# Energy and exergy analysis of Super-Critical Water Gasification (SCWG) cogeneration

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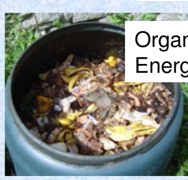
**Supported by**: Israel Ministry of National Infrastructure



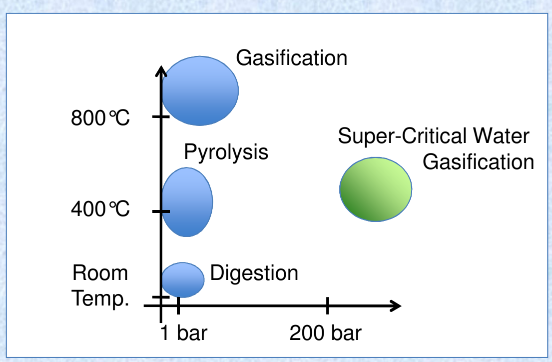


# Biofuels from Organic Matter

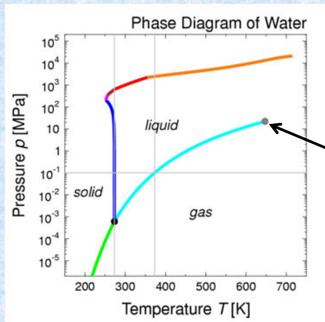


Heat (Solar) → Reactor → $H_2$, CO, $CH_4$

Organic waste, Energy crops → Reactor → $CO_2$ → Sequestration?



# Critical Water




**Critical point of water**:

$T_c = 374°C$

$P_c = 221$ bar

**Properties of SC water**:

Solvent for organic matter

Reactive

**SC Water Gasification (SCWG)**

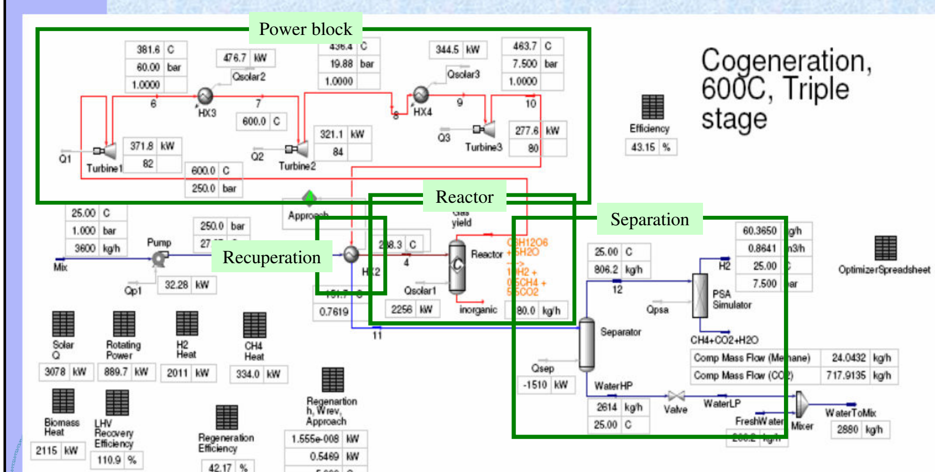
- Water as Carrier + Solvent + Reactant
- Complete conversion of organic matter
- Moderate temperature: solar heat
- Products at high pressure ➔ Mechanical energy





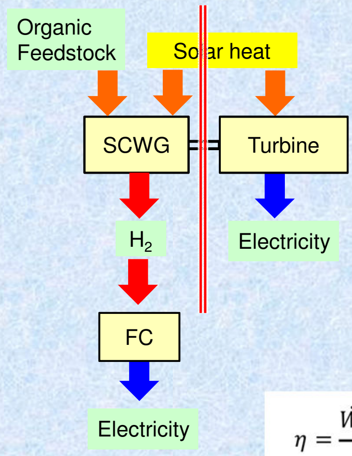
# Detailed Process Model

Developed in *UniSim Process Design* software (Honeywell)




$$C_6H_{12}O_6 + 5H_2O \rightleftharpoons 10H_2 + 0.5CH_4 + 5.5CO_2$$

# Cogeneration vs. Superposition




**Inputs:**
Heat
Biomass = Heat
**Outputs**:
Turbine work = Electricity
$H_2$ into FC = Electricity

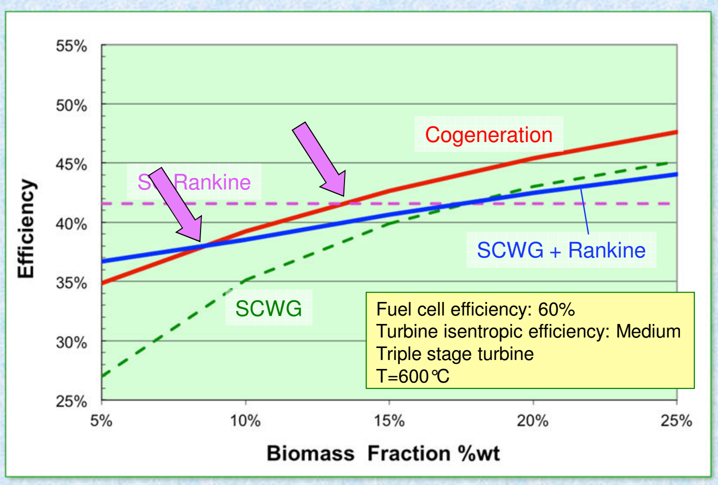
**Comparison:**
Equal inputs (biomass, heat)

$$\eta = \frac{\dot{W}_T \cdot \eta_{gen} - \dot{W}_C + \dot{m}_{H_2} \cdot LHV_{H_2} \cdot \eta_{FC}}{\dot{Q}_{React} + \dot{Q}_T + \dot{m}_{Org} \cdot LHV_{Org}}$$





# Efficiency vs. Biomass Fraction




High cogeneration cycle efficiency: up to **48%**

# Exergy Analysis

Exergy ≈ Potential to perform work (=electricity)

Exergy destruction ≈ Irreversibility
≈ Entropy generation

$$\dot{E}_d = \sum_j \dot{m}_j \left(h_j - h_{j0} - T_0(s_j - s_{j0}) + e_{ch}\right) + \sum_j \dot{Q}_j \left(1 - \frac{T_0}{T_j}\right) + \sum_j \dot{W}_j$$

In/out advection of exergy Physical / Chemical — Exergy in/out via Heat — Work in/out

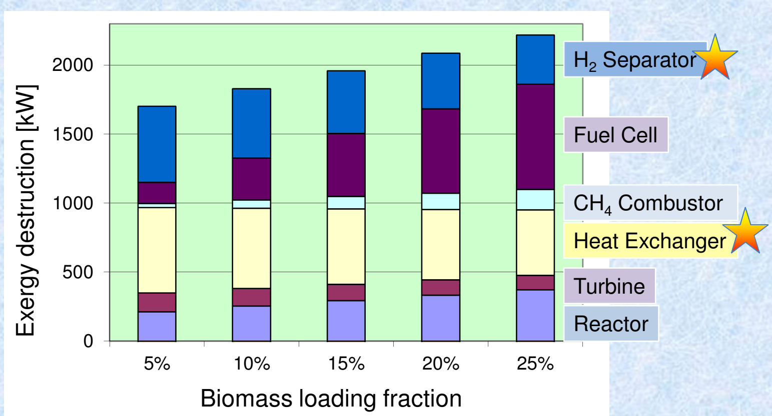
**Procedure**:
Simulate cycle, generate $h$, $s$, $T$, $Q$, $W$ at each point
Define each component as control volume
Perform exergy balance, compute $E_d$





# Exergy Results

Exergy destruction in main cycle components



# Exergy Destruction

**Pressure Swing Adsorption** (PSA):

Inlet pressure: 7 bar


❖ Inlet gas contains significant exergy

≈ Potential of turbine work is lost

➔ Seek separation at low pressure

**Heat Exchanger** exergy destruction

*ΔT* turbine exit – reactor inlet

Expansion to lower pressure in turbine:

➔ Lower temperature at exit

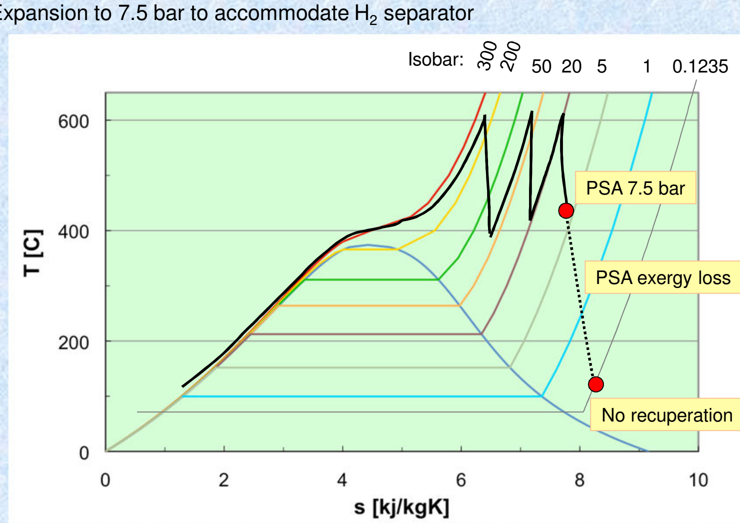
➔ Lower potential for recuperation



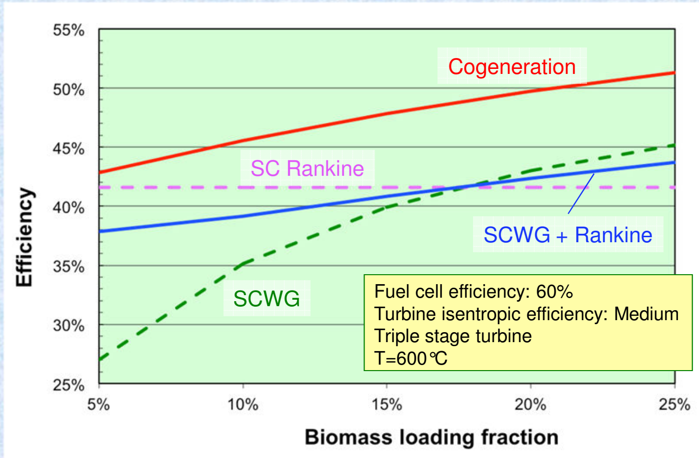


# Limited Expansion Effect

• Expansion to 7.5 bar to accommodate $H_2$ separator



# Full Expansion: Efficiency




- Higher cogeneration cycle efficiency: up to **51%**
- No threshold biomass fraction



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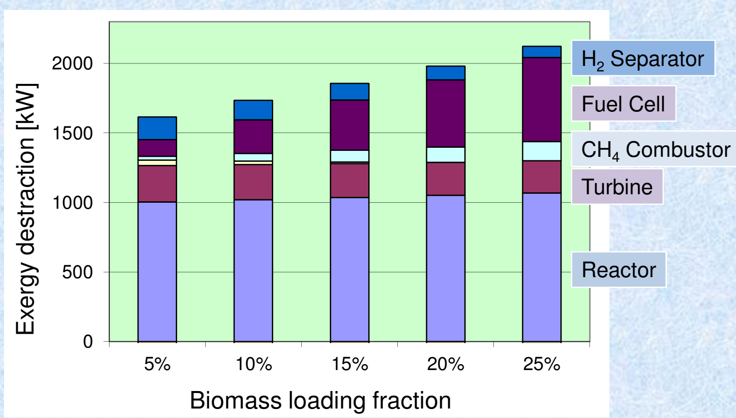
# Full Expansion: Exergy




**Total destruction** lower by 8–12%

**Heat Exchanger**: negligible; **Separator**: small

**Reactor**: Due to constant temperature heat source (600°C)
Reduced if heat source is sensible heat

# Conclusions

**Promising theoretical efficiency**:

Partial expansion: up to **48%** heat to electricity at **≤ 600℃**

Full expansion: up to **51%** efficiency

With better turbine: up to **54%** efficiency

**Exergy analysis**:

Partial expansion: High exergy destruction in Separator + HX

Full expansion: exergy destruction reduced 8 – 12%

**Technology Challenges**

- Gasification chemistry and reactor engineering
- Receiver / reactor at very high pressure
- Tailoring SC turbine to SCWG product mixture
- Separation at low pressure

**Implementation Challenges**

- Cost and complexity