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Steam Hydrogasification Research Overview

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Content

1. *Background of Gasification and GTL*
2. *Introduction to the Steam Hydrogasification Reaction*
3. *Applications/ Projects for Steam Hydrogasification Reaction*

What is Gasification Process ?

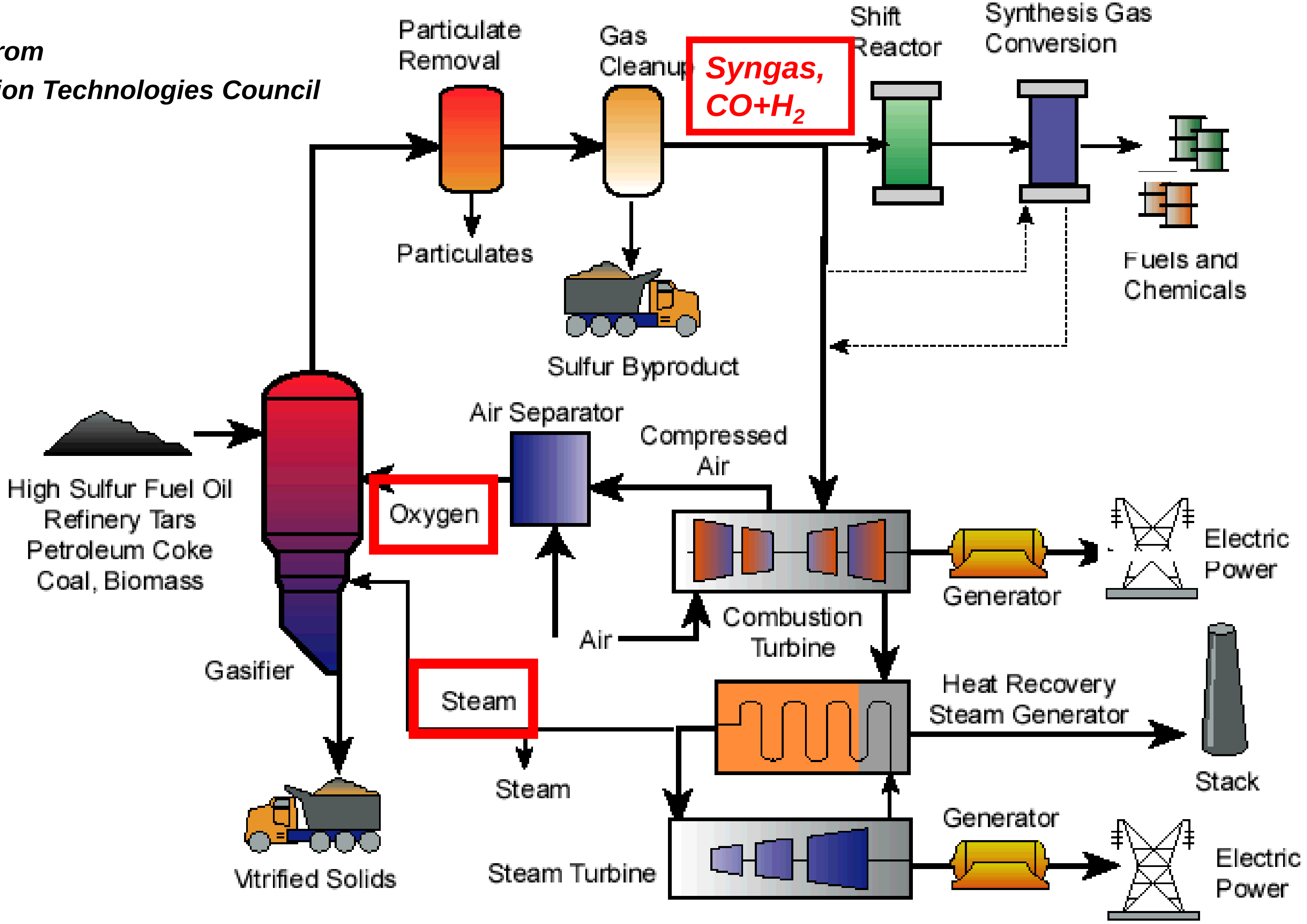
– A thermo-chemical process converts any carbon-containing material into a synthesis gas, usually via partial oxidation (POX) reaction.

- $C_xH_yO_z$ + Oxygen → $CO_2 + H_2O$: Combustion
- $C_xH_yO_z$ + less Oxygen → $CO + H_2$: POX

– The synthesis gas can be used as a fuel to generate electricity(IGCC) or used as a feedstock for synthetic fuel or chemicals (GTL Process)

Typical Gasification Technology with Fuel or Electricity production

•*Quoted from*
Gasification Technologies Council



Hydrogasification Process

$$C_xH_yO_z + 2H_2 \rightarrow CH_4 + Others$$

- Gasification in Hydrogen Environment
- Used for SNG production from coal and biomass since 1930s.
- Internal hydrogen supply thru water gas reaction of the char or steam methane reforming of the product gas
- Requires high pressure (~100atm) or catalyst.
  →Lack of commercial success or interest.

Steam Hydrogasification Process (SHR)

- The most unique feature of SHR is the introduction of water to reaction scheme

$$C_xH_yO_z + H_2O + 2H_2 \rightarrow CH_4 + H_2O + others$$

$$Others: CO, CO_2, C_{2+}$$

- Effect of steam on the hydrogasification of carbon had not been studied extensively
- Our initial research found that addition of water

  →Increased the reaction rate

  →High efficiency at lower temperature

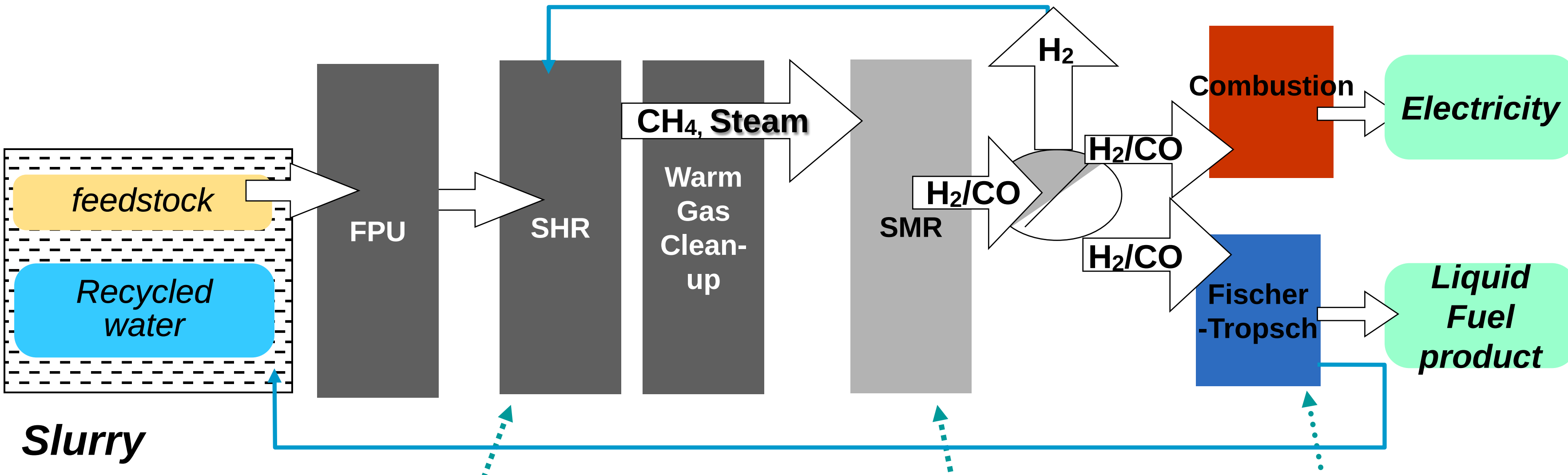
  →High efficiency at lower pressure

Advantages of Steam Hydrogasification Process (SHR)

$$C_xH_yO_z + H_2O + 2H_2 \rightarrow CH_4 + H_2O + CO, CO_2, C_{2+}$$

- **Process can handle wet feedstock w/o drying.**
  - Utilize a high pressure slurry pump to reduce costs
- **No expensive oxygen plant required**
  - Process is suitable for smaller scale, distributed facilities (ideal for biomass/waste, coal/biomass feedstock)
- **Can control slurry feed for desired synthesis gas product distribution**
  - Carbon, Water, Hydrogen input ratio
  - Does not require the Water-Gas Shift Process

CE-CERT Process



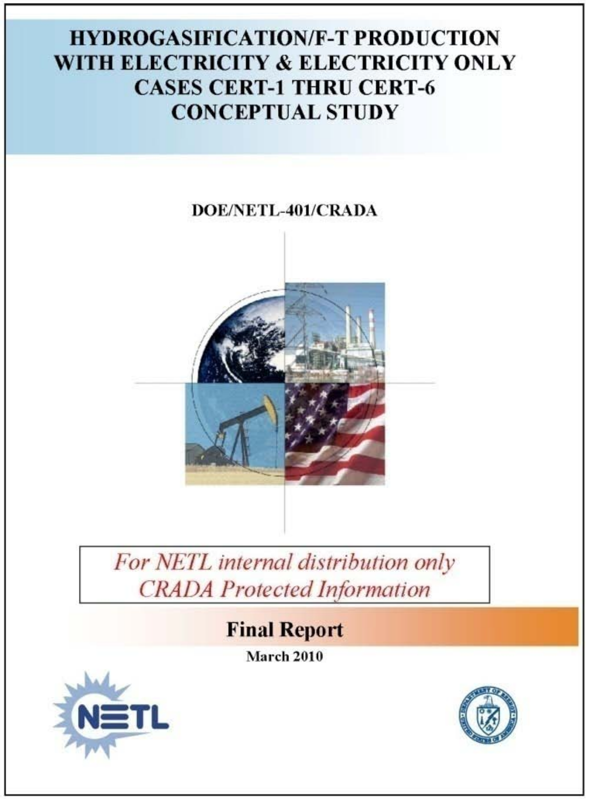
$$C + \mathbf{H_2O} + 2H_2 \rightarrow CH_4 + \mathbf{H_2O} + CO, CO_2, C_{2+}$$

$$CH_4 + \mathbf{H_2O} + CO, CO_2, C_{2+} \rightarrow 3H_2 + CO, + CO_2$$

$$2.1H_2 + CO \rightarrow C_{16}H_{34}(l) + H_2O(l)$$

SHR – Steam Hydrogasification Reactor, SMR – Steam Methane Reformer

Process Reviewed by DOE/NETL



- Since 2007, For the Independent Review of the Process
- Verify the flow-sheet for the several different cases
- Estimate TPC (Total Project Cost) and perform economic analysis

Their conclusion is that the CE-CERT process has 12 % higher efficiency with 18 % lower capital cost than the most up-to-date conventional mainstream gasification technologies.

Laboratory Bench Scale SHR, 1lb/ hour

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PDU scale Fluidized Bed Reactor

10 lb/ hr

Funded by PIER project from California Energy Commission (CEC)

(Demonstration of Syngas Production from Biosolid-Biomass)

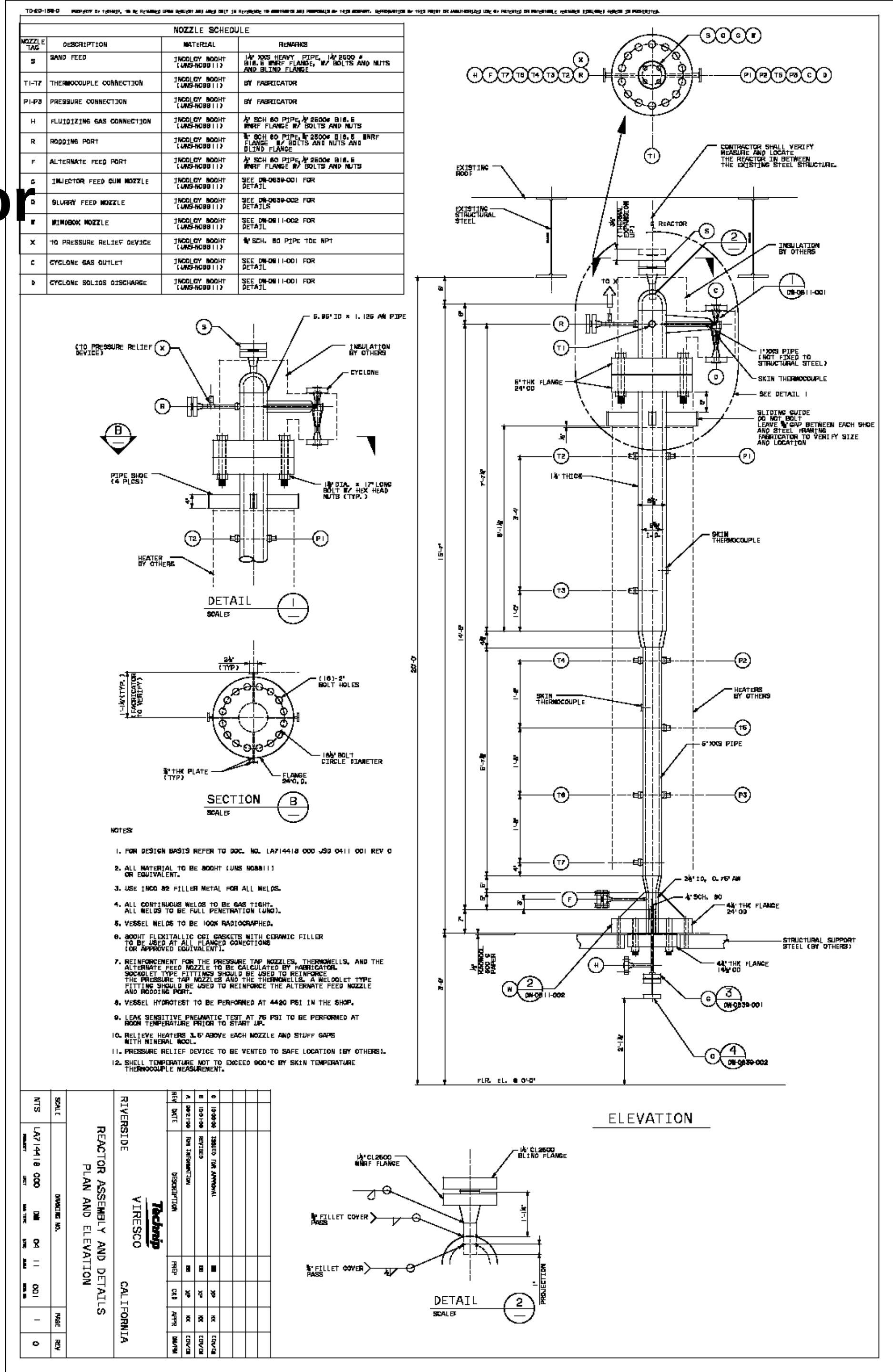
Period Oct. 09 – Sep.11

4/6/8 " OD x 22' height

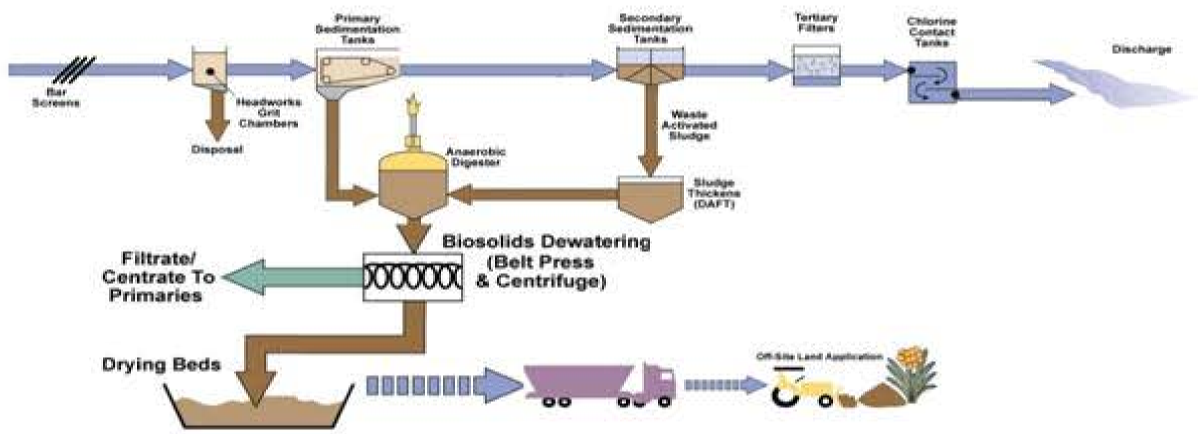
iHT800, 150 psi/825C

~20 sec gas residence

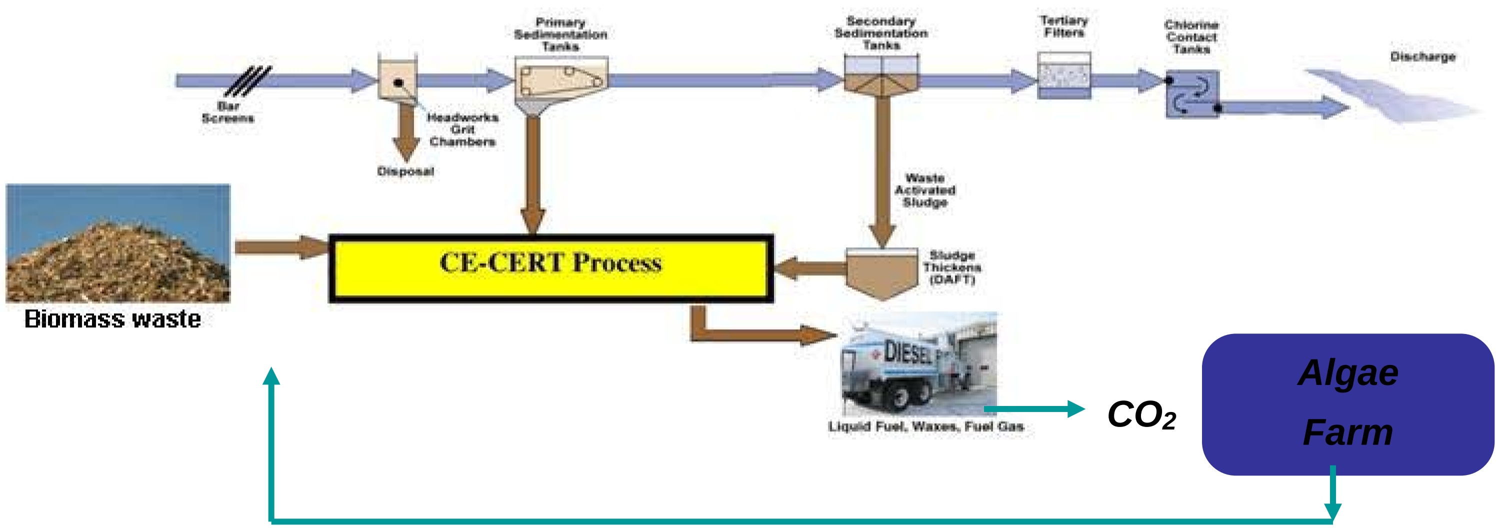
Time @ 1ft/sec v



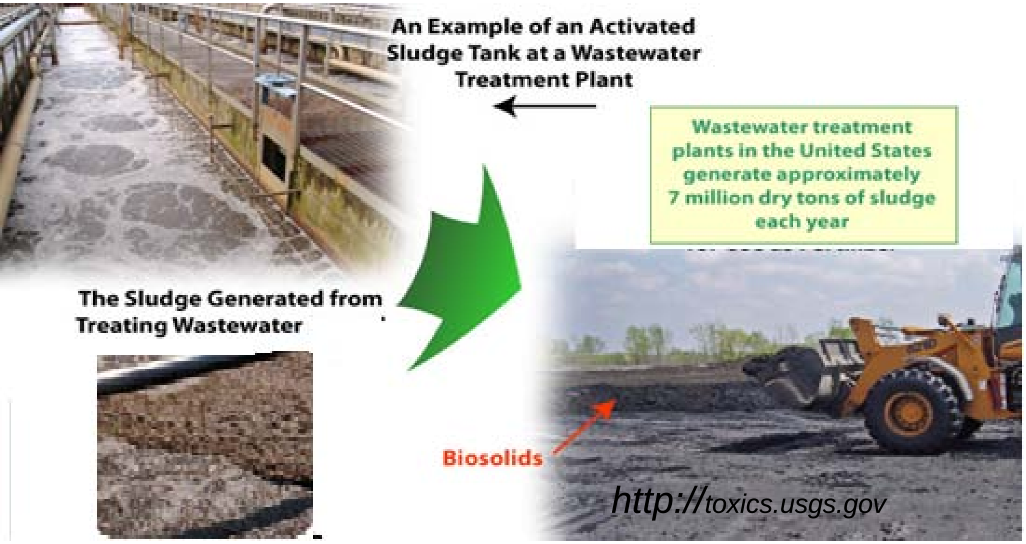
1. Current Process for the Municipal Waste Water Treatment

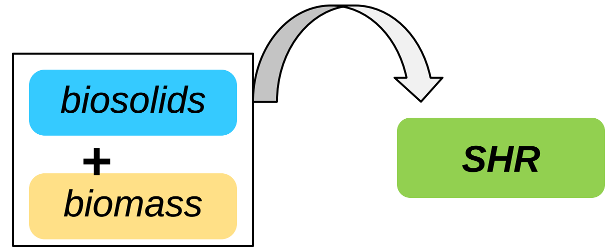


2. Suggested Process with Hydrogasification (CE-CERT process)



Co-mingling of biomass and biosolids





Biosolids samples (DAFT ,Dissolved Air Floatation Thickener after the secondary sedimentation treatment) are from Riverside Regional Water Quality Control Treatment Plant

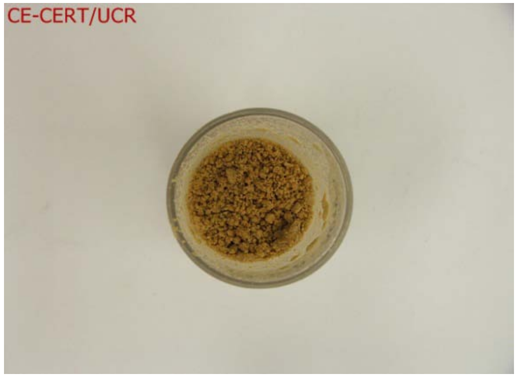
Table1 Proximate and Ultimate Analysis of biomass(pinewood) and biosolids

Analysis	Compound	pinewood	Biosolids
Proximate (wt%)	Moisture	5.65	92.9
	Volatile matter	81.52	4.9
	Fixed carbon	12.58	0.6
	Ash	0.25	1.6
Ultimate (dry basis (wt%)	C	47.56	40.8
	H	6.31	6.22
	N	0.05	7.47
	O	45.81	23.14
	Balance*	0.27	22.37

Balance includes other elements eg, S,Cl, metals

Feedstock Pretreatment Unit (FPU)
by Hydrothermal Reaction to produce Pumpable Slurry

Before



After

Initial studies

Figure 3 Carbon conversion of SHR in lab scale batch reactor at 700^0C

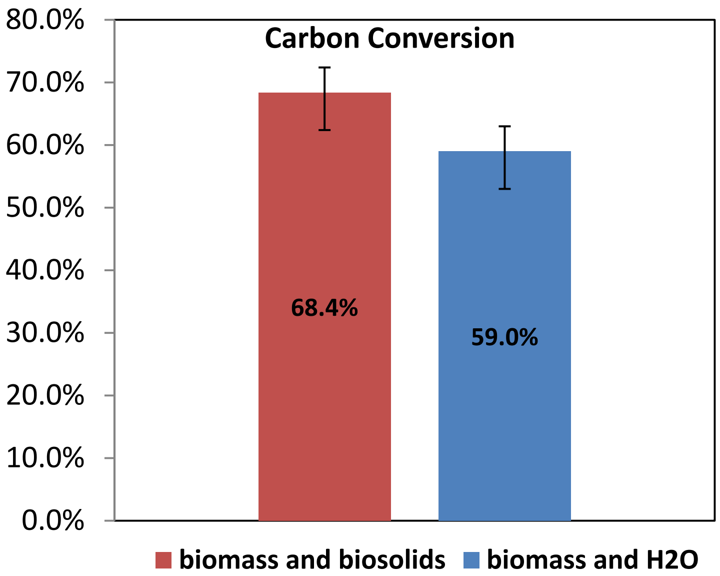
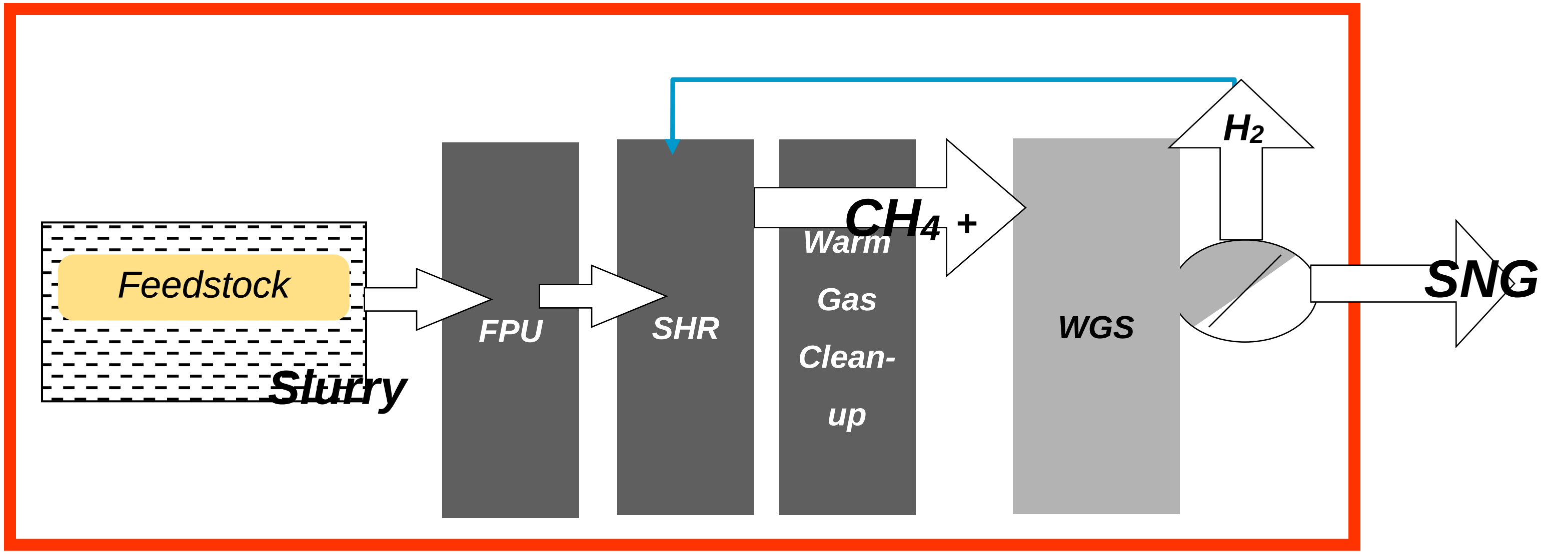


Table3. *Metal elements in biosolids (DAFT)*

Metal Element	Concentration Mass (ppm)
Iron (Fe)	14770
Calcium (Ca)	11440
Aluminum (Al)	3200
Magnesium (Mg)	1620
Potassium (K)	1620
Titanium (Ti)	1010
Sodium (Na)	690
Zinc (Zn)	400
Copper (Cu)	360
Manganese(Mn)	178
Strontium (Si)	100
Bismuth(Bi)	16
Nickel(Ni)	9

It has been speculated that the enhanced conversion efficiency may be the result of a catalytic action in the SHR caused by the metal species in the biosolids.

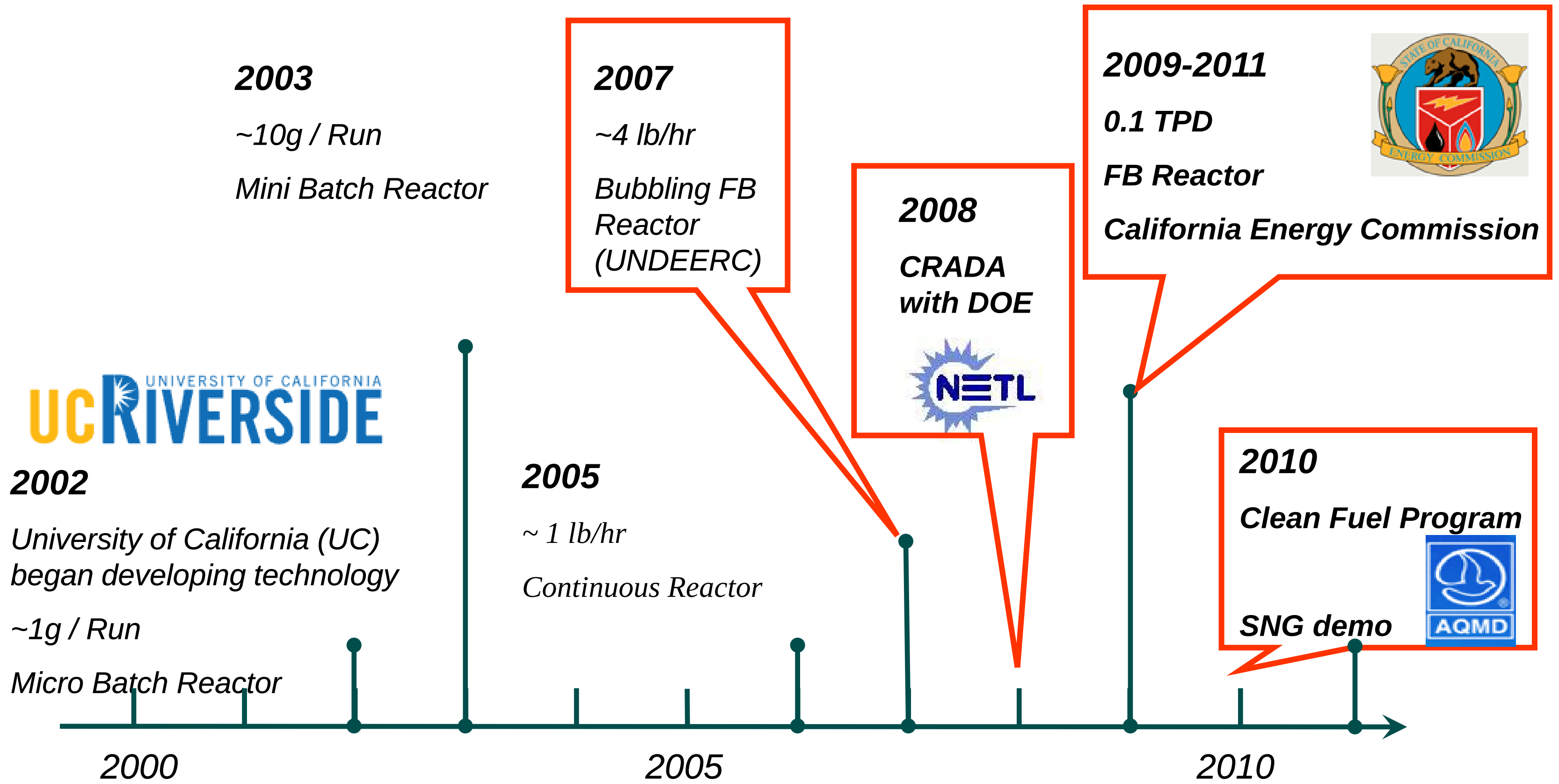
Alternative Process for the SNG Production



- DOE SBIR Research
  - High ash, moisture Lignite feedstock
- AQMD Clean Fuel Program
  - Co-mingled Biomass+ Biosolid

IP & Publications

1. **Patents**
   - Total 13 application since year 2002
   - 4 Patents awarded
   - In Year 2009, 1 new process patent applications
2. **Publications**
   - Total 6 Pier Reviewed Paper Published
   - In Year 2009, 1 Published, 3 in preparation.
   - 4 Conference Presentations
3. **Students/ Staff**
   - 2MS and 1 PhD in 2009
   - 9 PhD Applicants.
   - 2 Full Time Engineers
   - 2 Visiting Scholars


2003
~10g / Run
Mini Batch Reactor
2007
~4 lb/hr
Bubbling FB Reactor (UNDEERC)
2008
CRADA with DOE
NETL
2009-2011
0.1 TPD
FB Reactor
California Energy Commission
UC RIVERSIDE UNIVERSITY OF CALIFORNIA
2002
University of California (UC) began developing technology
~1g / Run
Micro Batch Reactor
2005
~ 1 lb/hr
Continuous Reactor
2010
Clean Fuel Program
SNG demo
AQMD
2000
2005
2010

Thank you, Question?

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Major Plant Parameters

	CTL w/ CE-CERT Process (CERT-2)	CTL w/ Conventional Entrained type Gasifier
Input	4000 TPD CTL Plant	3707 TPD CTL Plant
Out	107 MW electricity 7143 BPD (2.8 BPD/Metric Ton of Coal)	10.3 MW electricity 7143 BPD
HHV η	53.4%	47.6%
TPC/ TCR	$1,026 MM/$1,512 MM (Jan. 2008 $)	$1215 MM/$1,764 MM
IRR*	17% (@ $38/T) 20% (@ $18/T)	7% (@ $38/T) 12% (@ $18/T)

**By Power Systems Financial Model prepared for NETL by Nexant, Inc*

15%, interest rate, $2.69 /gallon of diesel, 4% IRR for CERT-1