CHILE´s Strategy: opportunities for collaboration

Manuel Cartes
Director of Business Innovation

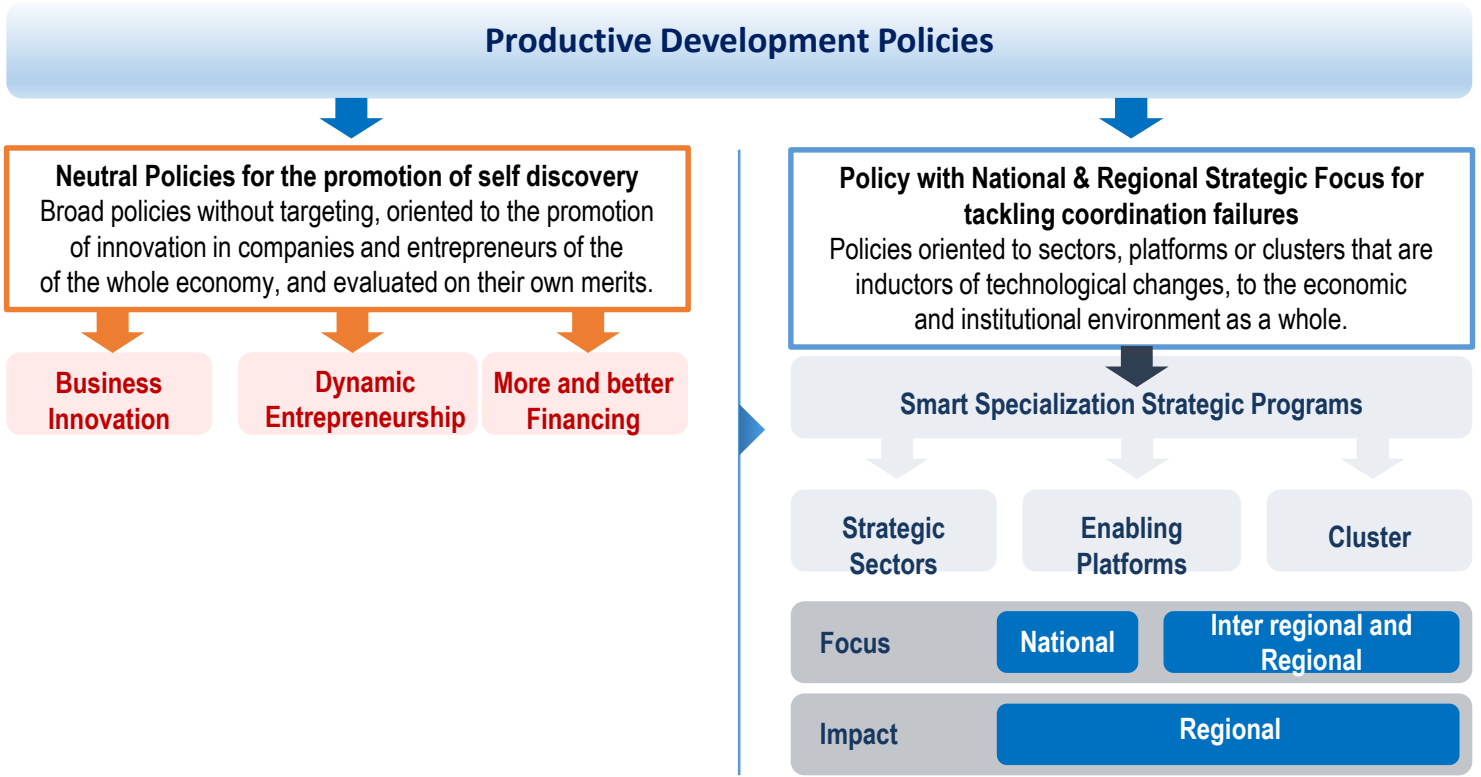
CORFO
ECONOMIC DEVELOPMENT & INNOVATION AGENCY

THE ECONOMIC DEVELOPMENT AGENCY

CORFO since 1939

Our Mission is to improve the competitiveness and the productive diversification of the country by encouraging **investment, innovation and entrepreneurship**, strengthening in addition the **human capital** and **technological capabilities** to achieve a sustainable and territorially balanced development.

CHILEAN PRODUCTIVE DEVELOPMENT POLICIES



CORFO AT A GLANCE

CORFO is Chile´s most experienced public organization in LAC in promoting business investment and innovation

MMUS$ 215 per year in matching grants for Business technology innovation.

MMUS$ 700 In funds for **Venture Capital** and **MMUS$ 500 credits through financial intermediaries**

MMUS$ 2.600 in **PCGs** (Partial Credit Guarantees) mobilizing more than **MMUS$ 4.000 in enhanced credits** in the market

MMUS$ 80 for supporting 1000 new start ups and university Spin outs every year

Associated member of:
EUREKA
innovation across borders

PUBLIC–PRIVATE PARTNERSHIPS FOR INNOVATION & PRODUCTIVITY

SMART SPECIALIZATION PROGRAMS IN KEY SECTORS/PLATFORMS OF CHILEAN ECONOMY

MINING CLUSTER

SUSTAINABLE SPECIAL INTEREST TOURISM

HEALTHY AND SPECIAL FOOD

CONSTRUCTION AND TIMBER SECTOR

CREATIVE INDUSTRIES

SUSTAINABLE AQUACULTURE AND FISHING

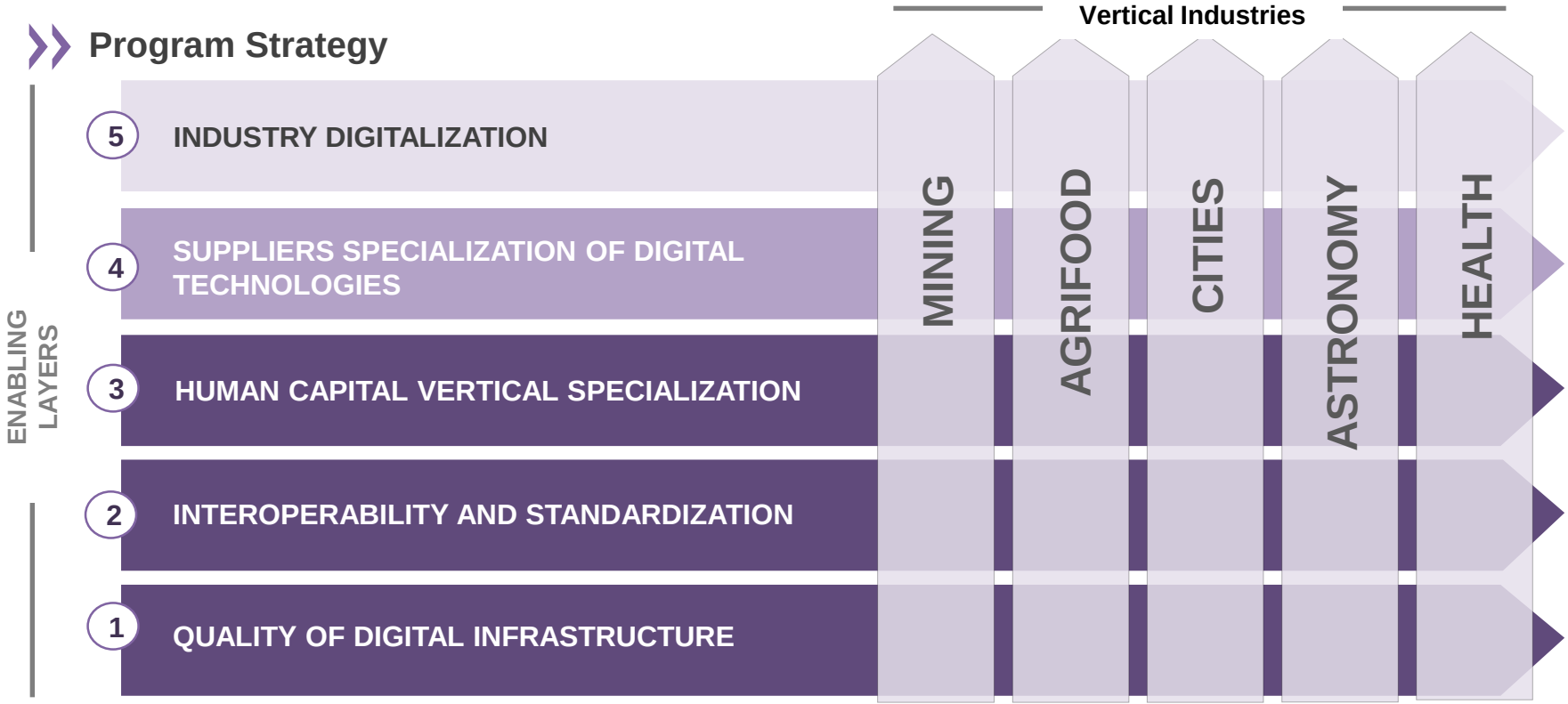
HEALTH TECHNOLOGY SERVICES

Sectors

Platforms

- Logistic
- Biotechnology
- Solar Industry / Water
- Digital Transformation and Smart Manufacturing

Program Strategy



The scope of the program includes the deployment of the first three layers

THE FOURTH INDUSTRIAL REVOLUTION:
DIGITAL TRANSFORMATION AND CLEAN PRODUCTION

Digital Revolution & Industry 4.0

Climate Change, Renewable Energy & Electro Mobility

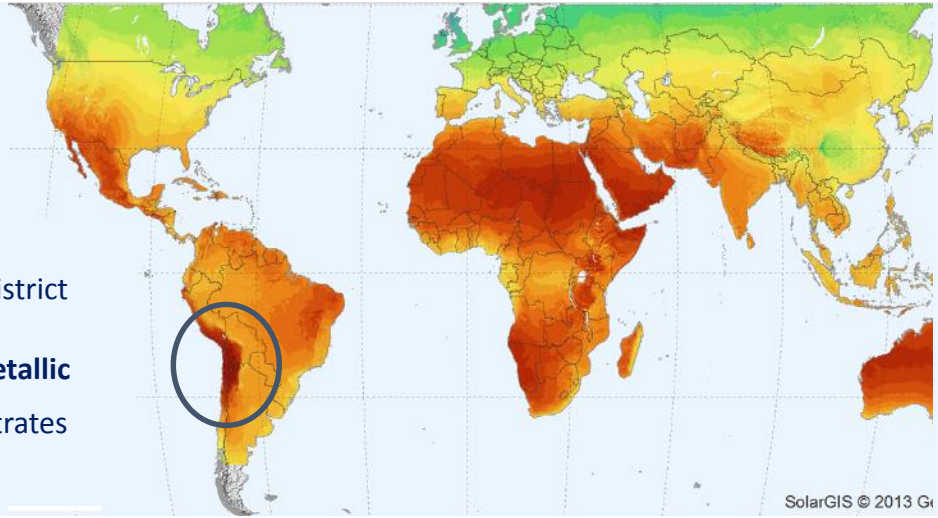
Systemic Innovation to address the challenges of disruptive technologies

A UNIQUE OPPORTUNITY

CLEAN MINING AND SOLAR ENERGY POTENTIAL

Atacama Desert singularities

- **Highest solar** potential
  >**3.500** kWh/m^2
  ~4**.000** sun hours/year
- **Biggest metallic mining** district in the world
- **Strong position in non metallic mining** -1rst in lithium production and natural nitrates (energy storage)



Opportunities for Chile

- **Global trend**: exponential growth of electro mobility and hydrogen-based economy
- Energy Storage for intermittent RE supply
- At 2030 there will be 40 millions of electrical vehicles.
- It will need a production of additional 3 millions tons of Copper (15% of world Production) and 1 million of low emission copper

VIRTUOUS RELATIONSHIP: ELECTROMOBILITY, RENEWABLE ENERGIES AND GREEN MINING

ELECTROMOBILITY

The demand for lithium and copper is driven by the use of electric cars and hybrid vehicles, in accordance with new environmental standards and consumers increasingly concerned about climate change.

RENEWABLE ENERGIES

NCRE are a great opportunity to reduce carbon footprint in mining.

On the one hand, NCREs have now a very competitive price offer, and on the other hand, they have zero emissions.

LITHIUM

GREEN MINING

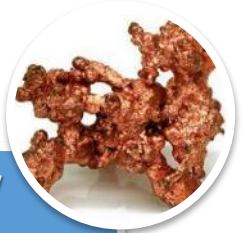
COPPER

Production of metals with a low and traceable carbon footprint that will open up new markets demanding minerals produced under higher environmental standards.

INNOVATION STRATEGY: VISION 2025

Chile: leading supplier of lithium and low-emission copper for the electric car industry

World's leading lithium producer



World's largest low emission copper producer

Long term supply of lithium carbonate/hydroxide (battery grade)

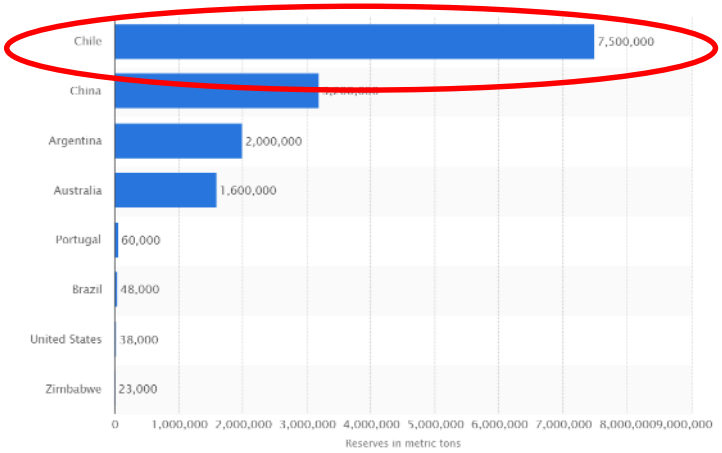
Lithium added value products (cathodes, others)

Solar energy for continuos electricity supply (mix PV/CSP) at average cost of 50 USD/MWh

Fossil fuels sustitution Hydrogen and Syntetic fuels based on circular economy approach

NATIONAL STRATEGY FOR LITHIUM DEVELOPMENT

- The Chilean government, through Corfo, owns the lithium resources in the Atacama salt flat. Albermarle and SQM are currently exploiting the mineral.
- Chile is expanding the production capacity through a recently signed agreement with Albermarle (ex Rockwood Lithium).
- Chile has the lowest production cost (evaporation of brines vs ore).
- Chile owns more than 50% of the world reserves.
- **With 70% of extraction efficiency, Chile could produce more than 500.000 tons/year – A third of the world production**

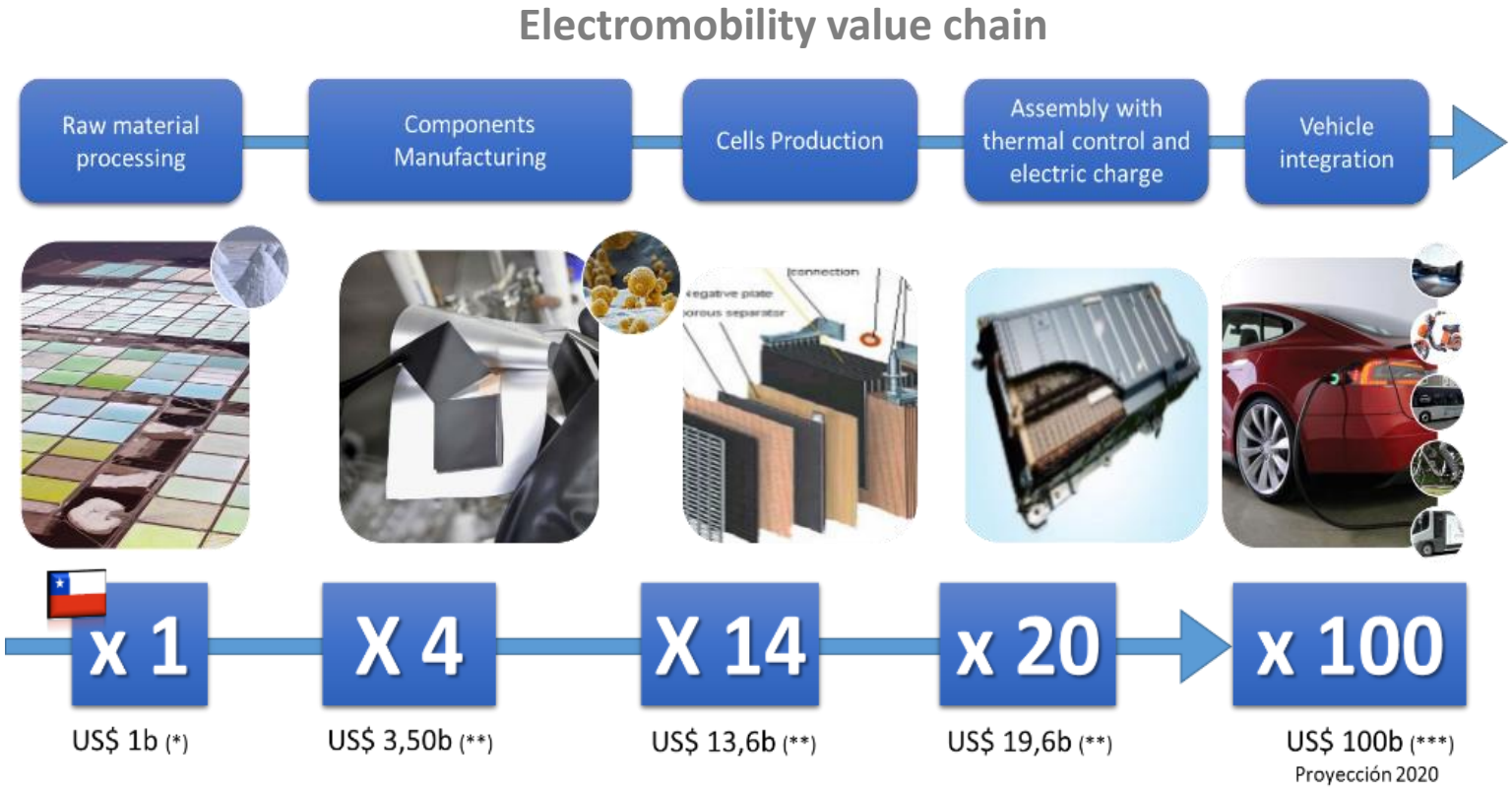


World Lithium Reserves
Source: STATISTA 2016





CALL FOR INVESTMENT IN LITHIUM ADDED VALUE PRODUCTS



Source: Technology Intelligence Unit – Technological Capabilities Division, Corfo, 2015

CALL FOR INVESTMENT IN LITHIUM ADDED VALUE PRODUCTS

Pre-qualified International companies

COMPANY	COUNTRY	PRODUCTS TO BE DEVELOPED IN CHILE
TVEL/Rosatom	Rusia	Metalic lithium; active material for cathodes type LFP, LCO, NMC, NCA, LTO
Fulin Group	China	Cathodes materials type LFP, NMC, LMO, and LTO
Gansu DET Co.	China	Cathodes materials type LMO, NMC and LFP
Jiangmen Kanhoo Ind. Co.	China	Cathodes materials type LMO
Molymet	Chile	Cathodes materials type LMO and LFP
Samsung SDI Co.	Corea	Cathodes materials type NMC; active materials type NCA
Umicore	Bélgica	Active materials for cathodes based on patent NMC

Ion Lithium Cathods Plant

Capacity:
20.000 Tons per year

Type of Cathods:
LiFePo / NCM / LMO / NCA

Estimated Investment
US$ 180-250 MM

Supply:
400.000 units for batteries of 25 Kwh for EV

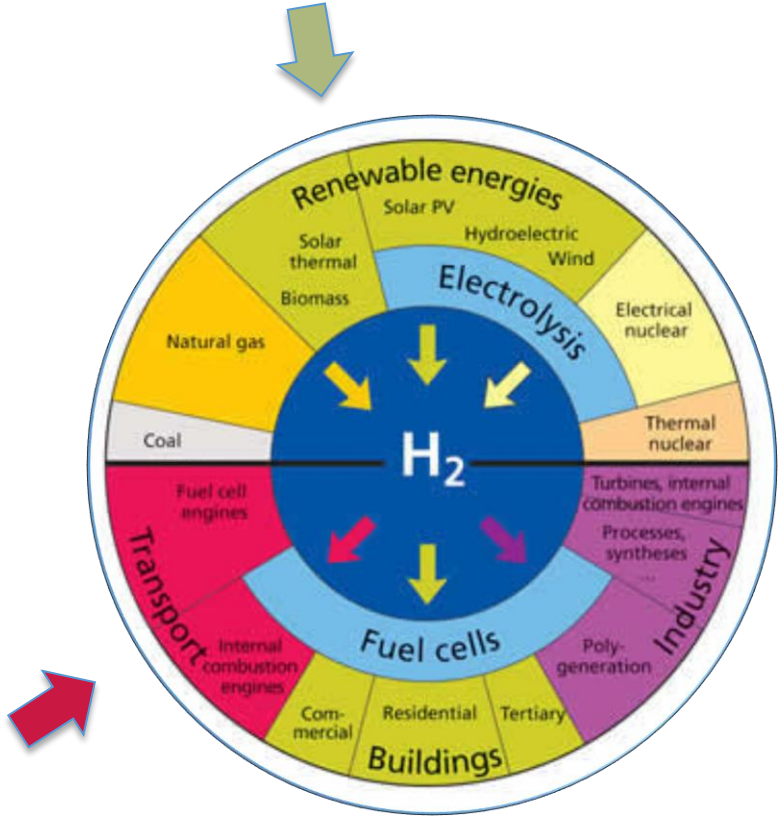
HYDROGEN OPPORTUNITIES

Chile has conditions to become a privileged site for zero-emission hydrogen production

- H2 production based on solar energy, with PV/CSP at average price of:
  - **USD 50/MWh by 2025**
  - **USD 40/MWh by 2035**

- Local consumption for **mining, maritime and public** transport, thermal energy plants and mining processes

- In the long term, to supply the **international demand** (e.g. Japan)

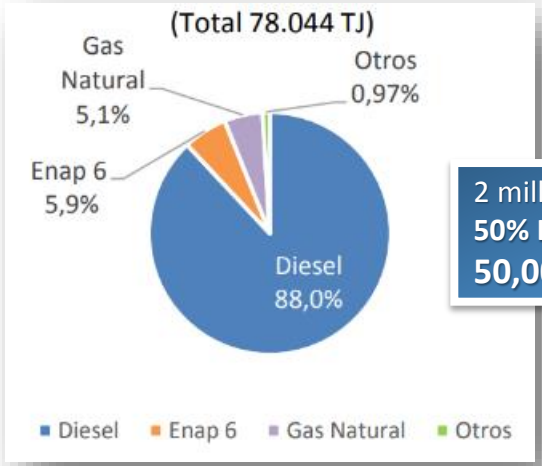


HYDROGEN OPPORTUNITIES

By 2025, cost of H2 produced using solar PV (LCOE 25 USD/MWh, 33% plant factor) might be competitive with diesel (WTI forecast)

Range: 2,2 – 2,6 USD/kgH_2

Mining Fuel Substitution



2 million m3 Diesel/ year
50% Hydrogen substitution
50,000 Nm3H2/h

- **900MW PV**
- **25 Large H_2** electrolysis plants **(750 MMUSD)**

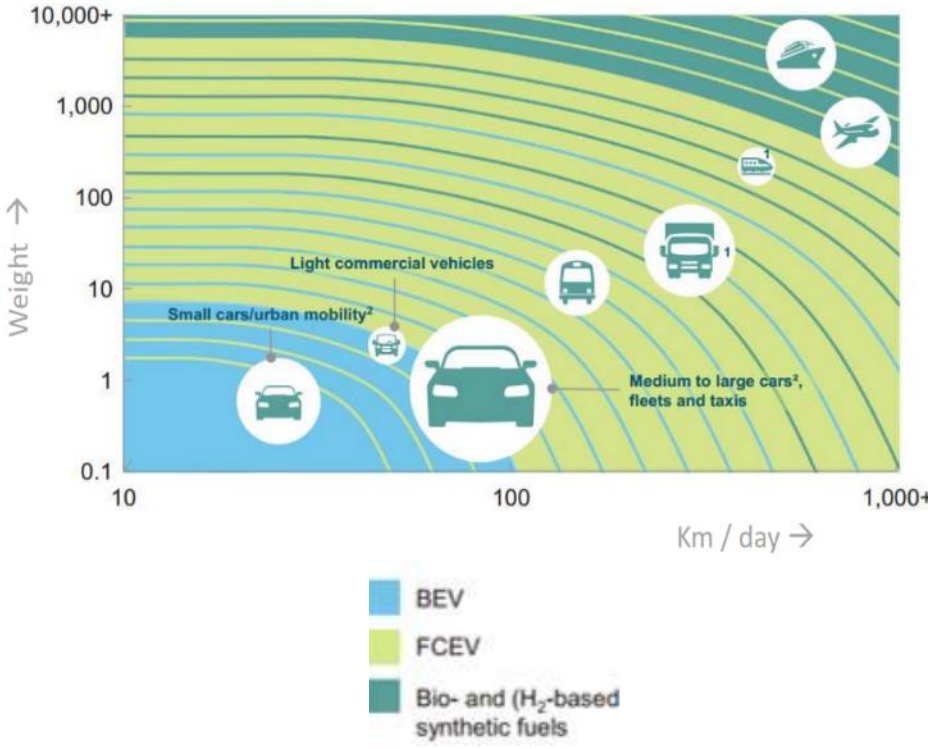
HYDROGEN STRATEGY 2025

Synthetic fuels or Dual combustion

- High tonnage mining haul trucks 100-450 ton (900-3.000 kW)
- Maritime transport (3.000-90.000 kW)
- Natural gas energy plants
- Replacement of diesel combustion in mining operations

Fuel Cells

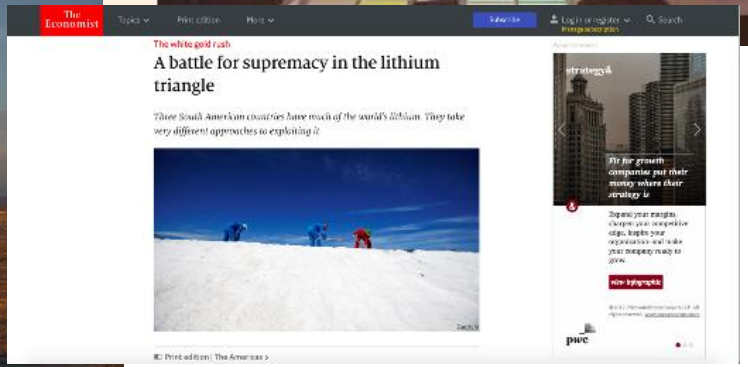
- Class 8 trucks 40-100 tons (300-450 kW)
- Shovels, excavators, other mining equipment
- Public Buses



Source: Hydrogen Council 2017

POSITIONING INTERNATIONALLY

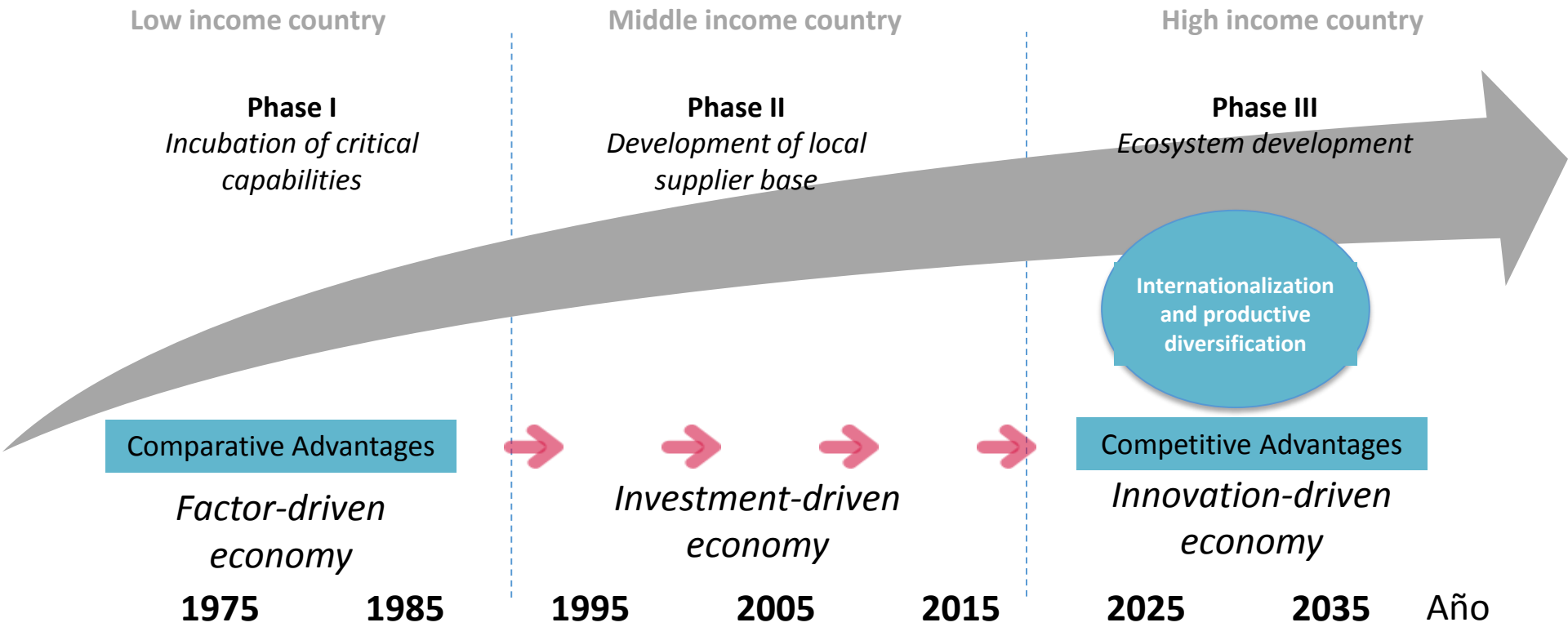
We are in the best place to be a leader in the development and deployment of Solar Energy technologies to support our copper, lithium and clean fuel industries.



FROM COPPER TO INNOVATION

Technological Mining Roadmap 2035

The development of mining as a dynamic goal : Long term evolutionary process



Fuente: Basado en Porter, M., C. Ketel y M. Delgado (2007 "The Microeconomic Foundations of Prosperity: Findings from the Business Competitiveness Index"; Capítulo 2, The Global Competitiveness Report 2007-2008, World Economic Forum; Paginas 51 a 81. Disponible en (Agosto 2015): http://www.weforum.org/pdf/Global_Competitiveness_Reports/Reports/gcr_2007/Chapter2.pdf

Urzúa, O. (2013) "The emergence and development of knowledge intensive mining service suppliers in the late 20th century", Tesis Doctoral (PhD), Univerdad de Sussex. Disponible en (Agosto 2015): http://Una Estrategia de Desarrollo en torno a los Recursos Naturales

GOALS 2035

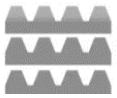
Chile has a developed a technology based mining **industry** that addresses productivity **challenges** with a robust **collaborative innovation ecosystem** with the industry, suppliers, R&D and Public Sector.

Direct goals

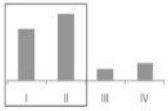
250 world class suppliers

US$ 4 billions exports in **goods** and **services**

Contribution



7,5 millions tons production of FCu



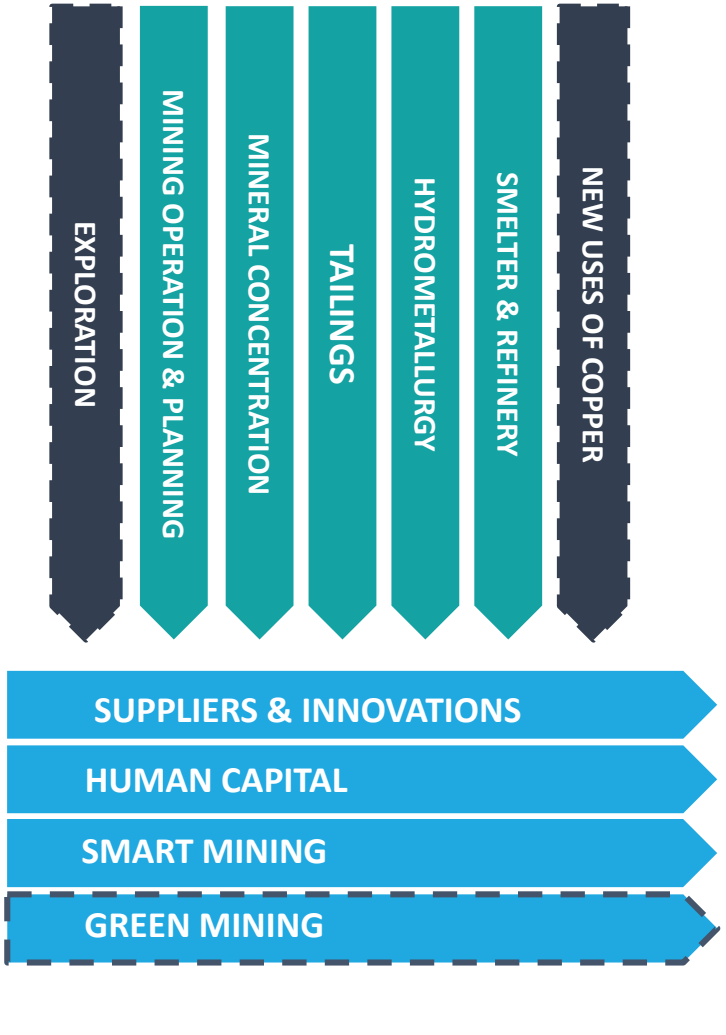
80% of **production** at **first global cost industry quartiles**

Technology Roadmap

Strategic Axis 2017

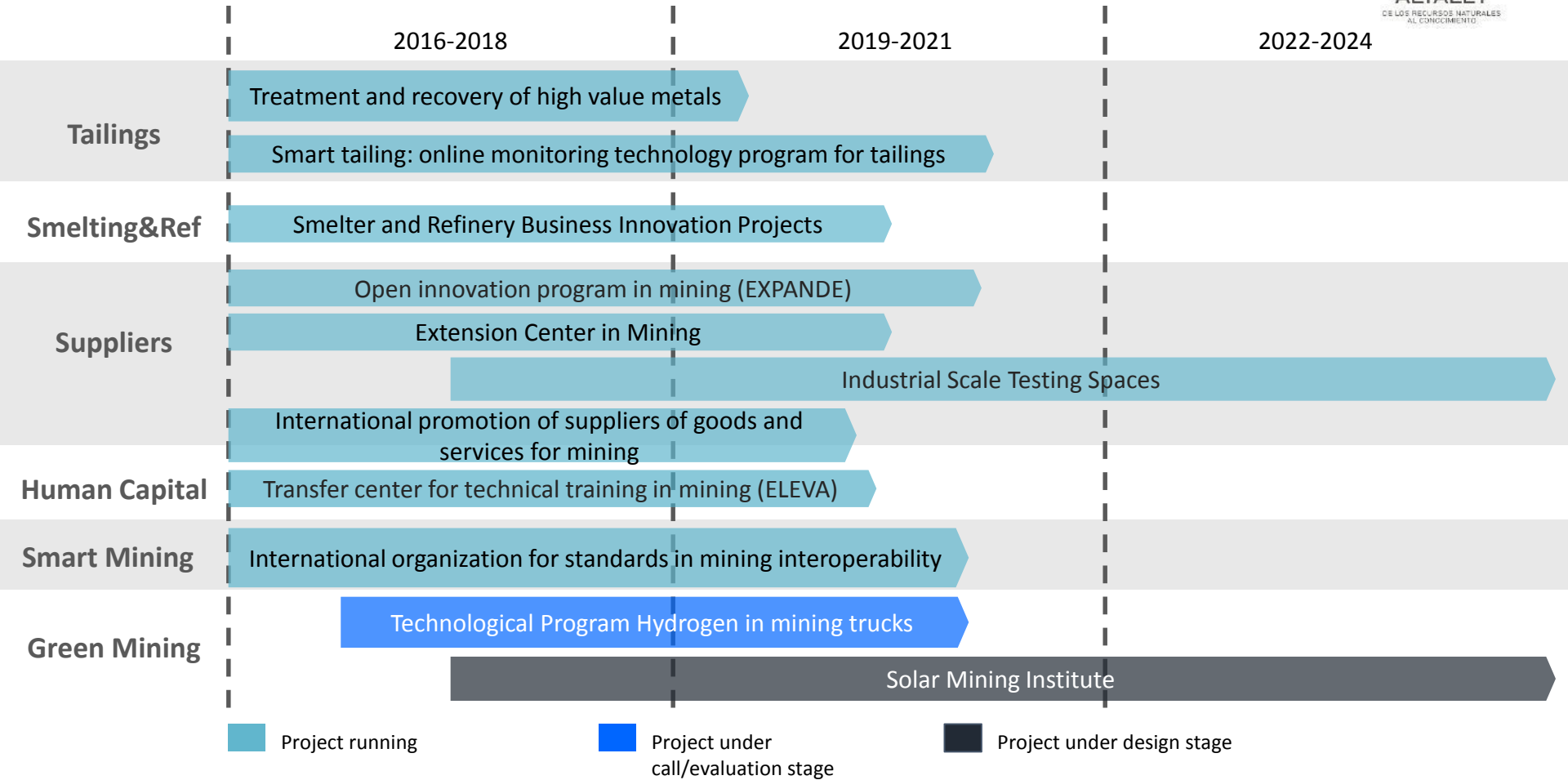
TRACTION CORES

ENABLING CORES



ALTALEY

PORTFOLIO OF STRATEGIC PROJECTS



TAILINGS: SOURCE OF SCARCE AND HIGH VALUE MINERALS

Promoting a secondary mining industry from Tailings

Consumer electronics, aeronautic industry and electro mobility require minerals that are very scarce in earth (Ga, Re, Ge, Co, rare earths, etc.)

Tailings represent an opportunity:

- 2 R&D Consortia supported by Corfo are developing strategies and technologies for recovering value from tailings
- In Chile, there are up to 400 tailings deposits (closed and operating) ~ 1 billion tons are produced annually
- A preliminary analysis shows 20% of them could be re-processed to extract remanent Copper and Molybdenum, as well as high value minerals

Source: AMTC - Tailings Consortium Codelco Tech-

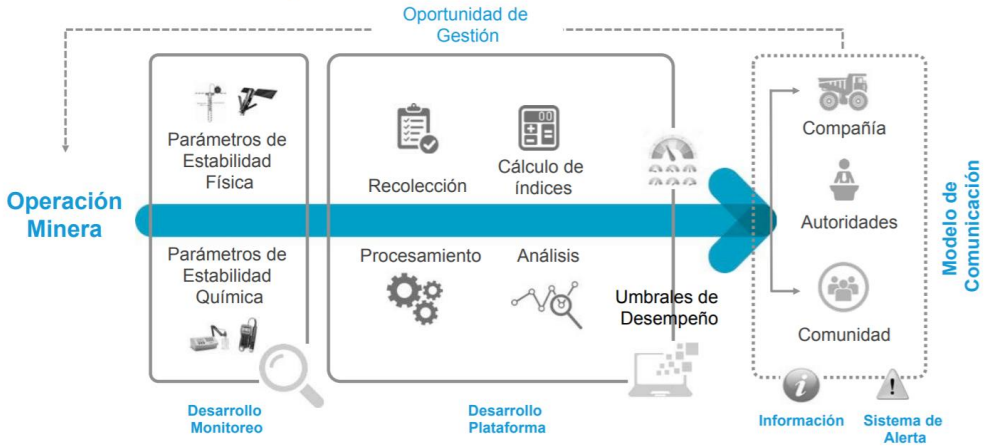
TAILINGS: ON-LINE MONITORING AND INFORMATION PLATFORM

programa tranque
Monitoreo de avanzada para una minería responsable

R&D consortia aimed to develop:

- Models for chemical and physical stability of tailings
- Sensors for on-line or off-line monitoring
- Information Platform - access to mining companies, authorities, communities.

Modelo Conceptual



Lidera:

FCH FUNDACIÓN CHILE

Socios estratégicos:

ANTOFAGASTA MINERALS · BHP · CODELCO

Gracias al aporte de:

FIE · Proyecto apoyado por CORFO

Apoyan:

SMA · TRANSFORMA Minería · ALTALEY

Co-desarrollado con:

DICTUC · ARCADIS · Valor Compartido · amtc · BGC

SMART MINING: PRODUCTIVITY, SAFETY, SUSTAINABILITY

Remote underground mining.

Real-time process management, predictive maintenance, remote control systems, autonomous fleets.

Applications for people safety, energy efficiency and water.

MINING INTEROPERABILITY

Raising needs to support and control:

- End-to-end process integration
- Remote operations
- Multi-vendor equipment automation
- Massive field data gathered, managed and processed

INTERNATIONAL CONSORTIA FOR MINING INTEROPERABILITY

Awarded to FCh, BHP, Codelco March 2017

Leaded by:

FCh FUNDACIÓN CHILE BHP CODELCO

In collaboration with:

CODELCO TECH CSIRO Chile GMSG amtc ADVANCED MINING TECHNOLOGY CENTER

Chile

SOLAR ENERGY PROGRAM

PROGRAMA
ENERGÍA SOLAR

TRANSFORMA

SOLAR ENERGY STRATEGY 2025

The Chilean Government has developed a collaborative process through CORFO (Chilean Economic Development Agency) and the Ministry of Energy to draft a 2025 Roadmap called Strategic Solar Program, which included participation by over 100 government, corporate, academic and civil society entities.

A common vision and a technology roadmap was developed.

SOLAR ENERGY PROGRAM

More than 170 stakeholders

1380 HH workshops

100 INSTITUTIONS

More than 50 Initiatives

Sociedad Civil

Gobierno

Industria

Empresas eléctricas

Ciencia y Tecnología

SOLAR ENERGY PROGRAM 2016-2025

SOLAR ENERGY
PROGRAM

This Roadmap seeks to take advantage of the Atacama Desert's unique features to develop a national solar power industry with technological capabilities and export-oriented. To this end, an initial portfolio of 50 initiatives was identified, with a total budget of US$800 million.

TECHNOLOGICAL DEVELOPMENT

- Photovoltaic systems for desert application
- Solar mining and metallurgy program
- CSP and Thermal energy storage system program
- Solar desalination
- Solar fuels program
- Advanced human capital program

INDUSTRIAL DEVELOPMENT

- Open innovation platform
- Innovation challenges financing
- High-tech investment attraction program

REINFORCING QUALITY INFRACTUCTURE AND HUMAN CAPITAL FOR INDUSTRY

- Climate characterization
- Metrological network
- Standards
- Conformity assessment schemes
- Certification of labor competencies program

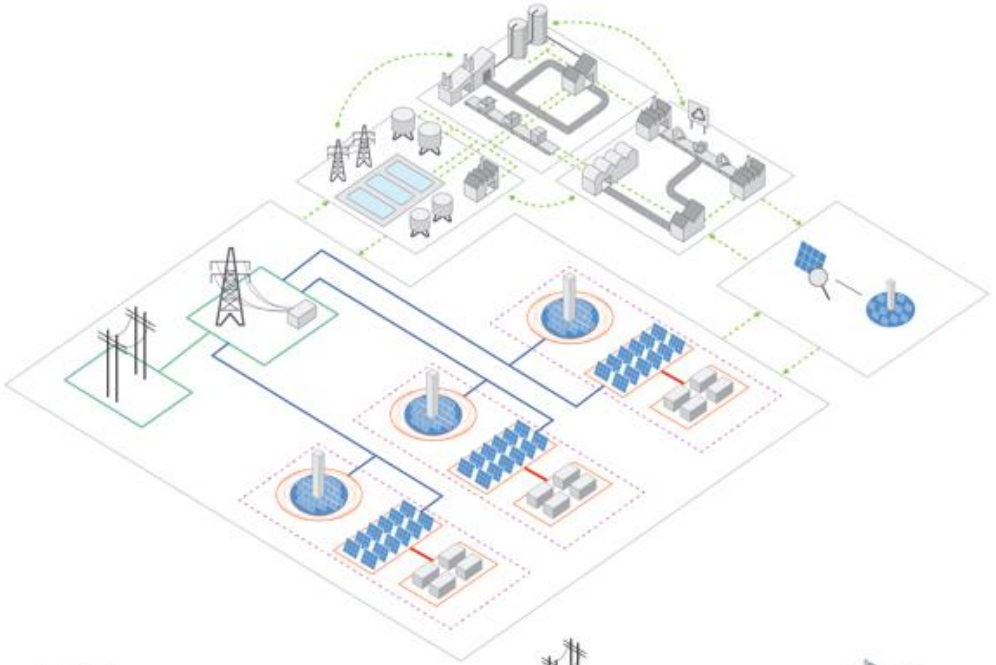
Solar Corridor "Cuenca del Salado"

Solar Technological District

SOLAR TECHNOLOGY DISTRICT IN PROGRESS

SOLAR ENERGY PROGRAM

- MEGA SOLAR POWER STATION (750 MW- 1GW)
- ECO INDUSTRIAL PARK
- PUBLIC LAND (NATIONAL ASSETS MINISTRY)
- COMPETITIVE PRICES
- SUPPLY QUALITY (~ 24/7)
- TECHNOLOGY MIX, ECONOMIES OF SCALE, DEVELOPMENT OF LOCAL SUPPLIERS



TOTAL INVESTMENT **4,000 MMUSD**

EMISSIONS REDUCTION **1,000,000**

TON CO2 EQ. (REF. COAL)

600,000

TON CO2 EQ. (REF. NG)

TYPICAL CSP INVESTMENT PROJECT (TOWER TECHNOLOGY)

SOLAR ENERGY PROGRAM

TIPICAL SIZE 115 MW-e (gross capacity)

SUPPLY QUALITY ~ 24/7 (mix CSP and FV)

MOLTEN SALT ~ 29,400 Ton.

THERMAL ENERGY STORAGE 12,5 hrs.

TOTAL LAND ~ 770 Has

TOTAL INVESTMENT ~ 500 MMUSD

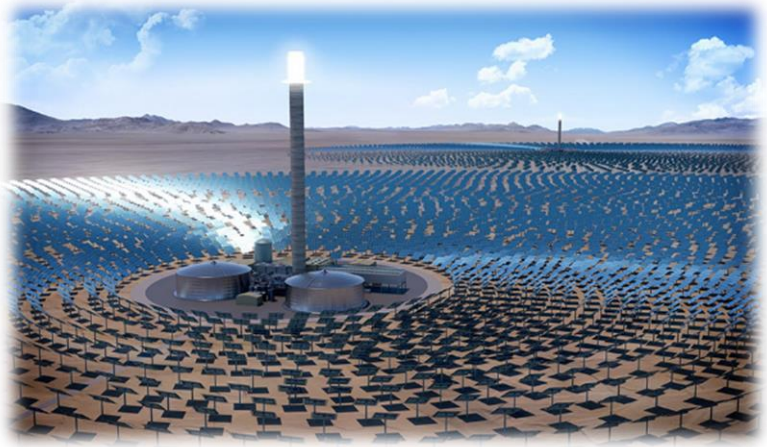
Investment per unit of power (MMUSD/MW-e) decreases if two CSP plants are implemented simultaneously.

COMPETITIVE LCOE ~ 50 USD/MWh

EMISSIONS REDUCTION
(TON CO2 EQ./YEAR)
(1 CSP 115 MW)

255,000
(REF. COAL)

152,000
(REF. NATURAL GAS)



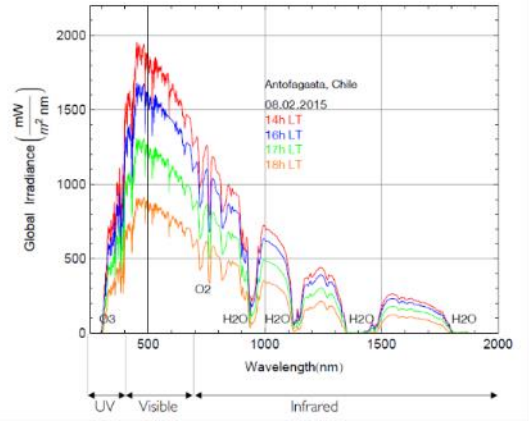
TECHNOLOGY CONSORTIA

PV TECHNOLOGIES ADAPTED TO HIGH RADIATION IN DESERT CLIMATES

Purpose: To adapt and/or develop solar photovoltaic power technologies that respond better to the unique conditions in desert and high-radiation regions in terms of their durability and expected performance that lowers the **levelized cost of energy to a target of US$25/MWh by 2025** and placing special emphasis on the development and strengthening of local suppliers to create a sophisticated industrial sector of goods and services for the local and international market.

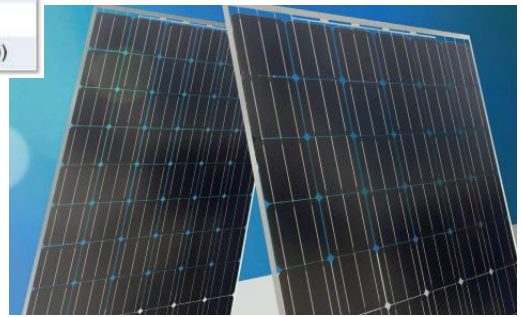
Awarded to AtaMoSTec Consortia August 2017

Corfo co-finance: USD 12 millon (up to 50%)



Source: Estudio Caracterización del Espectro Solar – Programa Solar

	Condiciones estándar (STC)	Desierto de Atacama
AM (air mass)	1.5	1.17
Irradiancia	1000 W/mt2	> 1100 W/mt2
Radiación UV		35 - 65 % UV-B más que en Europa
Temperatura de la celda	25 °C	> 60°C
Módulo tipo	250 Wp	± 30% (200 – 300 Wp)



ATAMOSTEC CONSORTIA

OPEN INNOVATION PLATFORM FOR SUPPLIER DEVELOPMENT

FCH FUNDACIÓN CHILE

Fraunhofer SOLAR CHILE

Industry Needs

Solar energy generating companies

Suppliers of goods & services for industry

Platform Focus

PV plants Utility Scale

Solar Energy for mining & agriculture

Distributed generation

Platform Challenges

Industry Providers

R&D centers & universities

Companies & industry associations

Entrepreneurship ecosystem (incubators & accelerators)

Examples of some industry challenges

Opportunity / Gap	Challenge
Management of fouling, water resources and cleaning of modules	Device for cleaning modules
Performance, deterioration and failure	Standardization and certification of designs, equipment and systems
Operations & Maintenance	Improve operation with local capacities and predictive maintenance

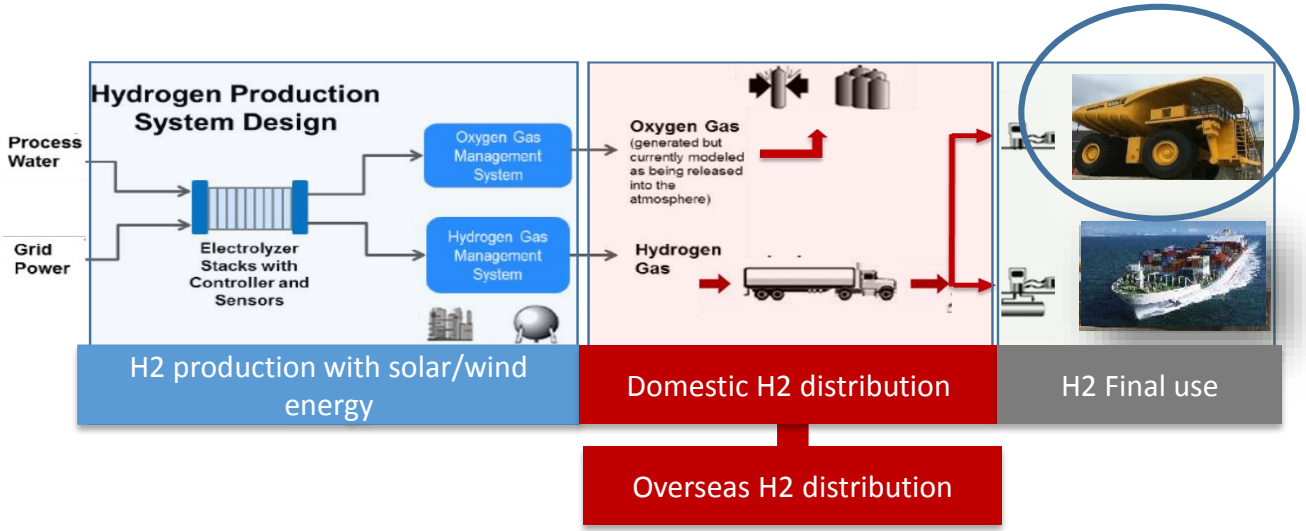
TECHNOLOGY CONSORTIA

PILOTING DUAL HYDROGEN-DIESEL COMBUSTION FOR MINING TRUCKS

Purpose: to create a technology consortium for the industrialization of technological solutions through the adoption, adaptation and/or development of technology to transform a conventional operation of high tonnage mining trucks, based on diesel, to an operation based on **dual hydrogen-diesel internal combustion engines**, with special attention to the development of technological capacities in Chile.

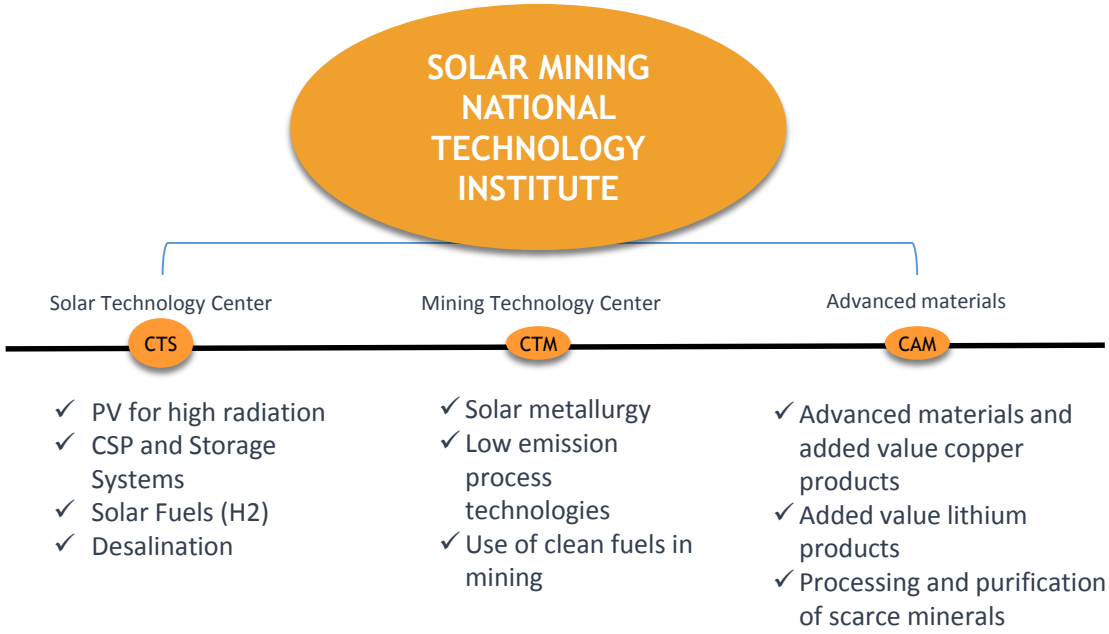
Under call/evaluation

Corfo co-finance: USD 6 millon (up to 50%)



SOLAR MINING NATIONAL TECHNOLOGY INSTITUTE

Currently under creation



ROLES AND SERVICES

- R&D&i: strategic lines with technology transfer models (sale or licensing, spin offs)
- Contract Research and Technological Development contracts with Industry
- Piloting and Technology validation services
- Specialized Technological Services
- Broad technological diffusion and extensionism
- Training of advanced human capital – in alliance with Universities

Thank you

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