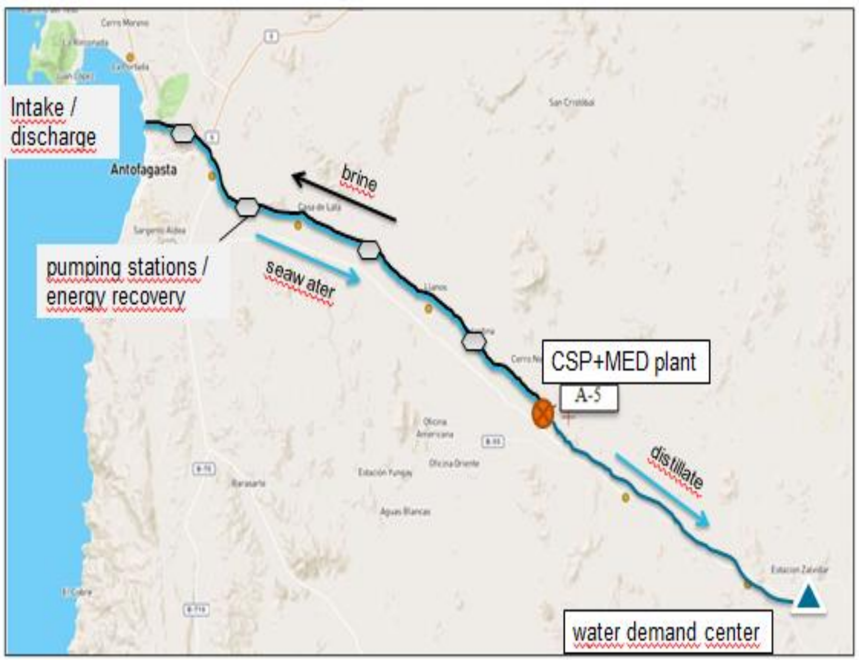
COMBINING CONCENTRATING SOLAR POWER WITH MULTIPLE EFFECT DISTILLATION AT INLAND LOCATIONS

- An economically viable option for Northern Chile?



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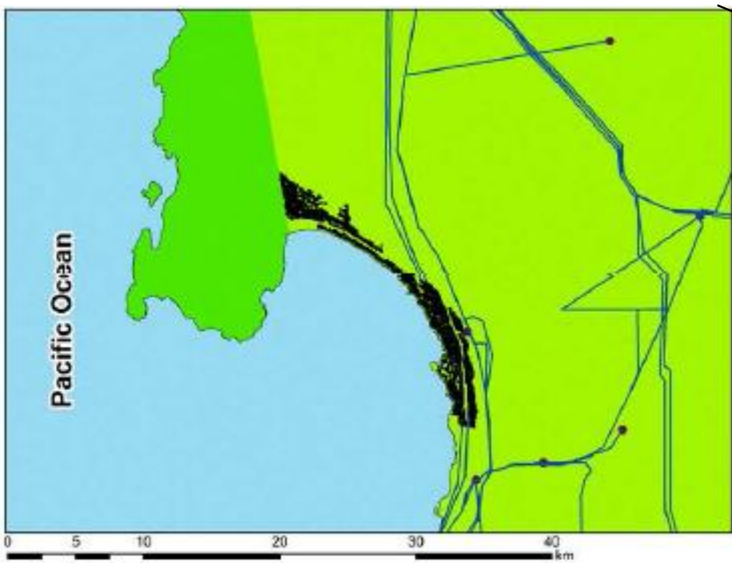
OUTLINE

- Motivation
- Concept and methodology
- Results
- Conclusions and Outlook

Motivation

Previous assumption: CSP+MED plants need to be located at coast

- solar resource not favorable
- high projected cost for power and water
- problem of land availability



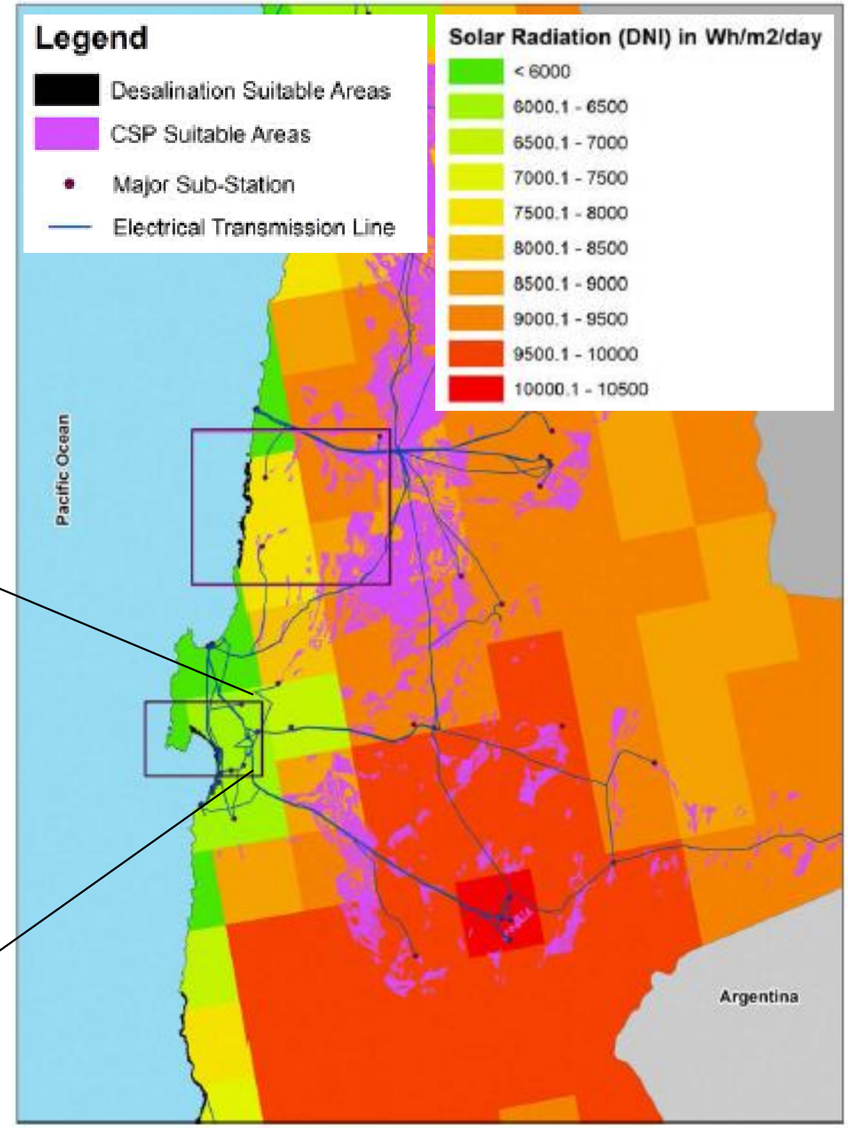


image: [Fluri et al. 2011]

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Motivation: Chilean Conditions

Image: KGHM

Several existing long distance seawater / desal water pipelines supplying Chilean mines

e.g. 145km seawater pipeline supplying Esperanza copper mine (Sierra Gorda)

Very high DNI inlands

Concept: Piping concept to selected CSP+MED plant locations along a path

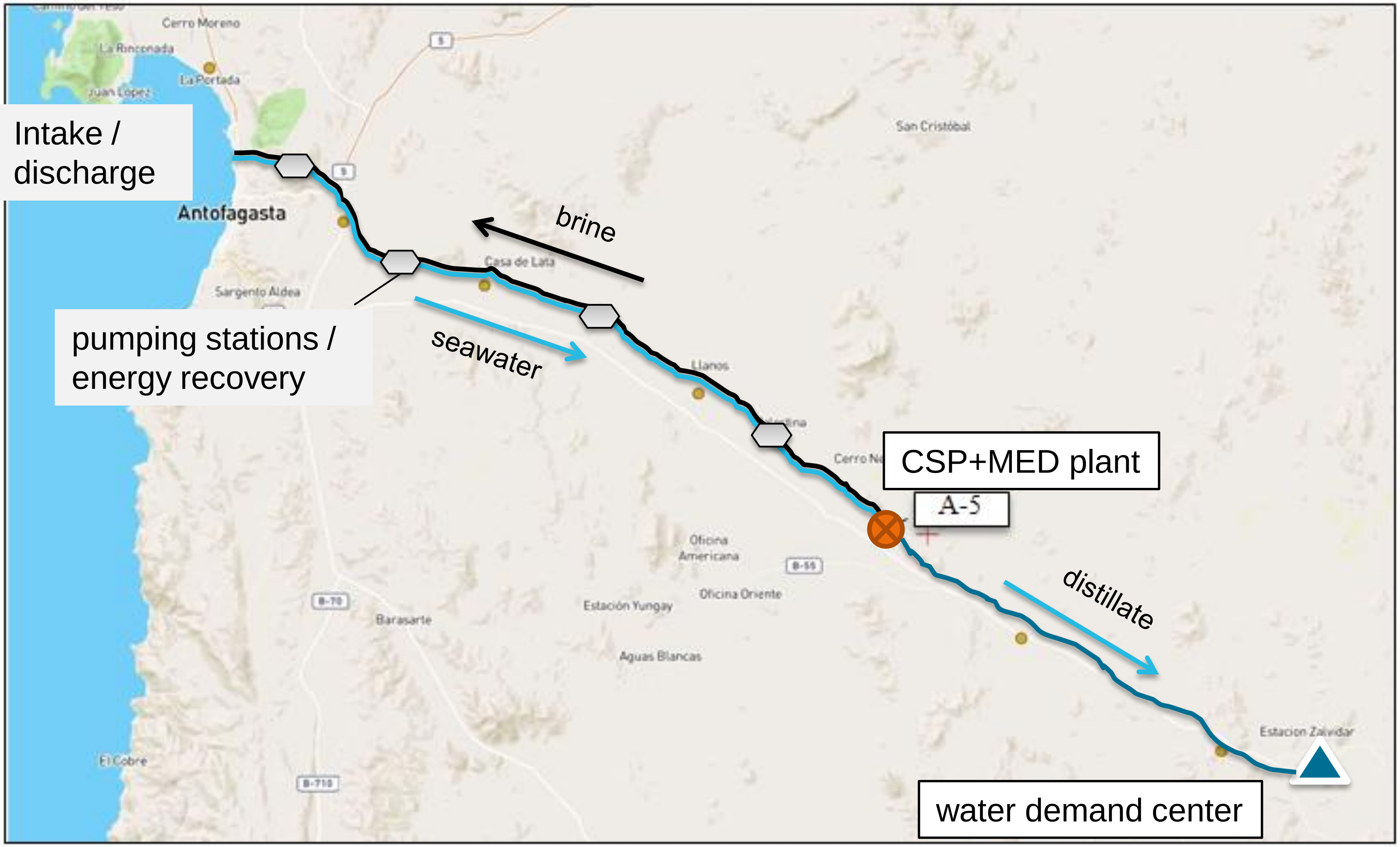

image: [openstreetmap 2017]

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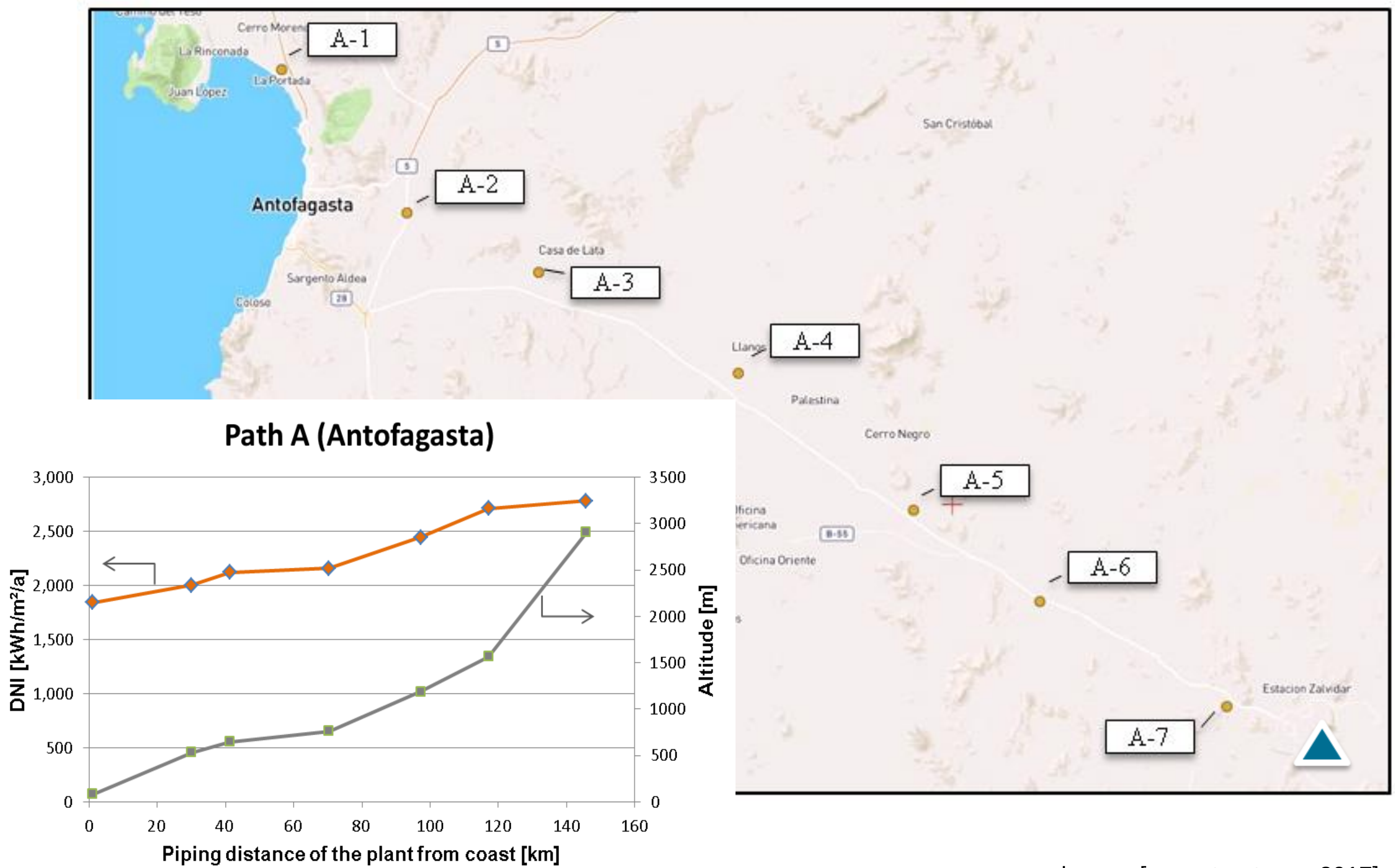
Selected locations on Path Antofagasta



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Selected locations on Path Copiapó

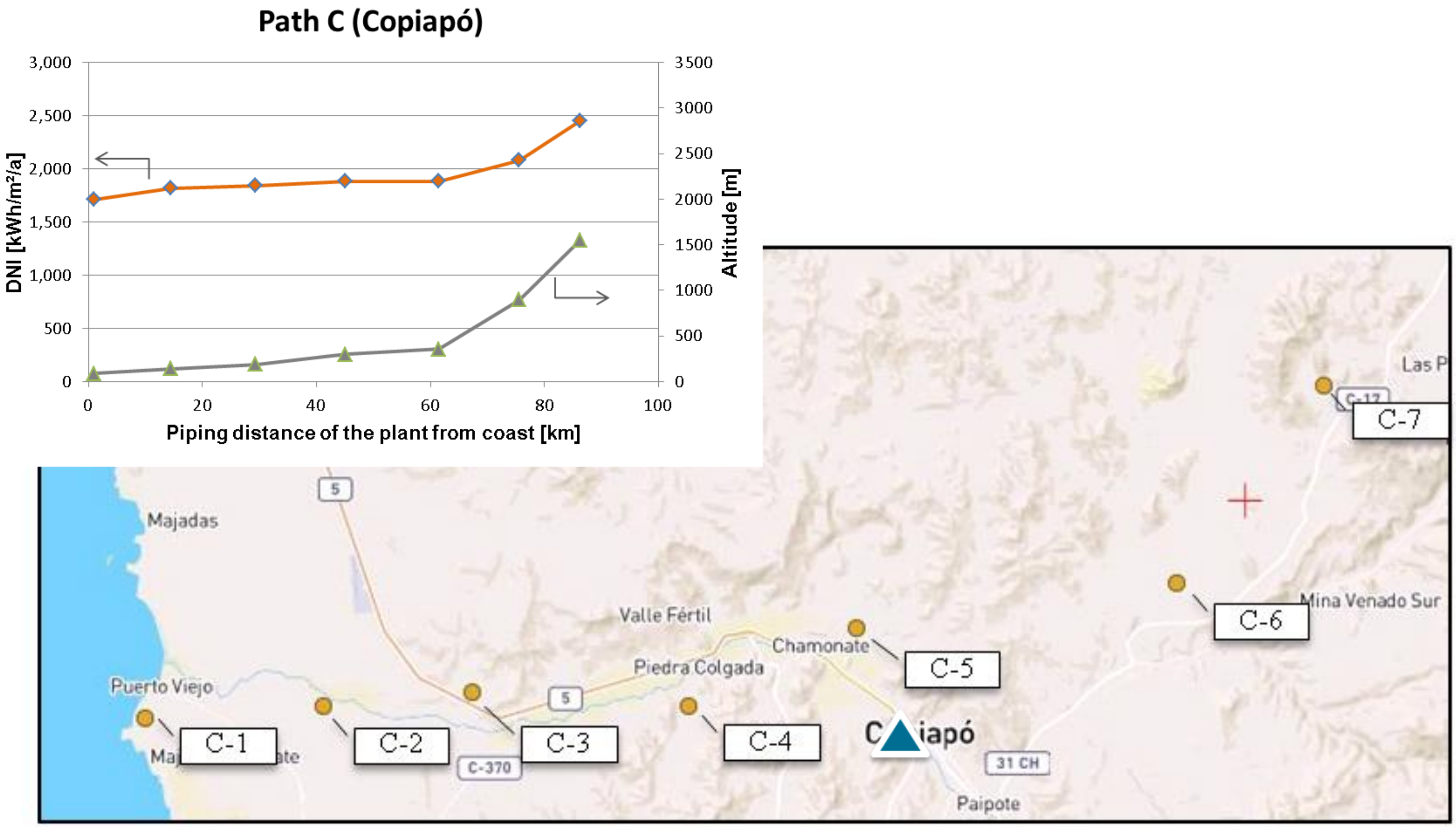

image: [openstreetmap 2017]

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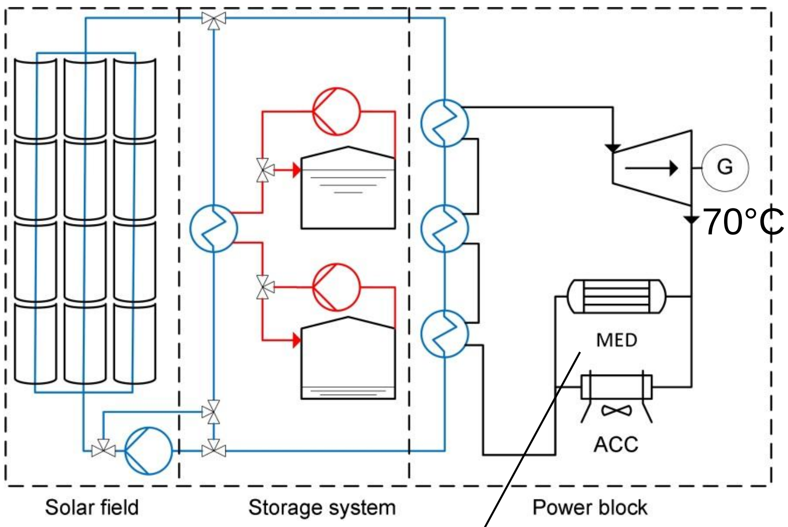
CSP+MED plant specs

Basic parameters of the CSP plant design.	
Turbine Capacity (Net)	**50.0 MW_{el}**
Storage Capacity Thermal Storage	**9.0 full load hours**
Storage Integration	2-tank indirect
Storage Medium	Solar Salt
Solar Field HTF	Therminol VP1
Solar-Field Temp. Difference	100 K
Solar Field Collector Model	SKAL-ET 150
Number of SCAs per Loop	4
Number of Loops	Optimized to lowest LCOE

Basic parameters of the MED unit.	
Capacity (Distillate volume flow)	**46,000 m³/d**
Number of stages	**10**
Yield rate	0.41
Gained Output Ratio GOR	8.08
Min / max allowed thermal load	40% … 110%
Specific thermal energy demand	81.8 kWh/m³
Specific electric energy demand	2.0 kWh/m³

Basic parameters of the pumping system	
Distillate volume flow	**46,000 m³/d**
Seawater volume flow	**112,000 m³/d**
Brine volume flow	**66,000 m³/d**
Pumping system efficiency	86%
Recovery turbine efficiency	89%

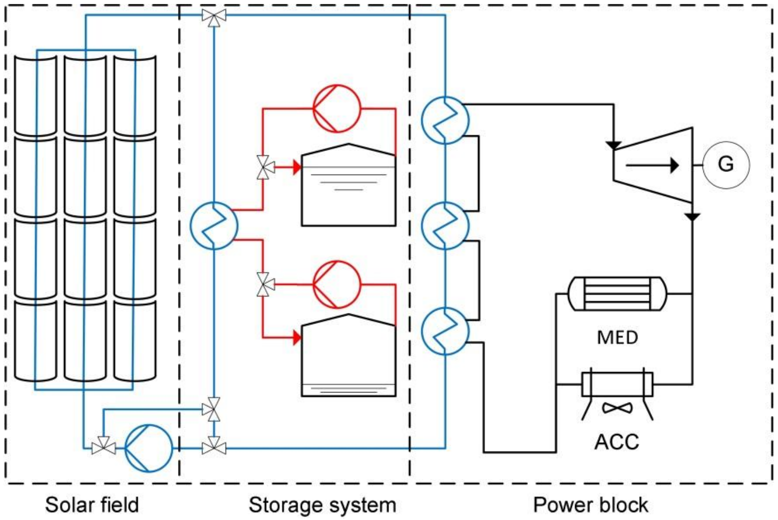
Thermal Oil Parabolic Trough Plant



ACC & MED designed for full cooling capacity

CSP+MED cost assumptions

Economic parameters of the PTC CSP plant (SAM cost model)	
Plant live time (CSP+MED)	25 years
Rate of interest	7%
Site Improvements	30 $/m²
Solar Field	170 $/m²
HTF System	70 $/m²
Storage	75 $/kWhth
Power Block	1150 $/kWe
Balance of Plant	120 $/kWe



Economic parameters of the MED unit and pumping system.	
Plant live time (CSP+MED)	25 years
Rate of interest	7%
Specific capital costs for MED Plant	1,253 US$/(m³*d)
Specific capital cost for water pipeline (by distance)	0.010 US$/(m³*100km)
Specific capital cost for pumping stations (by vertical lift)	0.052 US$/(m³*100m)

Sources: [Kurup2015], [Voutchkov2013], [Zhou2005]

methodology

- Aim: Proof of concept
- Generic plant locations along path (checked for slope and available area)
- CSP plant: 50MW thermal oil PTC with 2-tank molten salt storage
- Same CSP+MED plant design at all locations
  - fix MED size (at full condenser thermal load ~ 46,000 m^3/d distillate)
  - But: number of loops optimized to lowest LCOE
- CSP plant operation to provide continious operation
- Assumed that MED is therm. insulated to avoid cooling down up to 4h
- Annual CSP+MED plant simulations in ColSim CSP (Fraunhofer in-house software)
- For comparability along paths: meteonorm TMY3 data sets

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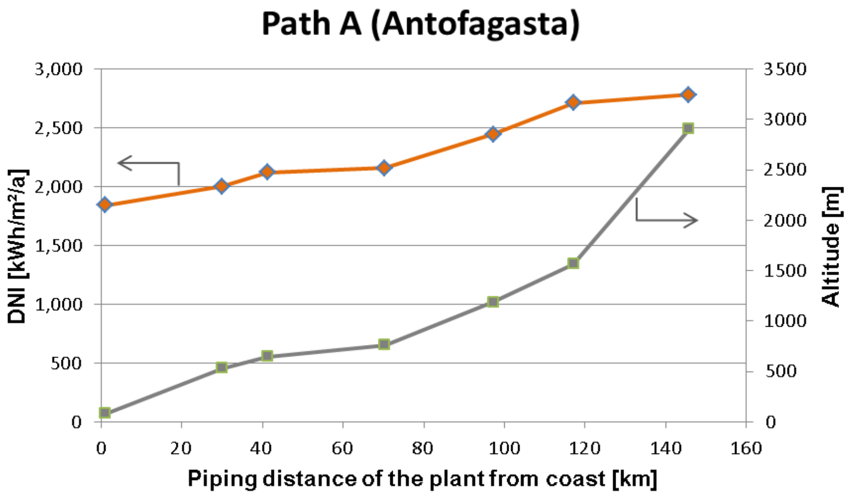
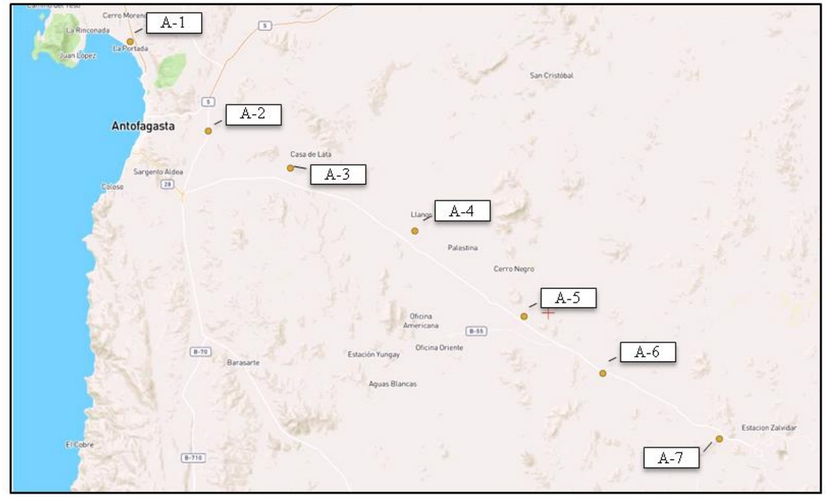
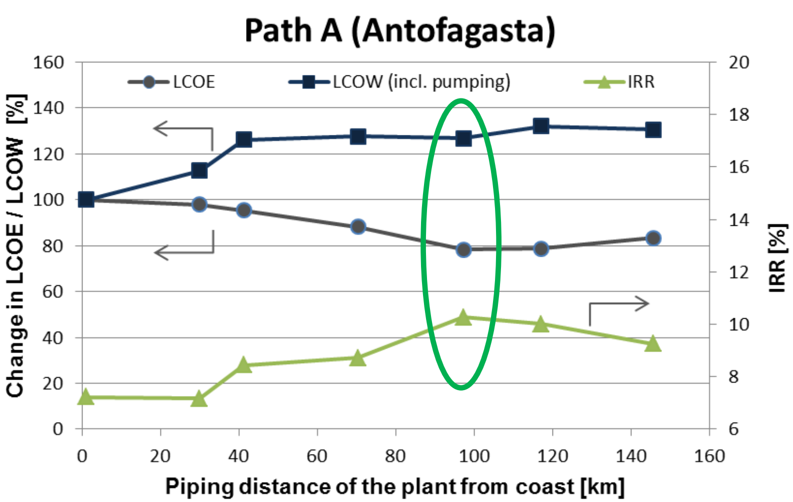
Results







- Solar resource and altitude of the plant define the best location of CSP+D cogeneration plants
- high annual DNI sum ~2,600kWh/(m²a) results in plants located 90 km away from the coast

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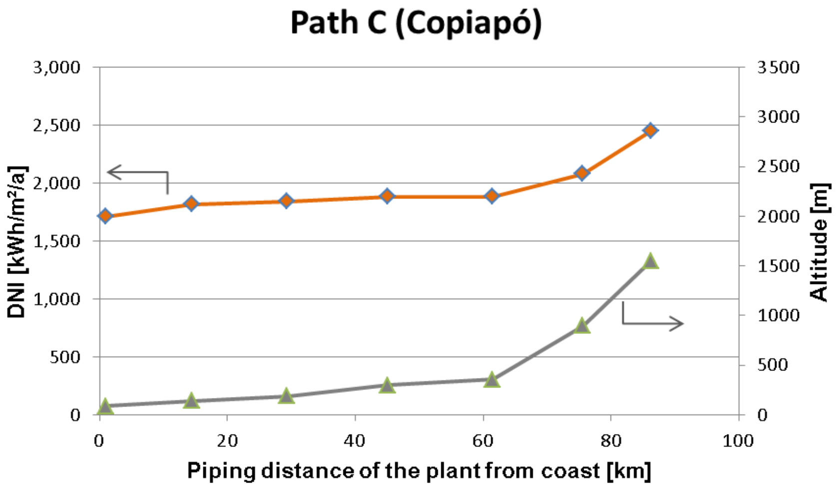
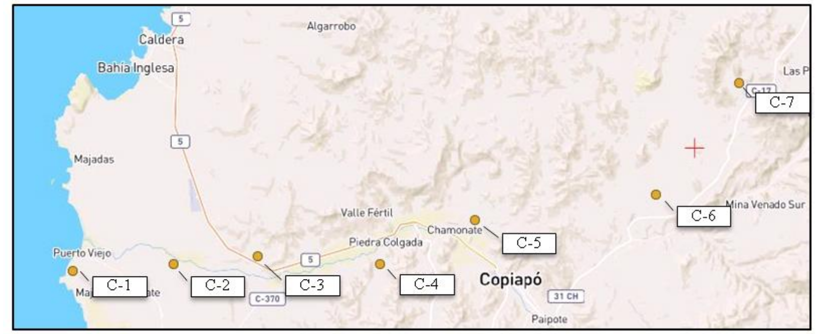
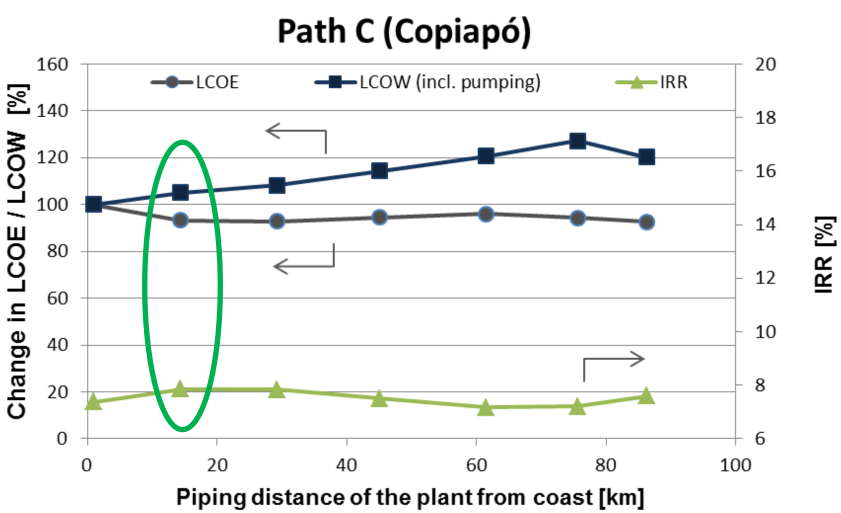
Results







- Solar resource and altitude of the plant define the best location of CSP+D cogeneration plants
- Even moderate DNI sums ~2,000 kWh/(m²a) justify a location ~20km inlands

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Conclusions

- Study used conservative assumtions:
  - Measured DNI probably higher than used meteonorm generic data
  - „small“ PTC CSP plant with maximum possible MED
  - CSP+MED layout was fixed, not optimized for each location
  - Publicly available cost data of 2015
- **Even with conservative assumptions inland desalination by means of CSP+MED seems feasable**
- LCOW (incl. pumping) < 1.70US$/m³ could compensate LCOE above market price

Outlook

- Further study:
  - larger (~100MW) CSP tower + MED
  - Case study: Match CSP/MED size with specific electricity & water demand (e.g. mine / settlement / agriculture)
  - Case studies for other locations with very good inland DNI: South Africa, Saudi Arabia etc.
- Improve plant concept:
  - Add medium temperature thermal storage for balanced MED operation
  - Run MED from thermal storage → keep PB efficiency
- Combine CSP+MED concept with seawater pumped storage

References

[Fluri2011]	Fluri, T. P.; Cuevas, F.; Pidaparthi, P. & Platzer, W. J.: “Assessment Of The Potential For Concentrating Solar Power In Northern Chile”. Proceedings of the 17th SolarPACES Conference, 20. - 23. September 2011, Granada, Spain, 2011
[Kurup2015]	P. Kurup and C. S. Turchi, “Parabolic Trough Collector Cost Update for the System Advisor Model (SAM),” National Renewable Energy Laboratory NREL, (2015).
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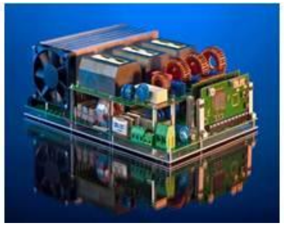
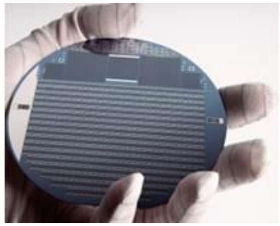
[Zhou2005]	Y. Zhou and R. S. Tol, “Evaluating the costs of desalination and water transport,” Water Resources Research, 14, (2005).

Thank you for your attention!

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