# Silicon

# A Critical Mineral for Australia's Future

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# WHAT IS SILICON

Silicon is the second most common element in the earth's crust after oxygen frequently found in the form of quartz or quartzite.

Whilst frequently referred to as "silicon metal", it is not a metal but rather a metalloid i.e. in the same category in the periodic table as carbon.

It is not an alloy but rather a matrix of pure silcon with impurities present as intermetallic compounds.

The Si $O_2$ bond in quartz is extremely strong and silicon smelting is therefore very energy intensive, requiring temperatures of several thousand degrees. Silicon is typically tapped from the furnace at around 1600$^{o}$C.

Silicon has special properties:

- It expands when it cools and solidifies
- It is a semi-conductor i.e. it is a conductor when hot but an insulator when cold
- Like carbon it can also form long chains, like hydrocarbons, which are the basis of silicones.

## APPLICATIONS

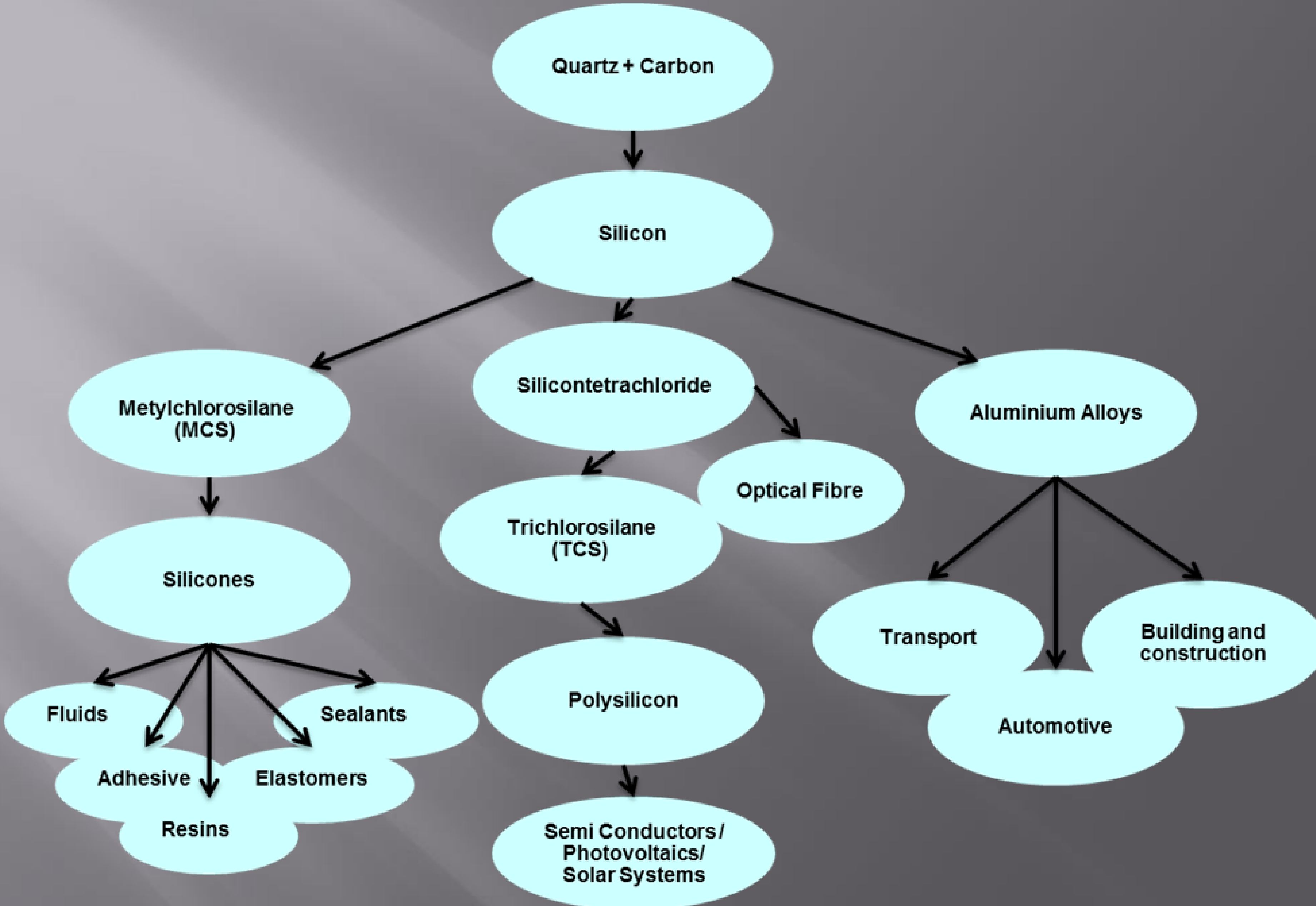
Two main markets for silicon: the metallurgical and chemical markets.

The metallurgical market refers to the aluminium industry. Silicon is added to aluminium at levels from 1% to 20% to improve the strength and the hardness of aluminium. One of the main applications in this sector is wheel alloys for cars.

High quality for the aluminium industry is represented by low levels of impurities, although lower grade silicon is acceptable if there is a cost incentive. Therefore most of the silicon for the Australian aluminium industry is supplied from China.

The other market sector is the chemical market.  This is diversified and includes the production of silicones, optical fibre, semi-conductors and photovoltaics.

In processing silicon for this sector, impurities play an important role with respect to both the rate and reactivity of the reactions. Chemical companies prefer long term supply arrangements with trusted suppliers.  For them quality is not high purity silicon but rather a consistent quality from shipment to shipment.


Quartz + Carbon
Silicon
Metylchlorosilane (MCS)
Silicontetrachloride
Aluminium Alloys
Optical Fibre
Trichlorosilane (TCS)
Silicones
Polysilicon
Transport
Automotive
Building and construction
Fluids
Sealants
Adhesive
Elastomers
Resins
Semi Conductors / Photovoltaics/ Solar Systems

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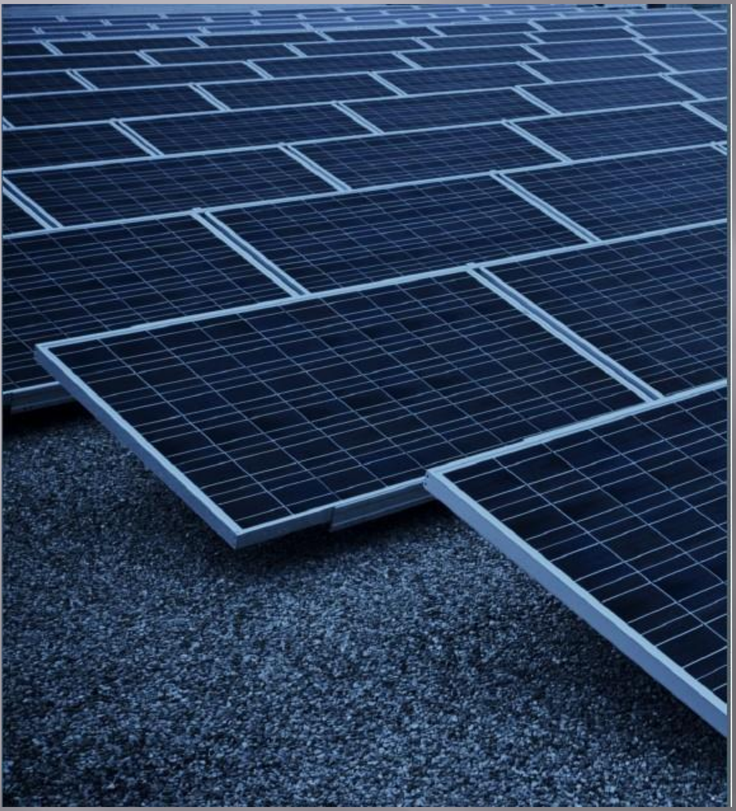
# Australian Silicon Action Plan

*“The global deployment of solar power technology will be critical to the success of the global energy transition. Australia has world-leading solar resources and a vast land mass that will allow us to facilitate deployment at scale.*

*These advantages must be leveraged to meet Australia’s national targets of cutting emissions by at least 43% by 2030 and reaching net zero by 2050. It will require a rapid and large-scale escalation in solar power installations.”*

- Achieving energy independence is a priority for the Australian Government yet Australia is entirely reliant on overseas supply chains for solar cells.
- The focus on environmental, social and governance means the solar cell supply chain – the production of silicon and polysilicon and the manufacture of solar cells poses risks, including the carbon footprint arising from its high energy intensity and modern slavery issues, that contribute to the urgent need for Australia to act.
- Australia has immense potential to develop more of the silicon and solar cell supply chain locally but needs to quickly to:
  - improve and stabilise our supply chain security and energy independence
  - develop new industries with high operating standards

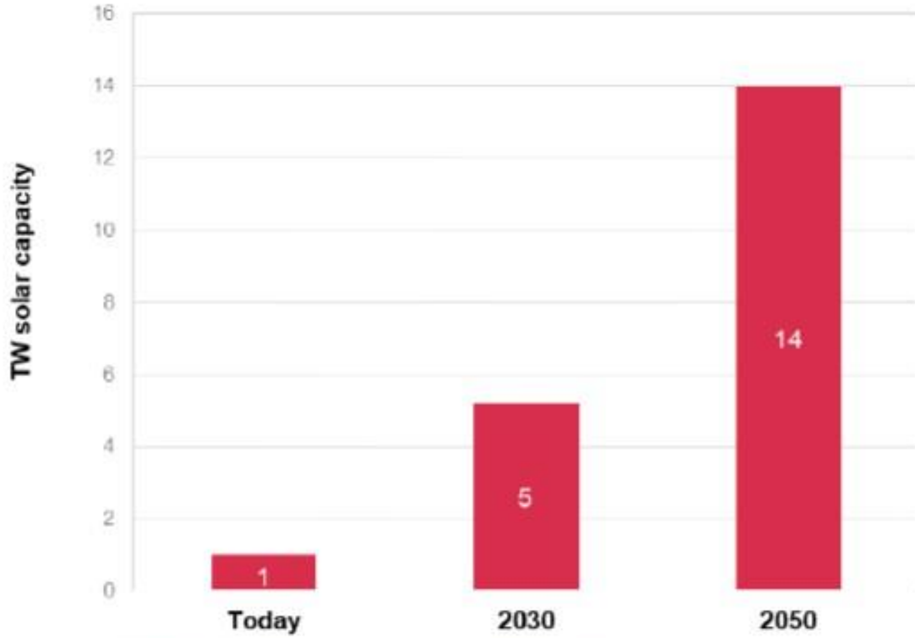


The vision presented in the Silicon Action Plan is for an integrated silicon and solar cell supply chain, including recycling, that is powered by renewable energy.

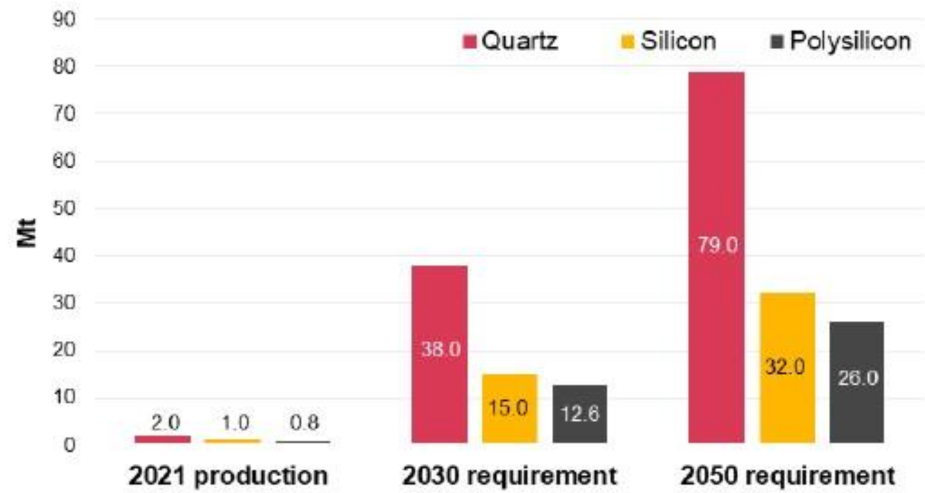
Focussing on the silicon supply chain it presents an opportunity for Australia to reduce its dependency on overseas supply chains for solar cells.

# SUPPLY & DEMAND

Figure 1: Global solar power generation




*Source: IRENA, World Energy Transitions Outlook 2022: 1.5°C Pathway.*




*Note: Quartz and silicon production are estimates of the volume required to produce polysilicon in any given year. This analysis does not include quartz and silicon production for other (non-polysilicon) markets.*

*Sources: IRENA, World Energy Transitions Outlook 2022: 1.5°C Pathway; PwC analysis and market research.*

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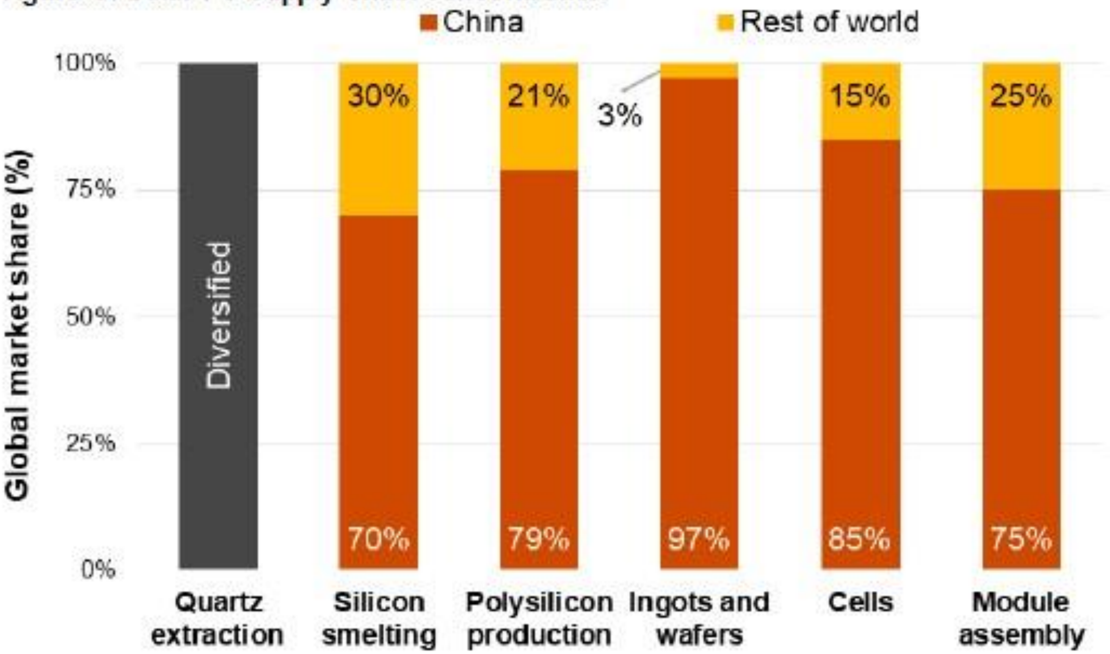
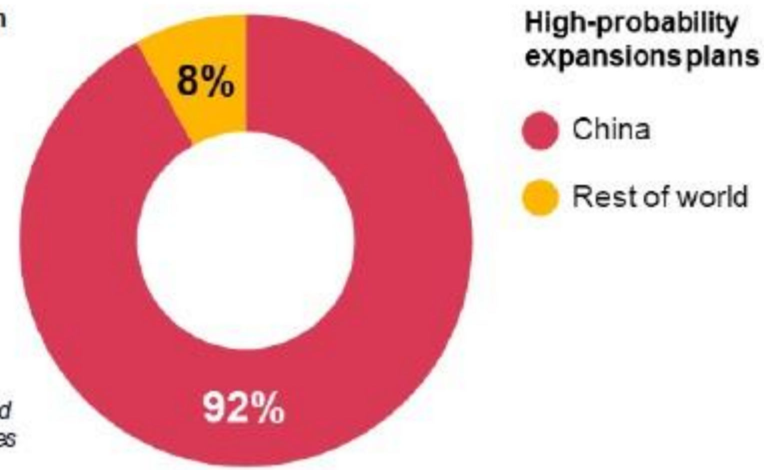
[a] *IEA, Special report on solar PV global supply chains, p. 22*

Figure 9: Solar PV supply chain concentration




*Sources: IEA, Executive summary of special report on solar PV global supply chains; CRU, Silicon and Polysilicon Report, p. 106; PwC analysis.*

Figure 11: Polysilicon capacity expansion




*Source: CRU, Silicon and Polysilicon Report, Tables 55 and 56.*

# HOW IS SILICON PRODUCED

Equipment and furnaces have been improved but the basic process for silicon production has been unchanged for 100 years.

Quartz is charged to a submerged arc furnace together with a reductant along with woodchips to improve bed porosity.

SiO gas produced in the furnace rises and reacts with the carbon reductant converting it to silicon carbide. The silicon carbide in turn reacts with fresh $SiO_2$ to produce Si which is tapped from the furnace and CO which burns to $CO_2$ on the surface of the charge.

Unreacted SiO oxidises to amorphous $SiO_2$ at the surface of the charge and is sold as a by-product.

The reductant must have low ash (1 – 2% max.) and a high level of reactivity with SiO gas.

Historically the main reductants has been low ash coal from Colombia and the US as well as charcoal where it is available.

Apart from the drive to achieve a zero carbon footprint, future supplies of suitable low ash coal are uncertain.

Charcoal is highly suitable but will require significant timber supply.

The other alternative is pellets / briquettes produced from a wide range of biomass based residues.

Some impurities such as Al & Ca can be managed by injecting oxygen into the ladle during tapping. Others such as Fe, Ti, P & B are managed through raw material selection.

After tapping the Si is cast, cooled, crushed and for the chemical customers ground to a powder.

# SILICON PROJECT DRIVERS

Quartz Supply: This is often a project driver but makes no sense as quartz is plentiful and easy to ship. Only about 10% of OPEX.

Reductant Supply: Limited coal supply options, more expensive to ship and unless charcoal is produced locally, it must be containerised. 20 – 25% OPEX.

Power Supply: Highest operating cost (around 12 MWh/t) and required 24/7. Must be available locally. 30 – 35% OPEX.

Labour Supply: Motivated local labour availability with heavy industry experience is a major advantage.

# SILICON PRODUCTION IN AUSTRALIA - SIMCOA

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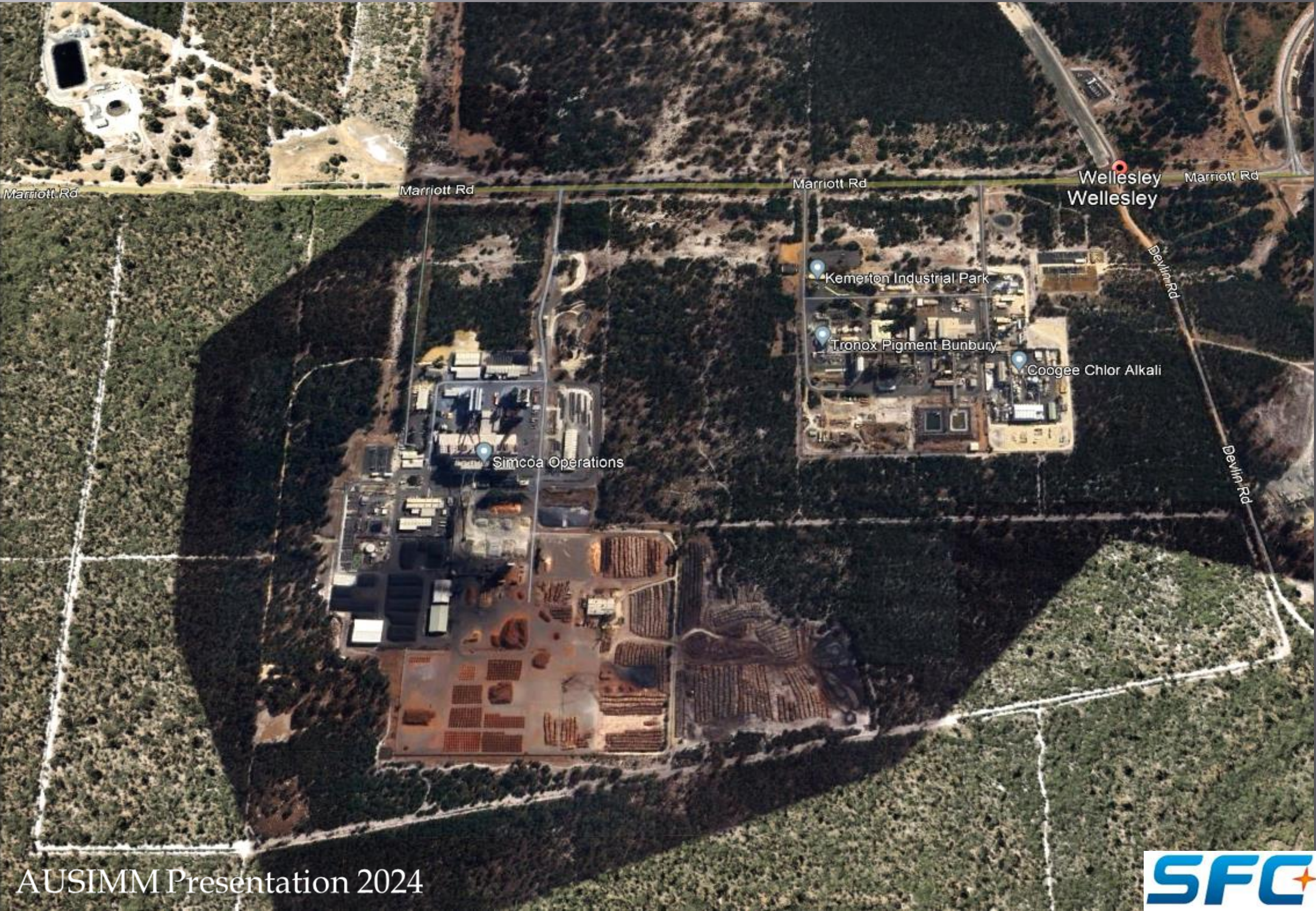


## SIMCOA

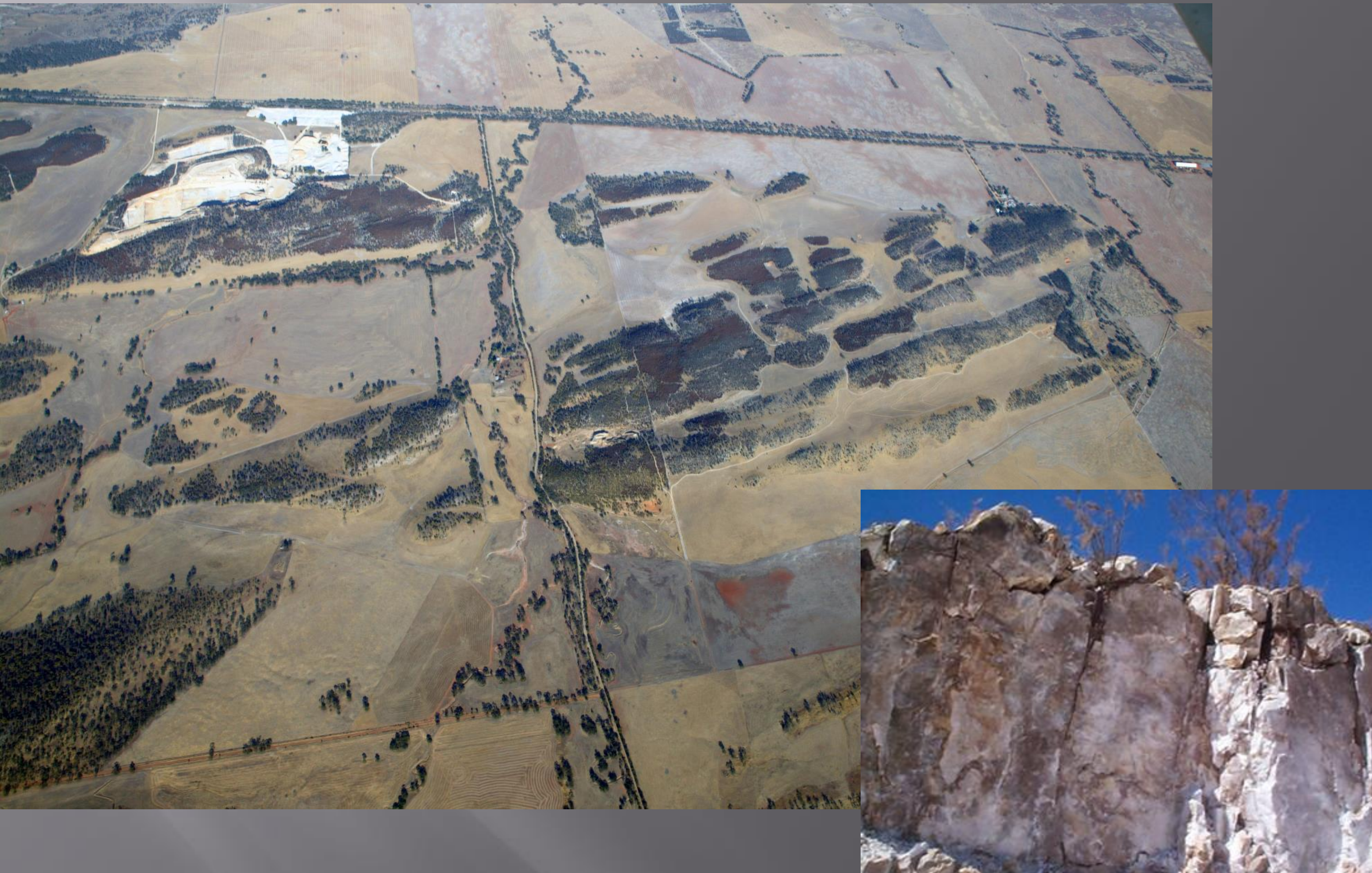
Production: Approx. 50,000 tpa Silicon

3 Submerged Arc Furnaces – total 65 MW
2 Charcoal Retorts (25,000 tpa)
Site Power Load approx. 70 MW

**Raw Materials**
Quartz – own mine at Moora
Reductants

- Charcoal – Produce on site & imported from Indonesia
- Local Collie coal
- Imported low ash coal from Colombia
- Woodchips – plantation & native forest thinnings
- Carbon Electrodes – imported from Poland & China

# SIMCOA QUARTZ MINE - MOORA



# TIMBER RESIDUE PROCESSING

# CHARCOAL RETORTS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# NEW PROJECTS IN AUSTRALIA

Quinbrook Infrastructure Partners (investment partner in Sun Cable), plans to build a polysilicon plant in Queensland costing up to $10 billion to supply solar panel manufacturers.

The project is earmarked for a 200-hectare site in the Lansdown eco-industrial precinct in Townsville sourcing  quartz from the region and incorporating a silicon smelter to process the quartz.

Quinbrook plans to build a plant powered by a large-scale solar and battery storage project that it hopes to develop on land next to Lansdown.

# ARENA / APVI SILICON TO SOLAR STUDY

Study advocates importance of developing poly Si production in Australia.

The value of this to Australia is indisputable but some of the recommendations to overcome challenges are questionable.

- Major benefit given is increased domestic employment whilst noting that mostly skilled workers are required who would be sourced overseas with subsidised migration.
- Advocates heavy financial subsidies for poly Si production but rather than supporting domestic silicon from quartz production (for which skills are available) recommends the removal of Si dumping penalties in Australia whilst relying on US dumping penalties against China to underpin poly Si prices.

# CHALLENGING TIMES FOR THE SILICON INDUSTRY

- Market flooded with cheap silicon from China

  A frequent justification for Gov't support for domestic production has been that this will reduce global pollution:

  - New plants in China have energy recovery as standard.
  - Many plants there have NOx & SOx scrubbing of the offgas.

  The main justification should be protection of supply chains.

- Dwindling supplies of suitable low ash coal

  Alternative carbon neutral reductant options must be developed

- Potential increased costs related to emissions from coal usage and non-renewable energy

- Increasing emissions controls on heavy metals, SOx & NOx

# FUTURE DEVELOPMENTS

Energy Storage: Australia has enormous wind & solar potential but reliable power required 24/7. Large scale energy storage is game changing for Si production in Australia

Energy Recovery: Si is energy intensive to produce but 25 – 30% of the energy input can be recovered from the off gas.

Alternative reductants: Charcoal is an attractive alternative to coal but finding sufficient feedstock will be a problem. Future options include a wide range of “waste” materials which may need to be briquetted (sawdust, agricultural waste, tyres etc).

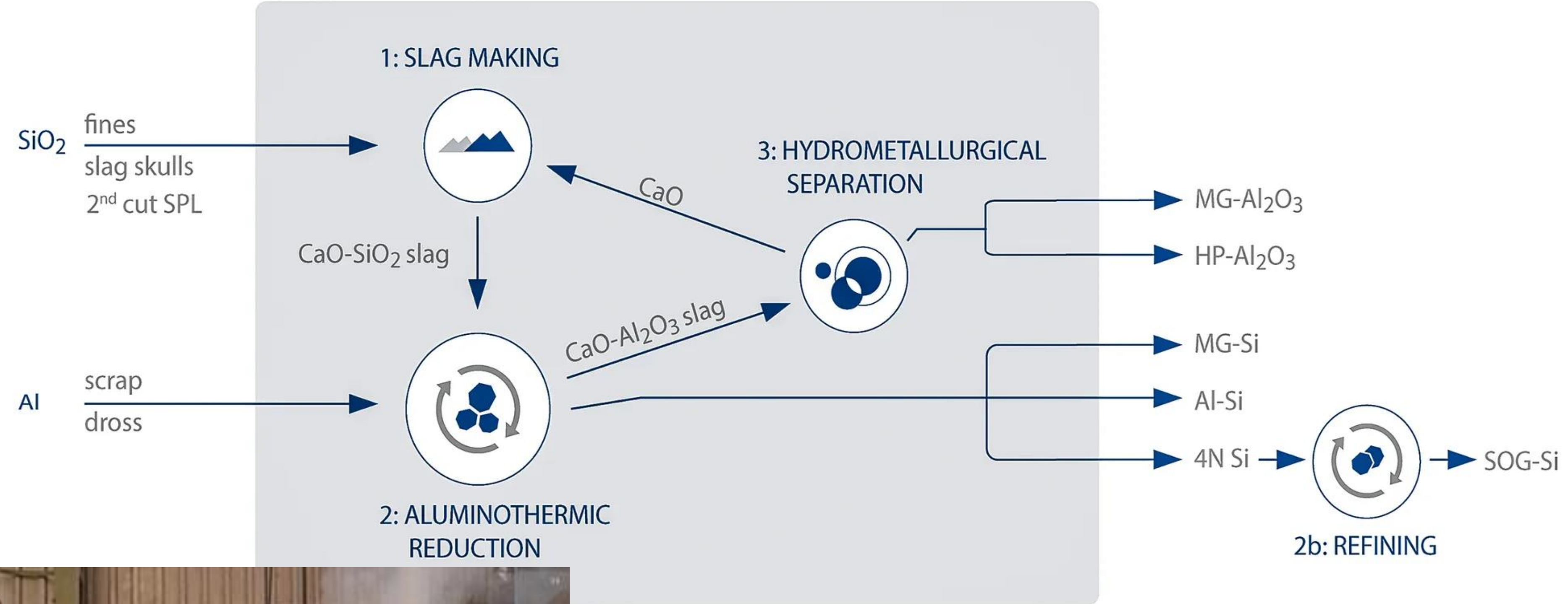
Carbon Capture & Storage from the furnace off-gas

# ALTERNATIVE TECHNOLOGIES TO CARBOTHERMIC REDUCTION

**Hydrogen reduction in a plasma furnace:** Very early stage R&D work at present, will be extremely difficult to implement on a large industrial scale

**Electrowinning:** Because of the high melting point of silicon, it will be necessary to operate with electrolytes at extremely high temperatures which will be very challenging.

**Metallothermic Reduction (Al or Mg):** The SisAl project is at pilot plant stage and involves melting lime with quartz to form a slag then reducing the silicon by adding low grade Al (skull, dross). The slag and silicon are separated and the Si cleaned up with leaching.





# SISAL PILOT PROJECT