Material flows of Selenium and Tellurium in Korea

Extract from "Establishment of Material Flow Analysis Statistics for Metals (VI), Hong-Yoon Kang et. al., 2015, KITECH (Resource productivity foundation establishment project report funded by Ministry of Trade, Industry and Energy of Korea)

Unofficial translation by: KD Nethmi Sewwandi, University of Ulsan, Ulsan, South Korea, December 2022

Chapter 13: Analysis of the material flow of Selenium (Se)

Section 1- Industrial Objectives and Performance Details

1. Investigating the material flow of Selenium

- Investigation of existing national statistics such as mining industry statistics and Korean trade statistics for the first and second resource flow analysis and investigating previously conducted MFA data.
- Visiting the companies in person and conducting surveys on insufficient data in cases such as the amount of resource content of the product and the place of demand for the product.

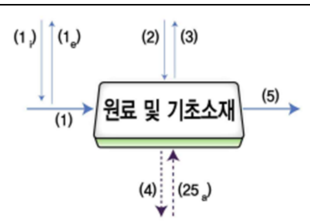
2. Constructing material flow statistics

A. Raw material and basic material steps

◦ Conducting MFA on the stage of producing Selenium-containing ores mined from abroad in the form of Selenium compounds or Selenium metals.

- Analysis of the domestic supply and demand of Selenium input into the raw material stage through the investigation and analysis of the raw material stage material flow.
- Securing unbuilt statistical data and verifying the accuracy of data through raw material stage producer surveys and visits.

Method and content of investigation

Step-by-step flow chart		Defining the steps	Materials used
	(1)	Domestic supply and demand of Selenium-containing ores	Literature review
	(1i)	Import of Selenium-containing ores	Literature review
 Raw materials and basic materials	(1e)	Export volume of Selenium-containing ores	Literature review
	(2)	Import volume of Selenium raw	

		materials and basic materials	
	(3)	Export volume of Selenium raw materials and basic materials	
	(4)	Scrap generation in raw and basic materials stage	
	(5)	Domestic supply and demand of Selenium raw materials and basic materials	
	(25a)	Input of secondary resource recycling to raw material and basic material phase	

B. Primary processed product stage

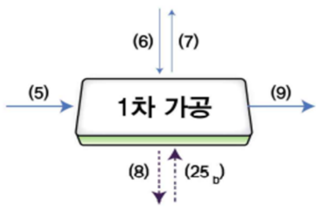
- Conducting MFA on the stage of manufacturing Selenium discharged through the raw material and basic material step in the form of re-examination of the product or examining the product through the first processing step.

- Analysis of the material flow survey of the primary processed product stage through domestic supply and demand survey and analysis of Selenium input into the primary processed product stage.
- Securing unbuilt statistical data (input to primary processed products, supply, and demand of primary processed products, etc.) and verifying the consistency of statistical data through direct phone calling investigation and visit of manufacturers in the primary processed product stage.

- Setting the primary processing product stage of Selenium
- Set the primary processing product stage for Selenium compounds and Selenium metals through data such as sector classification tables in the industry-related table, HS Code of Korea Trade Statistics, and expert advice. It can be noted that Selenium compounds and Selenium metals are established in the primary processing product stage.

Method and content of investigation

Step-by-step flow chart		Defining the steps	Materials used
	(5)	Domestic supply and demand at the raw material stage	Quantity discharged from the previous stage

	(6)	Import volume of primary processed products	Company surveys and Korea Trade Statistics
	(7)	Export volume of primary processed products	Company surveys and Korea Trade Statistics
	(8)	Primary processing product phase and secondary resource generation	No secondary resource generation
 Primary processed product	(9)	Domestic supply and demand for primary processed products	Use of company surveys data and literature survey data
	(25b)	The amount of secondary resource input to the primary processing product stage	No secondary resource inputs

Available materials

Category	Materials
Import volume and export volume of primary processed products	Use of company survey results and Korea Trade Statistics
Domestic supply and demand of primary processed products	Use of company surveys results
Secondary resource input	No secondary resource input

- Investigating raw material input (including primary and secondary resources), scrap generation, primary suppliers and ratios of primary processed products produced, resource content of production products, and market share of companies.

C. Intermediate product stage

- Conducting MFA on the stage of producing intermediate products for the use or production of final industries (products) as products produced from primary processed products

- Determination of the quantity of primary processed products into each intermediate product, including the production of intermediate products, and analysis of the material flow survey.

- Calculation of domestic supply and demand for intermediate products through company surveys data and literature survey data, and verification of consistency of statistics on intermediate production.

Setting the intermediate product level of Selenium

- Set as an intermediate product classification item out of 403 basic sector classifications in the industry association table.

- Method and content of investigation

- Based on the results of the first processing company surveys, the flow and quantity of intermediate products are identified, and if the results of the company surveys are insufficient, the flow and quantity are identified using statistics on intermediate production and related documents.

- The import and export volume of intermediate products is calculated using Korea Trade Statistics and company surveys results.

Available materials

Category	Materials
Import and export volumes in intermediate product stages	Use of Korea Trade Statistics and Company surveys results
Domestic supply and demand for intermediate products	Use of company surveys results and literature survey data

D. Final Industry (Product) Stage

- Conducting an MFA on the classification of electrical and electronic devices, non-metallic mineral products, power, gas and water, and chemical products and the stages of each industry's representative products as industries where Selenium-infused intermediate products are finally introduced.

- Determining the quantity of primary processed products and intermediate products into each final industry (product), including final industry (product) production, and analyzing the material flow survey.

- Verification of numerical accuracy through comparison between company surveys data and domestic statistical data.

- Establishment of the final industrial (product) stage of Selenium

- Items that fall under the category classification in the industry association table are set as the target of the final industry (product) classification

- Method and content of investigation

- Based on the results of the intermediate product manufacturer survey, the flow and quantity of the final industry (product) are identified, and if the results of the company surveys are insufficient, the flow and quantity are identified using statistics of the final industry (product) production and related documents.

- It is done using the final industry (product) import and export volume, final industry (product) supply and demand, secondary resource recycling input to the final industry (product) stage, Selenium content in the final industry (product), etc.

Available materials

Category	Materials
Final industrial (product) import volume export volume	Company surveys data
	Statistics of the Korea International Trade Association
Domestic supply and demand for final industry (product)	Selenium content of final industry (product) (company surveys data)
	Korea Pharmaceutical Association (domestic drug production statistics)
	Ministry of Food and Drug Safety (information on drug content)
	Literature research data

E. Use and stockpiling stage

- Considering the consumption and use of the final industrial (product) produced in the year and the durability of each final industrial (product) in the previous year, MFA needs to be performed on the stage of collection to be recycled as a secondary resource after the use of Selenium resources.
- Since there is not enough data for evaluation, including the accumulated number of Selenium-containing products considering the durability, it is divided into stages and calculated as the final product supply and demand.

F. Collection stage

- Conducting MFAs on the steps in which the primary resources of Selenium is collected and processed to be discharged after use and recycled as secondary resources.

- Determining the secondary resource collection amount and analyzing the material flow by considering the amount of waste generated by each product and the amount of Selenium content generated after use of the final industry (product) into which Selenium is injected.

- Calculation by considering the amount of waste generated by each product and the number of resources generated after the use of the final industry (product).

- Method and content of investigation

- Use of literature research data to calculate the input of secondary resources in Korea.

- Use of company surveys results and literature survey data to calculate input and collection throughput into secondary resources.

G. Recycling

- After the collection stage, MFA is performed on the stage of the recycling process to be re-entered as a primary resource.

- In the case of Selenium, major recycling companies have found that no recycling companies have existed to date and are not being recycled worldwide.

H. Disposal stage

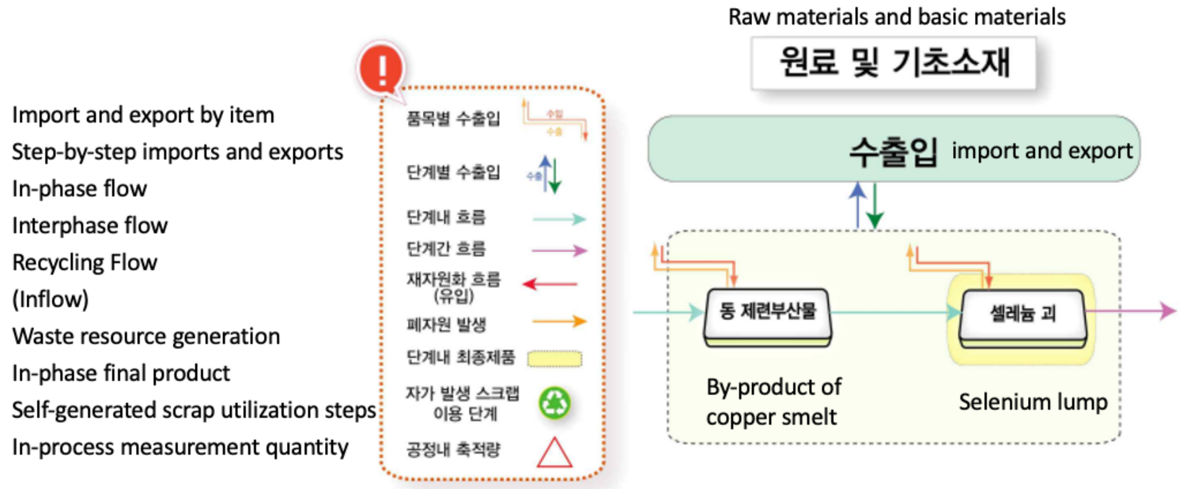
- Perform MFA on the stage of final disposal of Selenium

- Consideration is given to the collection processing waste of Selenium discharged in the collection stage and the final disposal of Selenium discharged in the recycling stage.

Section 2- Analysis of substance flow stage by stage

1. Raw material and basic material steps

The step of the raw material and the basic material of Selenium is defined as Selenium-containing ore. Selenium does not have its own mineral, and most of it is recovered as a by-product of Copper. Compounds such as Selenium (a compound of Se2-), Selenium salts (a salt of SeO42-), and Acetylene salts (a salt of SeO32-) were found to exist with normal Tellurium. It is also distributed in rocks and soil, but its existence ratio on the earth is about 0.05 ppm (5x10-6%), which is very small, and the soil is usually contained in water-soluble Selenium salts or Acetylene salts, so it is easily washed into the river. Sea water is dissolved at a concentration of 2x10-4 mg per liter, and Selenium is also contained in various organisms, usually instead of S (sulfur) in amino acids, and some toxic plants such as locoweed concentrate Selenium from the soil and contain high concentrations. Selenium is contained in sulfide ores such as Copper, lead, and silver in the form of Selenium and is mainly produced as a by-product of smelting of these ores (especially Copper ores) or sulfuric acid production. In Korea, it was investigated that Selenium masses are produced in LS Nikko-dong and Gorey Zinc, and all the Selenium masses produced are exported abroad. The flow of substances in the stages of Selenium raw materials and basic materials is shown in [Figure 13-1]



[그림 13-1] 셀레늄의 원료 및 기초소재단계 물질흐름도

[Figure 13-1] Flow chart of Selenium raw material and basic material stage

A. Supply and demand of Copper smelting by-products

As described above, Selenium-containing ores do not exist, and it has been investigated that Selenium masses are produced as by-products during Copper smelting. It was investigated that the HS code of smelting by-products did not exist.

Supply and demand of Copper smelting by products= (Domestic production of Copper smelting by-products + domestic production of Copper smelting by-products + import of Copper smelting by-products - export volume of Copper smelting by-products) × Resource content

Estimation of domestic supply and demand of Copper smelting by-products
Data used: Company surveys results, advisory results, and Korea Trade Statistics
Domestic supply and demand of copper by-products ◦ Selenium production of Copper smelting by-products: 384,481 kg ◦ Selenium import volume of Copper smelting by-products: 0 kg ◦ Selenium export volume of Copper smelting by-products: 0 kg
Domestic supply and demand of Copper by-products = 384,481 + 0 - 0 = 384,481 kg MFA of Copper smelting by-products

By-product of copper smelt

B. Domestic supply and demand of Selenium ingots

The HS code of the Selenium lump was found to have Selenium (2804.90.0000) as stated above.

In the same way, it was investigated that all domestic Selenium lumps are exported.

> Domestic supply and demand of Selenium ingots= (Domestic production of Selenium lumps + imports of Selenium lumps - exports of Selenium lumps) × Resource content

Calculation of domestic supply and demand of Selenium ingots
Data used: Company surveys results, advisory results, and Korea Trade Statistics
Domestic supply and demand of Selenium ingots -Selenium production of Selenium ingots: 384,481 kg -Selenium import volume of Selenium ingots: 88,605 kg -Selenium export volume of Selenium ingots: 473,086k
Domestic supply and demand of Selenium ingots = 384,481 + 88,605 – 473,086 = 0 kg Selenium ingot stage MFA  Selenium lump

C. Supply and demand for Selenium raw materials and basic materials

As for the supply and demand of domestic Selenium raw materials and basic materials, including Copper smelting byproducts and Selenium masses, was calculated as described above.

> Domestic supply and demand for Selenium raw materials and basic materials = Copper smelting byproduct supply and demand + Selenium bulk supply and demand

Estimation of domestic supply and demand for Selenium raw materials and basic materials

Data used: Company surveys results, advisory results, and Korea Trade Statistics

Supply and demand for Selenium raw materials and basic materials

◦ Selenium production in raw and basic materials: 384,481 kg

◦ Import volume of Selenium in the raw and basic materials stage: 88,605 kg

◦ Export volume of Selenium in the raw and basic materials stage: 473,086 kg

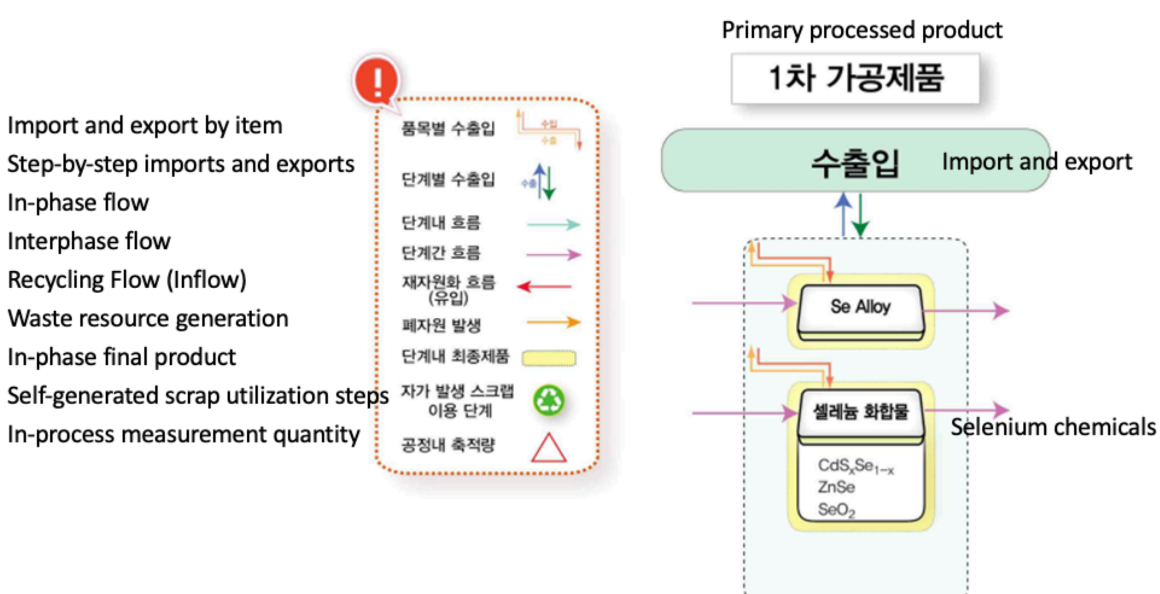
Domestic supply and demand for Selenium raw materials and basic materials

= 384,481 + 88,605 – 473,086 = 0 kg

Selenium raw materials and basic materials stage MFA

2. Primary Processed Product Stage

The primary processed product stage is defined as the stage of manufacturing in the form of a material for manufacturing a product through the stage of raw materials and basic materials and includes a Selenium compound and Selenium metal. The detailed flow of the primary processed product stage is shown in [Figure 13-2]



[그림 13-2] 셀레늄의 1차 가공제품 단계 물질흐름도

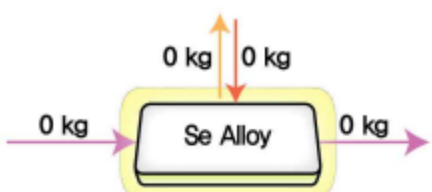
[Figure 13-2] Material flow chart of Selenium's primary processed products

A. Domestic supply and demand of Selenium metal

Selenium metal (Se Alloy) is sometimes used as an alloy material, and stainless steel is added in small amounts in the form of Ferrocenium (Fe/Se) to improve casting, forging, and cutting properties, and brass is added with Bismuth (Bi) instead of highly toxic lead. In the case of Korea, since metals containing Selenium are not produced or imported, there is no domestic production, so only the material flow is indicated.

Domestic supply and demand of Selenium metal = Production of Selenium metal + import of Selenium metal - export of Selenium metal

Calculation of domestic supply and demand of Selenium metal
Usage data: Company surveys results, literature survey data
Production, import and export volume of Selenium metal ◦ Domestic production of Selenium metal: 0 kg ◦ Import volume of Selenium metal: 0 kg ◦ Export volume of Selenium metal: 0 kg
Domestic supply and demand of Selenium metal = 0 + 0 - 0 = 0 kg MFA of Selenium metal



B. Domestic supply and demand of Selenium compounds

As a result of the company surveys and the literature survey, it was found that Selenium compounds have the form of Selenate and Selenium layers or salts, and most of them are used in the form of SeO_2. The supply and demand of Selenium compounds was calculated using company surveys data, related literature data, and statistical data.

Domestic supply and demand of Selenium compounds = Production of Selenium compounds + import of Selenium compounds - export of Selenium compounds

As shown in <Table 13-1>, the survey of companies handling Selenium compounds and the survey of Korean trade statistics reported the annual import volume as 2,248kg and the export volume as 5kg.

Selenium compounds used in Korea are not produced as compound type in Korea, and most of them are imported as selenite, indicating only material flow.

<Table 13-1> Calculation of import and export volume of Selenium compounds

	Selenium compound		
Category	The amount of imports (kg)	The amount of exports (kg)	Reference
Selenate	2248	0	Korea Trade Statistics
Selene's double inflammation or grafting	0	5	Korea Trade Statistics
The total	2248	5	-

Calculation of domestic supply and demand of Selenium compounds
Usage data: Company surveys data, Korea trade statistics
Production, import and export of Selenium compounds ◦ Domestic production of Selenium compounds: 0 kg ◦ Import volume of Selenium compound: 2,248 kg ◦ Export volume of Selenium compounds: 5 kg
Domestic supply and demand of Selenium compounds = 0 + 2,248 – 5 = 2,243 kg MFA of Selenium compounds

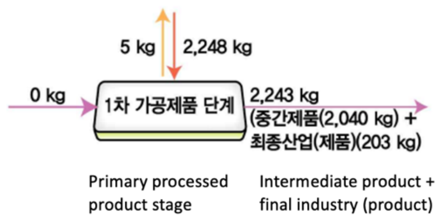
C. Supply and demand of primary processed products

The supply and demand of domestic Selenium in the primary processed product stage was calculated using the production amount, import amount, and export amount of Selenium compound and Selenium metal as described above. The input amount of Selenium for each product in the next stage was calculated based on the company surveys data.

Domestic supply and demand for Selenium primary processed products = Selenium oxide supply and demand + Selenium metal supply and demand

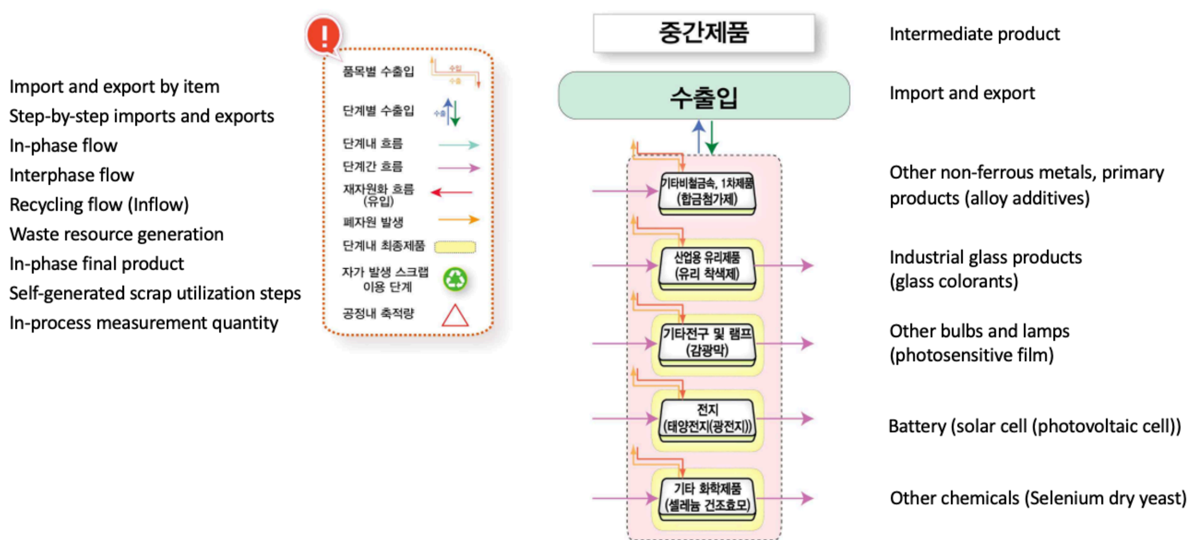
Estimation of domestic supply and demand for Selenium primary processed products
Usage data: Company surveys data and literature survey data
Supply and demand of Selenium primary processed products ◦ Selenium metal supply and demand: 0 kg ◦ Selenium compound supply and demand: 2,243 kg (intermediate product (2,243 kg) + final industry (product) (203 kg))
Domestic supply and demand of Selenium primary processed products = 0 + 2,243 = 2,243 kg

Primary processed product stage MFA of Selenium



3. Intermediate product stage

Intermediate products are divided into other nonferrous metals, primary products (alloy additives), industrial glass products (glass colorants), other bulbs and lamps (photosensitive films), batteries (solar cells), and other chemicals (Selenium dry yeast). The amount of supply and demand in the intermediate product stage was calculated using Korea Trade Statistics, Korea Pharmaceutical Association's pharmaceutical statistics, company surveys data, literature survey data, and expert advice. The calculation results are shown in Figure 13-3.



[그림 13-3] 셀레늄의 중간제품단계 물질흐름도

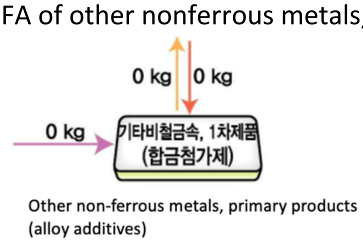
[Figure 13-3] Intermediate product flow chart of Selenium

A. Other non-ferrous metals, primary products (alloy additives)

To compensate for the difficulty of cutting steel, steel with improved stretchability such as Sulfur, Lead, Selenium, Tellurium, Calcium, Bismuth, and Zirconium is used and they are called fine cutting steel, and Selenium is used as an additive (0.05%) of this fine cutting steel.

In 2012, POSCO developed the world's first Bismuth (Bi) steel that can meet the needs of eco-friendly products, especially Lead and Sulfur-added steel, which is used for automobile transmission parts, TV parts, assembly parts, bolts, nuts, screws, and universal joint generators. As a result of the company's investigation, five types of fine cutting steel were found in Korea, including C, Si, Mn, Pb, and P. Selenium fine cutting steel was found to have no domestic production. It was investigated that there was no inflow or outflow of quick-cutting steel containing Selenium.

Domestic supply and demand of Selenium in other nonferrous metals and primary products (alloy additives) = (Other non-ferrous metals, primary product (alloy additives) production + other non-ferrous metals, primary product (alloy additives) import volume - other non-ferrous metals, primary product (alloy additives) export volume) × resource content

Calculation of domestic supply and demand of Selenium in other nonferrous metals and primary products (alloy additives)
Data used: Korea Trade Statistics, Company surveys, and Literature data
Production, import and export volume of other nonferrous metals and primary products (alloy additives) ◦ Domestic production of other nonferrous metals and primary products (alloy additives): 0 kg ◦ Import volume of other non-ferrous metals and primary products (alloy additives): 0 kg ◦ Export volume of other nonferrous metals and primary products (alloy additives): 0 kg
Domestic supply and demand of other nonferrous metals and primary products (alloy additives) = 0 + 0 - 0 = 0 kg MFA of other nonferrous metals, primary products (alloy additives) 

B. Industrial glass products (glass colorants)

If Selenium is added to glass in an amount of 0.001 to 0.015%, blue or yellow caused by iron (II) impurities will disappear, and if added in an amount of 0.1 to 0.2%, glass will be pink. Selenium rubies, known as the brightest red glass, are obtained by adding cadmium sulfoselenium sulfide (CdS_xSe_{1-x}), which is found to be dark red ruby color if CdS is 10% (x=0.1), medium red if CdS is 40%, orange if it is 75%, and yellow glass if it is 100% CdS.

Selenium compounds, which are mostly used as glass colorants, were found to be used in the manufacture of panes. According to a survey conducted by the Korea Pan Glass Association and major companies (Hanlas, KCC, etc.), domestic pan glass production is blue, green, bronze color, whereas pink pan glass is not produced in Korea, so only the material flow of pink glass is indicated.

Domestic supply and demand of Selenium in industrial glass products (glass colorants) = (Production volume of industrial glass products (glass colorants) + Import volume of industrial glass products (glass colorants) - Export volume of industrial glass products (glass colorants) × resource content

Calculation of domestic supply and demand of Selenium in industrial glass products (glass colorants)
Data used: Company surveys data, expert advice, and Korea Trade Statistics
Production, import and export volume of industrial glass products (glass colorants) ◦ Domestic production of industrial glass products (glass colorants): 0 kg ◦ Import volume of industrial glass products (glass colorants): 0 kg ◦ Export volume of industrial glass products (glass colorants): 0 kg
Domestic supply and demand of industrial glass products (glass colorants) = 0 + 0 - 0 = 0 kg MFA for industrial glass products (glass colorants)  Industrial glass products (glass colorants)

C. Other bulbs and lamps (photosensitive film)

Selenium ferro film used in copiers is used by applying a Selenium compound to the surface of a drum made of aluminum. This Selenium is charged with a (+) charge just before light reaches the charged Selenium, and when the light reflected on the original paper touches the charged Selenium, Selenium becomes an electrified conductor, which is copied through the charged change of the photocopier drum.

According to a survey conducted by a copier manufacturer, a drum coated with Selenium was used in the past, but now a drum replaced by an alternative material is used, and there is no domestic production, so only the material flow is indicated. The supply and demand of other domestic bulbs and lamps (photosensitive membranes) was calculated using the results of the company surveys and statistical data of the Korea International Trade Association.

Domestic supply and demand of Selenium in other bulbs and lamps (photosensitive film) = (Other bulbs and lamps (photosensitive film) production volume + other bulbs and lamps (photosensitive film) import volume - Other bulbs and lamps (photosensitive film) export volume) × resource content

Calculation of domestic supply and demand of Selenium in other bulbs and lamps (photosensitive film)

Data used: Korea Trade Statistics, Company surveys data, Literature survey data

Production, import and export volume of other bulbs and lamps (photosensitive film)

◦ Domestic production of other bulbs and lamps (photosensitive film): 0 kg

◦ Import volume of other bulbs and lamps (photosensitive film): 0 kg

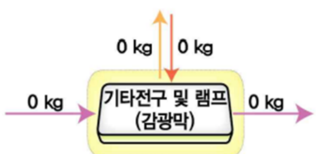
◦ Export volume of other bulbs and lamps (photosensitive film): 0 kg

Domestic supply and demand of other bulbs and lamps (photosensitive film)

= 0 + 0 - 0

= 0 kg

MFA of other bulbs and lamps (photosensitive film)



Other bulbs and lamps (photosensitive film)

D. Battery (solar cell (photovoltaic cell))

A battery (solar battery) is a photovoltaic cell manufactured to convert solar energy into electrical energy and is a semiconductor device that converts light energy generated from the sun into electrical energy. Depending on the material used, it is classified into silicon-based, compound, dye-sensitized, organic, etc. Among them, materials that have emerged as thin-film solar cells include CIGS (Copper Indium Gallium Selenide), CdTe (Cadium Telluride), and DSSC (Dye-Sensitized Solar Cell), a dye-sensitized material. In Korea, the Solar Energy Convergence Research Center succeeded in developing CZTSe (Copper-Zinc-Tin-Sulfur-Selenium) thin film solar cells. Currently, it is found that the dry manufacturing process has succeeded by using the vacuum sputtering process rather than the solution-based process using by the highly toxic hydrazine solution and dry process has not yet been commercialized.

The domestic supply and demand of Selenium in domestic batteries (solar cells (photovoltaic cells) was calculated using a company surveys and a literature survey.

Domestic supply and demand of Selenium in batteries (solar cells (photovoltaic cells)

= (Cell (solar cell (photovoltaic cell)) production amount + battery (solar cell (photovoltaic cell)) import amount - battery (solar cell (photovoltaic cell)) export volume) × resource content

Calculation of domestic supply and demand of Selenium in batteries (solar cells (photovoltaic cells)
Used materials: Company research data, literature data, expert advice
Production, import, and export volume of batteries (solar batteries (photovoltaic cells) ◦ Domestic production of batteries (solar cells (photovoltaic cells)): 0 kg ◦ Import amount of battery (solar battery (photovoltaic battery)): 0 kg ◦ Export amount of battery (solar battery (photovoltaic battery)): 0 kg
Domestic supply and demand of batteries (solar cells (photovoltaic cells) = 0 + 0 - 0 = 0 kg MFA for batteries (solar cells (photovoltaic cells)

Battery (solar cell (photovoltaic cell))

E. Other chemicals (Selenium dry yeast)

Selenium is toxic in excess but is an essential trace inorganic nutrient for many animals and plants. Selenium is a component of antioxidant enzymes such as glutathione peroxidase and thioredoxin reductase, which contributes to preventing heart disease and body tissue aging and degeneration. It also regulates thyroid function as an auxiliary factor for thyroid hormone deiodinase and plays an important role in the immune system.

Selenium used in other domestic chemicals (Selenium dry yeast) was found to be contained and used in vitamin/mineral supplements. Among the domestic medicines of the Korea Pharmaceutical Association, there are about 600 types of vitamin/mineral supplements, and various other types are being produced. The supply and demand of other chemical products (Selenium dry yeast) was calculated using statistics from the Korea Pharmaceutical Association and information on the drug content of the Ministry of Food and Drug Safety.

Domestic supply and demand of Selenium in other chemical products (Selenium dry yeast) = (Other chemicals (Selenium dry yeast) Production volume + Other chemicals (Selenium dry yeast) Import volume - Other chemicals (Selenium dry yeast) Export volume × resource content

Calculation of domestic supply and demand of Selenium in other chemical products (Selenium dry yeast)

Data used: Ministry of Food and Drug Safety, Statistics of the Korea Pharmaceutical Association, and Korea Trade Statistics
Production, import and export volume of other chemical products (Selenium dry yeast) ◦ Domestic production of other chemicals (Selenium dry yeast): 2,040 kg ◦ Import volume of other chemical products (Selenium dry yeast): 0 kg ◦ Export volume of other chemical products (Selenium dry yeast): 0 kg
Domestic supply and demand of other chemical products (Selenium dry yeast) = 2,040 + 0 - 0 = 2,040 kg MFA of other chemical products (Selenium dry yeast)  Other chemicals (Selenium dry yeast)

F. Supply and demand of intermediate products

The supply and demand of Selenium intermediate products were calculated by dividing them into other nonferrous metals, primary products (alloy additives), industrial glass products (glass colors), other bulbs and lamps (photosensitive films), batteries (solar cells), and other chemicals (Selenium dry yeast), and the results are shown in Table 13-2.

Domestic supply and demand for Selenium intermediate products = Other non-ferrous metals, primary products (alloy additives) supply and demand + industrial glass products (glass colorants) supply and demand + other bulbs and lamps (photosensitive films) supply and demand + battery (solar cells) supply and demand + other chemicals (Selenium dry yeast)

<Table 13-2> Supply and demand of intermediate products

(Unit: kg)

Category	Input	Income	Export	Supply and demand
Other nonferrous metals, primary products (alloy additives)	0	0	0	0
Industrial glass products (glass colorants)	0	0	0	0

Other bulbs and lamps (photosensitive film)	0	0	0	0
Battery (solar cell (photovoltaic cell))	0	0	0	0
Other Chemicals (Selenium Dry Yeast)	2040	0	0	2040
Total	2040	0	0	2040

Estimation of domestic supply and demand for Selenium intermediate products

Data used: Literature data and company surveys results, Korea Trade Statistics, Korea Pharmaceutical Association Drug statistics, Food and Drug safety administration, and expert advice

Supply and demand of Selenium intermediate product stage

◦ Supply and demand of other non-ferrous metals and primary products (alloy additives): 0 kg
◦ Supply and demand of industrial glass products (glass colorants): 0 kg
◦ Supply and demand of other bulbs and lamps (photosensitive film): 0 kg
◦ Battery (solar cell (photovoltaic cell) supply and demand: 0 kg
◦ Supply and demand of other chemical products (Selenium dry yeast): 2,040 kg

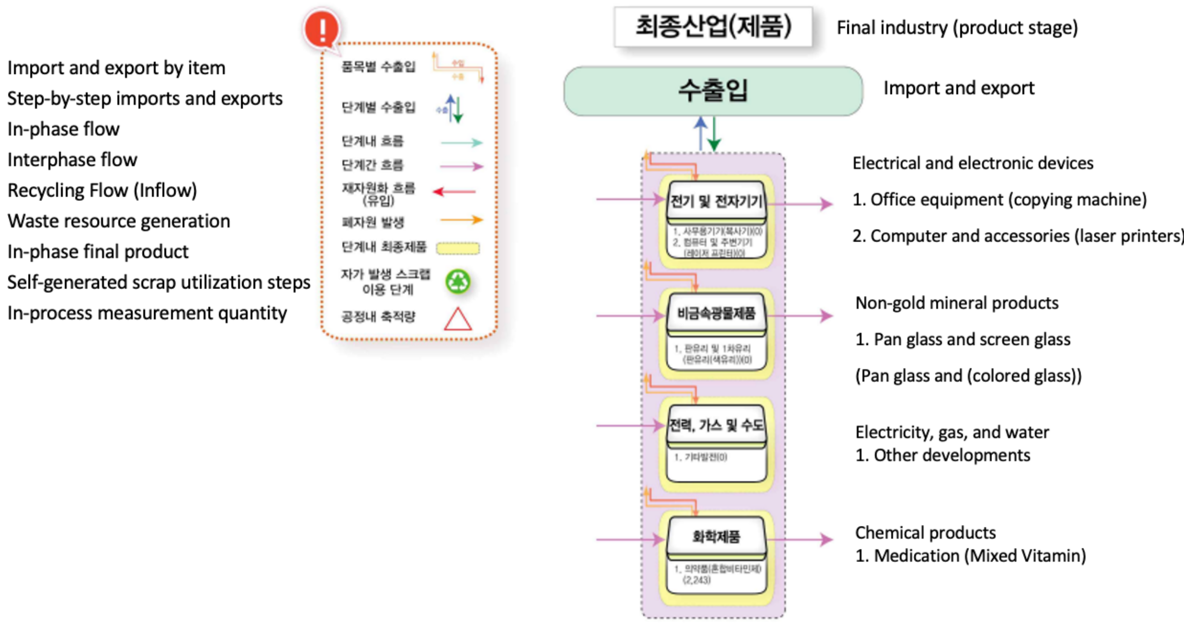
Domestic supply and demand for Selenium intermediate products
= 0 + 0 + 0 + 0 + 2,040
= 2,040 kg

Intermediate product phase MFA of Selenium

Intermediate product stage

4. Final industry (product) stage

In the final industry (product) stage, it is divided into electricity and electronic devices, non-metallic mineral products, power, gas and water, and chemical product industries, and the supply and demand for each item was calculated using Korean trade statistics, company surveys data, literature survey data, and expert advice. The results were calculated as shown in Figure 13-4.



[그림 13-4] 셀레늄의 최종산업(제품)단계 물질흐름도

[Figure 13-4] Material flow chart for the final industrial (product) stage of Selenium

Selenium input into the final industry (product) was classified into major classification items of the industry-related table as shown in <Table 13-3> using the IO-KSIC classification table to calculate the supply and demand.

<Table 13-3> Response of intermediate and final product items (using industry-related tables)

	Intermediate product		Final product	
Item name	Code number	403 basic categories	Code number	Major categories
Alloy additive	208	Other nonferrous metals, primary products	-	-
Glass colorant	173	Industrial glass products	09	Non-metallic mineral products
Photosensitive film	246	Other bulbs and lamps	13	Electrical and electronic devices
Solar cells (photovoltaic cells)	245	Batteries	17	Power, gas and water
Selenium-dried yeast	165	Pharmaceutical products	08	Chemicals

A. Domestic supply and demand of electrical and electronic devices

The supply and demand of Selenium in electrical and electronic devices was calculated using company surveys data and literature data, and input from other bulbs and lamps (photosensitive membranes).

Domestic supply and demand of Selenium in electrical and electronic devices = (Electrical and electronic device production + electrical and electronic device import - electrical and electronic device export) × resource content

Estimation of domestic supply and demand for electrical and electronic devices
Data used: Company surveys data, Korea trade statistics, Company surveys data
Production, import and export volume of electrical and electronic devices ◦ Domestic production of electrical and electronic devices: 0 kg ◦ Import volume of electrical and electronic devices: 0 kg ◦ Export volume of electrical and electronic devices: 0 kg
Domestic supply and demand for electrical and electronic devices = 0 + 0 - 0 = 0 kg MFA for electrical and electronic devices

Electrical and electronic devices

1. Office equipment (copying machine)

2. Computer and accessories (laser printers)

B. Domestic supply and demand of non-gold mineral products

The supply and demand of Selenium in non-metallic mineral products was calculated using company surveys data and literature data, and it is input for industrial glass products (glass colorants).

Domestic supply and demand of Selenium in non-metallic mineral products = (Non-metal mineral product production + Non-metal mineral product import - Non-metal mineral product) export volume) × resource content

Estimation of domestic supply and demand for non-metallic mineral products
Data used: Company surveys data, expert advice, and Pan Glass Association statistics
Production, import and export volume of non-metallic mineral products ◦ Domestic production of non-metallic mineral products: 0 kg ◦ Import volume of non-metallic mineral products: 0 kg ◦ Export volume of non-metallic mineral products: 0 kg

Domestic Supply and Demand of Non-Metallic Mineral Products
= 0 + 0 – 0 = 0 kg
MFA for non-metallic mineral products

Non-gold mineral products
1. Pan glass and screen glass
(Pan glass and (colored glass))

C. Domestic supply and demand of electricity, gas, and water

The supply and demand of power, gas, and Selenium in the water was calculated using company surveys data, literature data, and Korea Trade Statistics, and is input from batteries considered as solar cells (photovoltaic cells).

Domestic supply and demand of Selenium in power, gas, and water

= (power, gas, and water production + power, gas, and water electronics imports - power, gas and water exports) × resource content

Estimation of domestic supply and demand for electricity, gas and water
Usage data: Company surveys data, Literature data, Korea trade statistics
Power, gas and water production, imports, and exports ◦ Domestic production of electricity, gas and water: 0 kg ◦ Import of electricity, gas and water: 0 kg ◦ Export volume of electricity, gas and water: 0 kg
Domestic supply and demand of electricity, gas, and water = 0 + 0 – 0 = 0 kg

MFA of electricity, gas, and water

Electricity, gas, and water
1. Other developments

D. Domestic supply and demand of chemical products

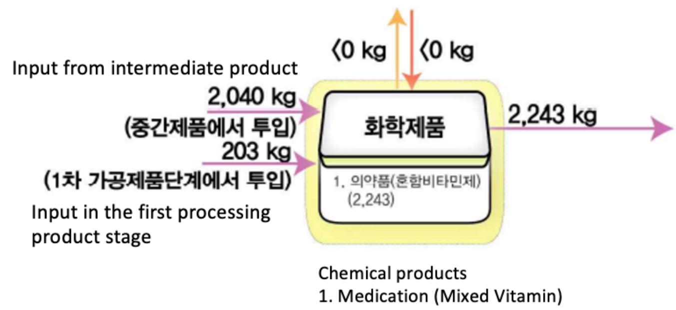
The supply and demand of Selenium in chemical products was calculated using company surveys data, literature data, Korea Pharmaceutical Association's drug production performance statistics, and Korea Trade Statistics, and input from Selenium compounds and other chemicals (Selenium dry yeast).

Domestic supply and demand of Selenium in chemical products

= (Chemical production volume + chemical product electronic device import volume - chemical product export volume) × resource content

In the case of chemicals (mixed vitamins), there are about 37 types of Selenium-containing vitamins in products exported to Korea, and the content of Selenium-dried yeast in the product is 50µg on average, which is very small. In the case of imported vitamin drugs and Selenium drugs, it was found that the average Selenium content was 80µg, which was extremely small.

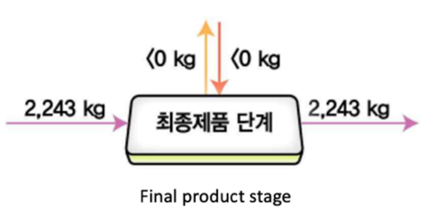
Estimation of domestic supply and demand for chemical products
Data used: Company surveys data, Korea Pharmaceutical Association's pharmaceutical production performance statistics
The amount of chemical production, imports, and exports ◦ Domestic production of chemical products: 2,243 kg ◦ Import volume of chemical products: <0 kg ◦ Export volume of chemical products: <0 kg
The domestic supply and demand of chemicals = 2,243 + <0 - <0 = 2,243 kg MFA of chemical products



D. Domestic supply and demand of final industries (products)

As mentioned above, the supply and demand of the final industry (product) of Selenium which is electrical and electronic devices, was calculated by dividing it into non-metallic mineral products, power, gas and water, and chemical products.

Domestic supply and demand of Selenium in the final industrial (product) stage = Supply and demand of electrical and electronic devices + supply and demand of non-metallic mineral products + supply and demand of electricity, gas and water + supply and demand of chemical products

Calculation of domestic supply and demand of Selenium final industry (product)
Data used: Company surveys data, Korea Trade Statistics, Korea Pharmaceutical Association's pharmaceutical production performance statistics
Supply and demand of Selenium final industrial (product) stage ◦ Supply and demand of electrical and electronic devices: 0 kg ◦ Supply and demand of non-metallic mineral products: 0 kg ◦ Power, gas and water supply: 0 kg ◦ Chemical supply and demand: 2,243 kg
Domestic supply and demand of Selenium in the final industrial (product) stage = 0 + 0 + 0 + 2,243 = 2,243 kg Selenium's final industrial (product) phase MFA 

5. The use and stockpiling stage

The use and stockpiling stage is the stage where Selenium is injected. The consumption and use of the final industry (product) produced in the relevant year is considered, and the final industry (product) produced before the analysis base year is injected into the material flow and accumulated by users and discharged after use.

It is necessary to estimate the stockpiling of residue material amount by considering the consumption and use of the final industry (products) produced before 2014, the base year of the material flow of this study, and the durability of the final industry (products). However, since it is impossible to calculate the accumulated amount before 2014 only with simple surveys and statistics, the amount of supply and demand for the final industry (product) derived through this project was calculated as the input to the use and stockpiling stage.

Used and accumulated products are generated as post-use products due to their function (life) or replacement, some of which are collected for recycling, and some are discarded. After use of Selenium, material flow analysis was performed in consideration of emissions of final products such as electronic and electrical equipment, non-metallic mineral products, power, gas, and water.

The amount of Selenium input from the use and stockpiling stage to the collection stage was calculated using company surveys and literature data.

Estimation of domestic supply and demand in the use and accumulation stage
Data used: Environmental protection system recycling results, company surveys results
Calculation of supply and demand during the use and stockpiling stage ◦ Input amount to use and stockpiling stage: 2,243 kg (supply and demand in final product) ◦ Among the inputs to the use and stockpiling stage, the inputs to the collection stage: 0 kg
Domestic supply and demand at the stage of use and stockpiling of residue material = 2,243 kg MFA of use and stockpiling stage

6. Collection stage

The primary resource is discharged after it is used, collected and processed to be recycled as a secondary resource and it is calculated as the amount collected in the use and stockpiling stages.

Domestic supply and demand during the collection stage = (Secondary resource generation × resource content) + (secondary resource import volume × resource content) - (secondary resource export volume × resource content)

Estimation of domestic supply and demand in the collection stage

Used data: Company consultation results, literature research data

Calculation of domestic supply and demand in the collection stage

◦ Secondary resource generation: 2,243 kg

◦ Secondary resource import volume: 0 kg

◦ Secondary resource export volume: 0 kg

Domestic supply and demand at the collection stage
= 2,243 + 0 - 0 = 2,243 kg

Collection phase MFA

7. Reuse of resources stage

The recycling stage is a stage that goes through the recycling process after the collection stage. In the case of Selenium, a survey of major recycling companies found that no companies have been recycling so far. The reason why recycling is not carried out is that Selenium used in Korea is mostly used as a medicine, and it was found that there are no separation and purification technologies included in waste products.

Domestic supply and demand during the recycling stage = (Secondary resource collection throughput × resource content) + (Secondary resource import volume × resource content) - (Secondary resource export volume × resource content) + (Input to disposal stage × resource content)

Estimation of domestic supply and demand in the recycling stage

Data used: Company surveys data

Calculation of the recycling stage

◦ Secondary resource collection throughput: 2,243 kg

Domestic supply and demand in the recycling stage
= 2,243 kg

MFA of recycling phase

8. Disposal stage

The disposal stage is the final disposal stage of Selenium, which was calculated by considering the disposal discharged from the Selenium final industry (product) stage and the amount of waste discharged from secondary resources.

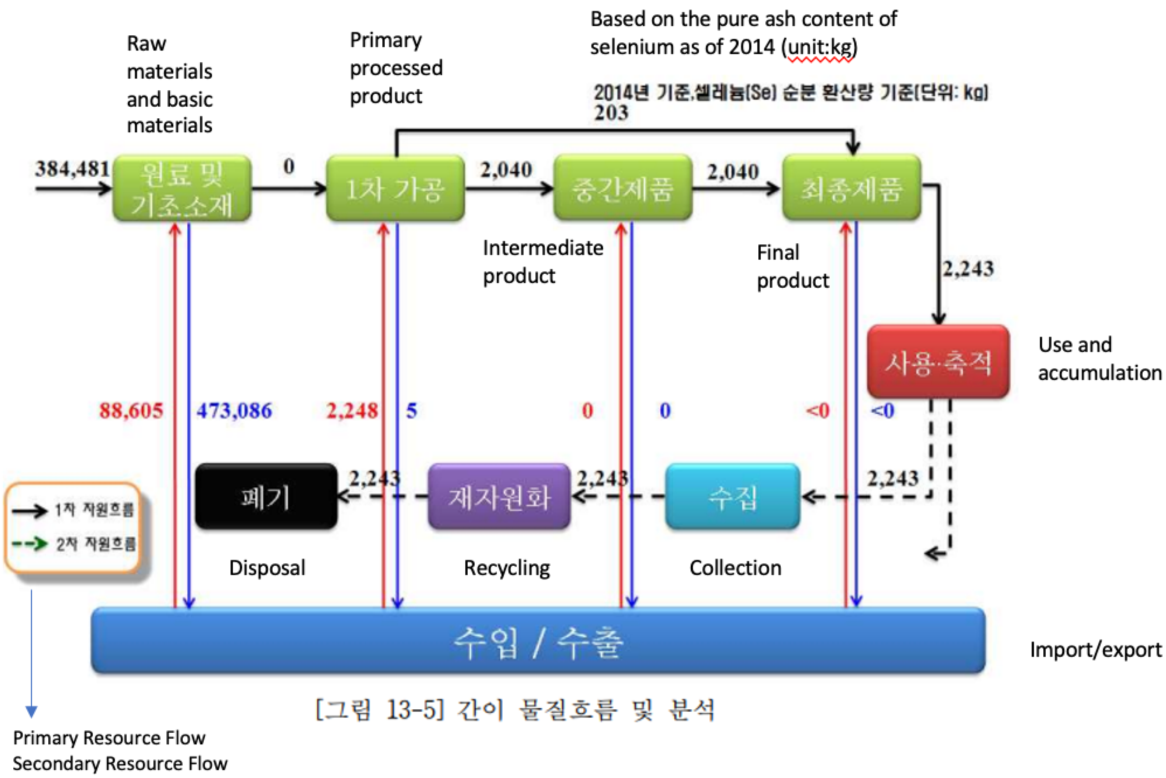
Estimation of domestic supply and demand in the disposal stage
Disposal stage supply and demand calculation ◦ Collection stage waste: 2,243 kg (final industrial (chemical) waste)
Domestic supply and demand in the disposal stage = 2,243 kg MFA of disposal phase 

Section 3: Results of Material Flow Analysis

1. Material flow chart

A. Simple flow chart

The simplified material flow diagram is shown in [Figure 13-5] by synthesizing the MFA results for each material flow stage of Selenium calculated above.



[Figure 13-5] Simplified Material Flow and Analysis

The simple material flow chart of Selenium is the data as of 2014 and represents the overall material flow from the stage of raw materials and basic materials to disposal. In the raw and basic material stage, all Selenium production was exported at 384,481kg, and all of it was imported as the primary processed product and put into the next stage. About 99% of the 2,243kg supply and demand in the primary processing product stage is injected into other chemicals (Selenium dry yeast), which are the main uses of Selenium, and about 1% of the other chemicals (mixed vitamins) in the final industry (product). For other light bulbs and lamps (photosensitive film) among intermediate products in the past, Selenium was used, but substitute materials were developed and are not currently used. It was found that batteries (solar cells) are under development and have not been commercialized until now. Among the final industries (products), chemicals (mixed vitamins) are consumed by humans and discharged directly to nature, so supply and demand are put into the disposal stage.

Input, import, export, and supply and demand by material flow stage are shown in <Table 13-4>.

<Table 13-4> Analysis results of Selenium material flow step by step

Category	Input	Import	Export	Recycling	Supply and demand
Raw materials and	384481	88605	473086	0	0

basic materials					
Primary processing	0	2248	5	0	2243
Intermediate product	2040	2	0	0	2040
Final product	2,243[1]	>0	>0	0	2243[2]
Use and stockpiling	2243	0	0	0	2243
Collection	2243	0	0	0	2243
Recycling	2243	0	0	0	2243
Disposal	2243	0	0	0	0

1) Supply and demand for intermediate products 2,040 kg + supply and demand for primary processed products 203 kg

2) The supply and demand of the final industrial (product) stage is the supply and demand of chemicals (mixed vitamins) and is included into the disposal stage

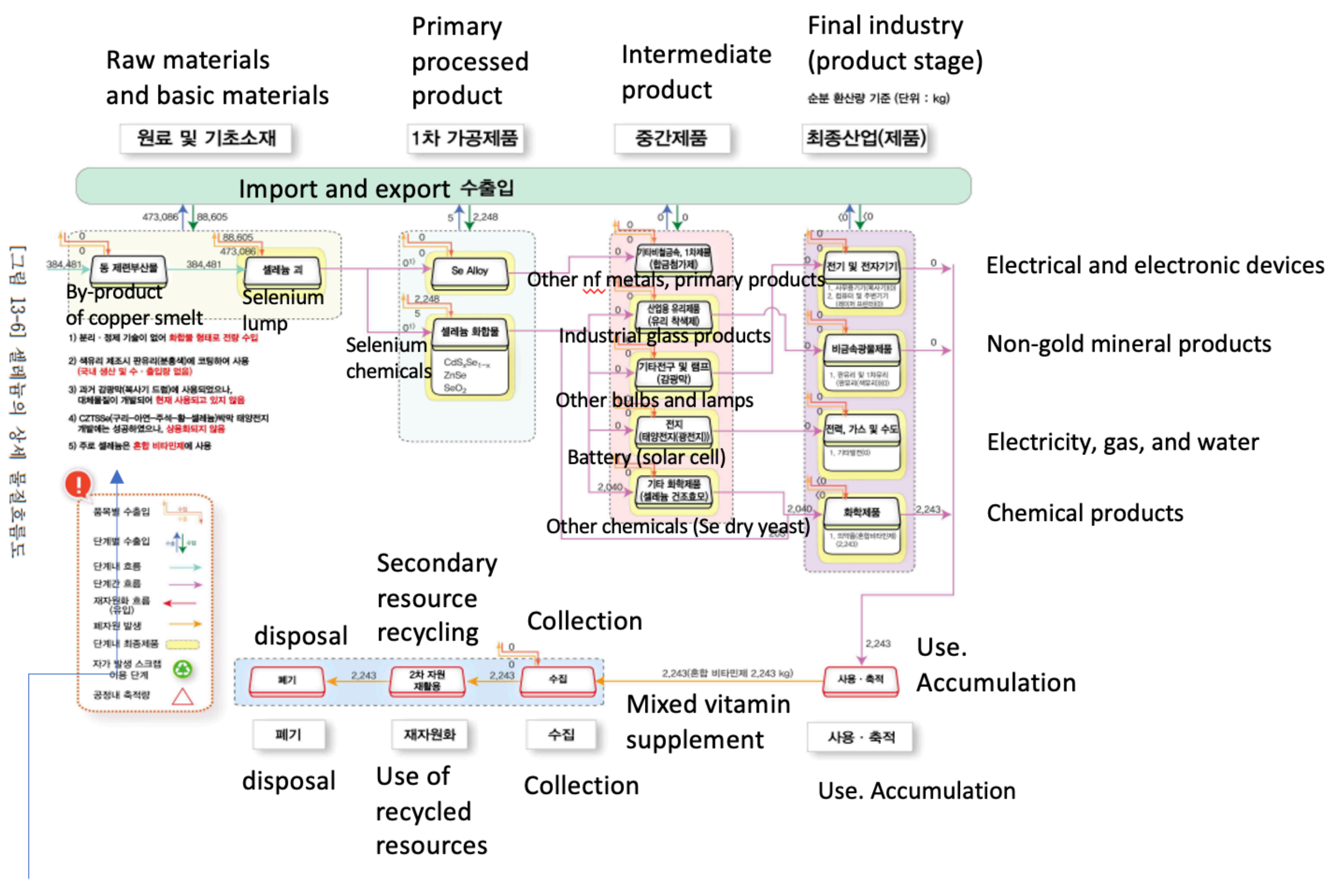
B. Detailed material flow

As for the detailed flow chart of Selenium, data from 2014 were used, and detailed flow at each stage was shown. In the case of raw materials and basic materials, it was found that Selenium gauze was produced as a Copper smelting by-product and exported in full. Therefore, it is possible to grasp the flow of Selenium imported in full in the form of Selenium compounds from the primary processing product stage. The flow of production, import and export, secondary resource input, and secondary resource generation is expressed at each stage, and Selenium is not currently being recycled and is immediately injected into the disposal stage.

The primary processed product, which is injected into the intermediate product stage, weighs 2,040kg, and about 99% of it is injected into other chemicals (Selenium dried yeast). In the case of other bulbs and lamps (photosensitive films), Selenium-coated drums were used in the past, but substitute materials were developed, and domestic production, imports, and exports currently do not exist. The development of batteries (solar cells (photovoltaic cells) is successful, but they are not commercialized, and other non-ferrous metals and primary products (alloy additives) are investigated by major domestic producers and found that there is no domestic production. Industrial glass products (glass colorants) are not produced by domestic Selenium-containing pan glass (pink), and most of them are produced only in blue, green, and bronze colors.

The amount of input into the final industrial (product) is 2,243kg, and 2,040kg is input in the intermediate product stage, 203kg is input in the primary processing product.

A detailed flow chart of Selenium is shown in [Figure 13-6].



1) Import all of them in the form of chemicals without separation and refining technology
2) When manufacturing colored glass, coat it with pan glass (pink)
(Domestic production and number; no volume)
3) Used in the past for photosensitive films (copying drum), substitute materials have been developed and are not currently being used
4) (Copper-Zinc-Tin-Sulfur-Selenium) It has been successful in developing thin-film solar cells, but has not been used
5) Selenium is mainly used in mixed vitamins

[Figure 13-6] Detailed material flow chart of Selenium

2. Completeness and reliability

A. Quantifying flow by step

The material flow of Selenium was analyzed by dividing it into a total of eight stages, as the MFA integration methodology. The material flow at each stage was quantified using statistics as shown in Table 13-5 and data from companies.

<Table 13-5> Quantification method of Selenium material flow step by step

Category	Output	Import and export	Supply and demand

Raw materials and basic materials	Literature survey data, company surveys data	Company surveys data, Korea International Trade Association data	
Primary processing	Literature survey data, company surveys data	Company surveys data, Korea International Trade Association data	
Intermediate product	Literature research data, expert advice, company research data	Company surveys data, Korea International Trade Association data, expert advice	
Final Industry (Product)	Literature survey data, company surveys data	Company surveys data, Korea International Trade Association data, and Korea Pharmaceutical Association statistics	MFA Integration Methodology[1]
Use and stockpiling	Company surveys data, literature survey data, Statistics of the Korea Pharmaceutical Association	-	
Collection	Company surveys data, Literature survey data, Statistics of the Korea Pharmaceutical Association	-	
Recycling	Company surveys data, Literature survey data, Statistics of the Korea Pharmaceutical Association	-	
Disposal	Company surveys data, Literature survey data, Statistics of the Korea Pharmaceutical Association	-	

1) Supply and demand = input + import - export + input of secondary resources

B. Verification of reliability

Selenium material flow was constructed in accordance with the integrated methodology through pre-established statistical data and company surveys data. When calculating the amount of material flow at each stage, a method was used to increase the reliability as much as possible. Selenium's material flow improved its reliability using monopoly company data and market share, focusing on company surveys. In the case of mixed vitamins, the reliability was improved by using data released by public organizations of statistical data and content information from the Korea Pharmaceutical Association and the Ministry of Food and Drug Safety. The detailed reliability review results are shown in Table 13-6.

<Table 13-6> Investigation of pharmaceutical manufacturers in intermediate product stages

Unit: kg

Category	Input volume				Reference
	Reflection of the material flow		Volume of goods		
Pharmaceutical products (Selenium) dried yeast)	2040	Category	Company name	Production survey results	Verification of the production volume of domestic Selenium-dried yeast manufacturers
			Company H	1000	
		Domestic Production	Company D	40	
			Company I	1000	

3. Discussions and improvements

A. Problems

- Primary resource flow

In the case of the raw material and foundation industry, Selenium masses were produced as Copper smelting by-products in Korea, and all the produced Selenium masses were found to be exported. In the case of the primary processing step, it was calculated as the amount of selenate and selenite or complex salt.

The main use of Selenium in Korea is other chemical products (Selenium dry yeast), and it can be said that it is important to understand the flow of substances in the intermediate and final product stages. However, it is very difficult to obtain Selenium content information of each drug through company surveys, and it is virtually impossible to obtain research data corresponding to the material flow construction year, so it was calculated using reliable statistical data.

- Secondary resource flow

According to research on domestic and foreign companies, there is currently no technology to recycle Selenium, and a research and development plan for recycling Selenium has not been established in Korea. Among the products containing Selenium, batteries (solar cells (photovoltaic cells) are not currently commercialized, but when they are commercialized in the future, further research on recycling technology is required.

B. Future improvements

As mentioned above, it is necessary to construct statistics on Selenium cells (solar cells) in the intermediate and final product stages and to collect reliable research data on Selenium content. In addition, since Selenium is not recycled at all, data on the recycling statistics and recycling technology are required if Selenium is to be recycled in the future.

4. Expected effects and utilization measures

A. Expected effect

Through the analysis of the material flow of Selenium, the supply and demand structure of domestic Selenium was identified, and its supply and demand characteristics were also identified in detail. By periodically updating the data using this research results, it is possible to track the supply and demand status and characteristics of Selenium-related industries and Selenium. Through the process, important indicators can be established for establishing and revising national resource management plans.

On the other hand, Selenium is contained in the product collected from batteries (solar cells), but there is no technology to separate and recover Selenium in the product, so it can be used as basic data for calculating the amount of reclamation through technology development and establishing expected effects through reclamation. In addition, it can lay the foundation for resource productivity improvement at each stage by improving the recycling rate, and since the amount of raw materials and basic materials exported abroad is large, it can be used for selecting major management industries and products as basic data such as resource management strategies.

B. Utilization plan

By grasping the material flow, which is the first half of Selenium, it can be used as evidence for major indicators such as the collection amount of Selenium compounds in the recycling stage and the resource productivity of Selenium compounds. Since there is no recycling technology to extract Selenium, developing recycling technology can be used as basic data such as a Selenium supply plan that can be covered by securing Selenium resources and by. It can be used as basic data such as a Selenium supply plan that can cover the use of Selenium compounds consumed in Korea through the development of refining technology of Selenium lumps produced in Korea. In addition, this research data can be used to calculate the economic effect of Selenium.

Chapter 14: Analysis of the Material Flow of Tellurium (Te)

Section 1- Business objectives and performance details

1. Investigate the flow of Tellurium substances

◦ Investigation of existing national statistics such as mining industry statistics and Korea trade statistics and previously conducted MFA data for the first and second resource flow analysis.

◦ In the case of insufficient data, such as the amount of resource content of the product and the place of demand for the product, the data survey is conducted by visiting the company and surveying the company.

2. Constructing material flow statistics

A. Raw material and basic material steps

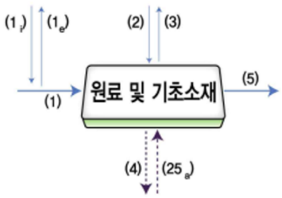
◦ Conducting MFA on the steps of processing or producing extracted Tellurium ore in the form of pulverized Tellurium

- Analysis of material flow in raw materials and basic materials through domestic supply and demand survey and analysis of Tellurium input into raw materials and basic materials.

- Supplementation of constructed statistical data through surveys and visits of producers at the raw and basic materials stage, secure unbuilt statistical data, and verify the consistency of statistical data.

Method and content of investigation

Step-by-step flow chart		Defining the steps	Materials used
	(1)	Domestic supply and demand of Tellurium-containing ore	Literature review
	(1i)	Import volume of Tellurium-containing ores	Literature review
	(1e)	Export volume of Tellurium-containing ores	Literature review
	(2)	Import volume of Tellurium raw materials and basic materials	
	(3)	Export volume of Tellurium raw materials and basic materials	

 Raw materials and basic materials	(4)	Scrap generation in raw and basic materials stage	
	(5)	Domestic supply and demand of Tellurium raw materials and basic materials	
	(25a)	Input of secondary resource recycling to raw material and basic material phase	

B. Primary Processed Product Stage

◦ MFA is performed on the stage where Tellurium discharged through the raw material and basic material step. It is manufactured in the form of reconditioning the part or product through the primary processing (Te Alloy, Tellurium compound).

- Analysis of material flow in the primary processing product stage through domestic supply and demand survey and analysis of Tellurium input into the primary processing product stage.

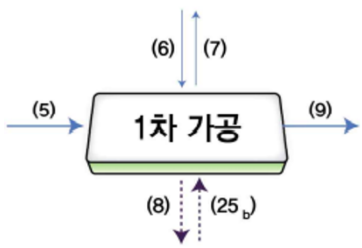
- Securing unbuilt statistical data (input to primary processed products, supply, and demand of primary processed products, etc.) and verifying consistency of statistical data through direct phone calling investigation and visiting of manufacturers in the primary processed product stage.

◦ Establishment of the primary processing product stage of Tellurium

- Establishing the primary processing product stage for Ba alloy and Tellurium compounds through data such as sector classification table of industrial association table, HS Code of Korea Trade Statistics, and expert advice

Method and content of investigation

Step-by-step flow chart		Defining Steps	Used materials
	(5)	Domestic supply and demand for raw materials and basic materials	Quantity discharged from the previous stage

	(6)	Import volume of primary processed products	Company surveys results
	(7)	Export volume of primary processed products	-
 Primary processing	(8)	Primary processing product phase and secondary resource generation	No secondary resource generation
	(9)	Number of domestic products in the primary processing stage	Use of company surveys data and literature review data
	(25b)	The amount of secondary resource input to the primary processing product stage	No secondary resource inputs

Available materials

Category	Materials
Import volume and export volume of primary processed products	Use statistical data and company surveys results
Domestic supply and demand of primary processed products	Use of company surveys results
Secondary resource inputs	No secondary resource inputs

- In the case of the company surveys data, the amount of raw material input, the main supplier and ratio of the primary processed products produced, and the market share of the manufactured product companies are investigated.

C. Intermediate product stage

◦ Conducting MFA on the stage of producing intermediate products for the use or production of final industries (products) as products produced from primary processed products.

- Determination of the quantity of primary processed products into each intermediate product, including the production of intermediate products, and analysis of the material flow survey.

- Calculation of domestic supply and demand for intermediate products through company surveys data and literature survey data, and verification of consistency of statistics on intermediate production.

◦ Establishment of intermediate product level of Tellurium

- Set as an intermediate product classification item out of 403 basic sector classifications in the industry association table

◦ Method and content of investigation

- Based on the results of the first processing company surveys, the flow and quantity of intermediate products are identified, and if the results of the company surveys are insufficient, the flow and quantity are identified using statistics on intermediate production and related documents.

- The import and export quantity of intermediate products are calculated using the results of the company surveys.

◦ Available Materials

Category	Materials
Import and export volumes in intermediate product stages	Using statistics on the import and export coefficient of the industry-related table (as of 2009) and the results of the company surveys
Domestic supply and demand for intermediate products	Company surveys results and literature survey data

D. Final industrial (product) stage

◦ Conducting MFA on the classification of electrical and electronic devices, general machinery, etc. and the stages consisting of representative products of each industry as industries where Tellurium-infused intermediate products are finally injected.

- Determining the quantity of primary processed products and intermediate products into each final industry (product), including final industry (product) production, and analyzing the material flow survey.

- Verification of numerical accuracy through comparison between company surveys data and domestic statistical data.

◦ Establishment of the final industrial (product) stage of Tellurium

- Items that fall under the category classification in the industry association table are set as the target of the final industry (product) classification

◦ Method and content of investigation

- Based on the results of the intermediate product manufacturer survey, the flow and quantity of the final industry (product) are identified, and if the results of the company surveys are insufficient, the flow and quantity are identified using statistics of the final industry (product) production and related documents.

- Export and import volume of final industries (products), supply and demand of final industries (products), secondary resource recycling input to final industries (products), Tellurium content in final industries (products), etc. (using statistics from the Korea Automobile Manufacturers Association, Korea Trade Association, and company surveys data)

◦ Available materials

Category	Materials used
Final industrial (product) imports and exports	Industry-related table import/export coefficient (as of 2009) used by company surveys results
Domestic supply and demand for final industry (product)	Tellurium content of final industry (product) (company surveys data)

E. Use and stockpiling stage

◦ It is necessary to perform MFA on the stage where Tellurium is injected into the final industry (product) stage to accumulate the final industry (product) produced in the previous year and to be recycled as a secondary resource after using Tellurium resources.

◦ Since data for evaluation including accumulated amount considering the durability of Tellurium-containing products are not sufficiently established, it is divided into stages and calculated as the final product supply and demand

F. Collection stage

◦ Conducting MFAs on the stages in which primary resources of Tellurium is collected and processed to be discharged after use and recycled as secondary resources.

- Determination of secondary resource collection and analysis of material flow investigation by considering the amount of waste generated by each product and the amount of Tellurium content generated after use of the final industry (product) into which Tellurium is injected.

- Calculation by considering the amount of waste generated by each product and the amount of resources generated after the use of the final industry (product) (use of company data survey results and statistical data)

◦ Method and content of investigation

- Use of literature research data to calculate the input of secondary resources in Korea

- Use of company surveys results and literature survey data to calculate input and collection throughput into secondary resources

- Survey details: Recycling performance by item and recycling performance of waste vehicles in the environmental protection system

◦ Available materials

Category	Used materials
Collection stage input amount	Recycling performance of environmental protection system by item Ministry of Land, Infrastructure and Transport's performance in recycling waste vehicles

G. Recycling stage

◦ After the collection stage, MFA is performed on the stage of the recycling process to be re-entered as a primary resource

- In the case of Tellurium, major recycling companies did not exist until now, and the status of Tellurium recycling for alternative resources announced by the US Geological Survey (USGS) states that Tellurium was not recycled globally as of 2014.

H. Disposal stage

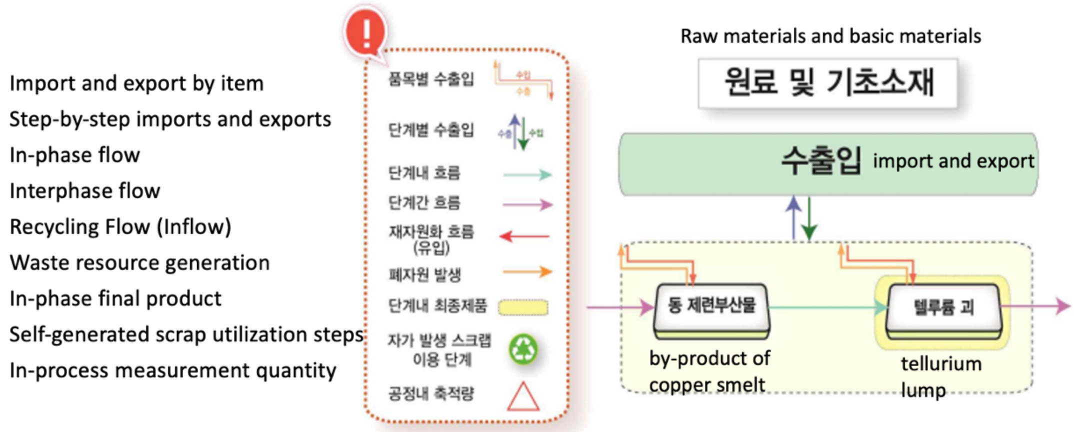
◦ Perform MFA on the stage of final disposal of Tellurium

- Consideration is given to the collection treatment waste of Tellurium discharged in the collection stage and the final disposal of Tellurium discharged in the recycling stage, i.e., the landfill amount.

Section 2- Analysis of Substance Flow by Flow Stage

1. Raw material and basic material steps

The steps of the raw material and basic material of Tellurium are defined as Copper smelting byproducts to Tellurium masses. Tellurium compounds or metal Tellurium is produced using Tellurium contained in Copper smelting by-products as a starting material, and it was investigated that a domestic Copper smelting company produces Tellurium lumps. However, because of company surveys, it was found that all the produced Tellurium lumps were exported. The flow of substances in the stages of the raw and basic materials of Tellurium is shown in [Figure 14-1].



[그림 14-1] 텔루륨의 원료 및 기초소재단계 물질흐름도

[Figure 14-1] Flow chart of materials in the stages of Tellurium raw materials and basic materials

A. Supply and demand of Copper smelting by-products

The Copper smelting by-products are not classified as HS Code, and the supply and demand of Copper smelting by-products was calculated by adding the amount of domestic Copper smelting by-products and excluding the export amount.

Supply and demand of Copper smelting by-products = Domestic Copper smelting by-products production + (Copper smelting by-products import volume × resource content) - (Export volume of copper smelting by-products × resource content)

The status of domestic Tellurium resources is reported to be formed around Taebaeksan Gwanghwa region and Hwanggang-ri Gwanghwa region, but this mine has not been developed due to its low content of Tellurium. Domestic Tellurium production is generated by removing impurities (Cu) contained in supporting smoke with a droop during Copper smelting and then casting a dopant removed Doyen into an anode plate of an electrolytic process. As of 2014, LS-Nikko Copper Smelting Co., Ltd. and Korea Zinc Co., Ltd. produced 99.99% pure Tellurium granules and sold them in units of 10kg and it was found that all supplies were exported.

It was classified as Tellur (HS Code 2804.50.2000) in Korean trade statistics and related statistics are being compiled, but it was investigated that they were aggregated without classification of compounds and ingot.

<Table 14-1> Import and export volume of Tellurium

			Tellur (2804.50.2000)	
HS Code		Import		Export
Year	Amount (in thousand dollars)	Weight (kg)	Amount (in thousand dollars)	Weight (kg)
2012	574	158	223741	9612
2013	2029	478	195144	8226
2014	2942	539	224657	9797

Source: Korea Trade Statistics

Estimation of domestic supply and demand of Copper smelting by-products

Data used: Korea Trade Statistics
Mineral supply and demand status

Copper smelting by-products production, import and export volume

◦ Domestic production of Copper smelting by-products: 224,657 kg
◦ Tellurium import volume of Copper smelting by-products: 0 kg
◦ Tellurium export volume of Copper smelting by-products: 0 kg

Domestic supply and demand of Copper smelting
= 224,657 + 0 - 0
= 224,657 kg

MFA of Copper smelting by-products

by-product of copper smelt

B. Tellurium mass supply and demand

Tellurium lumps are classified as 2804.50.2000 (Tellur) in HS Code, but the amount of Tellurium lumps cannot be calculated because the Tellurium compound and the volume are not distinguished.

Tellurium mass supply and demand

= Domestic Tellurium mass production + (Tellurium mass import volume × resource content) - (Tellurium mass export volume × resource content) + (secondary resource input × resource

According to a company surveys, Tellurium masses produced in Korea through Copper smelting by-products are currently exported with 99.999% purity, and Tellurium compounds are used in nonvolatile memory and semiconductor devices that are being imported from China, Belgium, and Japan.

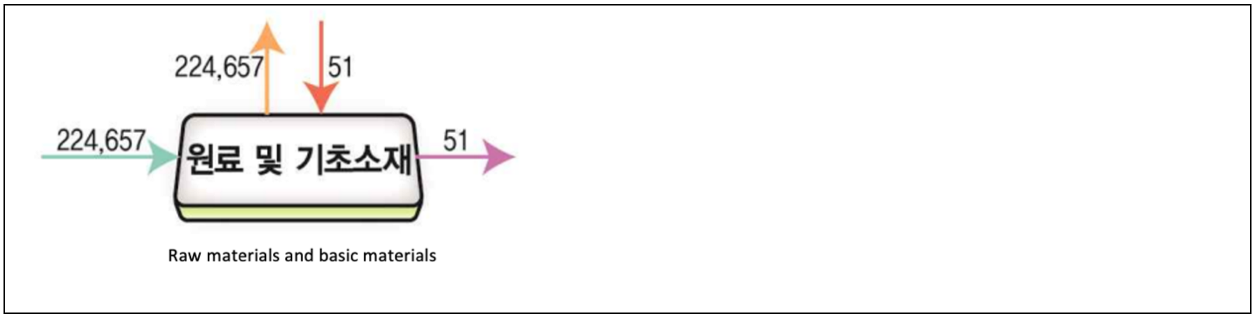
Estimation of domestic supply and demand of Tellurium lumps
Data used: Korea Trade Statistics Company surveys data
Tellurium mass production, import and export volume ◦ Domestic production of Tellurium lumps: 224,657 kg ◦ Tellurium ingestion: 51 kg ◦ Tellurium bullion export volume: 224,657 kg
Domestic supply and demand of Tellurium ingots = 224,657 + 51 - 224,657 = 51 kg MFA of Tellurium bulk  tellurium lump

C. Supply and demand of Tellurium raw materials and basic materials stage

As described above, the supply and demand of domestic Tellurium raw materials and basic materials were calculated using the production, import and export of Copper smelting byproducts and Tellurium masses.

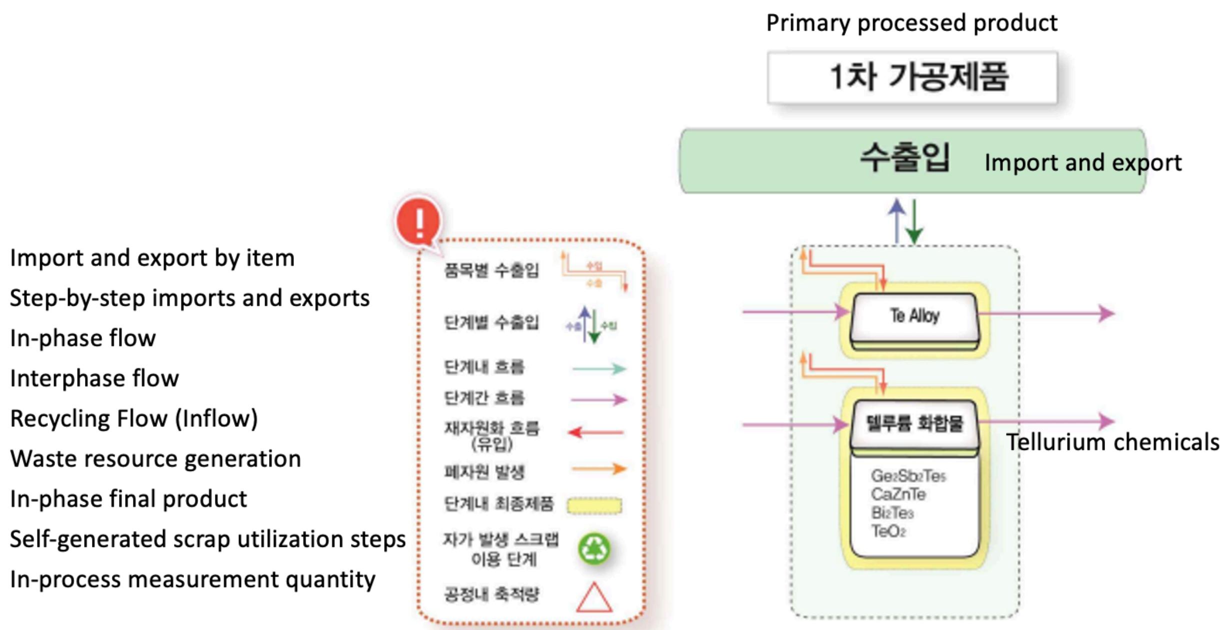
Domestic supply and demand for Tellurium raw materials and basic materials (net volume conversion) = (Tellurium mass domestic production volume × resource content) + (Tellurium mass import volume × resource content) - (Tellurium mass export volume × resource content)

Estimation of domestic supply and demand for Tellurium raw materials and basic materials
Data used: Korea Trade statistics Company surveys results
Production volume of Tellurium raw materials and basic materials, import and export volume ◦ Domestic production of Tellurium lumps: 224,657 kg ◦ Tellurium ingestion: 51 kg ◦ Tellurium bullion export volume: 224,657 kg
Domestic supply and demand of Tellurium raw materials and basic materials = 224,657 + 51 - 224,657 = 51 kg MFA of Tellurium raw materials and basic materials phase



2. Primary Processed Product Stage

The primary processed product stage is defined as the stage of manufacturing in the form of a material for manufacturing a product through the stage of raw materials and basic materials and includes Te Alloy and Tellurium compounds. The detailed flow of the primary processed product stage is shown in [Figure 14-2]



[그림 14-2] 텔루륨의 1차 가공제품 단계 물질흐름도

[Figure 14-2] Material flow diagram of the primary processed product of Tellurium

A. Te Alloy domestic supply and demand

Te Alloy means an alloy containing Tellurium, and Te Alloy used in Korea was found to be the only one with Tellurium Copper (CuTe). Pure Copper is a very flexible material, and ductility is a very beneficial property in many fields, but it is a very disadvantageous property for machining. However, when a CuTe (Copper Telluride) alloy is formed by adding 0.5% Tellurium to pure Copper, the processability of pure Copper is remarkably enhanced. Due to that, Tellurium Copper is called fast cutting Copper in the

Japanese mold industry. The electrical conductivity, thermal conductivity, and ductility of Tellurium Copper are only slightly affected. Tellurium forms a Copper alloy and a Copper Telluride deposit on a microstructure. This deposit serves to cut the cutting chip into small pieces, so it is possible to cut it at a faster speed than pure Copper. Machinability Index is an index of the processing speed that can be achieved while maintaining the same surface quality and tool life. Based on the machinability of Tellurium brass, if the processability of Tellurium brass is 100, pure Copper is only 20, while Tellurium Copper is 90. In other words, when processing with the same surface quality, Tellurium Copper can be processed at a speed 4.5 times faster in theory than when processing pure Copper.

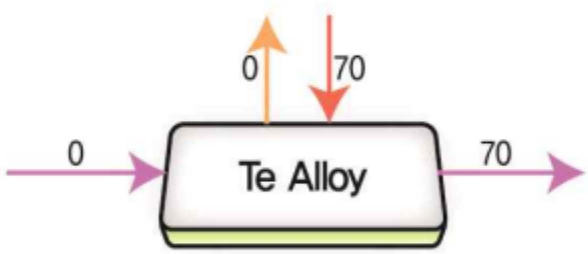
In other words, it means that the electrode to be processed for 9 hours in a pure motion can be processed in just 2 hours with Tellurium Copper. Therefore, in the case of processing an electrode using a high-speed processor with a high hourly wage rate, shortening the processing time using Tellurium Copper is a shortcut to reducing electrode processing costs. Compared to the workability, if Tellurium Copper is processed under the same processing conditions as pure Copper, the life span of the tool can be extended 4.5 times longer. In addition, Tellurium Copper is resistant to hydrogen weakening (a phenomenon in which hydrogen is absorbed by metals and changes in the metal lattice, weakening the crystal and becoming brittle). IACS is commonly used as a method of expressing the electrical conductivity of metals. Here, IACS means for International Annealed Copper Standard, and the electrical conductivity of Pure Cu is set to 100%, that is, the reference, and the relative electrical conductivity is expressed. For example, silver (Ag) is 105% IACS. That is, silver (Ag) means that it has an electrical conductivity that is 5% higher than that of pure Copper. Tellurium Copper also has high electrical conductivity, so it is about 52 m/W ㎟ (90% IACS). This means that the energy generated during discharge processing is also not significantly decreased compared to pure Copper. To produce high quality Tellurium Copper, it can produce high quality low oxygen content billet.

High-quality billet shall be produced in the same process as anaerobic production in which all free oxygen is removed from Copper using carbon powder or carbon monoxide gas in an atmosphere in which contact with oxygen is completely blocked. Oxygen quickly combines with Tellurium to form Tellurium oxide impurities, which must be thoroughly blocked because it makes Copper brittle. Another important property required to obtain good quality Tellurium Copper is the uniform distribution of Copper Telluride. As mentioned earlier, Copper Telluride is a precipitate that is distributed at the grain boundary of the Copper particles while forming, so that the length of the chip is cut short during cutting processing. Therefore, only when Copper Telluride is small and evenly distributed inside Tellurium Copper, the cutting property can be improved.

As a result of the company's investigation, it was found that Tellurium Copper was not produced in Korea because it was not economical but was imported and used in full. Therefore, the domestic supply and demand of Te Alloy was calculated using the company surveys data.

Domestic supply and demand of Te Alloy = (Te Alloy production × resource content) + (Te Alloy import volume × resource content) - (Te Alloy export volume × resource content)

Since the HS Code is not classified for Te Alloy, the results of the company surveys were used.

Estimation of domestic supply and demand for Te Alloy
Data used: Company surveys data and literature survey data
Te Alloy's output, import and export volumes ◦ Te Alloy's domestic production: 0 kg ◦ Import volume of Te Alloy: 70 kg ◦ Export volume of Te Alloy: 0 kg
Domestic supply and demand of Te Alloy = 0 + 70 - 0 = 70 kg MFA of Te Alloy 

C. Domestic supply and demand of Tellurium compounds

The Tellurium compound can be classified into Ge2Sb2Te5, CaZnTe, Bi2Te3, and TeO2 and other Tellurium compounds depending on their use. Ge2Sb2Te5 is a compound used to produce non-volatile memory in Korea, and CaZnTe is also in the research and development stage at the Korea Atomic Energy Research Institute as a compound used in semiconductors for next-generation radiation sensors. The amount of import and export of the two compounds was calculated through a survey by the institute. Bi2Te3 uses the most Tellurium in Korea. Since there are no export/import statistics for the compound as a compound injected into the production of thermoelectric devices, import/export and production volume were calculated through a survey of thermoelectric device producers.

The domestic supply and demand of Tellurium compounds was calculated using company surveys data and calculated through the following formula.

Domestic supply and demand of Tellurium compounds = (Tellurium compound production × resource content) + (Tellurium compound import volume × resource content) -(Tellurium compound export volume × resource content) + (Secondary resource input × resource content) -(Secondary resource generation × resource content)

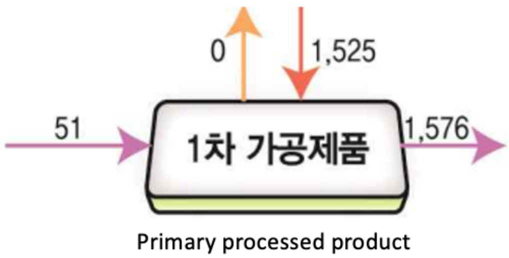
Estimation of domestic supply and demand of Tellurium compounds
Data used: Korea Trade Statistics, Company surveys data
Tellurium compound production, import and export volume ◦ Domestic production of Tellurium compounds: 51 kg (injected from Tellurium ingots) ◦ Import volume of Tellurium compound: 1,455 kg ◦ Export volume of Tellurium compounds: 0 kg ◦ Secondary resource input: 0 kg
Domestic supply and demand of Tellurium compounds = 51 + 1,455 – 0 + 0 = 1,506 kg MFA of Tellurium compounds  Tellurium chemicals

C. Supply and demand of primary processed products

As described above, the supply and demand of domestic Tellurium in the primary processing product stage was calculated using the production amount, import and export amount, secondary resource input amount, and generation amount of Te Alloy and Tellurium compounds.

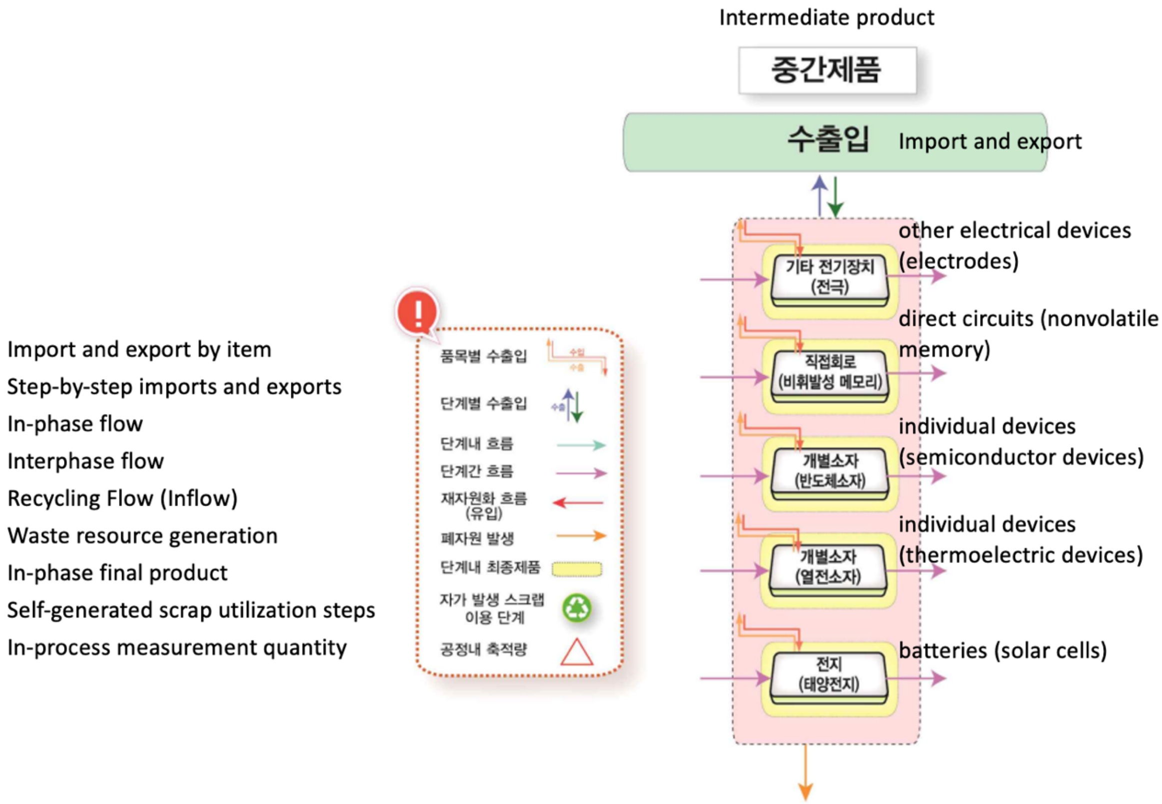
Domestic supply and demand for tellurium primary processed products = Te Alloy supply and demand + Tellurium compound supply and demand

Estimation of domestic supply and demand for primary processed products
Data used: Korea Trade Statistics, Company surveys data, and literature survey data
Supply and demand of Tellurium primary processed products ◦ Te Alloy's domestic production: 0 kg ◦ Domestic production of Tellurium compounds: 51 kg (injected from Tellurium ingots) ◦ Import volume of Te Alloy: 70 kg ◦ Import volume of Tellurium compound: 1,455 kg ◦ Export volume of Te Alloy: 0 kg ◦ Export volume of Tellurium compounds: 0 kg

◦ Secondary resource input: 0 kg ◦ Secondary resource generation: 0 kg
Domestic supply and demand of Tellurium in primary processed products = 0 + 51 + 70 + 1,455 – 0 – 0 + 0 – 0 = 1,576 kg MFA in the primary processing product phase of Tellurium 

3. Intermediate product stage

The intermediate product stage is defined as the stage of producing intermediate products for the use or production of final industries (products) as products produced from raw materials, basic materials, and primary processed products. Products in the intermediate product stage are divided into other electrical devices (electrodes), direct circuits (non-volatile memory), individual devices (semiconductor devices), individual devices (thermal electric devices), and batteries (solar cells), and the results are calculated using industrial association tables and company surveys data.



[그림 14-3] 텔루륨의 중간제품단계 물질흐름도

[Figure 14-3] Intermediate product flow diagram of Tellurium

A. Domestic supply and demand of Tellurium in other electrical devices (electrodes)

Pure Copper in other electrical devices (electrodes) is beneficial in many fields, but it is disadvantageous for machining, so if about 0.7% of Tellurium is added to form a CuTe (Tellurium Copper) alloy, processability is significantly improved. Since Tellurium Copper has high electric conductivity, it is used as electrode of hard loaded working electric discharge machine and when it is used as an electrode , sparks do not occur at the contact point. Tellurium Copper is imported and used in full due to low economic feasibility for production due to lack of domestic demand, and because of an investigation by a Tellurium Copper importer, it is investigated that it is used as an electrode producer.

Domestic supply and demand of tellurium in other electrical devices (electrodes) = (Electrode production volume × resource content) + (Electrode import volume × resource content) - (Electrode export volume × resource content) - (Secondary resource generation volume)

Calculation of domestic supply and demand of Tellurium in other electrical devices (electrodes)
Data used: Industry-related table, company surveys data

Production, import and export volume of Tellurium in other electrical devices (electrodes) ◦ Domestic production of Tellurium in other electrical devices (electrodes): 70 kg ◦ Amount of Tellurium imported from other electrical devices (electrodes): 33 kg ◦ Export volume of Tellurium in other electrical devices (electrodes): 21 kg ◦ Secondary resource generation: 0 kg
Domestic supply and demand of Tellurium in other electrical devices (electrodes) = 70 + 33 – 21 - 0 = 82 MFA of Tellurium in other electrical devices (electrodes)

Other electrical devices (electrodes)

B. Domestic supply and demand of Tellurium in direct circuits (nonvolatile memory)

Direct circuits (nonvolatile memory) are used in phase-change memory chips (PCME or PRAM) devices, a type of nonvolatile memory, using the Ge2Sb2Te5 Tellurium compound. PRAM is a next-generation memory that has the advantages of both RAM memory and flash memory with nonvolatile characteristics. Although the nonvolatile memory market including Tellurium has already been developed by Samsung Electronics and SK Hynix in its early stages, all information on mass production is kept private, and all Tellurium used to produce direct circuits (nonvolatile memory) is collected instead of being put into the final stage. Domestic supply and demand for direct circuits (nonvolatile memory) is calculated through the following.

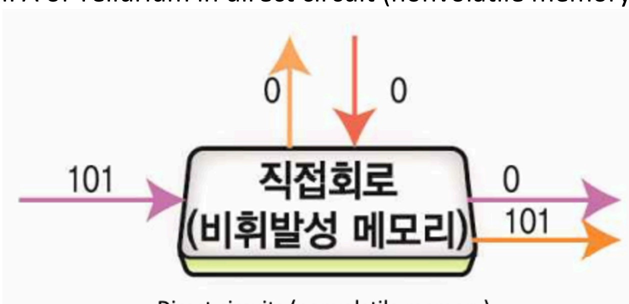
Domestic supply and demand of Tellurium in direct circuit (nonvolatile memory) = (Nonvolatile memory production × resource content) + (Nonvolatile memory import × resource content) - (Nonvolatile memory export × resource content) - (Secondary resource generation volume)

Calculation of domestic supply and demand of Tellurium in direct circuit (nonvolatile memory)
Data used: Industry-related table, company surveys data
Production, import and export of Tellurium in direct circuits (nonvolatile memory) ◦ Domestic production of Tellurium in direct circuits (nonvolatile memory): 101 kg ◦ Amount of Tellurium imported in direct circuit (nonvolatile memory): 0 kg

◦ Export volume of Tellurium in direct circuit (nonvolatile memory): 0 kg
◦ Secondary resource generation: 101 kg

Domestic supply and demand of Tellurium in direct circuit (nonvolatile memory)
= 101 + 0 – 0 - 101
= 0 kg

MFA of Tellurium in direct circuit (nonvolatile memory)



Direct circuits (nonvolatile memory)

C. Domestic supply and demand of Tellurium in individual devices (semiconductor devices)

The Tellurium compound CaZnTe is a next-generation material that is highly useful, including gamma-ray sensors in space telescopes for space radiation observation, 3D image radiation sensors for nuclear medical imaging devices such as PET and SPECT, gamma-ray sensors for small nuclear materials and isotope analysts, and next-generation solar cells. It is attracting attention as a source material for next-generation radiation sensors to replace Ge semiconductors because it has high energy resolution and large energy bandgap that can be operated by sensors without a separate cooling device at room temperature. CZT compound semiconductors also have twice the reaction efficiency of silicon semiconductors, which are currently widely used as solar cell materials, in narrow areas.

It is expected to produce a lot of electricity. The global market for radiation sensors is growing by more than 10% annually at $1.1 billion, and among them, the CZT sensor market is growing faster than average at $30 million as of 2006. While a small number of companies, including US eV products, which currently monopolize 70% of the global market, supply CZT single crystals, advanced nuclear medical imaging devices based on CZT are being developed using them. In addition, the U.S. Department of Homeland Security plans to distribute mobile phone CZT semiconductor radiation instruments worth less than $10,000 to all citizens to protect their citizens from nuclear and radiation attacks. Since the US classified CZT single crystals as strategic materials after the war on terrorism, and related companies only supply them in the form of finished radiation sensors with high added value, so there is no single crystal technology.

It is expected that it will be able to take the lead in the next-generation semiconductor sensor market in the future by developing its own large-scale single crystal growth technology in the face of a lack of raw material technology. As part of the Ministry of Science and Technology's nuclear research and development project since 2007, the Korea Atomic Energy Research Institute has succeeded in growing the CZT compound, a compound semiconductor material composed of three elements Cd, Zn, and Te, into a two-inch large-diameter single crystal. It is the world's sixth (the eighth in the world by development entity) to grow the CZT compound into a large-scale single crystal with a diameter of more than 1 inch after France, The United States, The United Kingdom, Canada, and Israel. According to the results of the Korea Atomic Energy Research Institute, there are no currently commercialized Tellurium semiconductor devices in Korea, and they are used in the full research stage and are not put into the final industrial stage but are all collected. The domestic supply and demand of Tellurium in individual devices (semiconductor devices) is calculated as follows.

Domestic supply and demand of Tellurium in individual devices (semiconductor devices) = (Semiconductor device production amount × resource content) + (Semiconductor device import amount × resource content) - (Semiconductor device export volume × resource content) - (Secondary resource generation volume)

Calculation of domestic supply and demand of Tellurium in individual devices (semiconductor devices)
Data used: Korea International Trade Association, company surveys data
Production, import, and export volume of Tellurium in individual devices (semiconductor devices) ◦ Domestic production of Tellurium in individual devices (semiconductor devices): 5,505 kg ◦ Import volume of Tellurium in individual devices (semiconductor devices): 0.01 kg ◦ Export volume of Tellurium in individual devices (semiconductor devices): 0.8 kg ◦ Secondary resource generation: 0 kg
Domestic supply and demand of Tellurium in individual devices (semiconductor devices) = 5,505 + 0.01 – 0.8 - 0 = 5,504.21 kg

MFA of Tellurium in individual devices (semiconductor devices)

Individual devices (semiconductor devices)

D. Domestic supply and demand of Tellurium in individual devices (Thermoelectric devices)

Thermoelectric devices generated from the Tellurium compound Bi2Te3 as raw materials are widely used, such as automobile temperature control sheets, semiconductor manufacturing machines, and as cooling devices for computers and home appliances. Thermoelectric devices are devices used to directly convert thermal energy into electric energy and convert electric energy into thermal energy, vice versa, and this technology is that the best meet the demands of the times; energy usage reduction. Developed countries are conducting research on thermoelectric materials to improve fuel efficiency, focusing on research institutes and companies, and these are also being conducted in Korea, focusing on research institutes and universities. In Korea, the base technology for manufacturing thermoelectric devices is lower than that of developed countries (ZT-0.8), and the government support is also insufficient. Research is underway to increase the efficiency of thermoelectric materials such as silicon and bismuth-telluride (Bi-Te)-based bulk, thin films, and nanowires, centering on universities and research institutes. According to a survey conducted by a domestic thermoelectric device manufacturer, Bi2Te3, a raw material for thermoelectric device production, was imported from China and produced. The amount of Tellurium used in thermoelectric devices was calculated through a company surveys, and the import and export statistics of the Korea International Trade Association and the average unit price and average Tellurium content of thermoelectric devices were calculated.

Domestic supply and demand of Tellurium in individual devices (thermoelectric devices) = (Thermoelectric element production amount × resource content) + (Thermoelectric element import amount × resource content) - (Export volume of thermoelectric devices × resource content) - (Secondary resource generation volume)

<Table 14-2> Ratio of import and export of Tellurium in individual devices (thermoelectric devices)

Category	Import	Export
Import and export volume (EA)①	716.638	726.522
Average weight of thermoelectric element (g)②	20.7	20.7
Average Te content (%)③	9.62	9.62
Net Te content (kg)(①×②)×③	1433	1453

Data: Export-Import Statistics of the Korea International Trade Association, Consultation with the Institute of Advanced Technology

Calculation of domestic supply and demand of Tellurium in individual devices (thermoelectric devices)
Data used: Industry-related table, company surveys data
Production, import, and export volume of Tellurium in individual devices (thermoelectric devices) ◦ Domestic production of Tellurium in individual devices (thermoelectric devices): 1,355 kg ◦ Import volume of Tellurium in individual devices (thermoelectric devices): 1,433 kg ◦ Export volume of Tellurium in individual devices (thermoelectric devices): 1,453 kg ◦ Secondary resource generation: 0 kg
Domestic supply and demand of Tellurium in individual devices (thermoelectric devices) = 1,355 + 1,433 – 1,453 - 0 = 1,355 MFA of Tellurium in individual components (thermoelectric elements)

Individual devices (thermoelectric devices)

E. Domestic supply and demand of Tellurium in batteries (solar cells)

A solar cell is a photovoltaic cell built for the purpose of converting solar energy into electrical energy and is a semiconductor device that converts light energy generated from the sun into electrical energy. Depending on the material used, it is classified into silicon-based, compound, dye-sensitized, organic, etc. Among them, materials that have emerged as thin-film solar cells are CIGS (Copper Indium Gallium Selenide), CdTe (Cadmium Telluride), and DSSC (Dye-Sensitized Solar Cell), a dye-sensitized material. Especially, CdTe solar cells are highly economical.

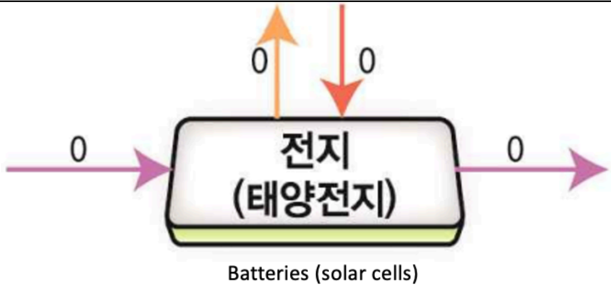
Due to over-efficiency, it has increased from 2.7% of the total solar cell market in 2006 to 12.3% in 2009, showing rapid growth. In Korea, the Korea Advanced Institute of Science and Technology is conducting research on synthesizing CdTe with screen printing techniques, but research and development on large-area measures necessary for practical use is insufficient. According to a survey conducted by the Korea Advanced Institute of Science and Technology and the Korea Energy Management Corporation, there was no CdTe solar cell production or import/export as of 2014, but the corresponding cell (solar cell) was added as an intermediate product as it may flow later.

Domestic supply and demand of Tellurium in batteries (solar cells)

= (Solar cell production volume × resource content) + (Solar cell import volume × resource content) -

(Solar cell export volume × resource content) - (Secondary resource generation volume)

Calculation of domestic supply and demand of Tellurium in a battery (solar cell)
Data used: Korea International Trade Association, company surveys data
Production, import, and export volume of Tellurium in batteries (solar cells) ◦ Domestic production of Tellurium in batteries (solar cells): 0 kg ◦ Tellurium import amount in a battery (solar cell): 0 kg ◦ Export amount of Tellurium in a battery (solar battery): 0 kg ◦ Secondary resource generation: 0 kg
Domestic supply and demand of Tellurium in batteries (solar cells) = 0 + 0 – 0 - 0 = 0 kg MFA of Tellurium in a cell (solar cell)



F. Supply and demand of intermediate products

As described above, the intermediate supply and demand of Tellurium was calculated by dividing it into other electrical devices (electrodes), direct circuits (non-volatile memory), individual devices (semiconductor devices), individual devices (thermal electric devices), and batteries (solar cells), and the results are shown in Table 14-3.

Domestic supply and demand for intermediate products of Tellurium

= Other electrical equipment (electrode) supply and demand + direct circuit (non-volatile memory) supply and demand + supply and demand of individual devices (semiconductor devices) + supply and demand of individual devices (thermoelectric devices) + supply and demand of batteries (solar cells)

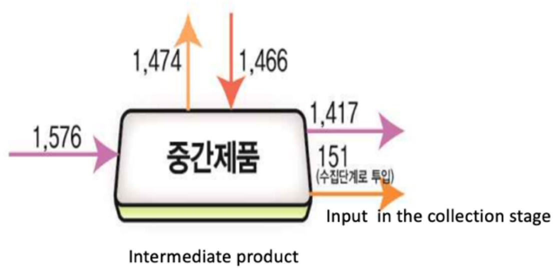
<Table 14-3> Supply and demand of intermediate products

Unit: kg

Category	Input	Import	Export	Supply and demand
Other electrical devices (electrode)	70	33	21	82
Direct circuit (non-volatile memory)	101	0	0	101*
Individual devices (semiconductor devices)	50	0	0	50*
Individual device (thermoelectric device)	1355	1433	1453	1335
Battery (solar battery)	0	0	0	0

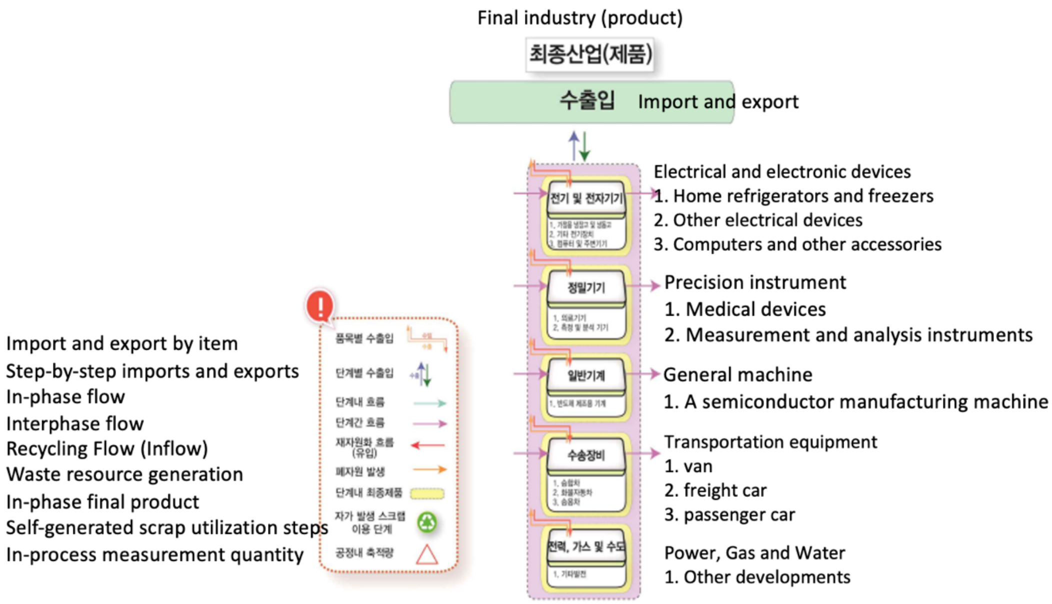
* Included into the collection phase

Estimation of domestic supply and demand for Tellurium intermediate products
Data used: Literature data, Company surveys results, Korea Trade Statistics, expert advice
Tellurium intermediate product stage supply and demand ◦ Supply and demand of other electrical devices (electrodes): 82 kg ◦ Direct circuit (nonvolatile memory) supply and demand: 101 kg ◦ Supply and demand of individual devices (semiconductor devices): 50 kg ◦ Supply and demand of individual devices (thermoelectric devices): 1335 kg ◦ Battery (solar cell) supply and demand: 0 kg
Domestic supply and demand for intermediate products of Tellurium = 82 + 101 + 50 + 1,335 + 0 = 1,568 kg MFA of Tellurium intermediate product phase



4. Final industry (product) stage

The final industry (product) stage is divided into electrical and electronic equipment, precision equipment, general machinery, transportation equipment, power, gas, and water industries, and the supply and demand for each item was calculated using Korea Trade Statistics, Company surveys data, 2009 Import and export coefficient, Literature survey data, and expert advisory.



[그림 14-4] 텔루륨의 최종산업(제품)단계 물질흐름도

[Figure 14-4] Material flow chart of the final industrial (product) stage of Tellurium

Tellurium input into the final industry (product) was classified into major classification items of the industry-related table as shown in <Table 14-4> using the IO-KSIC classification table to calculate the supply and demand.

<Table 14-4> Response of intermediate and final product items (using the industry-related table)

	Intermediate product			Final product
Item name	Code number	403 basic categories	Code number	Major classification
Electrode	247	Other electrical devices		Electrical and electronic devices
Non-volatile memory	251	a direct circuit		A precision instrument
Semiconductor devices	250	Individual components		A general machine
Thermoelectric element	250	Individual components		Transportation equipment
Solar cell	245	The battery		Power, gas and water

A. Domestic supply and demand of electronic and electrical devices

The supply and demand of Tellurium in electronic and electrical devices was calculated using company surveys data, literature data, and 2009 industry-related tables, and it is input from other electrical devices (electrodes), direct circuits (nonvolatile memory), and individual devices (thermal electric devices).

Domestic supply and demand of Tellurium in electronic and electrical appliances = (Electronic and electrical equipment production + electronic and electrical equipment imports - electronic and electrical equipment exports) × resource content

Electronic and electrical devices are divided into inputs from intermediate products and other electrical devices (electrodes), direct circuits (non-volatile memory), and individual devices (thermoelectric devices). Input from intermediate products of electronic and electrical devices was calculated using a company surveys and a top-down method using an industry-related table, and the import and export of each product was calculated through the ratio of imports to exports in the producer price evaluation table of 2009. Table 14-5 shows the results of calculating the input, import, and supply and demand of electronic and electricity

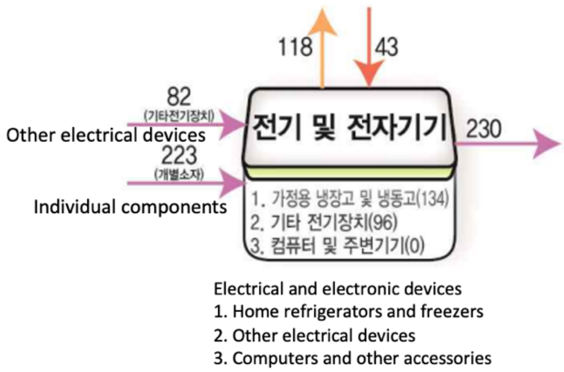
<Table 14-5> Domestic supply and demand of electronic and electrical devices (two other than home refrigerators and freezers)

Unit: kg

The product	Inputs	Imports	Exports	Supply and demand
Home refrigerators and freezers	223	4	93	134
Other electrical devices	82	39	25	96
Computers and peripherals	0	0	0	0

Estimation of domestic supply and demand for electronic and electrical appliances
Data used: Company surveys data, Korea Trade Statistics, 2009 industry-related table
Production, import and export volume of electronic and electrical appliances ◦ Domestic production of electronic and electrical appliances: 305 kg ◦ Import volume of electronic and electrical appliances: 43 kg ◦ Export volume of electronic and electrical appliances: 118 kg

Domestic supply and demand of electronic and electrical Appliances
= 6305 + 43 - 118
= 230 kg
MFA of electronic and electrical appliances



B. Domestic supply and demand of precision equipment

The supply and demand of Tellurium in precision equipment was calculated using company surveys data, literature data, and industry-related tables as of 2009, and it is input from individual devices (semiconductor devices).

Domestic supply and demand of Tellurium in precision equipment

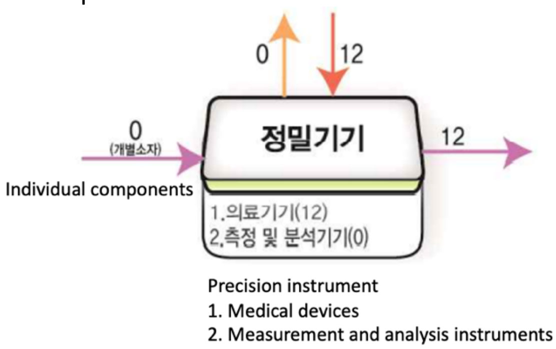
= (Precision equipment production volume + precision equipment import volume - precision equipment export volume) × resource content

Precision devices are input from individual intermediate products (semiconductor devices) and are calculated using the company surveys results, and the import and export amount of each product is calculated through the ratio of imports to exports in the producer price evaluation table of the 2009 industry-related table. Table 14-6 shows the results of calculating the input, import, and supply and demand of precision devices.

<Table 14-6> Domestic supply and demand of precision equipment (one other than medical equipment)

(Unit: kg)

The product	Input amount	Imports	Exports	Supply and demand
Medical devices	0	12	0	12
Measurement and analysis of instruments	0	0	0	0

Calculation of domestic supply and demand for precision equipment
Data used: Company surveys data, Korea Trade Statistics, 2009 industry-related table
Production, import and export volume of precision equipment ◦ Domestic production of precision equipment: 0 kg ◦ Import volume of precision equipment: 12 kg ◦ Export volume of precision equipment: 0 kg
Domestic supply and demand of precision equipment = 0 + 12 –0 = 12 kg MFA of precision instruments 

C. Domestic supply and demand of general machinery

The supply and demand of Tellurium in general machinery was calculated using company surveys data, literature data, and industry-related tables as of 2009, and it is input from individual devices (thermoelectric devices).

Domestic supply and demand of Tellurium in general machinery = (General machine production volume + general machine import volume - general machine export volume) × resource content

General machines are input from individual intermediate products (thermoelectric devices), and input from intermediate products is calculated using the top-down distribution coefficient using the industry-related table, and the import and export of each product is calculated through the ratio of imports to total output in the 2009 producer price evaluation table. Table 14-7 shows the results of calculating the input, import, and supply and demand of general machines.

<Table 14-7> Domestic supply and demand of general machines (semiconductor manufacturing machines)

(Unit: kg)

The product	Input amount	Imports	Exports	Supply and demand

Semiconductor manufacturing machine	1088	796	201	1683

Estimation of domestic supply and demand for general machines

Data used: Company surveys data, Korea Trade Statistics, 2009 industry-related table

Production, import, and export volume of general machinery

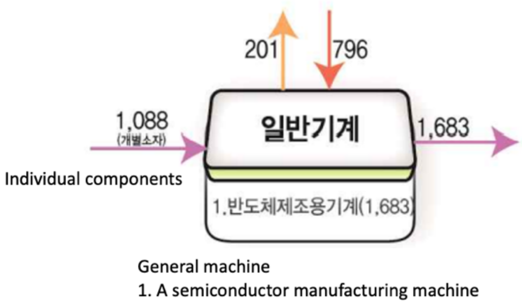
◦ Domestic production of general machinery: 1,088 kg

◦ Import volume of general machine: 796 kg

◦ Export volume of general machinery: 201 kg

The domestic supply and demand of general machinery
= 1,088 + 796 - 201
= 1,683 kg

MFA for general machinery



D. Domestic supply and demand of transportation equipment

The supply and demand of Tellurium in the transportation equipment was calculated using company surveys data, literature data, and industry-related tables as of 2009, and is input from individual devices (thermoelectric devices).

Domestic supply and demand of Tellurium in transportation equipment

= (Production volume of transportation equipment + Import volume of transportation equipment - Export volume of transportation equipment) × resource content

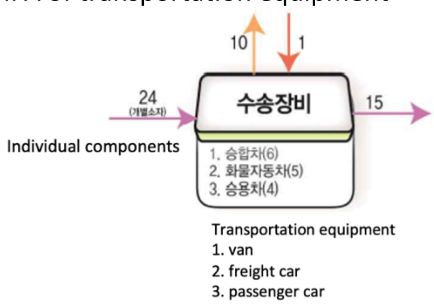
Transport equipment is input from individual intermediate products (thermoelectric devices), and input from intermediate products is calculated using the top-down distribution coefficient using the industry-related table, and the import and export of each product is calculated through the ratio of imports to total output in the 2009 producer price evaluation table. Table 14-8 shows the results of calculating the input, import, and supply and demand of transportation equipment.

<Table 14-8> Domestic supply and demand of transportation equipment (two other than vans)

(Unit: kg)

The product	Input amount	Imports	Exports	Supply and demand
van	7	0	1	6
freight car	8	0	3	5
passenger car	9	1	6	4

Estimation of domestic supply and demand for transportation equipment
Data used: Company surveys data, Korea Trade Statistics, 2009 industry-related table
Production, import and export volume of transportation equipment ◦ Domestic production of transportation equipment: 24 kg ◦ Import volume of transportation equipment: 1 kg ◦ Export volume of transportation equipment: 10 kg
Domestic supply and demand of transportation equipment = 24 + 1 – 10 = 15 kg MFA of transportation equipment



E. Domestic supply and demand of electricity, gas, and water supply systems

Tellurium input from intermediate product batteries (solar cells) is used to generate power, and Tellurium is not directly injected to produce power, gas, and water, and Tellurium is not included in the production, so there is no flow after the final industry.

F. Domestic supply and demand of final industries (products)

As described above, the supply and demand of Tellurium's final industry (products) was calculated by dividing it into electricity and electronic devices, precision equipment, general machinery, transportation equipment, power, gas, and water industries.

Domestic supply and demand of Tellurium at the final industrial (product) stage
= Supply and demand of electrical and electronic devices + supply and demand of precision devices + supply and demand of general machinery + supply and demand of transportation equipment + supply and demand of electricity, gas, and water

Estimation of domestic supply and demand of Tellurium final industry (products)
Data used: Company surveys data, Korea Trade Statistics, 2009 industry-related table
Supply and demand of Tellurium final industry (product) stage ◦ Supply and demand of electrical and electronic devices: 230 kg ◦ Supply and demand of precision equipment: 12 kg ◦ Supply and demand of general machine: 1,683 kg ◦ Supply and demand of transportation equipment: 15 kg ◦ Power, gas and water supply: 0 kg
Domestic supply and demand of Tellurium at the final industrial (product) stage = 230 + 12 + 1,683 + 15 + 0 = 1,940 kg MFA in the final industrial (product) phase of Tellurium  Final industry (product) stage

5. The stage of use and stockpiling

The use and stockpiling stage is the stage where Tellurium is injected and the consumption and use of the final industry (product) produced in the relevant year is considered, and the final industry (product) produced before the analysis base year is injected into the material flow and accumulated by users and discharged after use.

It is necessary to estimate the stockpiling of residue material amount by considering the consumption and use of the final industry (products) produced before 2014, the base year of the material flow of this study, and the durability of the final industry (products). However, since it is impossible to calculate the accumulated amount before 2014 only with simple surveys and statistics, the amount of supply and demand for the final industry (product) derived through this project was calculated as the input to the use and stockpiling stage.

Used and accumulated products are generated as post-use products due to their function (life) or replacement, some of which are collected for recycling, and some are discarded. After use of Tellurium, material flow analysis was performed in consideration of the emissions of electronic and electrical equipment and transport equipment, which are final products. The amount of Tellurium input from the use and stockpiling stage to the collection stage was calculated using company surveys data and environmental security system recycling results. The detailed calculation details of the recycling performance are shown in Table 14-9.

<Table 14-9> Tellurium collection volume according to the recycling performance of the environmental protection system

Category	Recycled amount (ton)	Tellurium Usage (g/large	Amount of Tellurium collected according to refrigerator collection (kg)
Refrigerator	86977	51	54

The amount of Tellurium input to the collection stage of transportation equipment was calculated using the automobile recycling amount and company surveys data (Tellurium content) of the Ministry of Land, Infrastructure and Transport. The detailed calculation details of the recycling performance are shown in <Table 14-10>.

<Table 14-10> Tellurium collection volume using the Ministry of Land, Infrastructure and Transport's automobile recycling performance

Category	Recycled amount (large)	Tellurium usage (mg/large)	Amount of Tellurium collected according to waste vehicle collection (kg)
Car	749094	5	4

Estimation of domestic supply and demand in the use and accumulation stage

Data used: Environmental protection system recycling results, statistics from the Ministry of Land, Infrastructure and Transport, and company surveys results

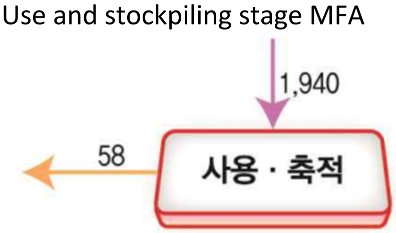
Calculation of supply and demand during the use and stockpiling stage

◦ Input amount to the use and stockpiling stage: 1,940 kg (supply and demand in the final product

◦ Among the inputs to the use and stockpiling stage, the inputs to the collection stage: 58 kg

Domestic supply and demand at the stage of use and stockpiling of residue material
= 58 kg

Use and stockpiling stage MFA



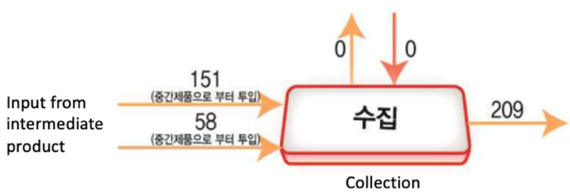
Use and stockpiling

6. Collection stage

The primary resource is discharged after use and collected and processed for recycling as a secondary resource. It is calculated by the collection of transport equipment and electrical and electronic devices in the intermediate product direct circuit (non-volatile memory), individual devices (semiconductor devices), and final industries (products).

Domestic supply and demand at the collection stage = (Secondary resource generation × resource content) + (Secondary resource import × resource content) - (Secondary resource export volume × resource content)

Estimation of domestic supply and demand in the collection stage
Data used: Company consultation results, literature survey data, environmental security system recycling results, statistics from the Ministry of Land, Infrastructure and Transport
Calculation of domestic supply and demand in the collection stage ◦ Secondary resource generation of intermediate products: 151 kg ◦ Secondary resource generation of the final product: 58 kg ◦ Secondary resource import volume: 0 kg ◦ Secondary resource export volume: 0 kg
Domestic supply and demand at the collection stage = 151 + 58 + 0 – 0 = 209 kg MFA of collection phase



7. Recycling stage

The recycling stage is a stage that goes through the recycling process after the collection stage. In the case of Tellurium, according to a survey by a major recycling company, there was no company recycling until now. The reason why recycling is not carried out is that there is no separation and purification technology included in waste products because the amount of collection is small, and the economic value is low by recycling.

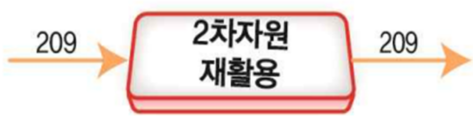
Domestic supply and demand in the recycling stage = (secondary resource collection throughput × resource content) + (secondary resource import volume × resource content) - (secondary resource export volume × resource content)

Estimation of domestic supply and demand in the recycling stage

Data used: Company surveys data, literature survey data

Calculation of the recycling stage
◦ Secondary resource collection throughput: 209 kg

Domestic supply and demand in the recycling stage
= 209 kg
MFA of the recycling phase



Secondary resource recycling

8. Disposal stage

The disposal stage is a stage in which Tellurium is finally discarded, and it was calculated in consideration of the waste discharged from the Tellurium collection stage and the amount of waste discharged from secondary resources.

Estimation of domestic supply and demand in the disposal stage

Disposal stage supply and demand calculation
◦ Collection stage waste: 209 kg

Domestic supply and demand in the disposal stage
= 209 kg
MFA of the disposal phase

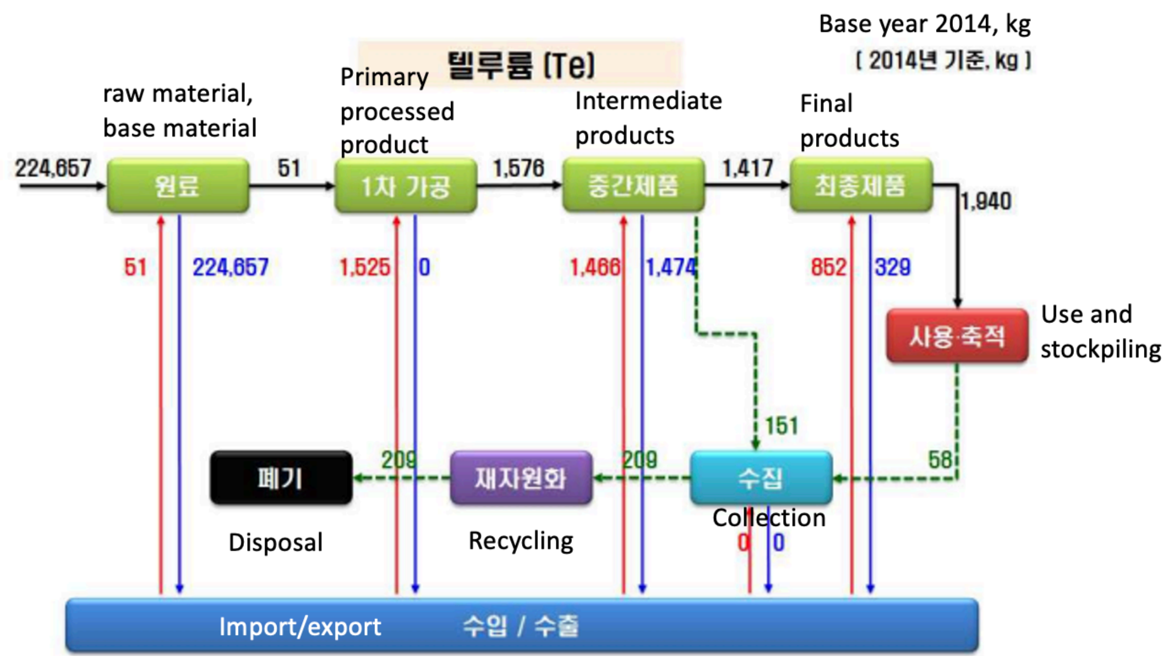
Disposal

Section 3- Results of Material Flow Analysis

1. Material flow chart

A. Simplified substance flow

The simple substance flow chart is shown in [Figure 14-5] by synthesizing the MFA results for each substance flow stage of Tellurium calculated above.



[Figure 14-5] Simplified Material Flow and Analysis

The simple material flow chart of Tellurium is the data as of 2014 and represents the overall material flow from the stage of raw materials and basic materials to disposal. In the raw and basic material stage, Tellurium is produced in a lump form through Copper smelting by-products and is exported in full. 51 kg of supply and demand in the raw and basic materials stage is injected into the production of Tellurium compounds, 1,525 kg of Tellurium compounds and Te Alloy are imported, and 1,576 kg of Tellurium is injected as intermediate products. Among the inputs of intermediate products, 151 kg of direct circuit (non-volatile memory) and individual device (semiconductor device) products will be put into the collection stage, and 1,417 kg will be put into the final product. About 77% of the final products are used as general machines (semiconductor manufacturing machines), 22% of electrical and electronic devices (e.g., low-priced refrigerators and freezers) and 1% of transportation equipment (vacuum trucks, etc.). The amount of Tellurium collected through the post-use and stockpiling stage is about 3% of the input of the use and stockpiling stage, and 58 kg of Tellurium is collected, but it is not economical when recycling, and it is investigated that all of it is put into the disposal stage due to lack of related technology. Input, import, export, and supply and demand by material flow stage are shown in <Table 14-11.

<Table 14-11> Analysis results of Tellurium material flow step by step

(Unit: kg)

Category	Input	Import	Export	Recycling	Supply and demand

Raw materials and basic materials	224657	51	224657	0	51
Primary processing	51	1525	0	0	1576
Intermediate product	1576	1466	1474	0	1471[1]
Final product	1417	852	329	0	1940
Use and stockpiling	1940	0	0	0	58[2]
Collection	209	0	0	0	209
Recycling	209	0	0	0	209
Disposal	209	0	0	0	209

1) 1,417 kg of intermediate product supply and demand is put into the stockpiling stage of use

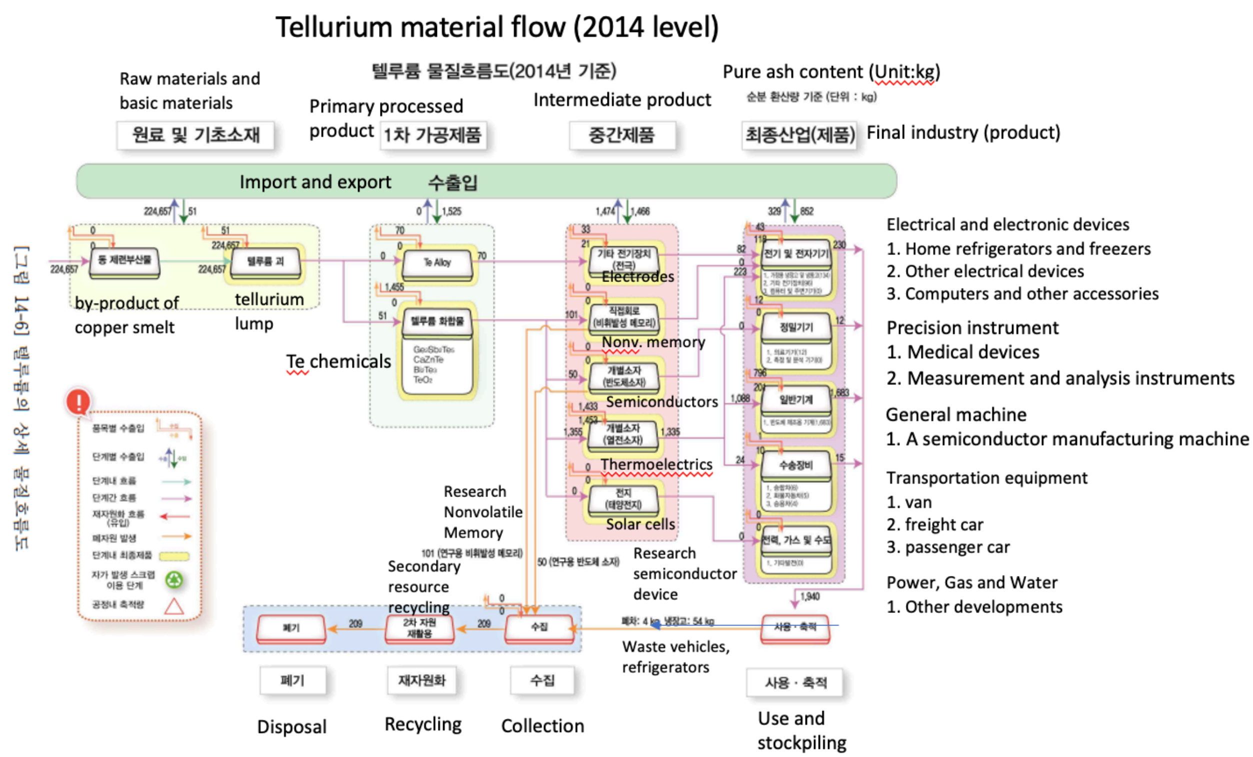
2) Out of the 1,940 kg input from the stockpiling stage of use, the input to the collection stage is calculated as 58 kg according to the environmental protection system recycling performance and the statistics of the Ministry of Land, Infrastructure and Transport

B. Detailed material flow

As for the detailed flow chart of Tellurium, data from 2014 were used, and detailed flow at each stage was shown. The flow of production, import and export, secondary resource input, and secondary resource generation is expressed at each stage, and Tellurium is not currently being recycled and shows the flow to the collection stage collected in product form. In the case of raw materials and basic materials, 224,657 kg of Tellurium lumps were produced through Copper smelting by-products from domestic Copper smelting companies, and all of them were exported and 51 kg of high purity Tellurium lumps were imported. It was found that 51 kg of domestic supply and demand at the stage of basic raw materials was fully injected into the Tellurium compound of the primary processed product. In the case of 1,576 kg of intermediate product supply and demand, about 86% will be put into individual devices (thermoelectric devices), 6% of direct circuits (non-volatile memory), 4% of other electrical devices (electrodes), and 3% of individual devices (semiconductor devices). Direct circuits (nonvolatile memory) and individual devices (semiconductor devices) among intermediate products are not put into the final industrial (product) stage but are put into the collection stage.

In the case of the final product, 77% of gunpowder is used as general machines (semiconductor manufacturing machines), 22% of electrical and electronic devices (e.g., low-priced refrigerators and freezers) and 1% of transportation equipment (vans, etc.). The amount of Tellurium collected through the post-use and stockpiling stage is about 3% compared to the input of the use and stockpiling stage, but 58 kg of Tellurium is currently not economical for recycling, and the total amount is put into the disposal stage along with 151 kg from the intermediate product stage due to lack of technology.

A detailed flow chart of Tellurium is shown in [Figure 14-6.]



[Figure 14-6] Detailed substance flow diagram of Tellurium

2. Completeness and reliability

A. Quantifying flow by step

The material flow of Tellurium was analyzed by dividing it into a total of eight stages, such as the MFA integration methodology. The material flow at each stage was quantified using statistics as shown in Table 14-12 and company data.

<Table 14-12> Quantification method of Tellurium material flow step by step

Category	The amount of production	Import and export	Supply and demand
Raw materials and basic materials	-	Company surveys data, Korea International Trade Association data	
Primary processing	Literature survey data, company surveys data	Company surveys data, Korea International Trade Association data	

Intermediate product	Literature research data, expert advice, company research data	Company surveys data, Korea International Trade Association data, Expert advisory, 2009 Industrial Relations Table	
Final Industry (Product)	Literature survey data, company surveys data, 2009 industry-related table	Company surveys data, Korea International Trade Association Data, 2009 Industrial Relations Table	MFA Integration Methodology[1]
Use and stockpiling	Company surveys data, literature survey data, environmental security system performance data, and statistics from the Ministry of Land, Infrastructure and Transport	-	
Collection	Company surveys data, literature survey data, environmental security system performance data, and statistics from the Ministry of Land, Infrastructure and Transport	-	
Recycling	Company surveys data, literature survey data, environmental security system performance data, and statistics from the Ministry of Land, Infrastructure and Transport	-	
Disposal	Company surveys data, literature survey data, environmental security system performance data, and statistics from the Ministry of Land,	-	

	Infrastructure and Transport		

1) Supply and demand = input + import - export + input of secondary resources

B. Verification of reliability

Tellurium material flow was constructed in accordance with the integrated methodology through structured statistical data and company surveys data. When calculating the amount of material flow at each stage, a method was performed to increase the reliability as much as possible. The material flow of Tellurium has improved its reliability by using data from monopoly companies and using market share, focusing on company surveys.

Among intermediate products using Tellurium compounds, only thermoelectric devices are commercially available, and other products are under R&D or not commercialized, and production of thermoelectric devices in Korea was compared with statistics from the Korea International Trade Association.

The import amount of thermoelectric devices was estimated through a survey of eight companies producing thermoelectric devices in Korea, and reliability was reviewed by comparing it with the company surveys and the import statistics of- the Korea International Trade Association. The results showed that the total amount of Tellurium contained in the thermoelectric element was calculated and the reliability was improved by considering the average unit price, average weight, and Tellurium combined flow derived from the Korea International Trade Association's import statistics and expert and company surveys results. The detailed reliability review results are shown in Table 14-13.

<Table 14-13> Results of thermoelectric device reliability review

Category		Value	Sources
Content	Remarks		
Imports of thermoelectric devices as of 2014 (kg)	-	1400	Cess, Sunflower Energy and 8 other companies surveyed
HS CODE (8418.69.2090)1) Import amount (KRW 1,000)	1	62863	Import and Export statistics of the Korea International Trade Association
Average unit price of thermoelectric elements (won/unit)	2	100000	Cess, Sunflower Energy and eight other companies surveyed
Number of thermoelectric element imports (pcs)	3	716638	(① X exchange rate (KRW 1140)/②
Average weight of thermoelectric element (g)	4	10.7	Institute of Advanced Technology

Average Te content in thermoelectric element (%)	5	9.62	Institute of Advanced Technology
Imports of thermoelectric devices as of 2014 (kg)	-	1433	③ X ④ X ⑤

1) As a result of the company's investigation, it is classified as HS CODE when exporting products

3. Discussions and improvements

A. Problems

○ Primary Resource Flow

In the case of raw materials and basic products, 99.99% of Tellurium lumps currently produced in Korea are exported in full due to the lack of refining technology of high-purity Tellurium, and high-purity Tellurium lumps are imported. In the case of Tellurium lumps and Tellurium compounds in the primary processing product stage, it is difficult to estimate the quantity due to a lack of import and export information because statistics are not collected separately from the import and export statistics (Korea International Trade Association). The main uses of Tellurium in Korea are other electrical devices (electrodes) and individual devices (thermal electric devices), and it is most important to understand the flow of substances in the intermediate and final product stages. However, it is very difficult to obtain Tellurium content information for each use through company research, and it is virtually impossible to obtain research data corresponding to the material flow construction year, so it is difficult to establish reliable material flow statistics using accurate content information. In addition, Tellurium used in integrated circuits (non-volatile memory), individual devices (semiconductor devices) and batteries (solar batteries) is difficult to accurately grasp the amount of usage because it is in the research stage.

○ Secondary resource flow

As of 2014, because of domestic and foreign companies' surveys and research data, it was found that there is currently no technology to recycle Tellurium. However, a basic study on recycling technology using individual devices (thermoelectric devices) with the largest amount of Tellurium is being conducted by the Institute of Advanced Technology. Therefore, through continuous research, it is necessary to develop a technology that can recycle Tellurium by recovering thermoelectric devices from the environmental protection system and waste vehicle collection.

B. Future improvements

As mentioned above, it is necessary to establish import and export statistics for raw materials, basic materials, and Tellurium compounds in the primary processing stage, and to collect reliable research data related to the content of Tellurium in the intermediate and final product stages. In addition, since Tellurium is not recycled at all at present, if Tellurium is recycled in the future, it is required to collect data on recycling statistics and recycling technologies.

4. Expected effects and utilization measures

A. Expected effect

Through the material flow analysis of Tellurium, the supply and demand structure of domestic Tellurium was identified, and the supply and demand characteristics were identified in detail. By periodically updating the data using the results of this study, it is possible to track the supply and demand status and characteristics of Tellurium-related industries, and through the process, important indicators can be established for establishing and revising national resource management plans.

On the other hand, in the recycling stage, Tellurium used as a thermoelectric element is contained in collected products such as refrigerators and waste cars, but there is no technology to separate and recover Tellurium in the product, so it can be used as a basis for calculating the expected effect through future technology development. In addition, by improving the recycling rate, it can lay the foundation for resource productivity improvement at each stage, and since the amount exported abroad at the final product stage is large, it can be used for selecting major management industries and products as basic data for policies such as resource management strategies.

B. Utilization plan

By grasping the material flow, which is the first half of Tellurium, it can be used as evidence for major indicators such as the collection amount of Tellurium metal in the recycling stage and the resource productivity of Tellurium metal. In addition, while about 86% of intermediate products are used as thermoelectric devices, there is no amount of recycling alternative resource through Tellurium extraction in thermoelectric devices, so it can be used as basic data such as Tellurium supply plans that can be covered by the development of recapitalization technology. In addition, this research data can be used to calculate the economic effect of Tellurium.