Economic Assessment of the Changes in the Energy Sources on the Chilean Mining Sector

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Motivation

- Chile is the leading cooper producer in the world (> 25%), and it represents more than 50% of its exports
- The energetic efficiency of the mining process has many components which are changing: ore proportion; open pit vs undergraund mines; technology for processig concentrate
- As December 2013, installed renewable capacity represented 6.3 per cent of the energy mix in Chile. By June 2016, this amount doubled, reaching 12.65 per cent of total electrical capacity (20,151 MW). The 2035 government plan has the target of 60% of electricity consumed in the country being produced by Renewable Sources

Overview of the presentation

- Energy sources in Chile
- Literature review
- Method
- Scenarios – Analysis
- Main Conclusions

Energy Sources in Chile

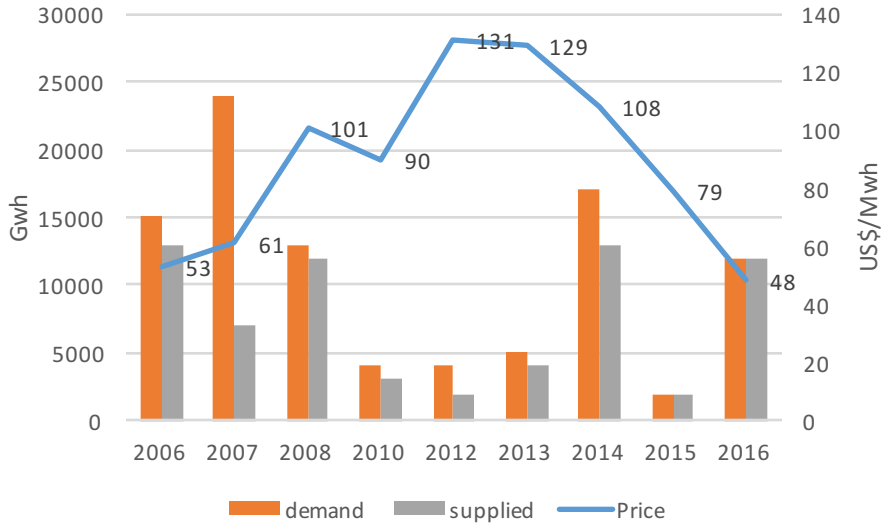
- During the period 2002-2004, the Argentina government decided to stop gas exports to Chile
  - Increasing local demand due to hard winter
  - Bolivia did not want to sell gas to Argentina to be re-sold to Chile
- Crisis, produced a period of research and policy conversations
  - Production of dirty energy. Electricity based on fuel and carbon
- 2015 produced the Energy Agenda
  - Change in Regulations, increasing competition and investments without public participation
  - Integration of the Transmission system
  - Increases the Energetic Efficiency
  - Territorial inclusion and equality, environmental care.
- Former Minister of Energy, Máximo Pachecho (2018), Revolucion Energética en Chile

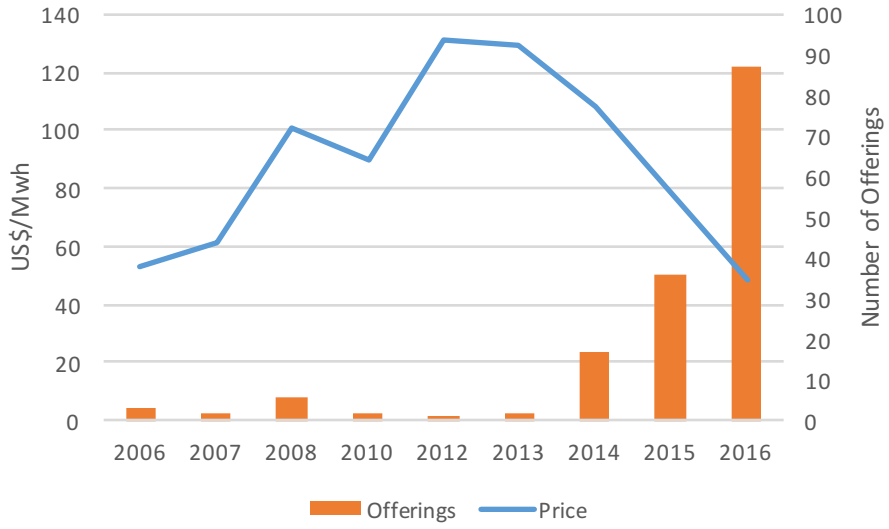
Agenda of Energy Policy

	Metas al 2035	Metas al 2050
Precio promedio de suministro eléctrico	Estar entre los 5 países de la OCDE con menores precios promedio	Estar entre los 3 países OCDE con menores precios promedio
Indisponibilidad de suministro eléctrico promedio	Menor a 4 horas/año en cualquier localidad	Menor a 1 hora/año en cualquier localidad
Familias vulnerables con acceso continuo y de calidad a los servicios energéticos.	Al menos 50% de viviendas de familias vulnerables con acceso continuo	Asegurar acceso universal y equitativo a servicios energéticos a toda la población.
Asociatividad (trabajo conjunto) comunidad/empresa	80% de los proyectos energéticos deben contar con mecanismos de asociatividad	100% de los proyectos energéticos deben contar con mecanismos de asociatividad
Generación eléctrica de fuentes renovables.	Al menos el 60%	Al menos el 70%
Estándares de construcción eficientes.	100% de las nuevas edificaciones de uso público y residencial cumplen con estándares de construcción eficientes.	El 100% de las nuevas edificaciones tienen altos estándares de construcción eficiente, y cuentan con sistemas de control inteligente de energía.
Transporte público de pasajeros	El 100% de vehículos nuevos licitados para transporte público de pasajeros incluyen criterios de eficiencia energética en las variables a evaluar.	-
Reducción de la intensidad de las emisiones de gases de efecto invernadero	A 2030 se reduce un 30% respecto al año 2007.	Las emisiones son coherentes con los límites definidos por la ciencia global.
Equipos energéticamente eficientes	-	100% de las principales categorías de artefactos y equipos que se venden serán equipos energéticamente eficientes.
PIB/Consumo energético	-	El crecimiento del consumo energético está desacoplado del crecimiento del PIB
Interconexión	-	Interconexión de Chile con el SINEA y con los países del Atlántico a través de Argentina y Mercosur.

Energía 2050, Energy Minister

Outcomes



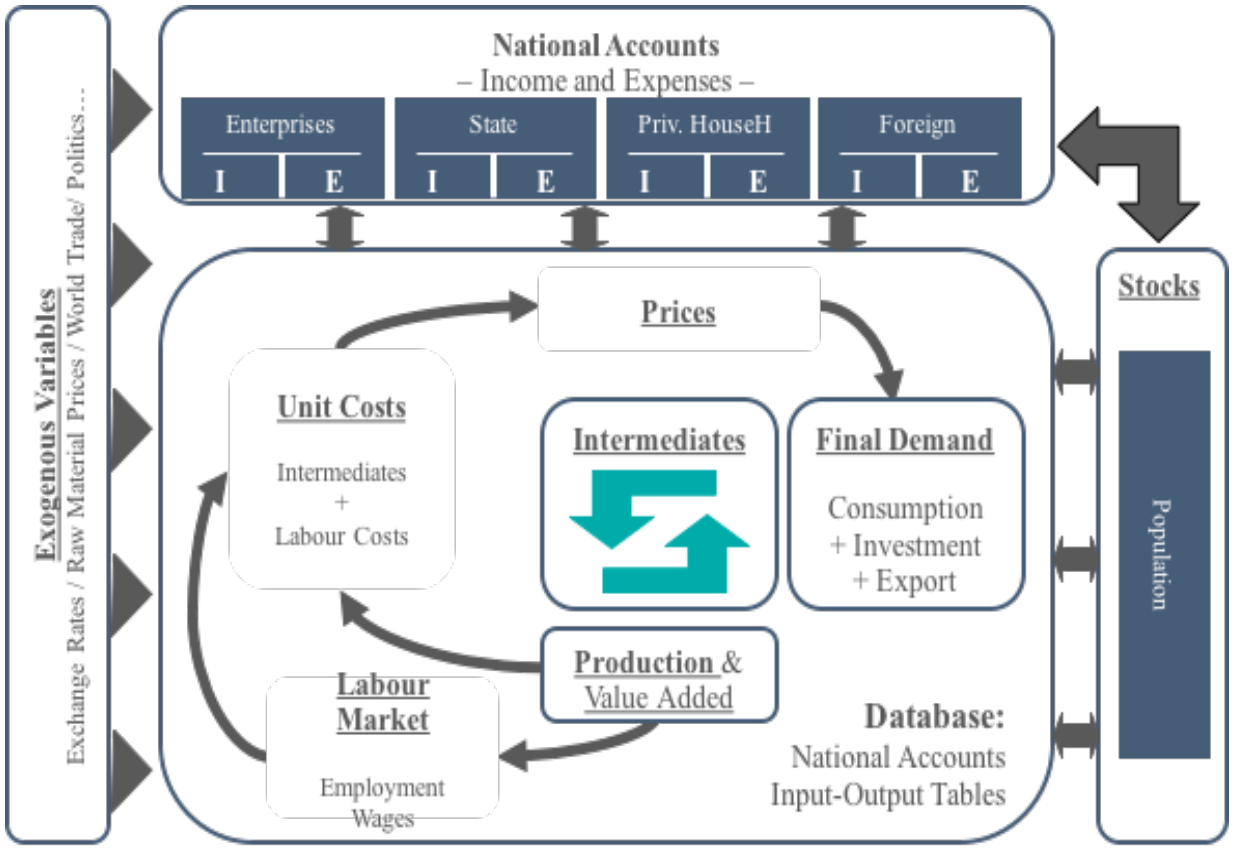


- What are the effects of this changes?
  - What is the effect on the GDP?
    - How investment plans does affect the economy?
  - What is the effect on labor market?
  - What is the effect on the mining production?

Literature

- The 70s oil crisis open many works on input-output models focused on energy, Blair (1979), Hybrid approach, Blair and Wyckoff (1989), Dietzenbacher and Sage (2006)
- Energy & Environmental analysis in Chile
  - R. O'Ryan; C. de Miguel & S. Miller, (2003), CGE, 100% increases on fuel taxes, -0.5% of Real GDP growth
  - C. Benavides; L. Gonzales; M. Diaz; R. Fuentes; G. García; R. Palma-Behnke; & C. Ravizza (2015), DSGE, increases on carbon tax reduces GDP growth
- Renewable Energy Frameworks
  - A. Stocker; A. Großmann; R. Madlener & M. Wolter (2011) Austria 2020

The Model



- Multisectorial model, input-output information
- Inforum phylosophy (Almon (1991))

Scenario Analysis

Change in the source of the energy

- Increases of investments in energy sector
- Price reduction of electricity
- Decreases of fuel consumption, due to substitution
- Decreases on the import of fuel and gas

Change in efficiencyiy of mininig

- Increases of investment in mining sector
- Small Reduction of fuel consumption, due to more efficiency
- Reduction in energy coefficients (gas, fuel and electricity)

Scenario Analysis

Change in the source of the energy

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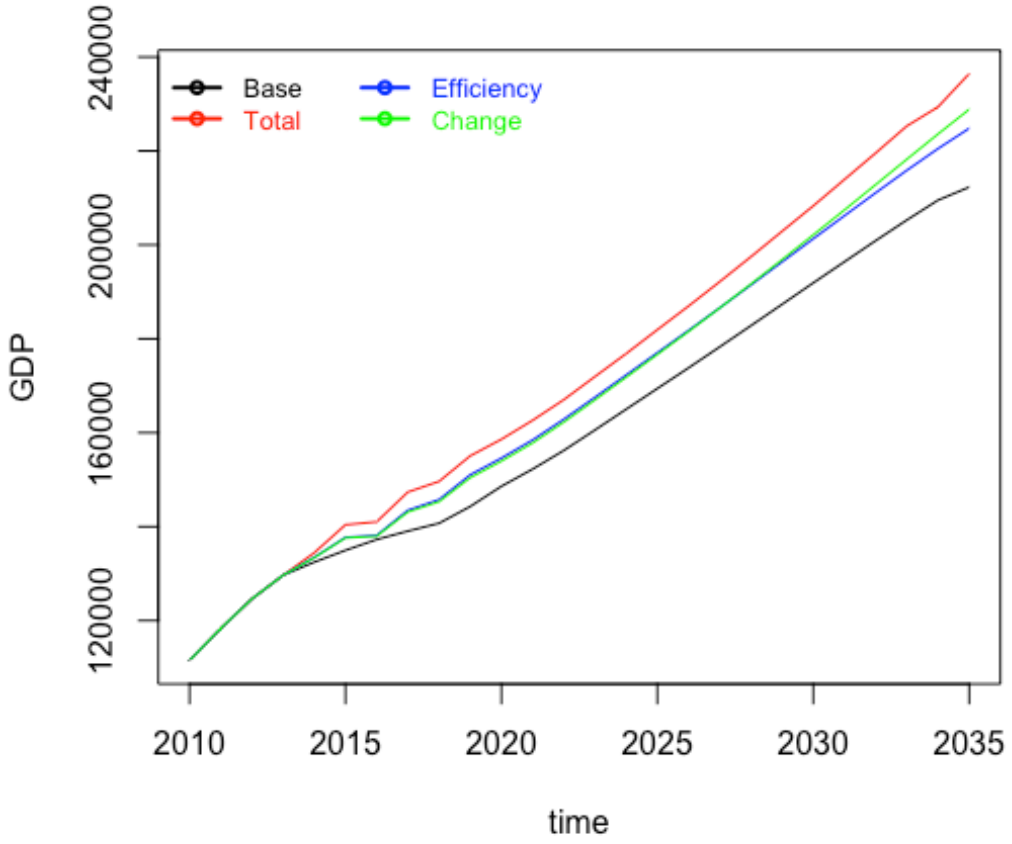
		Change the Sources of energy	
		Minimum Changes	60%
Efficiency Improvement	Keep the trend	*Base Line*	*Improve the Matrix*
	Increase efficiency	*Improve Efficiency*	*Total Improvement*

Increase the efficiency of mining

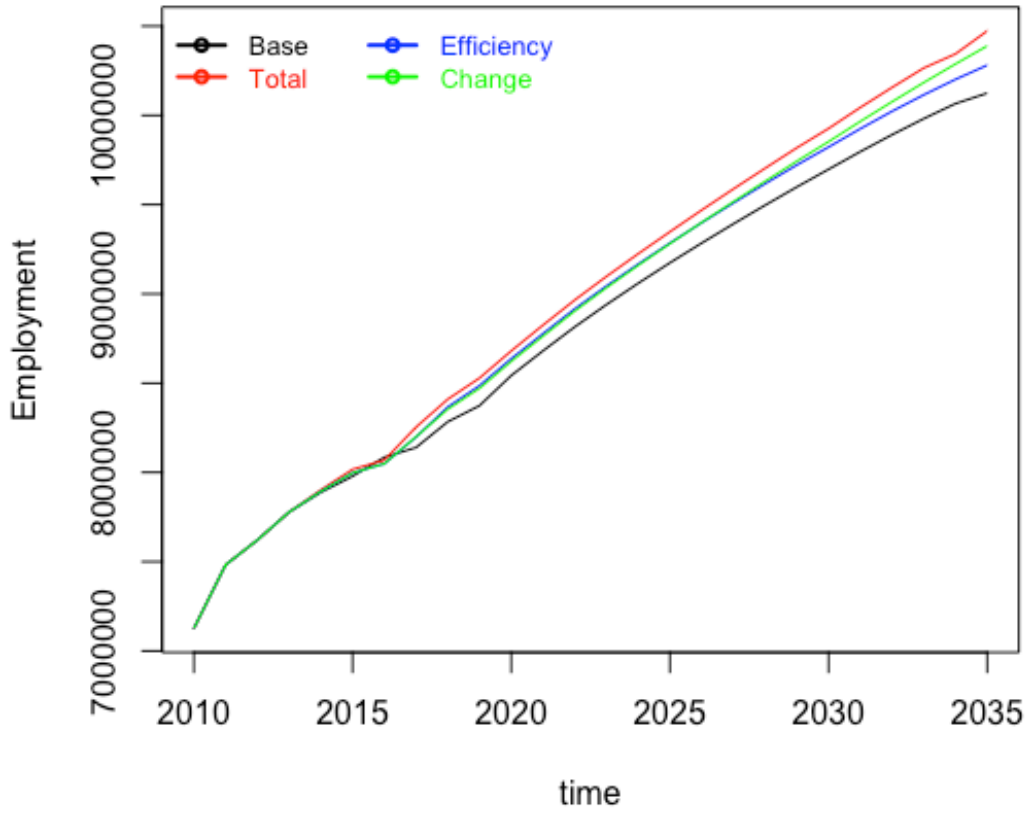
- Increases of investment in mining sector
- Small Reduction of fuel consumption, due to more efficiency
- Reduction in energy coefficients (gas, fuel and electricity)

- Data are calibrated until 2015
- Data representing scenario is introduced
- Simulation is made until 2035

Aggregate results



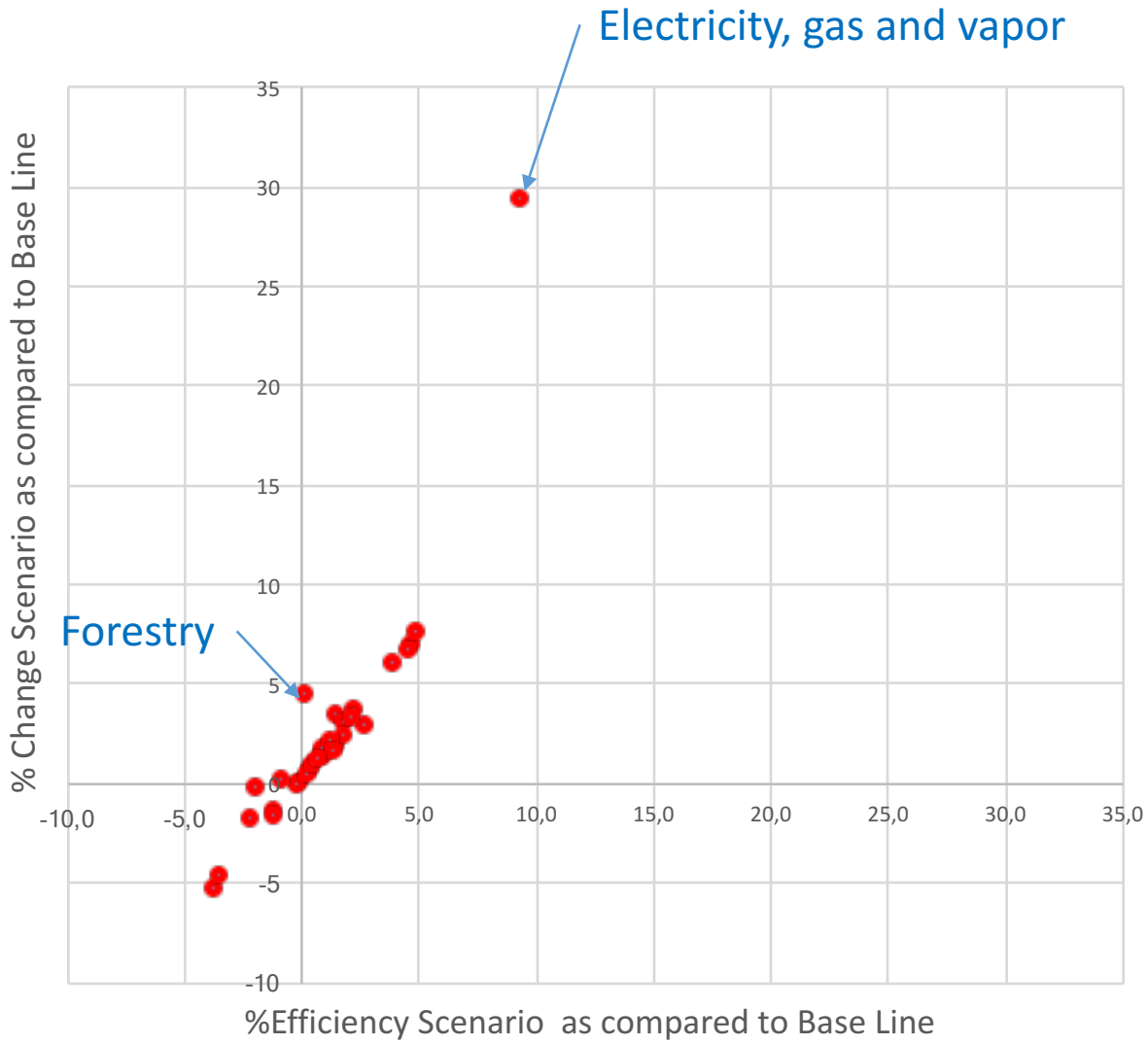
	Total	Efficiency	Change
Difference in Accumulated growth vs base line	11%	5%	7%



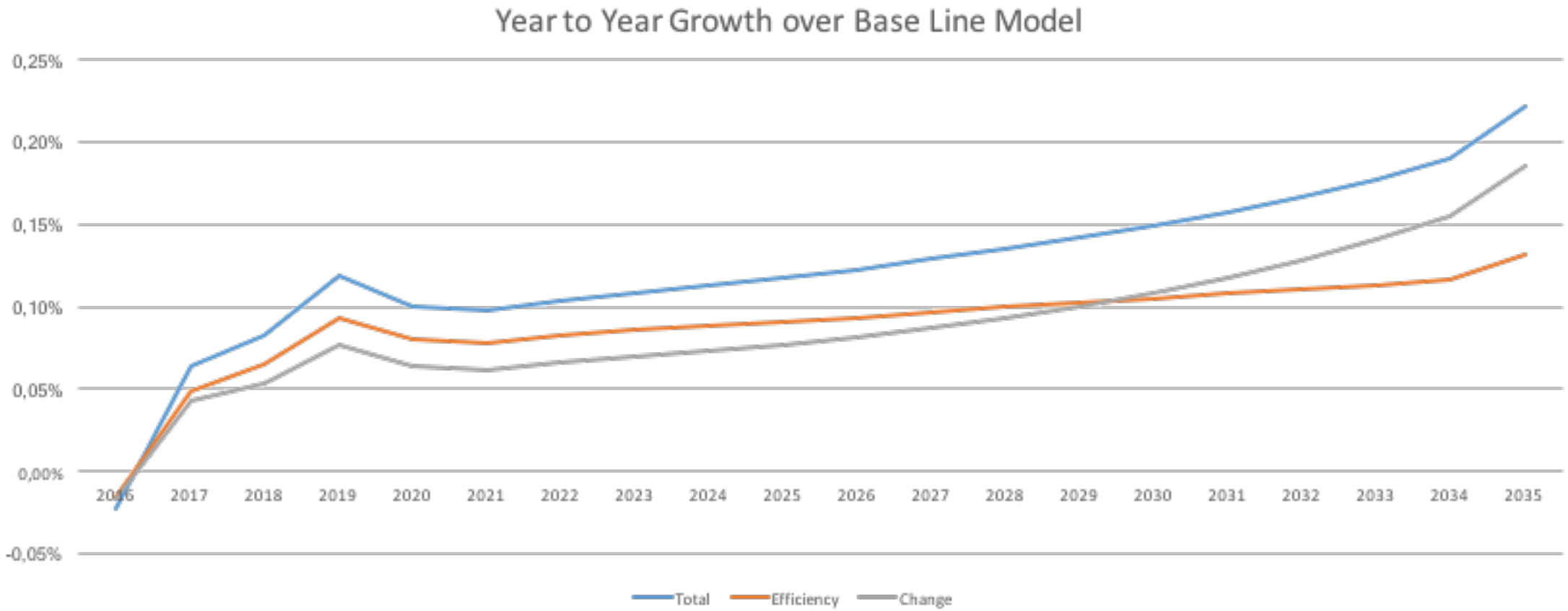
	Total	Efficiency	Change
Difference in Accumulated growth vs base line	3%	1%	2%

Employment by sector (32)

- The evolution of employment is compared for every sector.
- For instance, the employment of the *Electricity, gas and vapor* sector in the year 2035 will be
  - 10% greater in the Efficiency scenario than in the Base Line
  - 29% greater in the Change scenario than in the Base Line



Copper and metallic mining extraction sector Production

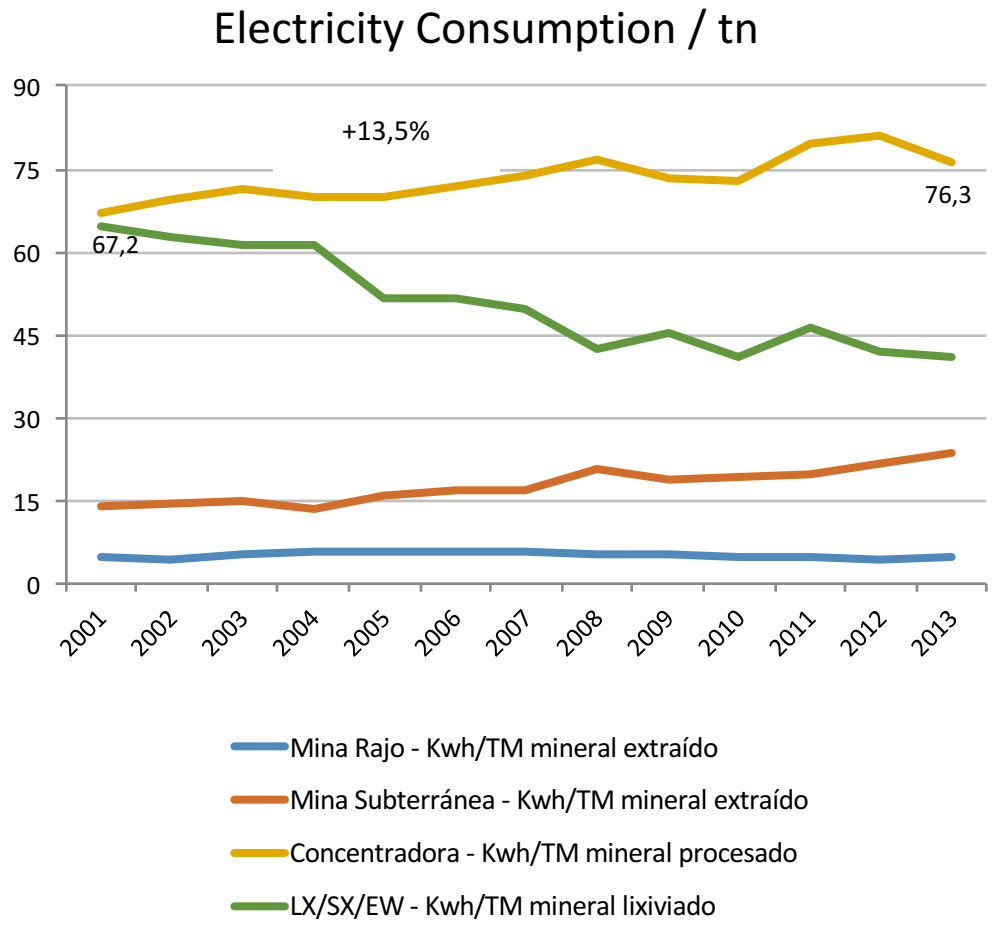


Conclusions

- Changes in the sources of energy in Chile are producing multiple impacts, and this work is in the way to contribute in the assesment of the economic impact that this change in generating
- There is no much increases on the sector of copper production as consequence in the three scenarios analyzed
- There are sectors that under the renewable energy scenario, get additional boost, like Forestry, where as biomass, wood offers some of the highest levels of energy and carbon efficiency

Additional Slides

Energetic Efficiency of Mining



- The energetic efficiency is given by exogenous factor and by the technology used to produce.
- Increase in investment could lead to better technology, therefore to increasing efficiency

Assumptions

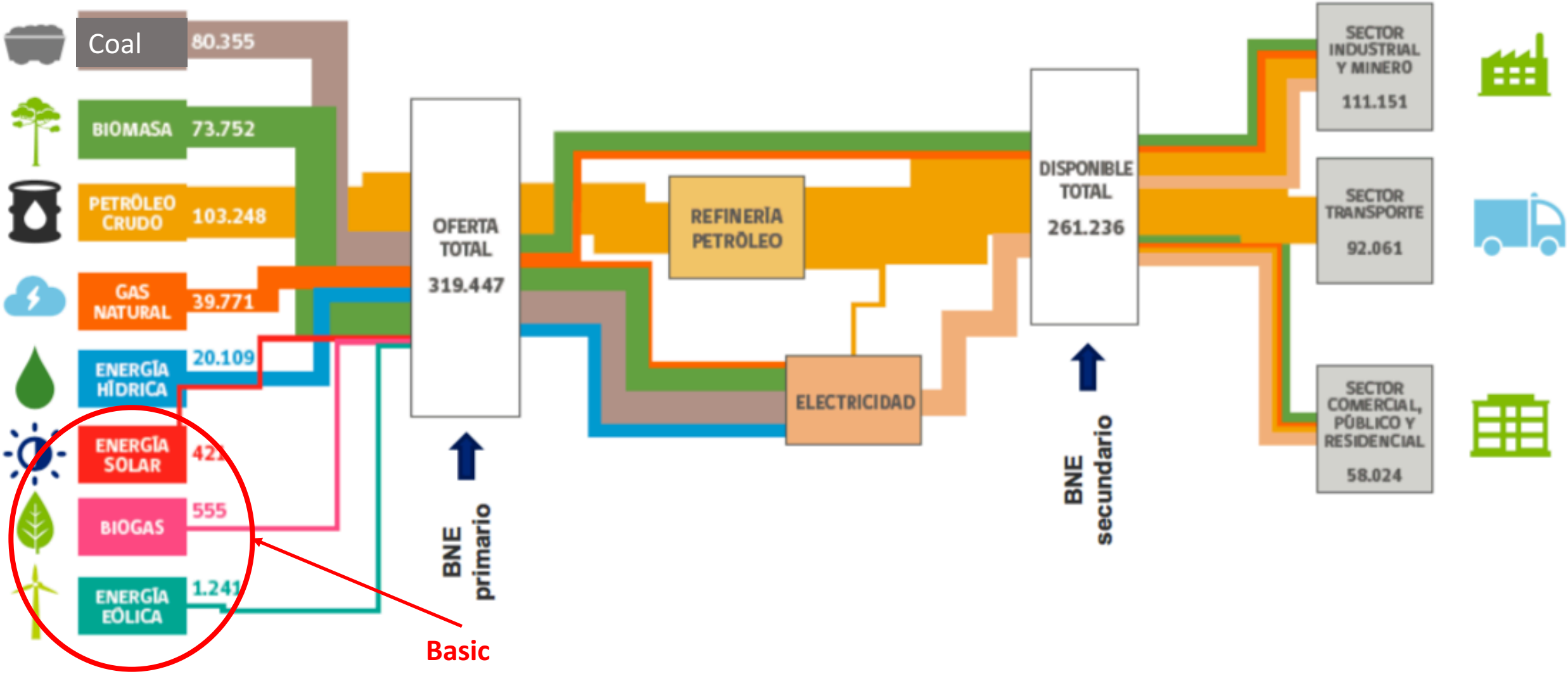
Process to Change

- Cost reduction in electricity
- Changes in investment
- Energetic efficiency

Process to keep historic evolution

- Copper Production
- Energetic efficiency
- Share between Fuel and Electricity in the production process
- Change in the process of production (from open pit to Underground)
    - Structural characteristics of the the Mining (Ore)

Energy Matrix



Construction of Variables

From 2013 to 2035

Output Price: copper mining

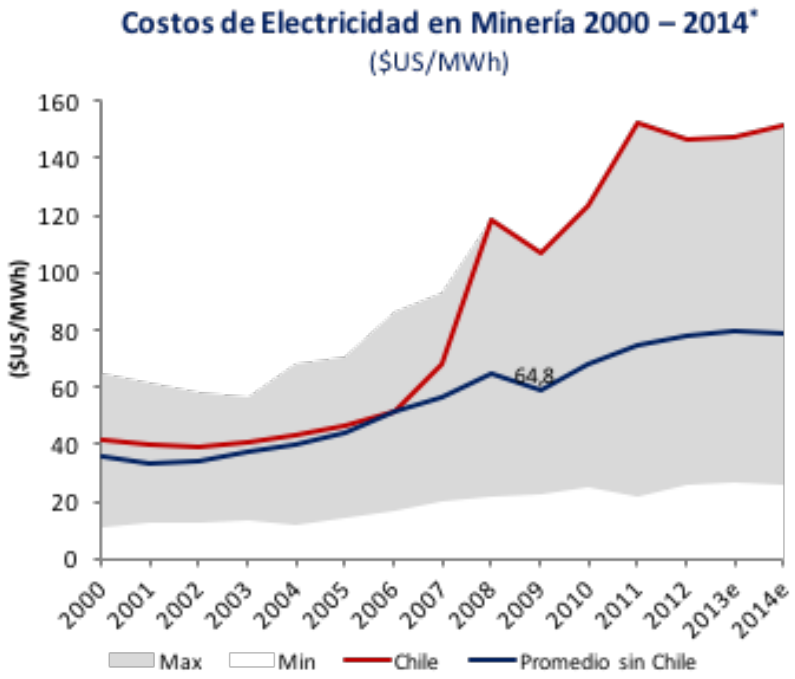
- Copper price was obtained from WorldBank forecast
  - http://pubdocs.worldbank.org/en/678421508960789762/CMO-October-2017-Forecasts.pdf
- Nominal Dollar each mt

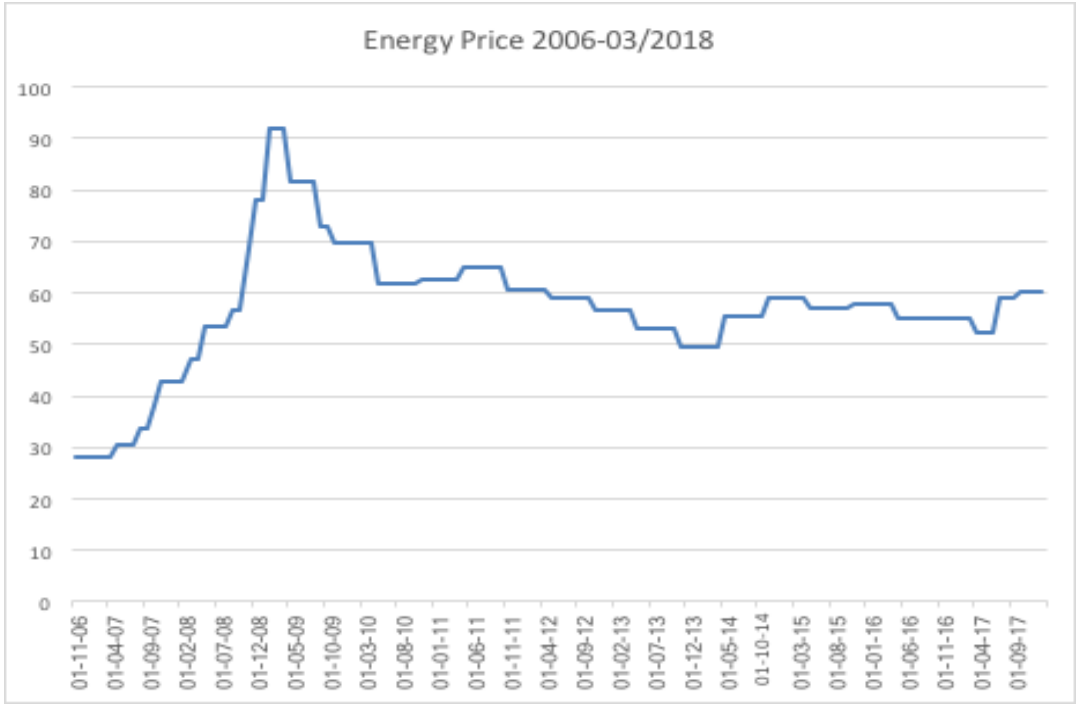
Output Price: Fuel Production

- Crude oil was obtained from WorldBank forecast
  - http://pubdocs.worldbank.org/en/678421508960789762/CMO-October-2017-Forecasts.pdf
- Nominal Dollar each bbl

Output Price: electricity supply

- The electricity prices for the north system was obtained from the CNE
  - https://www.cne.cl/estadisticas/electricidad/
- Prices/Costs





Output Price: Institution

- https://www.cne.cl/en/tarificacion

	Total	Efficiency	Change
Diff in Accumulated compared to base line case	11%	5%	7%

Domestic Input Coefficient: electricity supply to copper

- There are multiple process in the copper mining that requiere electricity.

ELECTRICITY USE PER TON OF ORE MINED AND PROCESSED, BY PROCESS
Weighted Average Unit Ratio, Chilean Copper Industry

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Open Pit (MJ/MT Ore Mined)	5,8	5,4	5,3	4,9	4,9	4,8	5,1	5,0	4,8	4,1
Underground Mine (MJ/MT Ore Mined)	17,1	20,7	18,8	19,2	19,8	21,7	23,8	21,3	22,3	19,2
Mine Weighted Average (MJ/MT Ore Mined)	7,2	6,8	6,6	6,2	6,4	6,0	6,5	6,4	5,9	5,3
Concentrating Plant (MJ/MT Ore Processed)	73,6	76,8	73,4	72,9	79,5	66,5	79,7	80,3	81,0	82,5
Smelter (MJ/MT Concentrate Processed)	1.207,2	1.229,4	1.112,3	1.143,0	1.171,4	1.212,0	1.337,3	1.219,8	1.129,5	1.157,0
LX / SX / EW (MJ/MT Ore Processed)	49,6	42,5	45,1	41,1	46,3	43,2	41,2	40,5	38,0	33,3

Source: Cochilco

Domestic input coefficient: fuel supply - copper

- Fuel Use per Ton of Ore Mined

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Open Pit (MJ/MT Ore Mined)	47,5	46,6	47,3	48,5	56,9	50,3	57,4	57,8	57,3	61,9
Underground Mine (MJ/MT Ore Mined)	18,2	12,8	14,6	10,4	12,6	9,7	10,4	9,1	17,9	21,5
Mine [(1)] (MJ/TM mineral extraído) (MJ/MT Ore Mined)	44,1	43,6	44,2	45,3	52,6	48,9	54,1	55,6	54,9	58,7
Concentrating Plant (MJ/MT Ore Processed)	1,5	2,0	1,9	1,6	1,8	1,4	1,9	1,6	1,8	2,3
Smelter (MJ/MT Concentrate Processed)	1.563,8	1.607,8	1.440,1	1.437,8	1.401,3	1.395,7	1.353,3	1.381,4	1.245,8	1.366,4
LX / SX / EW (MJ/MT Ore Processed)	14,7	12,2	13,2	12,3	12,5	11,3	11,5	9,8	8,2	6,3

Source: Cochilco

Copper by Product

- kMT Copper

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Mine Production	5.557,0	5.327,6	5.394,4	5.418,9	5.262,8	5.433,9	5.776,0	5.761,1	5.772,1	5.552,6
Smelter Production	1.514,3	1.369,2	1.522,3	1.559,8	1.522,3	1.342,4	1.358,3	1.356,2	1.496,2	1.490,8
Refined Production	2.936,5	3.057,6	3.276,6	3.243,9	3.092,4	2.902,0	2.754,9	2.729,4	2.688,4	2.612,5
Cátodos SX-EW /	1.832,1	1.971,0	2.117,5	2.088,5	2.024,8	2.028,8	1.932,9	1.844,0	1.778,4	1.660,3
Cátodos E.R. / ER cathodes	985,4	987,7	1.071,3	1.054,9	998,6	873,2	822,0	885,4	910,0	952,2
Refinado a fuego / Fire refined	119,0	98,9	87,8	100,5	69,0	0,0	0,0	0,0	0,0	0,0

Import of Fuel, Electricity, gas

- Comisión Nacional de Energía

Year	Coal	Fuel	Diesel	Fuel Oil 6	Gas Natural	Gasoline	GLP	IFO	Kerosene
2002	953.352.477	2.984.657.093	189.716.256	4	1.027.002.300	44	179.980.357	31.159.652	21.686.224
2003	2.518.754.341	8.576.796.209	591.500.693		3.039.432.197	73	458.690.694	73.546.620	15.842.560
2004	4.482.576.470	9.325.815.903	1.085.991.495	11	3.886.839.986	101	532.089.768	12.972	33.098.968
2005	3.641.484.547	7.357.348.602	1.367.709.878	112.083.969	2.730.741.613	72	454.985.403	150	65.958.477
2006	4.421.053.258	9.347.371.786	1.885.911.469		2.615.497.506	64	587.823.003	9.160.926	89.318.441
2007	6.289.971.981	10.094.519.351	4.807.820.438	190.706.905	1.886.508.409	164.970	974.359.917	47	285.115.641
2008	7.081.537.580	10.011.866.796	5.007.384.932	632.245.978	844.215.827	2.002.673	968.972.819	44.328.615	344.281.776
2009	6.399.646.997	9.554.125.041	4.223.195.437	105.854.090	1.217.429.075	2.591	926.581.898	374.393.107	142.236.241
2010	7.366.415.353	7.992.733.543	4.547.892.479		2.446.026.343	12.258.361	802.269.805	425.912.372	286.016.768
2011	9.115.690.535	8.642.274.081	4.064.481.557		2.936.087.449	96.357.274	788.921.875	529.040.217	202.991.903
2012	10.425.835.055	8.074.864.544	4.495.097.425	84.992.360	2.707.388.987	610.230.414	758.736.443	327.010.703	277.481.402
2013	11.284.197.248	8.940.872.466	4.264.049.585	67.003.591	2.682.274.147	513.053.698	1.044.909.084	20.736.852	305.327.366
2014	10.182.497.762	8.883.843.759	4.374.788.001		2.632.985.783	604.316.755	971.167.632	1.365	186.827.770
2015	9.873.498.710	8.461.964.645	4.764.780.531		2.683.222.689	554.239.103	984.560.756	606.465	398.263.670
2016	11.900.928.086	8.418.072.185	5.041.855.261		3.250.755.171	409.168.364	1.052.059.265	472	529.563.154
2017	11.130.924.953	8.828.131.001	4.833.062.993		3.145.085.197	525.024.988	1.182.853.562	688.620	296.148.289