WASTE MANAGEMENT AND ENERGY PRODUCTION FROM BIOMASS AND WASTE: THE AMRA'S ACTIVITIES

amra

analysis and monitoring of environmental risk

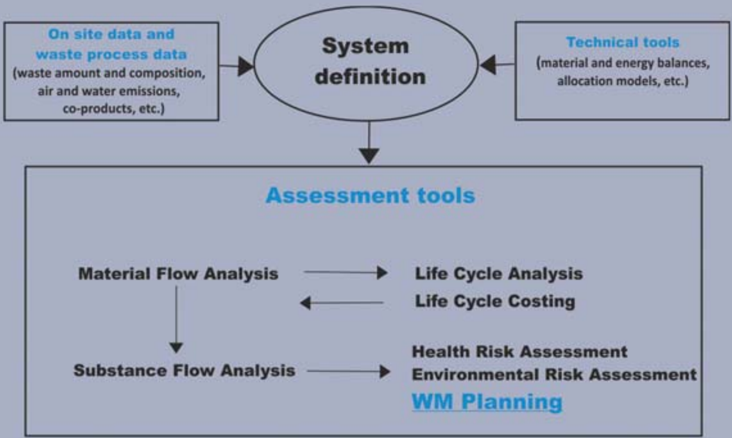
A TOOL-BOX FOR SUSTAINABLE AND INTEGRATED WASTE MANAGEMENT PLANNING

ENVIRONMENTAL ASSESSMENT TOOLS FOR WASTE MANAGEMENT OPTIONS

Waste management has to evaluate and adequately take into account the environmental impacts, technical aspects, implementation and operating costs as well as the social implications of each specific treatment and disposal option.
This framework becames more and more complicated in the last three decades, as a consequence of the increasing generation and complexity of solid wastes and of the deep and extensive changes that consequently occurred in their management. Oversimplified procedures (such as collection of unsorted wastes and their disposal in landfills) shifted to integrated and sustainable systems, which has to provide an adequate balance between waste reduction practices, material recycling techniques, biological and thermal processes, and engineered landfill disposal.
A comprehensive and systemic, goal-oriented approach is needed. It must be based on a deep knowledge of the system behavior, able to provide reliable information about how the environmental hazards can be minimized and the potential resources maximized. The related assessment tools cannot refer just to bulk flow of wastes and residues. Given that individual substances are responsible for environmental loadings and resource potentials, the flows of individual substances have also to be investigated, controlled, and directed to appropriate treatments and sinks.

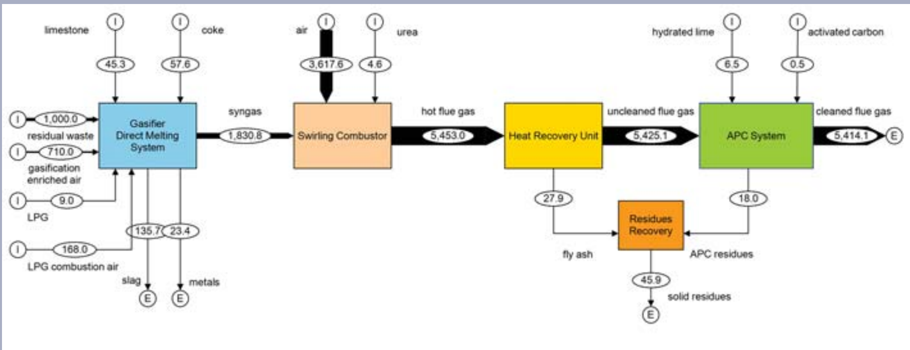
THE AMRA'S APPROACH

Amra utilizes a specific procedure to support waste management decisions on both strategic and operating levels. It is a combination of two valuable tools, the mate-



The "tool-box" for waste management planning

rial flow analysis (MFA) and the substance flow analysis (SFA), together with an environmental assessment method such as life cycle analysis (LCA).
An LCA approach defines the overall management scheme and individuates the specific technical solutions. Mass and energy balances applied at the different stages of the waste management system, and extended to some atomic species, provide the input data for the analysis. MFA and SFA are then developed on the basis of the transfer coefficients of all the waste treatment processes included in the management scheme. The aim is to provide a rigorous and scientific support to the decision making process.



An example of MFA applied to a gasification-based thermal treatment

THE RESEARCH AND CONSULTANCY AGREEMENTS

- **ARPAC (Environmental Protection Agency of Italy – Campania Dept.).** Planning of industrial waste management for Regione Campania in Italy, with definition of type and capability of treatment plants and their localization.
- **CONAI – Italian National Consortium for Packaging.** Life Cycle Assesment of plastic and paper recycling chains of Italy.
- **Env. Dept. of Regione Campania.** SFA of municipal solid waste management for Regione Campania (6 millions of inhabitants), with definition of future scenarios of waste management.
- **Env. Dept. of Regione Molise.** Planning of municipal solid waste management for Regione Molise in Italy, with definition of type and capability of treatment plants and their localization.

MAIN SCIENTIFIC PAPERS

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9. Arena U. (2012) *Material and substance flow analysis in waste management planning of different areas of Italy*, 13rd Meeting of Int. Expert Group on LCA for Waste Management, 14-15 May 2012, London.
10. Di Gregorio F., Arena N., Arena U. (2012) *A substance flow analysis of a combustion- and a gasification-based waste-to-energy units*. Proc. of SIDISA 2012-International Conference on “Material and energy recovery from waste: searching for optimum integration”, Milan, 26-28 June.

FLUIDIZED BED GASIFICATION FOR ENERGY PRODUCTION FROM BIOMASS AND WASTE

BIOMASS-TO-ENERGY AND WASTE-TO-ENERGY PROCESSES

The whole range of biomass and waste-to-energy technologies can be grouped into two main categories: combustion based- and gasification based-thermal treatment. The first includes moving grate furnaces and fluidized bed combustors among others: they are well established *flue gas technologies*, with thousands of plants in operation globally.

The gasification technologies involve a more complex chemical process: these *fuel gas technologies* tend to be less proven on a commercial scale, even though the number of biomass and waste gasifiers increases continuously. They offer a series of potential advantages and could today be proposed as a viable alternative solution for biomass and waste treatment with energy recovery.

THE AMRA’S APPROACH

Different gasification technologies are available today and fluidization appears as one of the most promising. This for a series of reasons, among which the possibility to use different fluidizing agents, reactor temperatures and gas residence times, to inject reagents along the reactor height and to operate with or without a specific catalyst.

One of the keys to achieving economically and environmentally efficient energy recovery from biomass and waste gasification is to overcome the problems associated with the formation and release of different contaminants (mainly tars, i.e. high molecular weight hydrocarbons that condensate at ambient temperature, but also heavy metals, halogens, ammonia and alkaline compounds) that create environmental and operating troubles. The syngas cleaning approaches can be classified in treatments inside the gasifier - such as adequate selection of main operating parameters, use of a proper bed additive or catalyst, specific gasifier design modifications - and hot gas treatments downstream of the gasifier - such as thermal or catalytic tar cracking and mechanical methods. Amra's research activity is focused on both these methods.

The aim is to support studies and projects:

– to evaluate and compare the technical and economic performance of the most promising design configurations for the small and medium scale gasifiers of biomass and waste;
– to approach and investigate the gas cleaning problem, in particular for removal or strong reduction of tar content.

To this end, a pilot-scale facility and two pre-pilot scale apparatus have been designed and put in operation in the Amra's experimental areas.

THE PILOT SCALE FLUIDIZED BED GASIFIER

The bubbling fluidized bed gasifier has an internal diameter of 0.38m and a total height of 6.2m, then it is able to provide data not affected by the scale and to define reliable design and operating criteria. The unit can treat up to 100kg/h of fuel and is equipped with a complete set of measurement and control devices. The operating flexibility of plant allows sufficiently wide ranges of the main operating parameters: reactor temperature (between 700 and 900°C); fluidizing velocity (between

The pilot scale fluidized bed gasifier

0.4 and 0.9m/s); type of oxidizing agent (air, oxygen-enriched air, oxygen and steam, carbon dioxide, in different ratios); equivalence ratio (between 0.2 and 0.4).
The reactor, made of Incoloy HT©, is heated up to the reaction temperature by the sensible heat of pre-heated blast gases and by a set of three external electrical furnaces. The producer gas is then cleaned in a section composed of a high efficiency cyclone, a wet scrubber and a flare. A new project will introduce new cleaning systems (special bag filters, oil-emulsion wet scrubber, plasma torch) in order to study their performances.

THE LABORATORY SCALE FLUIDIZED BED GASIFIERS

Preliminary tests on each of biomass or waste to be treated are typically carried out on laboratory scale apparatus. Two fluidized bed gasifiers (both having an internal diameter of 0.108m) are available and equipped with a complete set of measurement tools and analytical diagnostic devices. Their treatment capacity is of about 3kg/h.

The laboratory scale fluidized bed gasifiers

THE DIAGNOSTIC APPARATUS

- On-line analyzers for CO, CO_2, O_2, H_2, CH_4 content in the syngas
- On-line analyzer for tar content in the syngas
- On-line analyzer for PM2.5 in the syngas
- TG-DTA coupled with MS
- Gas-cromatograph with MS
- HPLC with MS
- ICP with MS
- CHNS elemental analyzer
- SEM and TEM microscopes

THE RESEARCH AND CONSULTANCY AGREEMENTS

- ANSALDO ENERGY. Research program to test different materials and surface coatings to be used in gasification and pyrolysis reactors.

- **CHEMTEX – M&G group.** Experimental tests of fluidized bed gasification of mixed natural biomass.
- **CONAI – Italian National Consortium for Packaging.** 3-years research program (2006-2008) aimed to define and design criteria for fluidized bed gasifiers of natural and industrial biomass as well as packaging- and refuse-derived fuels.
- **CONAI – Italian National Consortium for Packaging.** 2-years research program (2009-2011) aimed to optimizing the design of a medium-scale gasifier to be fired with plastics and/or wood from recycling chains.
- **ECO-ENGINEERING.** Support to the process design of a 1MWe fluidized bed gasifier of biomass and assistance to the commissioning.
- **Private Companies.** Experimental tests of fluidized bed gasification of packaging derived fuels, different type of natural biomass.

MAIN RECENT SCIENTIFIC PAPERS

1. Arena U., Romeo E., Mastellone M.L. (2008) Recursive Operability Analysis of a Pilot Plant Gasifier. *J. Loss Prevention in the Process Industries*, 21/1:50-65.
2. Mastellone M.L. and Arena U. (2008) Olivine as a Tar Removal Catalyst During Fluidized Bed Gasification of Plastic Waste. *AIChE Journal*, 54/6: 1656-1667.
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Via Nuova Agnano, 11
80125 Napoli (Italy)
Tel. +39 081 7685125
Fax +39 081 7685144
www.amracenter.com
info@amracenter.com

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