Proyectos de I+D en Energía Solar para la Minería Chilena

Experiencias y sugerencias

Prof. Dr. Werner Platzer

Director del Centro Energia Solar

Fraunhofer Chile Research – CSET

Santiago

16 Enero 2017

www.fraunhofer.cl

Fraunhofer CHILE

Fraunhofer Chile Research (FCR) Foundation

Center for Solar Energy Technologies (CSET)

- Center of Excellence, co-funded by CORFO
- Application CEI June 2013
- Inauguration on May 27, 2015
- Executing Partners:
  Fraunhofer ISE, Germany,
  Pontifica Universidad Católica de Chile
- Application oriented R&D and Support
  1. Solar Electricity (PV, CPV, CSP)
  2. Solar Heat (Industrial Processes, Agriculture)
  3. Water Treatment (Desalination / Waste water)
  4. Horizontal Integration (Building, Grid, Market,..)
- **Adaptation of Technologies for Chile**
- **Quality Assurance, Standards and Certification**

Objectives

Generate **innovations** to achieve large scale implementation of solar energy into the **main industrial** and **commercial/residential** sectors in Chile

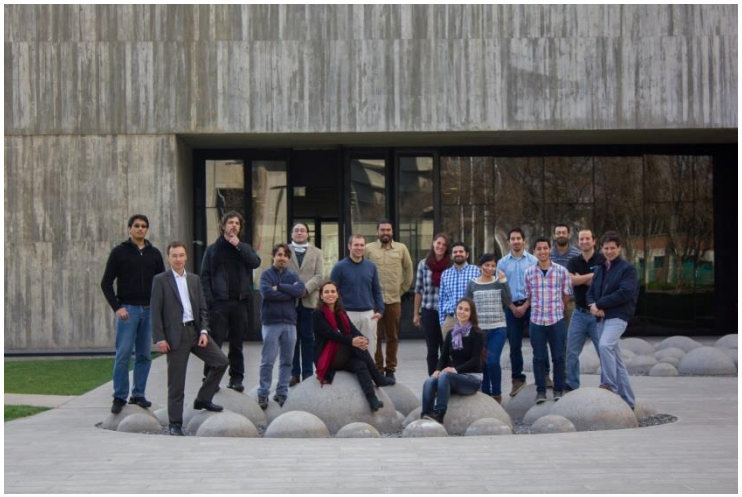
- Investigate and **address** the specific scientific, technological, economical and market **challenges for solar energy in Chile**
- **Education and training** of technicians, professionals, researchers, managers and decision makers in the design, construction, operation, maintenance, planning, financing, promotion of solar energy conversion systems
- **Development** of technological systems **adapted** to the particular conditions in Chile "**from laboratory to market**"
- **Support for state policies** with scientific methods to increase solar energy implementation in Chile.
- Bridging the gap between **academic research, industrial entrepreneurship**

CSET will help to **transform Chile** into a **Solar Economy**.

Fraunhofer CHILE

Fraunhofer Chile Research (FCR) Foundation

Center for Solar Energy Technologies (CSET)



Scientific Progress (Jan. 2017)

- 11 scientific papers published
- 3 scientific papers submitted
- 9 scientific conference papers published

Economic Progress (Jan. 2017)

- 17 completed industry contracts (425 kUS$)
- 7 ongoing industry contracts (100 kUS$)
- 11 high priority industry leads (410 kUS$)
- 5 public funded contracts (508 kUS$)
- 1 proposal for public funding under evaluation (300 kUS$)

Several projects with participation of Fraunhofer ISE

Fraunhofer CHILE

Customers and Industry Asociations

Fraunhofer CHILE

Cooperation National and International

Scientific and Industrial Advisory Boards

Scientific board

- Prof. Ricardo Ruther, Univ. Federal de Santa Catarina, Florianopolis, Brazil
- Prof. Wikus van Niekerk, Stellenbosch University, Stellenbosch, South Africa
- Prof. Manuel Collares Pereira, University of Evora, Evora, Portugal
- Prof. Barbara Loeb, Dean of Faculty for Chemistry, PUC, Santiago, Chile
- Prof. Hans-Martin Henning, Deputy Director Fraunhofer ISE, Freiburg, Germany

Last Meeting: 13th-14th April 2016

Industrial board

- Claudio Seebach, GENERADORAS Viecpresident
- Alvaro Acevedo, SOFOFA Innova Head Innovation and Entrepreneurship
- Carlos Zeppelin, CCHC-CDT President
- Pablo Pastene, ACESOL Honorary President
- Carlos Finat, ACERA Director (to be replaced)

Last Meeting: 24th May 2016

Research Lines

Solar Electricity Generation

- Solar resource assessment
- Concentrator PV
- PV power plants
- Solar Thermal Power CSP
- High-temperature storage

Solar Heat for Industry

- Heat for industrial processes in mining, food, others
- Solar cooling for food industry
- Solar polygeneration (heat, cold, el, water)
- Energy efficiency

Solar Water Treatment

- Water purification
- Water Desalination
- Industrial water treatment
- Water decontamination
- Irrigation with PV

Business Development

- Generating links, contacts and coordination with the industry and public sector.
- Integration, grid modelling, energy market studies
- Studies and strategic consulting to government agencies and private sector.
- Strategic support to the Research Lines.

Research Line 1 - Solar Electricity

Quality, Optimization and Innovation

- Photovoltaic PV power plants
- Concentrator PV technology
- Concentrated Solar Thermal Power
- High-temperature storage systems
- Resource assessment

Support of industry:

Quality testing and monitoring,
Simulation, Prefeasibility,
Optimization of plant operation

Adaptation of technology
Soiling investigations
Reliability and durability issues

Fraunhofer CHILE

Research Line 2 - Solar Heat

Big Potential for Industrial Applications

- Solar Process Heat
  - Mining
  - Agro and Food industry
- Combined Heat and Power
- Energy Efficiency Measures

Our Support for Industry:

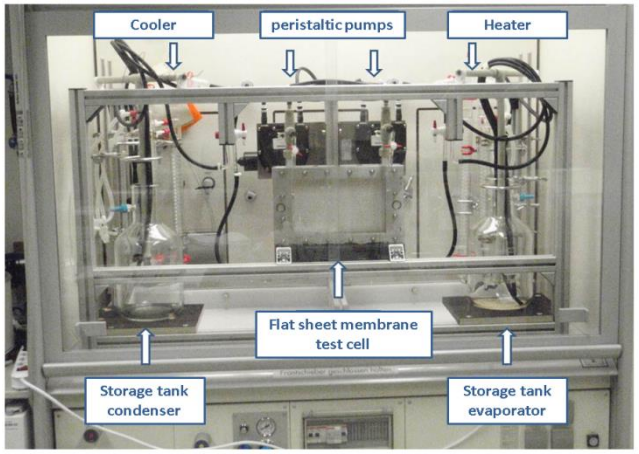
Feasibility studies, Simulation, Support of new Business Models, Quality Monitoring

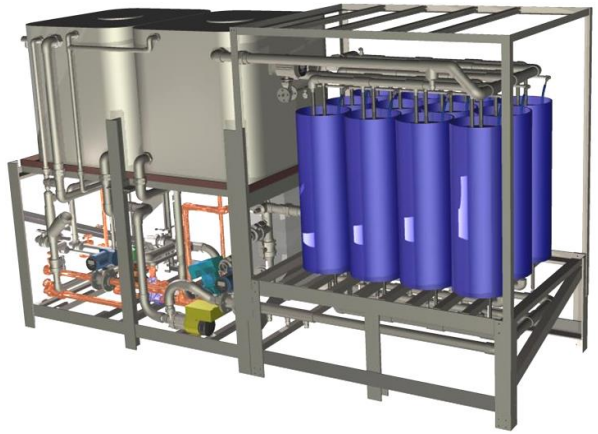
Adaptation of technology: Reliability and durability issues, Demonstration of new collectors

Research Line 3 - Water Treatment

Technology Transfer and Demonstration

- Membrane Distillation using solar heat or waste heat
- PV or wind driven Reverse Osmosis
- Water cleaning and irrigation (filtering, detoxification, pumping,..)





Our Support for Industry:

Feasibility studies
Concept development
Demonstration projects

Adaptation of technology
Prototype development
Reliability and durability issues

Fraunhofer CHILE

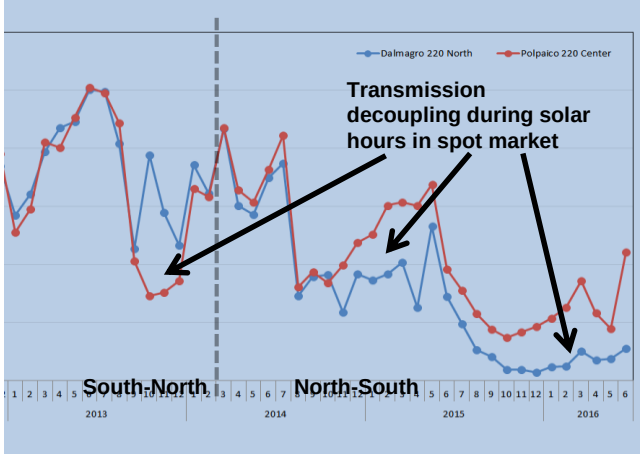
Business Development

Integration and Market - Horizontal Activities

- Contacts with Industry in general
- Coordination of horizontal projects / integration of different areas
- Government - Strategic Initiatives - PES
  - Cuenca del Salado Solar
  - National Quality System (IEC, INN)

Our Support for Industry:

Grid Integration
Integration with other Sectors:
Buildings, Sustainable Construction
Economic Studies – Financial Modelling
Energy Market Analysis



Fraunhofer CHILE

What can we do for mining?
Operation cost and process efficiency

Copper industry

- Heat management of (bio-)leaching / solar thermal integration
- Improvement of electrowinning process / solar thermal integration
- Water treatment / recuperation

Nonmetallic mining

- Drying processes with solar energy

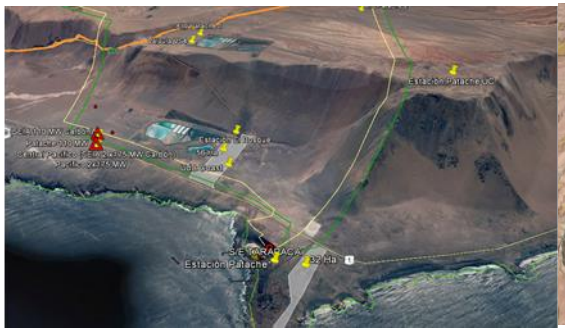
All mining industry

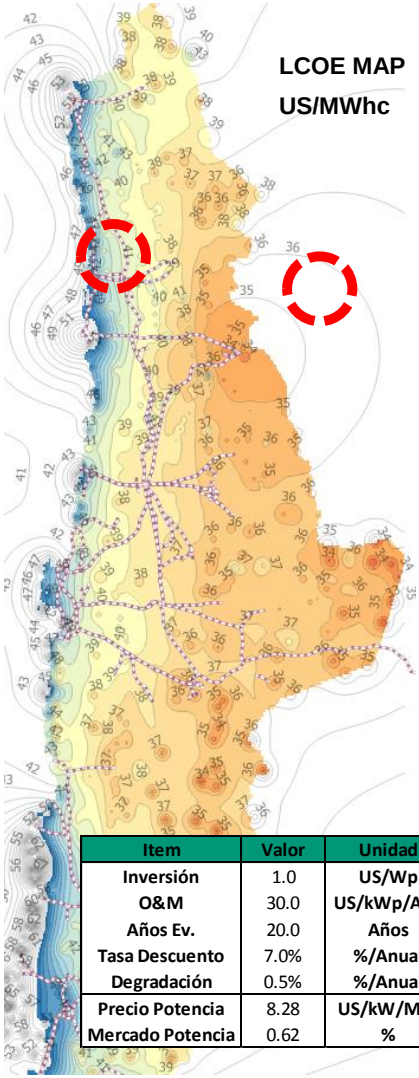
- Electricity and thermal energy supply with renewables
- Polygeneration
- PV and CSP (24h/7) power plants
- Energy efficiency concepts
- Sustainable hydrogen production
- Sustainable water treatment, desalination, waste water

Potential of Renewables for Collahuasi Mine

Project Collahuasi

- Characterization of renewable potentials in the mining zone (Wind, Solar and Storage)
- System simulation of generation potential in this region
- Estimation of specific energy generation per technology [MWh/MW(p)]
- Estimation of potential installation capacity [MW(p)]
- Cost estimation and analysis of generation profiles [US/MWh] according to market prices





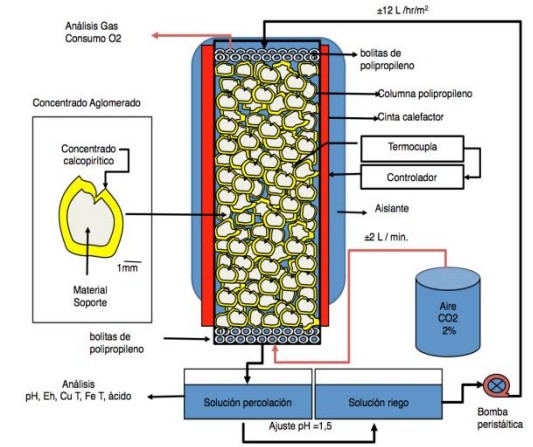
Item	Valor	Unidad
Inversión	1.0	US/Wp
O&M	30.0	US/kWp/Año
Años Ev.	20.0	Años
Tasa Descuento	7.0%	%/Anual
Degradación	0.5%	%/Anual
Precio Potencia	8.28	US/kW/Mes
Mercado Potencia	0.62	%

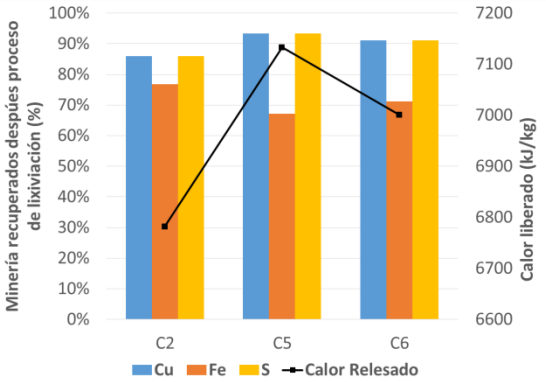
Fraunhofer CHILE

Biolixiviación Balance de Calor

Proyecto Pucobre

- Investigar la generación y el efecto de calor exotérmico en el proceso de biolixiviación en columnas
- Análisis de resultados experimentales para calcular generación de calor realizado en diferentes configuraciones y condiciones
- Estimación de evolución de las temperaturas de una pila de material dado los parámetros de extracción (perfil de minerales, tasa de irrigación) durante un año



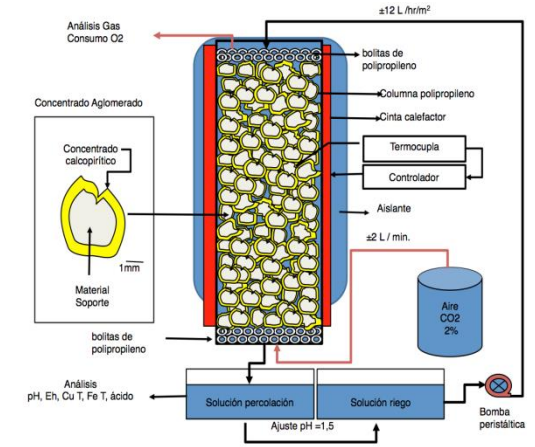


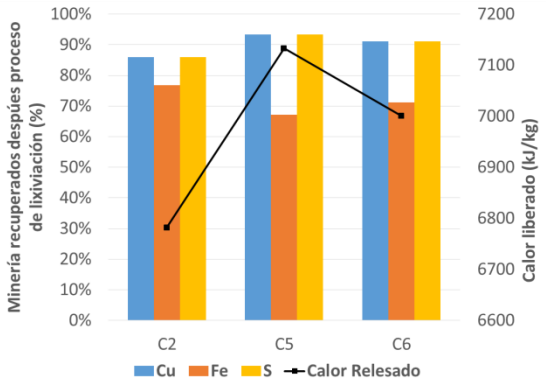
Fraunhofer CHILE

Bioleaching Heat Balance

Project Pucobre

- Investigation of the generation and effect of exothermic heat from the reaction of the bacteria in a bioleaching process in reactor columns
- Analysis of the experimental results in order to extrapolate the heat generation in differnt configurations and for different rection conditions
- Estimation of the temperature evolution in a bioleaching heap with given paarameters of extraction (profile of the minerales, concentration, irrigation rate, climate,..) during the year



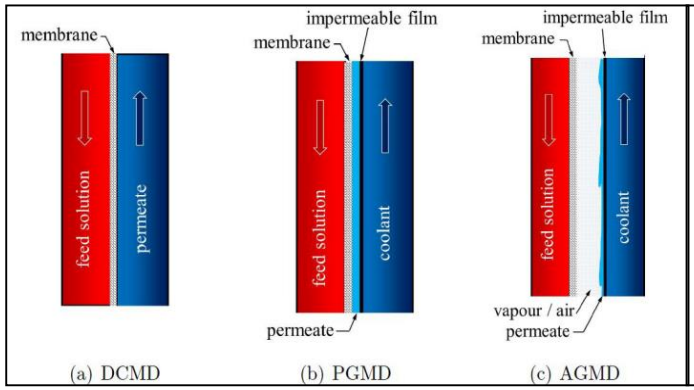


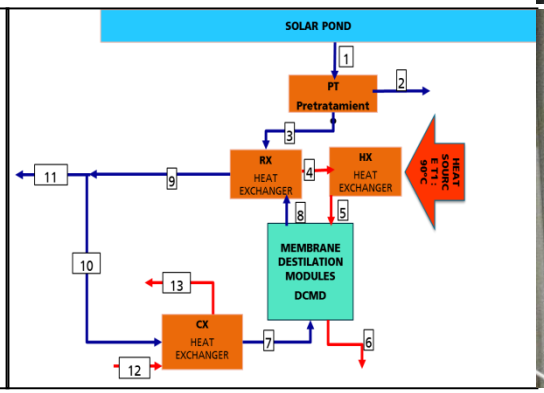
Fraunhofer CHILE

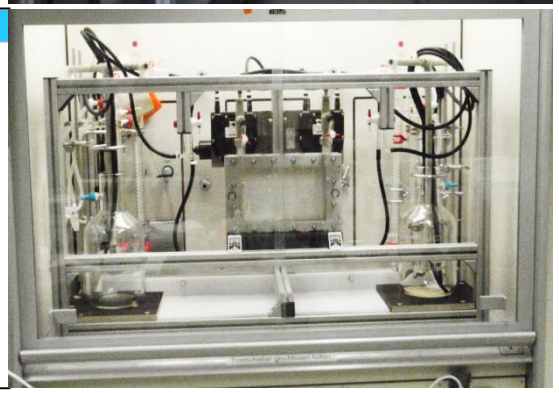
Membrane Destillation

Economical tool and Prefeasibility

- For membrane destillation the energy consumption is nearly not dependent on salt content of brine – contrary to reverse osmosis
  - Use for sea and brackish water desalination
  - Up-concentration of salt brine
- Use of low temperature waste heat 60-80°C (diesel gens, power plant) or solar heat
- Estimation of the investment and economy depending on plant size, salt concentration, energy costs







Fraunhofer CHILE

Copper mining industry in Chile

Top copper producer in the world

Production keeps growing, as new ores are found

Mines located inland, population settled on the coast

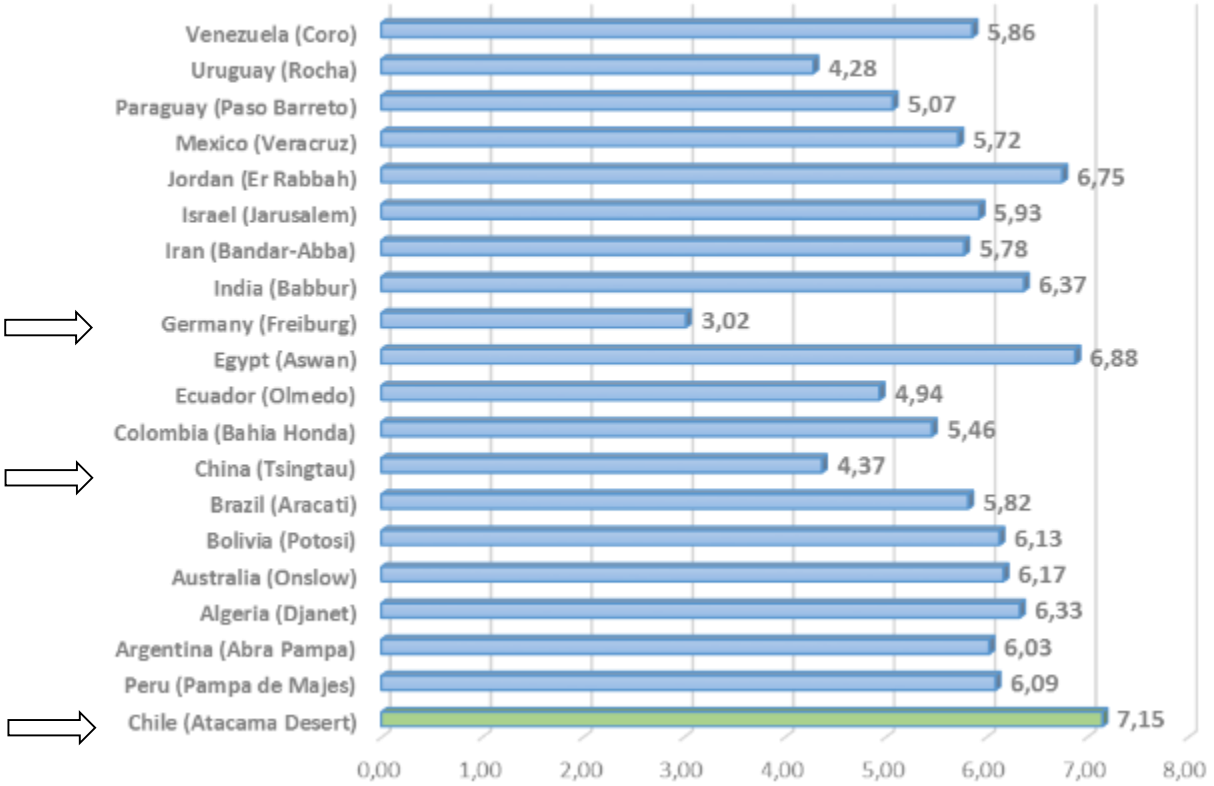
High energy demand, both electrical and thermal. High amount of water is required as well

About 70 % of electrical generation in northern Chile is demanded by the mining sector

Fraunhofer CHILE

Solar Energy in Chile:
A valuable natural resource

Global Solar Horizontal Radiation GHI [kWh/m^2-day]



No clouds -> Direct normal radiation
DNI: Up to 10 kWh/m2-day

Source:http://www.sealite.com.au/technical/solar_chart.php

Fraunhofer CHILE

Arguments for Use of Solar Energy

Why not wait until the energy becomes more expensive?

High upfront investment and nearly negligible O&M cost (no fuel cost!) make SOLAR a business with long-term horizon

- Energy costs are constant for 25 years to come!
- Large demand for many years is positive for the business case
- Financing options are needed for the investment

Increasing number of installations will drive investment cost down

- Know-How, trust and experience reduce the risk
- Market increase will result in strong competition of providers

Low fuel prices may suggest to wait for the moment

- However the next energy crisis will strike – and then everybody wants it => resulting high prices, low quality and waiting times!

Solar Heat

Key Component: Collector for Conversion of Solar Radiation into Heat

- Solar Tower: plant capacity ~ 10 - 120 MW_{el}, operating temperature 600-1200 °C
- Dish: unit capacity ~ 10-25 kW_{el}, operating temperature 200-1800 °C
- Linear Fresnel: plant capacity ~ 30-250 MW_{el}, operating temperature < 550°C
- Parabolic trough: plant capacity ~ 30-250 MW_{el}, operating temperature < 550°C
- Vacuum tube, stationary CPC: unit capacity ~ 1 kW_{th}, operating temperature < 150°C
- Flat plate: unit capacity ~ 1 kW_{th}, operating temperature < 100°C

Market available technology

Existing solar thermal plants in Chilean mining

	Gabriela Mistral	Minera Centinela (El Tesoro)	Minera Constanza
Annual Production or Power rating	51,800MWhth	24,800 MWhth	540MWhth
Type of collector	Flat plate collectors	Parabolic Trough	Flat plate collectors
Area	39,300m2	16,700m2	404m2
Temperature supplied	45-51°C	80-85°C	47°C
Storage system	4,700m3	Yes	25m3
Portion of heat supplied	85%	55%	80%

Solar thermal energy integration

Great potential for integrating solar thermal energy in electro-winning process

Temperatures needed in depend on the exact process

Two solar plants already operating

- 2010, Minera El Tesoro. Parabolic trough collector system. 16700 m² aperture area. 7.0 MWth. Turnkey project, executed by Abengoa, operated by Minera El Tesoro

Abengoa. Installed plants

Fraunhofer CHILE

Solar thermal energy integration

Second solar plant operating

- 2013, Gabriela Mistral - Flat plate collector system. 39000 m² aperture area. 32 MWth, 4700 m3 st orage
- Consortium between Sunmark (Denmark) and Energia Llaima (Chile). Minera Gaby buys energy. Thermal Power Purchase Agreement contract for 10 years

Ian Nelson. ISES Webinar, 31.01.2014. Sun is shining on mining thermal processes. Replacing fosil fuels with solar supply

Fraunhofer CHILE

Solar thermal at Gabriela Mistral

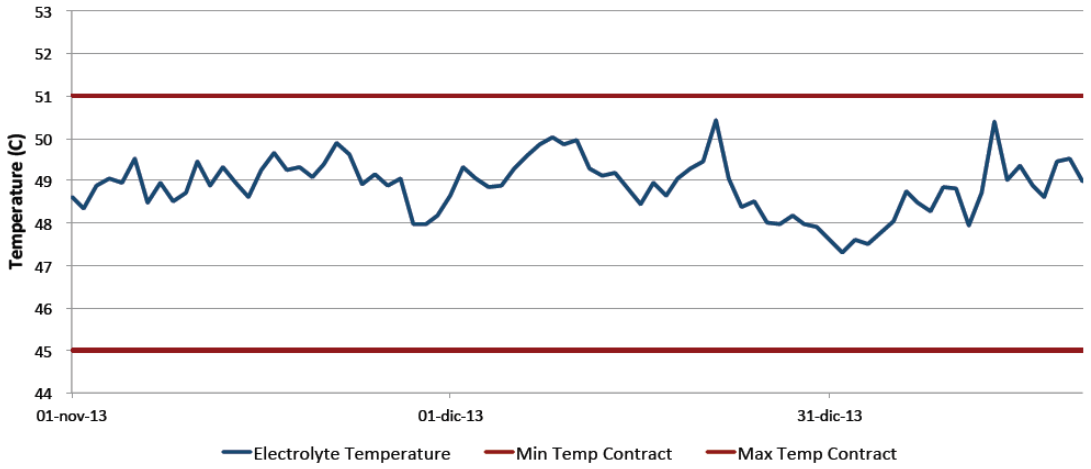
10 year contract

Stable energy tariff US$/MWh + Fixed charge heaters O&M

KPI: Electrolyte Temperature

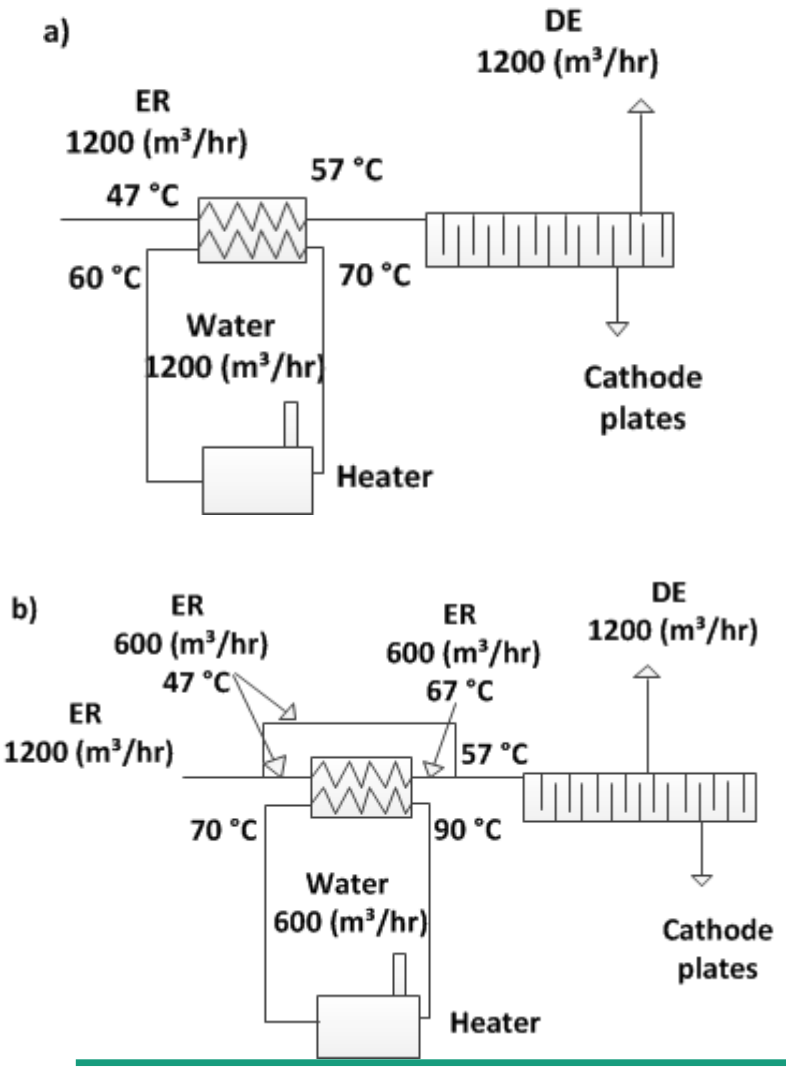
Has provided 10% more energy than contracted

Diesel savings: 6,500 ton/year



Fraunhofer CHILE

Electro-winning process. Case study



Expected copper production: 100000 tonnes/year (~12 tonnes/hour)

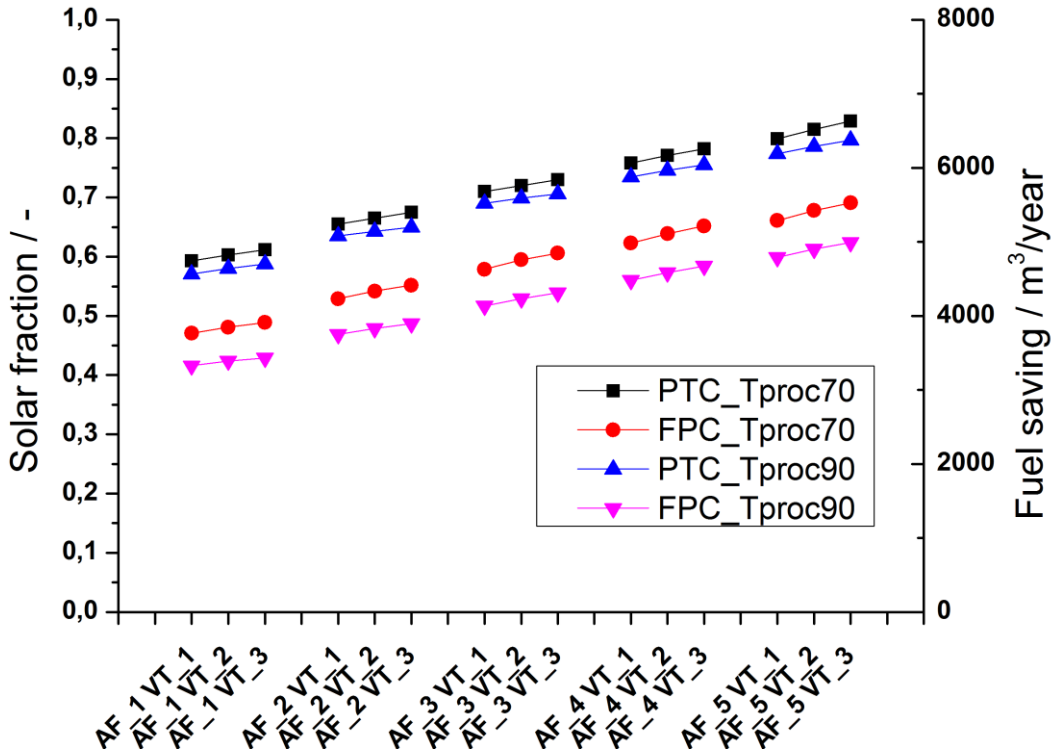
We study two possible configurations to warm up the electrolyte.

Configuration	**a)**	**b)**
Corresponding notation	TProc70	TProc90
Heater inlet temperature (°C)	60	70
Heater outlet temperature (°C)	70	90
Flow rate (m³/hour)	1200	600
Water specific heat (kJ/kg °C)	4.19	
Heater efficiency (%)	85	
Energy supplied (MJ/hour)	59150	
Diesel calorific power (MJ/kg)	44.8	
Diesel consumption (m³/year)	**13900**	

Fraunhofer CHILE

Results

Variable energy demand. Case 2



Solar field (m²)	30000 / 35000 / 40000/ 45000 / 50000
Corresponding notation	AF_1 / AF_2 / AF_3 / AF_4 / AF_5
Storage capacity (m³)	4000 / 5000/ 6000
Corresponding notation	VT_1 / VT_2 / VT_3

Annual energy consumption decreases considerable (from ~ 14000 m³/year to ~ 8000 m³/year)

As the storage size increases, the solar fraction increases. Solar system covers a significant part of the demand during the night

Under no demand conditions

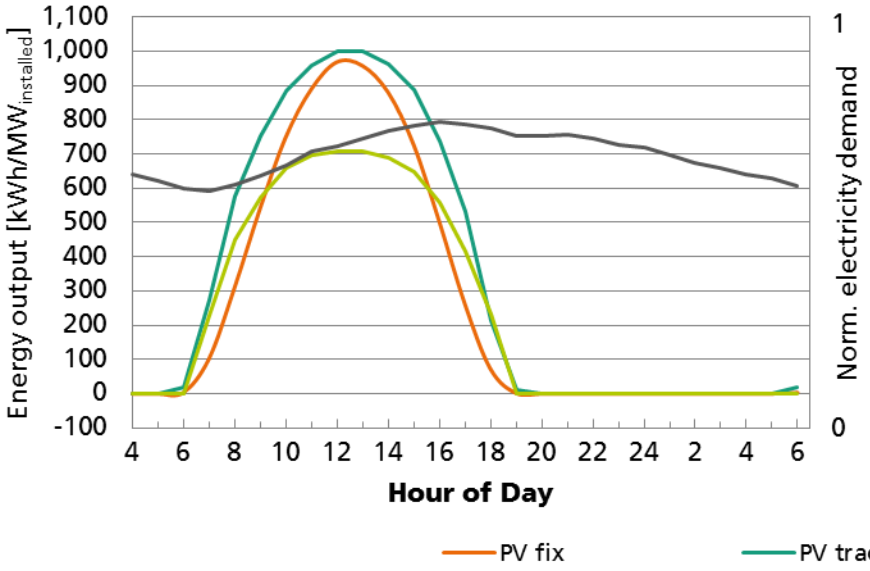
- Worst case: after two days solar tank reaches 120 °C. Increasing solar storage capacity extend the period of time

Fraunhofer CHILE

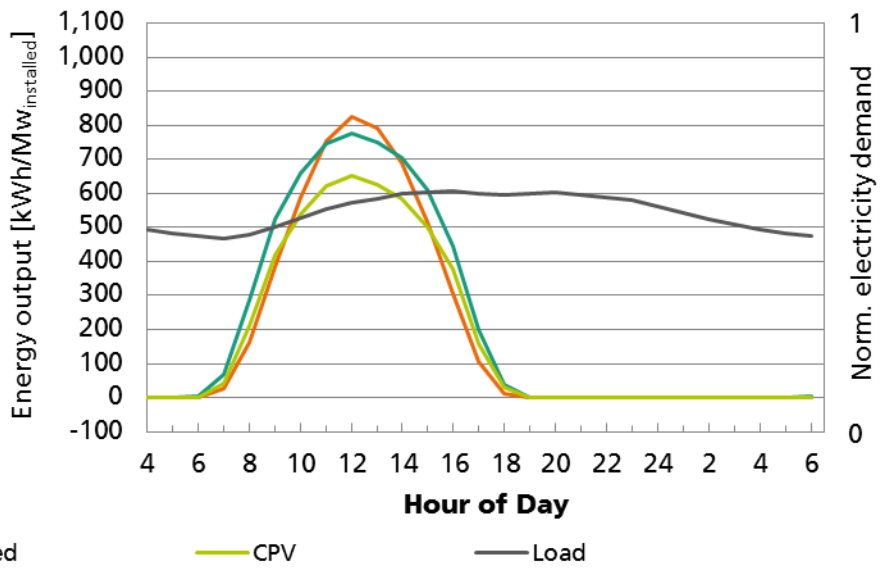
Photovoltaic power plants
PV power production profile vs. load

- PV production follows irradiation with peak at noon
- CPV has slightly lower output because it only uses direct irradiance

Exemplary day (June 28th)



Annual average

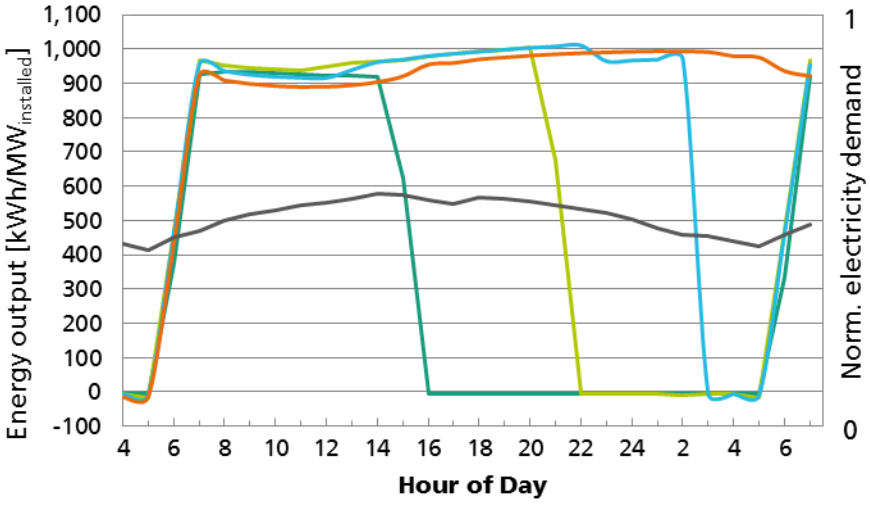


Fraunhofer CHILE

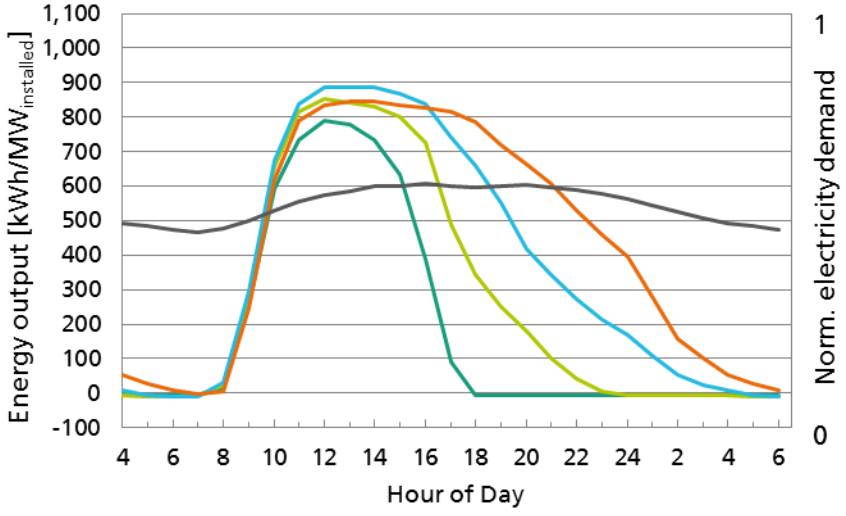
Why CSP?
CSP production profile vs. load

- On a good solar day, CSP storages are filled and the complete period of high load can be covered
- With large thermal storage, even 24/7 operation is possible
- Also the annual average shows the positive influence of storage

Exemplary day (May 5th)



Annual average



CSP no storage | CSP small storage | CSP medium storage | CSP large storage | Load

Fraunhofer CHILE

Hybrid CSP / PV plants may lower cost for 24h supply

CSP: Dispatchability using Thermal Energy Storage (TES) allows a generation of electricity in high-load situations, even at night time

PV: Decreased investment cost due to the large market growth lead to much lower LCOE compared to CSP

Combination of CSP + PV leads to low cost dispatchable solar power

Copiapó 130 MW CSP-150 MW PV
Chile (Solar Reserve)

Redstone 100 MW CSP-75/97 MW PV
South Africa (ACWA, Solar Reserve)

Complejo Atacama 1+2, 110 MW CSP-100 MW PV
Chile (Abengoa)

LCOE for HYBRID is lowered to about 60% when compared to pure CSP power plant with storage

Source: W.J.Platzer, Combined Solar Thermal and PV Power Plants – an Approach to 24h Solar Electricity? SolarPaces Conference 2015,Cape Town

Fraunhofer CHILE

System Integration and Grids — Electricity, Heat, Gas

The cross energy management of the different systems in the electricity, heat and gas grids is an important building block for the energy transformation.

Our research focus:

- Modeling and simulation of energy systems and grids
- Optimization, operation and storage management
- ICT in Smart Grid and Smart City
- Suppy concepts for cities and districts

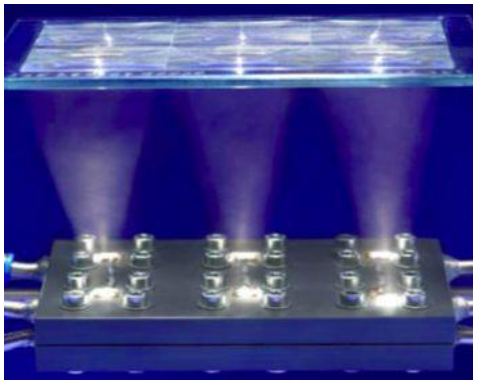
Fotos © Fraunhofer ISE

Fraunhofer ISE

Hydrogen Production by Water Electrolysis

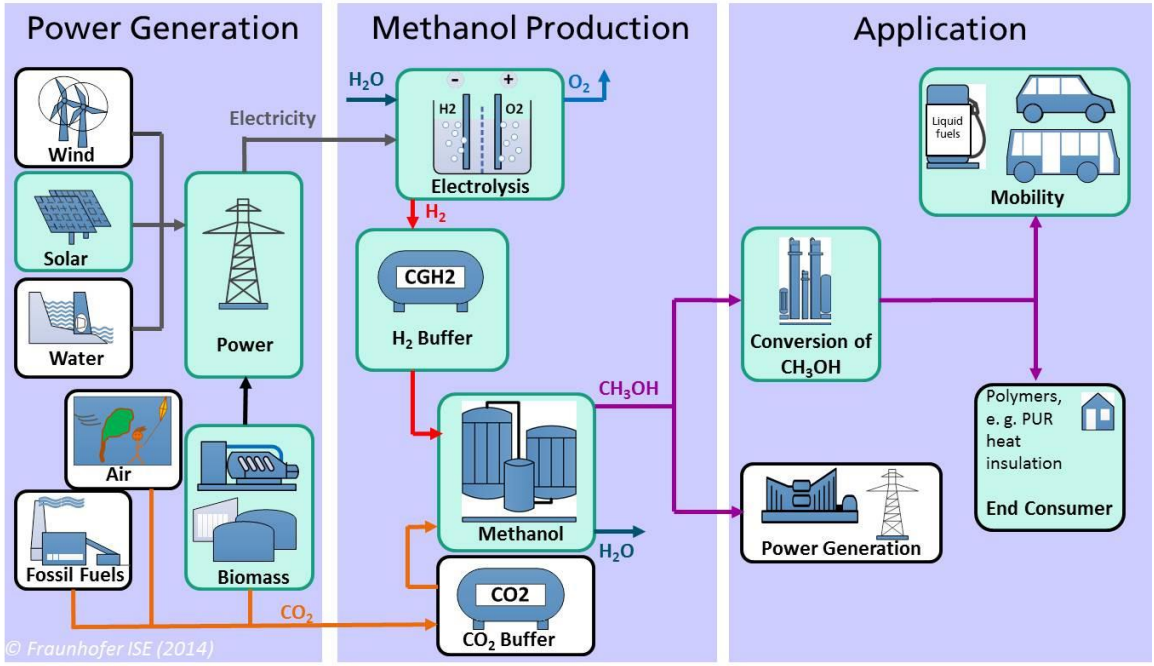
- Electrochemical modeling and material characterization
- Development and characterization of stacks up to 1 MWel
- Operation management and power electronics
- Integration in higher-level renewable energy systems
- System evaluation, monitoring, economic models






Power-to-Liquid (PtL)

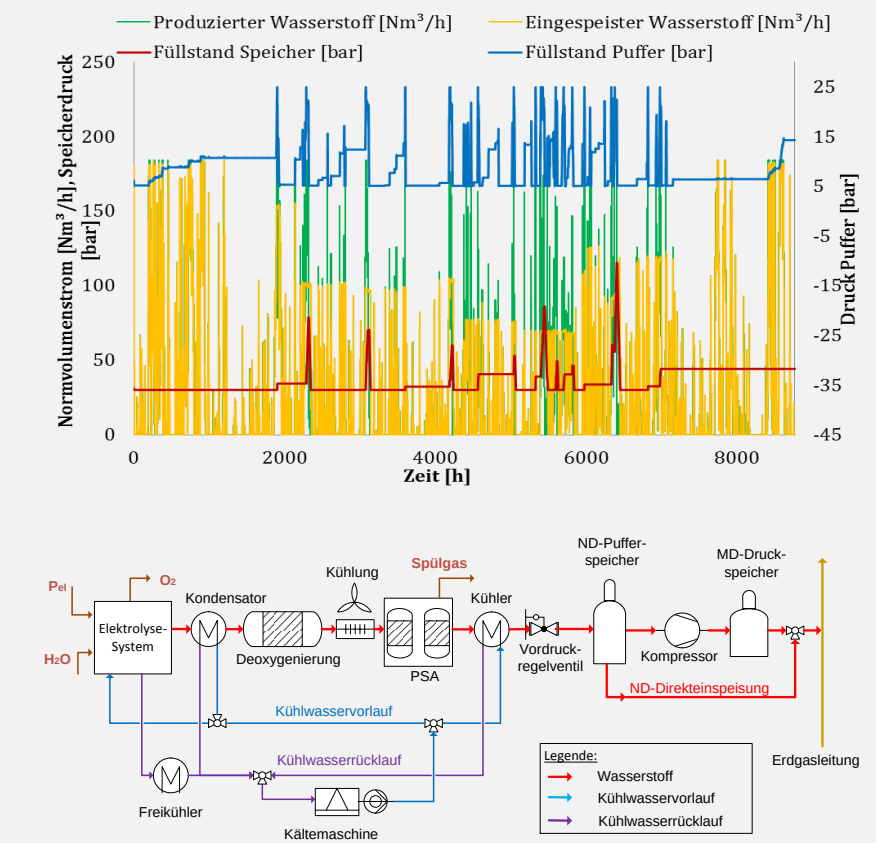
- High CO_2 reduction potential
- Methanol as versatile energy carrier
- Optimization of methanol production from H_2 and CO_2
  - Operation of mini-plants
  - Process simulations



Complete Power-to-Liquid process chain.

Power-to-Gas

- Technology consulting, evaluation and accompanying research for PtG installations
- Modeling and simulation of electrolysis and PtG plants
- Evaluation and optimisation of system concepts and strategies for operation management
- Development and assessment of business models for PtG systems



Solar Hydrogen Filling Station at Fraunhofer ISE

From Solar Energy to Sustainable Mobility

- Research platform and publicly accessible filling station
- On-site grid-connected 16 kWp PV system (expansion planned)
- On-site hydrogen production by PEM water electrolysis (0.5 kg/h, 7 kg/d)
- Fast-fill 700 bar in accordance with SAE J2601 standard and slow fill at 350 bar
- Max. 3 minutes to fill-up car tank
- Publicly accessible after briefing and receipt of fuel card

www.h2move.de

Fraunhofer ISE

Conclusion

Solar energy can provide not only electricity, but also heat for mining processes like electro-plating (copper)
-> reduction of electricity or fuel bill!

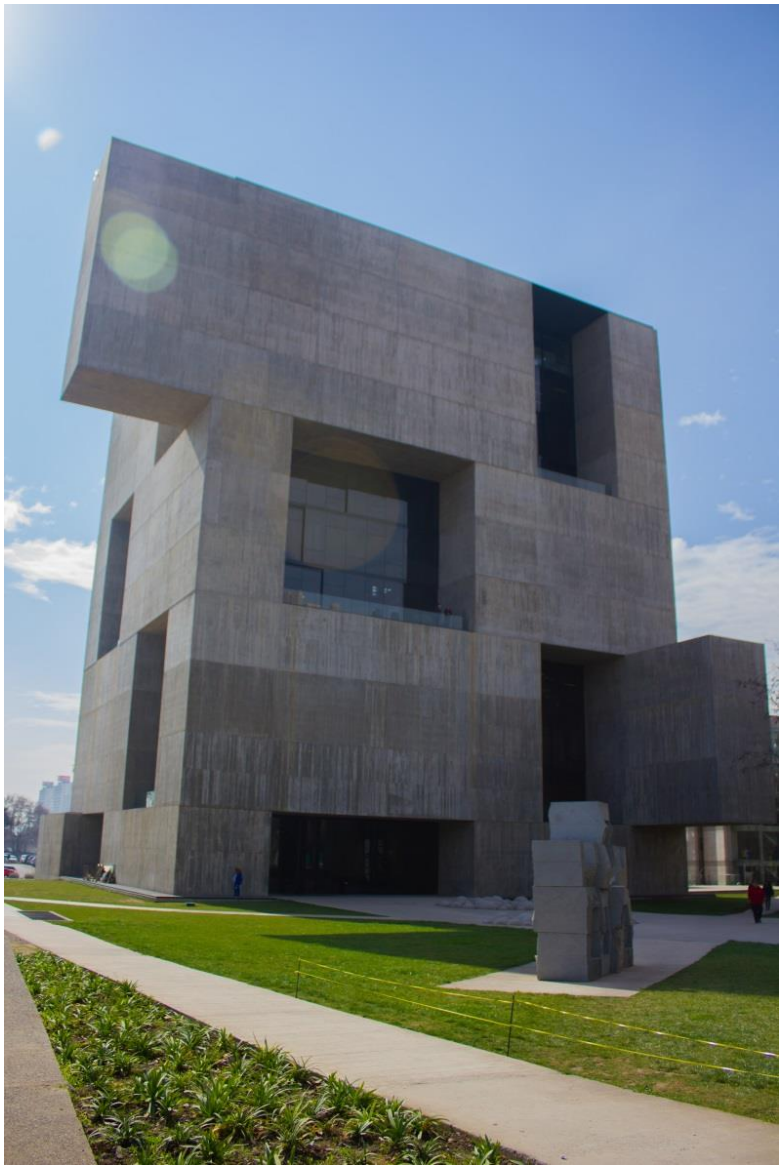
Solar thermal energy plants can provide heat for drying or water treatment as a side product to electricity generation
-> liquid waste treatment (zero liquid discharge)
-> non-metallic mining industry!

Hybridization of PV and CSP with storage allows a combination of both
-> competitive cost
-> dispatchable firm capacity

Individual case studies and advanced planning of concepts may lead to cost-optimized solutions – the potential is there!

Fraunhofer
CHILE

For a Solar Future of Chile



Contact:

Prof. Dr. Werner Platzer
werner.platzer@fraunhofer.cl

Center for Solar Energy Technology
Fraunhofer Chile Research

www.fraunhofer.cl