

Salt Partners

Environmental balance of salt
production speaks in favour of
solar saltworks

Vladimir M. Sedivy MSc (Hons) Chem Eng, IMD

President

Salt Partners Ltd, Zurich, Switzerland

Salt Partners

Salt production world-wide

Salt type	World production
Solar salt	80,000,000 t/y
Rock salt	60,000,000 t/y
Brines	70,000,000 t/y
Total	210,000,000 t/y

Salt Partners

Salt consumption world-wide

Salt user	Salt consumption
Chemical industry	130,000,000 t/y
Food	60,000,000 t/y
Other	20,000,000 t/y

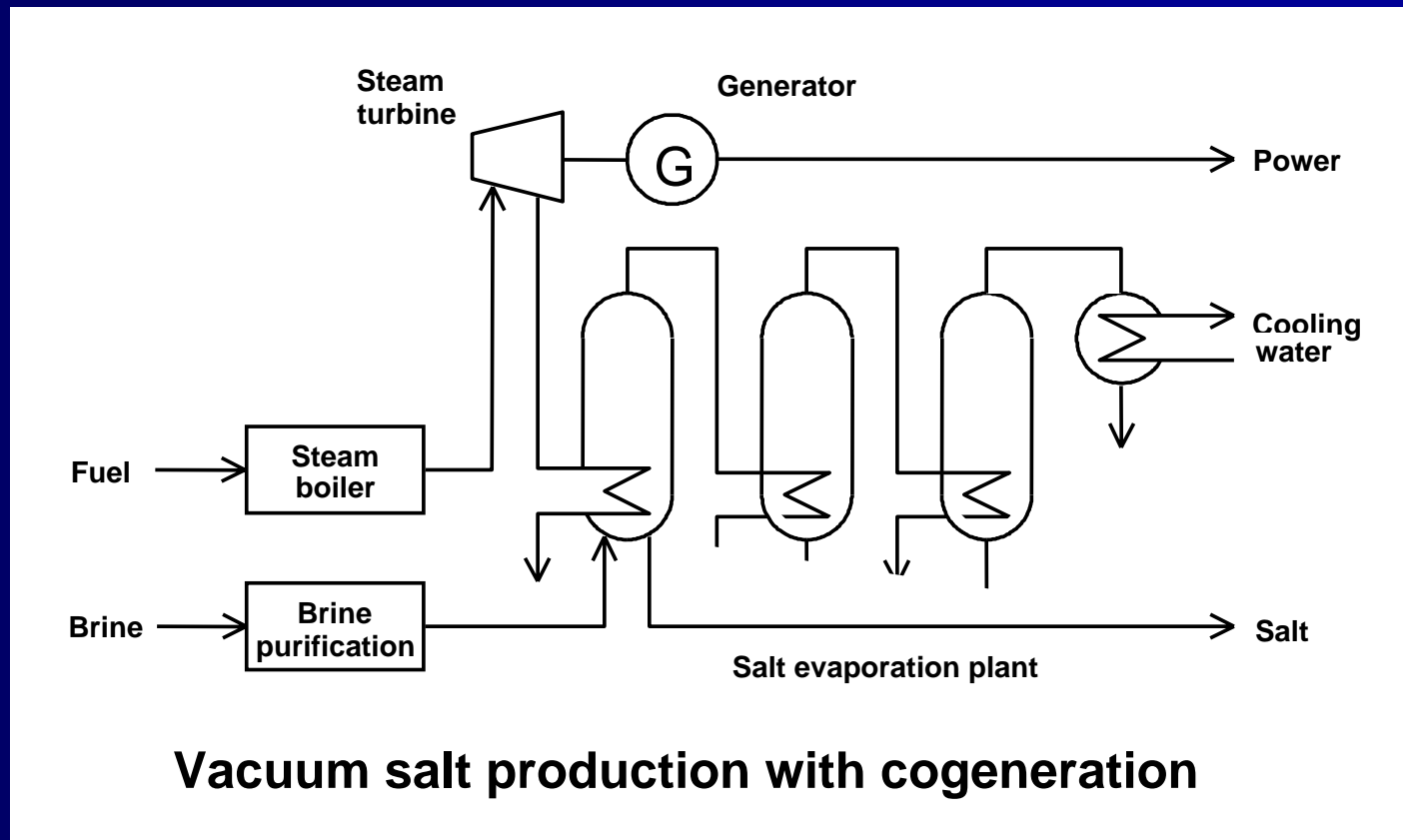
Salt Partners

Main salt uses world-wide

Caustic / Chlorine	36%
Soda Ash	17%
Other Chemicals	3%
Human Consumption	22%
Road De-icing	12%
Other Uses	10%

Salt Partners

Multiple Effect Crystallisation



Salt Partners

Prime energy consumption for multiple effect vacuum salt crystallisation

Water evaporation	3 t / t of salt
Steam to first effect	10 – 12 bar g
Number of effects	6
Steam consumption	0.62 t / t of salt
Boiler efficiency	75%
Prime energy consumption	450 kWh / t of salt

Salt Partners

Prime energy consumption for salt crystallisation by thermocompression with mechanical vapour recompression

Water evaporation	3 t / t of salt
Power consumption	160 kWh / t of salt
Power generation efficiency	35%
Prime energy consumption	450 kWh / t of salt

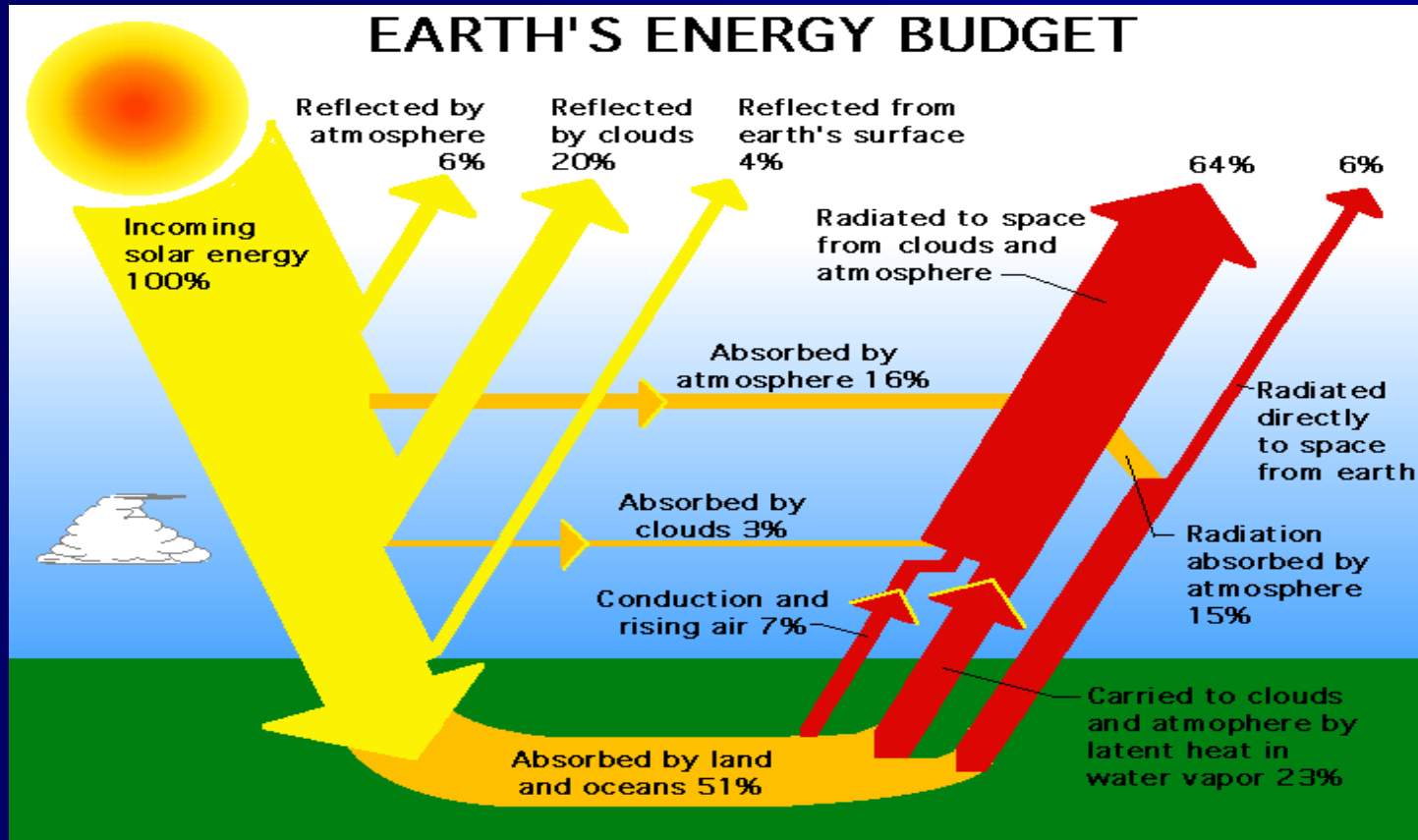
Salt Partners

Solar salt evaporation

Sea water density	3.85°Bè
NaCl content	30.09 kg NaCl / m ³
Bitterns density	28.53°Bè
NaCl in bitterns	8.37 kg
NaCl crystallised	21.72 kg
Water evaporated	949.93 kg
Water evaporation	43.74 t H ₂ O / t NaCl
Heat of water evaporation	0.675 kWh / kg H ₂ O
Solar energy consumption	29'520 kWh / t NaCl

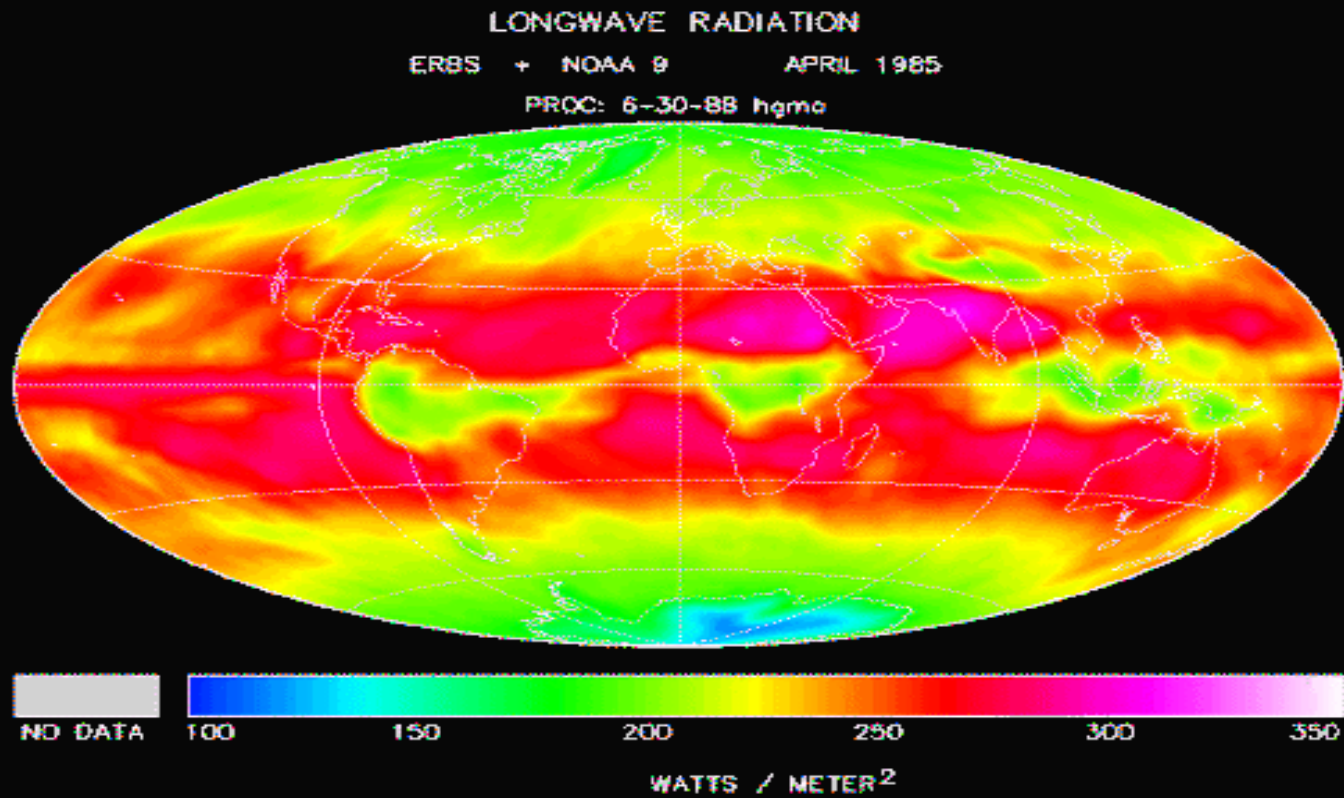
Salt Partners

Earth's solar energy budget



Salt Partners

Solar energy on the planet Earth



Salt Partners

Solar energy conversion into evaporation

Earth insolation	1.366 kW / m ²
Surface insolation absorbed	51%
Solar energy absorbed in zenith	0.697 kW / m ²
Daily solar energy absorption	5 – 7 kWh / m ² / day
Conversion efficiency	45%
Daily solar evaporation energy	2 – 3 kWh / m ² / day
Heat of water evaporation	0.675 kWh / kg H ₂ O
Daily evaporation	3 – 5 kg H ₂ O / day
Annual evaporation	1.1 – 1.8 m H ₂ O / year

Salt Partners

Solar evaporation conversion into salt

Annual evaporation	1.1 – 1.8 m H ₂ O / year
Salt crystallised per tonne of sea water evaporated	22.86 kg / t H ₂ O
Corresponding salt production	27 – 44 kg NaCl / m ² / year
Crystalliser area	10%
Salt layer in crystallisers	270 – 440 kg NaCl / m ² / year
Salt layer density	2 t / m ³
Salt layer thickness	13 – 22 cm

Salt Partners

Conversion efficiencies

Photovoltaic cells	8 – 15%
Solar collectors with stirling engine	30%
Super critical steam power plants	40 – 45%
Solar salt production	45%

Salt Partners

Impurities in salt

	Rock salt	Sea salt	Lake salt	Brines
CaSO₄	0.5 – 2%	0.5 – 1%	0.5 – 2%	Saturated
MgSO₄	Traces	0.2 – 0.6%	Traces	Traces
MgCl₂		0.3 – 1%	Traces	
CaCl₂			Traces	
Na₂SO₄			Traces	
KCl	Traces	Traces	Traces	Traces
NaBr	Traces	Traces	Traces	Traces
Insolubles	1 – 30%	0.1 – 1%	1 – 10%	

Salt Partners

What impurities in salt cause in mercury and membrane cells employed in chloralkali industry

- **Hydrogen evolution**
- **Mercury butter**
- **Membrane damage**
- **Incrustations**
- **Sludge deposits**

Salt Partners

Cost of salt and brine purification in the chloralkali industry

	Cost of brine treatment and disposal	Cost of salt, brine treatment and disposal
	(USD / t salt)	(USD / t salt)
Minimum	1.45	11.09
Average	9.20	25.09
Maximum	27.42	49.35

Salt Partners

Relative cost of salt and brine purification in the chloralkali industry

	Cost of brine treatment as percentage of salt cost	Percentage of chloralkali production cost
	%	%
Minimum	120	3.6
Average	166	15
Maximum	256	37

Salt Partners

Three saltworks areas that are critical to production of high quality solar sea salt

- **Sea water pre-concentration area**
- **Solar salt crystallisation area**
- **Salt purification plant**

Salt Partners

Sea water pre-concentration area



Salt Partners

What to do and what to avoid in the sea water pre-concentration area

- Increase concentration gradually, avoid back-mixing
- Prevent seepage
- Cultivate dark pre-concentration pond bottom
- Maintain clear brine
- Avoid calcium sulphate over-saturation
- Allow nutrients in brine to get consumed

Salt Partners

Solar salt crystallisation area

- Employ crystallisers in series
- Drain 28.5°Bè brine
- Support growth of *Halobacterium* that colours the brine red
- Allow thick brine layer to avoid reflection of solar radiation
- Avoid organic matter that causes formation of small crystal agglomerates
- Harvest under level control to avoid salt contamination with insolubles



Salt Partners

Solar salt from poorly managed saltworks



Salt that looks like a crystal, but it is an agglomerate.



The agglomerate can be broken by hand.

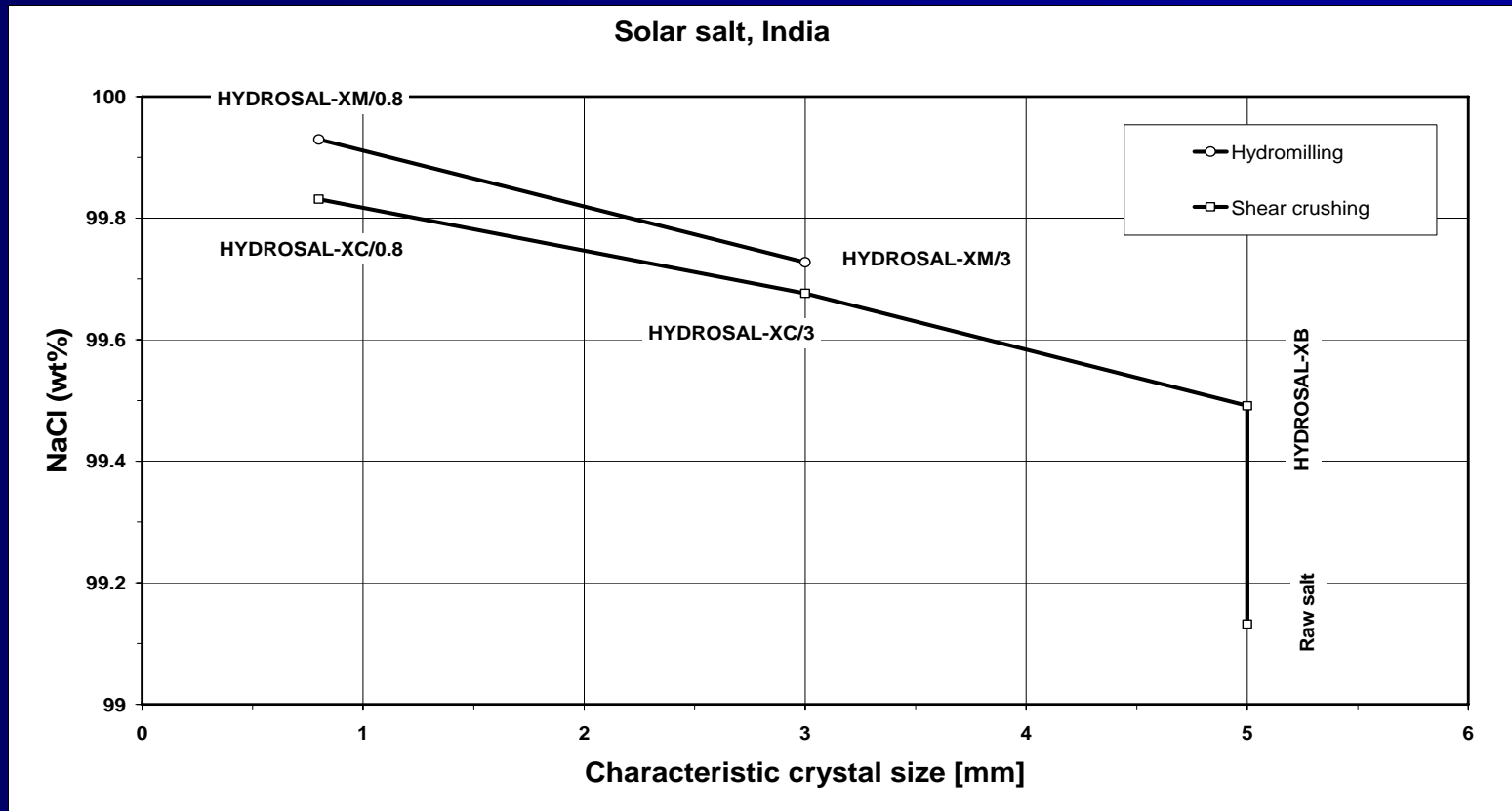


Impurities are imbedded between the small crystal fragments.

The salt is not well upgradeable.

Salt Partners

Salt upgradability test, NaCl content



Salt Partners

Solar salt from well managed saltworks



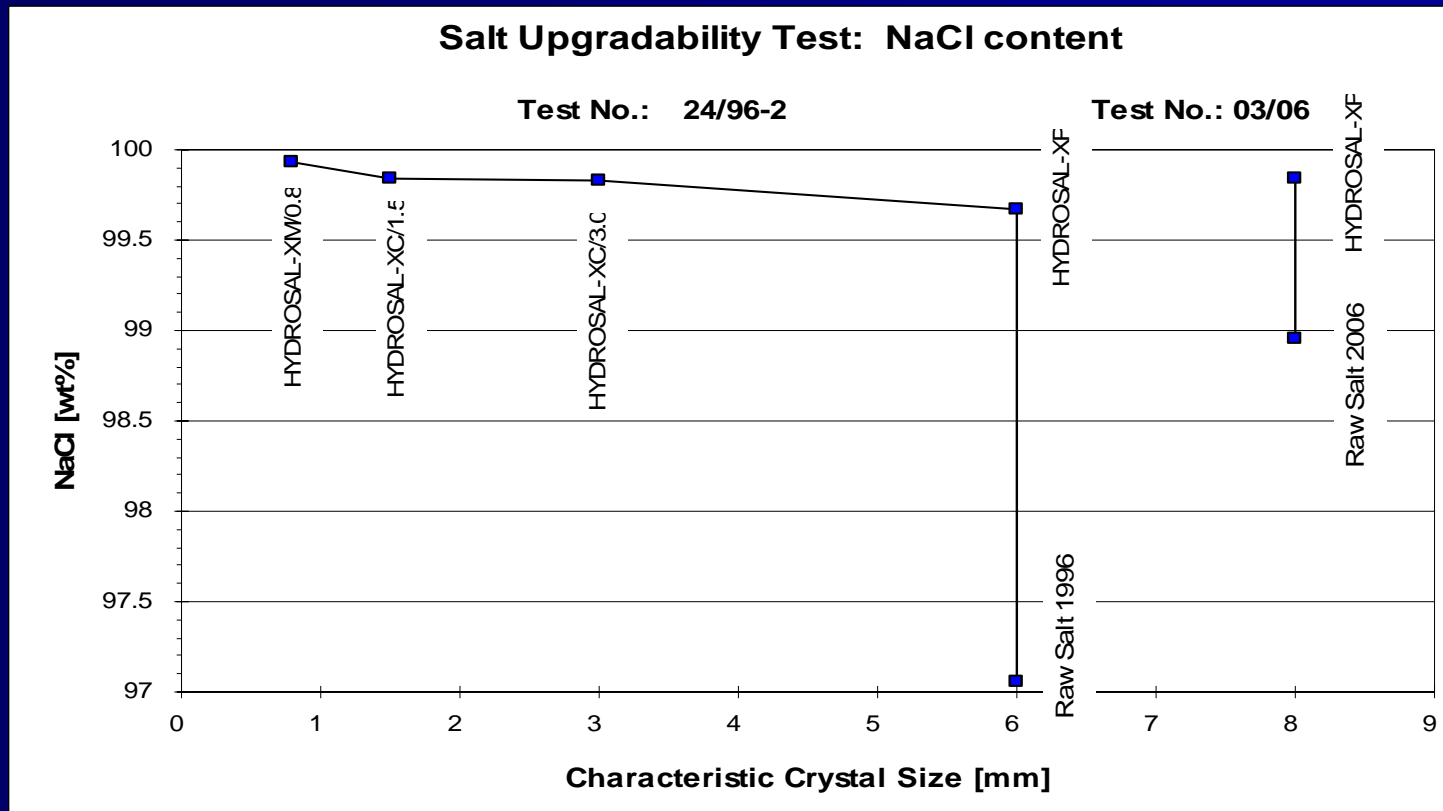
Hard, clear crystal, impossible to break by hand.



Impurities are only on the crystal surface. The salt is very well upgradeable with low losses.

Salt Partners

Salt upgradability test, NaCl content



Salt Partners

Vladimir M. Sedivy
Salt Partners Ltd, Zurich, Switzerland

**SALEXPOR 15 t/h
solar salt refining
plant in Portugal**



Salt Partners

Vladimir M. Sedivy
Salt Partners Ltd, Zurich, Switzerland

**100 t/h industrial
salt upgrading
plant in Spain**



Salt Partners

Vladimir M. Sedivy
Salt Partners Ltd, Zurich, Switzerland

**40 t/h salt upgrading
plant in Portugal
producing purest
industrial salt in Europe**

		Performance test
Ca	ppm	0.6
Mg	ppm	0.2
SO4	ppm	53

Efficiency	97.4%
NaCl losses	< 4%

