4.3-1). Demand is expected to grow further as the population and economy continues growing. The caustic soda chlorine manufacturing process consumes a relatively large amount of electricity in the petrochemical industry and converting this method will save energy and help ease the growing demand for electricity.
b) **UN Framework Convention on Climate Change**

Iran is a member country of the United Nations Framework Convention on Climate Change (UNFCCC) and in November 2015, submitted a new climate action plan to the UNFCCC, which presented a target for global warming gas emission reduction. The action plan cites “energy demand optimization and management” as one of its major technological requirements and “access to new and environmentally sound technologies for industrial production” to meet the requirement. In this sense, this project represents a positive test case for Iran to proceed with the action plan.

c) **Minamata Convention on Mercury**

Iran will ensure it phases out the use of mercury in the caustic soda chlorine manufacturing process under the supervision of the Department of Environment of Iran (DOE), which means the country will fulfill its obligations as a member of the Minamata Convention on Mercury.

d) **Employment**

Because of the provision of Article 5 of the Minamata Convention on Mercury, some caustic soda chlorine manufacturers will discontinue operation. However, the Abadan Petrochemical Company and the Kimiya Bandar Imam Company seek to convert the mercury method and continue manufacturing caustic soda, chlorine and related chemical products. This will boost employment in the cities of Abadan and Mahshahr and their surrounding areas.

(2) **Confirmation of environmental and social considerations**

In the event the business operator implementing the project obtains loans from any Japanese
financial institution, these institutions will examine the financial, economic and technological aspects of the project and confirm whether the project includes appropriate environmental and social considerations. These institutions and organizations have reference guidelines when confirming such environmental and social considerations. As a benchmark, Table 4.3-1 provides standards to confirm whether projects include sufficient environmental and social considerations.

Table 4.3-1 Standards for confirmation of appropriateness of the environmental and social considerations (Japan Bank for International Cooperation, JBIC)

<table>
<thead>
<tr>
<th>(1)</th>
<th>JBIC ascertains whether a project complies with the environmental laws and standards of the host national and local governments concerned, as well as their own environmental policies and plans.</th>
</tr>
</thead>
</table>
| (2) | JBIC also ascertains, regarding environmental and social considerations, whether the project meets the following standards:  
  - World Bank Safeguard Policies or  
  - International Finance Corporation (IFC) Performance Standards  
  In addition, if there is a relevant section of the Environmental, Health and Safety Guidelines (EHS Guidelines) of the World Bank Group, JBIC will confirm whether the projects meet that section. |
| (3) | Where appropriate, JBIC also refers to standards established by other international financial institutions, other internationally recognized standards, and/or standards or good practices established by developed countries such as Japan as benchmarks. If JBIC believes the environmental and social considerations of the project substantially deviate from these standards and good practices, it will consult with the host governments (including local governments), borrowers and project proponents to confirm the background and rationale for such deviation and measures to rectify it if necessary. |

Source: Japan Bank for International Cooperation Guidelines for Confirmation of the Environmental and Social Considerations (April 2015)

Moreover, Japan’s major private financial institutions have adopted the Equator Principles\(^\text{20}\). In the event that any project operator wishes to obtain a loan for its large-scale project\(^\text{21}\) from any Equator Principles financial institution (EPFI), the operator must satisfy ten principles of environmental and social considerations set forth under the Equator Principles, as listed in Table 4.3-2.

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\(^{20}\) The website of the Equator Principles: http://www.equator-principles.com/

\(^{21}\) Any project worth 10 million USD or more
### Table 4.3-2  Ten principles of the environmental and social considerations required under the Equator Principles

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>Review and Categorization</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>Environmental and Social Assessment</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>Applicable Environmental and Social Standards</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>Environmental and Social Management System and Equator Principles Action Plan</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>Stakeholder Engagement</td>
</tr>
<tr>
<td><strong>6</strong></td>
<td>Grievance Mechanism</td>
</tr>
<tr>
<td><strong>7</strong></td>
<td>Independent Review</td>
</tr>
<tr>
<td><strong>8</strong></td>
<td>Covenants</td>
</tr>
<tr>
<td><strong>9</strong></td>
<td>Independent Monitoring and Reporting</td>
</tr>
<tr>
<td><strong>10</strong></td>
<td>Reporting and Transparency</td>
</tr>
</tbody>
</table>


Accordingly, in the event that the Abadan Petrochemical Company intends to obtain project-related loans from JBIC or leading financial institutions of Japan, the company must include environmental and social considerations that meet the standards in Table 4.3-1 or the principles in Table 4.3-2 in relation to the dismantling and clearing of the caustic soda chlorine manufacturing
plant using the mercury method, measures against possible soil and groundwater mercury contamination and handling of mercury waste.

(3) Items for environmental and social considerations

In case the Abadan Petrochemical Company receives loans for the project from the Japan Bank for International Cooperation (JBIC), whether the environmental and social considerations are properly performed is confirmed using environmental checklists provided in the JBIC Guidelines for Confirmation of Environmental and Social Considerations. Table 4.3-3 shows the environmental checklists for the petrochemical sector.

Table 4.3-3 Environmental Items (for the Petrochemical Sector)

<table>
<thead>
<tr>
<th>Category</th>
<th>Environmental Item</th>
</tr>
</thead>
</table>
| 1. Permits and Approvals, Explanations | (1) ESIA and Environmental Permits  
(2) Explanations to the Public |
| 2. Anti-Pollution Measures | (1) Air Quality  
(2) Water Quality  
(3) Waste  
(4) Soil Contamination  
(5) Noise and Vibration  
(6) Subsidence  
(7) Odor |
| 3. Natural Environment | (1) Protected Area  
(2) Ecosystem and Biota  
(3) Topography and Geology |
| 4. Social Environment | (1) Resettlement  
(2) Living and Livelihood  
(3) Heritage  
(4) Landscape  
(5) Ethnic Minorities and Indigenous Peoples  
(6) Working Conditions (including occupational safety)  
(7) Community, Health, Safety and Security |
| 5. Other | (1) Impacts during Construction  
(2) Accident Prevention Measures  
(3) Monitoring |
| 6. Notes | (1) Reference to Checklists of Other Sectors  
(2) Notes on Using Environmental Checklists |
As described in Section 4.4, the construction of a new ion-exchange membrane plant is subject to the Environmental Impact Assessment system of Iran. The contents of approved EIA report are deemed to be mainly reflected in the columns confirming environmental and social considerations in the environmental checklists.

In terms of measures for pollution, the ion-exchange membrane method is an environmentally friendly process compared to the mercury method. However, when using hazardous substances in the new plant, the Abadan Petrochemical Company should examine alternative substances, reduce amounts in use, ensure treatment via wastewater treatment systems, etc., proper management of hazardous substances and other measures.

Since the new plant is constructed in an existing industrial area, deterioration of the natural and social environment is not considered when taking proper measures against pollution. Besides, the construction of new plant will assure employment by continuing caustic soda and chlorine manufacturing business.

In case that demolition and removal of a plant using the mercury method is included in the scope when confirming the environmental and social considerations of the project, the contents of the environmental management plan (EMP), as described in Section 4.4, are deemed to be mainly reflected in the columns confirming the environmental and social considerations in the environmental checklists.

4.4 Overview of laws related to environmental and social considerations and measures necessary to comply with the Laws

Iran established its Environmental Impact Assessment (EIA) system and industrial sectors to be covered by the same in 1994. The Department of Environment of Iran (DOE) is responsible for reviewing and approving EIA in these sectors. The EIA system covers any petrochemical complexes, regardless of size and according to DOE, the construction of a new caustic soda chlorine manufacturing plant will be subject to EIA. Dismantling and clearing of existing caustic soda chlorine manufacturing plant using the mercury method will not be subject to EIA, but an environmental management plan (EMP) prepared by the business operator will be examined by DOE.

The EIA report to obtain approval for constructing the new caustic soda chlorine manufacturing plant will be prepared by the business operator. With environmental and social considerations in mind, the report must include the following four items: (1) impacts on the physical environment, (2) impacts on the natural environment, (3) impacts on society and culture and (4) impacts on nearby development activities), as well as environmental and social impacts of business activities and measures to avoid, manage and mitigate such impacts.

The EMP report to obtain approval for dismantling and clearing the existing plant will also be prepared by the business operator. The report may well have to refer to safety and health measures
for workers engaging in dismantling, clearance and other direct operations of mercury-contaminated facilities; measures to prevent mercury contamination from diffusing; measures in case of soil and underground contamination; and an appropriate management plan for processing and treating mercury waste.

4.5 Matters to be borne by the recipient country (Implementing and other organizations)

Since responsibility for managing and disposing of mercury waste appropriately rests with the parties generating such waste, Abadan Petrochemical Company and Kimiya Bandar Imam Company will be required to store or dispose of mercury waste to be generated in future appropriately, if necessary, assisted by the Department of Environment of Iran (DOE), divisions in charge of health, safety and environment (HSE) within the company and other parties. According to DOE, no business in Iran engages in the disposal of mercury waste (extraction of mercury from mercury waste and its disposal). Therefore, if the mercury disposal process, including extraction of mercury from mercury waste and its disposal, is performed in Iran as in Japan, such a mercury waste disposal company must be established.
Chapter 5 Financial and Economic Feasibility

This Chapter involves examining the financial and economic feasibility of the Abadan Petrochemical Company.

5.1 Estimation of the project cost

Another survey must be conducted to consider the investment cost in detail. The following figures have been used to estimate the project cost at the Abadan Petrochemical Company:

- Scale of the new plant (on a chlorine basis)
  Because the new plant of Abadan Petrochemical Company will have annual production of 77,000 tons on a caustic soda basis, which is 70,572 tons on a chlorine basis.

- Investment cost at the time of conversion
  The investment cost per 1 ton of chlorine has been set at 600 USD/ton-Cl₂ in reference to data on chlor-alkali manufacturers having converted the mercury method to the ion-exchange membrane method.

- USD/JPY rate: 115 JPY/USD

Accordingly, the cost of constructing a new plant for the Abadan Petrochemical Company will be approximately 4.9 billion JPY (42 million USD).

5.2 Overview of the preliminary financial and economic analysis

This section gives details of the financial and economic analysis when converting the manufacturing method from mercury to ion-exchange membrane at the Abadan Petrochemical Company, the result of which is described in Section 9.3.

The cost of converting the manufacturing method of the caustic soda plant varies according to the extent to which existing machines are reused. The investment cost for converting to the ion-exchange membrane method from the mercury method is calculated as USD 500-700/ton-CI₂ referring to the following materials (USD 600/ton-Cl₂ is applied for the cash flow analysis).

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22 The data is based on a Project to Disseminate and Promote Global Warming Countermeasure Technology, “Energy-saving project for the manufacturing process of caustic soda & chlorine through brine electrolysis in Mexico and other Latin American countries”.

23 As of February 2017, the western Khuzestan Province, where the Abadan Petrochemical Company is located, is designated as an area where all travel is to be avoided (Level 3) in the Overseas Travel Safety Information of the Ministry of Foreign Affairs of Japan. It is therefore desirable to conduct a detailed field survey after security and safety conditions improve. 

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42
The Abadan Petrochemical Company is considering converting its manufacturing approach to the ion-exchange membrane method to process 77,000 tons of caustic soda. (30,000 ton/plant are processed with the current mercury method)

Using specifications given by the Abadan Petrochemical Company as far as possible, the prerequisites for economic analysis are as follows:

<Preconditions>
* Manufacturing method conversion cost: USD 52 million (77,000 ton/35.5 x40xUSD 600)
* Equipment invested: Conversion equipment and machines (ion-exchange membranes, electrolyzer, secondary brine refining system, transformer/rectifier, and caustic soda concentration unit), engineering, installation and construction costs
* Product sale price: USD 300/ton-NaOH
* Electric power consumption with mercury method: 3,300kw/NaOH
* Electric power consumption with ion-exchange membrane method: 2,100kw/NaOH
* Electric power unit price: USD 50/MWh
* Natural gas price: USD 100/1000m³
* Depreciation cost: 10 years
* Interest rate: 10%
* Debt : Equity: 70%:30%
* Tax: 25%

Currently, given the lack of operators handling mercury treatment in Iran, support from foreign business operators will be needed to implement the project. The cost required for mercury treatment and permanent storage is equivalent to EUR 2,000 per ton according to multiple European operators, including DELA of Germany. Although the investigation team did not visit the plants of the Abadan Petrochemical Company and confirm the situation in detail for safety reasons, the cost of mercury treatment must be included in the primary cost when implementing the project.
Chapter 6  Project Implementation Schedule

An implementation schedule was formulated for the new plant construction plan of the Abadan Petrochemical Company as shown in Figure 6-1. The blue arrows indicate the work flow from basic to detailed design, plant construction and operation. The red arrows indicate the survey, demonstration and monitoring, which require technological know-how on the Japanese side. The green allows indicates the schedule related to environmental and social considerations. Under the Minamata Convention, mercury method plants manufacture caustic soda and chlorine should be abolished by 2025. (The Department of Environment of Iran has instructed chlorine and alkali manufacturers to halt applying the mercury method for manufacturing them by 2020)

<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic design</td>
<td>Examination at the board meeting</td>
<td></td>
<td></td>
<td>Detailed design and plant construction</td>
<td>Operation (including trial operation)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Financial consideration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field detailed survey (data collection for basic design, etc.)</td>
<td></td>
<td>Preliminary survey for demonstration</td>
<td></td>
<td>Demonstration construction</td>
<td></td>
<td>Monitoring</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preparation of the EIA report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EIA approval procedures</td>
<td></td>
<td>Confirmation of environmental and social considerations by a financing institution*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Preparation of environmental check lists and conducting the field survey

Figure 6-1  Project Implementation Plan
Chapter 7 Implementation Capacity of the Iranian Executing Agency/Company

This Chapter describes the project implementation capacity of the Abadan Petrochemical Company and the Kimya Bandar Imam Company which plan to convert their manufacturing method at their caustic soda and chlorine plants to use ion-exchange membrane method (for the latter company, however, only its company outline is described). In addition, the organization and structure of the Department of Environment of Iran are also outlined, given its expected involvement in the abolishment of plants using the mercury method and the management, treatment and disposal of mercury waste handled by the aforementioned two companies.

7.1a Overview of the Iranian executing company (Abadan Petrochemical Company)

The Abadan Petrochemical Company was founded in 1966. The investment ratio of the company was 74% by the National Petrochemical Company (NPC) and 26% by BF Goodrich, a US material manufacturer. Following the Iran Revolution and recent privatization of affiliated NPC companies, the business is now a private company, in which domestic investment funds have stakes. The head office is located in Tehran city, while its petrochemical complex is in Abadan city, covering 50 ha. Major products include polyvinyl chloride (PVC), dodecylbenzene (DDB), caustic soda and chlorine.

<table>
<thead>
<tr>
<th>Table 7.1a-1 Outline of the Abadan Petrochemical Company</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Company name</strong></td>
</tr>
<tr>
<td><strong>Head office</strong></td>
</tr>
<tr>
<td><strong>Plant</strong></td>
</tr>
<tr>
<td><strong>Founded</strong></td>
</tr>
<tr>
<td><strong>Stakeholders</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Capital</strong></td>
</tr>
<tr>
<td><strong>Sales</strong></td>
</tr>
<tr>
<td><strong>Number of employees</strong></td>
</tr>
<tr>
<td><strong>Production items ('000t/y)</strong></td>
</tr>
</tbody>
</table>

Source: Data provided by the Abadan Petrochemical Company and EMIS Business Report

A view of the plant of Abadan Petrochemical Company is given as follows:

7.2a Iranian organizational framework for project implementation (Abadan Petrochemical Company)

Figure 7.2a-1 shows the organizational framework of the Abadan Petrochemical Company. The project for converting the manufacturing method to ion-exchange membrane is planned by the Engineering & Development Division while a project office will be newly established in the actual implementation.
Khuzestan Province is one of the sites for producing and developing crude oil in Iran, where Abadan Petrochemical Company is located. Industry using this crude oil and natural gas rose in Abadan city from the 1960s to 1970s, during which time the Company was founded and commenced operation. This makes the Company one of the oldest petrochemical complexes in Iran with long-term experience in operating chemical plants.

The Company has already started considering converting its manufacturing method to ion-exchange membrane and prepared conceptual design specifications for the project as described in Section 3.3. The field survey confirmed that the Company exchanged information with European suppliers as well as the Japanese study team.

Chlorine produced in parallel with caustic soda production is used as raw material for producing PVC in a downstream process at the Company complex. Since chlorine has become an important source of foreign currency revenue as the Company produces various grades of PVC, there are sufficient grounds for converting the manufacturing method to continue the caustic soda chlorine manufacturing project.

Accordingly, the Abadan Petrochemical Company is deemed to have sufficient capacity for implementing the project as (1) the company can operate a chemical plant at a certain level, (2) consideration of the project is substantially underway and a new project office is planned and (3)
there are sufficient grounds to confirm that the continuous implementation of caustic soda chlorine manufacturing project is a necessary business for the company.

7.1b **Overview of the Iranian executing company (Kimiya Bandar Imam Company)**

The Kimya Bandar Imam Company is a subsidiary of the Bandar Imam Petrochemical Company (BIPC), which comprises five subsidiaries. The operation of each subsidiary is shown in Table 7.1b-1. The predecessor to BIPC is the Iran-Japan Petrochemical Company (IJPC), the foundation of which was jointly invested in by a Japanese business operator (Iran Chemical Development Company: ICDC) and the National Petrochemical Company of Iran (NPC) in the 1970s.

<table>
<thead>
<tr>
<th>Companies</th>
<th>Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faravaresh Bandar Imam Company</td>
<td>Natural gasoline fractionation, olefin, aromatic series, paraxylene,</td>
</tr>
<tr>
<td></td>
<td>general facilities related</td>
</tr>
<tr>
<td>Kimya Bandar Imam Company</td>
<td>Salt refinement, chlor-alkali business, production of ethylene dichloride,</td>
</tr>
<tr>
<td></td>
<td>ethylene chloride monomer, and methyl tertiary butyl ether (MTBE)</td>
</tr>
<tr>
<td>Basparan Bandar Imam Company</td>
<td>Production of high density polyethylene, polypropylene, low density</td>
</tr>
<tr>
<td></td>
<td>polyethylene, polyvinyl chloride, and styrene butylene rubber</td>
</tr>
<tr>
<td>Abniroo Bandar Imam Company</td>
<td>Utility related</td>
</tr>
<tr>
<td>Kharazmi Bandar Imam Company</td>
<td>Maintenance &amp; non-base service</td>
</tr>
</tbody>
</table>

Source: BIPC

The Kimya Bandar Imam Company possesses 31 ha of plant premises and 1,550 ha of salt pans. Their plant is shown in Photo 7.1b-1.

Source: NPC (Complexes of Petrochemical Industry 2015)

Photo 7.1b-1 The Plant of the Kimiya Bandar Imam Company
7.1c  Overview of the Iranian executing agency (Department of Environment)

Established in 1971, the Department of Environment of Iran (DOE) is responsible for conserving and improving the environment, preventing and controlling environmental pollution or deterioration, which could impede the environmental balance and matters related to wild animals and aquatic organisms inhibiting territorial waters.

Since 2015, the Ministry of the Environment of Japan has conducted the Japan-Iran Environmental Policy Dialogue each year with DOE to discuss environmental conservation and improvement. JICA has also implemented projects related to natural environmental management, including the wetland ecological management project in cooperation with the DOE.

7.2c  Iranian organizational framework for project implementation (Department of Environment)

Figure 7.2c-1 shows the organizational framework of DOE. The Deputy Head of Human Environment comprises four sections: the National Center of Weather and Climate Change, the Water and Land Office, the Environmental Pollution Monitoring Office and the Environment Impact Assessment Office. The environmental items of the project include mercury waste management, mercury pollution, Environmental Impact Assessment (EIA), Environmental Management Plan (EMP) and reduction of greenhouse gas emissions. All these matters are of the Deputy Head of Human Environment. Management of mercury waste associated with abolishing and dismantling plants applying the mercury method is the responsibility of the Water and Land Office.

Since the project concerns the Minamata Convention on Mercury, which requires plants applying the mercury method to be abolished and proper management and disposal of mercury waste, the International Affairs and Conventions Center of DOE and the Planning and Budget Center will be involved in the project when Japan’s technical assistance and financial assistance provided to the Abadan Petrochemical Company via DOE are deemed effective schemes.
7.3c Capacity assessment and countermeasures of the Iranian executing agency (Department of Environment)

The Department of Environment of Iran (DOE) in the project has the role of examining and approving the EIA report concerning the new plant applying the ion-exchange membrane method and EMP for the use of mercury; both prepared by the Abadan Petrochemical Company. During the process of examination and approval, DOE can request that the Abadan Petrochemical Company conduct appropriate environmental and social considerations.

When Japan’s technical and financial assistance provided to the Abadan Petrochemical Company via DOE are deemed effective, the International Affairs and Conventions Center and Planning and Budget Center of DOE will be able to properly coordinate with the Japanese Government.
Chapter 8  Technological Superiority of Japanese Companies

8.1 Assumed scheme of participation by the Japanese private sector

The declaration of the final agreement concerning Iran’s nuclear development issue is expected to help boost the national business environment. At this moment, realistic schemes for the Japanese private sector to participate in the project targeting the Abadan Petrochemical Company are assumed to be EPC (Engineering, Procurement and Construction) or the provision of materials and equipment in which the technology of a Japanese company is used, such as ion-exchange membranes, electrolyzer secondary brine refining systems, transformers/rectifiers, and caustic soda concentration units) to an EPC contractor. Generally speaking, ion-exchange membranes, electrolyzers and other major equipment expected to be procured from Japan account for about 30% of the overall project budget.

As many view that the current diplomatic policy of the US for Iran will increase uncertainty, it is necessary to closely observe the situation to take a grasp of business environment in Iran.

8.2 Superiority of Japanese companies in the project implementation (technical and economic aspects)

(1) Technical aspect

Manufacturing a fluoropolymer ion-exchange membrane requires very high technology, which is why this product is only supplied by three companies: two Japanese (Asahi Glass Co., Ltd. and Asahi Kasei Corporation) and one American (Chemours Company). The American company takes its geographical advantage to expand its business in the North and Latin American markets. Since the establishment of basic technology in Japan in the 1970s, it has been still refined and improved. Figure 8.2-1 shows the data for the prototypes of next-generation ion-exchange membrane, which has been developed by Asahi Glass Co., Ltd.; indicating that the prototypes of next-generation membrane can operate stable at lower voltage compared to the current model.

(2) Economic aspect

As described above, since the prototypes of next-generation ion-exchange membrane can operate stable at a lower voltage than the current model, it is expected the reduction of electricity consumption.
Figure 8.2-1  Comparison of drive voltage and stability of ion-exchange membrane (current and next-generation models)

8.3 Necessary measures to encourage orders from Japanese companies

As described in Section 3.1 (3), there are only three manufacturers of the ion-exchange membrane used for caustic soda and chlorine manufacturing process: two Japanese companies and one US company. As the US’s sanctions against Iran continue, Japanese companies are deemed better placed than US companies to introduce ion-exchange membrane technology to Iran.

Ion-exchange membrane is introduced together with electrolyzers when constructing new caustic soda and chlorine manufacturing plants. Once electrolyzers using the ion-exchange membrane of a specific manufacturer have been installed, it is considered basically unfeasible to change it to units of another manufacturer in the same plant. Accordingly, Japanese manufacturers must continue strengthening partnership/relationship with electrolyzers manufacturers, research and development of ion-exchange membrane (enhancing the energy-saving effect, durability and stability, etc.) and highlighting their technology. At the same time, they should closely exchange information with partners or related electrolyzers manufacturers to know the demand for ion-exchange membranes so as to immediately respond to the demand. Moreover, establishing a field office or collaboration with a Japanese company (a related or trade company) will be effective to know the demand in a country such as Iran where the market is untapped and future growth is expected.

For those companies demanding financial support like the Petrochemical Company, proposing and providing such support from Japan will promote their orders with Japanese companies. The fundraising behind the project is described in Chapter 9.
Chapter 9  Prospect of Fundraising

9.1 Consideration of financing sources and fundraising plan

Significant capital investment is generally required to convert caustic soda and chlorine manufacturing methods but the loan interest of the current Iranian financing institutions (national commercial bank, national special bank, private commercial bank, etc.) is around 20% which is excessive. Accordingly, overseas financial support, especially in terms of fundraising, is important when examining project profitability prior to implementing the project.

(1) Use of public financing of Japan

To consider the viability of providing Japan’s public financing for the project, the survey team has engaged in discussion with the Japan International Cooperation Agency (JICA), Japan Bank for International Cooperation (JBIC), Nippon Export and Investment Insurance (NEXI) and other organizations.

a) JICA

In addition to Official Development Assistance (ODA) promoted by JICA such as Yen Loan and Grant Aid, JICA promote different category of supporting program so called Overseas Investment Loan which provide two aspects of service such as equity participation and loan toward to private sector business in developing country.

JICA’s overseas investment loan supports areas of (i) infrastructure and growth acceleration, (ii) SDGs and poverty reduction, and (iii) climate change countermeasures. Those projects are implemented in line with the development policy of the recipient government and with a high development effect but are difficult to implement funded by general financing institutions alone and also subject to its support.

Source: JICA website, https://www.jica.go.jp/topics/notice/20130215_01.html

Figure 9.1-1  Summary Comparison of Overseas Investment Loans and ODA Loans
b) JBIC

Regarding JBIC financial instruments, the use of buyer’s credit or a bank loan is considered, which presupposes a tied loan for the export of Japanese products to overseas. Other than this, JBIC offers loans to projects to introduce energy-saving facilities or preserve the environment by exploiting advanced environmental technologies (Global action for Reconciling Economic growth and Environmental preservation, or “GREEN”). This untied two-step loan scheme is indented for (1) projects with high earth-environment preservation effects, such as the effects of greenhouse gas emission reductions and (2) projects applying J-MRV (note) of the Global action for Reconciling Economic growth and Environmental preservation. As stated earlier, the electric power consumption rate of the ion-exchange membrane method is 30%-40% less than that of the mercury method and converting to the former paves the way for considerable energy saving. To implement GREEN, the project must seek private financing and formulate a loan and guarantee scheme under a JBIC untied loan.

(Note) JBIC’s method of Measurement, Reporting and Verification

Source: JBIC website, https://www.jbic.go.jp/ja/finance/untied-loan

Figure 9.1-2 JBIC Untied Loan Scheme

c) NEXI

Currently, the ceiling of each transaction under NEXI’s short term trade insurance limits to two billion yen with maximum usage of one year. However, in accordance with the “implementation of measures based on United Nations Security Council Resolution No. 2231 concerning Nuclear Issues of Iran” released on January 22, 2016 and approved at a Cabinet meeting the same year, NEXI has relaxed its policy to offer insurance and resumed insurance for medium- and long-term business. Accordingly, insurance schemes of NEXI are available for insurance policies of various types (export credit insurance, overseas unties loan insurance and overseas investment insurance) with
usance of two years or more. According to a comment from NEXI, however, they actually determine whether insurance is offered after appraising the amount, credit period, borrower, project feasibility, risk mitigation measures, etc. per project under their insurance policies.

(2) **Use of the financing mechanism of international organizations**

Besides public financing of Japan, the use of the financing mechanism of international organizations is also examined.

**a) Global Environment Facility (GEF)**

GEF is a trust fund of the World Bank; launched as an international financing mechanism and mainly providing grant aid to projects for global environmental issues. It comprises a partnership of 187 countries, including Japan and mainly supports activities intended to address global environmental issues by developed countries and countries with a transitional economy. The five conventions relevant to the environment, including mercury measures, benefit from this support: the United Nations Framework Convention on Climate Change, Convention on Biological Diversity, United Nations Convention to Combat Desertification, Stockholm Convention on Persistent Organic Pollutants (POPs Convention) and Minamata Convention on Mercury.

**b) Green Climate Fund (GCF)**

GCF is a multilateral fund for which the operation of a funding system based on the United Nations Framework Convention on Climate Change (UNFCCC) was commissioned to support efforts to reduce (mitigate) greenhouse gas emissions and cope with (adapt to) the impact of climate change. The Government of Japan contributes 1.5 billion dollars to GCF following a 3 billion dollar donation from the US and has also helped GCF operate as a board and alternate board member at the Board; its highest decision-making body. Accordingly, the proposal for made-in-Japan products and Japanese technologies equating to effective climate change countermeasures using GCF is worth examining.

**c) Climate Technology Centre and Network (CTCN)**

In the project implementation, the Climate Technology Center and Network (CTCN) established under the UNFCCC is also deemed usable for providing technical support, including capacity building, a feasibility study for assessing the project to convert the manufacturing method to one using ion-exchange membranes and other efforts.

An image of financial and technical support mechanisms is shown in Figure 9.1-3.
(3) Joint Crediting Mechanism (JCM)

JCM is striving to reduce greenhouse gas emission via cooperation between Japan and developing countries and share the result of such reduction. As well as boosting global warming countermeasures by disseminating excellent low-carbon technologies to developing countries, it is a mechanism properly evaluating Japan’s contribution to reduce greenhouse gas emissions and other measures and is utilized to achieve the reduction target of Japan. 17 countries have already signed up to the mechanism, while Japan has discussed joining the mechanism with other countries and also striven to expand the partner countries, according to the latest information provided on the website of the Ministry of Foreign Affairs, Japan. Survey feedback from related organizations revealed that the Iranian Government had a high interest in JCM.
Figure 9.1-4  JCM financed project scheme

9.2 Feasibility of fundraising

(1) Public financing of Japan

The petrochemical sector has been promoting the privatization of government-owned companies, including the Abadan Petrochemical Company covered by this survey. The majority of shares in the Abadan Petrochemical Company are held by the Tamin Petroleum & Petrochemical Investment Company, which, in turn, is majority-owned by the Social Security Investment. This project can be expected to receive the financing required to import equipment, etc. from Japan by the Abadan Petrochemical Company, or implement a project to introduce an energy-saving system or a project of the Global action for Reconciling Economic growth and Environmental preservation leveraging advanced environmental technologies. Accordingly, it is desirable to use JBIC’s export loan (buyer’s credit and bank loan), GREEN or NEXI.

Discussions concerning the operation of a financing facility between Japan and Iran are underway in accordance with the memorandum of cooperation (MOC) concerning the establishment of a financing facility and Iran’s provision of a sovereign guarantee, signed on February 5, 2016, by the

Source: Global Environmental Centre Foundation of Japan
Minister of Economy, Trade and Industry of Japan, the Minister of Economy and Finance of Iran and representatives of NEXI and JBIC. (as the discussion is expected to focus on export bank loans, GREEN, one of the project development loans, is not included in the discussion at present)

Table 9.2-1 Key points of MOC concerning the establishment of a financing facility and Iran's provision of sovereign guarantee

<table>
<thead>
<tr>
<th>Point</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>JBIC and NEXI will establish a financing facility, up to USD 10 billion JPY equivalent, which will be provided to projects with Japanese involvement in Iran.</td>
</tr>
<tr>
<td>(2)</td>
<td>The Ministry of Economic Affairs and Finance of Iran will provide a sovereign guarantee for the financing facility.</td>
</tr>
<tr>
<td>(3)</td>
<td>The Trade and Investment Working Group under the Japan-Iran Cooperation Council (bilateral governmental dialog framework) will recommend specific projects for this facility as necessary.</td>
</tr>
<tr>
<td>(4)</td>
<td>The terms and conditions for each financing will be subject to satisfactory due diligence for each project and a credit assessment by JBIC and NEXI.</td>
</tr>
<tr>
<td>(5)</td>
<td>Japan and Iran will endeavor to facilitate and implement projects which help enhance the economic relationship between the two countries.</td>
</tr>
</tbody>
</table>


In using NEXI, a deferred payment can be considered with general trade insurance for medium- and long-term business by taking risk mitigation measures, etc. (credit protection scheme via foreign currency transactions and the escrow account). According to a comment from NEXI, however, they actually determine insurance offers after appraising the amount, credit period, borrower, project feasibility and risk mitigation measures, etc. by project under their insurance policies.

At present, the Abadan Petrochemical Company supplies caustic soda - chlorine to the domestic market, but if it expands the sales channel to the foreign markets and secures stable revenues in foreign currency via, for example, long-term product supply contracts, options of fundraising, including NEXI, will increase.

(2) Financing mechanism of international organizations

From the perspectives of following the Minamata Convention by withdrawing from the mercury method or converting to other manufacturing methods and reducing greenhouse gas emissions by converting to the ion-exchange membrane with a high energy-saving effect, the use of GEF and GCF can be considered, respectively. Since both systems are operated by international organizations, it is
deemed desirable for a private company like Abadan Petrochemical Company to examine the scope for using the system with the support and advice of Iranian governmental organizations.

(3) Joint Crediting Mechanism (JCM)

According to the country report summarized by the UNFCCC in 2014, the CO2 emission quantity of Iran ranked ninth worldwide. Given the outstanding emission quantity in the power and petrochemical sectors, there is significant potential for JCM to make a contribution. Although Iran is not currently a JCM partner country, feedback from related ministries suggests that the Department of the Environment of Iran has a high interest in JCM, which means progress in future discussions between Japan and Iran is expected. As described, CO2 reduction of around 30% to 40% is expected by converting from the mercury method to the ion-exchange membrane method and the project to convert the manufacturing method will become applicable as a JCM project when Iran becomes a JCM partner country.

(4) Boosting the fundraising capacity by increasing the project value

Caustic soda and chlorine are generally usable for various purposes and subject to intense price competition, which will hinder efforts to obtain a high project return. With this in mind, measures to enhance the fundraising capacity can be considered, for example (i) developing overseas markets where foreign currency can be stably earned and (ii) producing high-value-addition products; using caustic soda and chlorine to boost the project value and return.

An example of (i) can be shown based on the fact that Euro Chlor, which controls the European chloralkali industry, advised the industry that plants using the mercury method would be abolished by the end of 2017 and this was expected to prompt the closure of some smaller-sized producers with insufficient financial resources in Europe, subsequent industry reorganization and adjustment of production and pricing. In this respect, leveraging the information network of a manufacturer with a global network with trade companies and the industry is deemed to play a key role in developing the market.

Regarding (ii), a concrete example of a high-value-addition product made from caustic soda is high absorbent polymer (with sodium polyacrylate as a mainstream material) which is used for disposable diapers. A Japanese chemical manufacturer provides almost all the raw materials, such as polyacrylic acid, which is the major raw material for highly absorbent polymer, as well as caustic soda and crosslinking agents by its own products. It is believed that there is potential for Japanese companies to provide advice and suggestions from such perspective.

As above, by increasing the value and profitability of the project, a wider scope of fundraising under favorable conditions will be possible, including attracting private funding.
9.3 Cash-flow analysis

An economic analysis was conducted on converting the manufacturing method to the ion-exchange membrane method at Abadan Petrochemical Company, in accordance with the prerequisites described in Section 5.2. The results are shown in Table 9.3-1.

<table>
<thead>
<tr>
<th>Payback period (years)</th>
<th>NPV (million USD)</th>
<th>IRR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.3 years</td>
<td>0.6</td>
<td>9.72%</td>
</tr>
</tbody>
</table>

The payback period in this case is 11.3 years, which is on a par with any other standard payback period in the sector. The price of caustic soda adopted as a prerequisite in this survey, 300 USD/ton, is also reasonable compared to long-term price trends and the actual price may well rise in future, which will boost the profitability of the project. Meanwhile, Euro-Chlor, an organization representing the chlor-alkali industry in Europe, is moving toward a phase-out of mercury cell technology by the end of 2017, which may force some small European producers lacking sufficient funding out of business and consequently affect the production level and prices in the sector.
Chapter 10  Issues for the Project Implementation and Future Measures to be Taken

10.1 Current efforts made by Japanese enterprises to implement the project

Two issues for the project implementation are currently identified as follows:

- Considerations of relevant laws and regulations concerning Iranian transactions
- Financing

(1) Considerations of relevant laws and regulations concerning to Iranian transactions

Matters to be taken into consideration in Iranian transactions are described as follows:

(i) Export Trade Control Order of Japan
(ii) The US Export Administration Regulations (EAR) provided by the US Bureau of Industry and Security (BIS)
(iii) Economic sanctions against Iran (particularly the trend of US sanctions over Iran)
(iv) Overseas travel safety information

Considering the actual transactions, careful investigation and data collection must be carried out with regard to each matter before implementing the project.

(2) Financing

a) Public financing of Japan

An export credit (buyer’s credit, bank loan) or GREEN loan of JBIC is assumed as a possible finance facility to implement the project; the former is a tied loan but the latter an untied loan and as well as continuously highlighting energy saving and other technical superiority of Japanese products, data on the price range of European manufacturers’ product for the Iranian market should be collected.

b) International financing mechanism for the environment protection

Generally speaking, the private sector lacks sufficient information about the international financing mechanisms and systems and how they are operated and utilized. Therefore, comprehending local needs and broadly introducing to the Iranian private sector about GEF, GCF and other international financing mechanism as financing tools corresponding to such needs are deemed to eventually contribute to successful sales activities for Japanese suppliers. In this respect, Asahi Glass Co., Ltd., a member of this survey, will proactively participate in various international conferences related to mercury regulations to disseminate and showcase Japanese technologies and
collect information about each country’s response to mercury issues. At the same time, it will also continue to participate in various international conferences; leveraging its expertise as an ion-exchange membrane manufacturer to build and strengthen relationships with international and governmental organizations, investigate the potential for fundraising applicable to the project in a multidimensional way and provide feedback to relevant customers and ministries of Iran. The following shows the major activities Asahi Glass carried out in 2016:

**INC (Seventh session of the intergovernmental negotiating committee on mercury)**

1. **Period:** March 10-15, 2016  
2. **Venue:** King Hussein Bin Talal Convention Center (Jordan)  
3. **Activity:**  
   - Building a relationship with governmental officials (Iranian government, UN organizations, the Ministry of the Environment of Japan)  
   - Technology for converting the mercury method in developing countries  
   - Introduction of the scheme of Feasibility Study

**Global Mercury Partnership, Expert Group Meeting (EGM) on elimination of the use of mercury in chlor alkali chemical processes**

1. **Period:** June 28 to July 1, 2016  
2. **Venue:** UNIDO Headquarters (Austria)  
3. **Purpose:**  
   - Presentation on ion-exchange technology (requested by the Ministry of the Environment of Japan)  
   - Interview with UNIDO Headquarters officials

**Global Mercury Partnership, Expert Group Meeting (EGM) on the Mercury Supply and Storage partnership area**

1. **Period:** October 25 to 26, 2016  
2. **Venue:** Ministry of Agriculture, Food and Environment of Spain  
3. **Purpose:**  
   - Sharing issues in the Supply and Storage partnership (SS partnership) (on how to manage and dispose of residual mercury generated by converting the mercury process in the chlor-alkali area.)  
   - Case study on chlor-alkali area in Spain and Uruguay (sharing cases of provisional management and final disposal of residual mercury)  
   - Confirmation of the importance of financing the costly management and disposal of residual mercury and disposal of mercury waste
c) **Joint Crediting Mechanism (JCM)**

Feedback from relevant ministries revealed that the Government of Iran has a great interest in JCM, even though Iran is not currently a JCM partner country. Referring to a past case in which a subsidy program of the Ministry of the Environment of Japan was implemented in a non-partner country, it is deemed possible to consider similar activity in Iran as well as preparing for future development through FS support, etc.

**d) Boosting the fundraising capacity by enhancing the project value**

The development of overseas markets, as examined in Section 9, is deemed possible collaboratively by the trade company, etc. leveraging its distribution and network functions and remaining open to market demands to provide information to the Iranian side. Meanwhile, introducing and matching Japanese manufacturers which are highly motivated to participate in the Iranian market may support and boost the use of high-value-addition of caustic soda and chlorine products.

10.2 **Efforts made by Iranian governments and executing agencies to implement the project**

(1) **Efforts for financing**

The Abadan Petrochemical Company needs to appeal to the Iranian Government and major banks for guarantees. To diversify financing, it should also strive to seek the possibility of long-term overseas supply contracts to earn foreign currency.

The Abadan Petrochemical Company should enhance its competitiveness, given that manufacturing of high-value products is considered one way to win such long-term contracts.

(2) **Efforts in the environmental sector**

Iran is a signatory to the Minamata Convention and the Department of Environment of Iran has instructed chlorine and alkali manufacturers using the mercury method to halt using the method by 2020. However, the Iranian Government currently lacks a scheme for supporting the manufacturing conversion from mercury method to ion-exchange membrane method and each company implements projects with their own financing. Some companies operate plants with the mercury method, like the Abadan Petrochemical Company, which cannot allocate all project funds under its own efforts. Accordingly, a support scheme is deemed required for the Iranian Government. Further, while proper management or treatment and disposal of mercury waste is needed when implementing the project, there are currently no business operators handling mercury treatment in Iran. Accordingly, mercury waste treatment/disposal companies should be developed in accordance with the situation and this point was raised as a question at a debriefing session for the Department of Environment of Iran. In response, it was reaffirmed that there are mercury recycling companies in Japan which import and
treat both domestic and overseas mercury waste in line with the international convention. In addition, the study team explained how Japan could contribute to Iran in the area of mercury waste management, treatment technologies, etc. as the Minamata Convention stipulates that developed countries should support proper mercury waste management in developing countries (Attachment-2 was used for the explanation.).

10.3 Legal and financial limitations in Iran

(1) Financial limitations

Since the target of the project, the Abadan Petrochemical Company, is a private company, the project implementation will not be directly affected by the financial constraints imposed on the Iranian Government. Provided that, however, the Iranian Government should guarantee the use of JBIC export loan (buyer’s credit and bank loan). In this respect, priority areas and management of external debt balance and debt framework of the Iranian Government are expected to affect the project implementation.

(2) Limitation on environmental management

Iran is a signatory to the Minamata Convention and the Department of Environment of Iran has instructed chlorine and alkali manufacturers using the mercury method to halt doing so by 2020. The fact that the mercury method has no environmental, health and operational advantages, as described in this report, as well as the principle of the market mechanism, has also been driving the conversion of the manufacturing method. As described in Section 4.4, the construction of caustic soda chlorine manufacturing plants applying the ion-exchange membrane method is subject to EIA. Accordingly, the Abadan Petrochemical Company should take the necessary procedures based on the EIA system of Iran. Considering further progress of mercury regulations on a global scale, laws related to mercury management are also expected to be further developed in Iran; initiated by the Department of Environment of Iran (DOE). In accordance with the legal development, therefore, the Abadan Petrochemical Company and the Kimiya Bandar Imam Company will have to manage mercury properly and complying with laws and regulations.

10.4 Items to be analyzed in further detail

The Study team did not visit the plants of the Abadan Petrochemical Company for safety reason, and no concrete and detailed field survey on the status of operating plants and diversion of existing machines has yet been completed. Diversion of existing plants and machines should therefore be confirmed and decided at the basic design phase before implementing the project.
**Conclusion**

This Survey investigates the potential to disseminate the fluoropolymer ion-exchange membrane, a technology in which Japan leads the world, as part of a study on the project to determine an efficient caustic soda chlorine manufacturing method in Iran. The survey confirmed that the Abadan Petrochemical Company, the main target, was converting its manufacturing method from mercury, as at present, to the ion-exchange membrane at their plant and simultaneously planning to boost production. During the discussion with the company, their trust in and expectation of Japanese technologies also emerged and their strong request for financial support was expressed.

Regarding the financing for the project implementation, the feasibility and issues of public financing of Japan and international financing mechanism were verified and high-value additions\(^{25}\) to caustic soda and chlorine products was recommended as measures to boost their financing ability. There seems to be room in particular for Japanese companies to help boost the high-value addition to products by extending their technology and know-how.

Given the current lack of domestic companies or facilities\(^{26}\) to treat mercury waste generated from caustic soda chlorine manufacturing plants in Iran, storage of such waste is usually incumbent on each operator. Moreover, given the limited number of facilities handling various types of mercury waste worldwide\(^{27}\), awareness-raising of mercury waste and support for the treatment and disposal of the same are areas in which Japan can contribute to Iran\(^{28}\).

It was remarkable achievement that we could build relationships with the Iranian petrochemical industry and the Department of Environment of Iran (DOE), throughout the survey. Despite the very limited direct effect of implementing the project on a stable energy supply in Japan, it is believed that implementing the project and Japan’s support to Iran, as aforementioned, will help expand the business expansion of the Japanese private sector and enhance bilateral relations through economic activities, thus boosting the long-term and stable energy supply in future as one of the national policies.

\(^{25}\) During the discussion at the field survey, Kimiya Bandar Imam Company / Bandar Imam Petrochemical Company also expressed considerable interest in Japan’s high-value-added chemical products besides the ion-exchange membranes of Japanese manufacturers.

\(^{26}\) According to the Department of Environment of Iran (DOE), there is a micro enterprise which recovers and treat fluorescent lamps. However, whether it also recovers mercury remains to be seen.

\(^{27}\) It is assumed that a few companies have facilities which can deal with various mercury wastes, and only two companies exist, one is in Japan and the other is in Spain, as far as we know.

\(^{28}\) At the reporting session with Iranian stakeholder organizations, the Department of the Environment of Iran expressed their strong demand to boost awareness of mercury waste management and Japan’s support for hazardous waste management and treatment, including mercury waste.
Attachment-1

Explanatory Material about Ion-Exchange Membrane Technology for Iranian Executing Agency/Company
Technical considerations from transformation of Mercury cell to non – mercury technologies in the Chlor – Alkali Industry

**Ion-Exchange Membrane Technology**

“Flemion®”

ASAHI GLASS CO., LTD.

September, 2016

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**Today’s Topics**

- Company overview
- Basics of Chloro alkali electrolysis
- Introduction of Flemion History
  - 40th Anniversary since IM technology developed
- The Key Membrane : F-8080 series
  - Low voltage and proven stability
- New Generation of Flemion
Today’s Topics

- Company overview
- Basics of Chloro alkali electrolysis
- Introduction of Flemion History
  - 40th Anniversary since IM technology developed
- The Key Membrane: F-8080 series
  - Low voltage and proven stability
- New Generation of Flemion

Company Overview as of 2014

- Name: ASAHI GLASS Co., Ltd. (Global brand AGC)
- MITSUBISHI Group Company
- HQ: Tokyo JAPAN
- Founded: 1907
- Employee: 51,000 (Consolidated)

AGC Glass plant São Paulo

Glass: 53%
Chemicals: 22%
Display Electronics: 23%
Others: 2%

Total Net Sales: US$ 11.2 billions as of 2014
Chemicals Business

- Fluorinated resins
- Fluoro ion-exchange membrane
- Non-mercury technologies
- Water and oil repellents
- Pharmaceutical and agrochemical intermediates
- Iodine-related materials
- Battery materials

Chlor-alkali & urethane
Basic and commodity chemicals
Sales 196.0 bn yen

- Caustic soda / chlorine
- Raw materials for vinyl chloride polymer
- Urethane
- Gases
- Solvents, etc.

AGC Group’s Chlor-Alkali Production site

The largest Chlor-Alkali Producer in Asia!
Today’s Topics

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What is brine electrolysis?

Brine
Sodium Chloride solution
(NaCl, H₂O) → Electrolysis

Chlorine (Cl₂)
Caustic soda (NaOH)
Hydrogen (H₂)

Global Caustic soda market size
approx. 80mil.Mton/year
Important chemicals in daily life

- Caustic soda (NaOH)
- Chlorine (Cl₂)
- Hydrogen (H₂)

Used in various industries!

Production technology: Electrolyzers

**Conventional**
- Mercury method: ~3300 kWh/ton NaOH
- Diaphragm method: ~3000 kWh/ton NaOH

**New**
- Ion exchange method: ~2300 kWh/ton NaOH

Benefits from conversion:
- Reduction in hazardous chemical substances (mercury, asbestos)
- Reduction in consumed energy (approximately 26-30%)
Energy efficiency comparison

Transition of Caustic Soda production method in Japan

Source: Japan Soda Industry Association

Today’s Topics

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AGC’s Flemion™

Flemion™
Fluoropolymer Ion-Exchange Membrane

AGC Group is the first company in the world to complete conversion to ion-exchange membrane method, at all its caustic soda production bases.
The Background of Membrane Technology

Minamata Disease Strong Needs of New Process
Prohibition of Mercury No Hg / High Quality / Less Energy

1973

The Background of Membrane Technology

Minamata Disease Strong Needs of New Process
Prohibition of Mercury No Hg / High Quality / Less Energy

Technology Held in AGC at That Time

Electrolysis Process
AGC Original Electrolyzer

Fluorochemicals
Laboratory at that Time

Hydrocarbon Membrane
Production Machine

New Electrolysis Process by Fluorinated Ion Exchange Membrane
### Start Year of Commercial IM Electrolyzer

**1975**

2015 is 40th Anniversary

---

### History of Flemion

<table>
<thead>
<tr>
<th>Year</th>
<th>Key word for development</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>Carboxylic base</td>
</tr>
<tr>
<td></td>
<td>Carboxylic membrane(Single Layer)</td>
</tr>
<tr>
<td></td>
<td>Hydrophilic Surface,(Two Layer)</td>
</tr>
<tr>
<td></td>
<td>Reinforcement Cloth, Multi Layer</td>
</tr>
<tr>
<td></td>
<td>IM for High Conc. producing</td>
</tr>
<tr>
<td>1980</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>Sulfonic base</td>
</tr>
<tr>
<td>1995</td>
<td>Sulfonic Base Membrane</td>
</tr>
<tr>
<td>2000</td>
<td>Low Voltage</td>
</tr>
<tr>
<td>2005</td>
<td>High Strength</td>
</tr>
<tr>
<td>2010</td>
<td>F-8000Series</td>
</tr>
<tr>
<td>2015</td>
<td>F-8020SPSeries</td>
</tr>
<tr>
<td>2020</td>
<td>F-8080Series</td>
</tr>
</tbody>
</table>

- **Next Generation**
- **Future Generation**

---

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- Attachment 1 -
Today’s Topics

- Company overview
- Basics of Chloro alkali electrolysis
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What are the needs for a membrane?

Good Profitability Operation

- Energy efficiency
  - Low Voltage
  - Current efficiency (CE)
- Stable operation
  - Stable Performance
  - High Resistance against Impurities
- Long life membrane
  - High Durability against Blistering
  - High Durability against Pinching between electrode
- Product quality (Lower impurities)
  - High Quality of Products (Low NaCl/NaOH)
  - etc

AGC Glass Co., Ltd. All rights reserved. 2015
Development in Each Position

- Low Voltage
- Resistance to Impurity
- Wider Operating Window
- High Temp
- Low Temp
- Membrane Supplier
- Operating Condition
- Pure Brine

Developments of Flemion

- Higher durability against impurities
- High stability of CE
- Lowest and stable CV

F-808X

F-8020 SP & F-8051

F-8000 Series

Membrane for NaOH Production

Attachment 1
Lineup of new Membranes

<table>
<thead>
<tr>
<th>R&amp;D Development Name</th>
<th>Type</th>
<th>Current Density (kA/m²) (*)</th>
<th>Cl- in NaOH</th>
<th>Current Efficiency (Initial, expected)</th>
<th>Voltage at same CD</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-8080</td>
<td>S/P</td>
<td>7 &gt;</td>
<td>medium</td>
<td>approx. 97%</td>
<td>lowest</td>
</tr>
<tr>
<td>F-8080HD</td>
<td>S/P</td>
<td>6 &gt;</td>
<td>low</td>
<td>approx. 97%</td>
<td>medium</td>
</tr>
<tr>
<td>F-8081</td>
<td>P</td>
<td>medium</td>
<td>approx. 97%</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td>F-8081HD</td>
<td>P</td>
<td>low</td>
<td>approx. 97%</td>
<td>medium</td>
<td></td>
</tr>
</tbody>
</table>

S/P: Sacrificial Fiber & Permanent Fibers
P: Permanet Fibers only (approx. 50% higher mechanical strength)
(*) Depending on Electrolyzer Types and Operating Conditions

Voltage Stability in AGC Plant (Bipolar)

Asahi Glass Chiba (F-8080, UHDE G5)

Voltage makes almost flat line for 2.5 years.
Comparison of cell Voltage F-8080 vs. other’s

<table>
<thead>
<tr>
<th>Electrolyzer type</th>
<th>Cell voltage</th>
<th>Comparison</th>
<th>Current density</th>
<th>Current efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>CEC n-BITAC</td>
<td>3.03V</td>
<td>-70mV(vs. Comp.-1)</td>
<td>6.2kA/m²</td>
</tr>
<tr>
<td>J</td>
<td>CEC n-BITAC</td>
<td>-</td>
<td>-70mV(vs. Comp.-1)</td>
<td>6.5kA/m²</td>
</tr>
<tr>
<td>K</td>
<td>CEC i-BITAC</td>
<td>-</td>
<td>-50mV(vs. Comp.-1)</td>
<td>5kA/m²</td>
</tr>
<tr>
<td>M</td>
<td>CEC n-BITAC</td>
<td>3.02V</td>
<td>-65mV(vs. Comp.-1)</td>
<td>5.5kA/m²</td>
</tr>
<tr>
<td>N</td>
<td>CEC i-BITAC</td>
<td>2.98V</td>
<td>-60mV</td>
<td>5.3kA/m²</td>
</tr>
<tr>
<td>O</td>
<td>CEC i-BITAC</td>
<td>3.0V</td>
<td>-50mV</td>
<td>5.5kA/m²</td>
</tr>
</tbody>
</table>

F-8080 is 50~80mV lower cell voltage than competitor’s membrane

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Further Low Voltage

Unit: mV at 6 kA/m²


F-8020  F-8020SP  F-8080  F-8080A  Next Generation

Voltage decrease

Fx-XXX

-30 ~ -50 mV

Resistance to Impurity

Next Generation: Higher resistance to l/Ba

6 kA/m², 80 °C, l/Ba=20/1 ppm

98
97
96
95
94
93
92

DOL after addition

AGC

Attachment-1
**Target of New Generation**  V.S F-8080, F-8080A

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>-30~ -50 mV at 6 kA/m²</td>
</tr>
<tr>
<td>CE</td>
<td>Higher</td>
</tr>
<tr>
<td>Resistance to I/Ba</td>
<td>More Durable</td>
</tr>
<tr>
<td>Resistance to Ca</td>
<td>Same Durability</td>
</tr>
<tr>
<td>Wider Operating Window</td>
<td>Wider Temperature</td>
</tr>
<tr>
<td>Durability</td>
<td>Same or More</td>
</tr>
</tbody>
</table>

New Generation will be released in Q3 2016.

---

**Road Map to Future Generation**

Present  Future

- **F-8080 Series**
- **Next Generation**
  - **Target**: Lower Voltage: -30 ~ -50 mV
- **Future Generation**
  - **Target**: Lower Voltage: -?? mV
Thank you for your attention

ご清聴ありがとうございました
Attachment-2

Explanatory Material about Mercury Waste Management for Department of Environment of Iran
Information Exchange & Vision in the Future on Mercury Waste Management

February, 2017

Contents

1. Minamata Convention on Mercury
2. Mercury Wastes from Mercury Chlor-alkali Plants
3. Mercury Treatment in Japan
4. Japan’s Support for Iran
5. Vision in the Future
1. Minamata Convention on Mercury

Minamata Convention on Mercury

Current status *1 (As of February 1, 2017)

- Number of Signatories: 128*2 nations
- Number of Parties: 36 nations

The Convention will become effective 90 days after it has been ratified by 50 nations.

*1 Source: [http://www.mercuryconvention.org/Countries](http://www.mercuryconvention.org/Countries)

*2 Iran signed in 10 October, 2012.
Organization Framework of DOE

Outline of Minamata Convention

<table>
<thead>
<tr>
<th>Item</th>
<th>Outlines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>- Hazards of mercury, criteria on lessons from Minamata disease</td>
</tr>
<tr>
<td>Introduction</td>
<td>- Purpose and definitions</td>
</tr>
<tr>
<td>Supply and trade</td>
<td>- Closure of mercury mines within 15 years of the Convention entering into force</td>
</tr>
<tr>
<td></td>
<td>- Regulation of the import and export of mercury</td>
</tr>
<tr>
<td>Product and production processes</td>
<td>- Prohibition of production and import/export of mercury compounds</td>
</tr>
<tr>
<td></td>
<td>- Prohibition of chloralkali production and methylmercury production, for which mercury is used as a catalyst</td>
</tr>
<tr>
<td></td>
<td>- Exclusions when requested by party states</td>
</tr>
<tr>
<td>Small-scale gold mining and reprocessing</td>
<td>- Reduction of mercury and mercury compounds, and release into the environment (amnesiation of use, where possible)</td>
</tr>
<tr>
<td></td>
<td>- Eliminating the diversion of mercury and mercury compounds for use in small-scale gold mining</td>
</tr>
<tr>
<td>Emissions and releases</td>
<td>- Reducing emissions by applying the best technology available/best practices for the environment</td>
</tr>
<tr>
<td>Inventory storage</td>
<td>- Environmentally sound management of mercury in accordance with the guidelines, etc. prepared at the Conference of the Parties</td>
</tr>
<tr>
<td>Storage, disposal, etc.</td>
<td>- Safe management taking the guidelines of the Basel Convention into consideration</td>
</tr>
<tr>
<td>Financial and technical support</td>
<td>- Creation of a funding mechanism which supports capacity development and technical assistance, etc. of developing countries</td>
</tr>
<tr>
<td>Dissemination, awareness, research, etc.</td>
<td>- Information sharing, information for the public, awareness and education, research, development, monitoring, an implementation plan, report and assessment of effectiveness</td>
</tr>
</tbody>
</table>

Source: Ministry of the Environment, Japan (partially edited by the Survey Team)
Chlor-alkali Processes using Mercury
Minamata Convention on Mercury
Annex B (Article 5, paragraph 2)

Chlor-alkali production using mercury is phased out in 2025.

Source: Mercury Environmental Contamination in Iran by Dr. Ghaemian, University of Tehran at the Iran-Japan Technical Cooperation Mercury Workshop, Tehran, Feb. 15-16, 2010

Current Situation of Mercury Chlor-alkali Plants

- **Abadan Petrochemical Co.**
  Plan to change the process and project planning is under progress.

- **Kimya Bandar Imam Petrochemical Co.**
  Mercury process has already been shut down and ion-exchange membrane project is under progress.

- **Shiraz Petrochemical Co.**
  Plant has been shut down and no plan for future operation both by old and new process.
Comparison of Mercury method & Ion-exchange method

(in the case of a caustic soda manufacturing plant with production capacity of 77,000 tons)

<table>
<thead>
<tr>
<th></th>
<th>Mercury method</th>
<th>Ion-exchange membrane method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric power consumption rate</td>
<td>3,300</td>
<td>2,100</td>
</tr>
<tr>
<td>(kWh/t-100% NaOH)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual electric power consumption</td>
<td>254.1</td>
<td>161.7</td>
</tr>
<tr>
<td>of caustic soda production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(GWh/year)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduction in annual electric power</td>
<td>—</td>
<td>92.4</td>
</tr>
<tr>
<td>consumption compared to mercury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>method (GWh/year)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduction in annual CO₂ emissions</td>
<td>—</td>
<td>61,446</td>
</tr>
<tr>
<td>compared to mercury method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Ton/year)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of hazardous material</td>
<td>Yes (mercury)</td>
<td>No</td>
</tr>
</tbody>
</table>

The CO₂ emission coefficient is set at 0.665 t-CO₂/MWh, which is an average of the OM and DM emission factors in 2016 published by the Ministry of Science, Technology and Innovation (MCTI). Steam for concentration of caustic soda has been converted to electric power and added to electrolysis power, whereby steam of 1 ton is converted at the rate of 200A/MWh.

2. Mercury Wastes from Mercury Chlor-alkali Plants
Definition of Mercury Wastes

Minamata Convention on Mercury
Article 11, paragraph 2

(a) Consisting of mercury or mercury compounds

(b) Containing mercury or mercury compounds

(c) Contaminated with mercury or mercury compounds

Mercury Wastes from Mercury Chlor-alkali Plants

- Mercury Wastes that are discharged by operation and stored

- Mercury Wastes discharged by the demolition of Mercury Cell
  - Mercury
  - Brine Mud
  - Facilities contaminated by Mercury
  - Buildings / Floor
  - Contaminated Soil and Ground water etc.
Mercury Waste Issues

- What kinds of wastes are discharged?
- How much are wastes discharged?
- How are the wastes managed/controlled?
  - How to treat, dispose, store
  - Are there any guidelines or management plans?
- How much does it cost?

Reference:
The cost required for mercury treatment and permanent storage is equivalent to **EUR 2,000 per ton** according to multiple European operators, including DELA of Germany.

3. Mercury Treatment in Japan
Technical Trend of Chlor-Alkali Process in Japan

The Mercury Cell was demolished more than 30 years ago in Japan.

How to Treat the Mercury Wastes in Japan

<table>
<thead>
<tr>
<th>Wastes</th>
<th>How to Treat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>• To sale if the purity of mercury was high</td>
</tr>
<tr>
<td></td>
<td>• To sale after Roasting Treatment if the purity of mercury was low</td>
</tr>
<tr>
<td>Brine Mud*</td>
<td>• Concrete solidification</td>
</tr>
<tr>
<td></td>
<td>• Roasting Treatment</td>
</tr>
<tr>
<td>Facilities contaminated by Mercury</td>
<td>Disposal or sell after cleaning (Pumps and pipes were sold as iron scrap after recovery of mercury)</td>
</tr>
<tr>
<td>Buildings / Floor</td>
<td>• Concrete solidification</td>
</tr>
<tr>
<td></td>
<td>• Roasting Treatment by</td>
</tr>
</tbody>
</table>

* It contains more than dozens ppm of mercury.

Source: Nomura Kosho Co., Ltd.
Current Mercury Treatment in Japan

- Mercury wastes from Chlor-Alkali plant are stored in some factories and storehouses temporarily. Mercury treatment company treats these stored wastes if there are offers / requirements.

- Also, Japanese mercury treatment company treats the mercury waste (like catalyst and oil sludge including mercury compounds) from foreign countries.

Export Mercury Wastes for Environmentally Sound Management

Elemental Mercury as a by product:
- Laboratory and research
- Previously: sent to Chlor Alkali Industry

Mercury Removal → Temporary Storage → Waste Transport → Waste Treatment Plant → Landfill

As there are no mercury recovery facilities in the country, spent catalyst exported to the other countries

Source: Management of Mercury containing Wastes from Oil and Gas Operation in Indonesia (Ministry of the Environment, Republic of Indonesia)
Transport across International Boundaries of Mercury Wastes

Minamata Convention on Mercury
Article 11, paragraph 3 (c)

- For Parties to the Basel Convention, not transported across international boundaries except for the purpose of environmentally sound disposal in conformity with this Article and with that Convention.

- In circumstances where the Basel Convention does not apply to transport across international boundaries, a Party shall allow such transport only after taking into account relevant international rules, standards, and guidelines.

Financial Resources and Mechanism

Minamata Convention on Mercury
Article 13, paragraph 6 (a)

- The Global Environment Facility (GEF)* Trust Fund

The Facility serves as financial mechanism for the following conventions:
- Convention on Biological Diversity
- UN Framework Convention on Climate Change
- UN Convention to Combat Desertification
- Stockholm Convention on Persistent Organic Pollutants
- Minamata Convention on Mercury

* GEF: The largest public funder of projects to improve the global environment
4. Japan’s Support for Iran

MINAS Program by MOEJ

MOYAI Initiative for Networking, Assessment and Strengthening (MINAS)

MOYAI Initiative

MINAS

Networking
Building networks of mercury-related activities (e.g., monitoring) and information between Japan and partner countries

Assessment
Accelerating developing countries’ mercury management efforts by supporting their situation assessment, taking advantage of Japan’s experience

Strengthening
Strengthening developing countries’ mercury management by providing Japan’s technology and know-how

Supporting developing countries for the implementation of the Convention

Source: MOEJ
UNEP Global Mercury Partnership (Since 2005)

- **Overall Goal**
  
  To protect human health and the global environment from the release of mercury

### Information Sharing Platform

- **Government**
- **International Organization**
- **NGOs**
- **Individuals**

### UNEP Global Mercury Partnership Areas

1. Reducing Mercury in Artisanal and Small-Scale Gold Mining
2. Mercury Control from Coal Combustion
3. Mercury Reduction in Chlor-alkali
4. Mercury Reduction in Products
5. Mercury Air Transportation and Fate Research
6. Mercury Waste Management (Lead: Ministry of Environment, Japan)
7. Mercury Supply and Storage
8. Mercury Releases from Cement Industry

Becoming a Partner is easy!

Support Subjects by Japan

1. Preparing the inventory about mercury wastes
2. Developing the guidelines and master plans about the preferable management of mercury wastes
3. Introduction of waste mercury recycle/treatment technology
4. Survey (Feasibility study of mercury treatment facility etc.)
5. Seminar/Workshop activities about the mercury wastes etc.
5. Vision in the Future

### Mercury Waste Management in the Future

<table>
<thead>
<tr>
<th></th>
<th>IRAN</th>
<th>JAPAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporary store at the factory or disposal site</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Preferable management after the recovery at the mercury wastes treatment facility</td>
<td>Future?</td>
<td>YES</td>
</tr>
<tr>
<td>Export of the mercury wastes</td>
<td>Future?</td>
<td>NO</td>
</tr>
<tr>
<td>Import of the mercury wastes</td>
<td>Future?</td>
<td>YES</td>
</tr>
</tbody>
</table>

How do you manage mercury wastes at present?
How are you going to manage mercury wastes in the future?
Road Map for Strengthening Mercury Waste Management in Iran

2017-2018
Capacity Building/System Construction
- Seminar / Workshop
- Support to develop the inventory and guideline

Support by
- JICA
- MOEJ

2020
Feasibility Study
- Survey of the recycling and waste treatment plant

Support by
- JICA
- MOEJ
- METI

Technical Support by
- Japanese company
- Financial Support by
- Japanese Funds

Example of the case if the Japanese technology/facility is introduced into Iran

2025
Introduction of the technology / facility
- Introduction of the Japanese technology / facility
- Establishment of the Iran-Japan waste treatment company

JICA: Japan International Cooperation Agency
MOEJ: Ministry of the Environment, Japan
METI: Ministry of Economy, Trade and Industry

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Iran-Japan Environmental Policy Dialogue
(Since 2015)

<table>
<thead>
<tr>
<th>Year</th>
<th>Venue</th>
<th>Outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Dialogue</td>
<td>Teheran</td>
<td>Shared policies and experiences in both countries, exchanged opinions in the areas such as wetland management, water pollution and air pollution. Agreed to continue accelerating bilateral environmental cooperation. Agreed in principle to cooperate in water pollution countermeasures in enclosed coastal seas and monitoring of sandstorms in 2015.</td>
</tr>
<tr>
<td>(2015)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2nd Dialogue (2016) @Teheran
Topics: (1) Review of progress, (2) Green Economy (Climate change mitigation, Low-carbon society, etc.), (3) Biodiversity, (4) Future cooperation

Bilateral Environmental Policy Dialogue:
China, Korea, Mongolia, Iran, Singapore, Indonesia, Vietnam, US, Germany

- Attachment-2 -
Thank You

Additional Information
Guidelines

- Decommissioning of mercury chlor-alkali plants
- Management of mercury contaminated sites


Guideline for Decommissioning of mercury chlor-alkali plants

Appendix 2 - Types of contaminated materials and possible mercury recovery treatments

<table>
<thead>
<tr>
<th>Material</th>
<th>Typical Hg content % m/m</th>
<th>Physical state</th>
<th>Physical/mechanical treatments/water washing</th>
<th>Chemical washing</th>
<th>Retorting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sludge from storage tanks and sumps</td>
<td>10 - 30</td>
<td>wet solid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sludge from settling catch pits, drains etc.</td>
<td>2 - 80</td>
<td>wet solid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphurised or iodised charcoal from hydrogen purification</td>
<td>10 - 20</td>
<td>dry solid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon from caustic filters</td>
<td>up to 40</td>
<td>wet solid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graphite from decomposers</td>
<td>2</td>
<td>porous solid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubber/packing</td>
<td>variable</td>
<td>variable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brick/rock/concrete</td>
<td>0.01-0.1</td>
<td>dry solid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ebonite-lined cell components (anodes, covers, end bases, side walls, pipework)</td>
<td>variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel (cells, decomposers, scrap components from baffles, H2 coolers, base plates, Mg pumps, pipework)</td>
<td>0.001 - 1</td>
<td>solid with surface contamination</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastic equipment</td>
<td>0.1</td>
<td>solid with surface contamination</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>