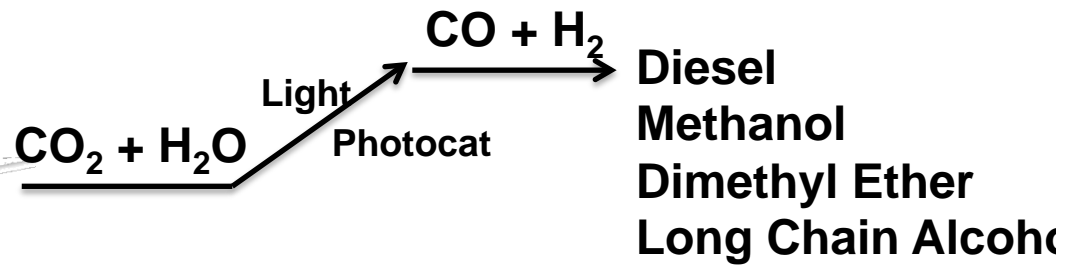
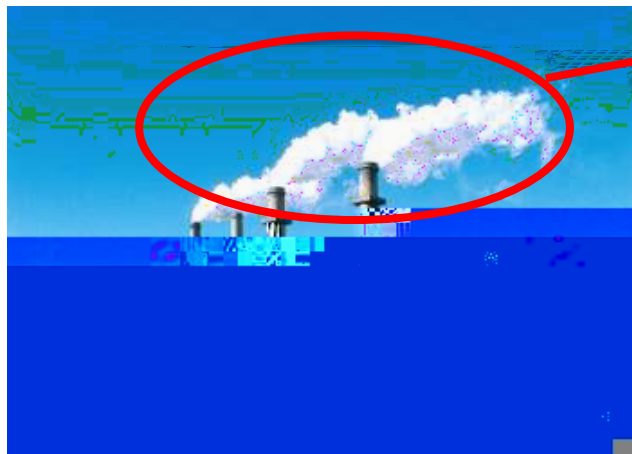
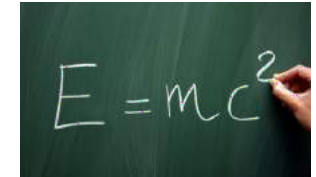
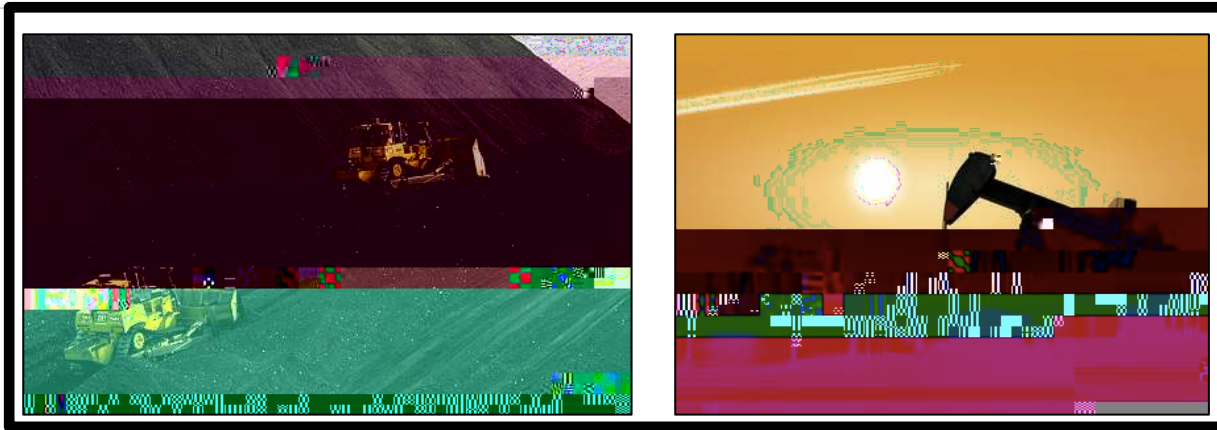




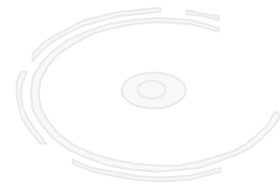


CO₂ - Birth, Death, and Reuse















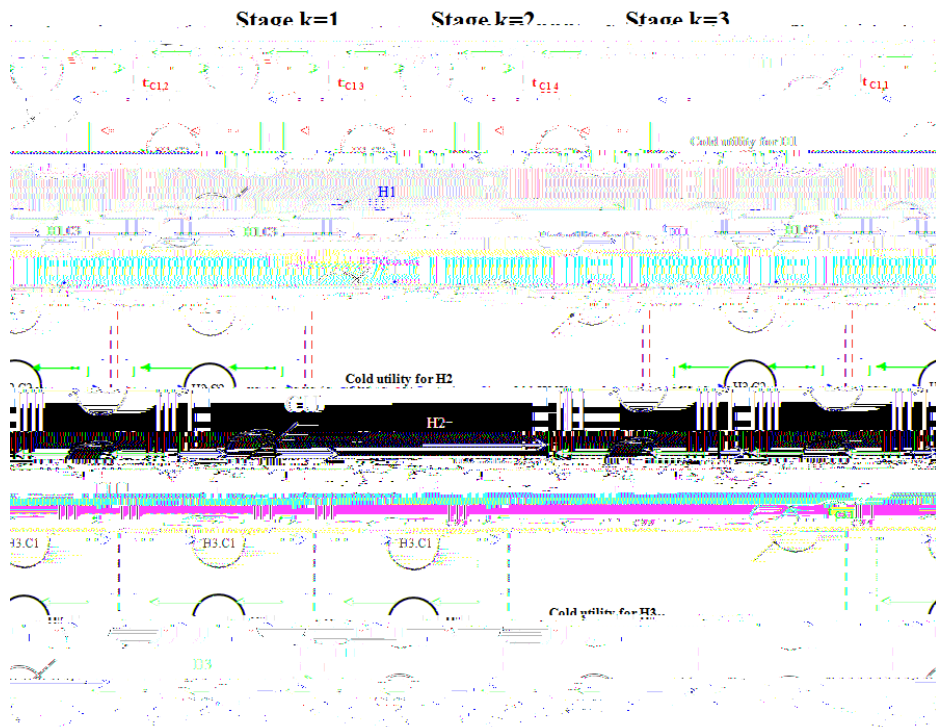


Transshipment model (Utility Cost)

Transshipment Model



Energy usage before heat integration		Energy usage after heat integration	
streams	Amount (kW)	streams	Amount (kW)
C1	12047	C1	1331
C2	14660	C2	8766
C3	10574	C3	0
H1	14208	H1	1550
H2	32975	H2	18697
H3	9637	H3	9396
% energy savings		57.8	



Three stage superstructure in MINLP model (Capital Cost)

Minimizing:

Utility cost ←

$$\text{Min} \quad \sum_{m \in HU} c_m Q_m^{HU} + \sum_{n \in CU} c_n Q_n^{CU} +$$

Fixed charges for the exchangers ←

$$\sum_{i \in HP, j \in CP, k \in ST} CF_{ij} z_{ijk} + \sum_{i \in HP, n \in CU} CF_{i,n} z_{cu_{i,n}} + \sum_{j \in CP, m \in HU} CF_{j,m} z_{hu_{j,m}} +$$

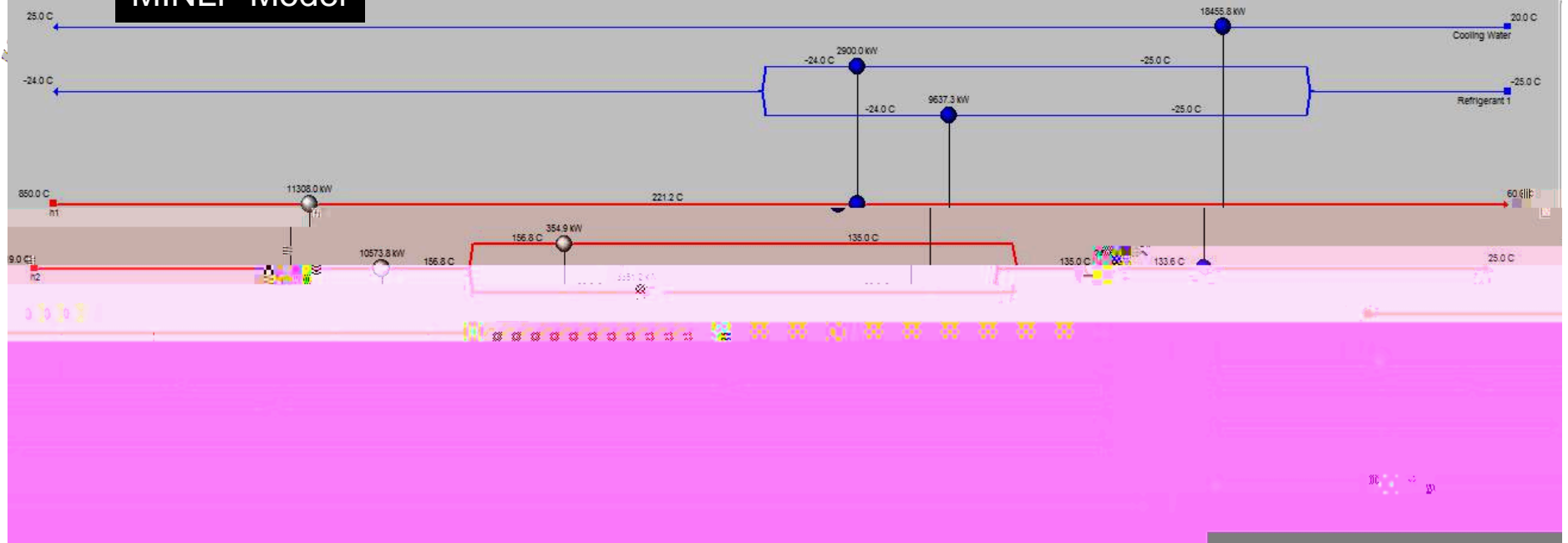
Area cost for each exchanger ←

$$\sum_{i \in HP, j \in CP, k \in ST} C_{ij} \frac{q_{ijk}}{U_{ij} \frac{dt_{ijk}}{dt_{ijk+}} \frac{dt_{ijk+}}{dt_{ijk} + dt_{ijk+}} -}^{B_{ij}} +$$

$$\sum_{i \in HP, n \in CU} C_{i,n} \frac{q_{cu_{i,n}}}{U_{i,n} \frac{dt_{cu_{i,n}}}{TOUT_i \# TIN_n} \frac{dt_{cu_{i,n}} + TOUT_i \# TIN_n}{-}}^{B_{i,n}} +$$

$$\sum_{j \in CP, m \in HU} C_{j,m} \frac{q_{hu_{j,m}}}{U_{j,m} \frac{dt_{hu_{j,m}}}{TIN_m \# TOUT_j} \frac{dt_{hu_{j,m}} + TIN_m \# TOUT_j}{-}}^{B_{j,m}}$$

MINLP Model



Energy usage before heat integration		Energy usage after heat integration	
streams	Amount (kW)	streams	Amount (kW)
C1	12047	C1	11448
C2	14660	C2	0
C3	10574	C3	0
H1	14208	H1	2911
H2	32975	H2	18455
H3	9637	H3	9637
% energy savings		54.9	





Developing Nanoparticle Catalyst



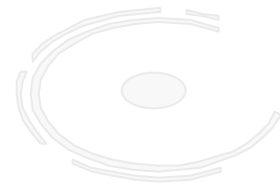
Synergism between active metal and support

Oxygen vacancies within support

Adsorption of hydrogen by active metal

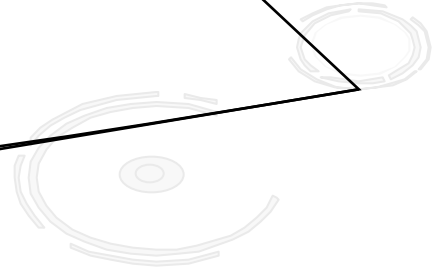














Band Gap Determination

