TLUD Gasifier in Ashden Award for Enterprise

(Draft document 19 Sept 2007, by Paul S. Anderson)

Introduction (and Summary):

The Daxu (pronounced daa'-shu) cookstove from China is evidently a TLUD (Top-Lit UpDraft) gasifier stove. The Daxu company won the First Prize Ashden Award for Enterprise in 2007, producing more than 25,000 units by the time of the competition. Sources of information are cited, but this is not a fully academic analysis because the author has not yet personally handled or operated a Daxu cookstove.

Sources of Information:

[1] http://www.ashdenawards.org/ (Home page about the nature of the Awards)
[2] http://www.ashdenawards.org/finalists_2007 (See second item on that page.)
[3] http://www.ashdenawards.org/media_summary07_daxu
[4] http://www.ashdenawards.org/files/2007_technical_summaries/Daxu_China_technical_report_2007.pdf
[5] http://www.ashdenawards.org/wmv_2007_daxu (Windows Movie Video; also available as a QuickTime Movie at source [2].) Excellent information about the Daxu cookstove, including views of making biomass briquettes from corn stover.
[6] http://www.vrac.iastate.edu/ethos/proceedings2007.php See "Session 2" and find: Dana Charron Biomass Stove Competition in China and click on (view). With co-author Bryan Willson. (A presentation to the ETHOS 2007 conference, 27 January 2007, entitled: "Promotion of Technology Innovation and Dissemination for High-Efficiency, Low-Emissions Biomass Household Stoves in China and Abroad."
[7] Photos provided by Bryan Willson (not published as far as I know).
[8] Personal conversations with staff of CEIDH who have seen the actual Daxu stove.
[9] Personal conversations with Chinese participants (associated with CAREI)l at ETHOS and PCIA III conferences.
[10] Comments by the author based on personal experiences with TLUD gasifiers and "reading between the lines" in the above sources. I also indicate my comments with my initials "PSA."

For full information, read the various websites. What is presented below are highlights related to the Daxu stove being a TLUD gasifier, and lessons learned from and about their success.

The Daxu cookstove:

[2] China: Beijing Shenzhou Daxu Bio-energy Technology Company Ltd (Daxu) has succeeded in developing an innovative stove design that replaces coal by burning widely available crop waste as well as burning wood much more efficiently.

[2] With its two hot plates, it also allows families to cook a stir-fry dish and steamed rice at the same time. Some Daxu stove models also come with a back boiler which provides hot running water and heating to rural families, often for the first time.

[6] & [7]

Shenzhou Daxu

[3] Some of the Daxu stoves also come with a back boiler (not shown here), bringing running hot water and central heating to rural families for the first time. [See the video [5] for glimpses of a 50 liter water tank and a wall-mounted hydronic radiant heater.]

Technology:

[3] The Daxu stove is specifically designed to use either loose or compressed crop waste as well as wood. The stove is over 40% efficient and produces hardly any smoke. This is achieved by burning the fuel using a controlled supply of air that produces gas which then rises to meet 'secondary' air causing the fuel to burn more thoroughly. This ensures that the fuel burns more efficiently and that heat is transferred to the pots more quickly which allows a meal to be cooked in 15 -20 minutes with minimal smoke pollution.

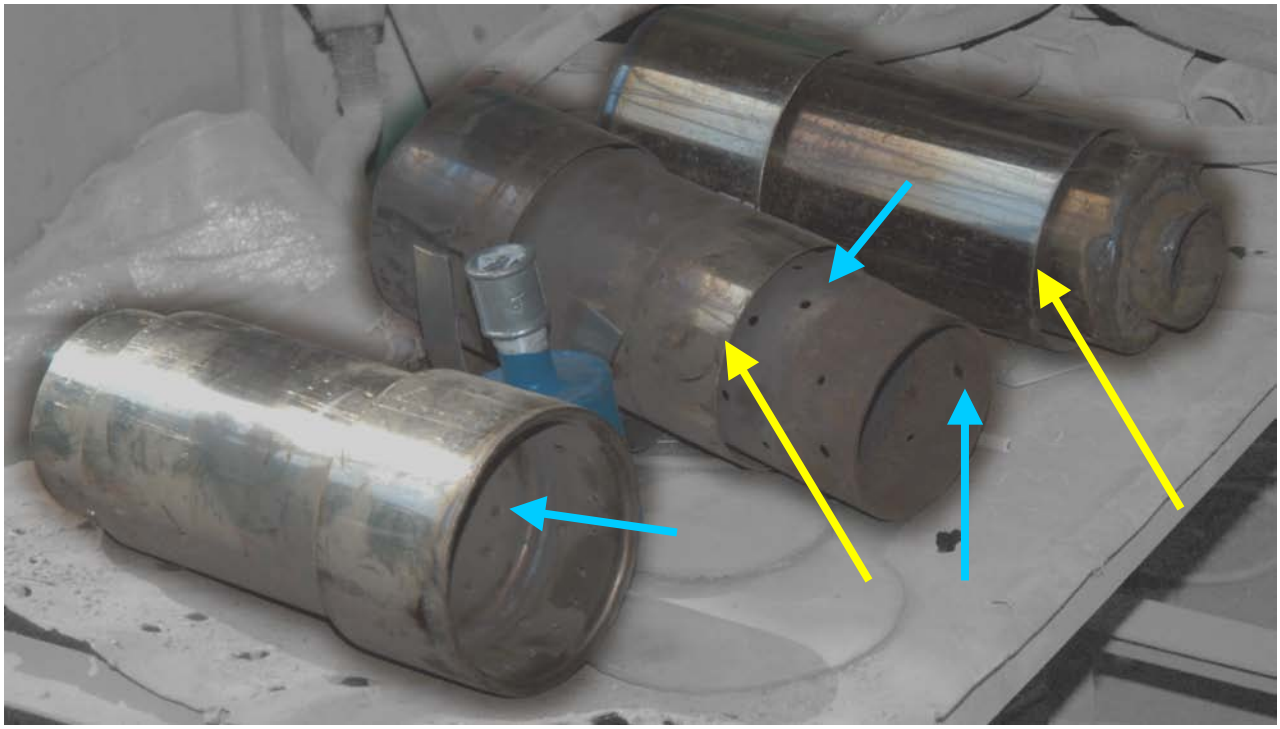
[4] In early designs the fuel in the firebox had to be lit separately outside the stove, the box being slotted into the stove once alight. This could be seen as causing a potential fire risk. But more recent stoves allow users to load the fuel directly into the stove, and then light it.

[10] These statements and photos clearly indicate some of the major distinguishing features of the Top-Lit UpDraft (TLUD) gasification technology. The fuel is in a container and is ignited at the top. The recent Daxu ability to load fuel from the top BEFORE IGNITION is found in other TLUD gasifiers. The addition of fuel from the top AFTER a period of TLUD gasification is also consistent with how some people utilize TLUD devices for extended burning, but that is no longer using the TLUD principles of pyrolytic gasification.

[4] The stove uses gasification techniques to burn the fuel efficiently, and also ensure efficient heat transfer to the cooking pots. The fuel is initially burned with a controlled supply of air in a combustion box in the base of the stove. At this stage the biomass is partially oxidised to carbon monoxide and other gases, releasing some heat. These gases rise up an insulated internal chimney, and an inlet higher up the stove introduces secondary air, which is used to burn the gases and release more heat from them.

[10] The term “internal chimney” is consistent with the language used to describe Anderson’s Champion Stove, which is also driven by natural draft. The internal chimney is seen in these photos by Willson [7].

PSA has added blue arrows to show some of apparently many lateral holes for air to enter into the central part of the internal chimney. The yellow arrows show a sheath, apparently to entrain the secondary air to the lateral holes. An additional sheath (shown by the white arrows) evidently encircles the entire internal chimney, bringing hot air to the holes.



[10] The use of lateral holes to introduce secondary air into the stream of flue gases is a major feature in the Reed Woodgas Campstove TLUD gasifier. But that unit has fan-forced air and the impact on the turbulent mixing of air and gases is pronounced. Such turbulence, force, volume of air, etc. is not evident in the Daxu stove, nor would it be expected because of the evident smallness of the holes and the inherent weakness of the suction of natural draft.

[4] The addition of secondary air enables more useful heat to be extracted from the fuel than in a stove with just a primary air supply,

[correction by PSA: Should read: …with just one air supply entrance for serve both the primary and secondary air,…

and it minimises the emission of gaseous pollutants and smoke. Because the secondary combustion takes place just under the hotplate, the heat transfer to the pot is very efficient. Waste gases are vented out of the kitchen through a chimney.

[4] To achieve high efficiency and low emissions, the air flow must be controlled very carefully, and in the current Daxu designs this is done by using a chimney to draw air through the two parts of the stove, rather than by using an electric fan. To achieve this, fuel is loaded into the firebox and lit, and the stove is then closed, rather than being accessible for continuous feeding. New Daxu designs have larger fireboxes so that re-loading needs to be done less frequently

[10] Like all true TLUD gasifier devices, the Daxu cookstoves operate with a "batch" of fuel defined in size by the fuel canister. There is no discussion of providing a second fuel canister to insert when the first batch of fuel is expended.

Origins of the Daxu TLUD gasifier cookstoves:

[3] In 2000 Mr Pan Shijiao together with others began researching and developing a stove design that could effectively burn crop waste in addition to burning wood much more efficiently. Satisfied that they had come up with an innovative new design that could do the job, in April 2005 Shijiao set up the Beijing Shenzhou Daxu Bio-energy Technology Company Ltd (Daxu) to commercialise the new improved stove.

[4] Development and piloting of the stove was carried out from 2003 to 2006, and factory production started in September 2006. Since then 25,000 improved stoves have been sold. Daxu now has the capacity to produce about 100,000 stoves per year from its five factories.

[10] These two statements leave unanswered the obvious question of whether Mr. Shijiao and/or his associates learned of or were influenced by the original concept of TLUD pyrolytic gasification by Dr. Thomas B. Reed. To acknowledge that link does not diminish Mr. Shijiao's accomplishments, which are many and truly significant. To state that no linkage existed would indicate a deficiency in researching the prior art about cookstove gasification, but that could be possible in light of the relative isolation of China concerning information flows.

Tom Reed invented what he originally called Inverted DownDraft – IDD - gasification in 1985, had a major publication (Reed – Larson 1996) about natural draft TLUD technology, developed and showed a prototype of the forced-air version in Pune, India, in 2000 while Alex English and others also showed TLUD technology in Pune. Reed and Anderson co-authored a widely available paper in 2004, and several presentations have been made at early ETHOS conferences. Also, the Archives of the Stoves ListServ show early discussions about TLUD / IDD experiments.

Others and I will be curious about this until Mr. Shijiao addresses the topic of origins. Only one person (to my knowledge) has implied he/she invented what is now called TLUD gasification independently from Dr. Reed, and that person has declined to answer my request for details about the initial moments of inspiration, and does not make open claims any longer.

Production of Daxu cookstoves:

[10] The Ashden Award for Enterprise is truly for enterprise, not specifically for a technology. Other stove technologies have played an important role in projects that won an Ashden Award, and there is no attempt by the Ashden Award organizers to compare different technologies, especially in different years. The Award is for accomplishments, and the Daxu efforts are highly noteworthy.

[2] …since September last year, 25,000 models have been sold, with 10,000 sold in the first three months of 2007. There is enormous potential for introducing this technology throughout China, since over 20 million wood and coal stoves are sold each year.

[2]

Stove parts are manufactured and assembled in five [rented] Daxu factories. The manufacturing processes are straightforward, and can be carried out with standard metal-working equipment. Most parts of the stove body are made from cold-pressed steel, which is bought in rolls from local suppliers, and mechanically cut and folded in the factory. Holes for pipework, vents and screws are drilled in the metal, and the main assembly is then welded, sanded and painted.

[4] Another health benefit is that the stove is well insulated, so the outside stays cool (below 50ºC) which minimises the risk of burns.

[10] The insulation comes in large part from the double-walled construction, a useful aspect not found in most natural-draft TLUDs.

[4] Daxu hopes to install 100,000 stoves during 2007, and has ambitious plans for continuing growth after that. Semi-gasification technology is a necessary development to increase stove efficiency in many parts of the world. Daxu has started marketing to other countries in South-East Asia, and there is potential to use the concept in many other countries.

[10] The use of the term “semi-gasification” here could cause some confusion. Perhaps “pyrolytic gasification” could be substituted. All terminology about these topics is not yet uniform.

[4] Potential for growth and replication

The potential demand for improved cooking stoves in China is huge, with around 20 million coal or firewood stoves being sold each year. It has been estimated that around 700 million tonnes of biomass residue are produced in China each year, consisting of crop and forestry waste, firewood, animal manure, sawmill waste and cooking waste. Theoretically, this is sufficient to meet all of rural China's cooking needs.

Location and financing of the project:

[4] Yanqing County is a rural area northwest of Beijing, where most people are farmers growing maize, wheat and vegetables. Briquetting plants have been set up to produce briquettes from some of the large quantities of crop residues. The Yanqing County Authorities are supporting the sale of Daxu's stoves through a subsidy and sales have been impressive: 10,000 of the most popular stove model were sold during the first three months of 2007 and 25,000 stoves have been sold in total.

[4]How users pay

£1 = 15 Chinese Yuan [March 2007] [= 2 US$ Sept 2007]

The full price of the recent stoves is about Y1,000 (£70). If a user wishes to use the stove to provide hot water and heat radiators, extra equipment must be purchased. In some regions, customers pay the full price, but in others the stoves are eligible for a government subsidy. For instance, in Yanqing county, where Daxu is the official supplier for a government programme, the cost to users is Y50 to Y200 (£3 to £13). For comparison, coal stoves are unsubsidised and cost around Y50 each. There are no official credit schemes, but some farmers borrow from family or friends. The cost of a Daxu stove can typically be paid back in six months from the money saved in reduced coal consumption.

Many farmers gather straw and take it to the briquetting plant, and are paid with an allocation of free briquettes. Any further briquettes have to be purchased.

[10] With a price subsidy of about 90%, the ability to sell tens of thousands of stoves becomes much easier. No statistics are given as to what percentage of the units sold were subsidized. This aspect of launching a new cookstove bears watching to see the impact on establishing a sustainable cookstove program. Also, the equipment for making the briquettes was another substantial investment.

[4] The initial capital investment was provided by Pan Shijiao and some associates, supplemented by a loan. Although local government subsidises have been very valuable in boosting sales, the lack of access to funds to expand production has been a barrier to growth.

[4] Owners who use wood for cooking can more than halve their consumption using a Daxu stove, from typically 10 – 12 kg of fuelwood per day to only 5 kg per day, a saving of about 2 tonnes per year.

Results of Testing:

[3] The Daxu stove model has proved so efficient that it was singled out for achieving the highest efficiency of any entrant in a stove competition organised by the China Association for Rural Energy Industries and the Shell Foundation.

[4] . By partially gasifying the fuel, and then burning the gas with secondary air, the stove achieves a high efficiency (over 40%) and low emissions.

[4] One of the major benefits of the Daxu stove is the high efficiency and associated low pollution. The Daxu stove was tested by staff from the Centre for Entrepreneurship in International Health and Development (CEHID) of the University of California. This testing was carried out for a stove competition, organised by the China Association for Rural Energy Industries (CAREI) and the Shell Foundation, to promote high performance biomass stoves for household use in China. The Daxu stove was the competition winner and achieved the highest efficiency of any entrant, reaching 41% with loose straw and over 42% with straw briquettes. This high efficiency conserves fuel and also means that a meal cooks quickly, typically in 20 to 30 minutes.

In addition, the level of air pollution and smoke in the kitchen was low, which reduces damage to health such as respiratory disease and eye infections, and keeps the kitchen clean. In CEHID tests, average concentrations of carbon monoxide (one of the most serious indoor air pollutants) were less than 7 mg per cubic metre of air. Particulate (smoke) concentrations were about 22 mg per cubic metre when burning briquettes, although somewhat higher at 36 mg per cubic metre when burning loose straw.

[6]

Summary Results from Chinese Biomass Stove Competition

Rank	Enterprise	Score									Price Rmb/ $ / Rupees
		Thermal perfor-mance	Flue gas emission	Indoor air quality	Technology innovation	Product quality	Ease of Use	Enterprise status	Others	Total	
1	Beijing Shenzhou Daxu Biomass Energy Technology Co., Ltd.	20.00	17.00	10.00	7.50	9.35	5.40	12.35	4.50	86.10	750/ 94 / 4300
2	Henan Luoyang Engineering Mech Designing Institute	16.80	18.30	7.70	7.15	9.00	8.00	12.20	4.20	83.35	520/ 65 / 3000
3	Shandong Tengzhou Xintai Machine Co., Ltd.	14.90	18.80	6.10	6.30	6.50	7.20	11.20	5.55	76.55	350/ 45 / 2000
4	Yunnan Zhenghong Environment Protection & Energy Conservation Co. Ltd.	15.40	18.20	5.70	6.35	7.80	6.55	11.30	4.45	75.75	350/ 45 / 2000
5	Hebei Xingtai Guangyuan Solar Energy Co. Ltd.	13.90	14.10	6.70	6.15	9.00	6.80	9.55	4.45	70.65	520/ 65 / 3000
6	Guangxi Cenxi Jianeng Water Heating Stove Factory	15.57	10.00	5.00	6.00	7.25	8.40	9.50	4.70	66.45	290/ 35/ 1600
7	Ningxia Nongjiale Environment Protection Gasified Stove Co. Ltd.	13.40	17.10	5.10	5.40	5.25	7.50	7.90	4.50	66.15	260/ 33 / 1500
8	Henan Jiajiawang Stove Co., Ltd.	12.90	13.40	5.80	4.50	3.25	8.05	5.60	4.80	58.30	180/ 23 / 1000

[10] Some of the first clues that the Daxu cookstove is a TLUD were from this table. In the first five columns of the scores, the Daxu unit is rated higher than any of the competition. Clean-burning was noted. But the Daxu unit has the very lowest score on "Ease of Use." This typical for TLUD devices because they are batch operated.

[6]

Stove Results: Briquettes

·Fuel consumer amount (kg/h)	**1.6**	**-**	**2.6**
·Cooking power (KW)	**2.2**	**-**	**3.4**
·Heat efficiency (%?	**32%**	**-**	**43%**
·Smoke:			
Avg. Concentration (mg/m³)	21	-	36
Emission factor (g/kg fuel)	.21	-	.39
·CO emission in flue:			
Average Concentration (mg/m³)	218	-	1520
High & low concentration? mg/m³)	6	-	7820
Emission factor (g/kg fuel)	.2	-	.26
CO /CO2	.011	-	.039
·Indoor CO (mg/m³):			
Average Concentration	4.4	-	28.0
High & low concentration	1.9	-	50.8

[10] The table above does not specify which stoves provided the high and low values. It is only an assumption that the low values were from the Daxu TLUD stove. Perhaps the CEIDH leaders could enlighten about the specific values of the Daxu stove, which should be reasonably similar to the emissions data from other TLUDs.

[10] Note to CEIDH: Are the data for the "Emission factor (g/kg fuel)" correct? There is almost no difference between 0.2 and 0.26. I suspect a typographical error might be present.

Experience in India:

[6]

Market Investigation in Maharashtra

- 4 UC Berkeley grad students
  - Developmental economics
  - Resource economics,
  - MBA/MPH
- 1 Chinese grad student
- 15 stoves shipped to Phaltan (3 models)
- Worked with ARTI training team in Phaltan
- Tested with local fuels in test center and households

- Focus groups were skeptical at first.
- Concerns about price.
- In-home tests worked well for 2 of 3 models.
- One model is easily adjustable, continuous feed, good for large families.
- One model is good in small restaurants.
- More work needed on design, fuels & manufacturing costs.

[10] The Daxu stove was not one of the three Chinese stoves taken to India for evaluation.

[10] I hope to be able to see and use a Daxu TLUD cookstove on my Sept – Nov 2007 trip to India where I will be presenting four to six different models of TLUDs and related microgasifiers to a target community. Then we will define and make what works best for those people. Perhaps we will find some ways to accomplish the collaboration the CEIDH has been seeking.