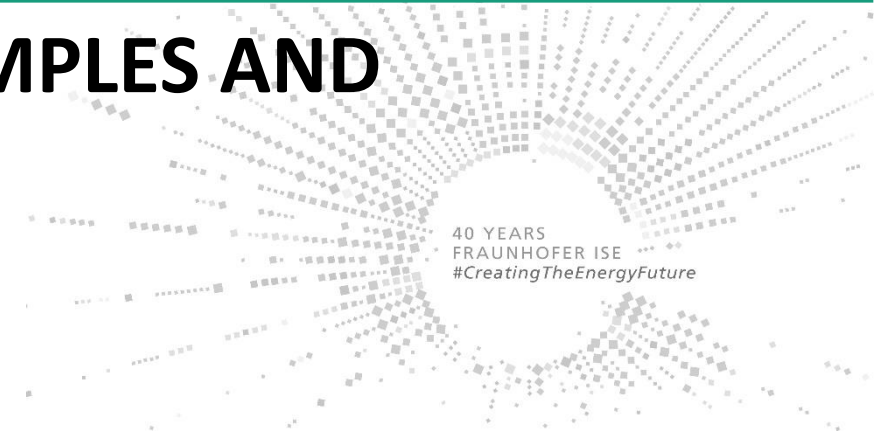


# SOLAR HEAT PRODUCTION IN CHILE: EXAMPLES AND PERSPECTIVES

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Speaker: Francisco Torres

Fraunhofer Institute for Solar Energy Systems ISE  
International Webinar, May 27, 2021

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# AGENDA

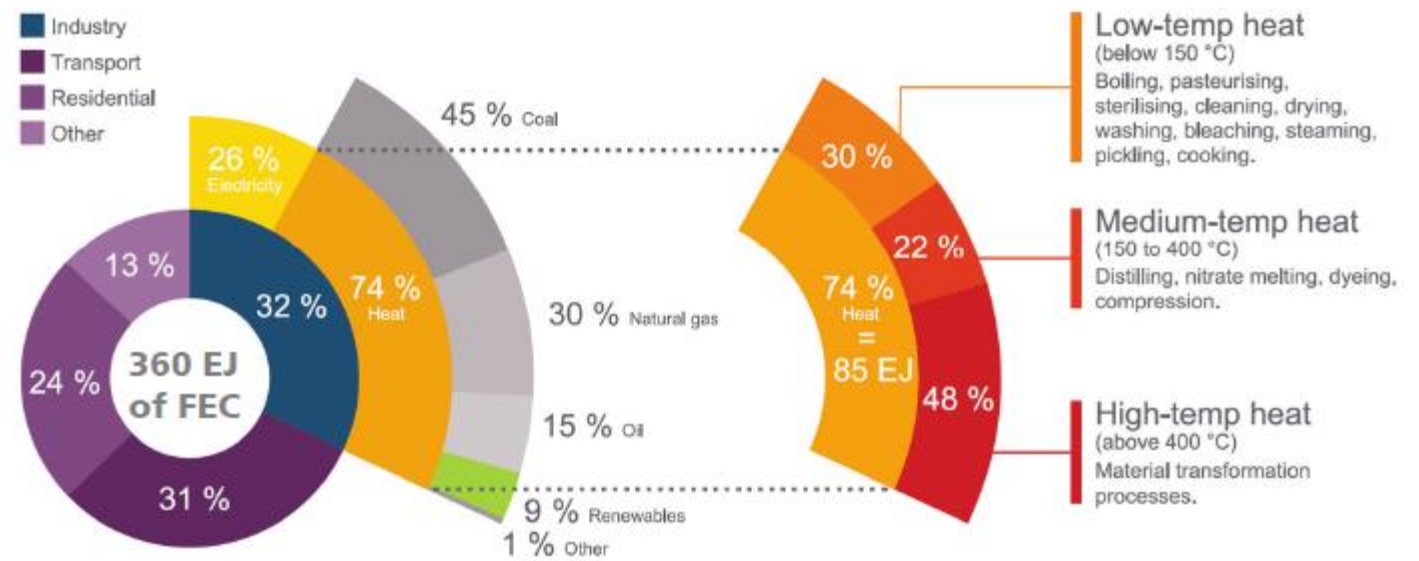
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- Energy Overview / *Panorama energético*
- Introduction SHIP / *Introducción SHIP*
- Solar Payback Tool
- Business case 1-2 / *Caso de negocio 1-2*
- Discussion and conclusion / *Discusión y conclusión*

# Energy Overview / *Panorama energético*

## Worldwide renewable share / *Porcentaje de renovables mundial*

- Industry: Accounts for the 32% of the total energy consumption / *La industria contabiliza el 32% del total de la energía consumida*
- 74% of the energy used in industry is for thermal end-uses / *74% de la energía utilizada en la industria es para fines térmicos*
- 90% of the energy consumed comes from fossil fuels / *De la energía consumida, el 90% proviene de combustibles fósiles*



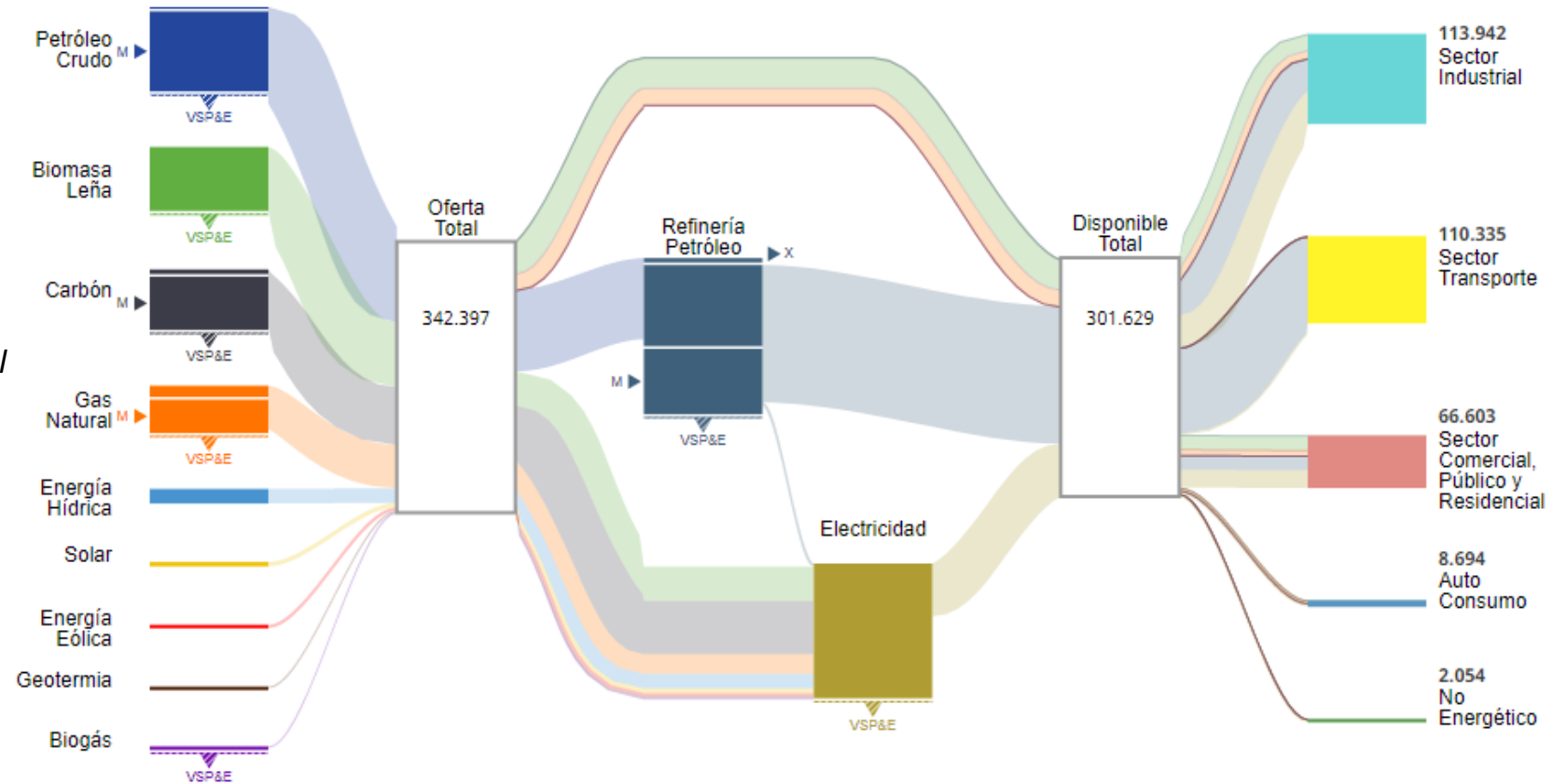
[1] International Energy Agency (IEA), World Energy Statistics 2016, online tables, [www.iea.org/statistics/](http://www.iea.org/statistics/)

[2] International Renewable Energy Agency (IRENA), calculations by Deger Saygin based on IEA source [1]

# Energy Overview / Panorama energético Chile

- 67% of energy inputs come from fossil fuels / *67% de los insumos energéticos provienen de combustibles fósiles*
- Industry consumption reaches 38% of the total energy / *La industria consume el 38% de energía total*
- 65% of the energy used in industry is for thermal end-uses / *65% de la energía utilizada en la industria es para fines térmicos*
- Large potential for SHIP! / *Gran potencial para SHIP!*

Todas las unidades están en TCal.

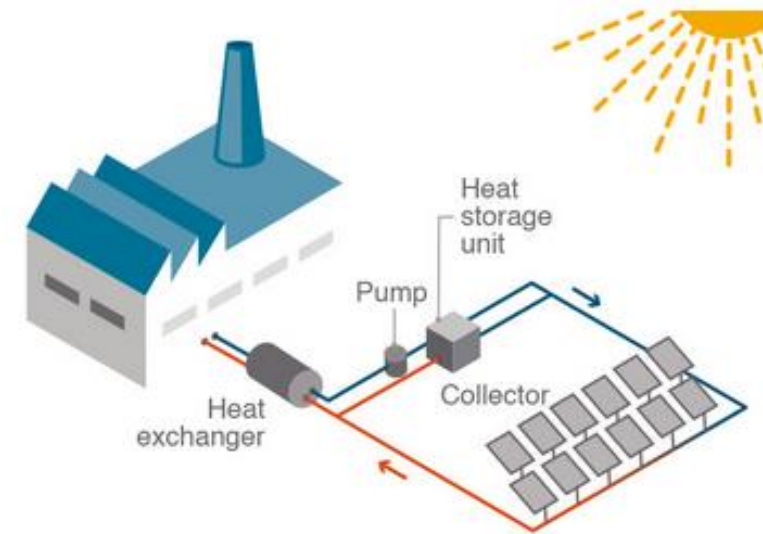


Fuente: Ministerio de Energía

# Solar Heat for Industrial Process (SHIP)

## What is it? / Qué es?

- SHIP is the acronym for **Solar Heat for Industrial Processes** and describes systems which provide solar heat in a factory / *SHIP es el acrónimo del inglés “Calor solar para procesos industriales” y describe los sistemas que proporcionan calor solar en una fábrica.*
- A collector field heats a process fluid by means of solar radiation and a heat exchanger transfers this heat to a supply system or production process in the factory as hot water, air flow or steam. Storage units make it possible to use the generated heat at night-time / *Un campo de colectores calienta un fluido de proceso por medio de la radiación solar y un intercambiador de calor transfiere este calor a un sistema de suministro o a un proceso de producción en la fábrica como agua caliente, flujo de aire o vapor. Las unidades de almacenamiento permiten utilizar el calor generado durante la noche.*



Source: Solar Heat Europe

# Solar Heat for Industrial Process (SHIP)

## Collectors / Colectores

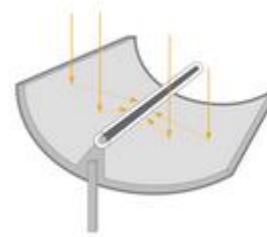
- Stationary collectors / *Colectores estacionarios* ( $C < 2$ )
- Flat plate and Evacuated Tube collectors / *Colectores planos y de tubo de vacío*:  $T < 120^\circ\text{C}$
- CPC:  $T < 100\text{-}200^\circ\text{C}$



Flat plate collector or vacuum tube collector



Vacuum tube collector with CPC



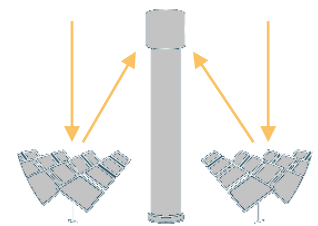
Parabolic trough collector



Linear Fresnel collector



Dish collector



Solar Tower

- Tracking collectors / *Colectores con seguimiento* ( $C > 10$ )
- Linear concentration : Parabolic trough and Linear Fresnel / *Concentración lineal: Cilindro parabólico y Fresnel*:
  - $100^\circ\text{C} < T < 250/550^\circ\text{C}$
- Point concentration: Dish and tower / *Concentración en punto: Discos y torres*:
  - $100^\circ\text{C} < T < 800^\circ\text{C}$



# Solar Payback Tool

## Online calculator



Solar Payback project: Promoting the use of SHIP / *Promover el uso de SHIP.* <https://www.solar-payback.com/>

Two forms are to be filled in / *Hay que completar dos formularios:*

### 1. Technical information / *Información técnica*

- Current consumption and cost / *Consumo y costo actual*
- Solar annual yield / *Rendimiento solar anual*
- Dimension of the solar system / *Dimensión de los componentes solar*

### 2. Financial information / *Información financiera*

- Investment / *Inversión*
- Operational cost / *Costo operacional*
- Fiscal and financial parameters / *Parámetros fiscales y financieros*

The screenshot displays the Solar Payback calculator interface, showing the 'FINANCIAL INFORMATION' section. The interface is divided into several sections:

- Location:** Country\*, City\*, Estimated solar resource (kWh) 1,69, Estimated annual Global Horizontal Radiation (kWh/m²) 214,2.
- Current heat source:** Energy source\*, Please select the energy source used in your current production of heat, Thermal conversion efficiency of the heat production, Current heat production (kW) 267,75, Coric rate target heat, In case you have a heat production, heat production costs will be a.
- System complexity:** System complexity\* refers to the final system layout and local conditions for its installation, affecting the final system costs. Use of additional heat exchangers, long piping distances, need of support structure or civil works are examples of questions adding complexity to the installation process. Components cost coefficient for solar 0,8, Total investment costs 2779106,15, Total specific investment costs 1973,81.
- Current heat load:** Daily profile\*, Thermal load evenly distributed night - from 20:00 - 08:00, Estimated annual energy demand (kWh) 150, Please identify the annual energy demand (e.g. fuel consumption), Estimated annual heat energy demand (kWh) 1870,61, Estimated annual heat energy demand considering the efficiency.
- Solar thermal:** Average collector efficiency, Investment lifetime\*, Investment lifetime depends on both the quality of the system components and on the local conditions for its operation. Project lifetime ranges usually from 10 to 20 years. General inflation rate [%] 2,9, Inflation rate for assets in the country along the project lifetime. This value affects operational costs. The user might use a value different from the default value by overwriting it. Energy inflation rate [%] 10,6, Inflation rate affecting conventional energy sources costs along the project lifetime. This value affects energy yield value. The user might use a value different from the default value by overwriting it.
- Operational cost parameters along investment lifetime:** Annual O&M costs\* 1, Unit\*, Total annual O&M costs 27791,06, Residual value\* 0, Unit\*.

Source: <https://www.solar-payback.com/calculator/>

# Online calculator

## Results / Resultados

Results are provided in tables / *Los resultados son entregados en tablas:*

- Technical summary / *Resumen técnico*
- Financial summary / *Resumen financiero*
- Investment Assessment results / *Resumen de evaluación de la inversión*
  - NPV / *VPN*
  - LCOH
  - IRR / *TIR*
  - Payback time / *Periodo de retorno de la inversión*
  - ...

The screenshot shows the 'SUMMARY' tab of an online calculator. The interface includes a navigation bar with icons for 'TECHNICAL INFORMATION', 'FINANCIAL INFORMATION', 'SUMMARY', 'RESULTS', 'IMPRINT', and 'DATA PROTECTION'. A 'CALCULATE INVESTMENT' button is visible. The main content area displays the 'Investment Assessment results' table, which is partially obscured by a 'Key data on investment' table.

Parameter	Value	Unit
Estimated annual final energy consumption	1870.61	MWh/year
Solar collector type	Linear Fresnel	
Average collector operation temperature	150	°C
Estimated solar fraction	35	%
Total investment costs	2779106.15	BRL
Non-refundable investment subsidy	0	BRL
Debt	53.22271316926598	BRL
Equity	28.97145697434954	BRL
Effective Cost of Capital (COC)	16.58	%
General inflation rate	2.9	%
Energy inflation rate	10.6	%
Corporate Tax Rate	34	%

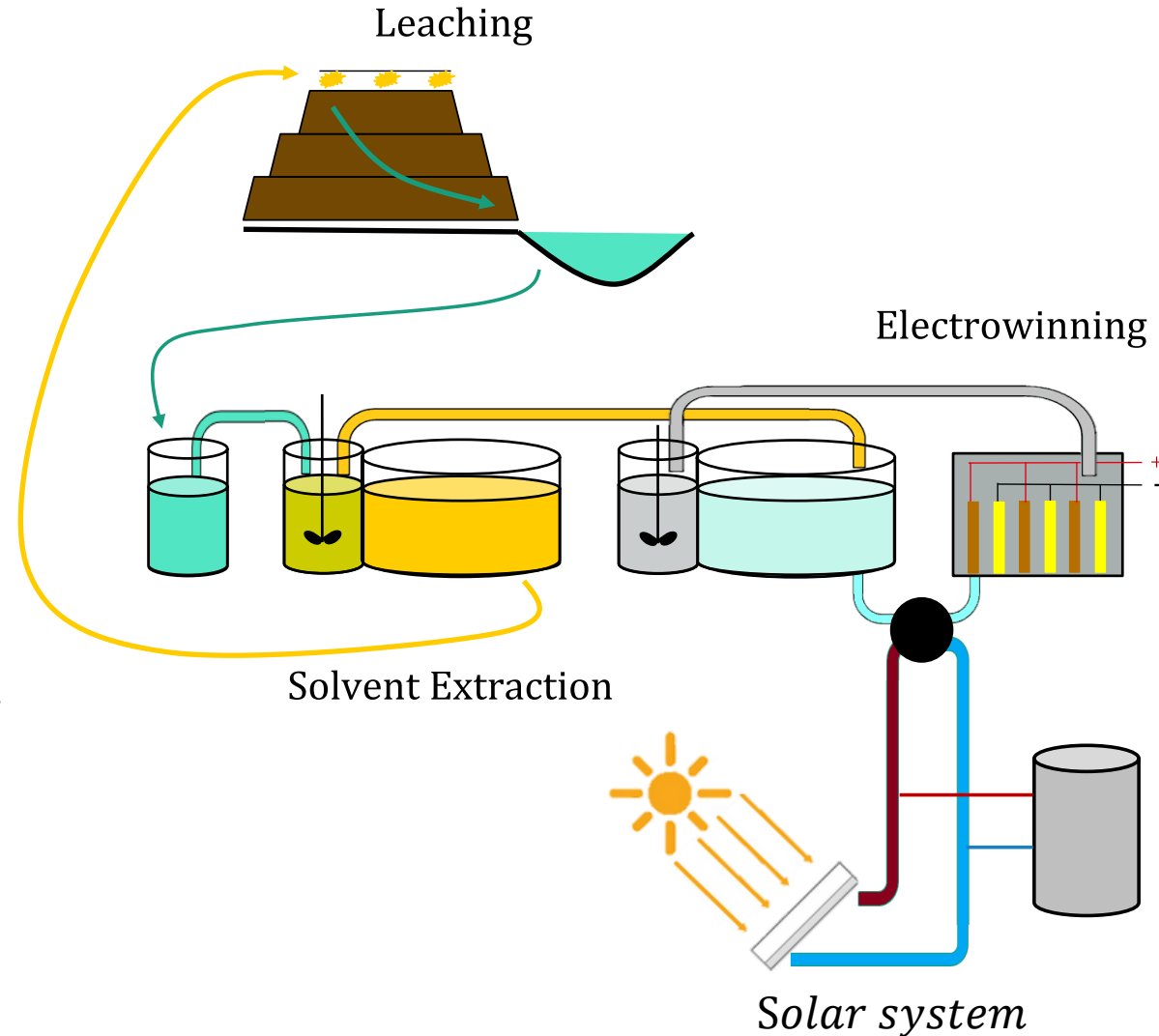
Source: <https://www.solar-payback.com/calculator/>



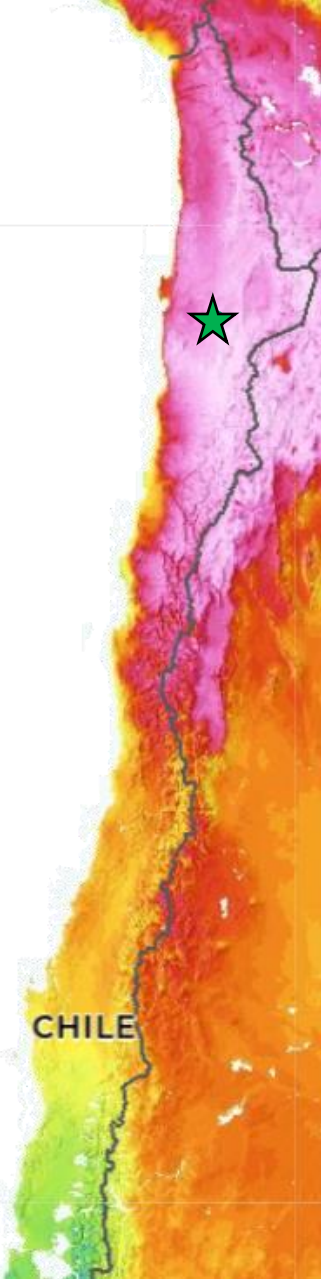
# Business case 1 / Caso de negocio 1

## Process / Proceso

- Leaching copper plant / *Planta de lixiviación de cobre*
- Antofagasta region / *Región de Antofagasta*
- Heat production for electrowinning / *Generación de calor para proceso de electro obtención*
- Low temperature / *Temperaturas bajas:  $T < 100^{\circ}\text{C}$*
- Addition of solar energy to cover part of the energy demand / *Incorporación de energía solar para cubrir parte de la demanda energética*



Source: Fraunhofer ISE



# Business case 1 / Caso de negocio 1

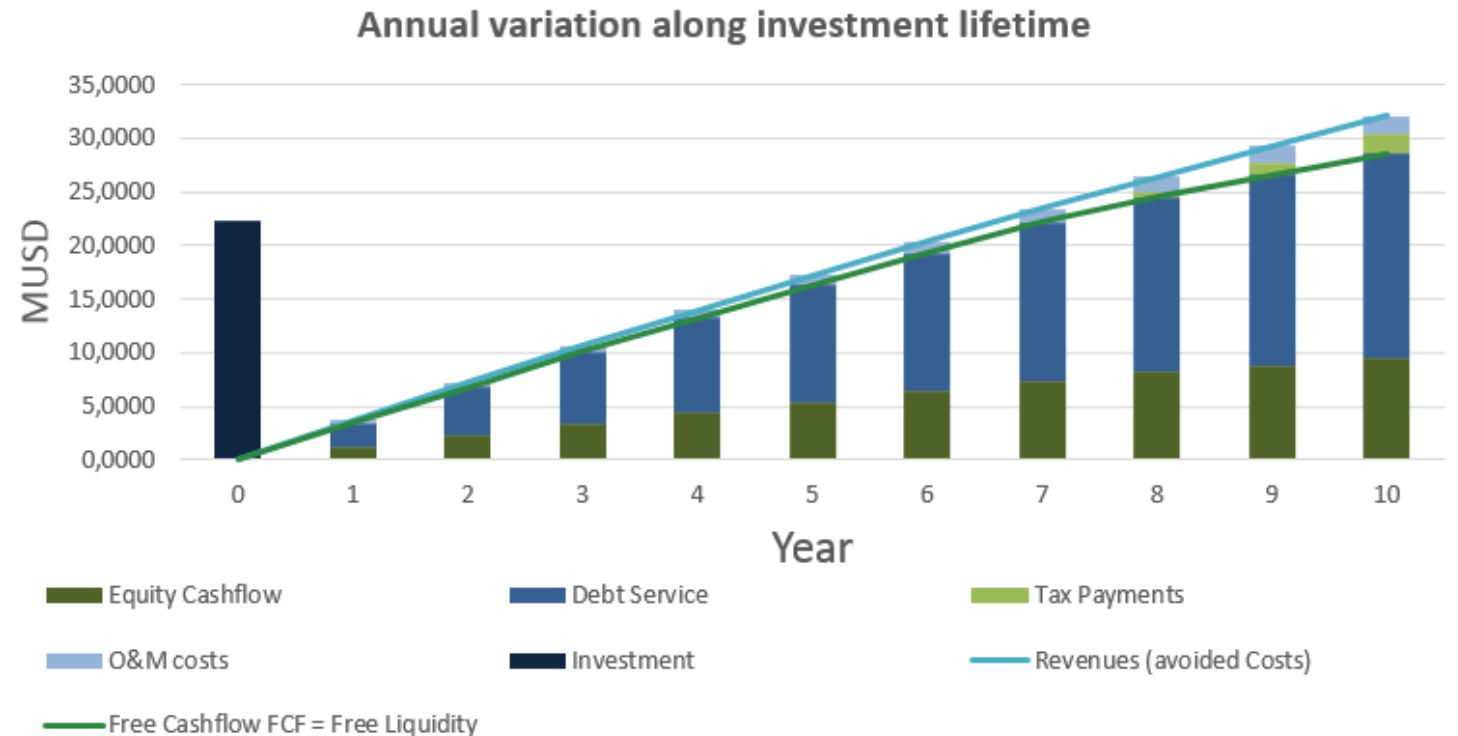
## Assumptions / Supuestos

Item	Value / Valor
Fuel Cost / Costo combustible	53,5 USD/MWh
<b>Solar Resource / Recurso solar</b>	<b>2,6 MWh/m2 Year</b>
Annual energy consumption / Energía consumida anual	62.400 MWth/Year
Heat load / Carga de calor	7 days/Week continuos
<b>Annual solar yield / Rendimiento solar anual</b>	<b>55.000 MWth/Year</b>
<b>Collector type / Tipo de colector</b>	<b>Flat plate</b>
Specific thermal storage volume / Almacenamiento térmico específico	100 lt/m2 collector
<b>Aperture / Apertura</b>	<b>40.000 m2</b>
<b>Investment / Inversión - CAPEX</b>	<b>22,4 MUSD</b>
Investment life time / Tiempo de inversión	10 Years
Inflation rate / Tasa de inflación	2,9%
Energy inflation rate / Tasa de inflación de la energía	5,5%
Discount rate / Tasa de descuento	8%
O&M	1% of the CAPEX a year
Corporate tax rate / Tasa de impuesto corporativo	27%
Avoided emissions revenue / Ingresos por emisiones evitadas	5 USD/TonCO2.Eq

# Business case 1 / Caso de negocio 1

## Results / Resultados

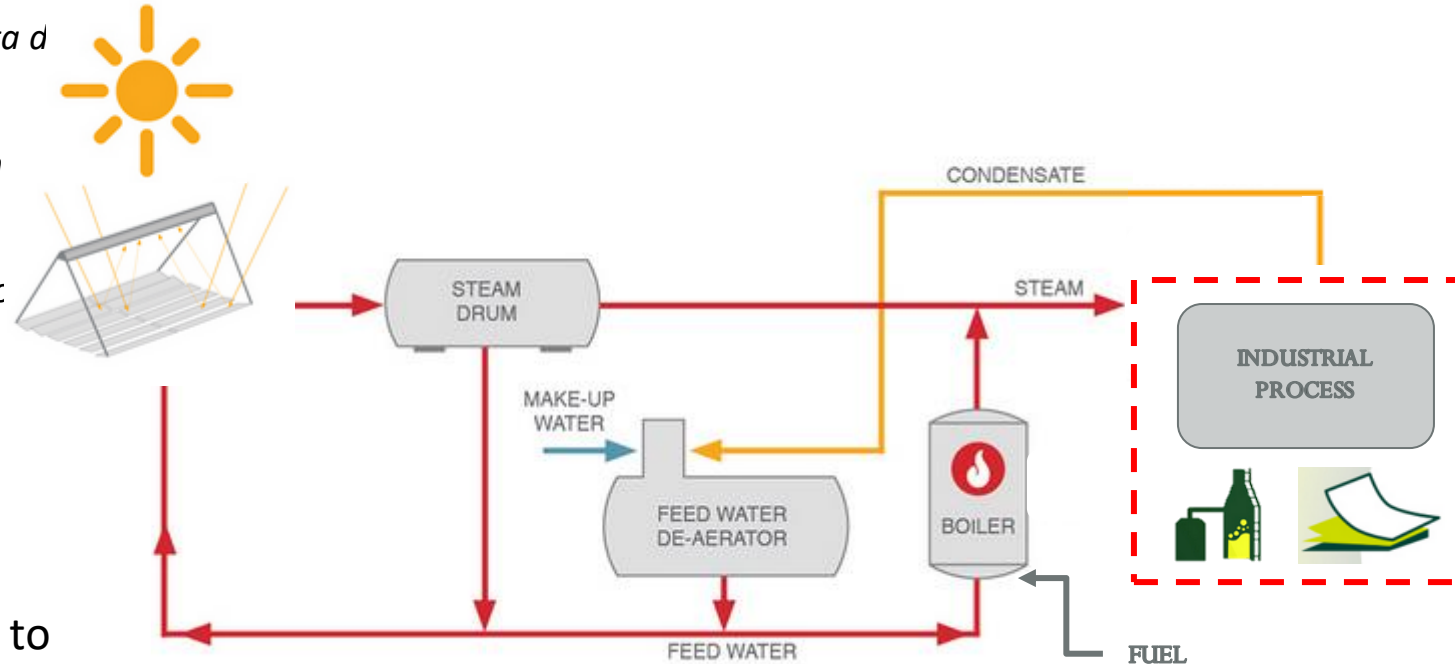
Item	Value / Valor
NPV / VPN	6.2 MUSD
IRR / TIR	14.4%
Discounted Payback/ <i>Periodo de retorno de la inversión</i>	6 Years
Current LCOH / LCOH Actual	90 USD/MWhth
Solar LCOH	72,7 USD/MWhth
Total avoided emissions / <i>Total emisiones evitadas</i>	17.500 Ton CO2eq/Year



# Business case 2 / Caso de negocio 2

## Process / Proceso

- Paper production plant / *Planta de producción de papel*
- Metropolitana Region / *Región Metropolitana*
- Heat production for / *Generación de calor para:*
  - Drying / *Secado*
  - Water process / *Agua de procesos*
- Incorporation of solar energy to cover part of the energy demand / *Incorporación de energía solar para cubrir parte de la demanda energética*



Source: Fraunhofer ISE

# Business case 2 / Caso de negocio 2

## Assumptions / Supuestos

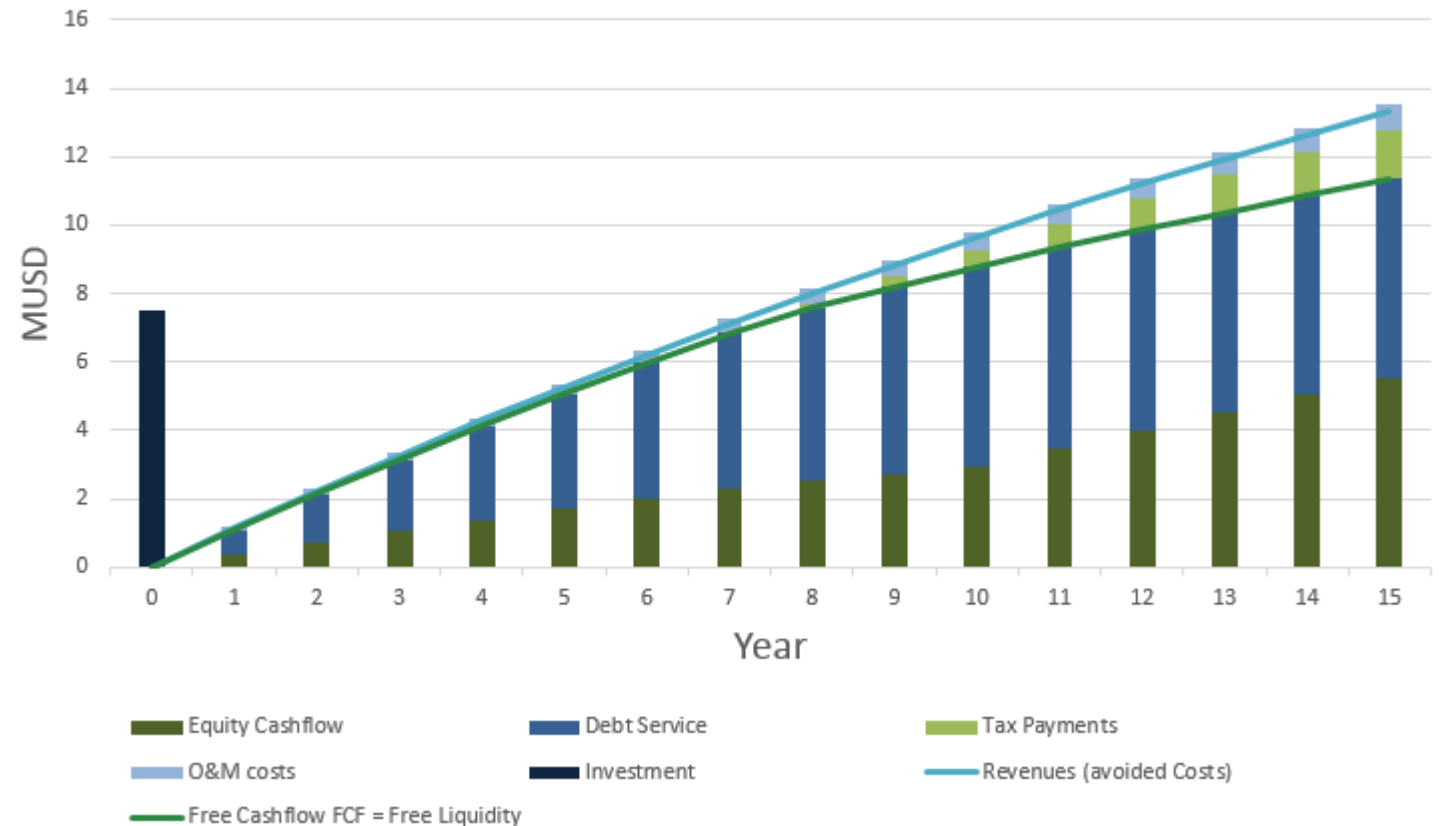
Item	Value / Valor
Fuel Cost / Costo combustible	50 USD/MWh
<b>Solar Resource / Recurso solar</b>	<b>1,75 MWh/m2 Year</b>
Anual energy consumption / Energía consumida anual	35.000 MWth/Year
Heat load / Carga de calor	7 days/Week continuos
<b>Anual solar yield / Rendimiento solar anual</b>	<b>16.500 MWth/Year</b>
<b>Collector type / Tipo de colector</b>	<b>Linear Fresnel</b>
Specific thermal storage volume / Almacenamiento térmico específico	100 lt/m2 collector
<b>Aperture / Apertura</b>	<b>20.000 m2</b>
<b>Investment / Inversion - CAPEX</b>	<b>7,5 MUSD</b>
Investment life time / Tiempo de inversión	15 Years
Inflation rate / Tasa de inflación	2,9%
Energy inflation rate / Tasa de inflación de la energía	5,5%
Discount rate / Tasa de descuento	8%
O&M	1% of the CAPEX a year
Corporate tax rate / Tasa de impuesto corporativo	27%
Avoided emissions revenue / Ingresos por emisiones evitadas	5 USD/TonCO2.Eq

# Business case 2 / Caso de negocio 2

## Results / Resultados

Item	Value / Valor
NPV / VPN	3.9 MUSD
IRR / TIR	17.0%
Discounted Payback/ <i>Periodo de retorno de la inversión</i>	6.75 Years
Current LCOH / LCOH Actual	103 USD/MWhth
Solar LCOH	75 USD/MWhth
Total avoided emissions / <i>Total emisiones evitadas</i>	5.167 Ton CO2eq/Year

Annual variations along investment lifetime



# Discussion / *Discusión*

## Benefits / *Beneficios*

- Benefits / *Beneficios*
  - Medium/long-term economic benefits/ *Económicos al mediano/largo plazo*
  - Energy Independence → Cost stability / *Independencia energética → Estabilización de costos*
- Long contracts... at least 10 years / *Contratos largos... Al menos de 10 años*
- Solutions? / *Soluciones?*



# Discussion / *Discusión*

## Results - credits / *Resultados - créditos*

- Chile's government promotes campaigns to foster renewable energy in Chile / *El gobierno de Chile impulsa campañas para el fomento de las energías renovables en Chile*
- CORFO delivers green credits to promote investment / CORFO entrega créditos verde para fomentar la inversión
- Refinancing up to 15 years term / Refinanciamiento hasta 15 años plazo
- 70% of the total amount with a maximum of 20 MMUSD / *70% del total del monto con tope de 20 MMUSD*
  
- [https://www.corfo.cl/sites/cpp/convocatorias/credito\\_verde](https://www.corfo.cl/sites/cpp/convocatorias/credito_verde)

## Discussion / *Discusión*

### Results – Carbon tax / *Resultados – Impuestos de carbono*

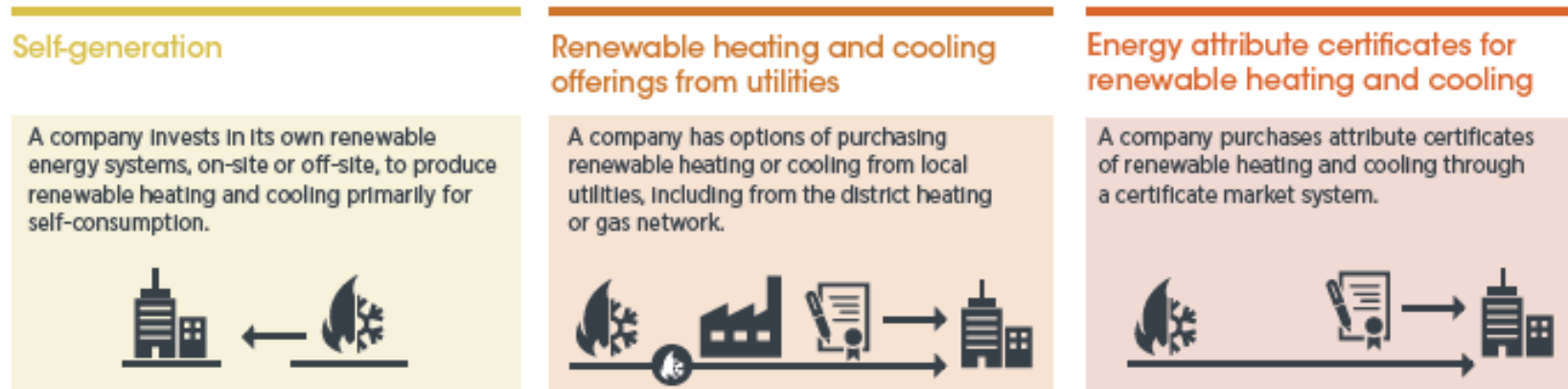
- Carbon taxing is a measure that can contribute to reduce the payback time / *El impuesto de carbono puede reducir el tiempo de retorno de la inversión*
- Example business case 2 / *Ejemplo caso de negocio 2*

Tax / Impuesto	Value / Valor USD/TonCO2.Eq	Payback time – Years Periodo de retorno - Años
Actual Chile	5	6,7
EUA	25	6
Paris Agreement (2030)	75	4,7

## Business case 2 / *Caso de negocio 2*

### New business models / *Nuevos modelos de negocio*

- New business models
  - Self-Generation / *Generación propia*
  - From Utilities / *De servicios*
  - Certificates / *Certificados*



Source: IRENA (2021)

# Conclusions / Conclusiones

- Both globally and in Chile, most of the energy used in industrial processes comes from fossil fuels / *Tanto a nivel global como en Chile, al energía utilizada en procesos industriales proviene en su mayoría de combustibles fosiles*
- The incorporation of renewable energies allows energy independence and price stabilization / *La incorporación de energías renovables permite independencia energética y estabilización de precios*
- In Chile, although the incorporation of renewable energies in industrial processes is profitable, the payback time is high, i.e., high risk / *En Chile, si bien la incorporacion de energías renovables en procesos industriales es rentable, el retorno temporal de la inversion es alto, i.e, alto riesgo.*
- To reduce the payback time, green credits, development of new business models and/or development of energy policies are needed / *Para reducir el retorno temporal de la inversion, se puede recurrir a créditos verdes, desarrollo de nuevos modelos de negocio y/o desarrollo de politicas energéticas*

# Thank You for Your Attention!

Francisco Torres Sartori

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