SEATA

Deconstructing the world's problems to create carbon negative solutions

SEATA Clean Energy & Carbon Sequestration Technology

- Technical Introduction

May 2024

How can we produce **sustainable** energy / hydrogen ***and*** remove excess carbon from the sky that's causing climate change, ***at the same time***?

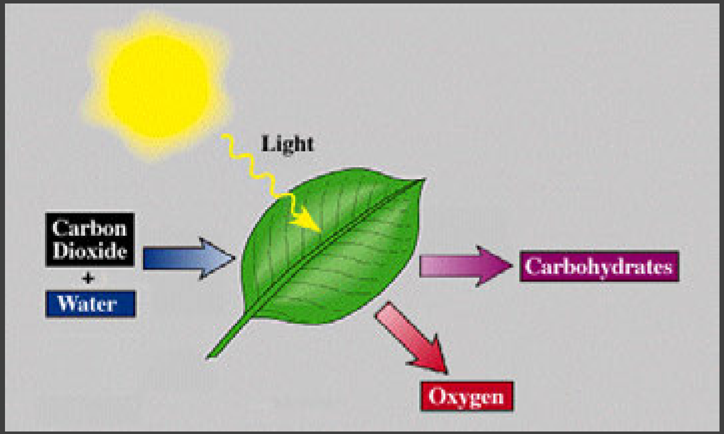
…The answer comes from nature:

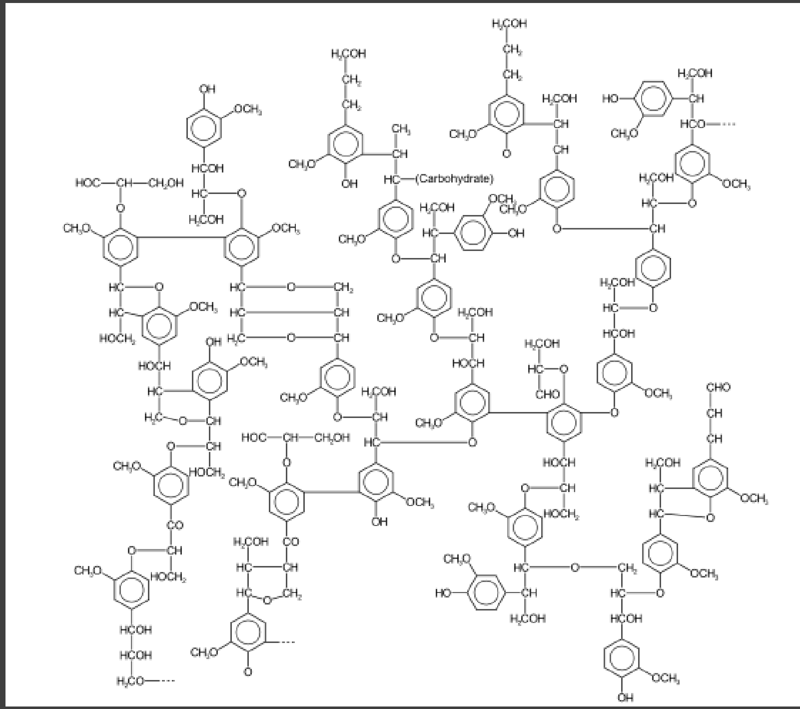
Leveraging on the very definition of *sustainable* energy:
….. *Over 3 Billion years of photosynthesis, C & H cycles…*

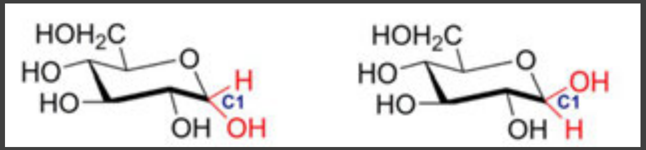
- ➔ ***Plants takes CO_2 out of the atmosphere and combine it with hydrogen & oxygen to make carbohydrates (sugar building blocks) for growth***
- ➔ *>20 Million tonnes of plant biowaste is generated in NSW alone each year which either biodegrades, is burned or landfilled. This is full of recoverable hydrogen and carbon.*

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

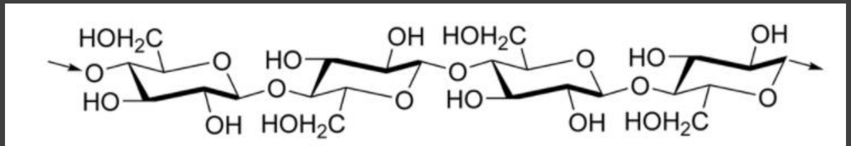
- *Photosynthesis*





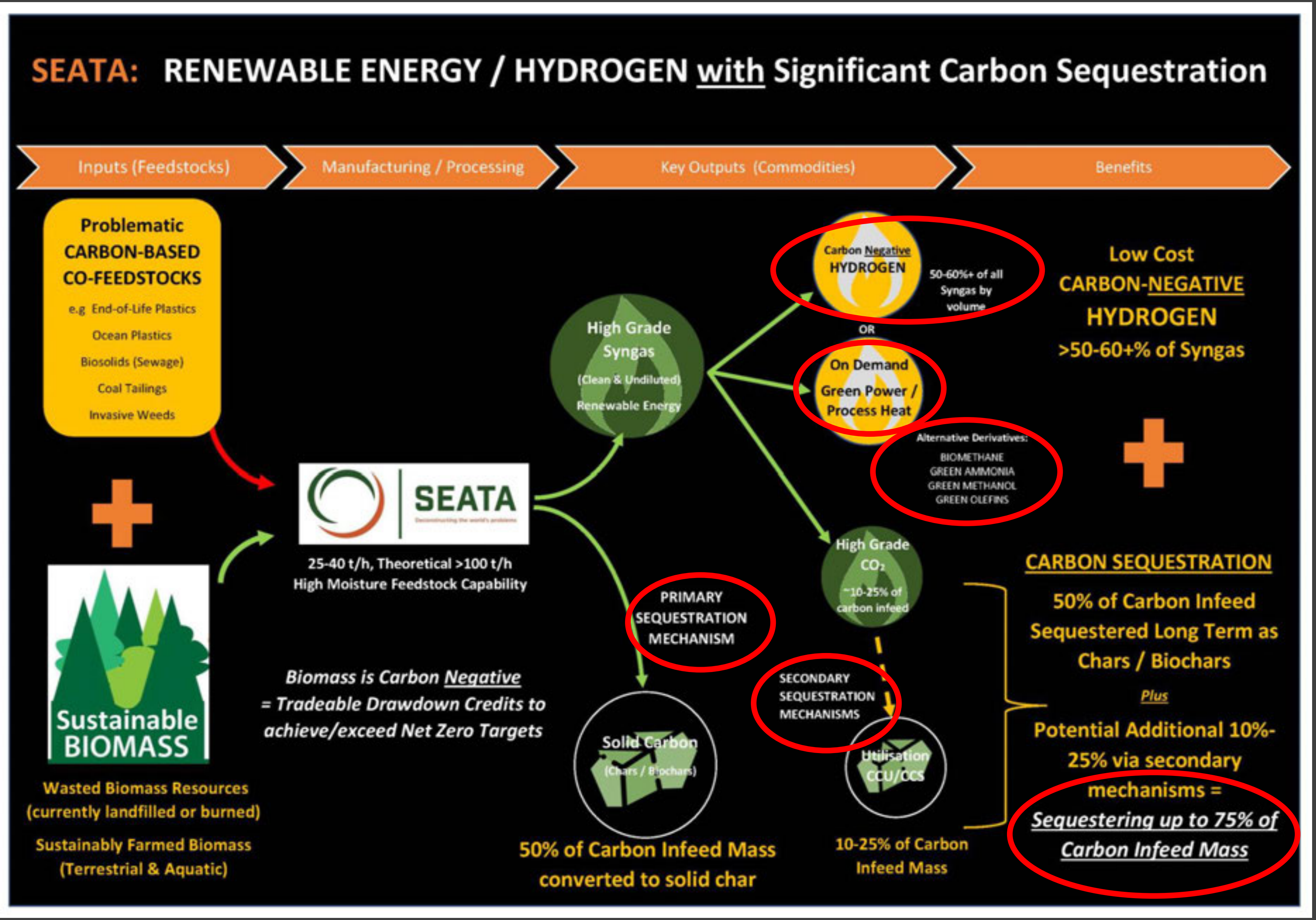


- Glucose



- Cellulose
- Lignin

SEATA - Carbon *Negative* Hydrogen with co-benefits



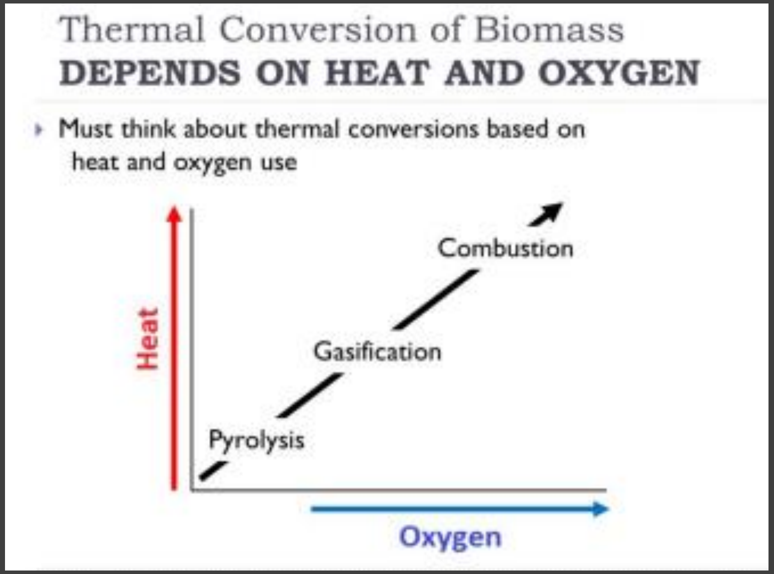
How does SEATA thermal technology work, and how does it differ to conventional technologies?

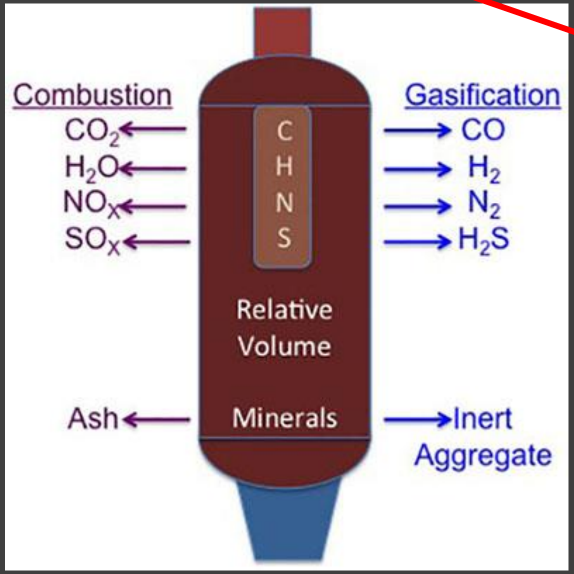
....We combine the best aspects of two thermal treatments called pyrolysis (no oxygen) and gasification, without the usual limitations of each.........we do this via **Chemical and Thermal looping (CTL)**

Conventional Thermal Treatment / Conversion Technologies:

Incineration Vs Gasification Vs Pyrolysis

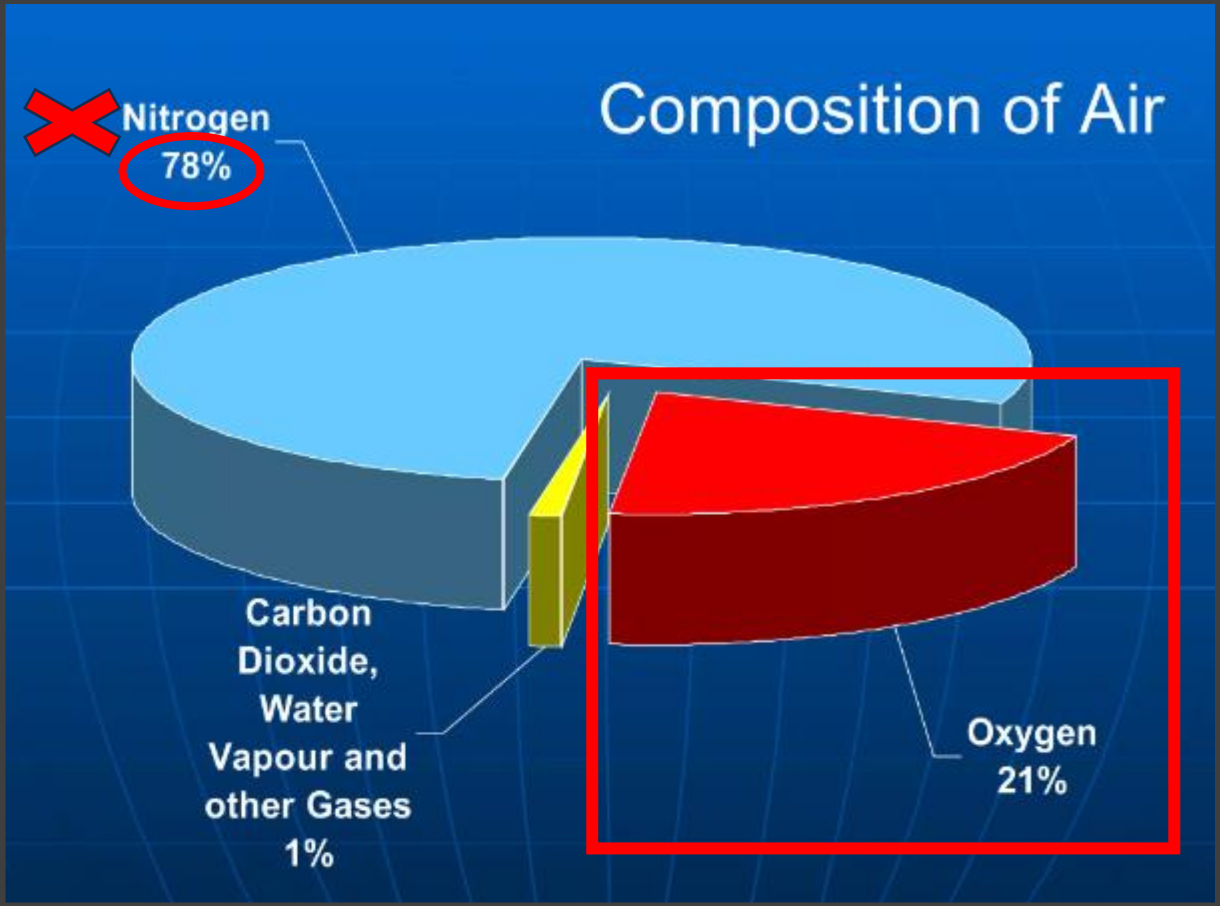
	Combustion	Gasification	Pyrolysis
Oxidizing Agent	Greater than stoichiometric supply of oxygen*	Less than stoichiometric oxygen* or steam as the oxidizing agent	Absence of oxygen or steam
Typical Temperature Range with Biomass Fuels	800°C to 1200°C (1450°F to 2200°F)	800°C to 1200°C (1450°F to 2200°F	350°C to 600°C (660°F to 1100°F)
Principle Products	Heat	Heat and Combustible gas	Heat, Combustible liquid and Combustible gas
Principle Components of Gas	CO_2 and H_2O	CO and H_2	CO and H_2

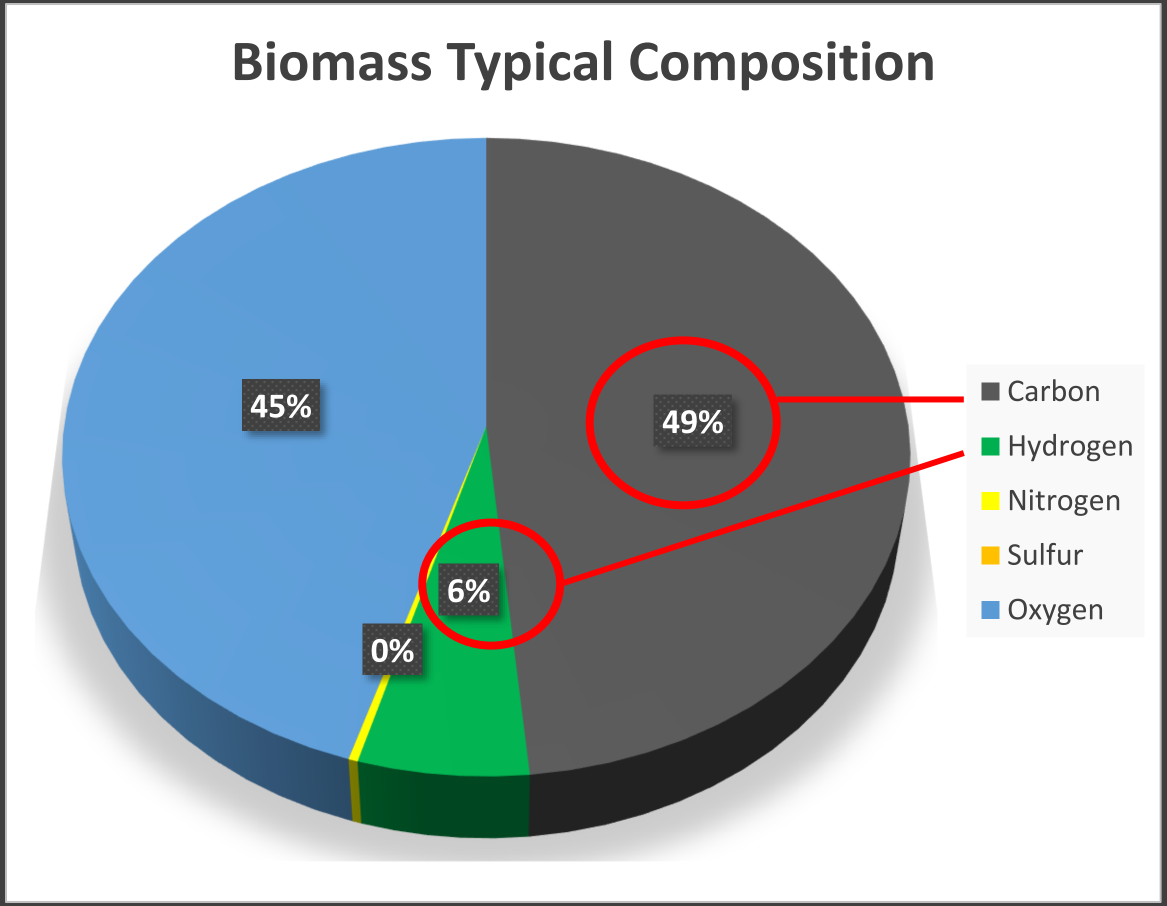




Combustion systems use **heat** to boil water (requires a lot of energy) for CC turbines, resulting in max 34% BMP conversion efficiency to electricity.

Gasification produces a *fuel-gas. Clean high energy* fuel gas could **directly power a gas engine** (avoiding boiling water), resulting in **>50% conversion efficiency to electricity**. At scale this has significant implications for peaking power and baseload generation.





Conventional combustion & gasification uses Air to get Oxygen = ~80% waste (atmospheric nitrogen!)

i.e. using air = significantly higher emission control & plant size/costs (high CAPEX)

➔ SEATA deliberately doesn't use air-blown gasification.

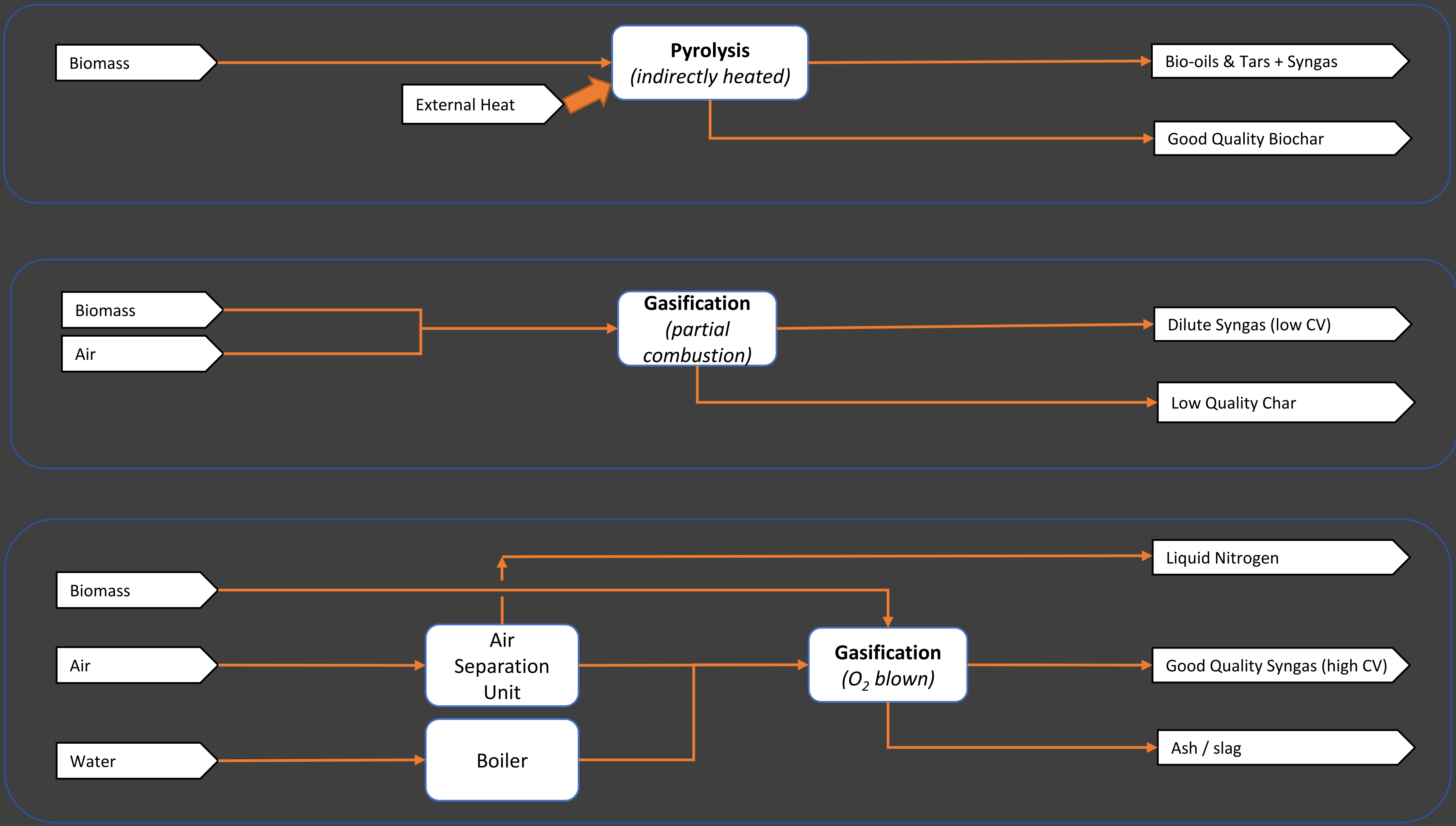
Incineration Vs Gasification Vs Pyrolysis…Vs SEATA CTL

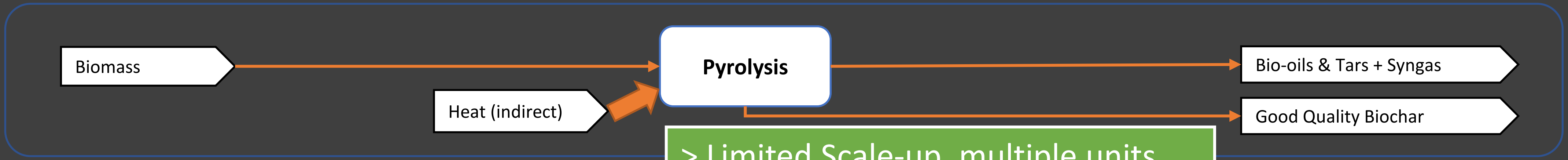
ENVIRONMENTAL PERFORMANCE Design Factors	Incineration *(combustion, excess oxygen)*	Conventional Air-blown Gasification *(partial oxidation)* *(air-blown= high N_2)*	Conventional Pyrolysis *(low/no Oxygen)*	SEATA Catalysed Pyrolysis & Partial Gasification via chemical looping *(indirect O_2 transfer from air, low N_2 in syngas)*
Off-gas volume to be treated	**Very high**	**High**	**Moderate**	**Low** *(not directly airblown (air is 78% N_2), therefore up to 78% less volume)*
General Environmental Performance	**Lowest**	**Lower** key advantage over combustion is lower NOx formation	**Better** (if bio-oils are dealt with correctly)	**Higher** benefits of pyrolysis and gasification combined, hence only clean syngas and biochar produced
Linear / Circular Economy *(Resource Recovery)*	**Linear, Poorest LCA** single use of resources	**Linear, Poor LCA** syngas linear due to dilution with N_2, marginal resource recovery as charcoal	**Circular** syngas linear due to tar contamination, some resource recovery as biochar, bio-oils difficult to process / limited uses	**Circular** syngas derivatives possible due to the high concentration of H_2 and CO plus functional biochar resource, with no bio-oils generated – all converted to useful syngas
Dispatchable Energy	**No** – heat must be used immediately via steam cycle (base load)	**No** – heat must be used immediately via steam cycle (base load)	**Yes** – via syngas storage and bio-oils, but multiple units required to scale with, no increase in thermal efficiency.	**Yes** – via syngas storage and derivative of syngas, e.g, H_2 Much higher thermal efficiency (particularly at scale) = net energy *producer*
GHG Emissions (incl CO_2)	Very High	High	Low to carbon **negative**	carbon **negative** energy
Carbon Abatement / Sequestration	**None** all carbon infeed is converted to CO_2	**Low** 10% Carbon in feed converted to charcoal, remainder to CO_2	**High** ~50% Carbon in feed reports to solid char	**High** ~50% Carbon in feed reports to solid char, *plus* potential future recovery of carbon in syngas (e.g. high grade CO_2 into CCUS, total removal potential increases to over 75%+)
Hydrogen *(Economic Recovery)*	**No**	**No** Not economic in air blown systems due to being highly diluted with N_2	**Yes**, but difficult due to contamination of the syngas with tars and oils, i.e., further processing required	**Yes,** Low cost, easy to separate Carbon **Negative** Hydrogen
Harmful Pollutant Emissions *(Particulates, Heavy Metals, VOC's, POPs, NOx, Dioxins & Furans)*	**Highest** Off-gas requires significant treatment	**Moderate** Lower off-gas volume to treat than incineration but still large, lower NOx	**Moderate** Low off-gas volume to treat, syngas still contains tars, dioxins and furans. Hence specially designed combustion systems required to destroy tars, dioxins & furans.	**Low** All syngas generated by the process is pre-cleaned at high temperature in the presence of a catalyst to destroy residual tars & halogenated compounds (second reactor), then wet quenched / scrubbed to remove soluble components and avoid reformation of dioxins and furans. Clean product syngas capable of economic recovery for derivatives, or for lower emission combustion without post-treatment (similar to natural gas or LPG for example)
Emission Control Systems (ECS)	**Critically Dependent** on Pollution Controls Multiple additives required to scrub pollutants, generating further waste streams for disposal, plus large unit operation to treat the high gas volume	**Highly Dependent** on Pollution Controls (Similar to incineration, but lower gas volume to treat and lower NOx)	**Highly Dependent** on Pollution Controls Syngas requires further pre-combustion cleaning before use. ECS requirements scale dependent. Complicated with halides and dioxins and furans.	**Low Dependency** Pollutants are dealt with as part of the process, e.g., alkali metals remain with the biochar; tars and oils destroyed (deconstructed), syngas is wet scrubbed; so the resulting syngas is clean & ready for use. Downstream users of syngas do not require additional ECS.
Water Usage	**High** Evaporative cooling and make-up water for the steam system	**High** (Same as incinerators)	**Low** Water consumed for capture of bio-oils and indirect cooling	**Low** Make-up water for wet quench / scrubber only
Problematic Liquid Produced (Oils, Tars, Resins, Water)	**Yes** Boiler blow-down brine and evaporative cooling system purge water plus scrubber water (if a wet system is utilised)	**Yes** Up & down draft gasifiers generate tars plus spent scrubber water	**Yes** Alot of tar and oil by-products, reported beneficial wood vinegar, plus scrubber water	**No** All oils and tars destroyed. Only a small purge of water from the quench / scrubber to manage solids accumulation. This can be further evaporated to form a solid if required
Bottom & Fly Ash for Disposal *(Potentially Toxic Solid Waste)*	**Significant** Ash dam required, portion of the ash is super-fine	**High** Ash dam required	**No Ash** Ash remains with the biochar	**No Ash** Ash remains with the biochar, metals bound / not bioavailable.

Incineration Vs Gasification Vs Pyrolysis…Vs SEATA CTL

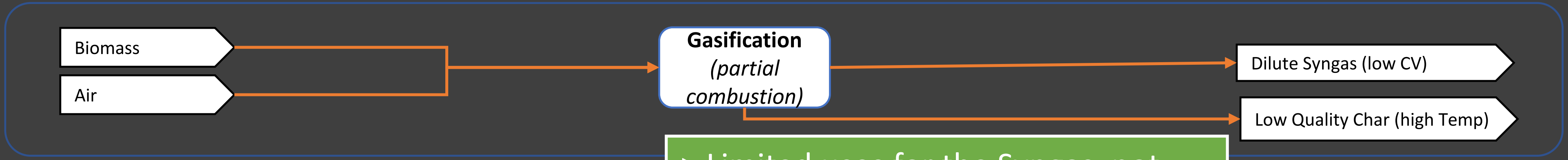
ECONOMIC PERFORMANCE Design Factors	Incineration* *(full combustion, high excess oxygen)*	Conventional Air-blown Gasification *(partial oxidation) (air-blown, high N_2)*	Conventional Pyrolysis *(low/no oxygen)*	SEATA Catalysed Pyrolysis & Partial Gasification via chemical looping *(indirect O_2 transfer from air, low N_2 in syngas)*
Economic Scalability & Throughput	**High** (>100's tph per module)	**Moderate** (10's tph per module)	**Low** (~1 tph per module)	**High** (5-40 tph per module current designs, with >100 tph possible in the future)
Target Application	Large Scale, centralised	Med scale centralised	Small scale decentralised	**Flexible small to large scale, central or decentral**
Energy Efficiency *(thermal energy available for other processes, i.e., generation of electricity)*	**Moderate** (50-60%), Using Rankine cycle	**Moderate** (40-65%) Two-stage combustion, plus Rankine cycle	**Moderate** (60%), **with C capture** High parasitic heat losses, only ~1/3 of the input energy available for combustion as syngas, syngas can use in combined cycle gas engines after further cleaning	**High** (70-80%), **with C capture** Lower heat losses due to scale of operation, higher process intensity, high proportion of clean syngas (~2/3 of the input feed) that is ready for use in gas engines, therefore combined cycle power generation possible
Technology Readiness	**Mature**, proven at scale	**Mature**, proven at scale	**Maturing**, proven at small scale	**Emerging** (TRL 6)
Parasitic Load Losses	**Moderate**	**Moderate**	**Moderate**	**Low**
Feedstock Moisture Content Capability *(Technical)*	**High**	**Moderate** Typically, 10-20%, max 50% feedstock pre-drying required	**Low** feedstock pre-drying to 10-20% required, as all heat transfer is indirect	**High** Typically, 20-30%, but can handle up to 70-80%, however net output energy is lowered
Linear Economy Vs Circular Economy	**Linear**	**Linear**	**Circular** (biochar & liquids, syngas for immediate energy only)	**Circular** (Full Potential) (biochar and storable syngas for derivatives/products OR energy on demand)
Feedstock Compatibility / Flexibility	**High**	**Moderate** Limited feedstocks and particle sizing is important	**Moderate**	**High** Good flexibility / versatility
Primary Reaction Temperature in commercial systems	**High** 800-1450°C	**Moderate** 750—1000°C (airblown)	**Low** 350-700°C	**Low** 350-700°C (primary reactor), all syngas from primary reactor treated to 850°C to achieve complete thermal decomposition of all volatile tars and oils.
Atmosphere	Air	Partial Air	Low /No Oxygen	Low Oxygen (O_2 supplied via chemical looping
Pressure (bar)	1	1-10	1	1 (and can be designed in future to be pressurised)
Stoichiometric Ratio	>1	<1	0	0 – 0.2
Principle Outputs (Products) *Products:*	**Heat & Combustion Products only**	**Lean Syngas**	**Char + Liquids + Rich Syngas (dirty)**	**Char + Rich Syngas (clean)**
Gases:	Combustion Products Only *(No Syngas)*	Combustible Lean Syngas	Combustible Rich Syngas	Clean Rich Syngas = economically recoverable products or energy, including energy on demand
Liquids:	No liquid products *(scrubber waste only)*	0-20% Liquid product, *(plus scrubber waste)*	Liquids (products & waste), *(plus scrubber waste)*	No problematic liquid products *(minor scrubber waste only)*
Solids:	High ash waste, No targeted products	Low char, High Ash waste (char <10% of feed by mass)	High quality but expensive biochar (~30% of feed by mass)	Low-cost, high-quality biochar (15-35% of feed by mass)
Principle Gas Components	**CO_2 and H_2O**, O_2, N_2 + Other gases e.g., SO_x, NO_x, etc.	**CO and H_2**, **N_2**, **CO_2**, CH_4, H_2O, + Other minor gases	**CO and H_2**, + hydrocarbons, H_2O, CO_2, CH_4 + Other minor gases including nitrogen compounds, dioxins and furans	**High purity H_2, CO, CO_2** No hydrocarbons dioxins & furans H_2 content >50% by volume.
By-Products / Waste *(throughput inefficiencies)*	Toxic bottom ash or slag to dispose, High volumes scrubber waste	Toxic Bottom Ash to dispose, High volumes scrubber waste	Tars, resins, oils, pyrolysis water (plus, syngas scrubber waste)	Minimal inert scrubber waste only. No Ash/Liquids (no tars, resins, oils)
CAPEX	**High** Due to extensive off-gas scrubbing requirements	**Moderate** Scalable with moderate off-gas cleaning requirements	**High** Due to limited reactor scale-up, requiring multiple units to achieve scale of operation	**Low to Moderate** Good scalability and low gas cleaning duty
OPEX	**Moderate** High cost for gas scrubbing reagents and disposal of the resulting waste streams	**Moderate**	**High** High maintenance and high number of operating personnel	**Low**

Existing Conventional Technologies:

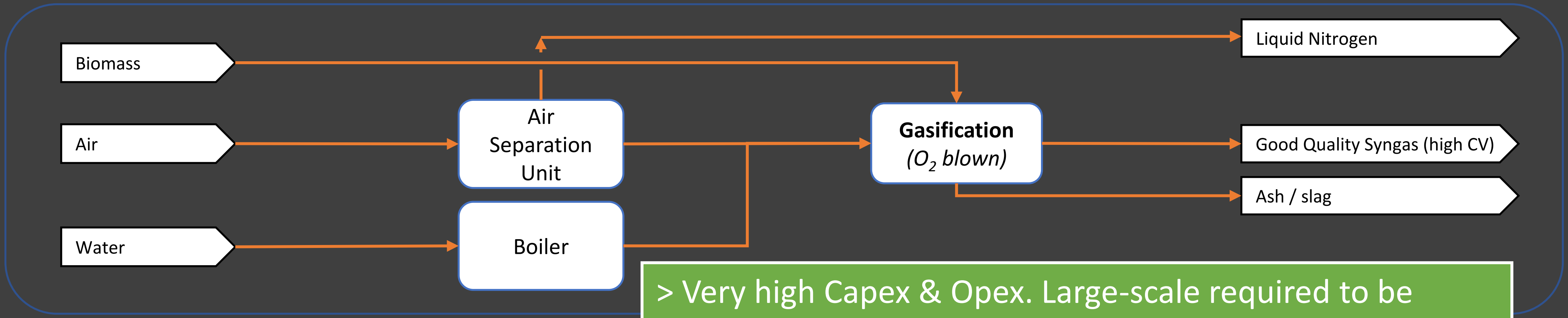




> Limited Scale-up, multiple units required, no economy-of-scale.
> Low yield to Syngas.

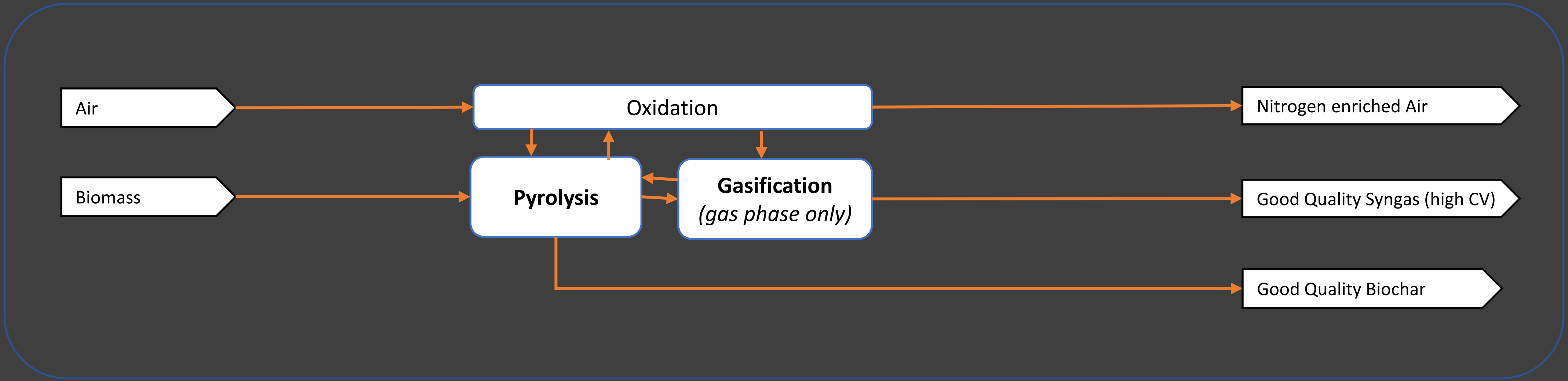


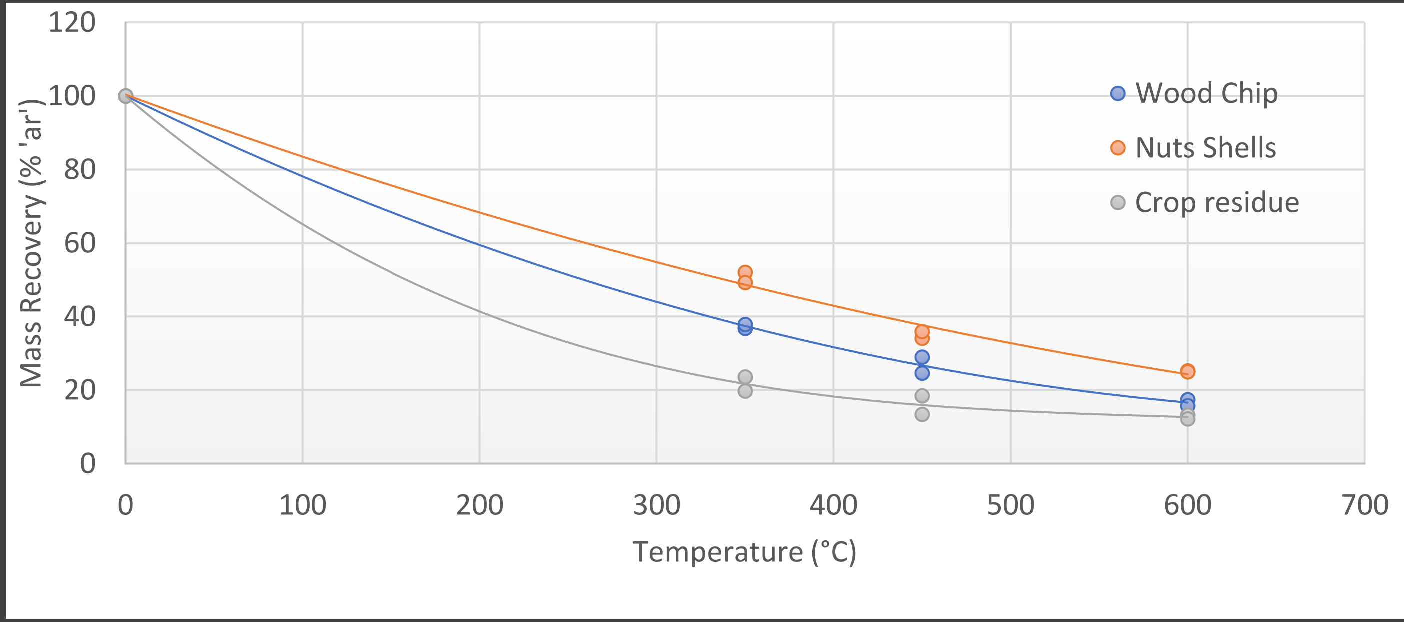
> Limited uses for the Syngas, not economic to separate H_2.



> Very high Capex & Opex. Large-scale required to be economic, therefore centralised operation.
* O_2 lost with C, adding 72% extra mass to sequester!

SEATA – Thermal + Chemical Looping (TCL)

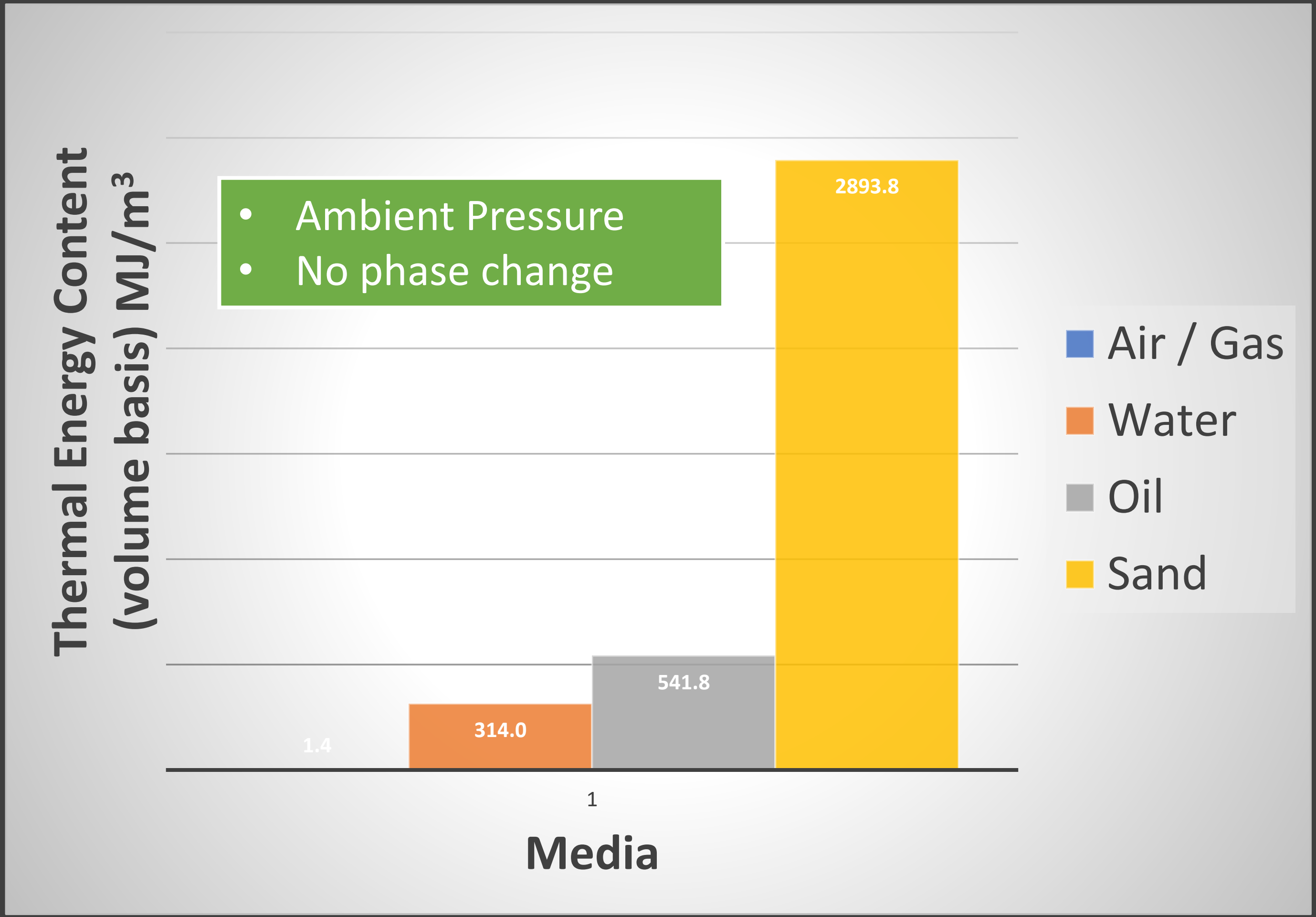




- High Quality Products, Syngas + Biochar.
- Scalable process design.
- Minimised energy consumption.
- Minimised syngas volume, Maximised concentration.
- Controllable Syngas composition.
- Syngas suitable for synthesis into methanol, F-T, methanation, etc.

Process Intensification:

Biomass feed rate = 1000 kg / h



Conventional Indirectly Heated Pyrolysis

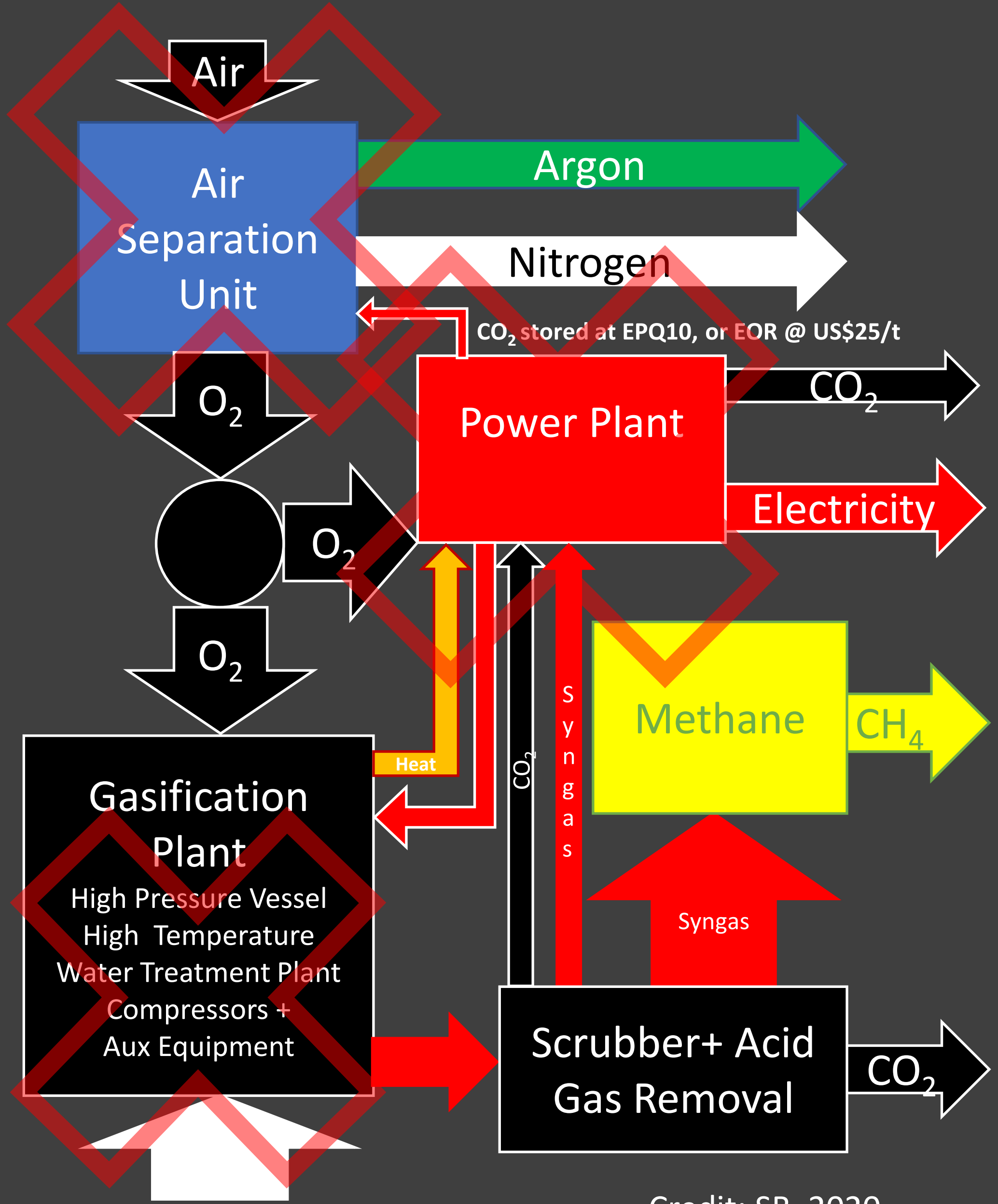
SEATA – Thermal + Chemical Looping equivalent (9 x increase)

SEATA vs Conventional Industrial-Scale Gasification Plants (including Methanation)

No expensive ASU + No Power Plant + No High Pressure

Chemical looping simplifies gasification

- Reduced Thermal Process Energy Losses
- No Air Separation Unit (ASU) - $$$ very high CAPEX
- No High Pressure Compressors
  - SEATA at atmospheric pressure
- No slag water quenching
  - No wastewater ('black water') treatment plant
- No Power Units
  - Low power consumption
  - Co-generation plant unnecessary



Credit: SB, 2020

Complementary/Synergistic with Conventional Technologies: Green & Blue Hydrogen & Conventional Renewables (solar/wind etc)

- **"Nature's Battery" - Night-time/dispatchable generation** optimizes CAPEX for integrated systems for **24/7 continuous generation**
- **CO_2 Removal** to assist genuine Net Zero for integrated systems with positive footprints.
- **Feedstock carbon for battery storage technologies** to support solar/wind renewables
  - **Sodium-Carbon Batteries –** potential to help turn desal brine wastes into *resources* to avoid ocean disposal ***(Zero Liquid Discharge)***
- **Biochar/H_2 to Enhance rNG/Biomethane production from Anaerobic Digestion (AD)**
- Potential to **further assist blue and grey hydrogen** (no $$ ASU unit needed, high purity CO_2 facilitates CCUS applications)
- **Additional Revenue streams** from co-benefit markets (carbon commodities & removal credits) to optimize CAPEX and OPEX
- **Potential for further emissions reduction and *displacement/avoidance* credits** (including via CCUS applications) in addition to providing carbon dioxide removal (CDR) credits via biochar.
- Provide additional "green" jobs, notably in rural and regional areas

Thankyou. Questions?

SEATA

Deconstructing the world's problems to create carbon negative solutions

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