Liquid Tin Anode Fuel Cell Direct Coal – 3 Alternative Configurations

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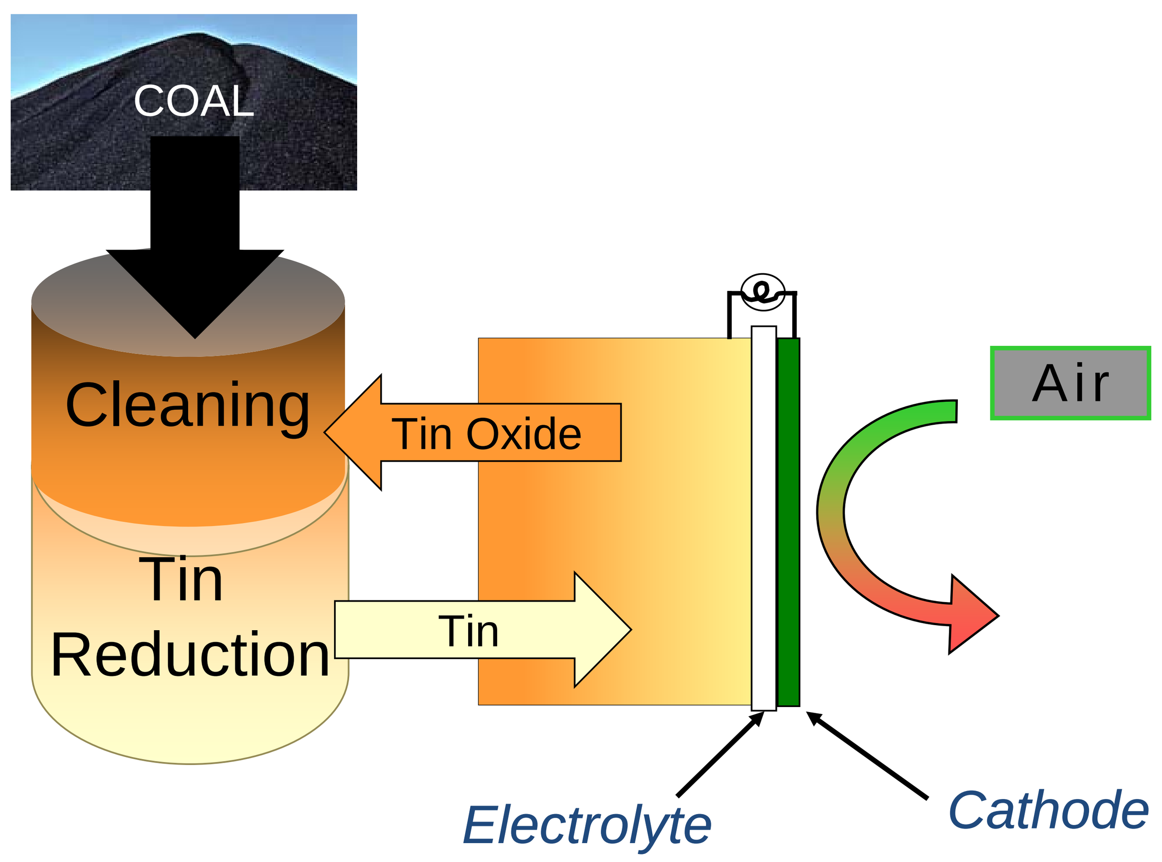
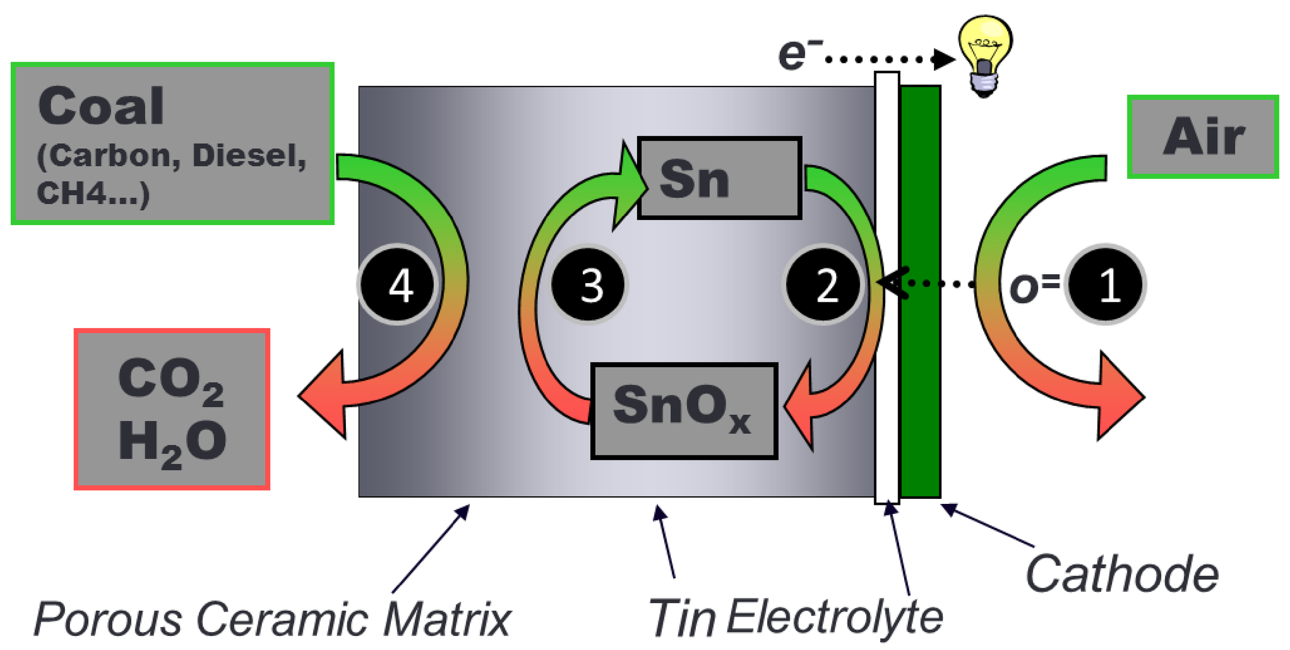
Electrochemical Looping

Based on Coal-Tin Reactor
DE-NT0004111, DE-ER85006

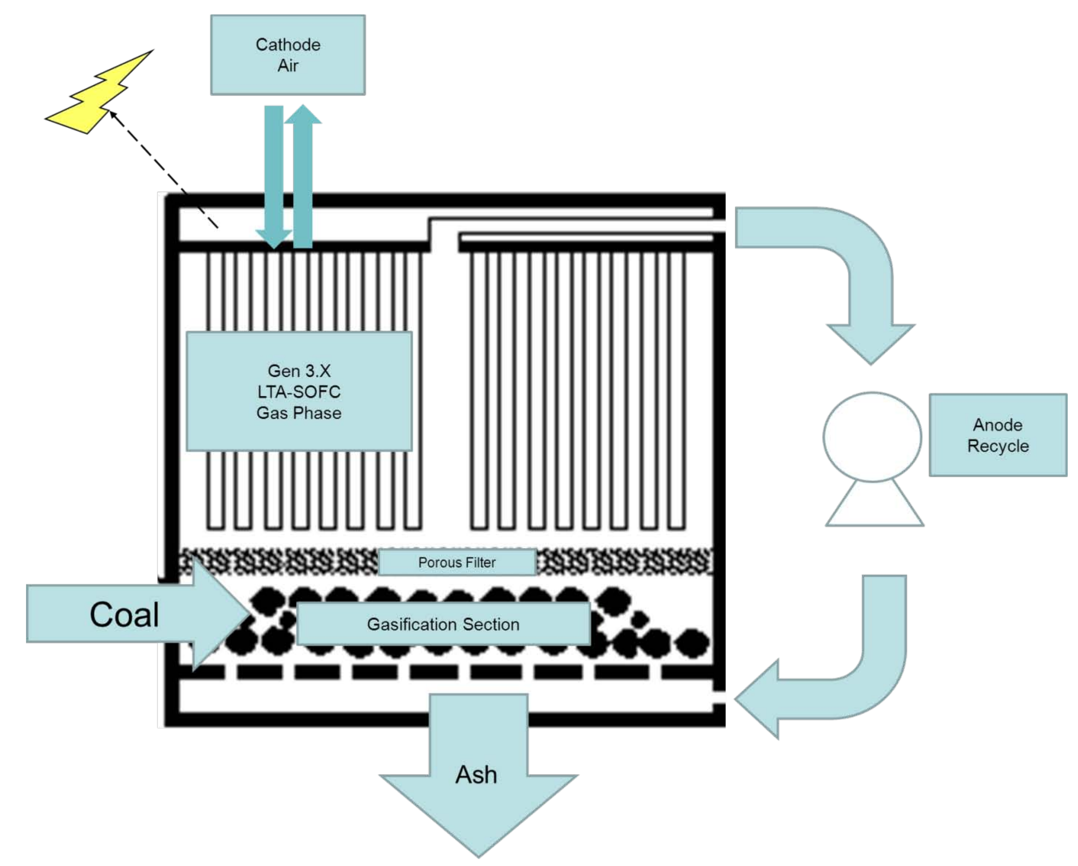


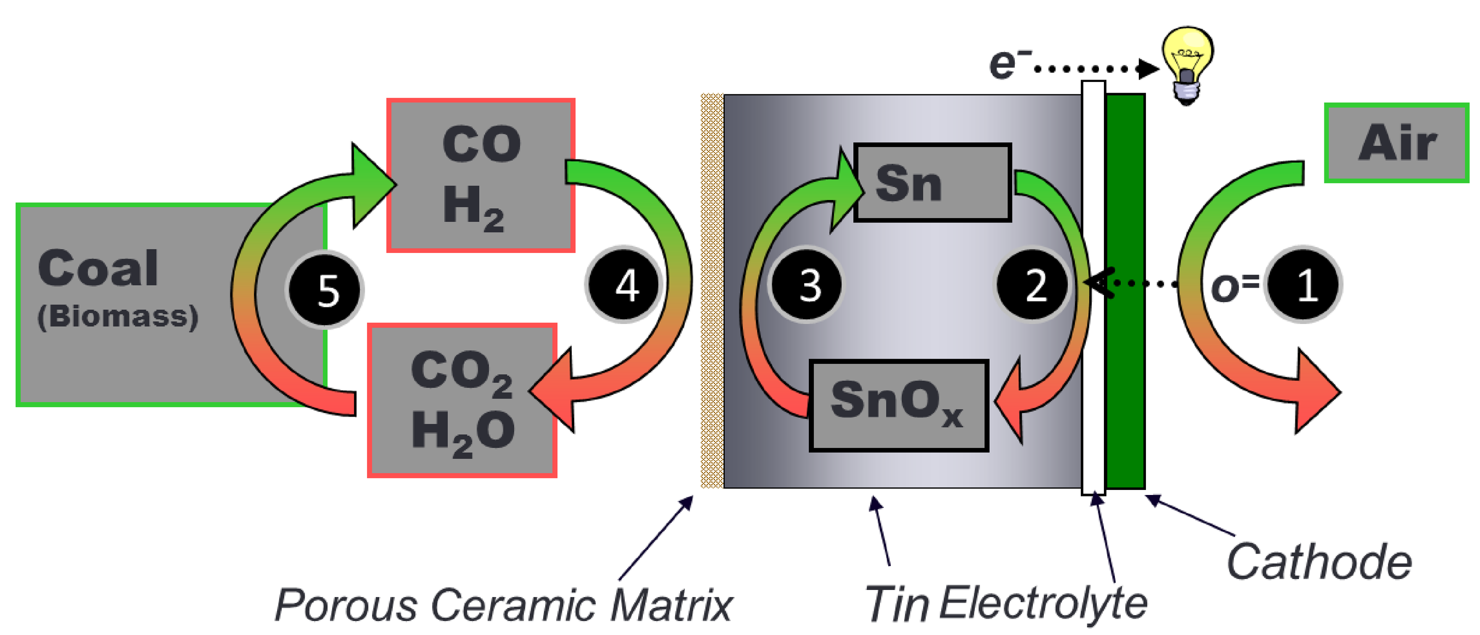


1. Oxygen ions extracted from air by cathode and cross the electrolyte
2. Ions react with tin, releasing electrons and forming tin oxide
3. Tin oxide is independently reduced back to tin by reaction with fuel
4. Fuel directly contacts tin

Insitu Gasifier

Based on Portable Power Cell
DE-ER95350S10

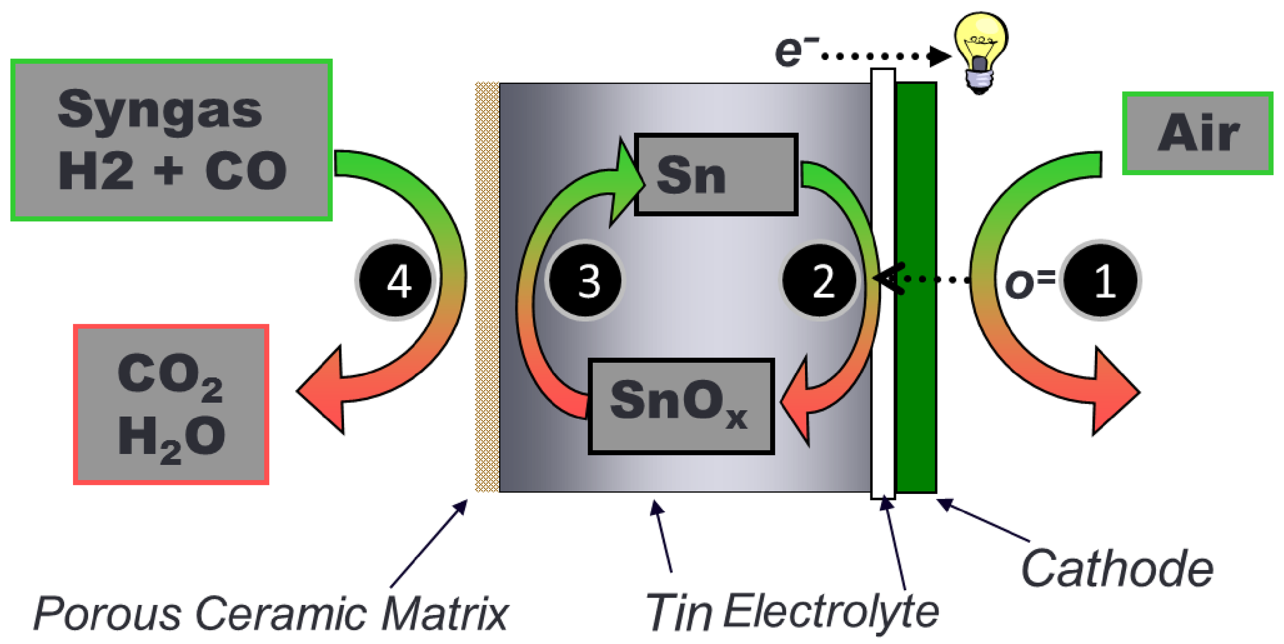




1. Oxygen ions extracted from air by cathode and cross the electrolyte
2. Ions react with tin, releasing electrons and forming tin oxide
3. Tin oxide is independently reduced back to tin by reaction with fuel
4. Tin-fuel interaction can occur inside tin or across a porous ceramic membrane
5. Coal or other solid fuel is gasified insitu by the cell reaction products

External Gasifier

Based on Portable Power Cell



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Most thoroughly analyzed concept to-date

- 63% System efficiency with CO2 capture and compression
- System CAPEX: $1400 – 2400/kW (similar to IGCF)
- Near 100% CO2 capture

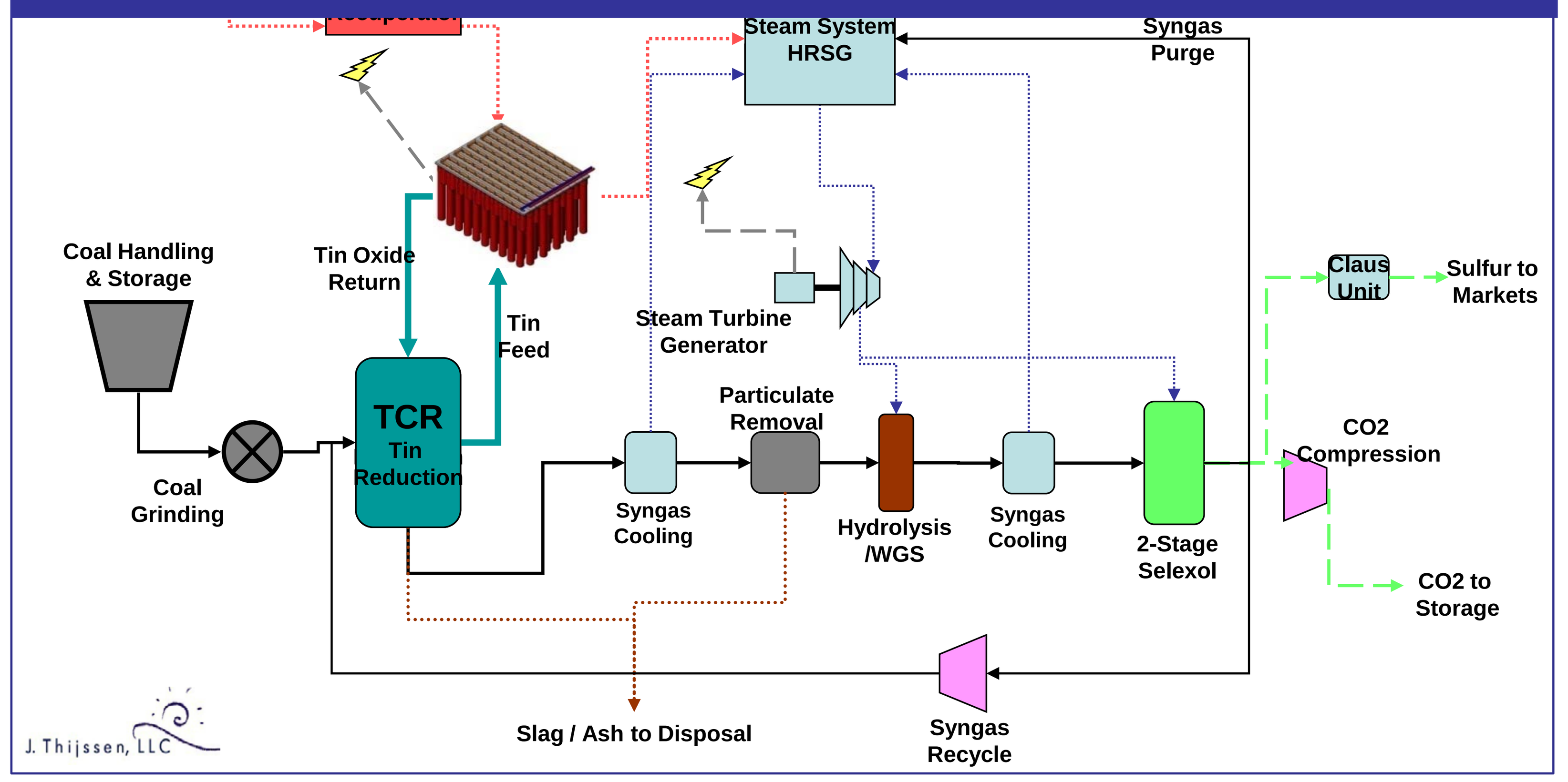
•Tin provides separation of ash/impurities

•Requires development of Tin Coal Reactor similar to liquid metal gasifiers

•High tin recirculation rate required to meet O2 transport requirements.

•Tin anode requires electric current break

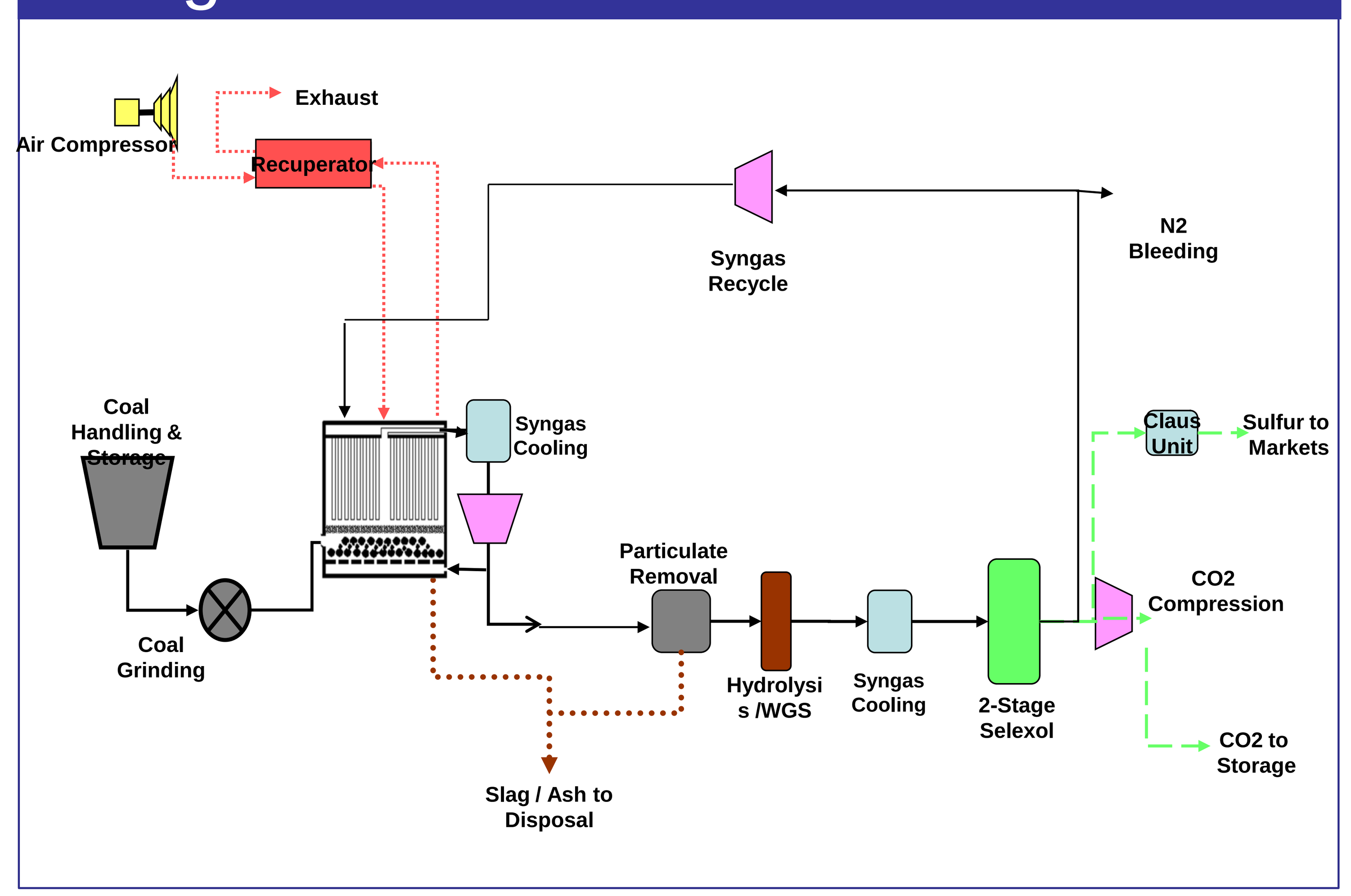
High Level of PFD of Electro Chem Looping with CCS



Uses cells with porous separator like existing CellTech Gen 3

- No direct contact between tin anode and solid fuel.
- Gasification is driven by CO_2 and H_20 produced by cells (no Oxy plant required).
- Isolated anodes allow cell voltage build up.
- Ash, tar and carbon clogging of separator could be an issue.
- Volatile metal oxides in coal impact on cells unknown.
- Could test concept with Gen 3.1 cells and lab gasifier.
- Cathode air flow may increase to remove cell heat load.

High Level of PFD of Insitu Gasifier



Uses cells with porous separator like existing CellTech Gen 3

•Compatible with existing gasifiers

•Reduced gas clean-up (Sulfur, CO)

•Lowest efficiency

Cross-section of a Gen 3 type cell