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Review

Potential and feasibility of solid municipal waste treatment with gasifiers in a developing country: a review for Burkina Faso

ABSTRACT

In this paper, a review is made in order to broaden our knowledge on the management systems of household waste in the five largest towns of Burkina Faso and propose an environmentally sound thermal way for their treatment. Data from the General Population and Housing Census of 2006 and the statistical handbook of the environment of year 2010 was used to estimate the five largest cities of Burkina Faso inhabitants' waste production, management and disposal methods. Descriptive statistics have been used to evaluate waste production, thermal energy and improvement to organized household waste collection rates. These cities produce continuously growing quantities of household waste, but infrastructure to manage it is insufficient or almost inexistent. Furthermore the majority of Burkina Faso's citizens poorly handles or disposes of their household waste. This results to an unhealthy urban environment. It appears that treating municipal waste in gasifiers will give an economical value to waste and possibly improve its collection rate. Gasification has been used several decades ago in Europe, USA and Australia and offers the advantage of accepting a big variety of feedstock. Municipal waste in Burkina Faso that mainly consists of carbonaceous materials appears as a good candidate for gasification. This review suggest that gasifiers represents a good opportunity for municipal waste treatment in Burkina Faso and downdraft gasifiers appears the most suitable technology that could be built, operated and maintained by local technicians without a need for very high special training.

Keywords: Municipal waste; Waste management; Gasification; Environmental impact; Energy

1. INTRODUCTION

There is no satisfactory definition of waste. This definition varies from a place to another. The United Nations Statistics Division (UNSD) [1] says that: "Wastes are materials that are not prime products for which the initial user has no further use in terms of his/her own purposes of production, transformation or consumption, and of which he/she wants to dispose. According to the Basel Convention, the United Nations Environment Program defines: "Wastes' are substances or objects, which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law [2]. In Burkina Faso, reference [3] describes municipal waste as "solid, liquid or gas rubbish from the living homes and related, administrative buildings, recreational, restoration and room and any other public installation receiving people". According to [4], in France, waste is defined as "any residue of a process of production, processing or use of any substance, material, product or more generally, any personal property abandoned or which its holder intends to abandon".

In many of developing countries, the management of waste is sidelined. Meanwhile, pollution transforms the environment into an epidemiologic space [5]. Waste management is one of the major challenges of urban management in Sub Saharan African countries. Burkina Faso, a country of more than 14,000,000 inhabitants, with seven (07) cities having more than 50,000 inhabitants [6], is no exception to this. Only Ouagadougou the political capital and biggest city of the country has a controlled waste land filling centre with a 20 years lifespan. By year 2025 this land filling centre will reach its end of life. However it has been proven that the remaining life span could be 3 times longer if incineration treatment can be associated to this land filling facility as of year 2015 and using incineration with sorting at this landfill centre was suggested [7].

Gasification, one the three thermal waste treatment methods is the process of partially oxidizing carbonaceous feedstock with an oxygen-containing reagent, usually oxygen, air, steam or carbon dioxide, generally at temperatures in excess of 800°C. This requires that oxygen be added but in insufficient amounts so that the fuel cannot be completely oxidized and full combustion doesn't occur. This process is largely exothermic even when some heat is required to initialize and sustain the gasification process [8].

Though gasification has almost gained maturity in developed countries [9, 10], these facilities cannot simply be transposed in developing countries because:

- Gasifier's performances depend of the fuel used. In the case of municipal waste, composition is very different,
- Latest gasifiers are of high thermal capacity , these are not suited for small scale testing,
- Gasifiers available on the international market are highly sophisticated equipments; these are too expensive and not convenient for developed countries contexts.

One concern we should keep in mind for development of gasification is sustainability. Fundamentally, gasification use coal, an inherently depletable and geologically limited resource. When used with very heterogeneous feedstock as municipal waste, non carbonaceous components such chlorine, metals, glass are sources of environmental pollution. That is why gasification is often opposed by environmental lobbying organizations [11, 12]. They argue that gasification is as pollutant as incineration. However several studies [13, 14] explain how gasification is different from incineration. Anyway, thanks to more strict environmental regulations, incineration is not pollutant anymore and is considered as an important solution for waste management in many countries. Today, gasification is proven to be environmentally harmless if an appropriate feedstock is used. These concerns will be kept in mind all along our study.

This prospective review paper will have four steps:

- a review of waste disposal methods and schemes in the five (05) biggest cities of Burkina Faso,
- a review of energy consumption in Burkina Faso

- proposition of which gasifiers are more adapted to developing countries,
- discussion of required conditions for gasifiers to be economically sound and environment friendly in the local context.

2. MATERIALS AND METHODS

2.1. Study area

This study is carried out in the five (05) largest cities of Burkina Faso, namely Ouagadougou, Bobo-Dioulasso, Koudougou, Banfora and Ouahigouya. Burkina Faso is a south Saharan country located in West Africa between 9°20' and 15°5' North latitudes, 2°20' East longitude and 5°30' West longitude (figure 1). Burkina Faso experience a mostly dry season with only a 4 months duration for rainy season [15]. The five largest cities of Burkina Faso concentrate a total population of 2,202,444 inhabitants.



Figure 1. The 13 administrative regions of Burkina Faso

2.2. Methodology

Firstly, statistical data was extracted from the General Population and Housing Census of year 2006, year 2010 statistical directory of the environment, monographs of the Cascades, Centre-West and North regions and the report of theme 9 "Urban growth" analysis of the general census of population and housing 2006. Collected data about these cities populations were: their number, waste management and disposal methods and energy consumption. Secondly a literature survey was made about gasifiers with respect to their thermal capacity and the best feedstock material. Thirdly, after calculating the probable available feedstock in each of the five cities, choice of the most suited gasifiers technologies have been made.

3. RESULTS AND DISCUSSION

3.1 Waste management and production in Burkina Faso

Waste management is one of the first concerns of cities in Burkina Faso. It is complicated by the rapid growth of cities which induce proliferation of waste of any kind in a difficult economic environment. This makes the city of Ouagadougou, the largest in the country struggles to collect and treat waste generated by its residents whose the number continues to grow.

In 2009 there was about 750,000 tons of municipal waste produced in Burkina Faso [15].

Only waste production in Ouagadougou and Bobo-Dioulasso are roughly exact. Those of medium cities, namely Koudougou, Banfora and Ouahigouya are estimations from regional municipal waste production [15]. Populations' figures are from the 2006 general census [6]. Table 1 summarizes present state of waste management in the main cities of Burkina Faso.

Table 1. Waste management data of the five largest cities in Burkina Faso

City	Population	Land filling facility	Annual municipal waste production
Ouagadougou	1,475,223	Yes : 2005-2025	330,000 tons ^(a)
Bobo-Dioulasso	489,967	Yes : not used	100,000 tons ^(b)
Koudougou	88,184	No	15,162 tons ^(c)
Banfora	75,917	No	13,077 tons ^(c)
Ouahigouya	73,153	No	10,379 tons ^(c)

(a): according to [16], (b): according to [17], (c): estimated from references [15 and 21]

We estimated data about annual municipal waste production from regional annual municipal waste production available in reference [15] and [21] as follows:

- Summation of the regional population weights of official municipal cities in the region, this gives a number W ;
- Division of each municipality weight by W , this give us a number M_i ;
- Multiplication of M_i by the annual regional municipal waste production: these give us figures of footnote (c) in table 1.

Of the 750,000 tons of municipal waste produced in Burkina Faso in year 2009, about 660 000 tons were sent to landfills (usually uncontrolled), gutters, old quarries; which carries the potential of groundwater contamination, proliferation of disease vectors such as rodents, flies, etc...The anaerobic decomposition of organic matter by methanogenic bacteria present in solid waste landfills is the source of greenhouse gas emissions such as methane [18]. Waste recycling is very important to several socio-professional groups: the direct recuperators, intermediaries, dealers and processors artisans. Recovered items are bottles, cans, scrap metal, shoes, aluminum and various packages. If their condition permits, these recovered items are sold directly to consumers or to processors and generate revenues. There also exists a recycling of compost in the country: topsoil resulting from the decomposition of garbage mixed with soil. This product is used as organic fertilizer for urban agriculture and gardening.

For the five biggest cities of Burkina Faso, organized municipal waste collection rate was less than 40% of the resident populations in 2009 [19]. Waste disposal methods in these cities are summarized in table 2.

Waste disposal is complicated by bad habits of citizen who, despite the existence of waste collection structures continues to dump waste elsewhere. Table 2 show that 28,8% citizens of Ouagadougou, 34,6% of Bobo-Dioulasso and more than 60% of Koudougou, Banfora and Ouahigouya dump their household waste into piles of garbage. Only around 5% of the populations in medium cities have their household waste collected by organized services. This rate come to 31% at Bobo-Dioulasso and culminates to 40% at Ouagadougou. It is true that often waste collection infrastructure doesn't suffice and the reason why population doesn't uses organized collection seems to be financial limits and weight of tradition [19]. Indeed, it turn out that people do not take the full extent of adverse consequences of poor disposal practices of household waste. They mention lack of financial resources as a pretext, but in truth, it is a bad cultural predisposition, given the relatively low cost of subscriptions to the organized waste removal services offered by the associations. It is difficult to understand that working families prefer to throw their garbage in the street or on piles of garbage than paying about US \$1.00 per month for the organized removal of their household waste.

149 **Table 2. Waste disposal methods in the five largest cities of Burkina Faso**

150

Waste disposal method	Ouagadougou	Bobo-Dioulasso	Koudougou (a)	Banfora (a)	Ouahigouya (a)
Piles of garbage	28,8	34,6	61,1	65	62,8
Gutters	7,7	9,2	9,7	18,7	8,5
Street	9,7	16,1	15,2	3,4	9,6
Organized collection	40,2	31	4,2	3,6	6,9
Tank	8,3	6,2	4	3,7	5,9
Other	4,3	2,2	5	5,1	5,6
Unknown	1	0,8	0,8	0,5	0,8
Total	100	100,1	100	100	100,1

151 (a): Figures shown are those of “Urban grown” from references [19]

152
 153 Only Ouagadougou has a functional modern land filling facility since 2005. That of Bobo-Dioulasso wasn't still functional by October 2011 [17]. Koudougou, Banfora and Ouahigouya don't have controlled (modern) landfills.

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 155 Municipal waste compositions vary from a city to another. Table 3 summarizes these from 2003 to 2009

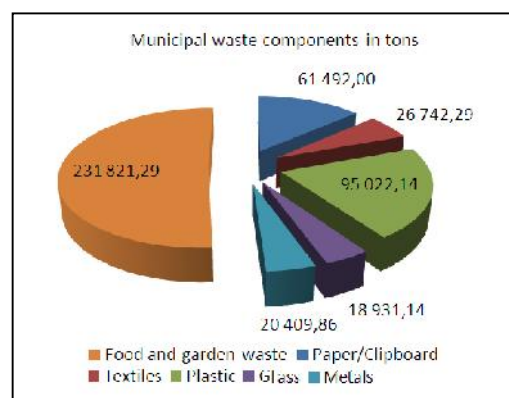
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 157
 158 **Table 3. Municipal waste production in Burkina Faso from 2003 to 2009**

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	2003	2004	2005	2006	2007	2008	2009
Paper/Clipboard	47 934	51 948	56 252	60 860	65 784	71 037	76 629
Textiles	24 244	25 070	25 903	26 740	27 578	28 415	29 246
Plastic	60 141	69 260	79 696	91 625	105 241	120 763	138 429
Glass	15 504	16 552	17 655	18 816	20 035	21 311	22 645
Metals	19 041	19 509	19 972	20 428	20 875	21 311	21 733
Food and garden waste	196 996	207 914	219 256	231 016	243 180	255 733	268 654
Other inorganic waste	150 443	158 208	166 236	174 520	183 046	191 800	200 763
Total	514 303	548 460	584 971	624 004	665 739	710 369	758 099

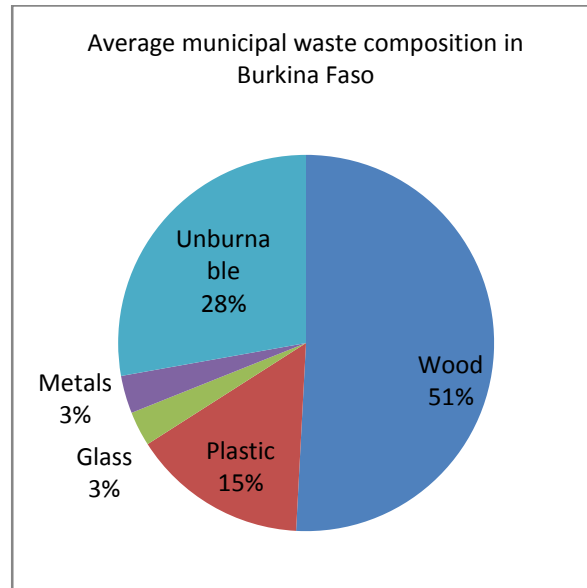
161 *Source: National Statistics and Demography Institute [19]*

162
 163 Calculated average percentages are given in figure 2.



178 **Figure 2. Municipal waste composition in Burkina Faso**

179 Food and garden waste are the dominant components of municipal waste in Burkina Faso
 180 with more than 50% of its' composition.
 181 Food waste, garden waste, paper and clipboard plus textiles are organic materials with basic
 182 components similar to that of wood.
 183 These can be therefore assimilated to wood as done in reference [20]. In this case we have
 184 the figure 3 distinguishing municipal waste components according to their combustion
 185 properties.
 186



187
 188
 189

190 **Figure 3. Average municipal waste composition of the five largest cities in Burkina**
 191 **Faso**

192

193 Because several items such as bottles, metal, and packaging materials have some
 194 economic value in Burkina Faso, these are scarce in municipal waste. This is why glass and
 195 metals only represents 3% of municipal waste in Burkina Faso.
 196

197 **3.2 Energy bill of Burkina Faso**

198

199 Burkina Faso faces two major problems: energy challenge with a big anthropogenic pressure
 200 on natural resources and poor waste management in cities with several negatives
 201 environmental effects.

202 Energetic bills for each year are found in megawatts per hour (MWh) from reference [15]. In
 203 Physics energy is expressed by the equation below:

$$204 \quad P = \frac{W}{t} \quad (1)$$

205 Where:

- 206 - W is energy expressed in joule (J);
- 207 - P is power expressed in watts (W);
- 208 - t is time expressed in seconds.

209 A year account for 366 days, a day account for 24 hours, thus time is

$$210 \quad t = 366 \times 24 = 8784 \text{ h} \quad (2)$$

211 Using equations (1) and (2), we derive figure 4 below from references [15] and [21]:
 212

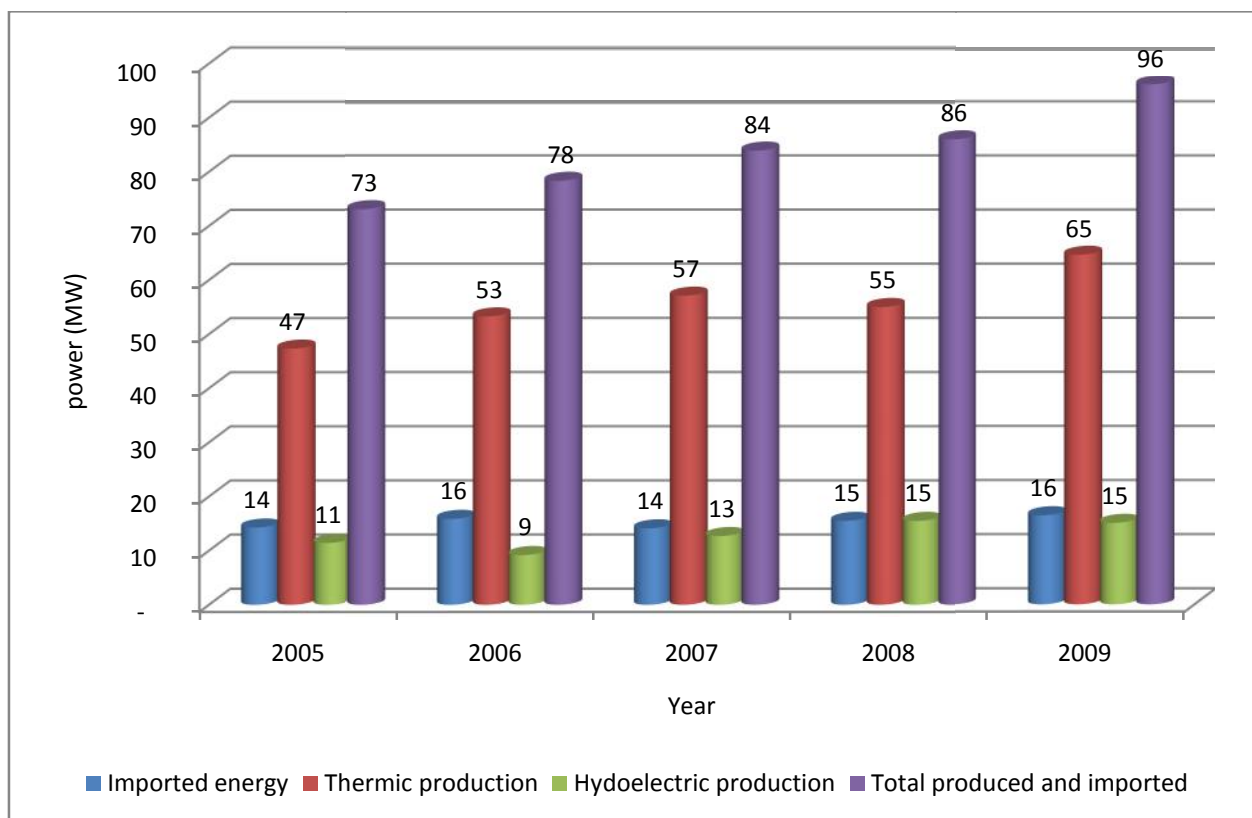


Figure 4. Electric energy production and importation in Burkina Faso from 2005 to 2009

This figure shows that electrical energy production mainly comes from thermal sources. This electricity is produced with thermal generators powered by fuel oil. This is not a sustainable energy and with the continuously growing price of oil derived products on the international market, the Burkina Faso's energetic bill continues to grow and becomes more and more difficult to bear.

3.3. Technical context of waste gasification in Burkina Faso

The main difficulty faced by the gasification of waste in developed countries is to achieve an acceptable energy balance (that is to say, positive) in terms of power production. The good performance of the conversion of synthesis gas into electrical energy is actually offset by a high energy consumption in the pretreatment of waste by the need to produce or inject large amounts of pure oxygen (which is often used as a gasifying agent), and the cost of disposing of the gases. Another problem arises when one implements the process at commercial scale: the maintenance time of a site because it is essential to clean the reactors after a few months of activity, and thus stop production, unless you have plants taking over. Today several gasification of waste projects are known, but few have really been developed and tested, and among the few that have been implemented in real waste treatment plants, they have always been associated with the employment fossils fuels [22].

However the economical context is quite different in Burkina Faso. Setting up energy independent municipal waste gasifiers in Burkina Faso would have the following advantages:

- Simple and affordable technology that can be handled by local technicians;
- Added value to household waste;
- Create more economic value from municipal waste by converting it to energy

- 241 - Production of electricity with the excess that could be resold to the National
- 242 Electricity Company (SONABEL);
- 243 - Modernization of transit centers and sorting of municipal waste and the landfill
- 244 through the use of electrical energy produced locally, mechanical sorting,
- 245 mechanical cutting bulky waste if necessary
- 246 - Possibility to produce methanol, which could be used in vehicles of municipal waste
- 247 collection;
- 248 - Improving livelihoods of people working on landfill
- 249 - Best gasifiers performance in respect of low waste moisture content as more of the
- 250 time, Burkina Faso experience a dry season that last 8 to 9 months a year [23]
- 251 - Reduce space required for land filling.

252
 253 Let us suppose that waste collection rate is 40% in Ouagadougou, 30% at Bobo-Dioulasso
 254 and 20% at Koudougou, Banfora and Ouahigouya (20% collection rate can be set as an
 255 objective to reach in first time). If gasification is considered, glass, metals and inorganic
 256 waste (inert materials) should not feed gasifiers. These must be picked out at the upstream.
 257 Therefore maximum available waste as gasifiers' feedstock would be as depicted in table 4:

258
 259 **Table 4. Combustible feedstock and reachable power by municipal waste gasification**
 260 **in Burkina Faso**

		Ouagadougou	Bobo-Dioulasso	Koudougou	Banfora	Ouahigouya
Textils +Paper)	50,85%	67 120,98	15 254,77	1541,95	1 329,9	1 055,5
Wood (Food+						
Plastic	15,10%	19 927,72	5 434,83	457,79	394,8	313,4
Glass	3,01%	3 970,18	1 082,78	91,21	78,7	62,4
Metals	3,24%	4 280,29	1 167,35	98,33	84,8	67,3
Unburnable	27,80%	36 700,89	10 009,33	843,12	727,2	577,1
Total	100,00%	132 000,06	32 949,06	3 032,40	2 615,4	2 075,8
Daily feedstock (kg)		183 390,66	41 679,69	4 212,98	3 633,6	2 884,0
Maximal thermal capacity (W)		8 490 308,19	1 929 615,50	195 045,53	168 223,88	133 516,53
Maximal electrical power(kW)		1 698,06	385,92	39,01	33,64	26,70

261
 262 Table 4 show that in Burkina Faso, only Ouagadougou and Bobo-Dioulasso can feed updraft
 263 gasifiers (1.1 to 12 MW thermal capacity) or bubbling fluidized bed gasifiers (1 to 50 MW
 264 thermal capacity). Medium cities of Burkina Faso could only feed downdraft gasifiers (1 to
 265 1000 kW thermal capacity). Electrical output is calculated with 30% conversion efficiency.

266
 267 **3.4 Proposal for gasification technology aimed at household waste management**
 268 Gasifiers' construction is a relatively simple task and can be accomplished in any well-
 269 equipped shop using basic sheet metal and welding techniques [24]; according to Kaupp
 270 and Goss [25] "The construction of a small gasifier, including the purification system, does
 271 not require sophisticated equipment or highly skilled mechanics. It can be built in workshops
 272 comparable to the auto repair shops found in most third world countries." Nowadays,
 273 gasification is a rapidly spreading technology in USA, Europe, Australia and India [26-32].
 274 Although high thermal capacities gasifiers can be setup in Ouagadougou and Bobo-
 275 Dioulasso, it is better to star with small and medium capacity downdraft gasifiers. These
 276 small capacity gasifiers will represent the following advantages and are more likely to

277 succeed [33]:
278 - require no sophisticated technology for setup;
279 - be built by local technicians;
280 - use locally available materials;
281 - allow thorough field testing;
282 - allow learning errors and improvements.

283 Per recommendations found in reference [34], Burkina Faso has the following advantages:

284 (i) Gasifiers are meeting the technical, economic and operational expectations of Burkina
285 Faso because it's a poor country with abundant and cheap labor, but well enough trained,
286 especially for craft where its reputation is recognized throughout the African continent;

287 (ii) Sorted municipal solid waste constitute fuel resources and operating conditions most
288 likely to ensure successful operation of gasifier technologies projects that could be feed with
289 abundant municipal wood and plastic like waste;

290 (iii) Only few aspects of the technology need of additional research and development for
291 adaptation purpose.

292 At our side, laboratory work is already in progress. We are now carrying out laboratory
293 experiments for wood, cardboard and plastic's gasification at temperatures of 700 to 1100°C
294 with a 100°C step. At first, these essential municipal waste components are studied alone
295 and at the second step, we will mix these according to municipal waste proportions. Work in
296 progress aim to simulate municipal waste gasification and serve as a starting point for
297 laboratory scale gasifiers construction, testing and adaptation with firstly model waste and
298 afterward real municipal waste as feedstock.

299

300

301 4. CONCLUSION

302 The situation of municipal waste management in the largest five cities in Burkina Faso
303 represents big challenges and call for innovative solutions in order to avoid negatives
304 environmental impacts. In the context of a developing country, this situation also represents
305 good opportunities if economic and technological adaptations are made. This way,
306 continuously growing quantities of municipal waste may be turned to a gold mine. Downdraft
307 gasifiers introduced at small scale appear the most affordable technology that can be setup,
308 adapted and maintained by local technicians. Ouagadougou and Bobo-Dioulasso can also
309 feed updraft or bubbling fluidized bed gasifiers with respectively about 8.5 and 2 MW thermal
310 capacity. Koudougou could feed a 200 kW thermal capacity downdraft gasifier where as
311 Banfora and Ouahigouya could feed a 170 and 130 kW downdraft gasifiers.

312 We highly recommend that gasification of municipal waste be introduced and developed in
313 Burkina Faso. This action could lead to waste collection rates improvement, waste reduction
314 at landfills, modern landfill operation, jobs creation, and production of energy.

315 Though the first responsibility is on municipalities managers because they have to set up
316 appropriate infrastructure and waste management facilities, researchers and technicians
317 also have to demonstrate the suitability and economics profits of small downdraft gasifiers
318 for waste management in Burkina Faso. It appears that upstream waste sorting is the key to
319 insuring the required feedstock quality for optimal operation of small gasifiers and less
320 environmental impact of these facilities. Local available working man force at affordable cost
321 is an advantage for Burkina Faso who should promptly catch that opportunity. Under this
322 scope, demonstrations plants at small scale should be quickly setup in the five largest cities
323 of Burkina Faso for further study, field testing and adaptation to the country's context.

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REFERENCES

1. United Nations Statistical Department. Glossary of Environment Statistics. 1997. Accessed 05 September 2013. Available: <http://unstats.un.org/unsd/environmentgl/>.
2. Basel Convention. 1989. Accessed 05 September 2013. Available: <http://www.basel.int>.
3. Assemblée des Députés du Peuple. Loi n° 005/97/ADP Portant Code de l'Environnement Burkina Faso. 1997. French
4. Assemblée Nationale Française. Code l'Environnement. Article L.541-1. 1975. French. Accessed 20 May 2013. Available : <http://www.legifrance.gouv.fr/>.
5. ENDA. Des déchets et des hommes : expériences de recyclage dans le tiers monde. ENDA-Tiers Monde. Dakar, Sénégal. 1990. 300p. French.
6. Centre National de la Statistique et de la Démographie. Résultats Définitifs du Recensement Général de la Population et de l'Habitat. French. Accessed 20 May 2013. Available: http://cns.bf/IMG/pdf/depliant_resultats_definitifs_du_rgph_2006-2.pdf.
7. Nzihou JF. 2013 Improving Municipal Solid Waste Land Filling Disposal Process: Experiments with a Laboratory Scale Rotary Kiln, Journal of Environmental Protection. 2013; 4(8). DOI: [10.4236/jep.2013.48087](https://doi.org/10.4236/jep.2013.48087).
8. Zafar S. 2009 Gasification of solid municipal waste Alternative Energy Magazine. Accessed 23 August 2013. Available: http://www.altenergymag.com/emagazine.php?issue_number=09.06.01&article=zafar.
9. Arena U. 2011, Process and technological aspects of municipal solid waste gasification. Waste Management. 2012; 32: 625–639.
10. Belgiorno G, Feo D, Della Rocca C, Napoli RMA. Energy from gasification of solid wastes. Waste Management. 2003; 23: 1–15.
11. Alternative Energy. 2008. Negative Impacts of Incineration-based Waste-to-Energy Technology. Accessed 23 August 2013. Available: <http://www.alternative-energy-news.info/negative-impacts-waste-to-energy/>.
12. The Blue Ridge Environmental Defense League. 2009. Waste gasification impacts on the environment and public health. Accessed 23 August 2013. Available: <http://www.bredl.org/pdf/wastegasification.pdf>.
13. Gasification Technology Council. Gasification : An investment in our energy future. Accessed 23 august 2013. Available: http://www.gasification.org/uploads/downloads/Final_whitepaper.pdf.
14. Klein A, Themelis NJ. 2003. Energy Recovery from Municipal Solid Wastes by Gasification, North American Waste to Energy Conference 11 Proceedings, ASME International, Tampa FL. April 2003: 241-252. Accessed 23 August 2013. Available: <http://www.seas.columbia.edu/earth/wtert/sofos/NAWTEC-gasification-klein.pdf>.
15. Ministère de l'Environnement et du Développement Durable. Annuaire Statistique de

383 l'Environnement 2010. French. Accessed 20 May 2013. Available:
 384 http://cns.bf/IMG/pdf/medd_annuaire_2010.pdf.
 385

386 16. Cissé SM. La Propreté, un outil de politique sociale. Interview in Slate Afrique. French.
 387 Accessed 23 November 2013. Available:
 388 <http://blog.slateafrique.com/terrafraica/2011/05/12/la-proprete-un-outil-de-politique-sociale/>.
 389

390 17. Soma I. Burkina Faso: 3 milliards de F CFA enterrés au Centre d'Enfouissement
 391 Technique de Bobo-Dioulasso. Story in Sidwaya Daily Journal of 11 October 2011. French.
 392 Accessed 10 September 2013. Available:
 393 <HTTP://FR.ALLAFRICA.COM/STORIES/201110131175.HTML>.
 394

395 18. Chalvatzaki E, Lazaridis M. Estimation of greenhouse gas emissions from landfills:
 396 Application to the akrotiri landfill site (Chania, Greece). 2010; Global Nest Journal; 12 (1):
 397 108-116.
 398

399 19. Institut National de la statistique et de la Démographie. Analyse des Résultats de
 400 l'Enquête Annuelle sur le Conditions de Vie des Ménages en 2007. 2007. French. Accessed
 401 23 August 2013. Available:
 402 http://cns.bf/IMG/pdf/eaquibb_2007.pdf.
 403

404 20. Nzihou JF, Rogaume T, Segda BG, Koulidiati J, Bouda M. Contribution à la mise en
 405 place du modèle de la fraction combustible des déchets ménagers de la ville de
 406 Ouagadougou. Revue du CAMES, Série A. 2008; 06: 78-84. French. Accessed 20 October
 407 2012. Available:
 408 <http://greenstone.lecames.org/collect/revu/import/A06/A-006-00-078-084.pdf>.
 409

410 21. Institut National de la Statistique et de la Démographie. Thème 9 : Croissance Urbaine
 411 du Recensement Général de la Population et de l'Habitat de 2006. 2009. French. Accessed
 412 20 August 2013. Available :
 413 http://cns.bf/IMG/pdf/theme_9_urbanisation_fin_f.pdf.
 414

415 22. Stassen HE. Small-Scale Biomass Gasifiers for Heat and Power: A Global Review Word
 416 Bank technical paper n° 296, UNDP Energy Sector Management Assistance Program.
 417 Accessed 20 June 2013. Available:
 418 http://www.woodgas.net/files/World_bank_tech_paper_296.pdf.
 419

420 23. Pankaj M, Prafull S, Prashant B. Impact of moisture level in atmosphere on Biomass
 421 Gasification: A Bioenergy for Sustainable Development. International Journal of
 422 Environmental Sciences. 2010; 1(4): 640-644.
 423

424 24. LaFontaine H, Zimmerman FP. Construction of a Simplified Wood Gas Generator for
 425 Fueling Internal Combustion Engines in a Petroleum Emergency. Federal Emergency
 426 Management Agency, Washington, D.C. 20472. 1989. Accessed: 12 October 2012.
 427 Available: <http://www.gasifyer.com/fema.woodgas.pdf>.
 428

429 25. Kaupp A, Goss JR. State-of-the -Art for Small (2-50kW) Gas Producer-Engine systems,
 430 Final Report to USDA, Forest Service, Contract N° 53-39R-0-141; 1945.
 431

432 26. Glover B, Mattingly J. Reconsidering Municipal Solid Waste as a Renewable Energy
 433 Feedstock, Environmental and Energy Study Institute 1112 16th Street, NW, Suite 300
 434 Washington, DC 20036. 2009. Accessed 10 September 2013. Available:

435 http://www.seas.columbia.edu/earth/wtert/sofos/eesi_msw_issuebrief_072109.pdf.
436
437 27. Chawdhury MA, Mahkamov K. Development of a Small Downdraft Biomass Gasifier for
438 Developing Countries. Journal of Scientific Research. 2011; 3 (1): 51-64.
439
440 28. Larson ED. Small-Scale Gasification-Based Biomass Power Generation. Biomass
441 Workshop Changchun, Jilin Province, China 12-13 January 1998. Accessed 20 August 2013.
442 Available:
443 [http://www.princeton.edu/pei/energy/publications/texts/Small scale_gasification.pdf](http://www.princeton.edu/pei/energy/publications/texts/Small_scale_gasification.pdf)
444
445 29. Rajvanshi AK. Biomass gasification, Chap N° 4, Alternative Energy in Agriculture. 1986;
446 D. Yogi Goswami, CRC Press (II) : 83-102 Accessed 22 August 2013. Available:
447 <http://www.nariphaltan.org/gasbook.pdf#page=20&zoom=auto,0,273>.
448
449 30. Wikipedia. Gasification. Accessed 20 August 2013. Available:
450 <http://en.wikipedia.org/wiki/Gasification>.
451
452 31. Reed TB, Das A. Handbook of Biomass gasifiers Chap. 6. Solar Energy Research
453 Institute, 1617 Cole Boulevard, Golden, Colorado 80401-3393; 1988. Accessed 10
454 September 2013. Available:
455 [http://taylor.ifas.ufl.edu/documents/Handbook_of Biomass Downdraft Gasifier Engine Sys](http://taylor.ifas.ufl.edu/documents/Handbook_of_Biomass_Downdraft_Gasifier_Engine_Systems.pdf)
456 [tems.pdf](http://taylor.ifas.ufl.edu/documents/Handbook_of_Biomass_Downdraft_Gasifier_Engine_Systems.pdf)
457
458 32. Reed TB, Das A. Handbook of Biomass gasifiers. Chap. 2. Solar Energy Research
459 Institute, 1617 Cole Boulevard, Golden, Colorado 80401-3393. 1988. Accessed 20 October
460 2012. Available:
461 [http://taylor.ifas.ufl.edu/documents/Handbook_of Biomass Downdraft Gasifier Engine Sys](http://taylor.ifas.ufl.edu/documents/Handbook_of_Biomass_Downdraft_Gasifier_Engine_Systems.pdf)
462 [tems.pdf](http://taylor.ifas.ufl.edu/documents/Handbook_of_Biomass_Downdraft_Gasifier_Engine_Systems.pdf).
463
464 33. Drucker PF. Innovation and Entrepreneurship: Principles and practice, 288p, ISBN 0-06-
465 09136-6, Harper Collins Publishers Inc; 1985.
466
467 34. FAO. Wood Gas as Engine Fuel. Mechanical Wood Products Branch, Forest Industries
468 Division, FAO Forestry paper n° 72; 1986. Accessed 13 May 2013. Available:
469 <http://www.gasifyer.com/t0512e00.pdf>.