A green alliance of biomass and coal (GABC)

Alex E. S. Green, Director ICAAS-CCTL, University of Florida, Admiral, Texas Navy (01/03)
Tel: (352) 392 2001 Fax: (352) 392 2003 E-mail: aesgreen@ufl.edu

Abstract: A sensible energy-environmental policy (SEEP) should include "a green alliance of biomass and coal." (GABC) to pursue eco-friendly technologies for co-utilizing biomass and other opportunity fuels with coal or natural gas. Florida and the gulf coast region of Texas with abundant rain and sunshine have large biomass to energy potential. Florida with its lack of fossil fuel resources and Texas with its good resources of natural gas and lignite and strong petrochemical industry have complimentary interests in advancing GABCs. This report describes the solar energy resources in biomass forms, technical impediments to their use and the need for GABCs to overcome these impediments. It calls attention to socio-political “turf” problems that make it difficult to mitigate current national, Florida and Texas energy/environmental (EE) problems. By closing ranks on a SEEP with GABCs Florida and Texas could overcome these problems and become national and international leaders.

.

1. ENERGY-ENVIRONMENTAL PROBLEMS

Figure 1 identifies major local, regional and global atmospheric environmental problems that the Interdisciplinary Center for Aeronomy and other Atmospheric Sciences (ICAAS) has considered in various studies [1,2]. The figure shows the phenomena of concern, the emissions suspected, the actions caused by them, the effects and possible solutions.

As a result of the "Oil Crises" of 1973 and 1979 ICAAS formed the Clean Combustion Technology Laboratory (CCTL) to search for eco-friendly alternatives to oil. We undertook a state supported study directed toward reducing Florida utilities’ use of oil while minimizing the environmental impacts of increased coal use. It led to our 1980 book Coal Burning Issues [3] and our 1981 book An Alternative to Oil, Burning Coal with Natural Gas [4] and our search for eco-friendly ways of co-utilizing domestic fuels [5].

Figure 2 shows the annual energy consumption of the USA at the millennium extrapolated from data in Energy Information Agency documents. The numbers are in quadrillion (a million-billion or 10^{15}) BTU (quads). We consumed 95 quads and with the 5 exported quads the total in round numbers was 100 quads. We would very soon exhaust our domestic oil at present consumption rates if we relied entirely on it for transportation. Our natural gas would follow later. Our coal reserves will last two or three centuries. Nuclear and renewables are smaller energy sources at this time. Biomass is the renewable with the greatest near term prospect for alleviating some of our national and regional EE problems. By photosynthesis solar energy together with water in the soil and carbon dioxide in the air are converted to cellulosic solids and gaseous oxygen via reactions such as

$$H_2O + CO_2 \rightarrow O_2 + CH_2O , \quad 5CH_2O \rightarrow C_5H_{10}O_5$$

With Florida's abundant sunshine and generally good rainfall it is perhaps the most favored state to exploit this form of solar energy. The parts of Texas with abundant (or over-abundant rain) and ample sunshine are also well endowed to utilize this form of solar energy. Whereas Florida must import coal and natural gas Texas is an exporter of these fossil fuels and has a dynamic petrochemical industry experienced in fuel conversion. Accordingly the two states have complementary reasons to advance biomass- fossil fuel co-utilization.

In 1986 I was appointed to the National Coal Council, an advisory council of the US Secretary of Energy. This coincided with my appointment to a UF Campus Co-gen Committee to plan a natural gas fired facility to heat the campus and generate its electricity. It occurred to me that if gas prices sky rocketed again UF could supplement its purchased gas with easily gasified cellulosic material that is abundantly generated on campus (administrative paper, paper towels, etc…). or received (junk mail, cardboard boxes, etc…). In response to a high level call to identify big potential campus projects I wrote a proposal to establish a Gasification R&D Center in conjunction with the Co-gen plant [6]. The proposal didn’t fly, but the exercise led me to focus my personal R&D on conversion of solid fuels to gaseous and liquid fuels suitable for efficient combustion turbines, fuel cells or efficient vehicles [7,8]. It also led me to the conclusion that there is an urgent need to develop omnivorous systems to convert biomass and coal and or natural gas to energy. Figure 3 illustrates conceptually the multiple public services advanced forms of co-utilization can serve with a green alliance of biomass with coal and other fossil fuels.

2. CCTL PROJECTS

With support from the Florida Gas Transmission Line based in Houston Texas, the Florida Gas Association and Peoples Gas (now a part of TECO-Energy) the CCTL in 1984 initiated coal-natural gas co-firing tests at an industrial scale (2 MWth). We succeeded in demonstrating large EE benefits but when oil prices plummeted in 1986 interest and funding for oil back-out studies also plummeted. The CCTL then shifted its focus to co-firing other domestically available fuels including municipal solid waste, energy crops, agricultural wastes and bio-solids together with coal and natural gas. However, for longer range EE needs the focus of our laboratory studies moved towards co-utilization via gasification-liquifaction processes.

In 1996 the CCTL began an effort to develop a small gasifier to convert biomass or waste material into suitable gases to power micro-turbines then being introduced to the market by Capstone, NREC, Elliot and Allied Signal. In pursuit of systems to convert solid fuels to useful gases, liquids and chars the CCTL has fabricated about ten batch type laboratory scale systems and three auger driven continuously fed systems capable of processing from about 1 kg/hr to 10 kg/hr. During the June 2002 meeting in Amsterdam of the International Gas Turbine Institute several of the most attended sessions were devoted to experiences with the initial commercialization of micro-turbine generators powered by natural gas. These sessions clearly showed that the process of moving from concept to prototype to production model to commercialization takes longer and requires more funds than most laymen recognize. Integrated micro-gasifier-micro-turbine systems will take somewhat longer.

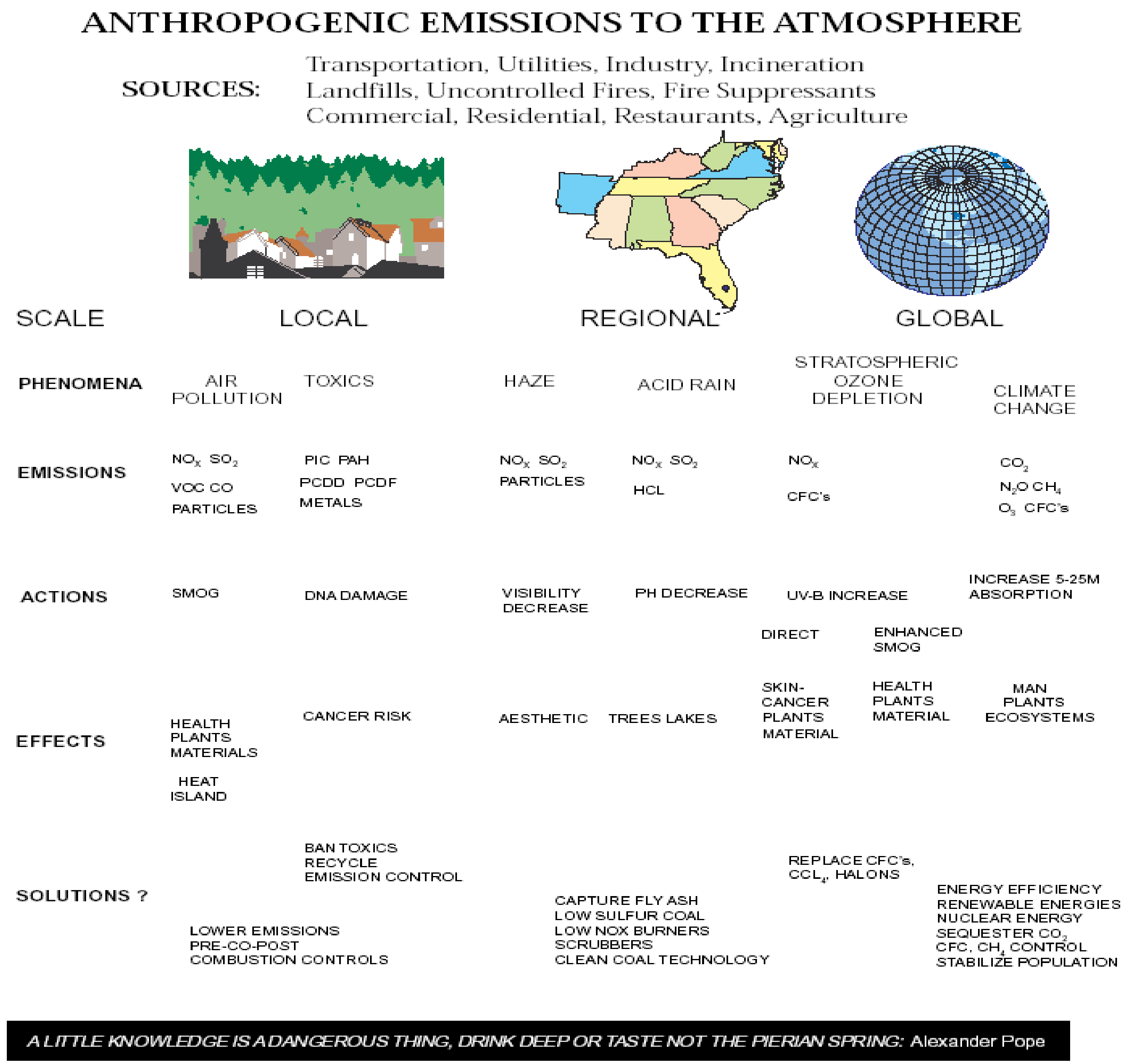

Figure 1: A diagram illustrating sources, phenomena, emissions, actions, effects and possible solutions of anthropogenic emission problems mostly associated with energy production and consumption [2]

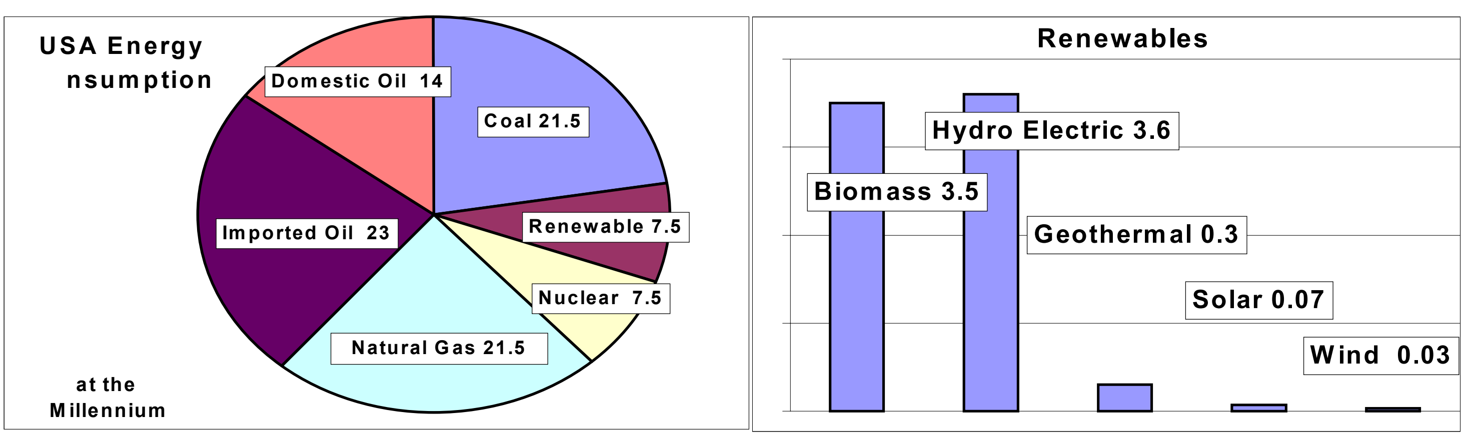

Figure 2: (Left) Total Annual USA energy consumption in quads at the millennium (Right) Renewables

3. BIOMASS AND OTHER OPPORTUNITY FUELS

A. Potential Sources

Table 1 lists various types of biomass and other opportunity fuels that should be considered in the United States and particularly in Florida, Texas and other Gulf coast states. Energy crops on under-utilized and marginal lands (No.1) and agricultural residues (No.2) probably have the largest potential for biomass to energy while potentially providing agricultural and land restoration benefits. Because biomass is more oxygenated than coal it is more easily converted to liquids and gases. These forms of biomass have been considered since the 1973 oil crises but interest increases or wanes with the price of oil set by the OPEC cartel. The forest under-story (in No.3), the cause of much of the risk of forest fire, is conventionally handled by "controlled burning". But this great waste of fuel leads to high levels of soot pollution and sometimes disastrous losses of property (remember Los Alamos!). Treating the under-story as an opportunity fuel for co-use at the closest fossil fuel plant could save millions in the values of otherwise burned lumber and homes. Preventative efforts could be more productive than fighting fires and might reduce the temptation to set fires.

No.4, infested trees is a large wood source and using them expediently would foster forest recovery. No.5, cellulosic components of municipal solid waste, No.6. urban yard waste, No.7, construction and deconstruction debris and No.8, food processing waste, are mainly sent to landfills. This usually leads to adverse environmental impacts larger than if the waste were used for energy with eco-friendly technologies. The wood energy in CCA treated wood (No.9) is substantial but the technology used must include an effective way of capturing the toxics. The same can be said for the energy opportunities and potential environmental problems with No.10, bio-solids. No.11, phyto-remediators, and No.12, algae, hydrilla, other water-remediators could render a great public service by reducing environmental impacts. In the Everglade restoration effort No.13, the disposal of melaluca, an invasive woody exotic could proceed at a much faster pace and with lower costs, if used as an opportunity fuel. Tires and waste plastics (No.14) might best be converted to liquid fuels.

B. Difficulties in Converting Biomass to Energy

Biomass to energy facilities have not done well in the USA, apart from special places where substantial waste wood is available or where substantial government subsidies are involved. Some of the problems are listed in Table 2. Problems 1-6 are mostly self-explanatory. On Problem 7-9 biomass seems to have lost out to solar cells, windmills and ethanol in the affection of the environmental community. This may be because some of the most productive energy crops are “exotics” such as kudsu and melaluca that are assumed to be uncontrollable. On Problem 10, after 15 years on the NCC the author has noted little affection for biomass (infant coal!) by the coal industry, probably out of concern for loss of market share. Yet the annual sustainable production for energy from biomass in the USA is much smaller than the economic annual production of coal, biomass naturally de-oxygenated over the past 300 million years. Problem 11 arises when biomass advocates fail to temper their enthusiasm with realistic estimates of locally available resources. Problem 12 is related to USA's low energy costs and is probably the main problem of biomass. It will be considered in the Conclusion after we have addressed technical problems. These arise largely because the potential fuels in Table 1, like coal, are solid fuels that cannot directly be used for efficient vehicles, combustion turbines, or fuel cells. "Omnivorous" fuel converters as illustrated in Figure 3 are urgently needed to change blends of domestic feedstock into clean gaseous or liquid fuels.

4. TECHNICAL ASPECTS

A. Ultimate and Proximate Analysis

To take advantage of potential national and regional EE benefits gained by harnessing the biomass and other opportunity fuels listed in Table 1 we must identify or develop eco-friendly technologies to overcome the technical problems listed in Table 2. Table 3 shows major ranks of coals as well as of peat, wood and cellulose and their ultimate and proximate analyses as measured by industry for over a century. The numbers listed are corrected to apply for dry, ash, sulfur and nitrogen free feedstock (DASNF), essentially pure carbon, hydrogen, and oxygen (CHO) materials. Figure 4 is a plot of [H], the wt% of hydrogen (solid diamonds with values read on the left scale) vs [O], the wt % of oxygen, for 185 representative DANSF CHO materials taken from ultimate analysis data available in the technical literature [9-11]. The bottom scales give conventional coal ranks, some potential names for the biomass region and some names that might foster more friendly discussions. This [H] vs [O] coalification plot shows that apart from the anthracite region all natural DANSF feedstock have [H] values that are close to 6%. Also shown on Fig. 4 by the open squares (read on right scale) are the data for [C] vs [O]. The near constancy of [H] and the smooth decline of [C] with increasing [O] provide strong reasons for treating peat and biomass simply as lower rank coals. Indeed, the diagram suggests that coals and biomass could be ranked simply by [O] to replace the different ranking systems of various countries (a Tower of Babel!). Using 34-O for peat, called "turf" in Ireland, might help reduce emotional and greed motivated responses associated with the many “turf wars” from fuel sector competitions and in energy/environmental (EE) confrontations.

Higher heating values of various fuels measured with calorimeters are usually reported with proximate analyses. Approximate HHVs in MJ/Kg for the seven representative CHOs are given in the fifth column in Table 3 according to our compromise between Dulong formulas used in the coal and biomass sectors [9-11]. Figure 5 gives the HHVs for the 185 CHO materials after somewhat iffy corrections were made for moisture, ash , sulfur and nitrogen. The Dulong formula is given in the table caption. Note that the carbon energy content (A[C]/3) is generally much larger than the hydrogen energy contribution (6A). Oxygen contributes negatively, (-A[O]/8). The sixth column of Table 3 gives representative "total volatiles", V_T, as determined by an American Standard Test Measurement Method (ASTM)). A coal sample is heated (pyrolyzed) in an inert atmosphere using a platinum crucible at 950 ^oC for seven minutes. The weight percent loss between the sample and its char is the total volatile yield. The increasing trend in V_T from high to low rank "coals" is important. The numbers in the seventh column of Table 3 represent $FC = 100 – V_T$, the fixed carbon for pure CHO materials. Figure 6 is a plot of V_T yields of the 185 representative DANSF CHO materials vs [O]. An approximate equation for V_T is given in the caption. Note the increasing trend

TABLE 1: Biomass and other Opportunity Fuels

1. Energy crops on underutilized or marginal lands.
2. Agricultural residues
3. Forest understory and forestry residues.
4. Infested trees, pine beetles, citrus canker, oak spore
5. Cellulosic components of municipal solid waste.
6. Urban yard waste,
7. Construction and deconstruction debris.
8. Food processing waste.
9. CCA and other treated wood.
10. Biosolids (sewage sludge).
11. Plants grown for phytoremediation of toxic sites.
12. Algae, hydrilla, water plant-remediators
13. Invasive species (melaluca in the Everglades),
14. Used Tires and waste plastics.

TABLE 2: Problems with Biomass Utilization

1. Hard to feed and mechanically process.
2. Low energy density limit economic transport distances.
3. Seasonal availability presents problems off season.
4. High moisture content of plant matter.
5. Higher alkali metal content fosters ash melting.
6. Difficulty of exploiting economy of scale.
7. Excluded from solar and windmill fraternities.
8. Excluded by ethanol fraternity
9. Not favored by environmentalists.
10. Not favored by the coal industry.
11. Resource over-estimates by biomass advocates.
12. Does not compete cost-wise with coal or natural gas.

Table 3: ASTM classification of coals by rank (for DASNF fuels)

	Ultimate Analysis			Proximate Analysis			Other properties					
Name	**C**	**H**	**O**	**HHV**	**VT**	**FCCh**	**Dens**	**E/vol**	**RelchR**	**H,OH Rad**	**O-Rank**	**Acron.**
Anthracite	94	3	3	36	7	93	1.6	58	1.5	v. low	3 –O	vlo O
Bituminous	85	5	10	35	33	67	1.4	49	5	low	10 -O	lo O
Sub Bitum	75	5	20	30	51	49	1.2	36	16	med	20 -O	slo O
Lignite	70	5	25	27	58	42	1	27	50	interm	25 -O	mod O
Peat	60	6	34	23	69	31	0.8	18	150	high	34 -O	shi O
Wood	49	7	44	18	81	19	0.6	11	500	v. high	44 -O	hi O
Cellulose	44	6	50	10	88	12	0.4	9	1600	v v.high	50 –O	vhi O

lo-low, hi- high, v-very, s-somewhat, mod-moderate

Table 4: Benefits of "coal and biomass alliance"

I. <u>What can Biomass do for Coal?</u>

A. Co-firing Biomass with Coal
1. Lower CO_2, SO_2 and NOx emissions
2. Foster renovation and ecofriendly use of coal facilities
3. Foster IGCC, IG-cogen, CHP and chem factories.

B. Co-gasifying Biomass with Coal
1. Facilitate conversion to gases and liquids
2. Provide important environmental roles for coal
3. Facilitate capture of toxics (mercury, arsenic…)

C. CO_2 Sequestration, Nature's Way
1. Federal, state land reforestation, new parks
2. Interstate highway plantings
3. Urban forestation (elms)
4. Wood buildings and carbon products
5. Reforestation abroad

D. Phytoremediation
1. Remediate toxic sites
2. Restoration of mined lands
3. Foster phyto-mining

E. Provide opportunities and challenges for power generation companies to develop eco-friendly solar energy resources and technologies in the public interest

II. <u>What can Coal do for Biomass?</u>

A. Make Opportunity fuels competitive
1. Lower capital cost of co-utilization (co-firing)
2. Foster use with turbine generators (co-gasifying)

B. Provide economic agricultural alternatives
1. Energy crops
2. Use of agricultural residues
3. Disposition of problem plant matter (Table1)
4. Overcome biomass-use problems (Table 2)

III. <u>What GABC do for the U.S.A, Florida and Texas?</u>

A. Foster ecofriendly use of existing facilities
1. Develop a biomass market and supply infrastructure
2. Foster biomass to liquid fuels chemicals.

B. Mitigate anti-environmental image of USA
1. Lower $CO_{2,}$ pollution and toxic emission problems
2. Foster advanced environmental technologies
3. Foster phyto-remediation, phyto-mining

C. Level the R&D playing field by fostering:
1. Cooperation with high energy cost countries
2. The long overdue development of pyrolysis science
3. A quantitative ranking system for all "coals"
4. General development of fuel co-utilization

D. A sensible energy- environmental policy (SEEP).

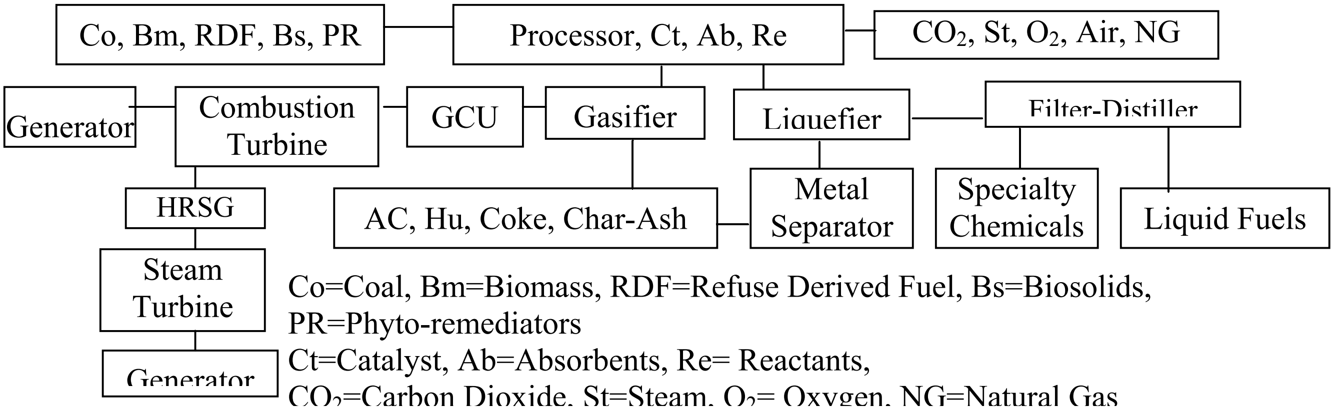

Figure 3: Conceptual diagram of an omnivorous feedstock converter

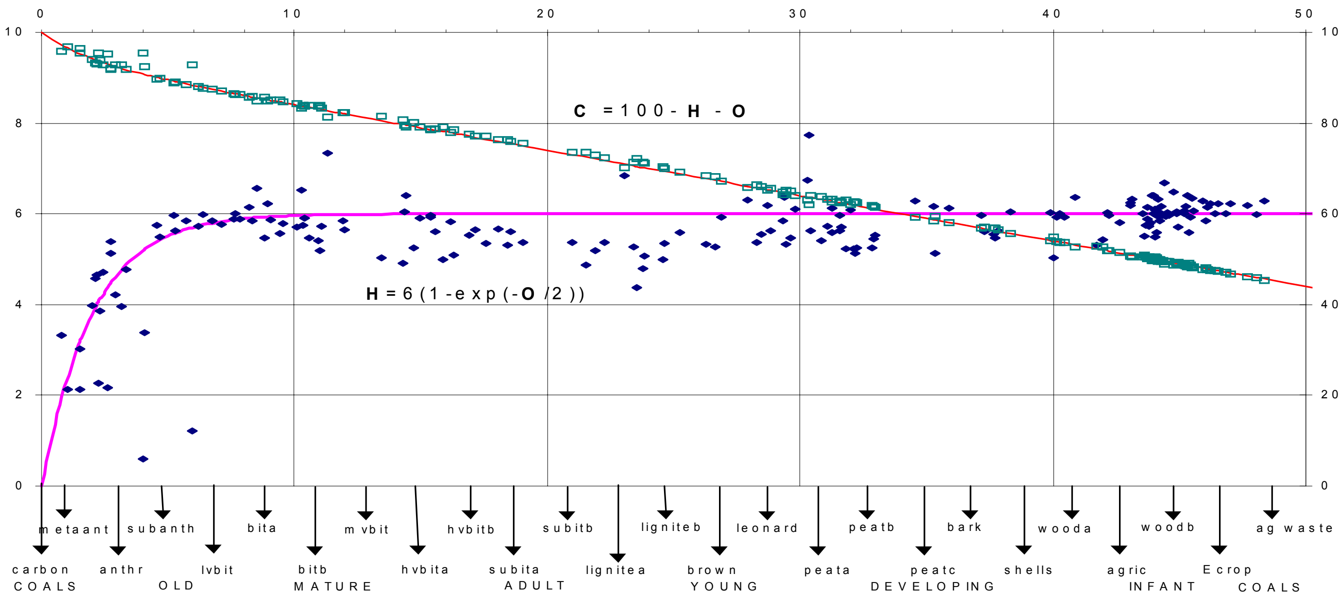

Figure 4: Weight percentages of hydrogen [H] vs [O] for 185 DASNF carbonaceous materials (black diamonds) vs oxygen wt% (read left scale) the upper curve and data shows [C] on right scale vs [O]. Rank labels are given at the bottom scale [O] values on top scale

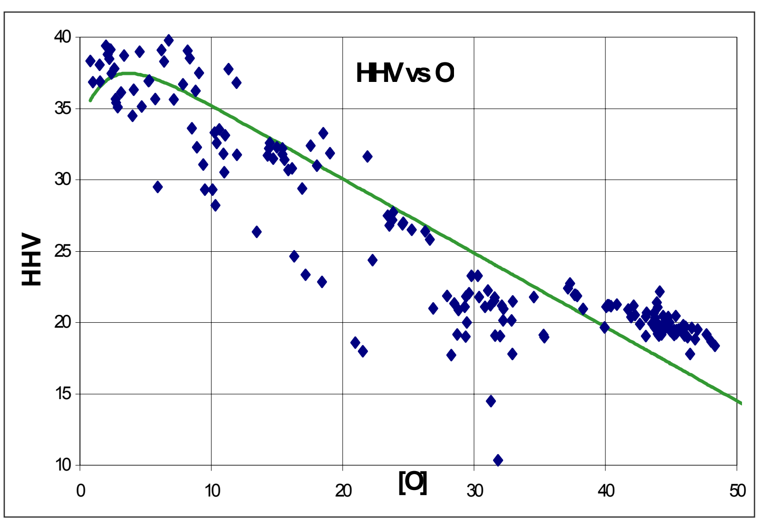

Figure 5: Higher heating values (HHV) of 185 carbonaceous materials (corrected to DASNF) vs. [O]. The smooth curve represents HHV= A([C]/3+[H]-[O]/8)

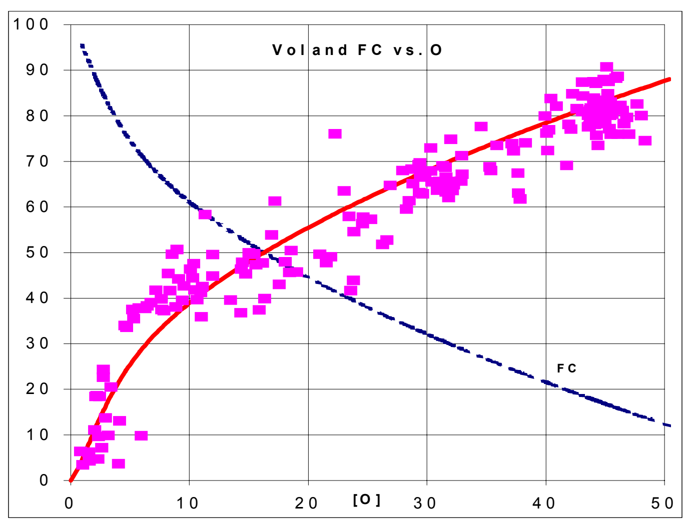

Figure 6: Total volatile weight percentages vs [O] for 185 DASNF carbonaceous materials (squares) from proximate analysis. The curve through the data points satisfies $V_T = 62([H]/6)([O]/25)^{1/2}$

in V_T from anthracite to bituminous, sub-bituminous, lignite, peat, wood and cellulose. The patterns in Tables 3 and Figures 4, 5 and 6 are crying out "We are Family".

The eighth column of Table 3 gives nominal densities (in Kg/liter) for the various CHO fuels. The ninth column gives E/vol, (in MJ/liter), the product of the heating value times the density. Low energy densities limits the economic transport distances of biomass. The tenth and eleventh columns of Table 3 shows some properties of CHO materials that are not yet well quantified but are relevant to co-utilization issues. The tenth column gives relative char re-activities [12]. In thermal processing and in steam, oxygen or CO_2 gasification HiO char has advantages. The eleventh column gives a qualitative picture of the free H and OH radicals that are released in high temperature pyrolysis. Since high char reactivity and free radicals facilitate thermo-chemical processes, HiO materials have advantages on both scores. We might blend HiOs with LoOs so that useful properties of one rank assist thermal processing of another. The twelfth column gives our proposed quantitative ranking system and acronyms.

B. What's in the Volatiles?

It was recognized throughout the 20th century that volatiles from solid fuels are very important properties that influence the design of solid fuel combustion, gasification or liquification systems. Nevertheless, at the beginning of the 21st century we still cannot predict the gaseous compounds in the volatiles released in proximate analysis measurements. Nor can we predict the rate constants for their release [13,14]. If the volatiles were mostly CO_2 or H_2O vapor they would have little fuel value. On the other hand if the volatiles are mostly CO, CH_4, and H_2 they could be suitable for reciprocating engines, combustion turbines, fuel cells and other applications. In 1995 we began an experimental and analytical effort to systematize and quantify what is in pyrolysis volatiles [15-17]. The fact that hundreds of complex organic compounds are found in the tars, chars, liquids and gases from coal and biomass pyrolysis [18] probably is the main reason that pyrolysis is still not a predictive science. Our analytic formulas can now generate output graphs for the hundreds of organic products that have been observed in pyrolysis. We have presented our still evolving formulas at technical society meetings [19-21] not as a final result but as a challenge to specialists in the coal and biomass fraternities and to ourselves to develop better formulas that are needed to optimize the design and application of co-utilization systems.

5. CO-UTILIZATION BENEFITS

A. The Co-firing Option

Many of the problems noted in Table 2 associated with exclusive use of the biomass noted in Table 1 can be overcome if these fuels are co-fired at a nearby utility or industrial plant in relatively small proportions (say 5-15% by energy) with the coal or natural gas normally used. While some problems arise several of the major forms of biomass listed in Table 1 can be handled at standard industrial or utility plants with modest retrofit costs. For smaller utilities, factory fabricated robust solid fuel systems can serve a valuable role in fostering "Distributed Generation", a concept that lends itself to co-utilization. If fueled mainly by biomass (HiO), co-firing with natural gas or coal could improve the flame and reduce emissions. Since HiOs are relatively easy to gasify another form of co-firing would be to build a separate HiO gasifier at a standard coal or natural gas plant and direct its gaseous products into a suitable combustion zone of the coal or natural gas flame. Co-firing HiOs or HiO generated gas in a LoO fireball can lower NOx, SO_2 as well as CO_2 emissions.

B. The Co- gasification Option

The omnivorous conversion system conceptually illustrated by Figure 3 is intended to change solid fuels into gaseous or liquid forms for use with efficient energy systems such as combustion turbines, co-gen systems, combined cycle systems, fuel cells and fuel cell-turbine combinations. A major environmental advantage of the co-gasification option comes when using or disposing of CHO materials laden with toxic materials. Here it should be possible to condense out, chemically scrub or adsorb toxic metallics such as arsenic, mercury, lead etc… after the gasifier but before the turbine. The volume of gas that must be scrubbed is then much smaller than the volume involved in combustion followed by stack gas scrubbing [22,23]. A recent economic analysis indicating that coal's mercury problem can be brought under control with much lower capital costs via the gasification route supports this general conclusion [24]. One would expect the same principle to apply to the disposal of arsenic laden lumber or phyto-remediators, deconstruction debris with lead paint or other toxic pigments. Detailed investigations are needed to optimize the gas cleaning additives, reactants and reactants.

C. Biomass Liquefaction

Liquefaction of biomass, mostly under development in Europe and Canada provide a complementary path to gasification. Because of their high oxygen content biomass is easier and requires less energy to bring into liquid (or gaseous) forms [25,26]. Liquids are easier to store than gaseous fuel and to use than solid fuels. These advantages, well recognized in the transportation sector [8], can also apply to industries and utilities. Thus when liquid production exceeds demand the full production rate can be maintained and the stored fuel used in times of high demand or sold to nearby utilities or industry. Technologies for improving the shelf life of these pyrolysis liquids are under development. Co--liquifying biomass with LoO coal would bring more abundant resources into the "pot" and use the reactive properties of the HiOs to help convert the LoOs [27].

It is well known and obvious from Figure 2 that the main energy problem in the USA is our excessive reliance on imported oil. A survey made by the author 5 years ago found that among the commercial organizations working on pyrolysis of biomass to liquid fuels and chemicals only one commercial firm out of 18 was based in the USA. The USA program to generate ethanol via fermentation of corn to produce high value gasoline additives probably consumes more liquid fuel than it generates. Extensive experience in Brazil showed that substantial government subsidies were required. It might do more for our liquid fuel deficit if the residue, xylage, were also converted to liquid fuels perhaps with HiO-LoO co-liquefying technology. Our obesity epidemic would escalate if the xylage were used for cattle feed.

Another liquid co-utilization technology would be to blend used vegetable oil from fast food restaurants with pyrolysis liquids for use in diesel engines. It would be useful to develop technologies to blend pyrolysis liquids from HiO-LoO mixtures or tires and plastics to multiply the impact of the limited used vegetable oil.

D. Phyto-remediation

The use of plants as pollution sponges to cleanse toxic sites and contaminated bodies of water is a rapidly developing technology. Specialized plants can: 1. Remove metal contaminants, 2. Treat organic contaminants, 3. Remove radioactive contaminants and 4. Extract contaminants from sewage sludge. With the very large number of toxic sites that need re-mediation the plant matter output should be very substantial. Recent cuts in Superfund aid could indirectly foster phyto-re-mediation as a low cost, albeit slower, means of re-mediating toxic sites. Work on the disposal of CCA treated wood [22,23] and the use of mercury laden coal [25] point to pyrolysis/gasification as the only viable eco-friendly approach to the disposal of toxic laden biomass. The same technology, when developed with adequate funds, should apply to the disposal of ferns that thrives on arsenic. Since widely differing plants are used as phyto-re-mediators it is essential to bring order into the science of pyrolysis.

Phyto-re-mediation of mined lands can convert many of Florida waste phosphate lands and Texas strip mined lands and depleted oil fields into productive energy plantations. In addition to re-mediation of used mine lands, the industry could make use of phyto-mining, a new technology for extraction of valuable metals. Furthermore, a GABC could encompass the use of coal and humates such as leonardite derived by mild oxidation of coal as useful soil amendments to foster biomass production. Such products could also be used for re-mediating ground water contaminated with mining waste by serving as chelating and detoxifying agents. Texas with its large lignite resources could make important contributions in this area. Restoring land, production of energy and valuable materials are all possible with adequate R&D funds and a sensible environmental -energy policy (SEEP).

6. DISCUSSION

Section 4, Technical Aspects, refers to an analytical model of slow pyrolysis product yields intended to provide detailed estimates of outputs for all "coals" and all temperatures. It is an encapsulation of experimental data versus the variables [O], [H], T and the a, b and c's of the products $C_aH_bO_c$.. Time is a very important dimension but since it brings into play additional variables (particle size, porosity, heat transfer properties etc…) it will take somewhat longer to find formulas that include the time dimension.

At this time large public funds are devoted to: 1. Esoteric basic sciences that are educational and of long term interest but somewhat irrelevant or of lower priority in times of national difficulties, 2. Major thermo-chemical engineering projects dependent on pyrolytic processes and 3. The current US proposal processing industry that consumes much of the National R&D resources. The possibility of devoting a minute fraction of these funds towards bringing order to the fundamentals of humankind's oldest technologies, (extracting energy from wood and coal) certainly warrants serious consideration.

7. CONCLUSIONS

In view of experiences when fuel availability were matters of life or death [28, links 3 and 4] the author has concluded that a sensible energy/environmental policy (SEEP) must include "A green alliance of biomass and coal" (GABC). I borrowed this title from an European Union (EU) program that began in 1992 (see europa and netherlands links). However, this "Green" has been trying, thus far unsuccessfully, to forge such an alliance between biomass, coal and environmentalists since joining the NCC in 1986. In the EU, where population densities and energy costs are higher, the need for co-utilization has arrived earlier than in the USA and R&D have received earlier support. Our best bibliography lists 50 publications from the EU [e.g. 29-37] on co-gasification/liquefaction and only 4 from the USA, other than the 16 from CCTL's program. In the USA, coal based Integrated Gasifier Combined Cycle (IGCC) systems solve some co-gasification problems but do not take advantage of the ease and low energy costs of biomass conversion.

Perhaps more difficult than the technical problems of co-utilization are the socio-political problems. There is a lack of public recognition of how our quality of life depends on energy resources and technologies (e.g., air conditioning in Florida and Texas!) and understanding of where the decimal place belongs in the numbers involved. Uniting domestic biomass, coal and natural gas sectors and environmentalists is very difficult because of our tendencies towards competition, confrontation and turf protection. With 9/11, the Enron, World-com and other corporate bankruptcies, public disenchantment with greed as the primary decision driver, the recession, the large unemployment rate, the trade and budget deficits the USA must now close ranks on a SEEP. Florida, because of its favorable biomass resources, and unfavorable fossil fuel resources would directly benefit from co-utilization. Texas because of its favorable fossil fuel resources and favorable biomass resources would also benefit by advancing and applying co-utilization technologies. The characteristics of the two are complementary and both could become national and international leaders by implementation of GABCs. Table 4 list advantages of a GABC in fostering a SEEP that will:

- Make practical and eco-friendly use of the solar energy resources available in Florida and Texas
- Make it possible to pursue energy and environmental goals without being considered SCHIZOPHRENIC.
- Deem those against eco-friendly applications of all domestic energy sources just plain NUTS.

8. ACKNOWLEDGEMENTS

This work was supported by a grant from the Mick A. Naulin Foundation, part of a National Science Foundation Grant for the disposal of phytoremediators, the College of Engineering and Green Liquids and Gas Technologies. I thank my many co-authors for their technical contributions and Professor John Cameron, Dr. Evan Hughes, Mr. Andrew Hines Jr, Professor Sanford Berg, and Texas Railroad Commissioner Charles Mathews for helpful comments and encouragement.

Footnote: A two-day International Conference (IC) specialized on technical aspects of Co-utilization of Domestic Fuels (CDF) will be held at the University of Florida, February 5-6, 2003.

9. REFERENCES

1. A. Green, ed. (1966), The Middle Ultraviolet, Its Science and Technology, J. Wiley New York, N.Y.
2. A. Green, ed. (1989), Greenhouse Mitigation, FACT-ASME, New York, NY.
3. A. Green, ed. (1980), Coal Burning Issues, University Presses of Florida.
4. A. Green, ed. (1981), An Alternative to Oil, Burning Coal with Gas, University Presses of Florida.
5. A. Green, et al., (1986), "Coal-Water-Gas, An All American Fuel for Oil Boilers", Proc. of the Eleventh Intern. Conf. on Slurry Technology, Hilton Head, SC.
6. A. Green, (1986), "University of Florida proposal for waste gasification facility for campus co-generator",
7. A. Green, ed. (1988), Co-Combustion, Fuel and Combustion Technology (FACT) Div. American Society of Mechanical Engineers (ASME), New York, NY.
8. A. Green, ed. (1991), Solid Fuel Conversions for the Transportation Sector, ASME-FACT, New York, NY.
9. S. Stultz, J. Kitto, ed. (1992), Babcock & Wilcox, Steam 40th Edition, Barberton, Ohio.
10. J. Singer, ed. (1981), Combustion-Fossil Power Systems, pp. 16-23 Combustion Engineering Inc., Windsor, CN.
11. S. Gaur, T. Reed, ed. (1998), Thermal Data for Natural and Synthetic Fuels, Marcel Dekker Inc., New York.
12. R. Hurt, (1998), "Structure, Properties and Reactivity of Solid fuels", Int. Combustion Symp.V 27.
13. D. Klass, (1998), "Biomass for Renewable Energy, Fuels, and Chemicals", Academic Press, San Diego, CA.
14. P. Solomon, M. Serio, E. Suuberg, (1992) "Coal Pyrolysis Experiments Kinetic Rates and Mechanisms", Progress38 Energy and Combustion Sciences Vol. 18, pp135-220.
15. Green, A. M. Zanardi and S. Peres, "Thermal Conversion of Biomass" (1996), Conf. on "Eco-friendly Technologies3 for Biomass Conversion to Energy and Industrial Chemicals" in Tirupati India, Chapter. 6 in Bioenergy, Vision for the New Millenium, (2000), R. Ramamurthy, S. Kastury and W. Smith Eds. Science Pub. Enfield NH.
16. A. Green, M. Zanardi, S. Peres, J. Mullin, (1996a) "Co-gasification of Coal and Other Domestic Fuels," Proc. 2 Ist Inter. Conf. on Coal Utilization, Clearwater FL,. 569.
17. A. Green, J. Mullin, (Oct 1998), "Feedstock Blending Studies with Laboratory Indirectly Heated Gasifiers", Jour. of Eng. for Gas Turbines and Power, V121, pg. 1-7.
18. T. Milne, N. Abatzoglou, R. Evans, (Nov 1998), "Biomass Gasifier 'Tars':", NREL/TP-570-25357.
19. A. Green, P. Venkatachalam, M. Sankar, (2001b), "Pyrolysis Systematics for Co-utilization Applications", IASTED's Power and Energy Syst. Conf., Tampa, FL.
20. A. Green, P. Venkatachalam, M. Sankar, (2002c), "Feedstock Blending in Gasifiers/Liqufiers", Proc. ASME Turbo Expo 2002, Amsterdam.
21. A. Green, S. Sankar, R. Chaube, (2002), "Multipurpose Solid Waste Disposal System for the ISS", Proc. 32nd ICES Conference, San Antonio, Texas.
22. A. Green, G. Schaefer,(1999), "Feedstock Blending in Indirectly Heated Gasifiers/liqueifers ", Paper 99-GT-81, Turbo Expo, 1999, Indianapolis, IN.
23. D. Nilsson, A.Green (1999), "Thermal Disposal of CCA Treated Wood" Paper 99-938, Air and Waste Management Conf. June , Sr Louis, Missouri
24. M. Klett, M. Rutkowski, (2002), "The Cost of Mercury Removal in an IGCC Plant", Letter Report to DOE.
25. T. Milne, R. Overend, (1994), "Fast Pyrolysis, Biomass and Bioeneregy", Vol 7, No.1-6.
26. A. Bridgewater, A. Peacocke, (2000), "Fast Pyrolysis Processes for Biomass, Renewable & Sustainable Energy Reviews",v. 4,1 1-73.
27. F. Karaca, E. Bolat, (2000), "Coprocessing of Turkish lignite with a cellulosic waste material", Fuel Process Technology, v. 64: n1-3 pp. 47-55.
28. A.Green, (2001), "A Physicist with the Air Force in World War II", Physics Today, Aug., pp. 40-44. (See link 4)
29. J. Bemtgen, K. Hein, A. Minchener, (1994), Cogasification of Coal/Biomass and Coal/Waste Mixtures, European Union Clean Coal Technology Programme 1992-1994, Stuttgart.
30. R. Van Ree (1997), "Cogasification of Coal and Biomass Waste in Entrained-Flow Gasifiers, ECN-C-97-021
31. C. Storm,., Rudiger, H., Spliethoff, H. and K.Hein (1998), Co-Pyrolysis of Coal/Biomass and Coal/Sewage Sludge Mixtures", Intern Gas Turbine and Aeroengine, Stockholm, June 2-5, 1998, 98-GT-103. ASME New York, NY.
32. A-G. Collot, A. Megaritis, A. Herod, D. Dugwell and R. Kandiyoti, (1998) Co-pyrolysis of coal and biomass in a pressurized fixed bed reactor ibid [31]
33. C. Guanxing, Y., Qizhuang, C. Brage, C. Rosén, C., and K. Sjöström, , (1999), "Co-Gasification of Coal/Biomass Blends" ASME TURBO-EXPO 99 paper 99-GT-191.
34. E. Kurkela, (1996), " Co-Gasification of Biomass and Coal- An Overview," Proc. Biomass for Energy and the Environment, 9th EU Bioenergy Conf..
35. A. Minchener, (1999), "Syngas Europa," Mech. Engineering,
36. Y. Pan, G. Velo, X. Roca, J. Manya and L. Puigjaner (2000) Fluidized-Bed Co-gasification of Residual Biomass/Poor Coal Blends for Fuel Gas Production, Fuel 79
37. A. Bridgewater, (2001) ThermoNet, No. 12
38. R Korbee, S. Eenkhoorn, P. Heere, J.. Kiel, "Co-gasification of coal and biomass waste in entrained-flow Gasifiers, Exploratory Lab scale Experimentation" ECN-C-98-056

1. http://europa.eu.int/comm/research/success/en/ene/0060e.html 'the green alliance of coal and biomass'
2. http://www.ecn.nl/library/reports/1997e/c97021.html is the link of Energy research Centre of the Netherlands, The Netherlands
3. http://plaza.ufl.edu/aesgreen/icaas/ is the web link for ICAAS-CCTL
4. http://www.physicstoday.org/pt/vol-54/1ss-8/p40.html

This work is an adaptation and expansion of Appendix F of the National al Council report submitted to the Secretary of Energy in June 2002.