

Micro-gasification Terminology:

An Instructional Summary of MG

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This summary of micro-gasification terminology is a reference guide presented in instructional order for non-specialists and for possible use in classrooms. Accurate understanding and usage of micro-gasification (MG) terminology facilitates consistency for learning, discussion, and writing about micro-gasification. The list below is focused on MG aspects of each term, and includes some generalizations for clarity and simplicity. The item numbering is only for convenience of discussions about the content of this document.

1. Energy: Micro-gasification (MG) mainly involves thermal energy. Small sizes of MG devices make difficult the production of kinetic (motive) energy, and electrical power in needed quantities, although Stirling engines, thermoelectric generators (TEG), and thermal acoustic power (electricity) are possible using MG heat.

2. MG focuses on dry biomass, but other fuels are of some related interest, if for no other reason than to make comparisons:

Non-biomass: Electricity from solar, wind, hydro, and nuclear sources.

Fossil fuels (originally from biomass): solids (coal), liquids (oil, kerosene, etc.), gas (natural gas), and special cases like LPG (liquid petroleum gas).

Processed liquid fuels from biomass: Alcohol and biodiesel.

Wet biomass for gas generation: Biogas from anaerobic digestion.

Dry biomass for burning and gasification: Wood, agricultural residue (cobs, stems, husks, etc), pellets, briquettes, bamboo, dung, and much more. Renewable and sustainable supplies are of high importance.

3. Heat: Thermal energy, which can be radiant (as in glowing), conductive (as in touching), or convective (as in moving in a substance such as hot gases). All three are important in micro-gasification, but convection is dominant.

4. Burning: Releasing of thermal energy from fuels, via the complex processes of oxidation. All burning of dry biomass involves the production and changes of gases, and therefore involves gasification.

5. Three main stages in gasification: Pyrolysis, char-gasification, and combustion of gases. Pyrolysis occurs first (creating char and gases), but all three can occur almost simultaneously in the heart of a common fire, or they can occur separately and distinctly in both time (when) and place (where) in gasifier devices. The necessary supplies of oxygen (from incoming air) for char-gasification (primary air) and for combustion of the gases (secondary air) enter together (undifferentiated) in standard fires, and enter separately in gasifiers. Pyrolysis is driven by heat, not by the presence of oxygen. Pyrolysis is the

thermal conversion of biomass that creates both char and gases. Pyrolysis is essentially the same as carbonization (making char), like two sides of the same coin.

6. Gasifier: A device that has one or more of the three stages of gasification occurring in a controlled situation that can allow some intentional and significant separation of the solid (char), liquid (oils), gases, and thermal energy that are being produced. Essentially all gasifiers have a reactor in which the solid dry biomass is converted into gases that can exit the reactor for diverse uses. There are many types of gasifiers, some of which (e.g., flash pyrolysis units) are left for explanations in other documents. Our focus is on the more traditional gasifiers that are classified in two main ways: by flow direction, and by size.

7. Size of gasifiers: Physical sizes generally relate to the output of thermal (t) or electrical (e) energy or derived chemicals. Therefore size relates closely to the amount of biomass feedstock consumed. Very large gasifiers consuming tons of biomass per hour produced town gas in the 1800s and operate currently in industrial installations. Smaller units for powering vehicles peaked in 1945. Individual little or tiny units such as for residential cooking using less than one kilogram per hour did not function well (or were too costly) until the 1980s when Reed and Wendelbo independently originated what are today called micro-gasifiers producing 2 to 6 kW(t) of heat.

8. Gasifier draft direction: The main and long-established classification of gasifiers relates to the direction of the movement of the gases inside of the reactor (where the gases are being created). Typically (historically), the intention is to create the maximum of combustible gases, leaving only the inert ashes to be removed. That is, the consumption of the produced charcoal is intentionally complete. Typically the hot zone (the reacting area) is ignited at the bottom where it remains, with the needed fuel arriving to the zone from above where raw biomass fuel can be continually added.

9. Down Draft (DD) gasifier: The hot zone (the reacting area) is at the bottom (Bottom Burning = BB) where hot char is consumed (by adding oxygen [incoming primary air]) along with the conversion of the pyrolytic gases (tars, oils, etc.) into cleaner-burning simpler fuels (H₂, CO, methane, etc.) that are extracted at the bottom for use elsewhere (in engines, chemical processing, remote burners). Note that the pyrolysis processes (creating charcoal and gases) occur higher in the fuel bed because the heat rises up to the biomass from the extremely hot zone below in DD gasifiers. DD is synonymous with DD-BB because no other variation of DownDraft is known.

10. Up Draft (UD) gasifier, better designated as UD-BB: The hot zone (the reacting area) is at the bottom (Bottom Burning = BB) where the hot char is consumed (by adding oxygen [incoming primary air]), with the resultant hot gases (mainly CO and CO₂) carrying the heat upward to the raw biomass fuel which is first dried (releasing water vapor) and then is pyrolyzed (by heat without oxygen present), yielding A) more char (that eventually moves downward to the hot zone) and B) additional combustible gases that flow upward and out of the reactor. These gases are rather dirty (with long-chain hydrocarbons such as tars and “smoke”) and are therefore usually either promptly combusted (in a close-coupled combustor with separate incoming secondary air) or cooled for the production of desired oils and gases.

[Note: The designation of UD (and DD) should not be used if the device is not a gasifier. For example, a charcoal-burning stove, a common burn-barrel, and a campfire or bonfire are not gasifiers even though the air flow is mostly from the bottom upward. Hot air rises, so most draft in common fires is upward, but without the control and ability to separate and move the gases intact (not combusted) from their site of production, which is fundamental to the definition of a gasifier.]

11. Cross-draft and other drafts: Of rather minor importance, and left for others to attempt to define.

12. TLUD as a name: “TLUD” (tee-lud) has become a *device-name identifying most micro-gasifiers*. The name originated as an acronym for “Top-Lit UpDraft” devices that are most correctly identified by a Migratory Pyrolytic Front (MPF) that is ignited at the top and slowly moves to the bottom. MPF is distinctly different from the non-moving hot zones of BB (Bottom Burning and bottom ignited) DD and UD gasifiers described above. TLUD gasifiers should have been called UD-MPF to distinguish them from the UD-BB gasifiers, but in 2004 “Top-Lit” was used and the char was not to be burned in the device, which would be BB. However, during the intervening decade, with increasing frequency it has been noted that when the UD-MPF process reaches the bottom (end of pyrolysis) of the batch of fuel, the gasification process can continue in the UD-BB mode. Therefore, there are actually two types of TLUD (device name) gasifiers, one being TLUD-MPF and the other being TLUD-BB. The two types are quite distinctive in operation, and deserve separate recognition and study. The common usage of the “TLUD” name today means more than the TL of “Top-Lit” can signify. Therefore, to appropriately expand the TLUD name and still preserve it, we note that the TL also carry the connotation of “Tiny Little,” as in Tiny Little UpDraft gasifier, or commonly known as “Micro-gasifier of the UpDraft style.” This designation preserves the established and commonly used designation of TLUD stoves and TLUD gasifiers to include not only the UD-MPF (or TLUD-MPF) gasifiers, but also the tiny little updraft UD-BB (or TLUD-BB) devices. In essence, TLUD is a name for the small updraft gasifier processes/stoves and is not a description of what process (MPF or BB) is actually happening. However, we expect that in common usage, the TLUD name will designate TLUD-MPF, unless the UD-BB mode is specified. [Note that TLUD does not include DownDraft (DD) small gasifiers, for which the term “DD-micro” would seem appropriate.]

13. TLUD-MPF gasifier: The UD-BB and the small TLUD-BB gasifiers are described above (9) in the Up Draft discussion, with emphasis there that the fuel bed moves downward and fresh fuel can be added to the top. In sharp contrast, TLUD-MPF (or UD-MPF) devices and processes are distinctive because the fuel bed is static in position as a batch of fuel through which the pyrolytic front (or zone) moves downward toward the up-rising primary air. After ignition and creation of the initial top layer of charcoal, the very limited supply of rising oxygen encounters abundant combustible pyrolytic gases that are coming out of the dry biomass fuel. Some of those gases are combusted, creating the heat necessary for the continuation of the pyrolysis/carbonization process. In regular operation, little or none of the char is char-gasified, [but this remains a topic of active research about char characterization and the presence of non-carbon substances (mobile matter)]. Again, in this extremely distinctive manner, the UD-MPF process clearly conducts virtually all of the pyrolysis/carbonization of the entire fuel batch before significant char-gasification begins in the UD-BB mode. The change-over from UD-MPF to UD-BB is clearly signaled by the ending of the yellow flames of combustion of pyrolytic gases, and the evidence of light bluish flames of combustion of carbon monoxide (CO).

14. Retort processes: Pyrolysis of biomass conducted in the absence of oxygen occurs in retorts and other confined environments such as traditional charcoal production in buried piles of biomass. Essentially, a retort type of pyrolysis occurs in the upper areas of standard UpDraft (UD-BB) and DownDraft (DD-BB) gasifiers, where there is biomass plus heat and without oxygen present. Retort processes also occur in Anila stoves, which are not gasifiers because there is no way to attain separate control and access to the creation of the gases.

15. Semi-gasifiers: Devices that are “sort of” or partially or “wanna be” gasifiers sometimes are labeled as “semi-gasifiers.” There is very little clarity about such devices and their claims, which can be left to others to attempt to define or justify.

16. Three T’s of Time, Temperature and Turbulence: Combustion can be enhanced (strengthened) by
1) Lengthening the time that the reactants (air/oxygen and fuels) have together,
2) Raising the temperature of the reactants (air and fuel) or their environment of contact,
3) Increasing the turbulence (turmoil) of the reactants to promote mixing.

17. Draft: Refers to the essential movement of air and combustible gases to reach other places during combustion processes. Because gasifiers are “air-controlled” devices, understanding of pressures and drafts is very important. [In contrast, most traditional burning is controlled by the supply of fuel, as in 5-sticks can make a bigger fire than 3 sticks of equal size.] Draft can result from either negative or positive pressure.

18. Pressure, negative and positive: Positive pressure from the blowing or pushing of air into the fire zone has many advantages, as experienced when a campfire is fanned. However, positive pressure accentuates any problems of leaks in the fire area or device. Such leaks can be dangerous because of emissions and even accumulation of combustible gases with risk of fire. Negative pressure from the pulling or sucking in of air or gases avoids the risk of outward leaks, but can cause a loss of control of the combustion processes because of entry of excessive primary or secondary air.

19. Natural Draft (ND): Natural draft is from the natural tendency for hot gases to rise in relation to the surrounding gases. The construction of a chimney or a “riser” serves to enhance (augment) that movement upward. Tall chimneys can create powerful natural drafts, but can be rather expensive and awkward for micro-gasifier devices such as cookstoves. Creating sufficient ND is a major topic of cookstove development. Natural Draft can only create negative pressure, that is, the pulling of air into the fire zone.

20. Forced Air (FA): Draft can be created by artificial means, such as fans, blowers and compressors. The forced air can be positive pressure (blowing or pushing air into the fire zone) or negative pressure (causing an induction or entrainment of the flow of the gases, resulting in the pulling in of air at the desired locations). FA can also refer to “Fan Assisted”, but not all FA is from fans. Forced air offers major advantages for the increase of turbulence for the mixing of the air and gases, which can result in better, more complete combustion.

21. Super-turbulent stoves/devices: When forced air (FA) is highly aggressive and carefully directed, turbulence can become the dominant aspect of the stove. Super-turbulent technology has also been called “fan-jet” technology, or perhaps “high-vortex” technology. In general, these are not gasifier stoves in that the jets of air impact all three gasification processes to occur in a confined space with very complete combustion. The pyrolysis/carbonization, char-gasification, and combustion of gases cannot nicely be separated, as in gasifiers. These devices include pellet stoves and several high-end cookstoves (ACE Philips-FA and Biolite campstove). To classify them as “fan stoves” is incorrect and a misrepresentation (understatement) of their super-turbulent/high-vortex/fan-jet attributes. They are one type of stoves in a major category of many “Stoves with Forced Air.”

22. Stoves with Forced Air: [Not “Fan stoves,” which is a term to be avoided and not used for several reasons]:

1. Classification systems should relate to major attributes and processes that are not as arbitrary as one of the component parts. Fans can and are being used in a wide variety of cookstoves with fans or Forced Air that can be discussed as a group just because they have a fan, but each combustion type is very different in fundamental scientific terms. Animals that fly include insects, Pterodactyls, birds and bats, but flight is not a basis for the biological classification system.
2. The super-turbulent stoves are usually driven by strong blowers, not by weaker co-axial fans, so to refer to them as if they were the only “fan stoves” is doubly incorrect.
3. Other stoves with fans include Reed’s Woodgas Campstove, Oorja, and several other TLUD-FA (micro-gasifiers with Forced Air) gasifiers that are competitive with super-turbulent stoves for cleanest emissions.
4. Similarly, the Biolite Home stove is somewhat a Rocket-FA stove that needs appropriate recognition.
5. “Fan stove” would include any other attempt to have a fan merely blowing on a fire to make it stronger. Technically, a three-stone fire with a fan, or any bucket-burner with a fan, or a charcoal stove with a fan, would qualify as a “fan stove”.
6. To use a simplistic “fan” name for the super-turbulent/fan-jet/high-vortex stoves greatly inhibits the development of a proper scientific nomenclature for many cookstoves. It even works against the classifying of a possible high-vortex stove using negative pressure from either Natural Draft (tall chimney) or an inducer with compressed air.

23. Other characteristics of stoves: For purposes of grouping to discuss a shared characteristic (but not for making a classification system), stoves can be characterized by the following single characteristics, or by combinations of what are listed:

1. Materials of construction: clay/mud/ceramic, sheet metal, thick/cast metal, wood, stones, special materials.
2. Size of device: Height is important in some cultures.
3. Amount of heat delivered: <2 kw; 2<5; 5<10; 10<25; etc, or in other amounts to suit the discussion.
4. Suitable for types of cooking: boiling, frying, baking, broiling, etc, including specific devices such as tandori, steamers, etc.
5. Socio-economic factors: cost, self-made vs. purchased-complete,
6. And previously mentioned characteristics of fuels and combustion types that are the main bases for most serious classifications of stoves.
7. Note that “good” and “bad” are designations derived by persons, and cannot be the basis of a scientific classification of stoves. However, a stove’s ability to attain accepted standardized criteria such as Tiers for efficiencies, emissions, safety, etc. are among the useful descriptions and groupings of stoves.
8. And there are further characteristics of stoves, especially referring to micro-gasifiers.

24. Stove stacking: This refers to the cooking practice of using more than one type of cookstove technology during the preparation of a meal. For example, the use of a TLUD or a Rocket stove to heat a pot of food that is then placed into a solar cooker for simmering would be stove stacking. It does not refer to putting stoves on top of each other. However, in the case (below) of the TChar stove, the stacking occurs both figuratively in time sequence and literally in physical height.

25. Charcoal-producing stove/device:

1. This does not refer to stoves that produce only small amounts of charcoal or from which charcoal can be extracted with considerable difficulty. Nor does this include traditional charcoal making in earthen pits that does not permit convenient cooking or other use of the generated heat or off-gas/smoke.

Throughout history, cookstoves (and most combustion devices) have generally been made to maximize the heat generated and to minimize the amount of charcoal produced.

2. Not by intention, but as an occurrence during TLUD-MPF processes, near-maximum amounts of charcoal are produced. TLUD originators Thomas Reed and Paal Wendelbo focused on the heat. Early TLUD “Pyroneer” Ronal Larson has focused on the charcoal production capabilities since the 1990s, with interests regarding atmospheric CO₂ levels and now biochar.

3. Although using different terminology, early efforts for micro-size UD-BB devices include the Dasifier by Agua Das, the Chip Energy Biomass Grill by Anderson & Wever, and TLUDs intentionally operated in BB mode, particularly the Estufa Finca by Art Donnelly. All are now recognized as UD-BB micro-gasifiers with some capacities for yielding charcoal.

4. The TChar variation of TLUD-MPF operation by Roth & Anderson focuses on placing the created hot char into stoves specifically appropriate for combustion of the char. The TLUD top is placed onto a charcoal stove that serves as a base. The dry biomass fuel is pyrolyzed in the TLUD top. When the MPF has concluded, the TLUD top is lifted off, with the resultant charcoal remaining in the charcoal stove (base of the TChar stove) where it is burned. This type of stove stacking could also be accomplished by dumping the char from a TLUD-MPF stove into any appropriate charcoal-burning stove.

5. The Anila retort-style stove also produces charcoal and merits separate consideration.

26. Biochar: In the 21st Century there is rapidly growing interest in biochar, which (simplistically) is charcoal that is placed into soils. Biochar is a separate topic worthy of major discussion. What is important regarding micro-gasification is that MG devices can produce biochar from so many different types of biomass in so many different households spread throughout the world and for so little cost. Biochar production has the potential to be a source of revenue or to improve soils especially for some of the poorest people and poorest soils in the world. Also, biochar production (and placement into soil) is the one, simple, low-cost method known to be “carbon negative” that can attain gigatons of CO₂ equivalents of near permanent REMOVAL OF CO₂ from the atmosphere. The importance of this will intensify with any increased recognition of the potential catastrophic impact of climate change or global warming. These biochar aspects of TLUD gasifier technology could be a major driving force to accomplish the introduction of Micro-gasification into many aspects of societies around the globe, including in classrooms for all future generations to study and understand. It is probable that micro-gasification will be part of everyone’s foreseeable future.

27. Conclusion: This initial *Micro-gasification Terminology: An Instructional Summary of MG* (first prepared in November 2013) is intended to stimulate discussion at meetings and at the Stove Listserv, generating further refinements. Updates will be placed at the Dr TLUD website and other places. At the Dr TLUD website, the latest version of this document will always be accessible from the Resources section (<http://www.drtilud.com/resources>) and from the convenient Quick Picks section on the home page (<http://www.drtilud.com>). Your comments will be appreciated. Send them to Dr TLUD at psanders@ilstu.edu