SWEATT

Solid Waste to Energy by Advanced Thermal Technologies

and

Making Gas

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ICAAS

Interdisciplinary Center for Aeronomy and other Atmospheric Sciences

- 1963 Optical remote sensing began at UF when AG joined and applied remote sensing to the detection of air pollutants.
- 1964 Used adaptations of techniques developed in anti-missile R&D at General Dynamics-Convair (Swords to Plowshares!)
- 1970 ICAAS formalized as campus wide center
- 1980 Clean Combustion Technology Laboratory (CCTL) added
  - focused on Alternatives to Oil for utilities.
- 1986 Energy prices down; CCTL began focus on Waste and Biomass to Energy
- 1988 National Energy Innovation Award

  Florida Governor's Energy Award

UNITED STATES
DEPARTMENT OF ENERGY

Award for Energy Innovation-1988

Presented to

University of Florida-
Sunland Training Center
Clean Combustion
Technology Laboratory

for a distinguished contribution to our Nation's energy efficiency

Secretary of Energy

October 7, 1988
Date

DOE F 6200.7
(9-88)

STATE OF FLORIDA GOVERNOR'S ENERGY OFFICE

Governor's Energy Award

Presented to

Professor Alex E. S. Green
Clean Combustion Technology Laboratory
University of Florida

For innovative leadership in Energy Conservation

Governor

October 1988
Date

SAVE IT, FLORIDA

Recent guest editorials in Gainesville Sun advocating co-utilization of waste and biomass with natural gas.

THE COMMENTATORS

Looming oil crisis may be our generation's Pearl Harboi

ALEX GREEN

Japan's surprise attack on the United States fleet at Pearl Harbor 65 years ago propelled the United States into the greatest war in human history. The attack basically was an attempt to destroy the only naval force that could stop Japan's takeover of the oil fields of the Dutch East Indies and Malaya.

To fuel their brutal 1937 expansion southward from Manchuria into mainland China, Japan had to import oil. Then in early 1941, in efforts to slow Japan's takeover of the Asian continent, the United States, Britain and Dutch authorities imposed embargoes on oil shipments to Japan. This plus Japan's joining a Tripartite with Fascist Germany and Italy cast the die that thrust us into WWII.

At that time I was a graduate student at Cal Tech but soon became involved in an aerial gunnery related project. In 1944, after induction into the Army Air Corp, my gunnery expertise led to my assignment to 20th Bomber Command in the China Burma India combat theater to assess the performance of General Electric's B-29 remote controlled gunnery system. Following a careful analysis, I gave GE a passing grade but suggested to our gunnery officers a better way to use the gun sight in frontal attacks that proved effective.

In my next assignment, a response to a problem posed by the Navy, I proposed using the B-29 gun sight, together with a special slide rule computer to measure the length of warships seen by our B-29 reconnaissance crews in their over water flights. This aid to ship identification led to my participation on March 12, 1945, on a reconnaissance mission that found most of the then surviving Japanese fleet. Some 77 warships were in Hiroshima Bay and Kure Anchorage, anchored for lack of oil. While in their sight, we consumed so much fuel fighting a 190 mph headwind (later called the jet stream) that we could not make it back to any B-29 base. Miraculously, our pilot managed to land our B-29 at a 14th AF fighter field still held by our Chinese allies that was barely within our fuel range.

Following our sighting, the Hornet and the Wasp sank almost half the 77 immobile Japanese warships where we found them. Shortly after this mission, I was transferred to 21st Bomber Command, on Guam, where as my first task I developed a slide rule computer for flight engineers to better calculate their fuel consumption. By August 1945, almost every B-29, including the Enola Gay, had one of these slide rule computers to help avoid running out of gas.

Tribune Media

At this time it is the United States that is running out of liquid as well as gaseous fuels. We now import some 60 percent of the oil we consume in our transportation sector, and over 15 percent of the natural gas we consume in our residential, industrial and utility sectors. The United States is well endowed with solid fuels that, unfortunately, cannot be used in the efficient engines that have been developed since WWII (jet engines, advanced diesels, fuel cells, etc.).

A number of industrial and government organizations are addressing the economic and technical problems of converting coal and petroleum coke to liquid and gaseous fuels. However, these feedstock are under a "cloud" because of their carbon dioxide-greenhouse impacts and other environmental impacts.

Fortunately, the United States annually has around 2 billion dry tons of solid waste, mostly CO2 neutral biomass, that could contribute some 10 times more to our primary energy supply than it currently does. Now posing disposal problems, the conversion of this solid waste into substitutes for oil or supplements to imported and expensive natu would create goo exportable jobs, an industries.

Converting solid fu more useful liquid and fuels is still at the cutt of technology. Thus, and development on f version is the most energy need of the States today. Of the twc conversion approaches chemical conversion (temperature) generally best with dry solid wa bio-chemical conversi microbes) works best v waste.

We can lower our i other imports by conse going "green" with re bicycling and energy ef while saving landfill sp can approach zero wa substantially reduce c imports by learning how vert the solid fuels we what we mostly need and gaseous fuels.

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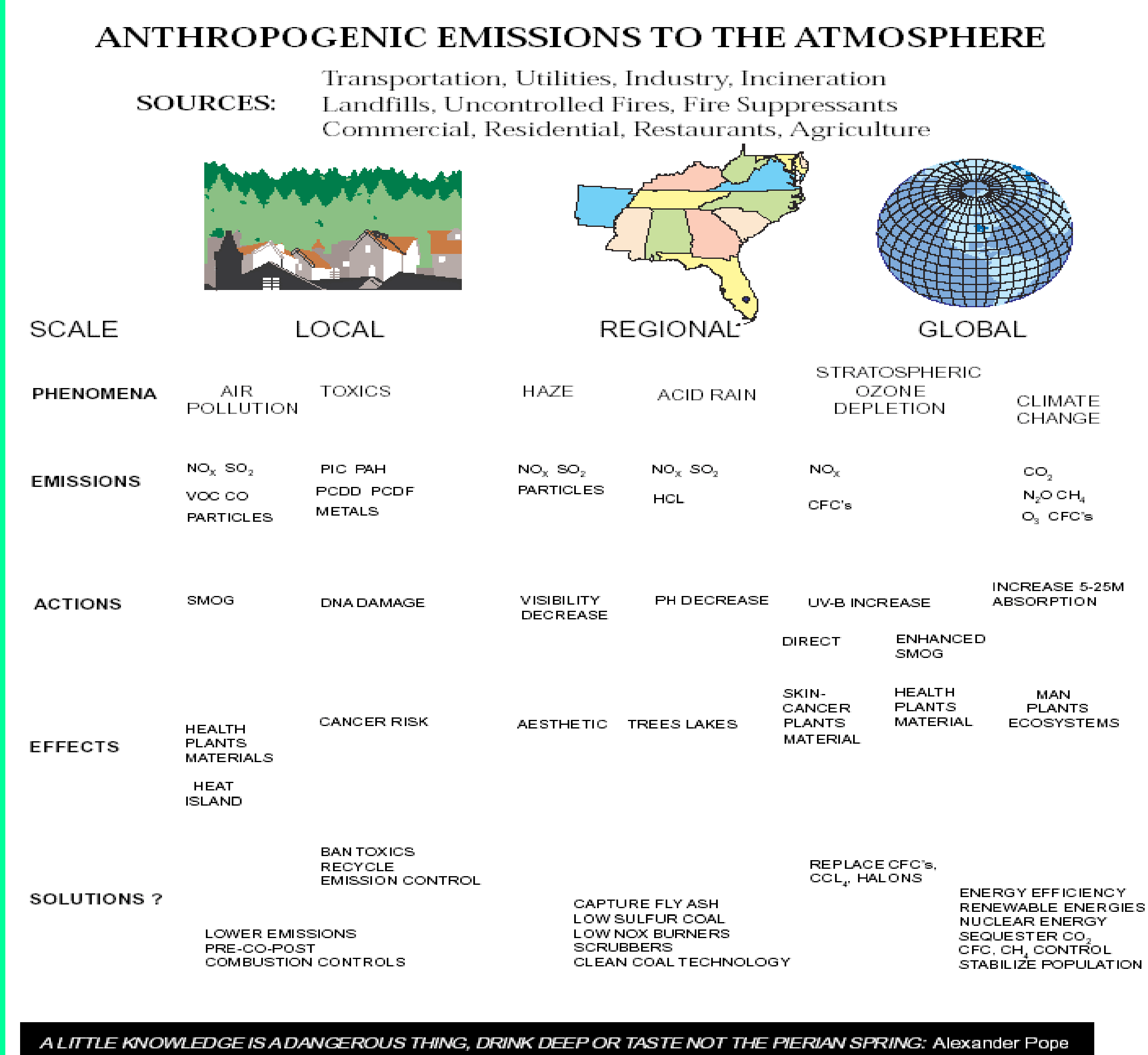


Figure 1: Anthropogenic emission problems,, and possible solutions. [A. Green Ed. Coal Burning Issues, 1980; Greenhouse Mitigation FACT-ASME, 1989].

The nuclear part goes back 50 years when AESG served as the advisor to Governor LeRoy Collins for his special 1957 \$5.3 M nuclear appropriation for UF's reactor and Nuclear Science building, FSU's Van de Graff and FA&M's radiation studies.

\$5.3 M 1957 = \$ 40 M 2007

STATE OF FLORIDA
OFFICE OF THE GOVERNOR
TALLAHASSEE

LEROY COLLINS
GOVERNOR

March 11, 1957

Dr. Alex E. S. Green
Physics Department
Florida State University
Tallahassee, Florida

Dear Dr. Green:

Thank you so much for the copy of your text, "Nuclear Physics," and the inscription, which means a great deal to me.

While I must confess the equations and graphs frighten me, I do understand something of what they mean in terms of the splendid work you are doing and for which we in Florida are grateful and proud.

With warmest personal regards, I am

Sincerely,

LeRoy Collins

Governor

LC/pbm

7) The CITATION FOR ALEX E. S. GREEN , Outstanding Scientist of Florida, 1975. The third paragraph is: "Dr. Green came to Florida State University in 1953 and soon became an advisor to Governor LeRoy Collins who then arranged legislative appropriations for nuclear research and development out of which grew the Van de Graaff program at Florida State University and the reactor program at the University of Florida".

A Board of Control action with great impact

$5 Million In Nuclear Research To Be Asked

FSU Voted $2.3 Million For Program

GAINESVILLE (AP) — The 1957 Legislature will be asked for more than five million dollars to launch a program in nuclear studies and research at state supported universities.

The Board of Control voted yesterday to ask $2,800,000 for the University of Florida; $2,300,000 for Florida State University; and $65,000 for Florida A&M University.

In addition, the board will ask $35,000 to pay consultants and expenses of an interinstitutional faculty committee on nuclear studies and research.

Although there had been rumors in Tallahassee that selection of a successor to Dr. Doak S. Campbell as president of Florida State University might come up, it was not discussed at the board meeting. Members of the board have had almost nothing to say about the position since Dr. Campbell announced his retirement, but have been conducting a search for a new president. The choice will be made jointly with the Cabinet Board of Education.

SCIENTISTS STUDY

Dr. Broward Culpepper, executive director of the board, told members that three leading nuclear scientists studied the board's proposed program and their recommendations were incorporated.

A nuclear science service building estimated at $1,950,000 is included in the $2,800,000 budget for the University of Florida. The structure would be part of a planned science and technology center.

The nuclear science building would house the "hot laboratories" for nuclear materials, equipment and physical facilities for nuclear engineering, chemistry, physics, agriculture, medicine and other sciences in the field.

FSU RESEARCH

Construction and equipping of a building for study and research is provided in the FSU budget. Its cost was estimated at $1,910,000. A $15,000 isotope laboratory is in the Florida A&M program.

Tallahassee Democrat

Friday, March 22, 1957

The fuel concern goes back to WW II and an unforgettable sight by AG on March 11, 1945

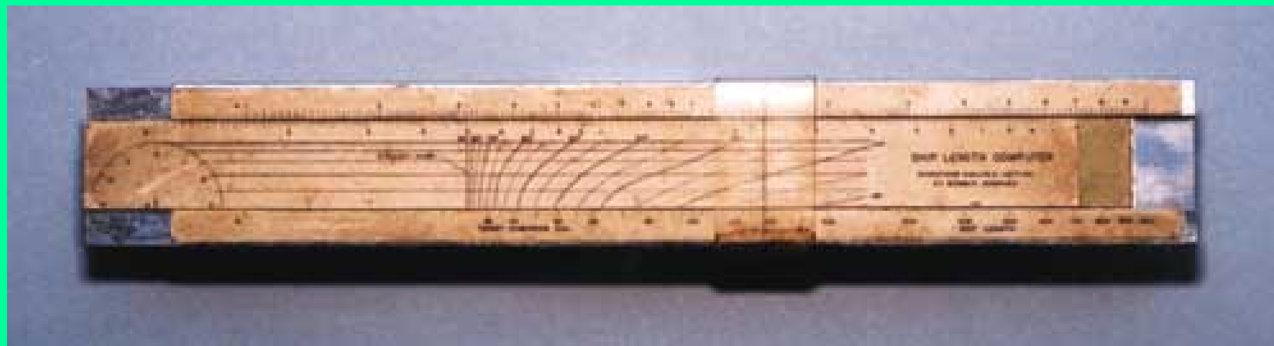
Japan’s fleet in Kure Anchorage. & Hiroshima Bay

Out of Oil

Our Navy soon sank most ships

Out of Gas(oline): After emergency landing at 14th AF fighter field, in Xian, China, 3/12/45. We sighted 77 Japanese warships at anchor without fuel in Hiroshima Bay and Kure Anchorage [16].

Two 20th AF WW II Slide-rules



Ship length computer used with gunsight

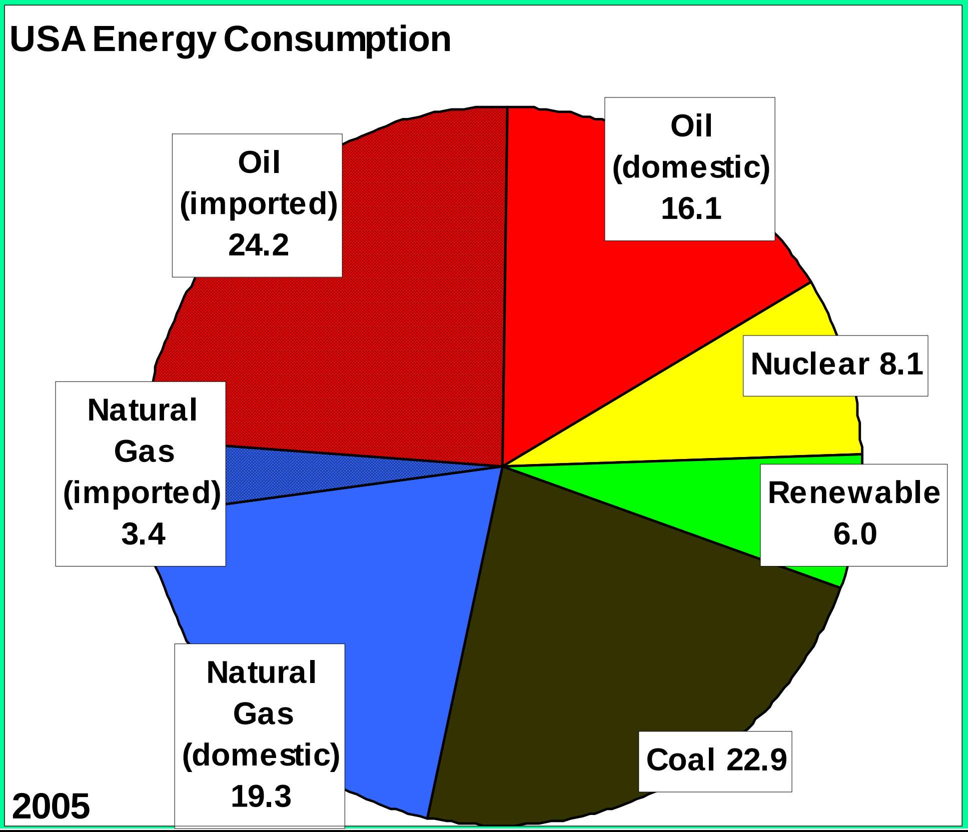
Flight engineer's computer (to minimize gasoline consumption on long, mostly overwater, missions)

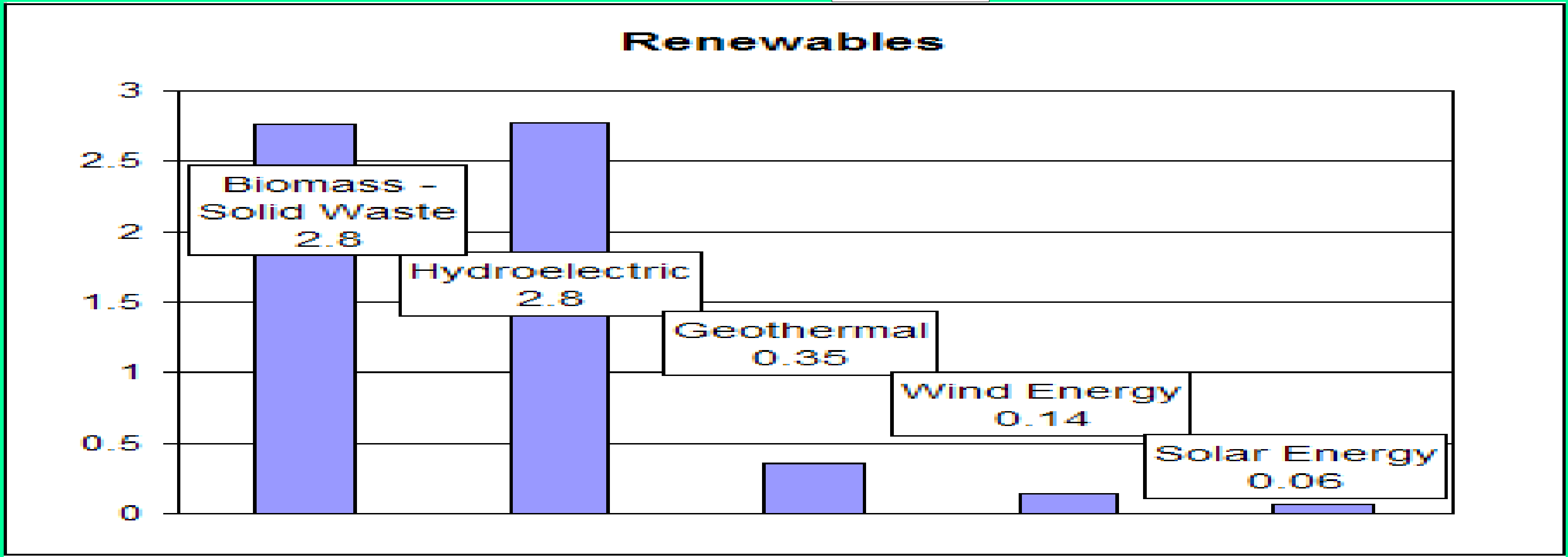
(Right) US Total primary energy supply (TPES) in quads (2005). ***Clearly we are running out of oil and natural gas***

(Below) Renewables.

Question: ***Which can help most in near term?***

Answer: ***Solid Waste***





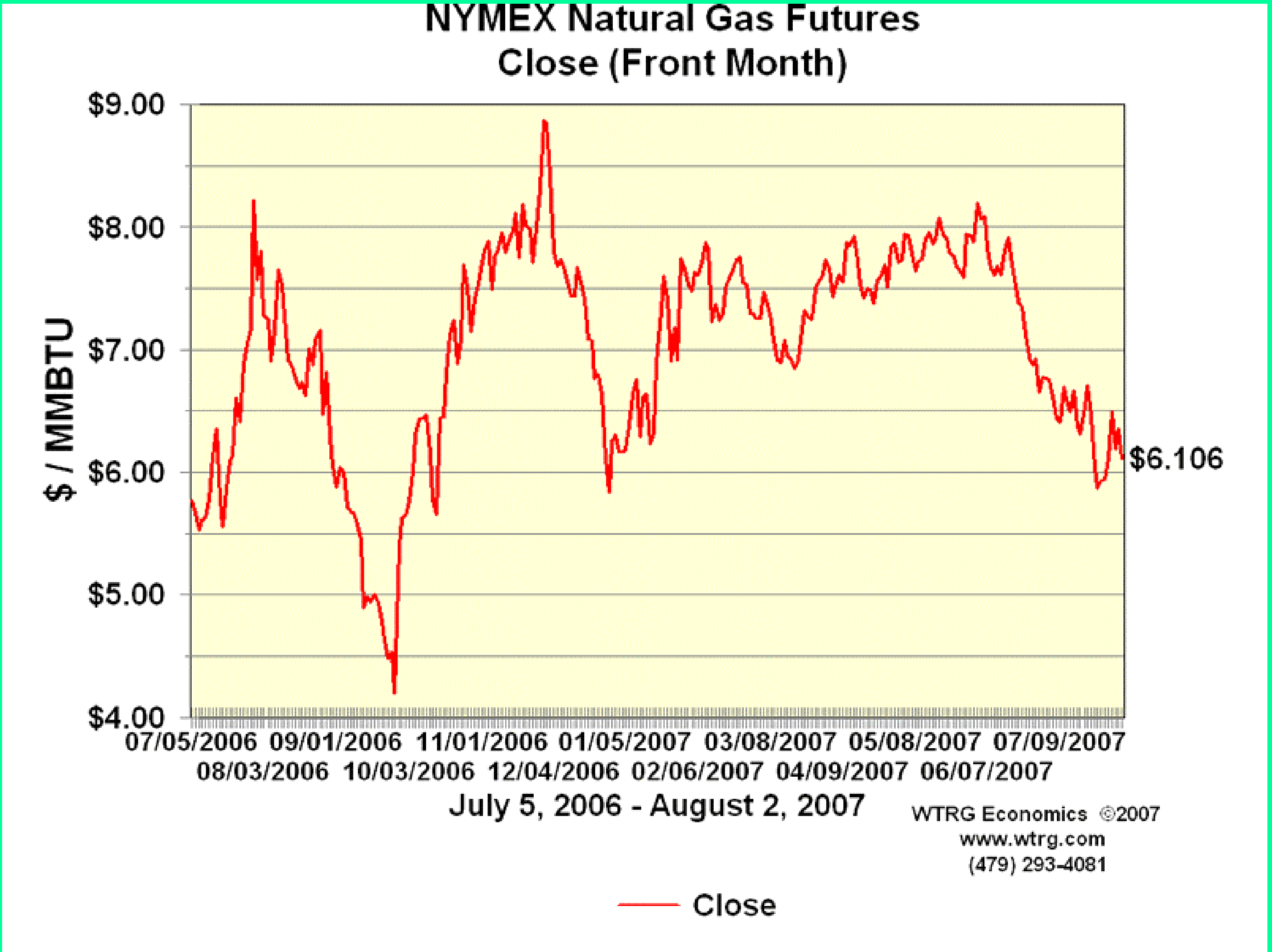
The Age of Gasification has returned

- Note every city made its own gas until after WW II when cheap natural gas (NG) became widely available.
- NG cost $1-2 /mmBtu when many NGCC electrical generating or NGCHP plants using jet engines (ex. PE-UF Co-gen, Kelley Plant NGCC)

NG Imports rose to 15 % and recently has ranged from 5-15 $/mmBtu

- A large gasification thrust is now based on coal and petroleum coke.
- A strong bio-chemical gasification thrust is developing for wet feedstock
- **Solid Waste to Energy by Advanced Thermal Technology (SWEATT)**
- SWEATT- pyrolysis/gasification to fuel efficient co-gen (CHP), combined cycle and (later) fuel cell systems is advocated by a few
- SWEATT can be used by utilities (GRU!), institutions (UF!), military bases, shopping centers, apartment buildings, farms, battalions (GLGT!).

Natural gas was $1-2/mm Btu when many natural gas combined cycle systems and natural gas cogeneration systems were built. It went up to $15/mmBtu during the Katina era.



Solid Waste Available in the U.S.

- Agricultural residues
- Forest under-story and forestry residues
- Construction and deconstruction debris
- Hurricane debris
- Refuse derived fuels
- Urban yard waste
- Food serving and food processing waste
- Used newspaper and paper towels
- Energy crops on under-utilized land
- Infested trees, (beetles, canker, spores)
- Invasive species (cogon-grass, melaluca..)

>1.5 billon dry tons biomass (ORNL report)

• Additional Solid Waste

- Ethanol (extends beer-liquor technology) production waste
- Anaerobic digestion (extends nature's technology) waste
- Bio-oil production and restaurant waste
- Bio-solids (sewage sludge)
- *Poultry and pig farm waste
- *Water plant-remediators (algae, hydrilla..)
- *Muck pumped to shore to remediate lakes
- *Manure from cattle feed lots
- Used tires
- auto fluff and waste plastics and
- Plastics mined when restoring landfills
- Plants for phyto-remediation of toxic sites
- Treated wood past its useful life

***helps in water remediation**

➢ **0.5 billion dry tons,** Est. aesg

➢ maybe more (EPA estimates 7.6 billion tons industrial waste!)

Energy Potential of Solid Waste (SW)

TOTAL SW potential 1.5+0.5 =2 Billion Dry Tons

$(2*10^9$ tons)*(2000lbs/ton)*(7500Btu/lb)=

$30 *10^{15}$ Btu = 30 quads

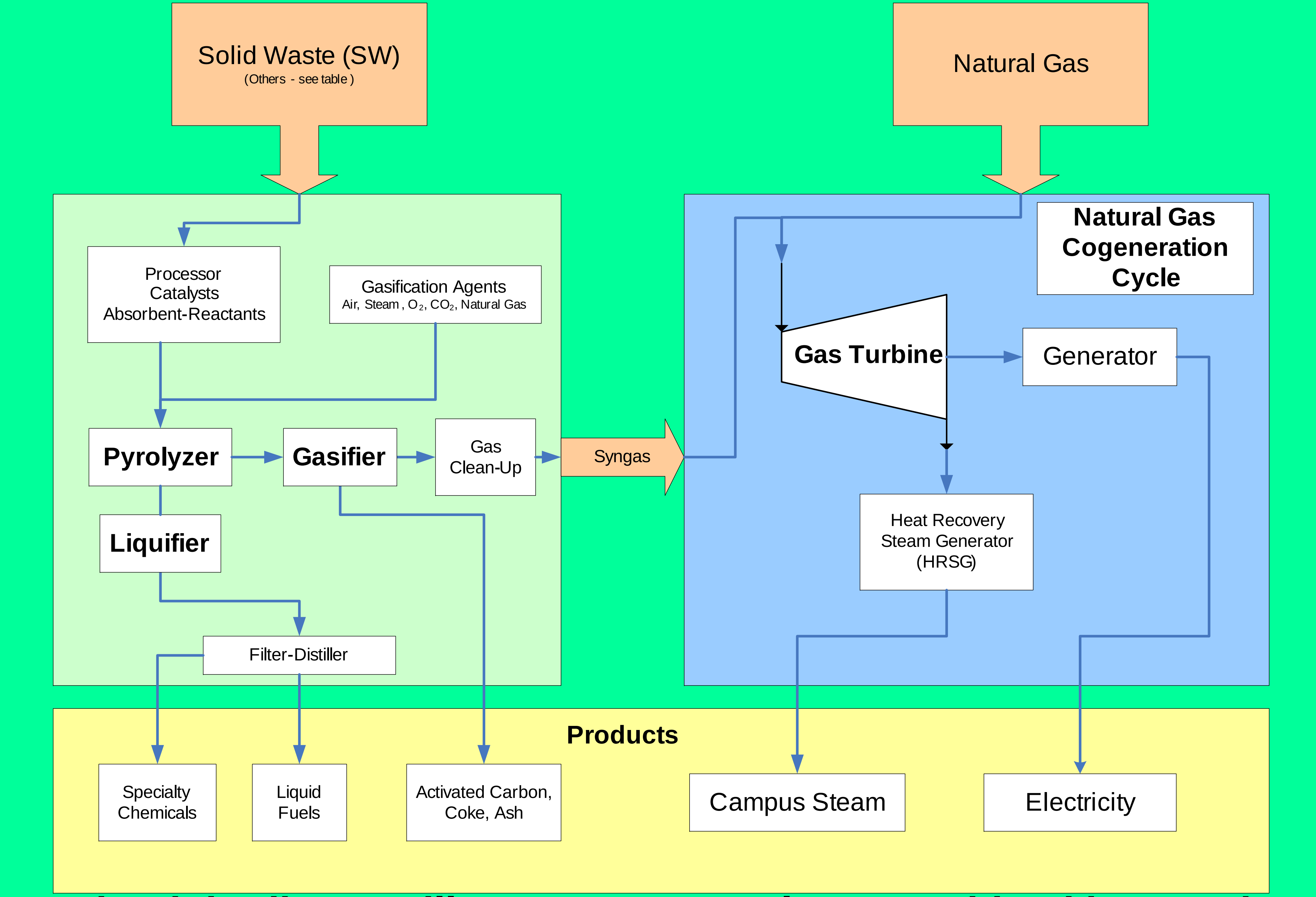
Compared to Coal

$(1*10^9$tons)*(2000lbs/ton)*(11,500Btu/lb)=

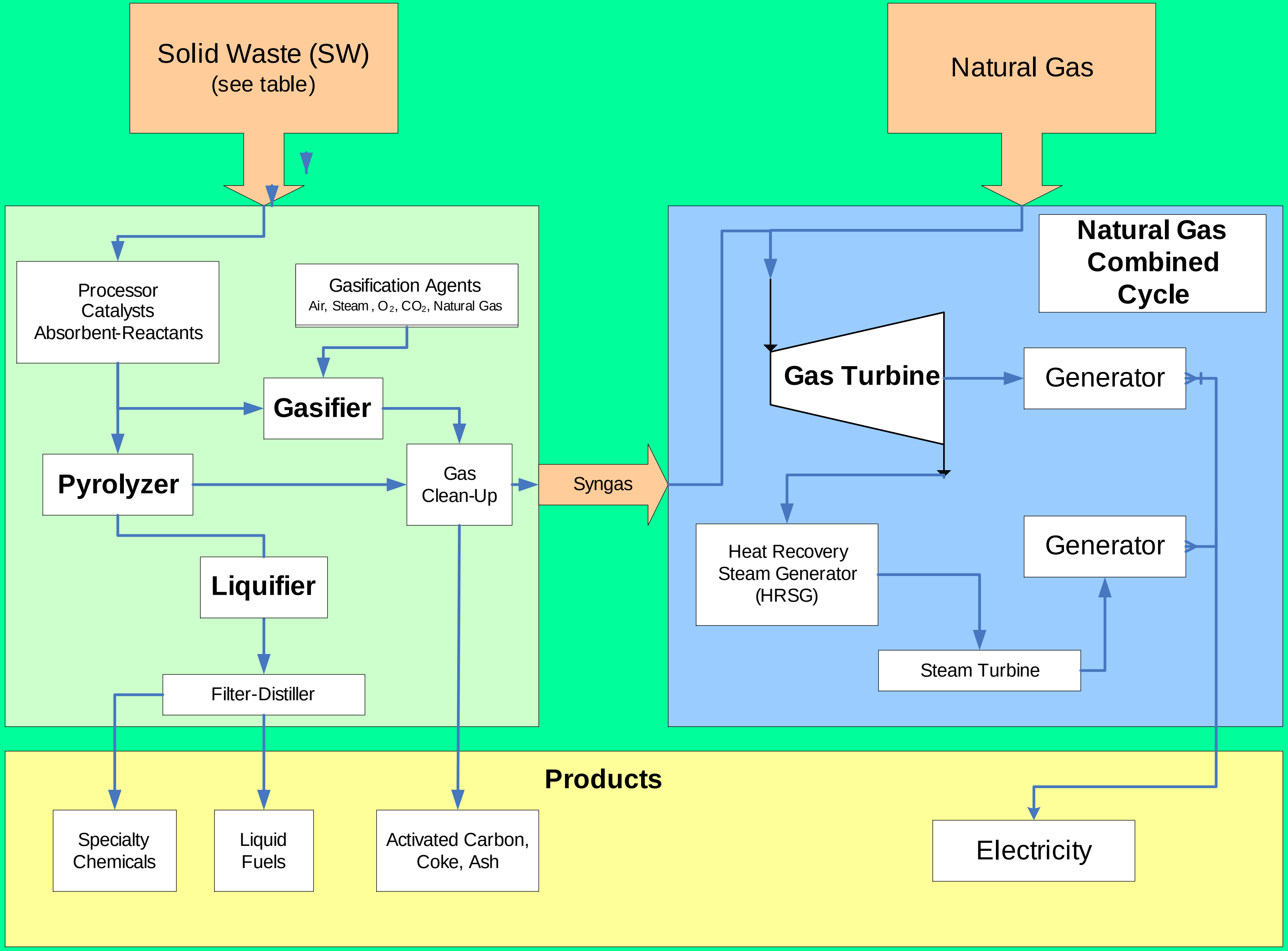
$23 *10^{15}$ Btu = 23 quads

Solid Waste now 3 quads could be 30 quads

The other renewables, hydroelectric (2.7q), geothermal 0.34q), wind (0.14q) and solar (0.06q). have much further to go to become a major primary energy supply (PES) in the U.S.



The right diagram illustrates a natural gas combined heat and power (CHP) system. The left diagram a solid waste gasifier.



The right diagram illustrates a Natural Gas Combined Cycle system, the left a Solid Waste Gasifier : now timely

Advanced Thermal Technologies (ATT)
SW Conversion to *Gaseous or Liquid Fuels*

- **Solid fuel combustion makes gas (emissions) but not a fuel gas.**
- **Air blown partial combustion (ABPC) gasifiers, (Clayton 1694). makes CO diluted by N2, Low heating value (HV~ 150 Btu/cft) producer gas.**
- **Oxygen blown partial combustion gasifiers (20^{th} century). Biomass Syngas, no N2, has HV ~ 320 Btu/cft. Oxygen plant is a major cost.**
- **Pyrolysis (Indirect heating) HV> 400. gives best gas from organic SW. The condensable pyrolysis gases can be liquid fuels.**
- **Natural gas (NG) HV ~ 1000.**
- **Hydrocarbon (e.g. HC plastics) pyrogas can have HV > 1000.**
- **How does all this apply to Gainesville and the University of Florida .**

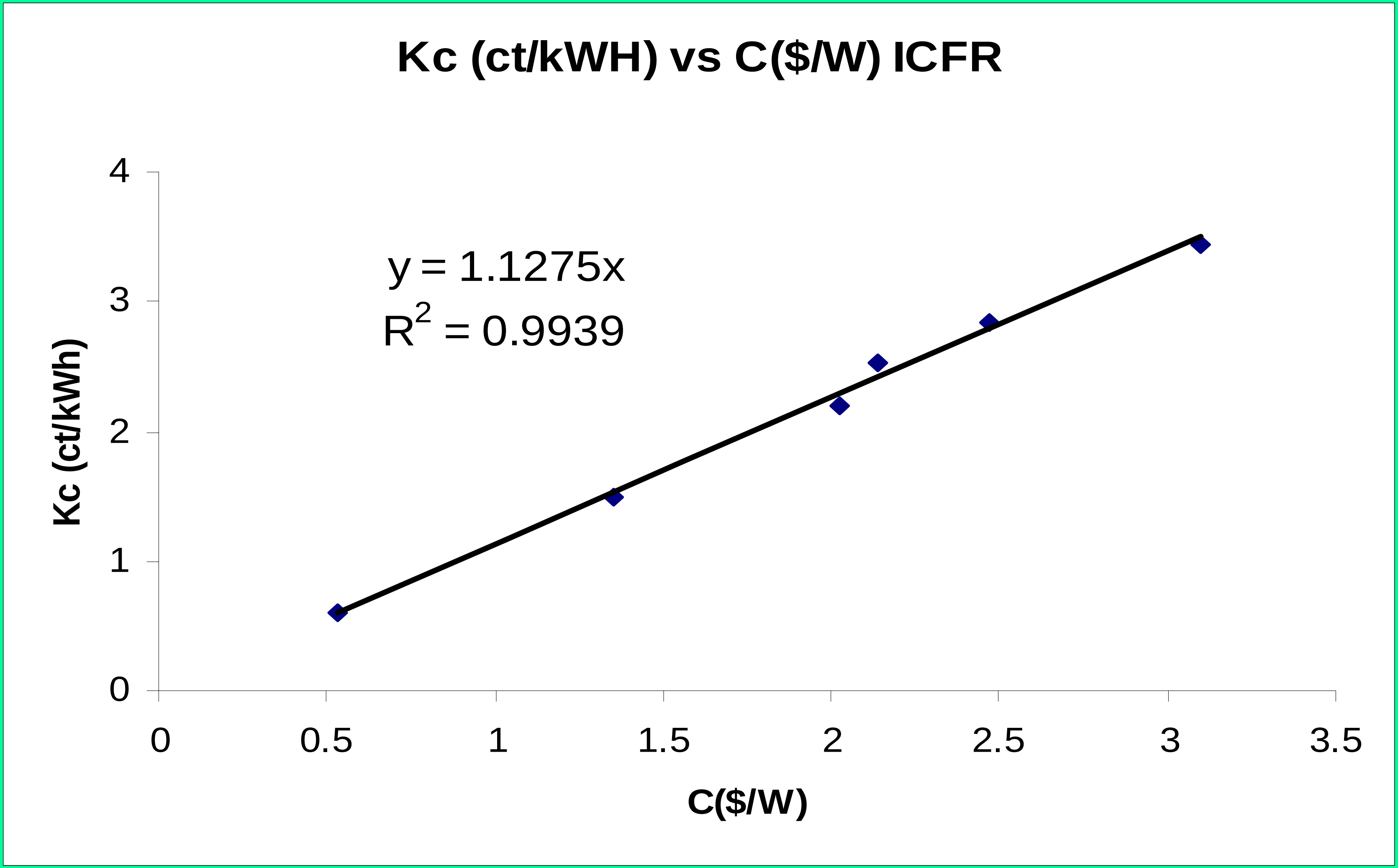
We first re-assess the $400,000 GRU expansion study by ICF using an analytic cost estimation (ACE) method, ACE uses variations of the simple algebraic equation

$$Y = COE = K + S*COF = K + S\ X$$

to compare five technologies examined in the 2006 ICF report commissioned by the Gainesville City Commission.

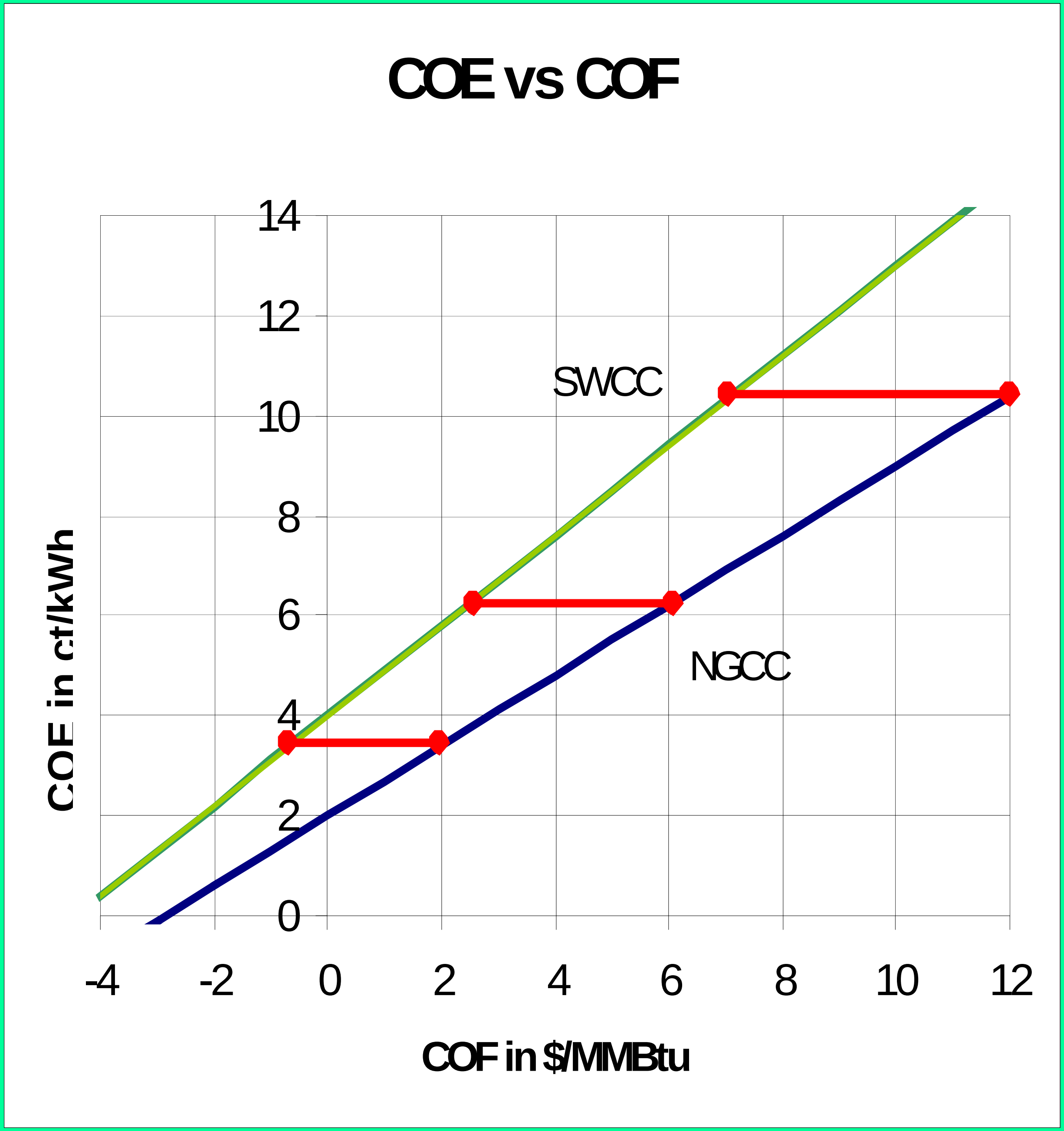
ACE: $COE = K + SX = Kc + Kom + Ke + SX$

ACE's relation between y, capital cost/watt and x, fixed capital component of the cost of electricity



Results from $400K ICFR Table 4-10 for 5 technologies plus 2 NGCC + 1 SWCC

Tech	Pr	C	Kc	Kom	Ken	COF	So	COE
	MW	$/W	c/kWh	c/kWh	c/kWh	$/mmBtu		ct/kWh
SCPC	800	1.35	1.491	0.299	1.714	1.91	0.93	5.28
CFB-CB	220	2.14	2.531	0.261	1.618	1.41	1.05	5.89
CFB- Bio	75	2.47	2.845	0.261	0.039	1.67	1.39	5.47
IGCC	220	2.03	2.2	0.196	1.407	1.41	0.86	5.02
SWCC	75	2.8	3	0.3	0.1	1.4	1	4.8
NGCCh	220	0.53	0.598	0.234	-0.170	11.34	0.68	8.37
NGCCm	220	0.53	0.598	0.234	-0.170	6.10	0.68	4.81
NGCCl	220	0.53	0.598	0.234	-0.170	5.00	0.68	4.06
NGCCp	220	0.53	0.598	0.234	-0.170	4.00	0.68	3.38



ACE

COE= Y, COF = X

Y = K + SX

NG = 12, SW = 7.1

good money,COE =10.4

NG=6, SW=2.4

reasonable, COE=6.2

NG = 2, SW =-0.7

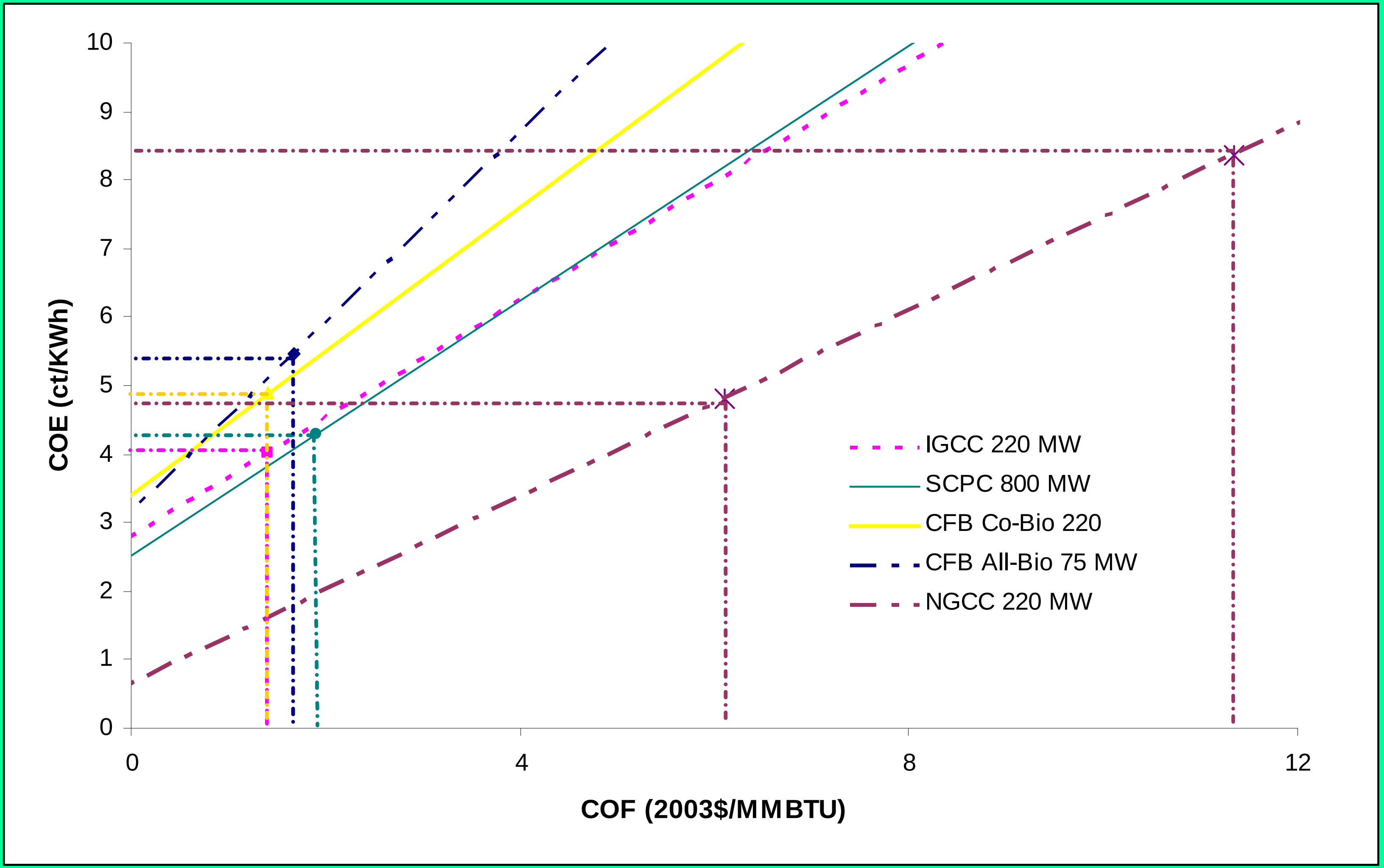
tipping fee, COE =3.4

with Sn = 0.7, Kn =2,

and Ss = 0.9, Ks = 4 ,

The major ACE conclusion is that a NGCC+SWCC can provide greatest flexibility in meeting future uncertainties

The dots represent Exh. 4-10 ICFR conclusions. The lines represent COE (Y) vs COF (X) . One differing ACE result is that if NG prices go back to lower levels NGCCs become lowest COE, particularly if coal is charged with carbon tax or externality costs.



Environmental Externalities (EEx)

- There are many different forms of environmental externalities, including air pollution, water pollution, and land-use effects.
- In general, the most significant of these is air pollution, such as NOx, SOx, PM10, and global greenhouse gases like CO_2, methane.
- Roth-Ambs *Energy,* 2004-03-16 find air pollution accounts for 85% of the environmental COE.
- How much and how to include environmental externalities (EEx) costs is still **unsettled.**

The Environmental COE

- The IFCR allows for environmental effects as a fixed cost independent of the heat rate S or X i.e.

$$Y = K + SX = Kc + Kom + \underline{Ke} + SX$$

- However, the air pollution is inextricably linked to the amount of fuel being consumed. ACE uses

$$Y = Kcr\{(Pr/P)^{\alpha}\}(1+fom) + SX(1+\underline{fe})...$$

where fe is an EEx correction to the fuel price X that can exceed 1 for some fuels and technologies effectively more than doubling true fuel costs.

$$X_{true} = X(1+fe)$$

Our ACE analysis suggest that GRU should use DSM and build a 50-100 MW SWAB-NG-CC system or retrofit the Kelley NGCC or Deerhaven gas turbine.

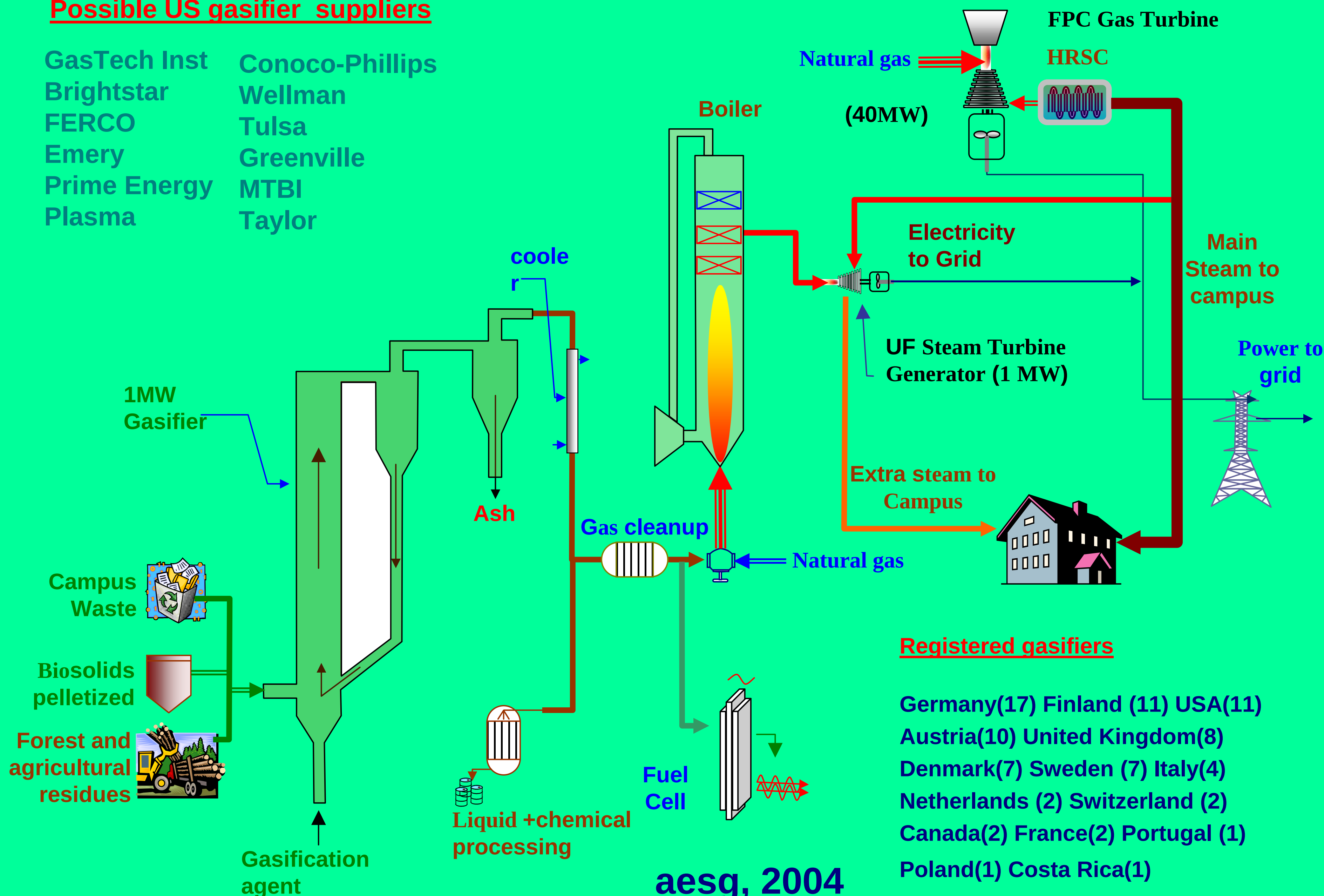
Using Roth-Ambs low EEx estimates we evaluate fe for 14 Technologies.

Technology	C/W	CF	PL	Kc	Ko	fom	S	Cof	Cex	fe	COE	COEe
Coal Boiler	1.80	85	35	2.81	1	0.36	0.995	1.06	4.45	4.20	4.86	9.29
Adv Fld Bed	2.20	83	35	3.52	1.73	0.49	0.975	1.04	2.86	2.75	6.26	9.05
IGCC (coal))	2.10	85	35	3.28	0.93	0.28	0.889	0.95	2.64	2.78	5.05	7.40
Oil Boiler	1.30	80	35	2.15	0.4	0.19	0.943	3.22	6.03	1.87	5.59	11.27
Gas Turb SC	0.70	10	25	10.1	1.24	0.12	1.15	3.47	4.62	1.33	15.28	20.59
Gas T Adv	0.40	70	25	0.82	0.42	0.51	1.09	3.29	4.45	1.35	4.83	9.68
NGCC	0.60	90	30	0.91	0.31	0.34	0.683	2.11	3.46	1.64	2.66	5.02
MSW Inc	5.70	85	25	9.63	4.22	0.44	1.687	-5.1	~0	~0	5.15	5.15
LFG	1.50	70	20	3.3	0.99	0.3	1.215	0	0.7		4.29	5.14
SOFC	1.60	95	25	2.42	6.55	2.71	0.758	2.29	2.75	1.20	10.71	12.79
Wind Turb	1.00	25	25	5.74	1.66	0.29	0	0	0.7		7.40	7.40
PV Utility	4.70	13	30	49.5	1	0.02	0	0	0.25		50.53	50.53
Hybred solar	3.70	25	30	20.3	3	0.15	0.346	1.07	2.38	2.22	23.64	24.46
Biomass	2.40	90	35	3.54	2.59	0.73	1.431	2.75	0.41	0.15	10.07	10.65

Conceptual U.F. MADBANG/SWEATT-CHP (1-5MW)

Possible US gasifier suppliers

GasTech Inst	Conoco-Phillips
Brightstar	Wellman
FERCO	Tulsa
Emery	Greenville
Prime Energy	MTBI
Plasma	Taylor

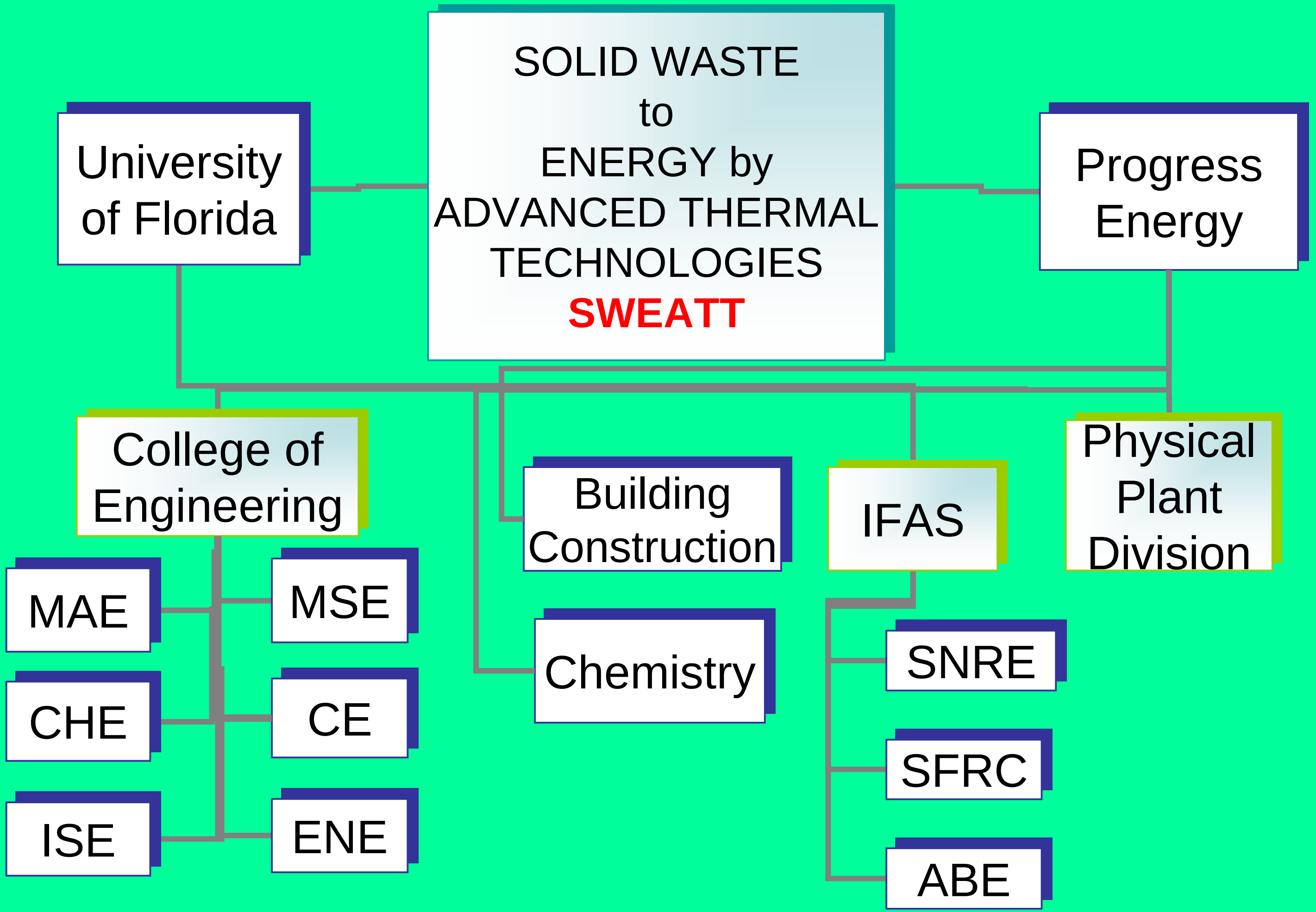


Registered gasifiers

Germany(17) Finland (11) USA(11)
Austria(10) United Kingdom(8)
Denmark(7) Sweden (7) Italy(4)
Netherlands (2) Switzerland (2)
Canada(2) France(2) Portugal (1)
Poland(1) Costa Rica(1)

aesg, 2004

Zero-Waste at UF with SWEATT



Proposed Zero Waste with SWEATT Organization at the University of Florida

Proposed Gasification Renewable Energy System for University of Florida submitted to FDEP with request for $2,500,000. We could use much more cost sharing!

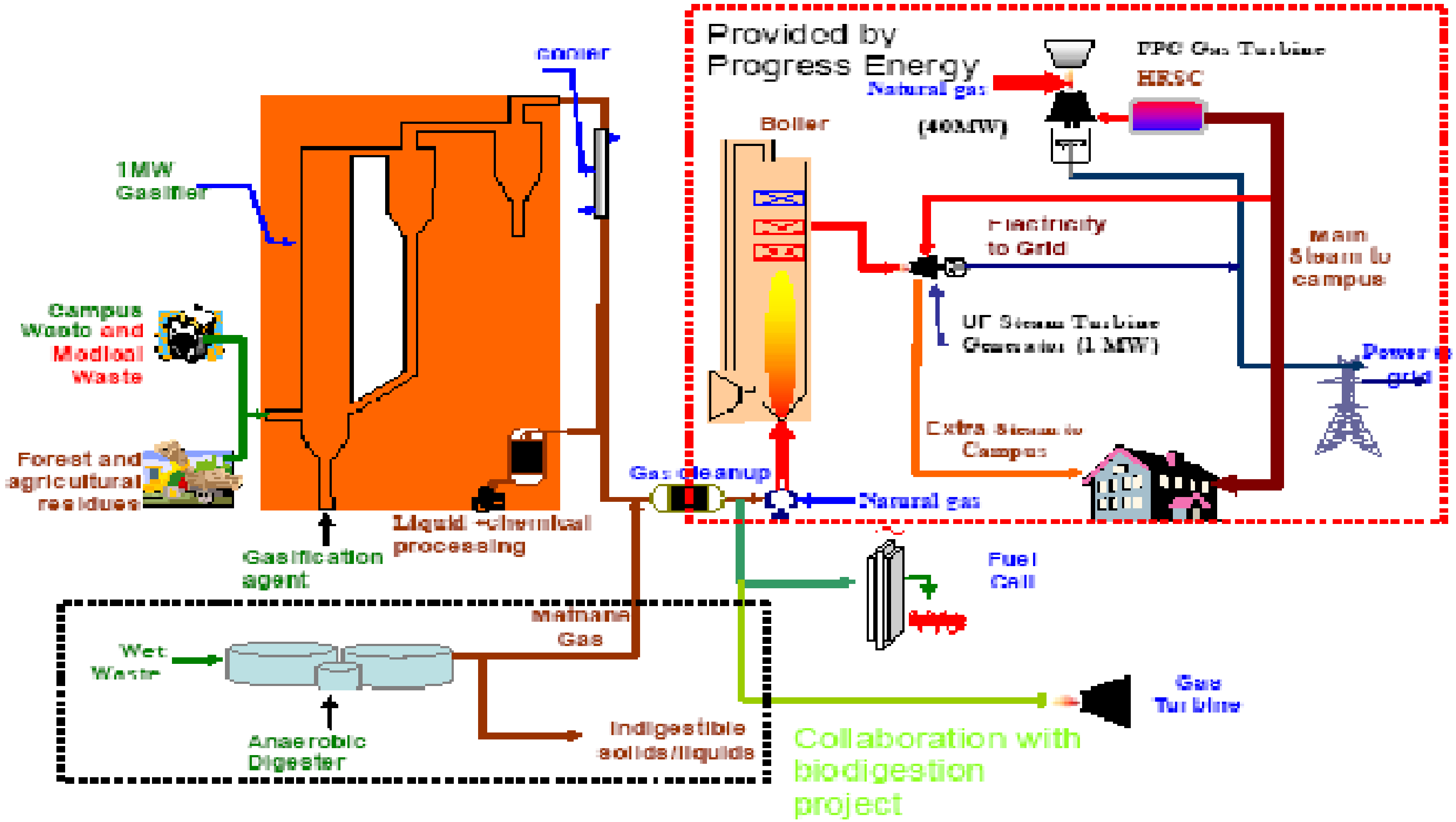


Figure 1. Schematic of Proposed Gasification-Based Renewable Energy System

Active Pyrolysis Facilities converting MSW showing technical feasibility and environmental acceptability in Green countries [15].

- Toyohashi City, Japan Mitsui Babcock, 2002, 2 x 220 TPD
- Hamm, GermanyTechtrade 2002, 353 TPD
- Koga Seibu, Japan Mitsui Babcock,2003, 2 x 143 TPD
- Yame Seibu, Japan Mitsui Babcock, 2000, 2 x 121TPD
- Izumo, JapanThidde/Hitachi 2003, 70,000 TPY
- Nishi Iburi, Japan Mitsui BabcockMarch 2003, 2 x 115 TPD
- Kokubu, JapanTakuma. 2003, 2 x 89 TPD
- Kyouhoku, Japan Mitsui Babcock, 2003, 2 x 88 TPD
- Ebetsu City, Japan, Mitsui Babcock. 2 x 77 TPD
- Oshima, Hokkaido Is., Japan Takuma 2 x 66 TPD
- Burgau, GermanyTechnip/Waste Gen 1987, 40,000 TPY
- Itoigawa, JapanThidde/Hitachi 2002, 25,000 TPY

California Integrated Waste Management Board's *Evaluation of Conversion Technology Processes and Products* (forthcoming part of conclusion)

- "Thermo-chemical conversion technologies, such as gasification and pyrolysis, can treat nearly all of the organic fraction of MSW and can, in general, treat a heterogeneous feedstock, including high energy content plastics. Pyrolysis and gasification applications for MSW have expanded considerably in the past five years, especially in Japan … Over 50 commercially active facilities were identified in Japan, Sweden and Germany-the most Green countries …"

Conclusion: Zero Waste with SWEATT

- **Conservation-going Green (DSM) with recycling, energy efficiency, bicycling etc.. reduces waste and dependence on imported fuels.**
- **Environmentally safe landfill space is limited as density of population increases (as in EU, Cal, Fla, USA). Tipping fees higher.**
- **We can approach Zero Waste and reduce US fuel imports by Solid Waste to Energy by Advanced Thermal Technologies (SWEATT)**
- **Co-use of SW gas with NG provides flexibility in responding to NG price fluctuations and SW availability.**
- **SWEATT sells well in Green countries: Japan, Sweden, Finland, Netherland, Germany…. How can we move ahead at UF, Florida, US ?**
- **By putting aside emotions or self interest and using logic and common sense, UF could show GRU, Florida and US the way to Zero Waste and to significantly reducing our dependence upon imported oil and gas.**

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[15] California Integrated Waste Management Board, (2005) Conversion Technologies Report to the Legislature, Draft, http://www.ciwmb.ca.gov/Organics/Conversion/Events.

[16] http://www.physicstoday.org/pt/vol-54/iss-8/p40.html

Green Liquids and Gas Technology (GLGT), Gainesville FL
Alex E. S. Green, President

- In 1973 AG, a UF physicist GRProfessor, refocused part of his R&D on alternatives to oil. His energy R&D awards were small and public and academic interest had not developed
- In 1996 AG invented a small Auger Driven Pyrolyzer/Gasifier to convert waste and biomass to gaseous or liquid fuels
- UF Office of Technology declined to patent, released IP to AG
- AG personally obtained Patents 6048374 and 6830597
- Concept proved by many tests with development units
- AG formed GLGT to commercialize inventions
- GLGT has DARPA SBIR Phase 2 award now in 18th month
- Goal to convert meals ready to eat (MRE) residues into fuel for a battalions feeding station

Left shows 1996 concept as first patented. Right side shows the Mark 3 process development unit (PDU)

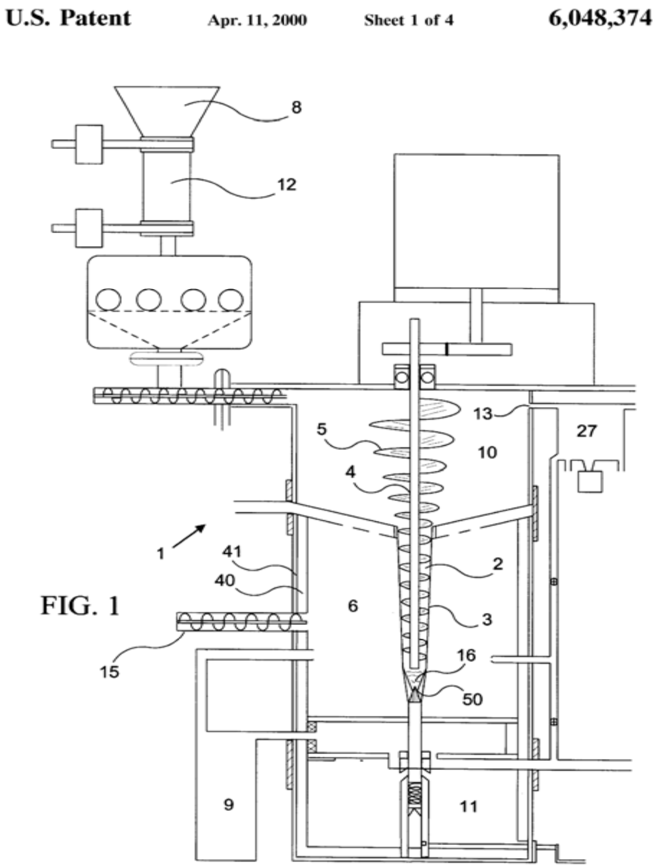
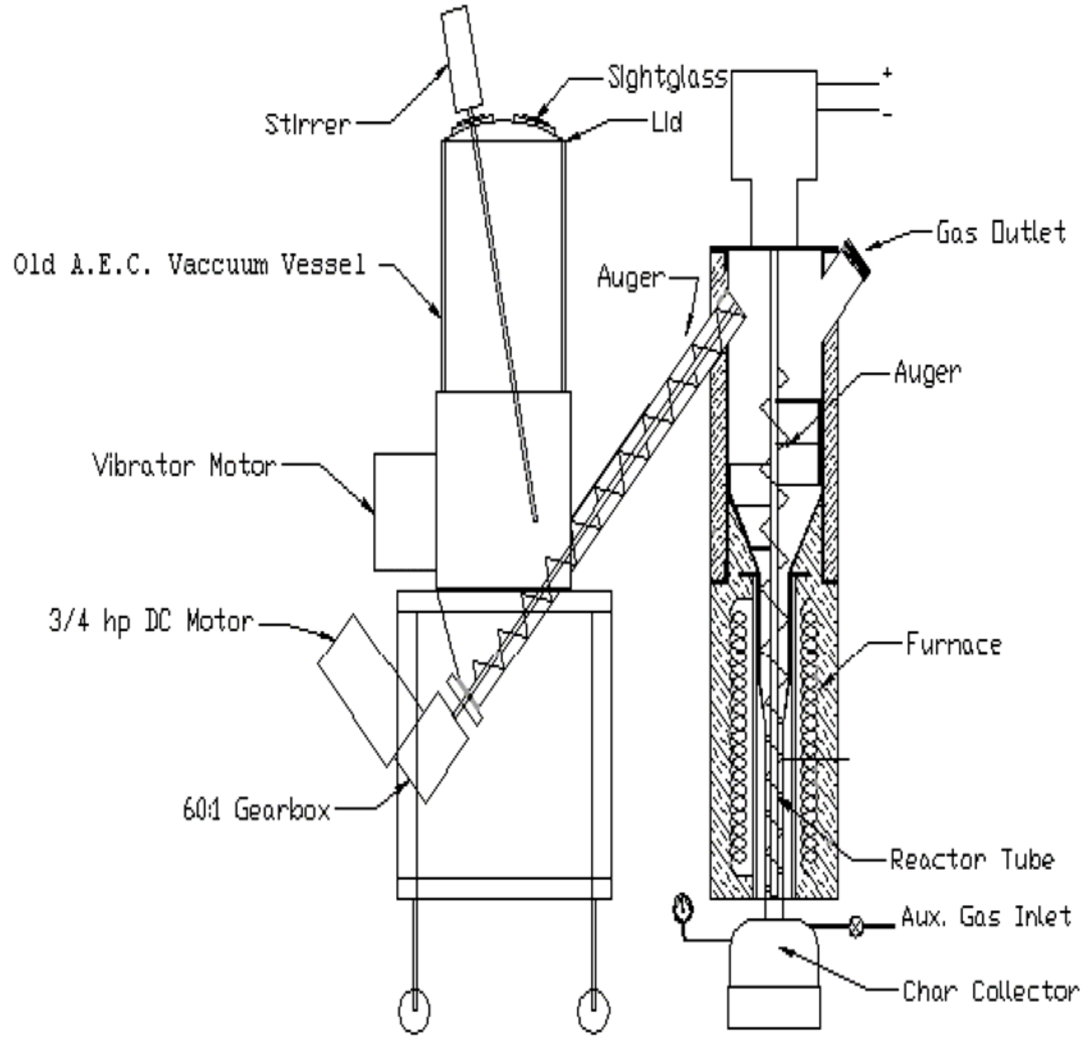
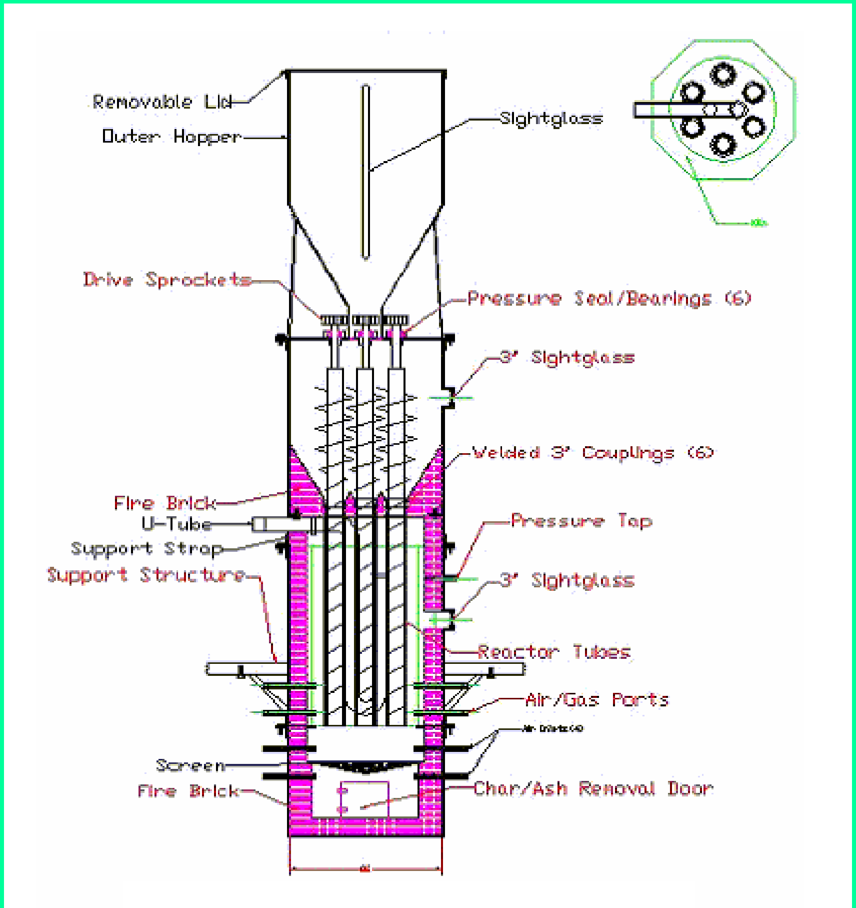
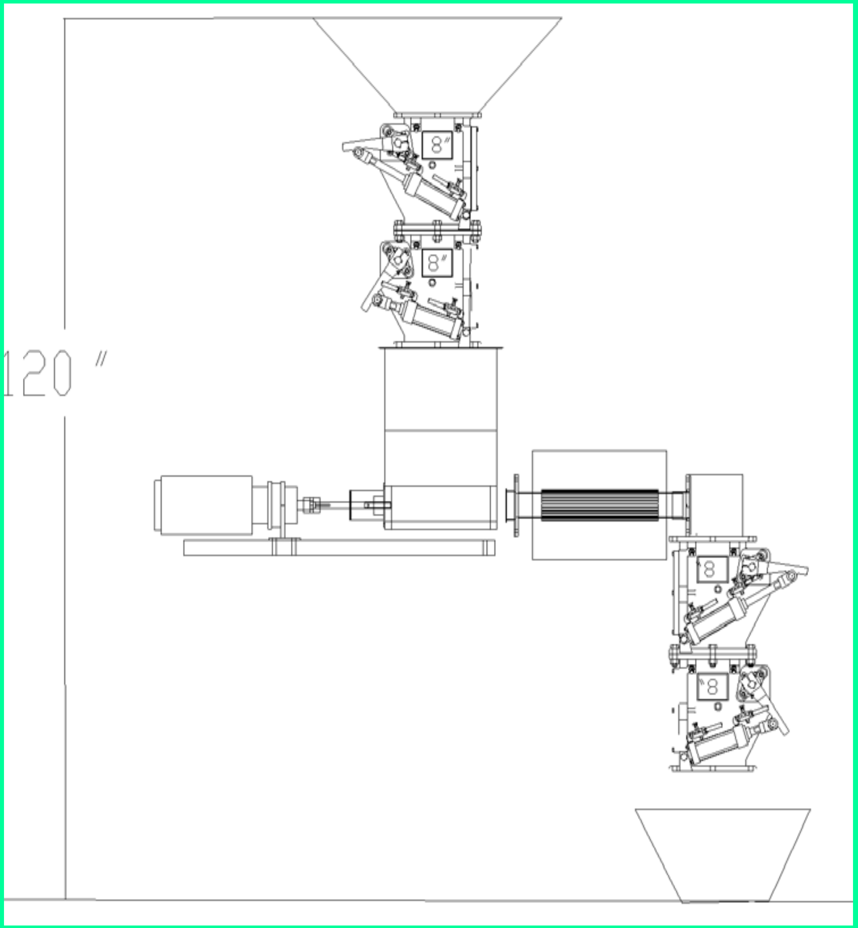


FIG. 1

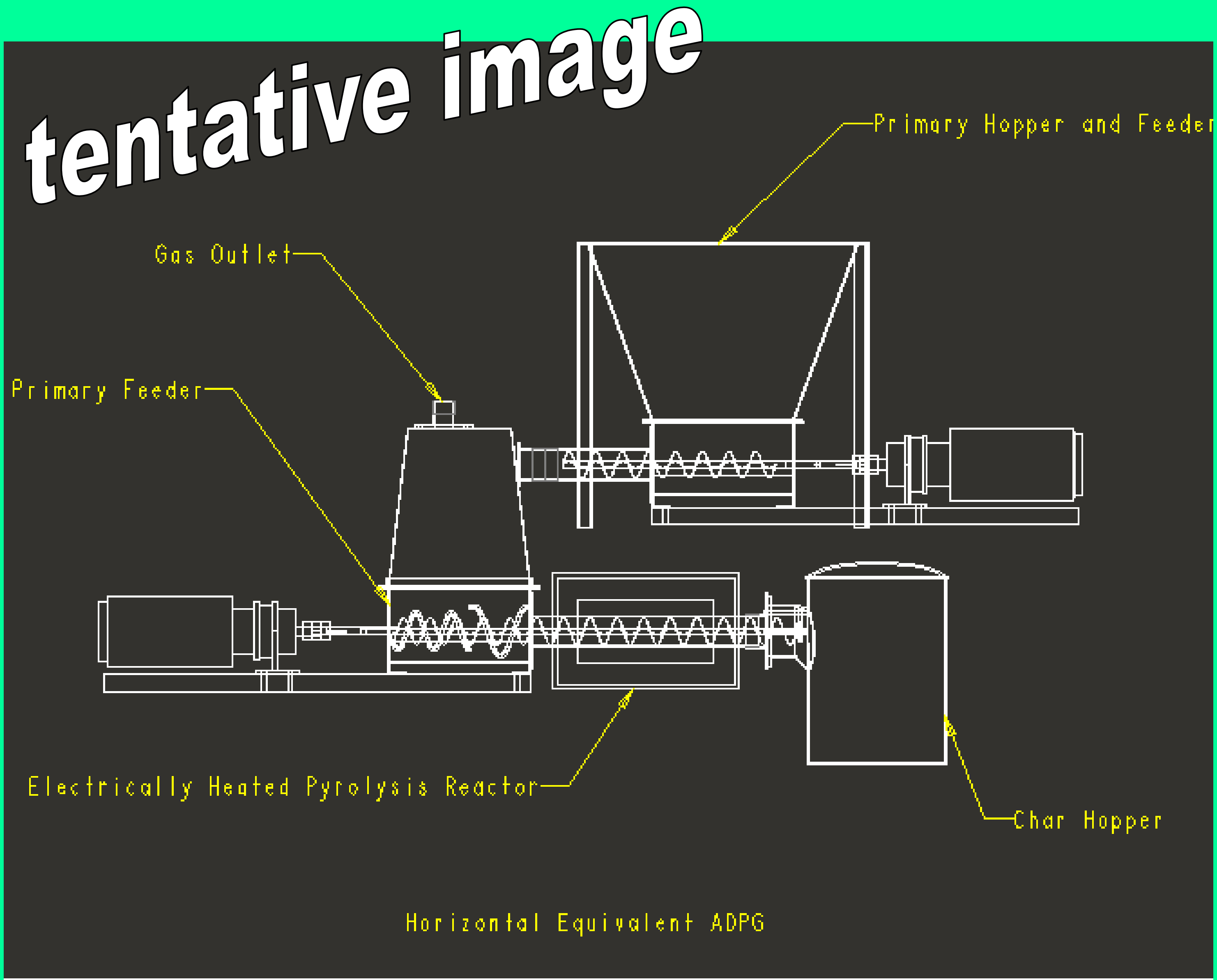


Multiple Auger Driven Pyrolyzer Gasifier (MADPG) left
ADPG with horizontal reactor right





GLGT's Mark 4 Auger Driven Pyrolyzer/Gasifier(ADPG)

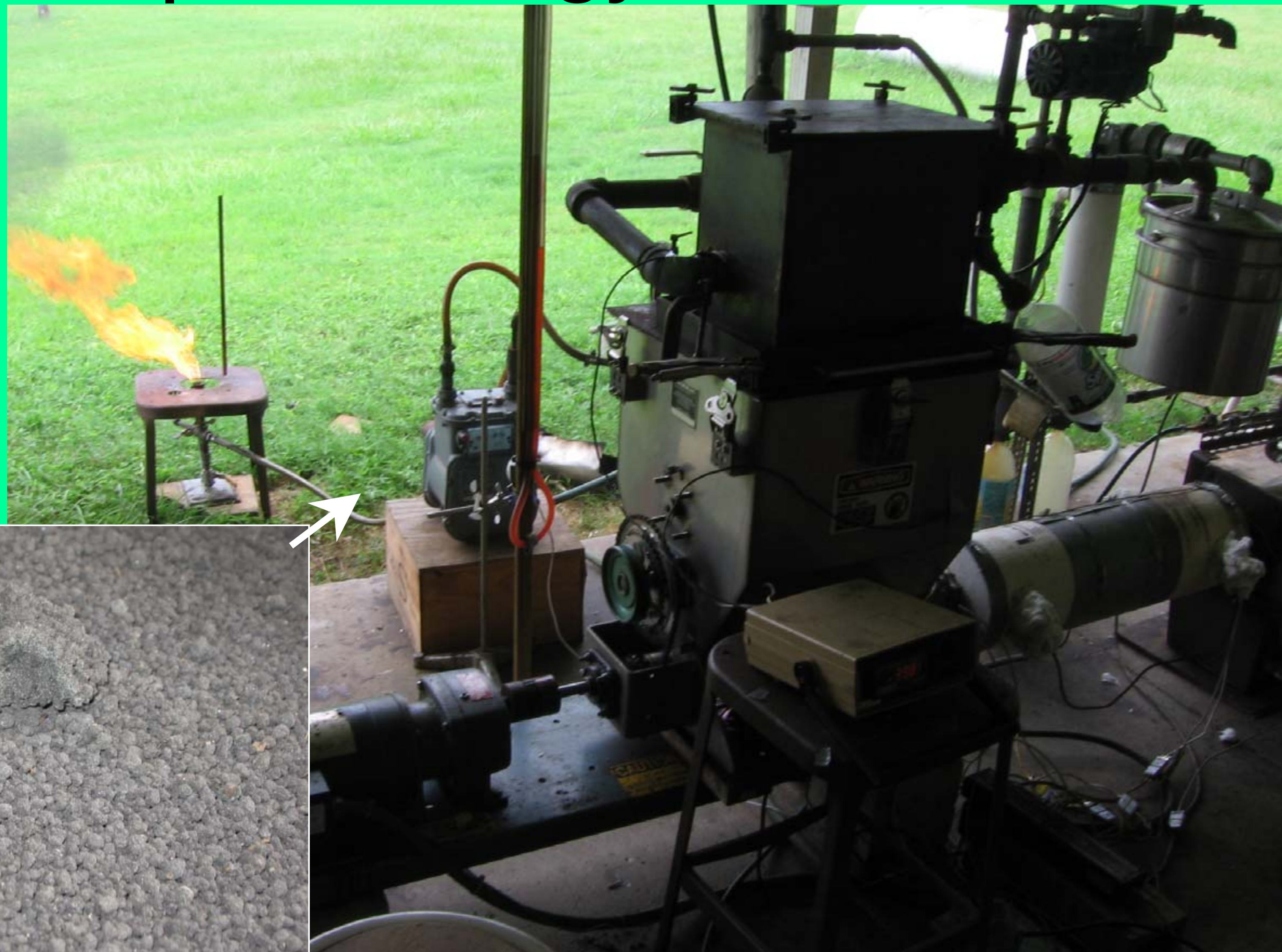


GLGT's intended products

- **Small scale 10-50 kW thermo-chemical-mechanical converters of solid waste and biomass to gaseous or liquid fuels**
- **Jet age externally heated gasifier that yields filtered-undiluted pyrogas**
- **Unlike "air blown partial combustion gasifiers" that yield low BTU gas diluted with N2, CO2 and H2O**
- **Single ADPG system will fuel 10 kW generator,**
- **Multiple ADPG will fuel 50 kW generator**
- **Now focused on needs of an Army battalion feeding station**
- **Later for locally fueling small co-generation systems**
- **Not applicable to UF SWEATT (needs 1-5 MW)**
- **Not applicable to GRU SWEATT (needs 50-100 MW)**
- **However, work elucidates basic princples of pyrolysis**

Current Mk5.7 PDU

Poop to energy 8/1/07



GLGT Officers, Staff and Board of Advisors

Officers

- Alex E. S. Green, President, Chief Technical Officer, CEO
- Alan C. Hill, Secretary. Treasurer, Chief Financial Officer
- Bruce A. Green, Vice President, technical advisor
- Victor W. Hwang, Chief Business Development Officer

Staff

- Sean M. Bell, Engineer 2, computer support, calculations, instruments,
- Piero de Campo, Laboratory Manager, mechanical, electrical, ovens

Board of Advisors

- John M. LeMoyne, Lt. Gen. Ret. Formerly Chief Functional Officer, U.S. Army
- Mr Donald Smally, formerly President of the Florida Consultant Engineering Society and CEO Smally, Wellford and Nalvin, of Sarasota FL
- Dr Philip Wyatt, founder and CEO of Wyatt Technologies, Santa Barbara, CA.

GLGT would welcome local investors seriously interested in alternative fuels